

## In Celebration of HRH Princess Maha Chakri Sirindhorn's 5<sup>th</sup> Cycle Birthday Anniversary

International Conference on Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals:

Policy and Practice





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Policy and Practice







HRH Princess Maha Chakri Sirindhorn was on royal duty for the conservation of natural resources and environment at Sirindhorn International Environmental Park,

Cha-am, Phetchaburi Province, Thailand.



On June 27, 2016, Her Royal Highness Princess Maha Chakri Sirindhorn graciously presided over the opening ceremony of the International Conference on Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals: Policy and Practice in Celebration of HRH Princess Maha Chakri Sirindhorn's 5th Cycle Birthday Anniversary at the Energy for Environment Centre, The Sirindhorn International Environmental Park, Cha-am, Phetchaburi, Thailand.

#### Royal Message of HRH Princess Maha Chakri Sirindhorn

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#### The International Conference on

"Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals: Policy and Practice"

At the Sirindhorn International Environmental Park, Phetchaburi Province, Thailand 27 June 2016

It gives me pleasure to be present at the opening of the International Conference on "Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals: Policy and Practice". May I extend my warm welcome to all participants.

At present, we are faced with problems which are complex. Importantly, the problems caused by climate change and on the degradation of biodiversity and ecosystem. These compel us to work together in an interdisciplinary fashion in order to achieve the sustainability all of us are wishing for. It is commendable that the academic and scientific communities, together with the development sector join hands in organizing this conference that provides a platform for bridging knowledge and education with development.

As we all know, the ever decreasing natural capital, due to excessive consumption of natural resources, particularly biological resources, threatens our planet's regeneration capacity and its sustainability to support life. It is believed that if we go on with current consumption patterns, we will surely be faced with immeasurable catastrophe. Looking back, it can be seen that we humans play a huge part in all these. Human's irresponsible behaviours and actions are destroying the gifts from Nature.

Sustainable development has been in the international agenda over a long period of time. It is strongly believed to be the right path to the solution of the critical global issue. Thus, there is the need for clear understanding of what it is all about and to accelerate and scale-up actions for the creation of sustainable solutions.

Sustainable development is about balancing the economic, environmental and social dimensions. When countries prioritize economic consideration to uplift prosperity, alleviate poverty and reduce inequality, they must recognize the fundamental truth that the economy is only a subset of society and the natural environment. In turn, society is constrained by the natural ecology of our planet, thus requiring integration of ecological thinking into all social and economic planning, policy and practice of all sectors of society.

I am pleased that the Sirindhorn International Environmental Park and the Regional Centre of Expertise on Education for Sustainable Development, RCE in Cha-am, in collaboration with partner organizations, are taking active roles in organizing this international conference. I wish that you will have productive and meaningful deliberations of issues facing all humanity.



*Left above*: Arrival of HRH Princess Maha Chakri Sirindhorn at the Sirindhorn International Environmental Park.

Right above and left below: HRH Princess Maha Chakri Sirindhorn is welcomed by Deputy Governor of Phetchaburi Province, Dr. Sumet Tantivejkul, Chairman of the Sirindhorn International Environmental Park Foundation under the Patronage of HRH Princess Maha Chakri Sirindhorn, Professor Sanit Aksornkoae, Chairman of the Executive Board Member of the Sirindhorn International Environmental Park and Mrs. Bussaba Pibulchol, Business School Alumni's President, National Institute of Development Administration (NIDA).

*Right below*: Wife of Deputy Governor of Phetchaburi Province, Thanpuying Putri Viravaidya, Vice Chairman of the Sirindhorn International Environmental Park Foundation under the Patronage of HRH Princess Maha Chakri Sirindhorn and Ms. Sukunya Theerakullert, Secretary General of National Research Council of Thailand present a garland to HRH Princess Maha Chakri Sirindhorn.



Left above: Professor Sanit Aksornkoae presents the program of the conference to HRH.

Right above: Professor Emeritus Doctor Soottiporn Chittmittrapap, Chairman, the National Research Council of Thailand Executive Board presents the book to HRH.

Left below: Mr. Wanchai Sarathultat, Board member of the Sirindhorn International Environmental Park Foundation under the Patronage of HRH Princess Maha Chakri Sirindhorn, and Head of Editorial Board presents the book of "The Shadow of Mangrove" to HRH.

Right below: Dr. Sumet Tantivejkul addresses an amiable welcome to HRH.

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# In Celebration of HRH Princess Maha Chakri Sirindhorn's 5th Cycle Birthday Anniversary



International Conference on Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals:

Policy and Practice

27-29 June 2016

The Sirindhorn International Environmental Park Cha-am, Phetchaburi, Thailand

27-29 June 2016

The Sirindhorn International Environmental Park

Cha-am, Phetchaburi, Thailand

#### **Preface**

It is a great honor to have contributed to organizing the International Conference on "Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals: Policy and Practice" hosted by the Sirindhorn International Environmental Park and its collaborating organizations during 27-29 June 2016.

The conference addressed the global development agenda – 2030 Agenda and the Sustainable Development Goals (SDGs) – and was designed to take on the thematic issues of climate change, biodiversity and ecosystem services in the context of science-policy-society interfaces. There were three streams of parallel sessions – climate change adaptation at the watershed level; biodiversity conservation; and ecosystem services protection – addressing a wide range of topics on policy, management, practice, and multi-stakeholder approaches, and their methodologies. Deliberations were in the form of key plenary presentations and panel discussions, paper and poster presentations of case studies.

At the closing session, there were technical reflections and briefs on what have been discussed and the outcomes including the adoption of the Cha-am Statement which symbolizes the collective wishes and aspirations of the participants. The final day of the conference was devoted to field visits to actual projects that demonstrate real changes and contributions on relevant SDG implementation issues on climate change, biodiversity and ecosystem services.

The conference was productive and it provided opportunities and potentials for networking amongst the participants. It is hoped that this conference proceedings provides a useful reading and reference to researchers, educators, practitioners and policymakers.

The Academic Committee Conference Organizers

27-29 June 2016, The Sirindhorn International Environmental Park

Cha-am, Phetchaburi, Thailand

Message of SIEP Foundation Chairman

It is with great pleasure that the Sirindhorn International Environmental Park (SIEP) Foundation under the Patronage of Her Royal Highness Princess Maha Chakri Sirindhorn produced this important publication out of the case studies and papers presented at the International Conference on "Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals: Policy and Practice" held in Cha-am, Phetchaburi, Thailand on 27-29 June 2016. SIEP is, by its mandate, positioned to promote education, public awareness, capacity building, and research innovations, and it builds international linkages and global partnerships in environment, energy and natural resource conservation. It engages strategic alliances through networking at the local, national and international levels. The production of this book contributes towards the aforementioned directions and aspirations.

It was through the initiative of Her Royal Highness that the previously environmentally degraded area of what is now the park has been rehabilitated and practically restored into its original natural condition. The rehabilitation of mangrove and beach forests to be a learning center on nature and environment, and the promotion of biodiversity, are among the major thrusts of SIEP to educate and train students, youth and citizens both in the community and region including officials of government agencies and private organizations. These goals are aimed at realizing energy, natural resources and environment conservations in order to cope up with the national strategies on biodiversity and climate change. SIEP also serves as lead organization of the Regional Centre of Expertise on Education for Sustainable Development, known as RCE Cha-am, which is acknowledged by the United Nations University.

The generosities of organizations that have provided funds to make the conference and this publication possible are gratefully acknowledged. We are thankful to the United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS) and the National Research Council of Thailand (NRCT), for partnering with SIEP in producing this important publication. We are appreciative of the support provided by the RCE Cha-am stakeholders, USAID ADAPT Asia-Pacific, US Forest Service, and the Office of the Natural Resources and Environmental Policy and Planning, and other partners.

It is hoped that this book publication would be useful to policymakers, academics, researchers and members of the wider scientific communities.

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Dr. Sumet Tantivejkul

Chairman

The Sirindhorn International Environmental Park Foundation Under the Patronage of HRH Princess Maha Chakri Sirindhorn

27-29 June 2016, The Sirindhorn International Environmental Park

Cha-am, Phetchaburi, Thailand

Message of NRCT Chairman of the Executive Board

Climate change is a global crisis without boundaries and Thailand is working to build capacity in natural resource research and management regarding changing climate as well as in assessment to support climate change preparedness. To make the best decisions in the face of climate change, the country also needs good examples of the best practices for integrating local and science-based knowledge into economic development and natural resources planning in advance of decision-making.

The National Research Council of Thailand (NRCT) has identified an opportunity to undertake a case study on assessing climate change vulnerability and adaptation options in a ridge-to-reef setting that can serve to strengthen national and regional knowledge on appropriate study methodologies.

On the occasion of Her Royal Highness Princess Maha Chakri Sirindhorn's 5<sup>th</sup> Cycle Birthday Anniversary on April 2, 2015, NRCT has designed a project entitled "Watershed-based Adaptation to Climate Change: A Case Study on Sirindhorn International Environmental Park and its vicinity". The project is being implemented by several agencies. There is an opportunity for Thai researchers to exchange science-based knowledge with US Forest Service's experts and to help foster regional learning on the methodologies that might work best in determining climate change vulnerabilities and option to addressing them in Asia. Papers on this subject were presented at the International Conference on "Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals: Policy and Practice" held in Cha-am, Phetchaburi, Thailand on 27-29 June 2016.

We are thankful for the support provided by the Sirindhorn International Environmental Park, USAID ADAPT Asia-Pacific, US Forest Service, and other partners.

Finally, we hope that this book is valuable for developing national capacity to meet climate change challenges.

Professor Emeritus Dr. Soottiporn Chittmittrapap

Chairman of the Executive Board

of an

National Research Council of Thailand

27-29 June 2016, The Sirindhorn International Environmental Park

Cha-am, Phetchaburi, Thailand

Message of UNU-IAS Director

On behalf of the United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS), I express profound gratitude to the Sirindhorn International Environmental Park Foundation under the Patronage of HRH Princess Maha Chakri Sirindhorn, together with RCE Cha-am and other partner organizations, for the honor of collaborating in this book publication.

This publication features case studies presented at the International Conference on "Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals: Policy and Practice" held in Cha-am, Phetchaburi, Thailand on 27-29 June 2016. Many of these case studies were conducted and authored by participants from various Regional Centres of Expertise on Education for Sustainable Development (RCEs) located in the Asia-Pacific region, which are acknowledged by the United Nations University.

UNU-IAS is committed to actively promoting and delivering Education for Sustainable Development (ESD) as a means to implement the 2030 Agenda and to achieve the Sustainable Development Goals (SDGs). All communities are expected to be able to use research, teaching and training to address their specific development needs, and to keep in mind that sustainable development goals and targets are interconnected. UNU-IAS' broader mission is to advance efforts towards a more sustainable future, through policy-oriented research and capacity development focused on sustainability.

UNU-IAS' collaboration in producing this book of proceedings is anchored in its ESD Programme towards advocacy and public awareness on ESD, promotion of RCEs, strengthening of ESD activities of higher education institutions, advancing ESD knowledge through capacity building, and participation in international ESD processes.

It is hoped that this publication will constitute a useful reading and inspire individuals and organizations to contribute towards actions to combating climate change as well as protecting biodiversity and ecosystem services.

Professor Dr. Kazuhiko Takemoto

Director

**United Nations University** 

Institute for the Advanced Study of Sustainability

## Cha-am Statement on Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals

The participants of the International Conference on "Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals: Policy and Practice", having met in Cha-am, Phetchaburi Province of Thailand during 27 to 29 June 2016 in celebration of Her Royal Highness Princess Maha Chakri Sirindhorn's Fifth Cycle Birthday Anniversary, and having recognized the moral imperative to address the new agenda for sustainable development through the Sustainable Development Goals (SDGs) and realizing the interlink ages and integrated nature of these goals, do hereby pledge to advocate for key interventions which were prominently raised during the Conference to further global, regional, national and local efforts in climate change adaptation, biodiversity conservation and management of ecosystem services. Towards this end, the participants do commit to the following actions and aspirations:

- Support global, regional and national efforts towards climate change adaptation at the watershed level, halt the loss of biodiversity, and secure sustainable ecosystem services through supporting the objectives and initiatives by the United Nations Framework Convention on Climate Change Conference of the Parties (UNFCCC COP), the Convention on Biological Diversity Conference of the Parties (CBD COP), as well as the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) and the Aichi Biodiversity Targets.
- Promote the application of meaningful and effective public consultation and participation that will allow stakeholders a clear role in how education, policies, strategies, programs and projects are developed and implemented.
- Because no country can effectively address climate change, biodiversity and ecosystem challenges alone, support partnerships and collaborations at the global, regional, national and local levels through existing formal, non-formal and informal channels, seek out opportunities to establish new partnership arrangements especially among stakeholders within the Asia-Pacific region and strengthen the interfaces of science-policy-society, at all levels of government, civil society, higher education and research institutions, and local communities and networks such as the Regional Centres of Expertise (RCEs) on Education for Sustainable Development (ESD).
- Recognizing that effective climate change adaptation and resilience programs will often be inextricably linked with the ecological services provided by healthy, biodiverse watersheds, take steps that will lead to effective action at priority watersheds, including preparation of climate change vulnerability assessments and recommendations; effective management of national parks and other protected areas, which are often among the major land use types in our watersheds; initiation of community-based adaptation and nature conservation programs; and other actions that will maintain water quality and quantity, species diversity, climate regulation, and other vital ecological services that enhance human well-being.

- Initiate, through multi-stakeholder consultations, the formulation of national and/or sectoral strategic plans for scientific research which will provide direction to researchers and research funders in identifying the most pressing questions regarding climate change, biodiversity conservation and ecosystem services, and encourage actions that will result in immediate application of this research through appropriate implementing agencies.
- Identify opportunities to enhance the professional training of key government and non-government actors in climate change, biodiversity and ecosystem services through existing programs and institutions within the region and globally or, when necessary, support new training efforts, which will include not only technical and policy matters but also training in gaining access to the financing required to put actions into practice.
- The participants will endeavor to inspire individuals and organizations to work towards attaining the SDGs by sharing examples of best practice, encouraging multi-stakeholder partnerships and co-management, promoting effective and wide leadership and public awareness of the values of climate change adaptation, biodiversity conservation and ecosystem services management, as well as the need for cooperation from all sectors.

This Cha-am Statement was adopted on the 28th of June 2016 at the closing session of the International Conference on "Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals: Policy and Practice" held at the Sirindhorn International Environmental Park in Cha-am, Phetchaburi Province, Thailand.

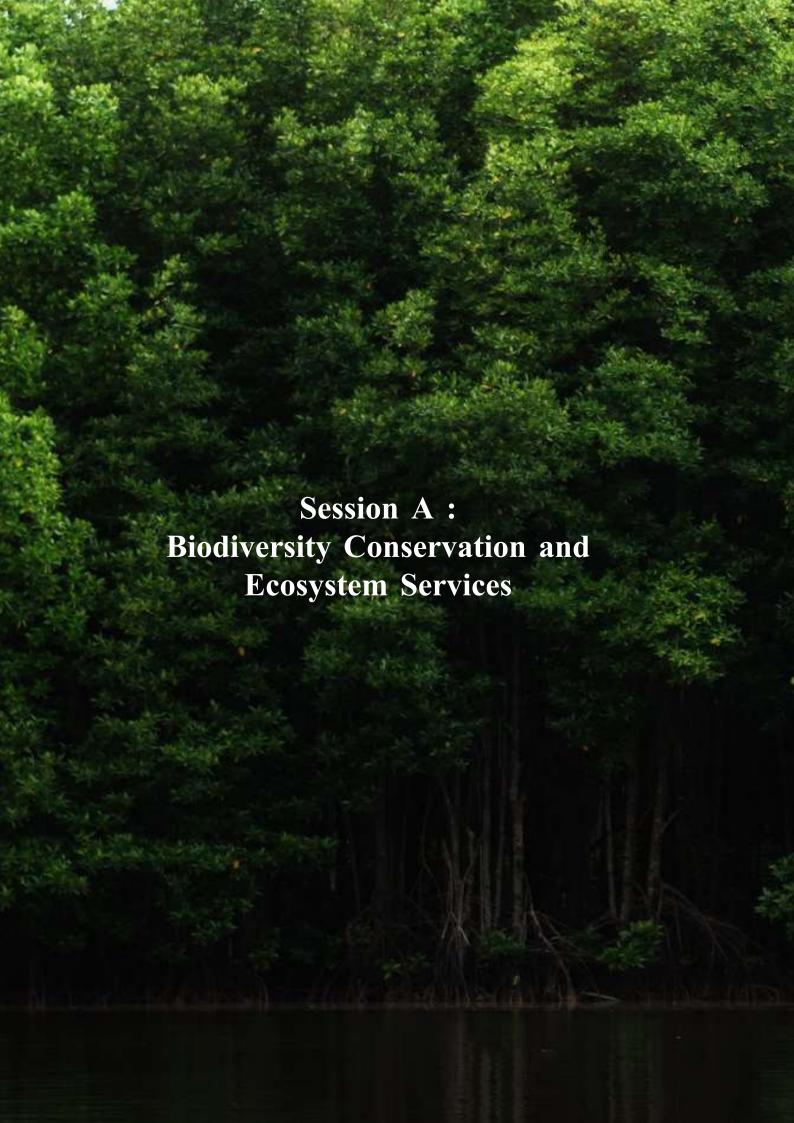
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Session A.1: Management



# Monitoring plant diversity and water storage in a dry dipterocarp forest at the Huai Hong Khrai Royal Development Study Center, Chiang Mai, northern Thailand

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Abstract-Monitoring plant species diversity and water storage in a dry dipterocarp forest (DDF) at the Huai Hong Khrai Royal Development Study (HHKRDS) Center, Chiang Mai province was carried out. The forest was assessed for species diversity and water storage in 2010 and 2015 using 12 permanent plots, each of size 40 x 40 m<sup>2</sup>, and arranged by a random sampling over the forest as reported in Part I. The plant data were obtained by measuring stem girths at 1.3 m above ground and heights of all trees with height over 1.5 m. Quantitative plant data, plant biomass and water amounts derived from water contents in stem, branch, leaf and root were measured. The DDF included 4 stands based on the most dominant tree species: Hiang (Dipterocapus obtusifolius), Pluang (D. tuberculatus), Teng (Shorea obtusa) and Rang (S. siamensis). It was found that

species richness, family richness, tree density and species diversity index (SWI) were decreased: 60 to 53 species (-7), 31 to 27 families (-4), 3,864 to 2,780 trees ha-1 (-1,084), and 3.17 to 3.06 (-0.11), respectively Death of many tree individuals in the forest was the main cause of decreasing species diversity and plant production. However, the Forest Condition Index (FCI) was adversely increased, and the average amount of plant biomass was also increased from 83.74±12.35 to 90.65±11.36 Mg ha<sup>-1</sup> (+6.91). As a result, the average amount of water stored in plant biomass during 2010 and 2015 increased from  $34.02\pm4.94$  to  $38.70\pm5.27$  m<sup>3</sup> ha<sup>-1</sup>, the net. increase of  $4.69 \text{ m}^3 \text{ ha}^{-1} (13.80\%)$  or only 0.94 m<sup>3</sup> ha<sup>-1</sup> yr<sup>-1</sup>.

*Keywords*: dry dipterocarp forest, monitoring, plant species diversity, water storage

#### I. INTRODUCTION

Changes of plant community in a forest involves species richness, composition, diversity and ecological roles by measuring these parameters during a period of time. It is assumed that either local environment or climate change have influenced these changes. The DDF covers dry sites in northern, northeastern and central Thailand. The forest vegetation has a major role on the hydrologic cycle in a watershed. The rate at which water infiltrates into soil, surface runoff and percolates into water table is affected by density and depth of roots and soil organic matter. Theories of forest hydrologic cycle have been described by Landberg and Gower (1997), Waring and Running (1998), Kimmins (2004) and Chang (2006). Most contents focus on water input and movement such as interception-evaporation by forest canopy, throughfall, stemflow, plant use, transpiration, water flow through vegetation, evaporation from soil, infiltration into soil, drainage and runoff and stream flow.

This research aims at monitoring plant species diversity and its role on water storage in plant biomass of a dry dipterocarp forest (DDF) at the HHKRDS Center. The data provides useful information for forest and watershed management.

#### II. MATERIALS AND METHODS

#### 1. Study area

The research was conducted in the HHKRDS Center, Chiang Mai province, about 27 km to the north of Chiang Mai city. The Center covers an area of about 1,360 ha with an altitude range between 350 and 591 meters above sea level.

#### 2. Plant community study

A method of plant community analysis was used for plant study in 2010 and 2015 using 12 plots, each of size 40 x 40 m<sup>2</sup>. All tree stems were numbered in sequence, and measured for stem girths at 1.3 m above ground (gbh) and tree heights. Plant data were calculated for frequency, density, importance value index and Shannon-Wiener Index (Krebs, 1985). Forest condition index (FCI) was based on an equation given by Seeloy-ounkeaw *et. al.* (2014).

FCI = 
$$\sum n_1 \cdot 10^{-4} + n_2 \cdot 10^{-3} + n_3 \cdot 10^{-2} + n_4 \cdot 10^{-1} + 1(n_5) + 2(n_6) + \dots$$

Where  $n_1 = number$  of tree individuals having GBH<25 cm

 $n_2$  = number of individuals having GBH 25 to <50 cm

 $n_3$  = number of individuals having GBH 50 to <75 cm

 $\rm n_4$  = number of individuals having GBH 75 to <100 cm

 $n_5$  = number of individuals having GBH 100 to < 200 cm

 $n_6$  = number of individuals having GBH 200 to < 300 cm

#### 3. Plant biomass estimation

Plant biomass was measured using allometric equations [Ogino et. al. (1967)].

 $W_S = 189 (D^2H)^{0.902}$ 

 $W_{\rm B} = 0.125 W s^{1.204}$ 

 $1/W_L = (11.4/ws^{0.90}) + 0.172$ 

Where  $W_S$  = stem biomass in kilogram

W<sub>B</sub> = branch biomass in kilogram
W = leaf biomass in kilogram

 $W_L$  = leaf biomass in kilogram

The unit of stem diameter (D) and tree height (H) was in meters. The root biomass was calculated using an equation of Ogawa *et. al.* (1965).

$$W_R = 0.026 (D^2H)^{0.775}$$

The unit was in kilogram for WR, centimeter for D and meter for H.

#### 4. Water storage in plant biomass

Fresh samples of leaf, branch and stem of dipterocarps were taken in December 2015 from four stem-gbh classes: <25 cm, 25-50 cm, 50-75 cm and >75 cm, oven-dried at 75°C until attaining constant weights, and later determined for water contents. The water amount in biomass was measured by multiplying water content with its biomass. Average water contents of dipterocarps were used for calculating biomass water amounts of other species.

#### III. RESULTS AND DISCUSSION

## 1. Changes in plant species richness and composition, and community structure

A total of 60 species (51 genera, 31 families) existed in the forest in 2010 and decreased to 53 species (44 genera, 27 families) in 2015. This indicated that 7 species, 7 genera and 4 families including 1,084 tree ha<sup>-1</sup> disappeared by 2015. Death of many tree individuals happened during this period caused mainly by competition for environmental factors such as space, light, moisture and nutrients. Tree cutting and forest fires were strongly protected in the Center, and were not the cause of tree death. The decrease of species richness resulted in a little change of species composition. In 2010, 7 species including Semecarpus albescens, Giniothalamus laoticus, Stereospermum neuranthum, Casearia grewiifolia, Bredelia retusa, Pterospermum semisagittatum and Ulmus labcaefolia, existed as only one individual within the 12 plots, and had disappeared by 2015.

#### 1.1 Plant community structure

Death of many individuals of dominant species resulted in a large change of densities and population structure (Fig.1). Hiang had the highest number of dead individuals, 279 tree per ha<sup>-1</sup>, followed by Teng (135),

Memecylonscutellatum (109), Dalbergia oliverli (76), Gluta usitata (66), Tristaniopsis burmanica (65), Pluang (62), Rang (60), Aporosa villosa (30), Canarium subulatum and Anneslea fragrans (29), Wendlandia tinctoria (23), Garcinia cowa (20), Catuanregum stellatum (18), and Buchanania lanzan (13). Most dead individuals were small trees.

## 2. Changes in plant species diversity and forest condition

#### 2.1 Plant species diversity

Shannon-Wiener Index (SWI) indicates species diversity according the combined concepts of species richness and heterogeneity (Krebs, 1985). Average SWI value was 3.17± 0.32 in 2010 and  $3.05\pm0.29$  in 2015; net. change of -0.11. This implied that a small decrease of plant species diversity in the forest had taken place. Tree density in the Hiang stand was 4,763 tree /ha<sup>-1</sup> in 2010 and 3,405 tree/ ha<sup>-1</sup> in 2015 (net<sup>-1</sup>, 359 tree/ ha<sup>-1</sup>). The net. decreases of tree density for the Rang, Pluang and Teng stands were -403 tree/ ha<sup>-1</sup>, -288 tree/ ha<sup>-1</sup> and -1,063 tree/ ha<sup>-1</sup>, respectively. The net. increase of importance value index (IVI) was the highest for G. usitata, 0.67%, followed by Hiang (+0.48%), Rang (+0.38%), A. villosa (0.11%), and *M. scutellatum* (0.06), while a net. decrease was found for Teng (-0.06) and Pluang (-0.17).

#### 2.2 Forest condition:

Average FCI values in 2010 and 2015 were  $1.94\pm1.98$  and  $2.27\pm1.36$ , respectively; with net change of +0.33. The DDF had a small FCI increase between the year 2010 and 2015. However, there were some differences among the stands. The net increase was observed in the Hiang, Rang, and Pluang stands (+0.43, +0.65 and +0.27, respectively), but the Teng stand had net decrease (-0.97).

#### 3. Changes of plant biomass in the DDF

Table 1 shows plant biomass in the DDF separated into stem, branch, leaf and root. Average biomass amount was increased from 83.74±12.35 Mg ha<sup>-1</sup> in 2010 to 90.65±11.36 Mg ha<sup>-1</sup> in 2015; a net. increase of 6.91 Mg ha<sup>-1</sup> (8.3%). The annual increment was

calculated to be 1.38 Mg ha<sup>-1</sup>; only 1.6% increase. The net. increases of plant biomass in the Hiang, Rang, Pluang and Teng stands were 5.07 Mg ha<sup>-1</sup> (1.02 Mg ha<sup>-1</sup> yr<sup>-1</sup>), 15.81 Mg ha<sup>-1</sup> (3.16 Mg ha<sup>-1</sup> yr<sup>-1</sup>), 5.03 Mg ha<sup>-1</sup> (1.01 Mg ha<sup>-1</sup> yr<sup>-1</sup>) and 5.63 Mg ha<sup>-1</sup> (1.12 Mg ha<sup>-1</sup> yr<sup>-1</sup>), respectively.

Table 1 Amount of plant biomass in 12 plots (4 stands) in the DDF between 2010 and 2015

Plot	Dominant	Plant biomass (Mg ha <sup>-1</sup> )										
No.	Tree	Stem		Branch		Leaf		Root			Total	
		2010	2015	2010	2015	2010	2015	2010	2015	2010	2015	Net
1	Hiang	58.53	62.8	16.43	18.59	2.39	2.41	12.81	13.36	90.16	95.96	5.80
2	Hiang	49.08	49.56	14.98	15.26	1.70	1.69	9.95	9.97	75.71	75.06	-0.65
3	Hiang	57.62	61.00	16.55	17.86	2.23	2.29	12.35	12.93	88.75	93.03	4.28
4	Hiang	53.98	58.79	14.57	16.50	2.29	2.33	11.88	12.54	82.72	88.44	5.72
5	Hiang	64.05	68.36	18.18	20.14	2.49	2.47	13.62	14.10	98.35	103.26	4.91
6	Hiang	63.21	68.20	18.44	20.60	2.35	2.36	13.23	13.90	97.23	103.58	6.35
7	Hiang	59.51	64.30	18.38	20.77	1.98	1.92	12.05	12.47	91.93	97.99	6.06
8	Hiang	62.88	69.21	17.30	19.34	2.62	2.80	13.77	14.96	96.57	104.69	8.12
	Mean	58.61	62.78	16.85	18.63	2.26	2.28	12.46	13.03	90.18	95.25	5.07
	S.D.	5.11	6.52	1.5	1.99	0.29	0.34	1.23	1.5	7.81	9.93	2.12
9	Rang	44.8	58.33	13.94	19.71	1.45	1.59	8.90	10.96	69.09	89.22	20.13
10	Rang	39.07	47.29	10.87	14.24	1.57	1.64	8.39	9.61	59.91	71.44	11.53
	Mean	41.93	52.81	12.41	16.98	1.51	1.61	8.65	10.29	64.50	80.33	15.83
11	Pluang	47.03	51.13	13.79	15.66	1.70	1.70	9.67	10.20	72.19	77.22	5.03
12	Teng	53.6	58.36	15.07	16.82	2.13	0.73	11.43	12.17	82.23	87.86	5.63
Mean		54.45	59.78	15.71	17.96	2.08	1.99	11.55	12.26	83.74	90.65	6.91
S.D.		8.02	7.42	2.27	2.23	0.39	0.56	1.85	1.74	12.35	11.36	-0.99

## 4. Changes of water amount stored in plant biomass

Average amount of water in plant biomass in the DDF increased from 34.20±4.94 m³ ha⁻¹ in 2010 to 38.70±5.27 m³ ha⁻¹ in 2015; a net. increase of 4.69 m³ ha⁻¹. The annual increment of water storage was calculated at 0.94 m³ ha⁻¹ yr¹ (2.74%) (Table 2). The average water amount stored the Hiang stand was 36.50 m³ ha⁻¹ in 2010 and 40.99 m³ ha⁻¹ in 2015; net. increase of 4.48 m³ ha⁻¹ (0.90 m³ ha⁻¹ yr⁻¹). As for the Rang stand, the value was 26.13 m³ ha⁻¹ in 2010 and 32.44 m³ ha⁻¹ in 2015; net. increase of 6.31 m³ ha⁻¹ (1.26 m³ ha⁻¹ yr⁻¹). The Pluang stand had the value of 29.50 m³ ha⁻¹ in 2010 and 33.52 m³ ha⁻¹ in 2015; net

increase of  $4.02 \text{ m}^3 \text{ ha}^{-1} (0.80 \text{ m}^3 \text{ ha}^{-1} \text{ yr}^{-1})$ , whereas the Teng stand had the value of  $34.41 \text{ m}^3 \text{ ha}^{-1}$  in 2010, and  $38.13 \text{ m}^3 \text{ ha}^{-1}$  in 2015; net increase of  $3.72 \text{ m}^3 \text{ ha}^{-1} (0.74 \text{ m}^3 \text{ ha}^{-1} \text{ yr}^{-1})$ .

A major forest disturbance in Thailand was selective cutting of big and medium trees in the past, this resulted in mainly secondary forest.

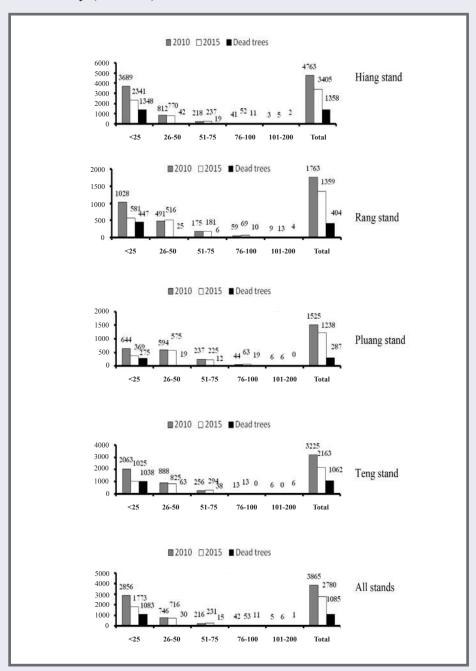
In National Parks, the forest is strongly protected from tree cutting, elsewhere such protection varies with forest stands (Oliver and Larson, 1996; Waring and Running, 1998). Since the DDF covers a xeric site where the soil is poor and usually disturbed by forest fire, natural regeneration is normally slow particularly seed germination. However,

sprouting from stumps and roots is a feature of most plants in this forest, especially the dipterocarps.

The tree density of this forest in 2010 was high, 3,864 trees ha<sup>-1</sup> (618 trees per plot). Death of many small trees were observed in

2015 caused by competition for environmental factors, with no impact of forest fires and timber harvesting in this protected forest. A few species of very low density disappeared, and resulted in a reduction of species richness.

Tree density (trees ha<sup>-1</sup>)



Stem-gbh class (cm.)

Fig.1 Plant population changes in 4 stands between the years 2010 and 2015

Table 2 Water amounts in plant biomass of 12 plots (4 stands), between 2010 and 2015

Plot	Dominan	Water amount in Plant biomass (m <sup>3</sup> ha <sup>-1</sup> )												
No.	tree	Bark		Stem		Branch		Leaf		Root		Total		
		2010	2015	2010	2015	2010	2015	2010	2015	2010	2015	2010	2015	Net
1	Hieng	2.69	2.70	19.87	22.1	6.25	7.46	2.13	3.20	5.18	5.51	36.1	40.99	4.88
2	Hieng	2.30	2.42	17.04	17.4	5.85	6.23	1.54	1.84	4.10	4.54	30.8	32.43	1.59
3	Hieng	2.68	2.71	19.83	21.3	6.41	7.55	2.00	3.13	5.07	5.36	35.9	40.06	4.08
4	Hieng	2.51	2.45	18.59	20.1	5.62	6.49	2.07	3.65	4.89	5.11	33.6	37.87	4.18
5	Hieng	2.97	3.05	22.05	24.2	7.02	7.99	2.24	4.60	5.63	5.82	39.9	45.67	5.74
6	Hieng	2.92	3.01	21.66	23.8	7.09	8.45	2.10	4.14	5.44	5.69	39.2	45.10	5.89
7	Hieng	2.74	2.65	20.30	21.0	7.03	8.74	1.77	2.87	4.92	5.04	36.7	40.36	3.60
8	Hieng	2.94	3.04	21.77	24.3	6.69	8.06	2.39	3.90	5.71	6.09	39.5	45.40	5.91
	Mean	2.72	2.75	20.14	21.8	6.49	7.62	2.03	3.42	5.12	5.40	36.5	40.99	4.48
	S.D.	0.23	0.25	1.72	2.36	0.56	0.89	0.27	0.86	0.51	0.49	3.13	4.51	1.38
9	Rang	2.08	2.26	15.39	19.5	5.39	7.43	1.30	1.99	3.65	4.07	27.8	35.26	7.46
10	Rang	1.82	1.95	13.52	15.7	4.23	5.72	1.42	2.12	3.48	4.06	24.4	29.63	5.16
	Mean	1.95	2.10	14.46	17.6	4.81	6.57	1.36	2.06	3.56	4.06	26.1	32.44	6.31
11	Pluang	2.20	2.57	16.35	17.7	5.39	6.64	1.54	1.85	4.03	4.72	29.5	33.52	4.02
12	Teng	2.56	2.89	19.01	19.6	6.02	6.82	1.96	2.53	4.85	6.24	34.4	38.13	3.72
Mean	of 12 plots	2.53	2.64	18.78	20.5	6.08	7.30	1.87	2.99	4.75	5.19	34.0	38.7	4.69
	S.D.	0.36	0.34	2.71	2.76	0.85	0.93	0.35	0.95	0.76	0.73	4.94	5.27	1.50

Tree death resulted in forest biomass decrease. However, the remaining trees could grow slowly, and gave a net. biomass increase  $(6.91 \text{ Mg ha}^{-1}, \text{ or } 1.38 \text{ Mg ha}^{-1} \text{ yr}^{-1}).$ Phongkhamphanh (2015) studied DDF in 5 stands: Shorea obtusa, S. siamensis, Dipterocarpus obtusifolius, D. tuberculatus, and Pinus merkusii, and found that there were 83 species (71 genera, 38 families), with a 2,269 tree ha<sup>-1</sup> density and 125.49 Mg ha<sup>-1</sup> biomass. Species diversity index (SWI) and FCI were measured to be 3.35 and 4.53, respectively. The water storage in the DDF ecosystem was measured as 5,005.36 m<sup>3</sup> ha<sup>-1</sup>; 126.0 (2.5%) m<sup>3</sup> ha<sup>-1</sup> in the plant biomass and 4,879.36 (97.5%) m<sup>3</sup> ha<sup>-1</sup> in the soil. Homchan (2014) reported that the DDF with planted bamboos, 69.52 Mg ha<sup>-1</sup> biomass, could store 1,206.75 m<sup>3</sup> ha<sup>-1</sup> of water; 57.53 (4.8%) m<sup>3</sup> ha<sup>-1</sup> in plant biomass and 1,149.22 (95.2%) m<sup>3</sup> ha<sup>-1</sup> in soil.

#### 5. Research applications

This research was taken in the restored forest watershed managed by the HHKRDS Center to examine changes in plant community of the DDF and its functional role in water storage. The watershed was recovering from a poor forest at the time of establishment of the Center, and increasing water storage in plant biomass has been observed. This is useful as a guideline for forest management in Lao PDR. The recovering forest watershed will increase the potential of water supply to the streams which are useful for agriculture in lower land areas as well as providing non-wood forest products for food securities and sufficient economic livelihoods of villagers. This biodiversity conservation is an important part of the Sustainable Development Goal 15 of the 2030 Agenda for Sustainable Development.

#### IV. CONCLUSION

During the years 2010 and 2015 of monitoring plant diversity and water storage in the DDF at the HHKRDS Center, enables us to conclude that:

- 1. Species richness decreased by 7 species (7 genera and 4 families), but resulted in a little change of species composition. Species Diversity Index (SWI) of species diversity was reduced from 3.17 to 3.05. Tree density was decreased from 3,865 to 2,336 trees ha<sup>-1</sup> caused by the death of many mostly small individuals.
- 2. Plant biomass was increased from  $83.74\pm12.35~Mg~ha^{-1}$  in 2010 to  $90.65\pm11.36~Mg~ha^{-1}$  in 2015; a net. increase of 6.91 Mg ha<sup>-1</sup> (1.38 Mg ha<sup>-1</sup>). The water amounts in plant biomass was icreased from  $34.02\pm4.94~m^3~ha^{-1}$  in 2010 to  $38.70\pm5.27~m^3~ha^{-1}$  in 2015; a net. increase of 4.69 m³ ha<sup>-1</sup> (0.94 m³ ha<sup>-1</sup> yr<sup>-1</sup>) or 13.80% increase.
- 3. The study demonstrated that a forested watershed enhances the potential water supply to streams and therefore agriculture.

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## Distribution and conservation status of Water Onion (*Crinum thaianum J. Schulze*) in Thailand

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Abstract-Water Onion (Crinum thaianum J. Schulze) is an endemic plant species found in southern Thailand. It's natural habitat is severely fragmented due to deforestation and dredging and it has been extinct in some streams. The objectives of this research were to investigate the current extent of occurrence and to assess the conservation status of Water Onion in Thailand using species distribution models and the IUCN Red List categories and criteria version 3.1, respectively. The results revealed that the distributions of Water Onion generated by the maximum entropy (MaxEnt) model had overall prediction accuracy of 94%, which was greater than the map generated by the logistic regression (accuracy of 86%). Environmental factors contributing to the distributions were annual precipitation, mean temperature of driest quarter, maximum temperature of warmest month, elevation, alluvium soil, land use type and distance to dredging. The predicted extent of occurrence covered 126 km<sup>2</sup> in Ranong and Phang-Nga provinces. As compared to previous studies, the extent of occurrence of Water Onion is to continuing decline and shows extreme

fluctuation. Therefore, Water Onion is categorized as endangered species. Essential measures for long-term conservation include *in-situ* conservation in suitable habitats and propagation for domestic and international trading rather than collection from natural habitat.

Keywords: Crinum thaianum, Water Onion, Species distribution model, Conservation status

#### I. INTRODUCTION

The Water Onion (*Crinum thaianum* J. Schulze) is an aquatic plant in Amaryllidaceae family listed as endemic species found only in southern Thailand, especially Ranong and Phang-Nga provinces. Water Onion prefers wet. area, riverside or the flat plain in running stream and having wet-dry climate seasonal cycle. Its growth increases in wet. season and declines in dry season. Water Onion plays important roles in sediment retention, reducing the rate of water flow and providing food for caterpillar stages of some insects. In addition, Water Onion is an important commercial plant for domestic and international trading

(Department of Agriculture, 2015).

The natural habitat of Water Onion is severely fragmented due to deforestation, land use change and dredging. Based on limited survey, Soothornnawaphat (2010) indicated that the remaining habitat of Water Onion in Thailand covered only 1.90 rai or less than 1 ha. It is most likely however that this species may exist in remote streams in Ranong, Phang-Nga and nearby provinces. In connection to this, there is a global and national concern about over exploitation of Water Onion and its conservation status. The objectives of this research were to investigate the current extent of occurrence and to assess the conservation status of Water Onion in Thailand using species distribution models and the IUCN Red List categories and criteria version 3.1

#### II. METHOD

#### 2.1 Study area and sampling

The research was conducted in Ranong and Phang-Nga Provinces in southern Thailand. The study area was sub-divided into 3 parts. The first part covers three districts in upper Ranong, namely Kraburi, Laoun and Mueng Ranong. The second part is located in four districts (Kraper, Suksamran, Kruraburi and Takaopha) of lower Ranong and upper Phang-Nga provinces. In addition, the third part area covers 6 districts in lower Phang-Nga province, including Kapong, Mueng, Thaimeung, Thabpud, Takouthung and Kaoyoa. Actual ground survey was carried out in parts 1 and 3 because these areas have not been investigated. Occurrence data in part 2 were gathered from previous studies (Ranong Provincial Natural Resources and Environment office, 2012; Soothornnawaphat, 2010; Thailand Institute of Scientific and Technological Research, 2013). Seventy-five percentage of the sample point data was used to generate species distribution models, while the remaining 25% was kept as independent data to test the omission errors.

Assuming that the surveyed localities without occurrence data for each species have a higher probability of being considered as reliable absences, we randomly selected a similar number of these probable absences to estimate commission errors.

#### 2.2 Environmental factors for species distribution

Potential environmental factors that may contribute to the distributions include 17 variables from 4 datasets. Physical factors include elevation, slope, aspect, soil group and accumulated flow. Bio-physical factors consist of land use and normalized difference vegetation index (NDVI) derived from Landsat-TM data. Six annual and seasonal bioclimatic variables important in species distribution include annual mean temperature, maximum temperature of warmest month, mean temperature of driest quarter, annual precipitation, precipitation of wettest quarter and precipitation of driest quarter. In addition, human pressures that influences its distribution include distance to road, distance to village and distance to dredging. All environmental variables were geo-referenced and resampled to grid cell of 30 x 30 m resolution for spatial analyses.

#### 2.3 Species distribution modeling

Two species distribution models were selected to map the predicted extent of Water Onion.

1. Logistic regression is a multivariate statistical technique to predict a binary dependent variable (presence or absence) before entering them in the model (Atkinson and Massari, 1988). It is one of common species distribution modeling techniques (Trisurat et. al., 2011). In this research, it was used to estimate the probability of the occurrence of Water Onion in the landscape. The logistic regression model is written as:

Prob <sub>event</sub> = 
$$e^{Zi}$$
  $1+e^{zi}$ 

Where Z, is the linear combination model of species I (Water Onion) as follows:

Z= 
$$\beta_0$$
 +  $\beta_1 X_1$  +  $\beta_2 X_2$  +...+  $\beta_n X_n$   
 $\beta_1$  = coefficient

Xi = independent variables (environment factors)

The probability values derived from the regression models range from 0.0-0.1. The higher the value, the greater the likelihood of occupancy of the Water Onion and the lower value suggests an unlikely occurrence. A cut-off value of 0.5 was used for binary classification. Thus, any pixel containing the probability values equal or greater than 0.5 was categorized as presence, otherwise classified as absence.

Besides contingency table, the performance of the logistic regression model was assessed by using the area under curve (AUC) of a receiver operating characteristic curve (ROC) (Hosmer and Lemeshow, 2000).

2. Maximum entropy (MaxEnt) which operates by establishing a relationship between a presence-only data and ecological variables within that region and then identifying other suitable areas (Phillips et. al., 2006). Default setting in MaxEnt as outlined in Phillips and Dudik (2008) were used and a 25% random test percentage and five cross validate replicated runs were applied. The performance and accuracy of MaxEnt were evaluated similar to the logistic regression model.

#### 2.4 Assessment of conservation status

The current conservation status of Water Onion in Thailand was evaluated using the IUCN Red List categories and criteria version 3.1 (**criterion** Geographic range in the form of B1-predicted extent of occurrence (IUCN, 2001).

#### III. RESULTS

#### 3.1 Distribution of Water Onion

The results of the logistic regressions indicated that elevation, NDVI, annual mean Temperature, max Temperature of warmest month, annual precipitation, precipitation of wettest quarter, precipitation of driest quarter, dredging, distance to village and distance to road were significantly related to the distribution of Water Onion as shown below.

Where:

dem = elevation (meter)

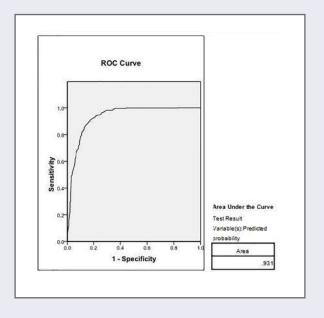
NDVI = normalized difference vegetation Index

bio\_1 = annual mean temperature

bio  $5 = \max$  temperature of warmest month

bio 12 = annual precipitation

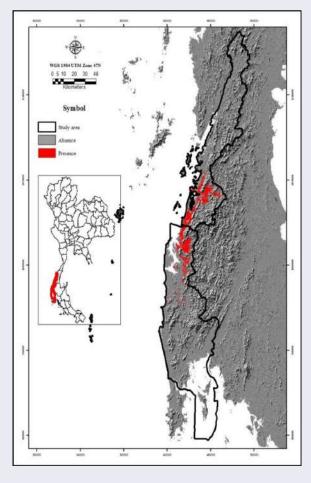
bio 16 = precipitation of wettest quarter



**Fig.1** The area under curve (AUC) for Water Onion from logistic regression

bio\_17 = precipitation of driest quarter, dred = dredging Village\_dist = distance to village road dist = distance to road

The performance of logistic model was excellent (AUC = 0.93; Fig.1). In addition, the overall prediction accuracy was 85.77%. The predicted distributions of Water Onion cover an area of 395.07 km² or 0.08% of the study area (Fig.2). Suitable areas were located in Mueng Ranong, Kraper, Suksamran, Kruraburi, Takaopha Kapong, Thaimeung districts.



**Fig.2** The distribution of Water Onion in Thailand by logistic regression

#### 3.2 Maximum entropy (MaxEnt)

The probability of distribution of Water Onion was classified by using the equal training sensitivity and specificity logistic threshold because it provided the highest accuracy among 93.72 logistic thresholds (85.77). The logistic value of 0.31 was used for binary classification. The likely distributions for Water Onion cover an area of 126.08 km<sup>2</sup> (Fig.3).

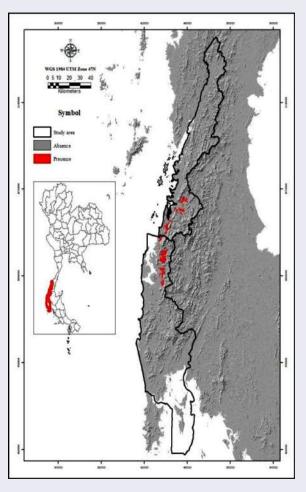
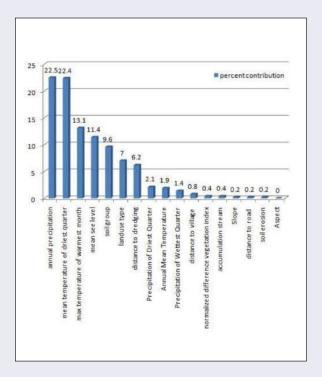


Fig.3 The distribution of Water Onion in Thailand by MaxEnt

The result revealed that the distributions of Water Onion generated by the maximum entropy (MaxEnt) model had overall prediction accuracy of 94%, which was greater than the map generated by the logistic regression (accuracy of 86%).

The AUC value of MaxEnt model was 0.97 and its overall prediction accuracy was 93.72%. Among the 17 environment factors, annual precipitation made the highest percentage contribution to spatial distribution model, followed

by mean temperature of driest quarter, maximum temperature of warmest month, elevation, alluvium soil, land use type and distance to dredging. The lowest contribution was from aspect. (Fig.4)



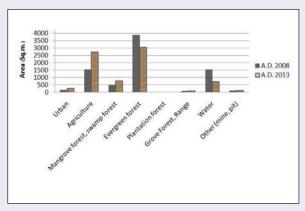
**Fig.4** Relative percentage contribution of environmental variables to Water Onion distribution according to MaxEnt model

## 3.3 The conservation status of the Water Onion plant in Thailand

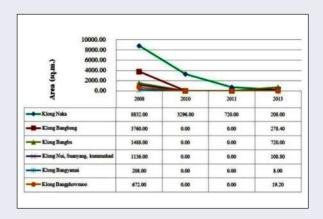
The predicted distributions derived from the MaxEnt was used to evaluate the conservation status for Water Onion because it generated higher accuracy than the logistic regression model. Based on the criterion B1 of the IUCN Red List categories and criteria (IUCN, 2001) Water Onion is categorized as an endangered species. This is due to the fact that the current extent of occurrence covers approximately 126 km². In addition, it shows a continuing decline during the last decade. Soonthornnawaphat et. al. (2011) reported that suitable habitats of Water Onion covered less than 641 km². Further evidence showed that

Water Onion disappeared from Klong Namdang, Klong Kapur and Klong Tumnung and its population had dropped by 25% during 2008-2013 (Thailand Institute of Scientific and Technological Research, 2013).

Besides, there was an extreme fluctuation in many of number of locations or sub-populations, where water onion could be found in the span of 3 years. That decrease of 80% (Fig.5) could be due to the dredging, land reclamation activities, and the drastic drop of population that reaches the reproductive stage. From this, within a period of 4 years there has been 98% decrease in Klong Naka, 92% in Klong Bangbong, 90% decrease in Klong Nui/Klong Suanyang/ Klong Kumnunhud and 97% decrease in Klong Bangboamoo (Fig.6).



**Fig.5** Land use Change in Ranong and Phang-Nga Province, Thailand



**Fig.6** Extreme fluctuation of sub-populations of Water Onion

#### IV. DISCUSSION

- 4.1 Using a simulation as base to create a mapping of the predicted distributions will result in high number of discrepancy with the true number. This is due to most of the area where the vegetables found are in streams with an average width of less than 15 meters while the simulations are usually run on a model with the minimum width 30 meters.
- 4.2 The status of Water Onion right now is close to being upgraded to critically endangered. This is due to the area of occurrence being only 26 km<sup>2</sup> greater than the area defined for critically endangered. In a worse case scenario, it may become extint in the wild in near future because of a severe drop of suitable habitat by 80% in 3 years (2008-2011). Therefore, effective measures to protect and to conserve the Water Onion in a natural habitat (in-situ conservation) for long-term viability and propagation for domestic and international trading rather than collection from natural habitat, are urgently needed. If the above measures cannot lessen its threats, it is prposed that it should be listed in the CITES Apendix III following the treaty under the trades between countries relating to endangered fauna and flora.

#### ACKNOWLEDGMENT

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# Mass awareness as an effective tool for biodiversity and wildlife conservation

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Abstract-Biodiversity is the variety of life in an area as determined by number of different species. Awareness is a fundamental need for conservation of wildlife and biodiversity. Department of Zoology, University of Lucknow, Lucknow, Uttar Pradesh (UP) has done various awreness programmes in collaboration with U.P. State Biodiversity Board, RSC (Regional Science Centre) and CEE (Centre for Environment Education) to provide an opportunity to open up a whole new world of curiosity and interest as well as sensitize local people regarding the value and need for conservation. The major tools for mass awareness incorporates distribution of awareness materials in English and in Hindi (pamphlets, flyers, posters, calenders). Since 2009 various awareness programmes related to wildlife and biodiversity regularly being organized as Exhibitions, Competitions, Awareness car, Field trips, Workshops, Training Programmes, lectures, wildlife movies. Involvement of media has also emerged as an effective way of spreading awareness. According to a Green Calender we celebrate different days and weeks related to Wildlife and Biodiversity such as 2<sup>nd</sup> February World Wetlands Day and 20<sup>th</sup> March World Sparrow Day. In our country different animals have their mythological importance such as snake associated with Lord Shiva, Lion associated with Goddess Durga

which also helps to encourage and sensitize the general people regarding conservation.

#### **INTRODUCTION**

Awareness Programmes provide an opportunity to open up a whole new world of curiosity and interest as well as sensitize local people regarding the value and need for conservation of natural resources biodiversity apart from environmental issues. The environmental conditions are deteriorating day by day due to human negligence and population pressure. So there is an urgent need to increase awareness and sensitize the local people, especially teachers and students of educational institutes and general public to know their environment and the existence of upcoming problems leading to decline or extinction of species. Due to increasing population pressure, urbanization, industrial development and change in climatic conditions the number of floral and faunal species will decline rapidly.

The human impact on the global environment has triggered a mass extinction event of significance on a geological time scale as well as causing widespread changes in the global distribution of organisms (Chapin *et. al.* 2000; Thomas *et. al.* 2004). Advocacy, education and awareness raising are cross-cutting components aimed at all possible actors.

Mass awareness focuses on four key approaches:

- · campaigns
- participatory learning
- informal education
- formal school-based interventions.

Public awareness and education programmes can be started modestly, and tailored to meet, the needs of specific populations, risks, and target, groups. These approaches can be integrated into almost all existing initiatives, whenever and wherever they take place. They can build on and support existing volunteer mobilization and peer-to-peer communications.

The Convention on Biological Diversity (CBD) recognises that humans are a major force in changing nature. Vast parts of the earth's surface are transformed to meet. human needs and wants for agricultural production, water, energy, urbanisation, construction, tourism, transport and industry. In the process humans are causing threats to and massive extinction of species, depleting natural resources, reducing ecosystems and unwittingly increasing threats from natural disasters. Cultural practices that use particular species for ceremonies or medicinal purposes can put pressure on people to act in certain ways that threaten species. With climate warming, threats to the diversity of life on earth and to human well-being increase.

#### What is CEPA?

Article 13 of the Convention on Biological Diversity directs the Parties to promote and encourage understanding and develop education and public awareness programs. This Article has been interpreted in subsequent decisions to encompass communication, education and public awareness or CEPA. It is not enough to simply tell people about biodiversity and what is happening so that they can correct what they do. The changes required will not come about

by rational individual choice alone. Biodiversity planners need to think differently about using communication, educationand public awareness rather than just as a way to make scientific information available to the public.

#### What does CEPA mean?

CEPA stands for Communication, Education and Public Awareness and is a term introduced for the work program of the CBD on this cross cutting theme.

- CEPA deals with the processes that attract motivate and mobilize individual and collective action for biodiversity.
- CEPA comprises a broad range of social instruments including information exchange, participatory dialogue, education and social marketing.
- CEPA brings out common interests amongst stakeholders to conserve and use resources sustainably.
- CEPA provides the means to develop networks, partnerships and support knowledge management.
- CEPA provides the ways to manage the processes of multi stakeholder dialogue, and to gain cooperation of different groups.
- CEPA includes action learning or action research as means to learn reflectively from experience, such as in adaptive management.
- CEPA provides the tools to develop capacity to support biodiversity.
- CEPA is a change management process vital to implement National Biodiversity Strategies and Action Plans (NBSAPs).

#### The terms associated with CEPA

C for communicating, connecting, capacity building, change in behaviour;

E for educating, empowerment (learning and professional updating);

**P** for public, public awareness, public participation, policy instrument;

A for awareness, action, action research.

## Education as a Vehicle for Behavioural Change

The decade 2005-2014 was selected as the United Nations Decade of Education for Sustainable Development. The aim was "to promote education as the basis for a more sustainable human society and integrate sustainable development into education systems at all levels". Education for Sustainable Development (ESD), sometimes called Education for Sustainable Living (ESL) or Education for Sustainability (EfS), evolved partially out of Environmental Education (EE) and is one of the ways in which information on how to achieve a more sustainable way of living has been disseminated among wide portions of society in many countries. Environmental education was first propounded in the Belgrade Chapter (UNESCO-UNEP 1976) with the goal of "a world population aware and concerned about the environment and associated problems and which has the knowledge, skills, attitudes, motivations, and commitment to work individually and collectively toward solutions for current problems and prevention of new ones".

Even though growing public awareness about environmental issues is evident, lack of adequate environmental knowledge can play a big role as an obstacle towards achieving a sustainable future for humankind at both global and local scales.

There is urgent need for effective mass communication strategies to create environmental awareness among the rural people in the world.

Proper education and awareness campaigns regarding the importance of Biodiversity and environmental issues are vital to enhance the protection and wise use of natural resources, and to reach a sustainable future in any community. This study distinguishes and relates environmental awareness and environmental education, and the affects that how they are successfully implemented.

#### **Environmental Education in Children:**

Childhood is perhaps the age that fathers the most important memories in a person's life. Most adults retain and unconsciously use information commencing from upbringing experiences. It is during this early stage where personality begins to take form. Almost everything that children learn is provided in different ways by the outside world. The natural environment is a significant component in this learning process.

Children are very emotional and sensitive about everything they learn. They can easily be attracted or repelled by any topic. Environmental education must not be presented to them with a sense of doom or disaster so they don't avoid or dislike it. If they feel the natural world is a universe of problems they might not want to deal with it at all. Children should be given a chance to bond with the natural world before they are asked to heal it.

Kids learn better when they practically do activities like taking part in debate competitions, drawing competitions, quiz competitions, Rangoli competitions with their themes based on Biodiversity and Wildlife. They should become aware and focused first on local issues and globalize later. Therefore students of different age groups are involved accordingly in these events on every day according to Green Calender. Only after they are able to think in an analytical manner can they learn in a global way.

Environmental Education and community conservation needs should be viewed in a continuous and progressive perspective. In this way in rural areas, parents and other adults could also get benefit from them. Knowledge gain passed on from children to parents (and

other adults) indicates that awareness can be delivered in a consecutive way from the classroom to the community.

#### Effective Use of Media:

The media plays an important role in environmental education because it is through newspapers, magazines, radio, and television that people gain awareness. Awareness is a major step in Environmental education. We publish articles related to wildlife and Biodiversity in environmental magazines, newsletters, and journals, along with radio programs. Communicating environmental information is very challenging due to the dynamics and complexity of natural systems. The ways in which science has conventionally related with society must be reassessed and adapted to get. in touch with current environmental and social realities. With good design, media can offer us good communication tools that can be used as educational aids to reduce the gap between scientific knowledge and civic awareness. Scientific groups, journalists and non-governmental organizations like CEE (Centre for Environment Education) play a major role in environmental public education processes.

Month	Date	Event
February	2nd	World Wetlands Day
March	20th	World Sparrow Day
April	Last Saturday	Save the frogs Day
	of April	Biodiversity Festival
May	16 -21st	International Day for
	22nd	Biological Diversity
June	5th	World Environment Day
September	1st Saturday	International Vulture
	of September	Awareness Day
October	1st-7th	Wildlife Week

#### Awareness According to Green Calendar

#### Various awareness programmes celebrated:

- ➤ World Wetlands Day (2<sup>nd</sup> February) for awareness and conservation of remaining wetlands.
- World Sparrow Day (20th March) for awareness and conservation of the little sparrow
- ➤ Save The Frogs Day (Last Saturday of April), for awareness and conservation of Frogs
- ➤ Biodiversity Festival (16<sup>th</sup>-22<sup>nd</sup> May) on the occasion of International Day for Biological Diversity
- ➤ World Environment Day (5th June)
- ➤ International Vulture Awareness Day (First Saturday of September) for conservation of this endangered species
- Wildlife Week (1-7 October), for awareness about the wild animals and other flora and fauna

#### **World Wetlands Day**

- The 2<sup>nd</sup> February, the day when the Ramsar Convention was signed in 1971, is the **World Wetlands Day**. It marks the anniversary of the signing of the Convention on Wetlands of International Importance (Ramsar Convention) in Ramsar, Iran, on 2<sup>nd</sup> February 1971.
- World Wetlands Day was **first celebrated in 1997**. Since then government agencies,
  non-government organizations and community
  groups have celebrated World Wetlands Day
  by undertaking actions to raise public
  awareness of wetland values and benefits and
  promote the conservation and wise use of
  wetlands.
- World Wetlands Day (2<sup>nd</sup> February): we were celebrating world wetlands day form 2013 to 2016 for awareness and conservation of declining number of wetlands biodiversity



Fig.1 World Wetlands Day, 2<sup>nd</sup> February



Fig.2 Wetlands awareness car flag off



Fig.3 Awareness among students



Fig.4 Interaction with local people



Fig.5 Interaction with forest personnel during survey



Fig.6 Sparrow Day was first celebrated in 2010

#### **World Sparrow Day**

- The first World Sparrow Day was celebrated in 2010 in different parts of the world by Nature Forever Society. The day was celebrated by carrying out various kinds of activities and events like art competitions, awareness campaigns, and sparrow processions as well as interactions with media.
- To encourage efforts made towards this cause and to selflessly conserve the environment, Nature Forever Society instituted the first Sparrow Awards in Ahmedabad, Gujarat, on 20th March 2011.
- World Sparrow Day (20<sup>th</sup> March): We have celebrated World Sparrow Day from 2012 to 2016 for awareness and conservation of the declining Sparrow number in Lucknow district.





Fig.7 Some photographs of World Sparrow Day



Fig.8 Awareness through sparrow nest box stall



Fig.9 Sparrow nest-Box distribution

#### Save the Frogs Day

- SAVE THE FROGS! is America's first public charity dedicated exclusively to amphibian conservation. SAVE THE FROGS! was founded by Ecologist Dr. Kerry Kriger in May 2008.

- SAVE THE FROGS! is the world's leading amphibian conservation organization. Our mission is to protect amphibian populations and to promote a society that respects and appreciates nature and wildlife.
- Save The Frogs Day (Last Saturday of April): We celebrated a Save The Frogs day from 2012 to 2016.



Fig.10 Save the Frogs Day

## Biodiversity Festival (16<sup>th</sup>-22<sup>nd</sup> May) on the occasion of International Day for Biological Diversity

- In December **2000**, the **United Nations** General Assembly adopted 22 May as IDB (International Day for Biological Diversity), to commemorate the adoption of the text of the Convention on 22 May 1992 by the Nairobi Final Act of the Conference for the Adoption of the Agreed Text of the Convention on Biological Diversity.
- Biodiversity Festival (16<sup>th</sup>-22<sup>nd</sup> May): We celebrated a Biodiversity Festival from **2013 to 2016** for awareness and conservation of Floral and Faunal diversity.



Fig.13 Awareness material distribution



Fig.11 Workshop for students



Fig.14 Plant identification



Fig.12 Nukkad-Natak

#### **World Environment Day**

- The World Environment Day was established by the United Nations General Assembly in 1972. Currently in its 42nd edition, the first Environment Day was celebrated in 1973. India hosted the World Environment Day 2015 under the theme, "One World, One Environment".
- WORLD ENVIRONMENT DAY (5<sup>th</sup> June): We celebrated World Environment Day from 2010 to 2016.



Fig.15 Signature campaign



Fig.17 Awareness among school students



Fig.16 World Environment Day (5th June)



Fig.18 Awareness amongst students

## **International Vulture Awareness Day** (First Saturday of September)

- The International Vulture Awareness Day has grown from Vulture Awareness Days run by the Birds of Prey Programme in **South Africa** and the Hawk Conservancy Trust in England, who decided to work together and expand the initiative into an international event.
- This event which was celebrated for the **first time in 2009,** provides a central place for all participants to outline these activities and see the extent of vulture conservation across the world.



Fig.19 Public interaction



Fig.20 Lecture on Vultures

#### Wildlife Week (1st-7th October)

- In the year 1952 with a view to preserve the fauna of India, particularly to take urgent steps to prevent extinction of any species, the Government of India established an Indian Board of Wild Life (IBWL). The Board has since been doing pioneering work to arouse public consciousness in favor of wildlife preservation.

   To arouse a general awakening in the common
- To arouse a general awakening in the common man in favour of protection of wildlife, the Indian Board of Wild Life (IBWL) decided to observe the Wildlife Week and since then from October 2<sup>nd</sup>-8<sup>th</sup> every year organize different activities related to wildlife conservation to commemorate this week.

**Wildlife Week** (1<sup>st</sup>-7<sup>th</sup> October): We celebrated Wildlife Week from **2008 to 2015** for awareness and conservation of wildlife. Notice the use of tiger masks ("Tiger faces").



Fig.22 Rangoli by participant



Fig.23 Wildlife play

One Day Training Programmes on Biodiversity awareness and conservation, workshops on Vulture conservation, House Sparrow conservation and Wetlands conservation for students, teachers, forests guards and local people are also organized from time to time. Every year vulture census and Sparrow counts are also initiated.



Fig.21 Wildlife Week



Fig.24 Puppet. show



Fig.26 Nature trail



Fig.25 Games on wildlife



Fig.27 Awareness car

Table 1 Event wise celebration of days from green calendar

EVENTS	A	В	С	D	Е	F	G	Н	I	J	K	L
DAYS												
World	✓	✓								✓		
Wetlands												
Day												
World	<b> </b>	✓	✓	✓	✓		✓	$\checkmark$	✓			$\checkmark$
Sparrow												
Day												
Save the		✓	✓	✓		✓		✓			✓	✓
Frogs Day												
Biodiversity	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Festival												
International												
Day for												
Biological Diversity												
World												
Environment												
Day												
International	<b>√</b>	<b>√</b>	<b>√</b>			<b>√</b>		<b>√</b>		<b>√</b>		<b>√</b>
Vulture												
Awareness												
Day												
Wildlife	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Week												

#### **Abbreviations:**

- A QUIZ COMPETITION
- B LECTURE
- C PAINTING COMPETITION
- D SLOGAN WRITING
- E TATTOO COMPETITION
- F POWERPOINT COMPETITION
- G NUKKAD NATAK
- H RANGOLI COMPETITION
- I PUPPEt SHOW
- J NATURE TRAIL
- K GREETING CARD
- L AWARENESS STALL

#### Workshops

- ➤ To train volunteers for raising general awareness regarding habitat conservation and providing water and food regularly to birds.
- > To enhance student awareness and residential people of the area to conserve the rapidly declining species.
- ➤ To bring the students and local people closer to nature. The children nowadays are more used to watching TV, playing video games and surfing the Internet. than doing something that is close to the nature. The workshops help to counter three trends.



Fig.28 Some of the photographs of workshops organized

- ➤ During the last 8 years, a total of 1,600 schools, 1,000 colleges and 5 universities representing about 12,000 students of higher secondary, graduates and postgraduates were involved together with 10,000 local People.
- > Programmes are also associated with
- distribution of plants as mementos and books as prizes.
- ➤ Currently, 2,100 plants and 2,500 of books related to Biodiversity, Wildlife and Environment have been distributed together with the circulation of 50,000 items of awareness material.

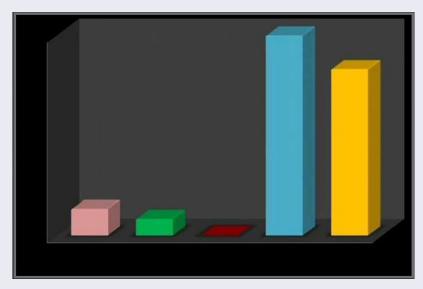


Fig.29 Schools, colleges, universities, students and local people involved from 2007-2016



Fig.30 Awareness through mobile exhibition on biodiversity: Prakriti Bus

#### **About the Bus**

- Name of the bus is "Prakriti" in Hindi which means Nature.
- It runs on Compressed Natural Gas, helps to create awareness and motivation to use CNG, a clean fuel.
- CEE team developed the content and designed the exhibition with technical inputs, photographs, references etc. from UP State Biodiversity Board and University of Lucknow.
- Several institutions working on biodiversity conservation in UP also contributed with photos and references.

#### Structure of Exhibition

- Exhibition includes eighteen panels (24 panels)
  - Understanding Biodiversity, Eco Zone of India and UP
  - River Biodiversity
  - Wetlands Biodiversity
  - Agriculture, horticulture, livestock biodiversity
  - Forest Biodiversity
  - Threats to Biodiversity and Conservation efforts



Fig.31 A bus that promotes hand print action ideas for visitors as take back messages

## Experiences with Prakriti Bus (Aug 2014-June 2016)

A good response has been achieved from this Prakriti Bus to help younger students, elder/college students, youth, teachers/principal, rural community, urban community, as mobile media.

#### **Educational Activities**

 Science Educators travel with the bus for facilitating and conducting educational activities.

- Games are conducted around bus focusing on biodiversity to reinforce conservation messages.
- Biodiversity Quiz for visitors of the exhibition.
- A variety of other educational resources such as posters, brochures, are also disseminated.
- "Map biodiversity of your School Campus" has been announced for schools to promote documentation.



Fig.32 Education Activities

#### Outreach of bus

- Prakriti Bus started its journey from 4 August, 2014
- Networking with Education Department, Forest Department and other block level officials for planning visits of the bus in different districts of Uttar Pradesh
- Overall status of outreach of the bus:
  - Total Visitors: 238, 326
  - Total No. of Schools and Colleges Visited: **385**
  - Total Villages and Communities Visited: 125
  - Total Kilometers travelled by bus: **Over 16.973**
  - Number of District/s travelled: 13

(Lucknow, Barabanki, Kannauj, Unnao, Hardoi, Sitapur, Kanpur, Faizabad, Agra, Bahraich, Etawah, Raibaraeli, Fatehpur)

#### **Educational material**

- Brochure on the bus in Hindi
- Oath cum certificate for schools where bus visits
- Flyers for visitors
- Cap with bus logo as prize for quiz winners
- Prakriti Bus mug as souvenir for guests
- Pamphlet. on Biodiversity Campaign in English and Hindi. Campaign was launched during wildlife week.
- Booklet. on Biodiversity of Uttar Pradesh as reference material
- Set. of posters on Biodiversity and National Targets

#### **Outcomes**

- Bus has reached to good number of visitors including school children, teachers, youth, common masses, media, urban and rural community.
- Bus acts as resource centre to create awareness about environment and sustainability with a focus on biodiversity of Uttar Pradesh.
- It is able to create higher interest level among the students, teachers and local

- community towards biodiversity conservation.
- Bus is helping to enrich classroom experience by bringing biodiversity as core concept.
- It is also helping in assessing effectiveness of such medium for reaching masses, youth and schools. Bus also motivates students to document biodiversity around them.

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# Identification of a natural mangrove hybrid of Rhizophora in Thailand using SNPs in nuclear and chloroplast regions

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Abstract-One vigorously established 9 m tall putative hybrid of Rhizophora mucronata and R. apiculata was found in the regenerating mangrove forest within the Sirindhorn International Environmental Park (SIEP) at Phetchaburi Thailand. To confirm the hybrid status of this tree, nucleotide variation was examined at three nuclear regions together with one chloroplast region. The nuclear regions were DLDH, SBE2 and FMRrmll; atpB-rbcL spacer was the chloroplast region. All were PCR amplified and sequenced. The single nucleotide polymorphisms (SNPs) in the three nuclear regions demonstrated nucleotide variation specific to R. mucronata and R. apiculata. The putative hybrid displayed the same nucleoptide polymorphisms as those from both R. mucronata and R. apiculata, thus revealing that this hybrid is a natural hybrid of R. mucronata and R.

apiculata. The single nucleotide polymorphisms in atpB-rbcL chloroplast region in the hybrid were identical to those of *R. mucronata*, showing that the mother tree of this hybrid was *R. mucronata*. This finding may present useful genetic resources for mangrove reforestation in more challenging habitats where hybrid vigour may be advantageous.

Keywords: natural hybrid, Rhizorphora mucronata x R. apiculata, single nucleotide polymorphisms (SNP's) novel hybrid vigour.

#### I. INTRODUCTION

There are approximately 73 species and hybrids described as true mangroves distributed worldwide (Spalding et. al., 2010). Thailand has 34 species designated as true mangroves (Department of Marine and Coastal Resources,

2016). Natural hybridization is common in plants and has been observed with mangrove species. Putative hybrids have been reported within the major genera of Rhizophora, Sonneratia, Lumnitzera and Brugueira (Tomlinson, 1986; Duke and Ge, 2001). To identify natural hybrids of the mangroves *Rhizophora apiculata, R. mucronata* and *R. stylosa* in Malaysia Ng et. al. (2013) and Ng and Smidt (2013) used single nucleotide polymorphisms (SNPs) from nuclear genomes.

In Thailand one putative hybrid of Rhizophora spp. was discovered at Sirindhorn International Environment Park (SIEP), Cha-am, Phetchaburi Province (12°42′ 17.57"N; 99°57′ 43.67"E). At the time of discovery this hybrid had the following attributes: height 9.0 m; Girth above uppermost prop roots 40.0 cm with prop roots of 20 cm in girth. Rhizophora mucronata and R. apiculata trees near this hybrid were only 5.8 m in height. While leaf size of the hybrid did not differ from those of parental types, some colour pigmentation differences were observed near the base of the midrib: here R. mucronta was light green, R. apiculata was red and the putative hybrid displayed a much lighter red pigmentation. Likewise, differences were displayed in flower attributes; those of R. apiculata were paired on short stalks; R. mucronata flowers were organized in groups of 3-8 flowers on long stalks. Those of the putative hybrid were paired with a 2-3 cm stalk (Figure 1).

Interestingly, some hybrid prop roots were oriented on angles greater than 90 degrees from the main trunk in contrast to those of *R. apiculata* which displayed more typical angles of 90 degrees or less. Additionally, the hybrid produced many branches within the prop root zone (Figure 2).

Based on these observations of morphological attributes the aim of this study was to seek evidence that this hybrid was in fact a putative hybrid of two Rhizophora species using SNPs from nuclear and chloroplast regions.



**Fig.1** Leaves and flowers of putative hybrid (above), *Rhizophora mucronata* (left) and *Rhizophora apiculata* (right)



Fig.2 Prop roots of hybrid mangrove

#### II. MATERIALS AND METHODS

Leaf samples from individual trees of 1 Rhizophora apiculata, 1 Rhizophora mucronata and 1 putatively natural mangrove hybrid were collected from the Sirindhorn International Environmental Park, Phetchaburi, Thailand. Leaf samples were stored in silica gel before further analyses. DNA extraction, PCR amplification, and sequencing. Genomic DNA was extracted from approximately 20 mg of silica gel-dried leaf material using the DNeasy Plant Mini Kit (QIAGEN). One chloroplast DNA (cpDNA) region: atpB-rbcL intergenic spacer; and 3 partial nuclear gene (nDNA) regions: DLDH (dihydrolipoamide dehydrogenase), SBE2 (starch branching enzyme) and FMRrm11 were amplified from the genomic DNA of R. apiculata (Figure 3)

*R. mucronata* (Figure 4) and putatively natural mangrove hybrid (Figure 5 and 6).

Genomic DNA was extracted from approximately 20 mg of dried leaf material using the DNeasy Plant Mini Kit (QIAGEN). Three nuclear regions: DLDH, SBE2 and FMRrm11 and One cpDNA region: atpB-rbcL intergenic spacer were PCR-amplified in all sampled individuals. The primers used for PCR are listed in Table 1. Primers for loci atp-BrbcL, DLDH, and SBE2 were previously described by Inomata et. al. (2009), while the primers for the FMRrm11 locus were described by Cerón-Souza et. al. (2010). PCR amplifications were performed in 20 µl reaction mixtures, each containing 10-50 ng of genomic DNA, 1×Ex-Taq buffer (2 mM of Mg2+), dNTP mixture (0.2 mM of each dNTP, 0.2 µM of each primer, and 1.0 U of Ex-Taq DNA polymerase. The



Fig.3 Rhizophora apiculata



Fig.4 Rhizophora mucronata



Fig.5 Putative hybrid

PCR reaction profile comprised an initial denaturation of 3 min at 95°C; followed by 35 cycles of 30 s at 95°C, 30 s at Ta, and 2 min at 72°C; and finally an extension step at 72°C for 7 min. Purified PCR products were used for direct sequencing. Sequencing reactions were carried out using the BigDye® Terminator v3.1 Cycle Sequencing Kit (Applied Biosystems) and analyzed on an ABI 3730 DNA Analyzer (Applied Biosystems). Data analyses Nucleotide sequences were assembled and edited using the software BioEdit version 7.2 Sequences of each locus were then aligned using ClustalW (Thompson *et. al.* 1997).

#### III. RESULTS

The final aligned lengths of the nDNA loci were 1221 bp for DLDH, 947 bp for SBE2 and 609 bp for FMRrm11. Species-specific sites were observed at all the loci. The putative natural hybrid individual from SIEP

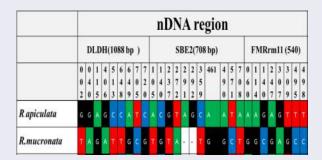


**Fig.6** Pictures of *Rhizophora mucronata* putative hybrid of Rhizophora and *Rhizophora apiculata* 

Table 1 PCR primers used in this study

Locus	Primer sequence (5'-3')	Source									
cpDNA re	cpDNA region										
atpB- rbcL spacer	F: GAAATGGAAGTTAGCACTCG R: AAGATTCAGCAGCTACCGCA	Inomata et al. (2009) Ng et al. (2015)									
nDNA region											
DLDH	F: TGGATGGTCATATAGCTCT R: GAACAAGCTCCCCTGCATTAG	Inomata et al. (2009) Ng et al. (2015)									
SBE2	F: CAAAGTTTGTGAGTCTTATC R: GTCCTGACATTAAAACAGCC	Inomata et al. (2009) Ng et al. (2015)									
FMRrm11	F: TTTCTATTTATGATCCCATCATCTC R: GCGTTTAACTGCCACAATTC	Cerón-Souza et al. (2010) Ng et al. (2015)									

had the same single nucleotide polymorphisms as from both R. mucronata and R. apiculata (Figure 7). This reveals that the putative natural hybrid is a natural hybrid of R. mucronata and R. apiculata. As the chloroplast genome is inherited uniparetally, to identify which Rhizophora species would be the mother tree of the natural hybrid, the DNA sequence of the cholorplast gene (atpB-rbcL intergenic spacer) from R. apiculata, R. mucronata and the putative hybrid was compared. The natural hybrid individual from SIEP had the same single nucleotide polymorphisms as R. mucronata. As shown in Figure 8 the results indicate that R. mucronata is the mother tree of this natural hybrid.



**Fig.7** Single nucleotide polymorphisms (SNPs) which is specific to *Rhizophora mucronata*, *Rhizophora apiculata* and Putative hybrid in 3 Nucleus regions (DLDH SBE2 and FMRrm11)

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											a	tp	В	-r	b	сL	(	1	3	bį	)										Ī
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3	5	5
	1	7	7	7	8	8	8	8	8	8	8	8	8	8	9	9	4	4	4	4	4	4	4	4	5	5	5	5	5	5	7
	9	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	3	3
R apiculata	٨				*														A						G	Ť		A			G
R.mucronata	c	c	A	Ť	T	т	G	7	c	т	A	Ŧ	c	A	Ť	ī							. 4							т	i
Putative hybrid	c		A				G	1			A			A														×.			

**Fig.8** Single nucleotide polymorphisms (SNPs) which is specific to *Rhizophora mucronata*, *Rhizophora apiculata* and Putative hybrid in chloroplast region (atpB-rbcL intergenic spacer)

#### IV. CONCLUSIONS

The SNPs identified at three nuclear regions, indicated that the putative hybrid of Rhizophora found at SIEP is a natural hybrid of *R. apiculata* and *R. mucronata*. SNPs from the chloroplast region indicated that the mother tree of this hybrid was *R. mucronata*. Thus we suggest that this hybrid be named as a natural hybrid of *R. mucronata* and *R. apiculata* (*R. mucronata* x *R. apiculata*). The hybrid vigour detected in this putative hybrid point to its potential value in mangrove reforestation programs.

#### **ACKNOWLEDGMENT**

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# Genetic diversity of *Gloriosa superba* from southern India based on chemical profiling, horticultural traits and RAPD analysis

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Abstract-Genetic, morphological and chemical variations of Gloriosa superba Linn from South India were assessed using RAPD markers, colchicine content and morphological traits. An estimate of genetic diversity and differentiation between genotypes of breeding germplasm is of key importance for its improvement. Populations were collected from different geographical regions. Data obtained through three different methods were compared and the correlation among them was estimated. Statistical analysis showed significant differences for all horticultural characteristics among the populations suggesting that selection for relevant characteristics could be possible. Variation in the content of colchicine ranges from 0.192 g/100 g (population from Shimoga) to 1.312 g/100 g (population from Aliyar dam). A high diversity within population and high genetic differentiation among them based on RAPDs were revealed caused both by habitat fragmentation of the low size of most populations and the low level of gene flow among them. The UPGMA dendrogram and PCA analysis based on colchicine content vielded higher separation among populations indicated specific adaptation of populations into clusters each of them including populations close to their geographical origin. Genetic, chemical and morphological data were

correlated based on Mantel test. Given the high differentiation among populations conservation strategies should take into account genetic diversity and chemical variation levels in relation to bioclimatic and geographic location of populations. The results also indicate that RAPD approach along with horticultural analysis seemed to be best suited for assessing with high accuracy the genetic relationships among distinct *Gloriosa superba* populations.

#### I. INTRODUCTION

Gloriosa superba L., a climber belonging to the family Liliaceae is a highly valuable medicinal crop. It is one of the major medicinal plants in India cultivated for its seeds and tubers which are exported to developed countries for pharmaceutical use. In India, it is usually found in Himalayan foothills, Central India, Tamil Nadu, Andhra Pradesh and Bengal. Seeds and tubers contain valuable alkaloids, namely, colchicine and colchicoside as the major constituents, used to treat gout and rheumatism, and also for the treatment of bruises, colic, chronic ulcers, haemorrhoids and cancer [1].

Gloriosa superba was found in the wild on natural fences a decade back, but now it has been domesticated for economic gain in as much as all parts of the plant having medicinal value. In nature, less seed germination with poor viability is responsible for its diminishing population size. The poor propagation coupled with over-exploitation companies has put this plant into acutely threatened status for the local population as well as a pharmaceutical species [2]. Therefore, tracing successfully adapted variants at genetic level of *G. superba* is of immediate necessity for the long-term preservation of the species. For efficient conservation and management, the genetic composition of the species in different geographic locations needs to be assessed [3].

There are also studies on correlation between genetic diversity and variation in chemical constituents [4]. Quantitative and qualitative status of active constituents along with genetic diversity in a medicinal plant would help to devise conservation strategies and selection of right sample for maximum yield. Therefore, knowledge of genetic diversity and structure among *Gloriosa superba* populations is required for the development of

appropriate conservation and breeding programs.

Thus, we address the following questions: (i) do chemical and molecular markers provide similar conclusions about population differentiation; (ii) is there a relationship between chemical and RAPD data and (iii) what is the implication of the detected genetic variation for conservation strategies? Traditionally, genetic diversity is determined through the analyses of morphological parameters. This method includes serious limitations such as the influence of environmental conditions, giving results that represent just a part of total genetic diversity [5].

#### II. MATERIALS AND METHODS

The plant materials were collected from various parts of south India (Fig.1) during August 2015 to March 2016. A total of 10 populations of Gloriosa superba were used in this study. A complete list of populations and their sources are available in Fig.1 and Table 1.

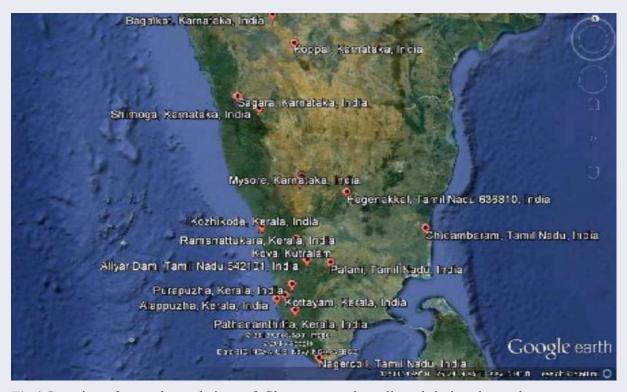


Fig.1 Location of natural populations of Gloriosa superba collected during the study

Propagules of collected plants (each population) were raised from root cuttings and plants were grown in the greenhouse of Botanical Garden, Department of Botany, Annamalai University, Annamalai Nagar, Tamil Nadu. Stem cuttings were collected from 15

individuals of each population. Individuals were chosen at random and young shoots were sprouted from the cuttings after one month of planting. From each population, 10 individuals each were selected for molecular genetic analyses.

Table 1 Populations and collection details of Gloriosa superba from the study area

Sl.no	Location	Population code	State	District	Geographic location/ latitude and longitude
1	Udaiyarpalaiyam	1	TamilNadu	Ariyalur	11.18°N, 79.29°E
2	Yelagiri Hills	2	TamilNadu	Vellore	12.57° N, 78.63°E
3	Pallakkodu	3	TamilNadu	Dharmapuri	12.29° N, 78.07°E
4	Kalrayan Hills	4	TamilNadu	Villupuram	11.85°N, 78.63°E
5	Nagercoil	9	TamilNadu	Kanyakumari	8.18° N, 77.41°E
6	Bhavani	10	TamilNadu	Erode	11.45°N,77.68°E
7	Mandya	5	Karnataka	Mandya	12.56°N, 76.73°E
8	Bangalore	6	Karnataka	Bangalore	12. 58°N, 77. 38° E
9	Kozhikode	7	Kerala	Kollam	11.25°N, 75.78°E
10	Kottayam	8	Kerala	Kollam	9.591°N, 76.52°E

The plant samples were collected from ten populations of the different geographical positions of South India. Such as Udaiyarpalaiyam, Yelagiri Hills, Pallakkodu, Kalrayan Hills, Nagercoil, Bhavani, Mandya, Bangalore, Kozhikode and Kottayam.

#### Morphological characterization

Morphological features utilized for characterization were plant height, number of branches/plant, leaf length, leaf width, number of flowers per cyme, number of fruits per cyme, tuber length and tuber yield.

## Assessment of alkaloid content of various populations of *Gloriosa superba*

Total alkaloid contents were estimated from tubers of *Gloriosa superb* collected from different habitats. 100 g of powdered dry samples

of Gloriosa superb was soaked in 200 mL methanol and left for 30 min. After 30 min, the soaked plant material was filtered. The residue obtained after filtration is further dissolved in 5 mL methanol and filtered. After 10 mins, the same step is repeated once again and the final filtrate is collected in 50 mL conical flask. The extract was evaporated to dryness in the Soxhlet. evaporator. The crude extract was dissolved in 100 mL of 0.01 M HCl. The pH of filtered solutions was adjusted to 6.0 with 0.01 M NaOH. The crude extracts obtained were used for HPLC analysis [6]. The crude extract obtained was concentrated to dryness to yield crude alkaloid fraction (CAF). The extract of each plant was transferred to 5 mL volumetric flasks separately with the help of methanol (HPL Cgrade), sonicated for a few minutes and filtered and the volume was made up to mark with methanol; 0.004% of Colchicine in methanol was used as standard.

#### Quantification of Colchicine

Identification of the colchicines was done by comparing the retention time of the sample with that of the standard obtained from Sigma. Water HPLC systems equipped with a binary pump 1525 (Max. Pressure: 6000 psi.) and a porous silica with 5 $\mu$ m diameter C18 4.6  $\times$  150 mm column was used for separation. The mobile phase consisted of Acetonitrile: 3% Acetic acid (60:40), at a flow rate of 1mL min-1 and an injection volume of 20  $\mu$ L. The peaks eluted were detected at 245 nm and identified with authentic standards.

#### Extraction of genomic DNA

DNA was isolated using a modified cetyltrimethylammonium bromide (CTAB) method [7]. For each population, about 5 g of bulked leaf tissue collected from five plants each was ground to a fine powder using liquid nitrogen and then suspended in 20 mL of extraction buffer [20 mM EDTA (pH 8.0), 100 mMTris-HCl (pH 8.0), 1.4 M NaCl, 2% CTAB, and 1% β-mercaptoethanol]. The suspension was mixed well, incubated at 60°C for 45 min, followed by chloroform isoamyl alcohol (24:1) extraction and precipitation with 2/3 of the volume of isopropanol at -20°C for 1 h. The DNA was pelleted down by centrifugation at 12,000 rpm for 10 min and suspended in TE buffer [10 m MTris-HCl, 1 mM EDTA (pH 8.0)]. The DNA was purified from RNA and proteins by standard procedures [8] and DNA concentration was estimated by agarose gel electrophoresis and staining with ethidium bromide.

#### **Primer screening**

Thirty decamer primers from Operon, Advanced Biotechnologies Inc., Almeda, USA were initially screened using one individual clone to determinate the suitability of each primer for the study. Primers were selected for further analyses based on their ability to detect distinct clearly resolved and polymorphic amplified products within the population. To ensure reproducibility the primers generating no, weak, or complex patterns were discarded.

#### PCR amplification

PCR amplification was performed in a total volume of 25 µL containing 10 × Taq buffer (2.5 µL) (Genei, Bangalore), dNTPs (2.5 µL) (10 Mm each) (Genei, Bangalore), Taq DNA polymerase (0.5  $\mu$ L) (3 U/ $\mu$ L) (Genei, Bangalore), Primer (1 μL) (40 μM/μL) (Sigma Aldrich, Bangalore), template DNA  $(0.5 \mu L)$  (40 ng/ $\mu$ L) and sterile nanopure water (18 µL) in Eppendorf Master Cycler (AG 22331 Harmburg, Germany) using the following conditions: (a) initial denaturation at 94°C for 5 min; (b) 45 cycles each consisting of denaturation step at 94°C for 1 min, annealing step at 35°C for 1 min, amplification at 72°C for 2 min step; and (c) final extension at 72°C for 5 min followed by arresting the reaction at 4°C for infinite period. Control reactions without template DNA (negative control) were also run in the experiments. All the experiments were repeated thrice to ensure reproducibility. PCR amplified products (12.5 µl) were subjected to electrophoresis in a 1.5% agarose gel in 1X Tris-borate-EDTA (TBE) buffer at 100 V for 3.5 h using submarine electrophoresis unit. The DNA profile was photographed using biorad gel documentation system.

### Data scoring and statistical analysis of RAPD data

Data of RAPD marker analysis (band size of all amplification products, estimated from the gel by comparison with standard marker) were scored as discrete variables using (+) to indicate presence and (-) to indicate

absence of bands for each primer. The faint and unclear bands were not considered for data scoring. Bands with similar mobility to those detected in the negative control were not scored. The binary data so generated were used to estimate levels of polymorphism by dividing the polymorphic bands by the total number of scored bands.

The following genetic parameters were calculated using a POPGENE computer program (ver. 32) developed by Yeh et. al. [9] the percentage of polymorphic loci (PP), observed number of alleles per locus (na), effective number of alleles per locus (ne), and Nei's [10] gene diversity and (h), degree of polymorphism was quantified using Shannon's index (I) of phenotypic diversity [11]. A dendrogram (Based [12] Genetic distance, UPGMA method) was constructed by the neighbor joining (NJ) method using the NEIGHBOR program in PHYLIP version 3.57 [13].

#### **AMOVA** analysis

The analyses of molecular variance (AMOVA, [14] were carried out on the RAPDs, to describe genetic structure and variability among the populations. The significance of F values was tested non-parametrically after 1000 permutations.

#### III. RESULTS

Morphological and phytochemical diversity among various populations of *Gloriosa* superba Evaluation of *Gloriosa* superba germplasm showed a large variation in the quantitative traits between the populations (Table 2). Leaf shape of most of the populations is thin, lanceolate, acute, bright green above and pale beneath as they have length ranging from 8.20 cm in population 1 (Udaiyarpalaiyam) to 12.10 cm in population 6 (Bhavani) and width almost equal. Maximum

plant height was found in population 2 (Yelagiri Hills) (132.91 cm) and minimum in population 4 (Kalrayan Hills) (42.91 cm). Among all populations the percent of fruit set. was maximum in population 3 (Pallakkodu) followed by population 5 (Nagercoil) and population 7 (Mandya). Number of flowers per cyme was found maximum in population 1 (Udaiyarpalaiyam) (15.2) followed by population 8 (Bangalore) (12.8) and minimum was in population 2. (Yelagiri Hills) (9.2). The other morphological variability ranges observed were number of branches per plant (2.30-8.02), root length (31.87 cm-13.03 cm), and root yield (18.75g/plant-7.11g/plant).

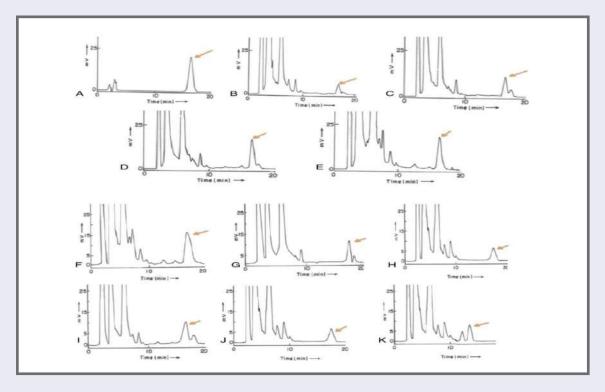
#### Quantification of colchicines content

Colchicine has shown a peak at 18.596 min retention time (Plate 1). Variation in the content of colchicine ranges from 0.192 g/100 g to 1.312 g/100 g (Table 2). Population 7 (Mandya) (1.312±0.001 g/100 g) has a maximum amount of colchicine content whereas population 2 (Yelagiri Hills) (0.192 g/100 g) has shown minimum amount of colchicine content.

Table 2 Morphological diversity of various populations of Gloriosa superba

Popula tion	Plant height (cm)	No of branches/plant	Leaf length (cm)	Leaf width (cm)	No of flowers per	No of fruits per	Tuber length (cm)	Tuber yield (g/plant)	Colchicines content (g/100 g)
					cyme	cyme			
Popl	125.92 ± 5.92 <sup>b</sup>	$5.33 \pm 0.024^{\circ}$	$8.20 \pm 0.032^{e}$	$2.9 \pm 0.099^{d}$	$15.2 \pm 0.69^{a}$	$\begin{vmatrix} 4.1 & \pm \\ 0.019^{b} \end{vmatrix}$	11.87 $\pm 1.4^{a}$	$18.75 \pm 0.87^{a}$	$0.470\pm 0.088^{\circ}$
Pop2	132.91 ± 6.41 <sup>a</sup>	$5.18 \pm 0.023^{\circ}$	9.72± 0.041 <sup>d</sup>	$3.1 \pm 0.010^{c}$	11.6 ± 0.56°	$3.9 \pm 0.013^{\circ}$	16.43 ± 1.1 <sup>b</sup>	$11.82 \pm 0.46^{b}$	0.192± 0.009°
Pop3	101.94 ± 4.91°	$8.02 \pm 0.038^{a}$	11.41± 0.97 <sup>b</sup>	$4.5 \pm 0.015^{a}$	$12.4 \pm 0.49^{b}$	$5.1 \pm 0.024^{a}$	14.70 ± 1.2°	10.46 ± 0.51°	0.463± 0.005°
Pop4	42.91 ± 1.91 <sup>g</sup>	$2.30 \pm 0.018^{e}$	$9.91\pm 0.046_{\rm d}$	$3.4 \pm 0.012_{c}$	$9.2 \pm 0.044^{d}$	2.4 ± 0.091 <sup>f</sup>	13.6 ± 0.51 <sup>e</sup>	$7.11 \pm 0.034^{\rm f}$	0.383 ±0.002°
Pop5	94.55 ± 5.22 <sup>d</sup>	$4.67 \pm 0.021^{d}$	$10.61 \pm 0.52^{c}$	$3.7 \pm 0.014^{b}$	$8.9 \pm 0.039^{e}$	$2.2 \pm 0.090^{f}$	14.87± 0.69 <sup>d</sup>	$10.61 \pm 0.52^{\circ}$	0.529± 0.029 <sup>b</sup>
Pop6	88.28 ± 3.93 <sup>e</sup>	$5.00 \pm 0.022^{\circ}$	$12.10 \pm 0.59^{a}$	4.1 ± 0.015 <sup>a</sup>	10.3 ± 0.47°	3.1 ± 0.011 <sup>d</sup>	21.03 $\pm 0.46^{\circ}$	$9.42 \pm 0.044^{d}$	0.6557± 0.015 <sup>b</sup>
Pop7	103.89 ± 5.71°	$6.33 \pm 0.026^{b}$	11.83± 0.51 <sup>b</sup>	3.9 ± 0.019 <sup>b</sup>	$9.3 \pm 0.043^{d}$	$2.2 \pm 0.090^{f}$	11.23 ± 0.48°	$9.11 \pm 0.042^{d}$	1.312± 0.001 <sup>a</sup>
Pop8	$72.77 \pm 3.52^{\rm f}$	$2.33 \pm 0.080^{\text{e}}$	11.44± 0.47 <sup>b</sup>	$3.6 \pm 0.013^{b}$	10.9 ± 0.6°	42.9 ± 0.098 <sup>e</sup>	15.17± 0.53 <sup>d</sup>	$8.58 \pm 0.040^{e}$	0.928± 0.050 <sup>b</sup>
Pop9	44.05 ± 2.11 <sup>g</sup>	$2.40 \pm 0.090^{\rm e}$	10.96 ± 0.45°	$3.8 \pm 0.018^{b}$	$12.8 \pm 0.50^{b}$	4.3 ± 0.019 <sup>b</sup>	13.03 ± 0.51 <sup>e</sup>	$7.72 \pm 0.039^{\rm f}$	0.862± 0.008 <sup>b</sup>
Pop10	97.14 ± 5.32 <sup>d</sup>	$4.50 \pm 0.020^{d}$	$12.6 \pm 0.61^{a}$	$4.4 \pm 0.016^{a}$	$9.8 \pm 0.45^{d}$	$2.7 \pm 0.096^{e}$	14.57± 0.49 <sup>d</sup>	$10.79 \pm 0.54^{c}$	1.02± 0.035 <sup>a</sup>

Means (mean  $\pm$  SD; n = 6) within the column followed by different superscript letters were significantly different at pb 0.05



**Plate 1** HPLC chromatogram of acid hydrolyzed methanolic extract (root) of various populations of *Gloriosa superba* for alkaloid colchicines. (A): Standard (B): Pop1 (C): Pop 2 (D): Popu 3 (E): Pop 4 (F): Pop 5 (G): Pop (H): Pop 7 (I): Pop 8 (J): Pop 9 (K): Pop 10

## Population genetic structure and level of genetic diversity in *Gloriosa superba*

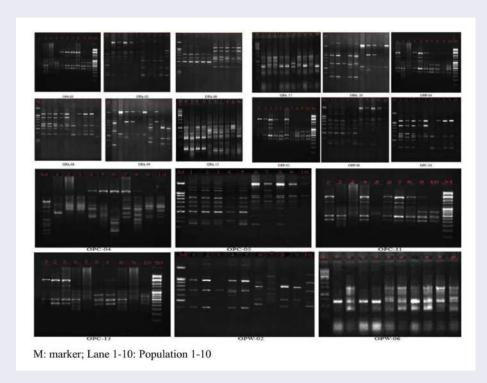
After screening 30 primers 18 primers produced polymorphic and repeatable products (Table 3). The banding profile and polymorphism generated are shown in Plate 2. The total number of amplified DNA band varied between 21 (Primer OPC-05) and 8 (primer OPW-02) with the average of 13 band per primer. The maximum number of polymorphic bands (21) was obtained with primer OPC-05. The polymorphism percentage ranges from 81.25%

(OPA-03) to as high as 100% for 3 primers (Primer OPC-13, OPP-08, and OPP-05). Average polymorphism across population was found to be 91.94% (Table 3). Overall size of the PCR amplified product band ranged from 319 bp to 2260 bp (Table 3). The intraspecific level of RAPD polymorphism was measured as the proportions of polymorphic loci to the total number of loci scored in all accessions of the same species. The average gene diversity (HT) over all loci was 0.4265, while for individual loci it ranged from 0.2344 (Yelagiri Hills,) to 0.2968 (Kozhikode).

**Table 3** The nucleotide sequence of the selected primers and the numbers of amplified and polymorphic bands scored

Primer code	Primer sequence 5'-3'	Total band	Polymorphic band	Percentage of polymorphism	Size range (bp)
OPA-02	TGCCGAGCTG	19	19	100	374-2064
OPA-03	AGTCAGCCAC	16	13	81.25	528-1747
OPA-06	GGTCCCTGAC	15	13	86.66	973-2018
OPA-07	GAAACGGGTG	**	**	**	**
OPA-08	GTGACGTAGG	12	11	91.66	560-1668
OPA-09	GGGTAACGCC	16	15	93.75	425-1558
OPA-11	CAATCGCCGT	**	**	**	**
OPA-13	CAGCACCCAC	12	11	91.66	525-1800
OPA-17	GACCGCTTGT	10	9	90	582-1100
OPA-20	GTTGCGATCC	15	13	86.66	373-2200
OPP-02	TCGGCACGAC	**	**	**	**
OPP-03	GTGATACGCC	**	**	**	**
OPP-04	GTGTCTCAGG	9	8	88.88	913-2026
OPP-05	CCCCGGTAAG	19	19	100	475–1883
OPP-08	ACATCGCCTA	10	10	100	437-2072
OPC-01	TTCGAGCCAG	9	8	88.88	576–1372
OPC-02	GTGAGGCGTC	**	**	**	**
OPC-03	GGGGGTCTTT	**	**	**	**
OPC-04	CCGCATCTAC	12	11	91.66	794–1823
OPC-05	GATGACCGCC	21	20	95.23	352-1950
OPC-06	GAACGGACTC	**	**	**	**
OPC-07	GTCCCGACGA	**	**	**	**
OPC-11	AAAGCTGCGG	10	9	90	437-2260
OPC-12	TGTCATCCCC	**	**	**	**
OPC-13	AAGCCTCGTC	10	10	100	583-1686
OPW-01	CTCAGTGTCC	**	**	**	**
OPW-02	ACCCCGCCAA	8	7	87.5	739-2018
OPW-05	GGCGGATAAG	**	**	**	**
OPW-06	AGGCCCGATG	13	11	84.62	319-1686
OPW-08	GACTGCCTCT	**	**	**	**
Total		236	217	91.94	

<sup>\*\*</sup> Those not replicated.



**Plate 2** RAPD-PCR ampliflication of genomic DNA from *Gloriosa superba* M: marker; Lanes 1-10: Populations 1-10

The average expected heterozygosity (Hs) across all loci in the total sample was 0.2600. The average coefficient of gene differentiation (GST) over total loci was 0.3903 (P 0.01). The observed number of alleles (Na) per population varied from 1.5784 to 1.7459 (Table 4) and for all populations is 2.000. The mean effective number of alleles (Ne) [15] for all populations

was 1.7657 with a range from 1.4121 to 1.5236. Populations from Kozhikode (population 9) had the largest value of Ne and h while the population from Udaiyarpalaiyam (population 1) had the lowest (Table 4). Using Slatkin and Barton [16] formula for estimated gene flow (Nm) = 0.25 (1-GST)/GST the gene flow between all population was 0.7811.

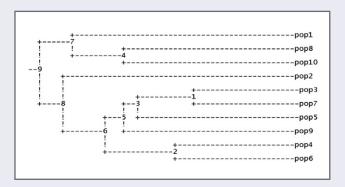
**Table 4** Analysis of genetic polymorphism obtained with RAPD primers in various populations of *Gloriosa superba* 

Population	Na	Ne	h	I	NPL	PPL(%)
1	1.6378	1.4121	0.2410	0.3582	118	78
2	1.5784	1.4179	0.2344	0.3420	107	84
3	1.7459	1.5009	0.2887	0.4263	138	74.59
4	1.6595	1.4469	0.2567	0.3784	122	65.95
5	1.6919	1.4750	0.2715	0.3994	128	69.19
6	1.6432	1.4257	0.2467	0.3652	119	64.32
7	1.6270	1.4216	0.2429	0.3586	116	62.70
8	1.6541	1.4673	0.2632	0.3847	121	65.41
9	1.7459	1.5236	0.2968	0.4351	138	74.59
10	1.6757	1.4453	0.2585	0.3829	125	67.57
Total	2.000	1.7657	0.4265	0.6156		

Ne-Effective number of alleles, h-Nei's gene diversity, I-Shannon's Information index, NPL-The number of polymorphic loci, PPL-The percentage of polymorphic loci

The cluster analysis indicates that 10 populations of Gloriosa superba formed three major cluster groups (Fig.2). Cluster I represents three populations, populations 1, 8 and 10. Cluster II represents population 2. Cluster III represents 6 populations (populations 3, 7, 5, 9, 4 and 6). The UPGMA dendrogram in the present study showed that some populations from different regions were located in the same clusters for eg. The population 1 (Udaiyarpalaiyam) and the population 10 (Kottayam) were grouped together despite the geographical distance of 236 km between them. On the contrary two geographically close populations, those of Kozhikode and Yelagiri Hills, were distributed into separate clusters and showed a rather large genetic distance.

**Fig.2** UPGMA (based on Nei's genetic distance) dendrogram showing the relationship between various populations of *Gloriosa superba* 



An AMOVA analysis (Table 5) and PCA (based on morphological characters) also did not show any regional assemblage among the populations.

## Genetic relationships among various populations of *Gloriosa superba*

The proportion of RAPD loci polymorphic per population ranged from 57.84% (Yelagiri Hills) to 74.59% (Kottayam). Amova analysis reveals that 95.9% of the total molecular variation is due to genetic difference within populations and only 4.1% is due to genetic difference among populations (Table 5). RAPD result based on

AMOVA studies show that most of genetic variation in *Gloriosa superba* is distributed within populations rather than between them, indicating restricted populations.

**Table 5** Analysis of molecular variance (AMOVA) for various populations of *Gloriosa* superba from the study area employing RAPD markers

#### IV. DISCUSSION

Source of variation	Sum of square	Variance component	Percentage variation	F-statistics
Among population	419.367	1.76543	4.09942	FST=0.0 4099 (Pb 0.001)
Within Population	826.000	41.30000	95.90058	
Total	1245,367	43.06543		

There is much environmental influence accounting for the horticultural variability observed. Therefore, when compared with RAPD techniques, horticultural traits are relatively less reliable and inefficient for precise discrimination of closely related genotypes and analysis of their genetic similarities. In particular, knowledge of population genetic structure provides a historical perspective of evolutionary changes that characterize a species and allow us to predict how populations will respond to future events of natural and artificial origin [17]. Under the climate change scenario, for management and protection programs, the genetic structure of species at population level has received special attention in the past few years [18]. The presence of unique genetic characteristics distinguishes members of a given population from those of any other. High diversity is an indicator of better adaptability of a population.

Irrespective of the plant parts used,

DNA analysis will remain the most effective tool for identification because phytochemical content will vary with the plant parts used, physiological status and environmental conditions. The medicinal effectiveness of the plant species is related to the quantity of that compound in question; hence the species, strain and geographical origin can be distinguished using chemical fingerprinting. The HPLC estimation carried out by us showed considerable phytochemical variation in the genotypes of Gloriosa superba. The phytochemical diversity measured as quantitative difference in the accumulated colchicine ranged from 0.192 to 1.312 (mg/g dw). The concentration of colchicine in different populations of this plant varied with geographical conditions. The variation may be largely due to interplay of environmental conditions and genetic variation. The diversity of chemotypes linked to geographical distances could explain the low level of gene flow among populations as a result of the level of seed and pollen migration expected to be low among populations.

Different types of molecular markers have been used to ascertain DNA polymorphism is considered as a one of the most efficient molecular methods in terms of ability to produce abundant polymorphic markers within a short time and limited budget, the RAPD-DNA, a PCR based technique is a simple and cost-effective tool for analysis of plant genome. It is technically least demanding and offers a fast method for providing information from a large number of loci. RAPD has become widely used in various areas of plant research and it has proved to be a valuable tool in studying inter and intraspecific genetic variation, patterns of gene expression, and identification of specific genes using nearly isogenic variants [19]. More recently, RAPD has been used for estimation of genetic diversity in Withania somnifera [20] collected from different geographical regions.

Systematic morphological characterization

of *Gloriosa* germplasm is of great significance for future programs on quality enhancement of the crop. The present study aimed at identification of elite collections of populations and their spatial distribution in the study area linking the phenotypic variability with the chemical relatedness of populations based on alkaloid Colchicine content.

In this study ten populations from different regions of the study area grown at a single location were subjected to same environmental conditions. Therefore observed variations could be largely genetic. Present studies are in conformity with the earlier workers like Arunkumar et. al. [21] indicating no significant correlation between environment (edaphic factors) and morphological charactersor with alkaloid content confirming that phytochemical variations are by and large gene related.

It has been claimed that molecular data are superior to morphological characters because they are more numerous and easier to define as they are linear rather than multidimensional. Nevertheless this premise has not been fulfilled in majority of events [22]. In this study there is no correlation between the geographical distance among populations of Gloriosa superba and genetic diversity. The UPGMA dendrogram in the present study showed that some populations from different regions of the study area were located in the same cluster. The lack of such correlation could be partially explained by a possible adaptive RAPD ecogeographical differentiation associated with habitat fragmentation [23].

However RAPD markers are dominant and thus are less suitable for linkage analysis than co-dominant markers. This advantage could be overcome by using several statistical methods such as analysis of molecular variance [24].Our RAPD based AMOVA studies show that most genetic variation in *Gloriosa superba* distributed within population rather than between them, indicating a relatively restricted population

differentiation as expected in outcrossing species. The high level of genetic polymorphism and genetic differentiation revealed by RAPD analysis might play a role in the dynamic evolution of *Gloriosa* in south India.

#### V. CONCLUSION

The results of this study indicated that RAPD are sufficiently informative and powerful to assess genetic variability in *Gloriosa superba*. The estimate ofgenetic variation reported herein provides a basis for the in situ conservation and exploitation of genetics resources in this species.

From a conservation point of view population 7 (Mandya) and population 9 (Kozhikode) deserve special consideration as the former displayed elite population due to the high level of alkaloid content (colchicine) and the later expressed high genetic diversity there by denoting maximum phylogenetic adaptation. The present study assumes significance as it provides valuable information on the nature and pattern of genetic variation existing in this medicinally important species.

Evaluation of Gloriosa superba germplasm showed a large variation in the quantitative traits between populations. The population from Mandya was considered as the elite population of Gloriosa superba as a result of linking the phenotypic variability with the chemical relatedness of population the cluster based on the important alkaloid colchicine.

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## Perspectives on mangrove biodiversity in an unstable climate

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Abstract-There are three outstanding threats to the ecosphere's biodiversity: climate change, human overpopulation and dollar-driven environmental degradation. This paper will focus on key aspects of climate change, both anthropogenic and natural. Today, most climate change discussion and decision-making is dominated by concerns about elevations in atmospheric CO<sub>2</sub> and associated 'Green House' mean temperature increases.

Derived from global elevations in mean temperature are polar ice cap melts and consequent sea-level rise. Mangrove coastal forest ecosystems may be especially vulnerable to both temperature and sea-level increases. Although only a few species of mangrove dominate most mangrove forests worldwide, there is an important bank of plant biodiversity within these ecosystems. This paper argues that a wise and much needed approach to assessing the eco-economic values of mangrove biodiversity lies in placing far more emphasis on species which show the widest eco-physiological tolerances.

I contended that important parameters of these tolerances include: temperature increases and decreases (global warming and global cooling); how changes in mangrove species biodiversity operate at the ecosystem level of function and what species are best adapted to handle sedimentation and or S.L.

rise. It is unwise to neglect or underestimate these factors in assessing the ecological versatility and values of mangrove biodiversity.

Keywords: climate change, temperature rise and decrease, ecosystem function, ecophysiology.

#### I. INTRODUCTION AND OVERVIEW

The literature of contemporary ecology and conservation biology is replete with mentions of the importance of biodiversity. Mangrove literature is no exception to this thematic trend. The term biodiversity is often uttered by modern politicians when they try to make impressive statements about sustainability. "Green Groups" love the word and it would be rare to find textbooks and EIA (Environmental Impact Assessment) Guidelines, laws, ordinances and statutes that fail to mention biodiversity, almost as an essential sister word alongside sustainability (Maxwell & Fung, 2015). Despite all the hype and popularity associated with the concept of biodiversity, the links between biodiversity and ecosystem processes remain very difficult to demonstrate and confirm experimentally. (Schulze et. al., 2005): a situation that may have led long established ecologists like Smith and Smith (2012) in their 8th Edition text, "Elements of Ecology" to address the importance of biodiversity in terms of environmental ethics. This approach may be good if it results in buying time and enabling

ecologists to gain robust data that can, at last, tie up all the links between biodiversity, ecosystem processes and stability. But we may not have time.

What do we mean by the term biodiversity? For most ecologists, the term is usually taken to mean, the number of different species in an area or within an ecosystem (Smith & Smith, 2012).

Can ecologists put a number beside the notion of ideal species diversity in an ecosystem, especially an ecotonal ecosystem like a mangrove forest? No, we cannot provide such a number! Other writers express the same essential idea in a different way by stating that links between measures of biodiversity (e.g. species richness) and ecological services that directly affect human well-being are patchy (Cardinale et. al., 2012; Balvenera et. al., 2014). These writers have, however, ignored the impressive correlations between mangroves and shrimp and or fish catch (e.g. Alongi, 2009) and the fish communities of Mangrove forests in Thailand (Paphavasit et. al., 2009). Clearly, rather than uncertain or patchy, the outstanding ecological service of fishery support is evident. For *non*-mangrove ecologists, the relatively low overt biodiversity of mangrove trees and shrubs in a mangrove ecosystem often hides the outstanding ecological diversity and the associated covert non-mangrove faunal biodiversity. That of polychaetes, crustacea (many subclasses and orders from copepods to decapods), mollusca, urochordates and, importantly, the finding that Thai mangrove forests could support 19 finfish families. Significantly, the Rhizophora forests with their complex root systems supported the highest fish diversity and density (Paphavasit et. al., 2009).

While we cannot easily provide a number to reflect ideal species diversity for our

mangroves, the relevance and power of Lawton's (1994) question remains. "What do species do in ecosystems?" Clearly, *Rhizophora* forests in tropical Thailand or an *Avicennia marina* (unispecific) forest in subtropical northern New Zealand must be providing many ecological functions and services.

However, the unexpected discoveries by Havanond (2015) with a new hybrid of *Rhizophora* [R.a x R.m] here at SIEP and Hidetoshi Kudo with *Bruguiera hainesii* (Haines Orange Mangrove)—a species largely unknown in the southern hemisphere and never before recorded in Australia (MAP, 2016)—can serve to re-affirm the *likely* importance of biodiversity in mangrove ecosystems. Clearly, some processes must be contributing to the evolutionary diversity as part of a deeper survival process within mangrove ecosystems.

Yes, many gaps remain in mangrove science not least of which being the question: how much biodiversity is necessary to maintain *full* ecosystem functionality and services (Maxwell, 2015).

This paper will highlight and explore some of the important ideas which may help to contribute to developing a perspective on mangrove biodiversity appropriate for today.

These ideas include: Overt and covert biodiversity, diversity in eco-physiology (coping with flooding, salinity and anoxia; coping with herbivores (camels to cattle, monkeys to humans); coping with natural succession modifiers (mud-lobsters); coping with temperature extremes (too hot *and* too cold); coping with storms and typhoons and coping with ecological insults like oil spills.

Despite the fact that global warming dominates discussion on climate change and it did, again, at the Paris Climate Change Agreement (PCCA) of December 2015, when we attempt to relate climate change to mangroves it is wise to adopt a "big eye" approach. Such an approach may help us to both identify keystone mangrove species and gaps in our existing knowledge. Even in the absence of global warming and sea level rise, global mangrove resources continue to face destruction and degradation (Macintosh et. al., 2013). With this threat comes the pragmatic need for mangrove eco-repair, eco-restoration and afforestation. It is against this important backdrop that my paper is structured.

### II. OVERT AND COVERT MANGROVE BIODIVERSITY

Some 84 trees, shrubs and ferns have been recognized as mangroves (Saenger, 2002; Maxwell, 2015): an impressive lineup at the overt taxonomic level. But how much of this biodiversity is necessary to sustain full ecosystem functionality (Maxwell, 2015)? Indeed, low biodiversity mangrove stands, where one or a handful of species dominate and characterize the forest, are the norm globally. This situation is most strongly illustrated at the present biogeographic limits of mangrove, in Japan to the north (where Kandelia candel survives) and New Zealand to the south (where Avicennia marina survives Maxwell, 2002). Even in the optimal mangrove environment-in tropical Thailand and Indonesia -two Rhizophora species (R. mucronata and R. apiculata) rule the ecosystem. In both cases, tropical and temperate, good, productive fisheries are positively associated with these species-poor yet. ecologically diverse mangrove forests (Paphavasit et. al., 2009; Maxwell, 1991). The direct causal links may need more study as they are not always easy to demonstrate (Macintosh et. al., 2013). This problem is probably part of a larger ecological uncertainty: to demonstrate experimentally links between diversity and ecosystem processes (Schulze et. al., 2005; Ives, 2007). It may be easy (perhaps too easy and too tempting) to deduce that because some mangrove ecosystems can do well with just a few mangrove species, we should downgrade our worries about biodiversity loss. Such an "easy" way is packed with ecological uncertainty and conservation danger. The danger lies in the fact that we still do not know everything we need to know about what species do in and for ecosystems and, importantly, how currently uncommon species fit into the story. Their latent eco-biological potentials are unknown in a world of climate change. At present, discussion and documentation in climate change is dominated by the expectation that global warming will remain the trajectory taken. The alternative, global cooling, is mostly relegated to the status of unlikely. This is unwise. A major explosion of widespread volcanism could easily add particulate matter-volcanic dust-to the Earth's atmosphere resulting in global cooling. Thus, wise mangrove scientists should also place cool-tolerant mangroves into our formula for mangrove biodiversity awareness. To date, only two mangrove species have displayed clear eco-physiological tolerance to 'cold shock'. These are Avicennia marina and Kandelia candel (Maxwell, 2002). And not all ecotypes of these species may be the same (Maxwell, 2002). The ecology of biodiversity awaits far more work. The discovery of an unexpected new hybrid mangrove at SIEP by Dr. Sonjai Havanond is another perfectly timed and welcome reminder for all in mangrove science to be on the alert for new genetic diversity and emergent speciation. Importantly, the projected environmental dynamics associated with climate change may well contribute to both extinctions and, in contrast, to speciation and new patterns in mangrove forest structure.

Myers (1988) introduced the compelling and attractive concept of biodiversity "hotspots" into the literature of ecological conservation Dr. Sonjai Havanond's discovery could serve to show that even relatively *small* mangrove protected areas like **SIEP** have an important place in biodiversity banking. When such discoveries occur in relatively small protected areas like SIEP which themselves are located within globally importantly biodiversity hotspots like Thailand, the significance of SIEP is magnified.

Subtle or covert biodiversity can be hard to find in mangrove ecosystems that are often dominated by one or a few tree species. This is the case in Florida (USA) where Rhizophora mangle rules and hides a huge hidden non-tree biodiversity of ~4,000 insect species (Wilson & Simberloff, 1969 In: Molles, 2016). Part of the covert biodiversity of which this impressive non-tree animal biodiversity is an example, lies in the bio-complexity associated with such mangrove morphology as tangled root architecture. These complex forms furnish complex habitats over microgeographic scales. This covert (hidden) unexpected and impressive mangrove ecosystem biodiversity was also highlighted for Singapore's mangrove mudflats by Tan (2016). Here mangrove tree and shrub biodiversity is low yet. Tan reports from the Comprehensive Marine Biodiversity of Singapore (CMBS) five year study, an outstandingly diverse mud fauna.

Perhaps the most attractive (in terms of research grants from industry) and exciting (in terms of Health science) covert mangrove biodiversity comes from their importance to *medicine* and *pharmacy*. The bioactive and biomedically important compounds so far identified from mangroves invites much more work to extend the limited yet. encouraging findings to date. Following the Indian Ocean tsunami of 2004, some inspiring work was reported from *Thailand* (e.g. Homhual et. al., 2004 with *Bruguiera gymnorrhiza*). More recently, this theme has been kept in welcome focus by Baba et. al. (2016, a) with *Xylocarpus* 

granatum and Avicennia marina (Baba et. al., 2016, b) and Maxwell (2015) with mangrove species biodiversity generally.

It is wise to mention that some of the potential values of mangrove bioactive products are very hidden and may e.g. lie within the subtle biochemistry of interactions between endophytes within a mangrove higher plant. The recent work by Zheng et. al., (2014) is an example of just how covert the biology may be. The Zheng group identified anti-proliferative metabolites from the endophytic fungus Penicillium sp FJ-1 isolated from *Avicennia marina*.

Several decades ago Maxwell (1968; 1971) demonstrated that the well-known plant destroyer, *Phytophthora* had limited pathogenic power with the New Zealand ecotype of *Avicennia marina*. Here we have an example of how both overt and covert levels of mangrove biodiversity may combine: for this biogeograhically diverse mangrove, A. marina, has a wide spectrum of ecological tolerance and economic importance.

It is time to broaden our perspectives and consider some more *eco-physiological* issues.

## III. WHAT MANGROVE SPECIES ARE THE MOST TOLERANT OF ENVIRONMENTAL CHANGE?

- 3.1 Essentially, this question asks mangrove ecologists, forests and managers to identify the mangroves best adapted to cope with climate change and its many ecological consequences.
- 3.2 As mentioned above, the big challenge facing mangrove science today is that of mangrove eco-restoration: perhaps the most appropriate paradigm for the 21st Century

(Maxwell, 2015).

The long and impressive history of sustained use and management of Malaysia's Matang mangroves has provided a foundation for confidence in mangrove restoration, management and wise use (conservation). Chan (2014) discussed the successional dynamics of this *Avicennia-Sonneratia* forest merging with an ecotone of *Rhizorphora-Bruguiera* forest. Geomorphology (a physical process), mud lobster (*Thalassina anomala*) activity (a biological process) (Havanond, 2000) and forestry (anthropogenic activity) have all combined to help sustain a successful mangrove ecosystem. Here overt mangrove biodiversity may be poor but the hidden subtle biodiversities invite more attention.

Importantly, the long term success of Malaysia's mangrove forestry when combined with decades of mangrove eco-repair and conservation in Thailand by Akornkoae, Havanond & Paphavasit and their teams have shown that limited-species mangrove plantations are both sustainable and eco-economically multifunctional (e.g. Aksornkoae et. al., 1993; Aksornkoae et. al., 1996; Havanond, 2000; Paphavasit, 1995; Paphavasit et. al., 2004).

However, the many eco-restoration opportunities on offer invite us to include more sub-dominant species which display properties such as anti-fouling (anti-barnacle) e.g. *Ceriops tangel* (Chan et. al., 2015; Chen et. al., 2008) and *Kandelia candel* (Maxwell & Li, 2006) and emerging bio-medical features as in the case of *Bruguiera gymnorrhiza* and *Xylocarpus granatum*.

3.3 Is *Avicennia marina* our "A class" candidate mangrove in an unstable climate?

A. marina is one of eight Avicennia spp globally (Spalding et. al, 2010) with this remarkable species showing the greatest range of eco-physiological tolerance and adaptations to temperature (hot and cold) tidal inundation, rainfall, salinity, anoxia and substratum type (Aksornkoae et. al., 1993; Saenger, 2002; Maxwell, 2015). A. marina also offers hope in terms of this species placing a clearly visible utility on mangrove vegetation: it has multiple eco-economic values. These include its role in human food (Hong & San, 1993); high protein quality fodder for milk-producing cattle at Gujart, India (Baba et. al., 2013) and on New Zealand dairy farms (Maxwell & Lai, 2012); as estuarine river stop-bank, sea-dyke storm and tsunami protectors (Maxwell, 1976; Hong & San, 1993; Aksornkoae, 2004 and Havanond, 2005) and perhaps most attractive of all, as a source of bioactive cytotoxic compounds to contain human leukemia and breast cancer cells (Baba et. al., 2016) together with a mosquito larvacide property associated with tanninpolyphenols exuded mangrove material acting as a mosquito repellent (Primavera et. al., 2004). The recent discovery of the Rhizophora (R.a x R.m) hybrid reported above and the displays of ecotypicity by Avicennia marina and Kandelia candel (Maxwell, 2007) also serves to remind us that biodiversity is dynamic and even in our short time spans is part of a big, holistic picture of pragmatic approaches to biodiversity in today's world.

## IV. CONCLUDING THOUGHTS: TIGERS AND BIG MANGROVE ECOSYSTEMS

4.1 With almost 140,000 ha, we could easily contend that The Sundarbans of Bangladesh is the world's greatest and most important biodiversity bank for the mangrove ecosystem. In December 2014 an oil tanker carrying some 358,000 L of furnace oil capsized in Sela River near its confluence with the larger Pasur in Chandpai. The ecological impact of this disaster is not yet. fully known but will need to be approached at an ecosystem

level. Bhui-yan (2015) highlighted the importance of this disaster and, wisely, made reference to some key aspects of its ecological impact such as oil on soil, partly smothered vegetation, propagule mortality, contaminated herbivore food and the need for Government level law enforcement to seriously protect this UNESCO World Heritage Site.

Since the full picture of the Sundarbans food web is not yet. known but does involve iconic wildlife such as the Bengal tiger, dolphins (Ganetic & Irrawaddy), Indian fishing cat and spotted deer, ecosystem level thinking is essential. Although not always easy to do and not the norm in mangrove forest plantation

forestry, this Sundarbans oil disaster can be used to re-affirm the wisdom of accepting the ecological principle that biodiversity facilitates ecosystem stability, resilience and sustainability. (See e.g. Smith & Smith, 2012; Molles, 2016). Although, post-oil spill recovery is still under assessment, the size and biodiversity of the Sundarbans brings an expectation of recovery. We, in mangrove ecosystem wise use, should be positively inclined towards the view that if these large scale ecotonal ecosystems can sustain a tiger (*Panthera tigris*) population, then perhaps mangrove forest size and wide biodiversity does matter. (Fig.1)



Source: "Daily Sun" News, Bangladesh, 11 Feb., 2016

**Fig.1** What sustains the world's biggest single mangrove forest: the Sundarbans of Bangladesh? Is it biodiversity? Although we do not yet. fully know the structure and function of the Sundardbans food web, If this forest can sustain the Irawaddy dolphins and Tigers we would be wise to assume that mangrove forest biodiversity does matter a lot.

Here we return to our central question mentioned above, what do species do in and for ecosystems? Clearly, while most surviving mangrove ecosystems world-wide are dominated by a few tree species, this should not deflect us from keeping the currently uncommon species in focus, especially when opportunities for eco-restoration present themselves.

Recently, Tangah et. al. (2012) used a more ecosystem-oriented approach to mangrove forest restoration in a degraded habitat by applying a cluster planting technique using three true mangroves (Avicennia alba, Ceriops tagal and Xylocarpus granatum) and one associate (Aglaia cucullata) in Sabah. Good success was the welcome outcome and it was

found that this cluster was able to serve as habitat and forage for important mangrove food chain species such as proboscis monkeys and fireflies.

4.2 Natural vs Human-assisted mangrove regeneration!

As mentioned, we live today in the age of eco-restoration and the need for humans to work *with* natural ecosystems.

Applied to mangrove biodiversity there are many considerations which indicate that mangroves could benefit from our help (Maxwell, 1995; Primavera et. al., 2012). These range from the management of natural challenges to mangrove succession such as the

mud-lobster—which, at times, can be a major modifier of the mangrove forest floor (Havanond, 2002)—to herbivores such as camels, monkeys and humans, who may not always use mangrove resources sustainably.

When we use mangroves as tools for eco-engineering (sea dyke and stop bank protection; repair of disused aquaculture ponds; filters for land-based run-off or non-point pollutants) we may well need to apply what we have in our existing banks of ecological knowledge to assisting mangrove ecosystems to assist themselves. Within this context and perspective, excellent biodiversity enhancement opportunities exist to combine pragmatic ecoengineering aims with the sustainable harvest of mangrove bio-medical and nutritional resources. In short, we can apply scientific forestry and farming to the emerging ecorestoration paradigm of mangroves for the 21st Century.

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Session A.2 : Policy



# Intersectoral linkages of health and biodiversity—A science-policy-society perspective

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"Health is both a resource for, as well as an outcome of, sustainable development. The goals of sustainable development cannot be achieved when there is a high prevalence of debilitating illness and poverty, and the health of a population cannot be maintained without a responsive health system and a healthy environment. Environmental degradation, mismanagement of natural resources, and unhealthy consumption patterns and lifestyles impact health. Ill-health, in turn, hampers poverty alleviation and economic development." (WHO 2002)<sup>(1)</sup>

#### Introduction

Studies suggest that one fourth of the global burden of diseases in economically poor countries is related to environmental factors. Much has been written about the environmental and social determinants and drivers of health. The recent report by the World Health Organization (WHO 2016) "Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks", is a latest addition to the list. The report primarily looks at specific diseases and their links with environmental factors and not the overall health and well-being impacts of environment.

Over the last two decades there have been considerable academic literature on the link between biodiversity and health and call for a stronger science-policy-society interface. The convention on biological diversity (CBD) has also taken due note of this and has initiated significant, proactive policy efforts on health and biodiversity for nearly a decade now. This is evidenced in the various reports and decisions of the CBD such as living in harmony with nature (2010)<sup>(2)</sup> and the strategic plan for biodiversity 2020. What is to be noted is that health is not considered here in isolation but integrated within a holistic approach of health and well-being. From the health policy point of view this goes beyond traditional notions of access to health and brings us back to the WHO definition of health as, "a complete state of physical and mental well-being". This holistic perspective is well highlighted in the Aichi biodiversity target fourteen-"Ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded taking into account the needs of women, indigenous and local communities, and the poor and vulnerable."

There are well-known publications such as, "Sustaining Life: How Human Health Depends on Biodiversity" (Chivian and Aaron

Bernstein 2008) which was the first report to fully explore how loss of biodiversity endangers human health. This was jointly supported by the Convention on Biological Diversity (CBD) Secretariat, United Nations Environment Program (UNEP), United Nations Development Program (UNDP) and the International Union for Conservation of Nature (IUCN). This covered systematic documentation of various specific sectors of biodiversity in relation to health.

The Millennium Ecosystem Assessment (2005) conducted over a decade ago which was another milestone publication in the area. This came up with a unique framework to capture the biodiversity and ecosystem services viz. provisioning services, regulating services, supporting services and cultural services. Provisioning services include genetic resources, food, water, medicines, fuel, biochemicals, timber, fibre, and other resources that directly support life. Regulating services include air quality, fresh water, climate, preventing natural disasters, regulating diseases, pests and other microorganisms, other insects including pollination. Supporting services include photosynthesis, soil formation, nutrient cycling, water cycling. Cultural services include spiritual, cognitive, aesthetic, therapeutic values of ecosystems and landscapes. Based on this framework, one of the outcomes of the Millennium assessment was a report on, "Ecosystems and Human well-being-a Health Synthesis" which in detail captured various health and well-being related linkages. This also highlighted three dimensions such as, Direct negative health impacts due to ecosystem changes (increased disasters, pollutants and water shortage); Ecosystem mediated health impacts (infectious disease risk, reduced food and nutrition, natural medicines and cultural services) and Indirect health impacts (livelihood loss, population displacement and conflicts). Apart from highlighting these links and implications, the report also critically reflected on questions of priority actions at global, regional and local level and policy implications (MA Synthesis, WHO 2005).

In 2012, WHO along with UNFCCC, SCBD and UNCCD published a report, "Our Planet, Our Health, Our Future". This report looked at the three Rio de Jeneiro conventions on Biodiversity, Climate change and Desertification. The report specifically suggested the need for more integrated indicators related to health and natural systems in the sustainable development goals. Another unique feature of the report is the highlight on traditional knowledge and their importance in health and well-being (WHO 2012). It is pertinent here to mention that, though these links have been clearly established, this is not adequately and explicitly reflected in the SDG health related goals or indicators directly.

Another recent report that has comprehensively highlighted the nexus is, "Connecting Global Priorities-Biodiversity and Human Health-A State of Knowledge Review"-Jointly published by WHO and CBD (2015). This report covered an array of topics including broad science-policy perspectives to more specific areas such as water and air quality; sustainable production and consumption; agrobiodiversity and nutrition; physical, mental and spiritual health including landscapes and healing; infectious diseases; lifestyle, and non-communicable diseases and microbial diversity; climate change and disasters; traditional medicine and natural products and so on. This has resulted in certain key policy decisions to strengthen the area of work between the Convention on Biological Diversity and the World Health Organization and a Liaison group on Biodiversity and Health has been constituted.

In the recent past, there have also new perspectives such as One health, Eco-social

health, and planetary health that have also looked at this link between natural systems and health in a comprehensive and integrated manner. These are multidisciplinary and multisectoral processes and can help us to better analyse and evaluate the interactions between different variables to better develop more coordinated, coherent and integrated science-policy-practice interfaces. In 2015, "Safeguarding human health in the Anthropocene epoch" was published by the Rockefeller Foundation-Lancet Commission on planetary health. The report highlights the inseparable link between human life and natural systems and the challenges relating to high degradation of natural systems and the attendant challenges of governance and organization of knowledge. Apart from these there is a swiftly growing body of academic literature on one Health, eco-social health and other innovative approaches.

## **Developments in the Context of Biodiversity Policy Processes**

Strengthening linkages explicitly between biodiversity conservation and health goals have gained increasing emphasis since the COP-10 of the CBD (Decision X/20). COP-12 of the CBD calls for specific action on biodiversity and health urging related sectors and agencies to work in a more coherent matter (Decision XII/21). The different dimensions related to biodiversity and health objectives are captured across various goals and targets of the Aichi Targets of the New Strategic Plan of the CBD (Targets 4, 5, 7, 12, 13, 14 and 18); and further strengthened by subsequent decisions of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA). Associated indicators relevant to biodiversity and health include trends in benefits that humans derive from selected ecosystem services, trends in health and well-being of communities that depend

directly on local ecosystem goods and services, and trends in the nutritional contribution of biodiversity and food composition. This contributes also to implementing in spirit Articles 8 (j) and 10 (c) of the CBD, the Nagoya Protocol on ABS and the objectives of the UN Declaration of the Rights of Indigenous Peoples. Other major processes that have an interest in such a linked approach include the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) and the Sustainable Development Goals (SDGs).

## **Examples of Local Community Engagement and Actions**

The nexus between biodiversity and health is highly multisectoral. While there are several areas where a combination of sectors may be deployed, this article focuses on a few areas and highlight some impactful initiatives that are enabling co-achievement of health, biodiversity and sustainable development goals and which, importantly, can potentially be replicated elsewhere. These initiatives also highlight strategies for multistakeholder partnerships and new forms of international cooperation and financing. At the same time, they also address certain important issues of equity and inclusivity of marginalized and vulnerable groups towards access to resources and healthcare as well as rights to their knowledge and health practices.

#### Traditional medicine, health and livelihoods:

The relevance of biodiversity to modern health care is understood better due to the high visibility of innovative compounds and novel drugs that have been developed based on plants and other natural resources. At the same time, the significance of ecosystem specific plants and other resources and related indigenous and local traditional knowledge towards the health and nutritional security

of people in insufficiently connected and marginalized regions of the world is much more profound. The paradox is that the regions which have poor access to formal public health care infrastructure or personnel often are abundant in bio-cultural resources that can have major impact on community health and well-being.

Most of us are quite familiar with the WHO statistic that around 70% of the world's population continues to use traditional medicine and resources for health care needs. Estimates suggest that globally between 50,000 and 70,000 species of medicinal plants are used in traditional and modern medicinal systems, and around 6,000 plants are actively in trade in the global markets. As per the IPCC Fourth Assessment Report, in many sub-Saharan African rural communities non-timber forest produce such as medicinal plants and forest foods form over 50 percent of cash income and provide health needs for over 80 percent of the population. While the likely impacts of climate change on such medicinal and nutritional resources is high, there is no comprehensive data on this. This highlights the importance of more integrated approaches to assessment of status of biodiversity, health and well-being and of ensuring conservation and sustainable use of such resources at various scales

To improve health care access for communities, there is a renewed interest to strengthen the potential of traditional knowledge and health practitioners and augment medicinal and nutritional resources to fulfill this role. Identifying local health priorities and supplementing them with ecosystem and community specific traditional medical knowledge and resources through primary health programs is critical both to ensure conservation of biodiversity and health security at the local level. Furthermore, it provides a

platform to develop more effective education and capacity building tools given that it is easier for people to relate to the above concepts given their close association with biological resources and search for good health at low cost. This is especially important in the context where progressively high out of pocket spending for health, increasing privatization, over medicalization of healthcare and curative focus are becoming important challenges of health systems. While there are several models at the local level on diverse nodes of interventions, concerted policy attention and integrated frameworks/approaches for bringing together multiple institutions and stakeholders are missing.

Strengthening the capacities and credibility of traditional health practitioners, often the first and sometimes, the only point of healthcare intervention in remote and marginalized communities has become an immediate necessity. Organizations such as the FRLHT and the Medicinal Plant Conservation Network in India have been involved in countrywide, large-scale conservation initiatives for endangered medicinal plants through publicprivate partnerships. Systematic national assessments carried out under this initiative show that around 300 important medicinal plants fall into various categories of threat in the country. They have also been engaged in mobilizing community health practitioners to identify local health priorities and solutions for more than two decades and engaging them in participatory conservation, primary health and livelihoods program. This has created a country-wide healers' and indigenous and local knowledge holders' network in India. A main objective is also for enabling the development and promotion of appropriate integrative methodologies for assuring evidence on quality, safety and efficacy of health practices based on standards within and across health systems and various disciplines. Furthermore, development

of local documentation of knowledge linked to Peoples' Biodiversity Registers and further linking them to intangible property rights are happening in a dynamic fashion within the ambit of international and national legal systems.

Global platforms are also valuable at bringing together communities of practice. For example, the Biodiversity and Community Health (BaCH) Initiative hosted by the United Nations University brings together the expertise of several multistakeholder agencies with an interest in community health to leverage on and synergize multiple efforts mentioned earlier. This global partnership has led to innovative capacity building initiatives such as peer learning exchange programs between communities from different developing countries across continents and with plans to replicate such efforts through stronger South-South cooperation.

#### Biopharmaceuticals and neutraceuticals:

Over 50% of all pharmaceuticals of last 25 years are directly derived from or modeled after natural compounds (Newman & Cragg 2007). Of the 155 small molecules of last seventy years, 73% are 'non-synthetic', 47% either natural products or directly derived there from (Newman and Cragg 2007). 119 pure chemical substances extracted from higher plants are used in conventional medicine. Of this, 74% of the chemical compounds have the same or related use as in folk knowledge (Farnsworth et al. 1985). Aspirin, Quinine, Morphine, Artemisinin, Taxol, Vincristine/ vinblastine are the most popular and widely used examples. Natural product discoveries still account for a significant part of biopharma research and development. This has key implications for the discourse on the fair and equitable sharing of resources, including under the CBD's Nagoya Protocol. Apart from the more notable discussions on its potential to

alleviate poverty and support conservation efforts, there are also examples involving communities in South and Southeast Asia that trade in raw herbs supplied to major pharmaceutical companies providing even passport data on source of origin of every consignment. There are also several examples of communities partnering in local research and development efforts to develop medicines and nutritional products to meet local consumer demands and devising ways locally to effect equitable benefit distribution.

#### Agriculture, food, and nutrition:

It is no surprise that agro-biodiversity and nutritional security go together. This is one of the most important sectors in the nexus between biodiversity and health. The Biodiversity for Nutrition (BfN)(3) initiative co-ordinated by Biodiversity International and funded by the Global Environmental Facility (GEF), a multi-country project, has been spearheading the facilitation of policy developments to promote agro-diverse farming and diets, especially for children and women. This initiative led by Brazil, Kenya, Sri Lanka and Turkey is coordinated by Biodiversity International with implementation support from the United Nations Environment Programme and the Food and Agriculture Organization of the United Nations. National partners come from relevant ministries, the scientific community, non-government organizations, civil society and local communities. Similar initiatives on health, food, and traditional knowledge are also being undertaken by education networks like the ProSPER. Net and the Regional Centres of Expertise of the United Nations University and several other networks and NGOs with local communities.

#### One Health:

Demonstrably, the Natural Livestock Farming (NLF)<sup>(4)</sup> network co-ordinated from the Netherlands has embarked on a multicountry partnership in the field of One Health using Ethno-veterinary care of livestock as an entry point to reduce antibiotic use and resistance while looking at other dimensions such as local breeds, integration of traditional medicine, animal management and so on. There are several such examples of one health approach. While the rise in non-communicable diseases has begun to trigger greater uptake and new recommendations in this area-much more is needed. To get there we not only have to address the common drivers already described but also consider governance and institutional challenges in conservation and sustainable use

#### Landscapes, health and healing:

There is increasing evidence suggesting natural/therapeutic/sacred landscapes can contribute to our mental and spiritual needs. Initiatives such as the IUCN commission on Cultural and Spiritual Values of Protected Areas<sup>(5)</sup> and specifically case studies from countries like Guatemala, by community based organizations are well documented examples of local and global efforts in this area. The World Parks Congress in 2014 has this as an important agenda and had specific recommendations to strengthen this theme.

## Health education, biodiversity and traditional knowledge:

A proactive approach to raising awareness of health and measures requires the buy-in of most, if not all, relevant actors. In this context, work on health, as well as sustainable development education by the Regional Centres of Expertise of the United

Nations University (which is a network of local networks in 156 locations) demonstrates the power of decentralized multistakeholder planning and action.

#### **Conclusion**

We already know what is wrong with the socio-ecological systems that are affecting our health and well-being. This bring us back to the WHO definition of health which refers to, "a complete state of physical and mental well-being" and reinforces the need for more holistic approaches. We have attempted here to highlight some reflections on "being healthy" that goes beyond traditional notions of access to health. Though there is much written about environmental and social determinants of health including biodiversity and ecosystems, yet this is still a slowly emerging area in the health policy community. Consequently, these links also not explicitly reflected in the healthrelated SDG goals.

Actions to achieve the broader mandate of good health and well-being requires us to connect sectoral implementation plans and strategically consider how to make best use of available resources-natural, human and financial. This requires us to understand interdependencies of natural ecosystems and health, and to adopt a systemic approach to jointly address issues and thereby allow us to leverage on the strengths and synergize efforts to achieve concurrent benefits. Such approaches and practices are not entirely new to related communities of practice and there is growing evidence that several initiatives have moved beyond pilot phases and are being adopted by different stakeholder groups.

For further strengthening these initiatives there is a need for strategically focusing on appropriate efforts in the realms of research, awareness raising, capacity building, sciencepolicy interfacing, advocacy, and further upscaling successful pilot models. In this context, facilitating Inter-agency cooperation has become an urgent requirement. As the management of natural resources typically falls outside the traditional role of health ministries and departments, it is important that the conservation community takes an active role in pursuing this agenda by bringing together health, development and other relevant sectors. This needs concerted action on in the following areas-Integrated assessment and research methods; Inter sectoral coordination and science-policy linkages; Education and capacity building; Upscaling pilot models, expanding partnerships, linking to development objectives-Address issues of equity and inclusivity; Inter-agency cooperation, innovative models of South-South links.

Within a policy space, we see around us that successes come when bottom up initiatives are first acknowledged and mainstreamed. To reiterate, it is clearly time to invest and foster existing efforts and resources.

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#### Links:

- (1) http://www.who.int/wssd/en/World Summit on Sustainable Development.
- (2) https://www.cbd.int/undb/media/factsheets/undb-factsheets-en-web.pdf
- (3), (4) http://www.b4fn.org/
- (5) https://www.iucn.org/theme/protected-areas/wcpa/what-we-do/cultural-and-spiritual-values-protected-areas

## Myanmar forestry policy and institutional arrangement: Case study of mangrove deforestation between 1980 and 2015

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Abstract-Mangrove forest in Myanmar, among 8 major forest types, is playing a key role in providing ecosystem services to coastal communities and the nation. It is found along the coast (2,400 km), from Naff River in Rakhine State to Pachyan River in Tanintharyi Region. It is threatened by increase of socioeconomic needs, and climate change. Objectives of the study include understanding existing law and policy, and institutional arrangement status, the cause and barriers, and ways cope with deforestation. The results are expected to be supportive in achieving sustainable development in parallel with conservation. There have been several reports on mangrove cover change in Myanmar. FAO (FRA 2007 & 2015) reported the mangrove cover decreasing from 555,500 ha (1980) to 299,000 ha (2015). In addition Forest Department (FD) reported the degradation rate of about 11,088 ha/yr. In terms of policies and institutional arrangements, forest Law was amended in 1992, Forest Policy in 1994 and Environmental Conservation Law (2012) were enacted. The

Mangrove Section under Watershed Management Division of FD, Environmental Conservation Department (2012) has been established, and the ministry was reformed in 2016. Despite specific law, policy, and regulations, forest degradation in Myanmar is still happening in many ways. Consequently, mangroves are conserved by establishing administrative boundary such as Reserved Forest and Protected Area since 1896 but (e.g. in Ayeyarwaddy) 136,448.26 ha of mangroves were degraded between 1980 and 2002. Myanmar needs clear and strong legal framework followed by enhancing institutional conservation methods activities, collaboration, raising awareness and alternative job opportunities, to protect mangroves taking into account these data from FAO and FD.

Keywords: Mangrove, Ecosystem services, institution, deforestation, policy

#### I. INTRODUCTION

Myanmar, the largest country in mainland Southeast Asia with varied topographic regions, is a country rich in natural resources, with forest covering 46.69% of the total land area (677,000 km²), and a population of 51.42 million as of 2014 census. Its socio-economic development is very reliant on natural resources including territorial and coastal forest or mangrove. It consists of diverse topographies including a long coast line bordering with Bay of Bengal in the West and with Andaman Sea in the South; a low and flat dry zone, mountainous zones, and even snowcapped mountains in the northernmost part of the country.

Mangrove in Myanmar, among 8 major forest types, is playing a key role in providing ecosystem services to coastal communities and the nation. Myanmar had mangrove vegetation of 555,500 ha in 1980; 536,100 ha in 1990; 518,646 ha in 1999; 516,700 in 2000 but this drops to 507,000 ha in 2005 (FAO, 2007) and to 502,911 ha in 2010 (Spalding, Kainuma, & Collins, 2010). It stood at third with its area in Ayeyarwaddy Delfa Coastal zone (ADCZ) in 2005 in Asia even though it had declined since 1980. This followed Indonesia (2,900,000 ha) and Malaysia (565,000 ha). Annual change is (-1,940 ha) or (-0.3% of its total) between 1980 and 1990, (-1,940 ha) or (-0.4%) between 1990 and 2000, (-1,940 ha) or (-0.4%) between 2000 and 2005 (FAO, 2007).

Myanmar forests were systematically managed especially with selection system known as Myanmar Selection System (MSS) since 18th century, during British colonial times. Forest Department (FD), Ministry of Natural Resources and Environmental Conservation (MONREC) is focal agency in Ayeyarwaddy Delta Coastal Zone (ADCZ) in terms of forest management and conservation.

MONREC is also the focal agency addressing climate change. FD has been planning to set up a "Mangrove Section" under Watershed Management Division, FD since 2014 for strengthening mangrove management. In the context of policy, Forest Policy, forest law, forest rules, wildlife and wild animal protection law, community forestry instruction, periodical regulations are critical tools of Myanmar forest management system.

Even though it has policy tools and institutional systems, mangrove forest had deteriorated, both by natural and anthropogenic actions, outbreaks of insects; outbreaks of diseases, severe weather events, such as snow, storm and drought (FRA, 2015). The current study is conducted to understand existing law and policy, and institutional arrangement status; the cause and barriers, and ways to cope with deforestation.

#### II. METHODOLOGY

#### A. Study area

A 2,400 km long coast line (between (southern most of 9°54'22.63"N, 98°30'26.94" E) and (northern most of 21°24'49.75"N, 92°21' 28.44"E) and between (eastern most of 11°39' 14.24"N, 99°37'34.92"E) and (western most of 21°6'43.44"N, 92°9'54.48"E) belongs to Myanmar and facing Bay of Bengal in the west of the country and Andaman Sea in the south. It composes 3 main coastal zones; Rakhine coastal zone (RCZ) of 740 km; Ayeyarwaddy Delta Coastal zone (ADCZ) of 460 km; and Tanintharyi Coastal zone (TCZ) of 1,200 km. It belongs to 6 (2 States and 4 Regions) out of 14 States and Regions nationwide.

Mangroves grow well along the coast but these are being degraded and deforested due to natural and anthropogenic pressures. FD is trying to protect these resources in terms of enhancing institutional capacity, establishing plantation and community forest (CF) in degraded areas, extending numbers of reserved forest (RF), and international cooperation.

#### B. Methods

This study firstly evaluates the overall mangrove cover change and then analyzes the causes of barriers to mangrove deforestation, and current policy and institutional arrangement to find potential and suitable measures or ways of coping with mangrove deforestation for sustainable mangrove management.

Mangrove cover changes over 30 years were analyzed based on official documents, Forest Department's Management Plan (1995-2005), (2005-2015), and (2015-2025), reports such as "Myanmar forest register" (JAFTA, 1995), and FAO's forest assessment reports (FRA 2007 and FRA 2015). Cause and vulnerability assessment has been analyzed by conducting questionnaire interview with local

community and semi structured interview with FD officials reviewing official records of FD. Policy and institutional system has been assessed based on in-depth study on existing governance system and tools. During a preliminary survey in Ayeyarwaddy Delta Coastal Zone, questionnaire interview with 16 heads of households and semi-structured interview with 12 forest officers were carried out. Their degree of satisfaction with and comments on policy and management activities were analyzed. Causes of barriers to mangrove deforestation are extracted from interview results. Necessary information and knowledge were also documented during both questionnaire and semi-structured interviews and field observation.

All data collected were put into excel sheet and SPSS programme, and analyzed for frequency of individual variables by applying descriptive statistics tool so that mangroves changes and local livelihoods status can be assessed.

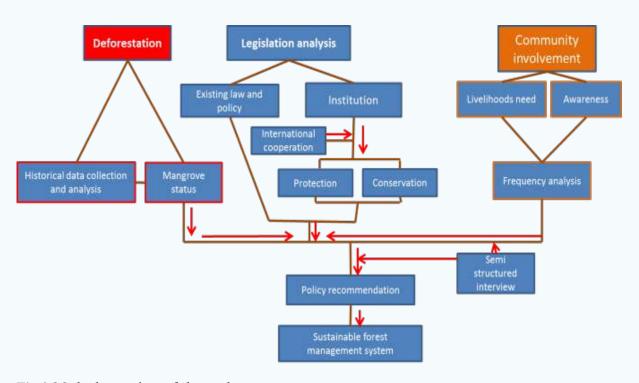


Fig.1 Method overview of the study

Table B1 Governance tools in environment and forest management

Categories	Components	Sources
Policy	International policy	IPCC, UNFCCC, IUCN
	National policy	ECD, FD of MOECAF, DOA of
	-Environmental Policy	MOAI, DOF of MOLFRD, MOT,
	-Forest Policy	MOE (official documents and
	-Land use policy	their websites)
	-Agriculture policy	
	-Fishery policy	
	-Tourism policy	
	-Transportation policy	
Law	Sectoral laws including Forest Law,	ECD, FD of MOECAF, DOA of
	Environmental Conservation Law,	MOAI, DOF of MOLFRD, MOT,
	and Disaster Risk Management Law	MOE, DRR of MOSWRR, GAD
		of MOHA (official documents
		and their websites)
Regulations	Regulations and instructions released	Departments and local
and instruction	by local governments and	governments
	departmental	
Plan	Forest Management Plan for every	Forest Department
	ten years since 1995	

#### III. RESULTS

Mangroves are growing well in 9 out of 17 Townships (TSPs) along Rakhine coast line of (RCZ). Its cover area in Rakhine State in 1995-1996 of 152,111.8 ha or 9.28% of total forest area of 1,639,378.25 ha (Figure B1).

In Ayeyarwaddy Region, mangrove grows in 7 out of 26 Townships. It is surveyed as of 81,851.75 ha or 19.22% of total forest of 425,832.75 ha (Figure B2). Altogether 21

reserved forests (RFs) and unreserved forests (URFs) covering mangrove of 253,118.3 ha, 8 RFs in Ayeyarwaddy Region, one RF and one URF in Rakhine State, and 11 RFs in Tanintharyi Region are observed in 2013 (Forest Department, Mangrove brief report, 2015) (Table B2). Four Protected Areas or wildlife sanctuaries, 2 in Ayeyarwaddy Region and 2 in Tanintharyi, have also been established (Table B3). Furthermore, 10,421 ha of URPFs and CF are being processed for approval by cabinet (Table B4).

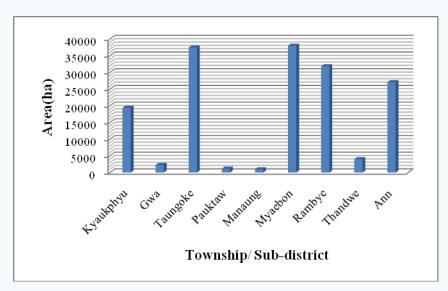
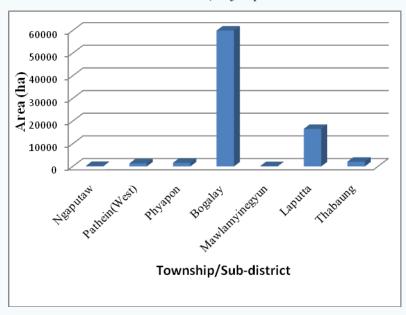


Fig.B1 Mangrove in Rakhine State in 1995-1996 (Major part of Rakhine Coastal Zone)



**Fig.B2** Mangrove in Ayeyarwaddy Region in 1995-1996 (including a part (Pathein-west) of Rakhine Coastal Zone)

Mangrove coverage has significantly declined from 659,018.83 ha in 1980, to 299,000.00 ha (FRA, 2015) in 2015 (Figure B3) due to various factors such as population pressure, weakness and gaps in forest policy, environmental policy, forest law, forest rules, regulations, instructions, and conservation activities.

Mangrove deforestation at a rate of 72,003.77 ha/yr has been observed (Figure B3). Deforestation rate of 0.51% in RF and 1.21% in unreserved forest were observed. Within 25 years, from 1980 to 2015, mangrove area of 405,581.99 ha was lost (Figure B3). Areas lost included: 64,730.06 ha in Rakhine State, 19,789.24 ha in Ayeyarwaddy Region, and 111,062.69 ha in Tanintharyi Region (Figure B4). This means deforestation rate in unreserved forests is 2.37 times higher than that of in RFs (FRA, 2015).

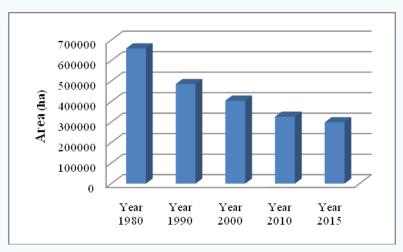


Fig.B3 Mangrove cover changes over 30 years in Myanmar: 1980 to 2015

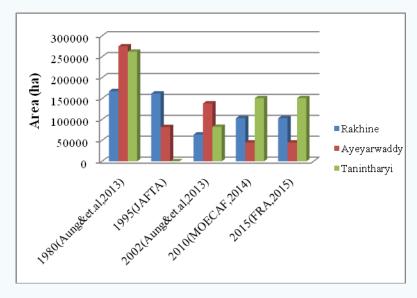


Fig.B4 Mangrove cover change in three main States and Regions between 1980 and 2015

Two main causes; anthropogenic and natural actions, have been identified as cause of mangrove deforestation.

Forest Department is trying to reforest mangrove or establish mangrove forest plantation of 997.98 ha in Rakhine, 5,789.47 ha in Ayeyarwaddy, and 121.46 ha in Tanintharyi between 1981 and 2015 (Figure B) in the degraded areas but area of mangrove forest plantation are still far below what is needed to meet the lost and degraded mangrove area of 405,581.99 ha (Figure B4).

In the context of international cooperation for mangrove and its ecosystem conservation, the government attention can be seen getting higher based on some progress such as: development of national strategy (NSDPM) and action plan on mangrove, forming a national coordinating body (NCB) on 10<sup>th</sup> Oct 2014, membership of mangroves for future (MFF) in 2014.

In the context of policy, Ministry of Natural Resources and Environmental Conservation (MONREC) has the main responsibility to manage and conserve the forests, forest products, their ecosystems, and finally environmental conservation and addressing climate change. Forest Department (FD) has the mandate to manage and protect forests and their ecosystems. Simultaneously, Environmental Conservation Department (ECD)

has the mandate for coordinating environmental affairs among stakeholders and mainstreaming environmental conservation and addressing climate change for those different sectors (Figure B5).

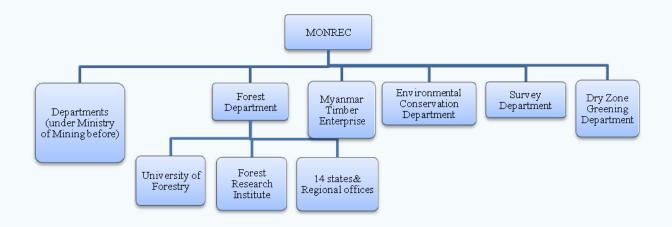


Fig.B5 MONREC organization structure

Forest Law was enacted in 1902 and amended in 1992 after 90 years by the Ministry of Forestry (MOF); currently MONREC for meeting existing politics and socioeconomic status. The article 4 and 6 of the Forest Law amended states that the reserved forest is an area to conserve the environmental factors and to maintain a sustained yield of forest products. The Ministry may, with the approval of the Government, constitute the following categories of reserved forest by demarcating land at the disposal of the Government:

- 1) commercial reserved forest;
- 2) local supply reserved forest;

- 3) watershed or catchment protection reserved forest;
- 4) environment and biodiversity conservation reserved forest;
  - 5) other categories of reserved forest.

Forest and forestry are defined as the allowed land use and activities in the reserved forest in Forest Law. Any trespassing, felling, burning and settlement in the reserved forest (RF) without permission of FD are not allowed, and the person who violates the act can be punished in accordance with the Forest Law (Ministry of Forestry, 1992).

Table B2 Mangrove RFs and URPFs establishment in Myanmar coast

State/Region	RF no.	Established
Rakhine	2	Since 1931
Ayeyarwaddy	8	Since 1896
Tanintharyi	11	Since 1920
YGN	3 URPFs	Since 2015

**Table B3** Protected Areas (PAs) established in Myanmar coast (as at 2015)

State/Region	PA no.	Established
Rakhine	0	
Ayeyarwaddy	2	Since 1970
Tanintharyi	2	Since 1927
YGN	0	

Table B4 Mangrove URPFs to be establishment

State/Region	Proposed / Proposing	No. of URPFs/ CF
Rakhine	Proposed	4 URPFs
	Proposing	4 URPFs
	Proposed	1 CF
Ayeyarwaddy	Both	0
Tanintharyi	Proposed	3 URPFs
YGN	Both	0

Article 42 in Forest Law highlights restriction and punishment, "whoever commits any of following acts shall be punished with a fine 20,000 kyats or imprisonment, or both:

- a) felling, cutting, girdling, injuring trees in RF
- b) extracting, moving or keeping timber from RF
- c) establishing saw mill in environment and biodiversity conservation RFs
- d) other categories of reserved forest."

Forest policy has been announced in 1994 in consideration with six main categories such as protection, sustainability, basic needs, efficiency, people participation, and public awareness. FD has submitted its policy being amended for the cabinet approval.

Environmental policy (1994) is being amended and environmental policy framework (EPF) is being developed under a joint project between UNDP-Myanmar and ECD since 2015 (Environmental Conservation Department, 2015). EPF would include a mission, "committed to leading the integration of environmental

perspectives into socio-economic policies, laws, regulations, plans, strategies, programmes and projects across the Republic of the Union of Myanmar".

Community Forest Instruction (CFI) was notified in 1995 (Forest Department, Community Forestry Instruction, 1995). In this regards, MONREC is encouraging community forest (CF) in both degraded RFs and other land. Currently, FD is amending CFI to meets actual needs and overcome its weakness based on 20 years of experience.

On the other hand, national land use policy has been developed through coordination of different ministries in January 2016 and forest law is being amended by FD. It includes 13 parts. But, illegal timber and forest production extraction and conversion of forest into other land use are still observed.

Simultaneously, development of national strategy (NSDPM) and action plan on mangrove is being processed and a national coordinating body (NCB) on 10<sup>th</sup> Oct 2014, membership of

mangroves for future (MFF) has been formed with the ministry's order number of "10-9-2014" in September 2014. NCB has been reformed in 2015 with main objective of managing coastal and mangrove resources in effective and sustainable ways.

Regarding lesson learnt from Cyclone Nargis's impacts on mangrove ecosystems, local community in 2008, awareness has been highly enhanced. Except TCZ, ADCZ has been most destroyed and RCZ secondly in the disaster. Mangrove section is being established in Watershed Management Division (WMD) of FD since 2014.

Institutional structure has been reformed for twice within 5 years; Ministry of Forestry to Ministry of Environmental Conservation and Forestry (MOECAF) in 2011 and MOECAF to Ministry of Natural Resources and Environmental Conservation (MONREC) in 2016 (Figure B3).

Results of questionnaire and semistructured interviews conducted during preliminary survey with 16 local interviewees living among mangroves in Ayeyarwaddy Region confirm that mangrove areas are decreasing by conversion of mangrove into agriculture land/shrimp ponds (56.3% agree), degrading by cutting trees for fire woods and construction (31.3% agree), and (12.5% did not answer). Most of mangrove deforestation was caused by livelihoods needs (87.5% agree and 12.5% did not answer) as 18.8% of respondents are working on agriculture/rice farming, 18.8% on shrimp pond farming, 18.0% on fishing, and 43.8% on both agriculture and shrimp pond farming (Figure B6).

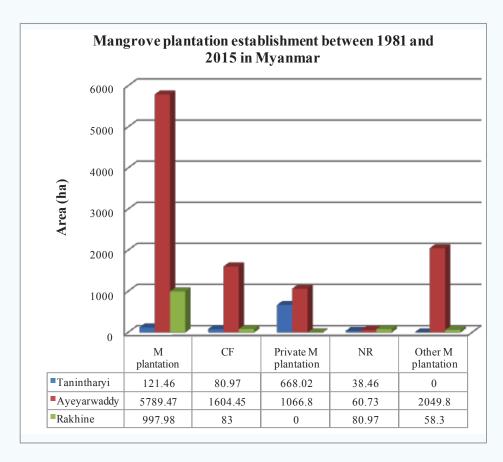


Fig.B6 Mangrove plantation in Myanmar

#### IV. DISCUSSION

Land use policy recently developed in 2016 is expected to be a tool to minimize deforestation and conversion of forest to other land use. There is significant mangrove deforestation at a rate of 72,003.77 ha/yr even though analyzed data variation are observed among different researchers, JAFTA, FAO, and FD. Two main drivers, anthropogenic and natural actions, on mangrove deforestation are observed. Anthropogenic actions includes population pressure; increasing from 28.91 million in 1973 to 35.31 million in 1983 and 51.49 million of 10,877,832 households in 2014 (Department of Population, 2015), limited job opportunity, increasing community needs on forest products such as wood, pole, post, for construction, different aquatic animals such as fish, shrimp, crab, medicinal plants, and low income of community, land conversion (both illegal & legal), are all observed. In the context of natural actions, Cyclone Nargis among 11 cyclones within 126 years is observed as most destructive natural disasters on both community and mangrove ecosystem in Myanmar. Illegal conversion of mangrove into agriculture land and cutting trees is more significant issues than climate change impacts even though there are forest law, rules, and policy.

Weakness in law enforcement, limited quantity, capacity, and facility of human resource and institution; overlapping or not clear items among sectoral policy, laws, and rules, and too few of researches on mangrove ecosystem, coastal ecosystem are identified as potential barriers in mitigating process of mangrove deforestation.

To fulfill the needs of people is one of 6 categories of Myanmar forest policy but people demand is exceeding the potential supply of mangrove ecosystem and government support through a milling and marketing service of Myanmar Timber Enterprise (MTE). There are also weaknesses in law enforcement due to insufficient human resources capacity and quantity, lack of logistic support or facility for patrolling among mangrove, weakness of policy concern on mangrove ecosystem and its vulnerability. Laws, rules, and regulation exist but policing is a concern. Community Forest Instruction (CFI) is technically sound but it is filled with risky issues of legislation, socioeconomy, management, communities, and institutional constraints in development of CF. After CF certificates were issued as confirmed by the results of semi-structured interview and self-experience. It is clear that Myanmar needs clear and strong legal framework followed by enhancing institutions, collaboration, raising awareness, alternative job opportunities, to protect mangrove taking into account data from FAO, FD, and other available technical data.

#### V. CONCLUSION

Myanmar has systematic forest management known as sustainable forest management plan (SFM) and institutional arrangement but mangrove degradation and deforestation are still ongoing and are a complicated issue. Due to construction of massive bunds, excessive land reclamation for agriculture and aquaculture, tree cutting for timber, fuel wood and charcoal production on a commercial scale, 10 out of 13 unreserved and reserved forests in the Ayeyarwaddy Delta Coastal Zone have been converted into agricultural land, shrimp pond and settlements. To fulfill the needs of people it should be considered by the MONREC in alternative ways including CF establishment. The ministry should try to strengthen law enforcement, human resources capacity and quantity, logistic support or facility for patrolling among mangrove through coordination with ministries concerned and international technical and financial support.

The ministry concerned should encourage mangrove management techniques, research and development, such as plantation establishment, natural regeneration activities, and research on mangrove ecosystem, coastal ecosystem. Finally, we strongly advocate that a specific Mangrove Management Working Plan (MMWP) be developed as the existing Forest Working Plan (FWP) is generally focused on terrestrial forest rather than on mangroves. The new MMWP would be a catalyst for more effective and regular community awareness programmes.

Mangrove forest plantation establishment and natural regeneration activities should be encouraged much more than at present. Community forestry practice being applied by FD technically sounds good but monitoring and evaluations on user groups are still weak. Beyond ecosystem matters, the importance of amendment to and enhancement of law and policy applicable at multisectors is needed in forest law. Community level instruction in law and forestry should be encouraged.

#### **ACKNOWLEDGEMENT**

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Session A.3: Practice



### Biodiversity conservation model in Karst ecosystem: Case study in Gunungsewu-Indonesia

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Abstract-Gunung Sewu is an enormous mountainous limestone zone, marked by conic karst hills spanning Yogyakarta, central and east Java. The karst landforms grew through dissolution, when the limestone was uplifted from the seabed about 1.8 million years ago. The uplift notably led to the formation of coastal and river terraces as well as sandstone outcrops. The objective of the research is to investigate the model of conservation and the characteristic biodiversity in Gunungseweu. The field survey and interview method were conducted. The flora and fauna field measurement and observation were used to identify the biodiversity of flora fauna. The result shows that local wisdom has a significant role in flora and fauna conservation instead of managing by local government. In order to meet the needs of local biodiversity conservation, biodiversity conservation goal which are agroforestry system, save lake program, cultural perform program, environment program at junior and elementary school, environment education

program to local community, local activities organized by local government and conservation in local belief perception. The impact of the study is a growing local awareness in terms of conserving the aspects of biodiversity which are abiotic, biotic and social-economic aspects in karstic ecosystem. This experience will encourage replicating in other areas by sharing the biodiversity conservation method, providing opportunities for poverty eradication, human well-being and the livelihood and socio-cultural integrity of people. Two main conservation strategies for the growth corridors have been approved by local government and local people which are environmental conservation efforts for biodiversity sources and institutional strategy: establishment of community-based biodiversity conservation.

Keywords: Biodiversity, Conservation, Gunungsewu, Karst

#### **INTRODUCTION**

Gunungkidul is one of the 5 districts and city in Yogyakarta province, located in the Southeast. Geographically, the area is located at coordinates of 110°28'12"-110°50'24" E and 7°46'48"- 8°12'36" S. Gunungkidul consists of 18 sub districts and 144 villages. Gunungkidul has a very interesting physiography; it can be divided into three distinctive landscapes, namely: Baturagung Hills, Wonosari Basin and Gunungsewu Karst. Rock constituents of almost all regions of the Ecosystem of Baturagung Hills is old volcanic material that has undergone much weathering, which include: Formation of Kebo-Butak, Semilir, Nglanggeran, Sambipitu, Oyo, and Wonosari. Wonosari Basin generaly is a basin formed by the folding plateau in the south of Java island that is experiencing peneplain formation. This unit has a height of between 150 to 200 meters asl, which is composed of limestone and clay base material of Wonosari Formation, Oyo, and Kepek. Gunung Sewu Karst Hill is karst is composed by fasises of reef limestone. Geologically, in addition to the dominant reef limestones, there are also an inserted layer of limestone marl, and conglomeratic limestones. Limestone reefs are coloured dirty white to light brown and are compact, solid and hard, with a primary porosity that is quite large. These rocks are composed by corals, algae, foraminifera, mollusca and bryozoa.

Karst is a landscape that has relief and typical drainage, caused by the higher degree of rock dissolution compared to other rock types. One rock that is very susceptible to dissolution is limestone. This rock formation can form karst topography characterized with soluble rock, in thick layers, many cracks or diaklas, all associated with high rainfall, and being located at a high elevation. In addition to limestone, karst topography can also be formed on the rock subjected to intense evaporation such as halite, gypsum, and

anhydrous. The formation of karst topography is a slow process, with three (3) phases or stages, namely: young, mature, and old or advanced.

## Karst Biodiversity Case study in Winong Lake

From the observation and inventory, it is known that the Winong Lake has a wealth of biodiversity which is quite high, (> 50 spp.) especially in species of flora and insects. This is quite interesting because in karst, it is relatively narrow area. Winong lake has 68 species of flora, 32 species of insects, other arthropods 7 species, 18 species of birds, 13 species of herpetofauna, 8 species of aquatic animals, six species of mammals, and three molluses. Noteworthy is the presence of various types of Ficus spp. on the edge of the lake, two endemic birds, the presence of butterflies and dragonflies as bio-indicators, the existence of jungle cats, and of fish populations blooms that need to be controlled. In conservation efforts, it is necessary to take advantage of local knowledge to support these efforts as well as to socialize the importance of this primarily karst ecosystem and lake ecosystem. Winong Lake as one of the biodiversity hotspots within the karst Gunungsewu needing attention.

## Challenge to Lake conservation and sustainable ecosystem management

Our work indicated that Winong Lake was a valuable ecological resource. However on-going challenges to the ecological health of the Lake were indentified and included:

- Mining
- Unplanned, illegal and ecosystem degrading waste disposal activities
- Non-control of non-local invasive species
- Irresponsible tourism
- Infective water resource management

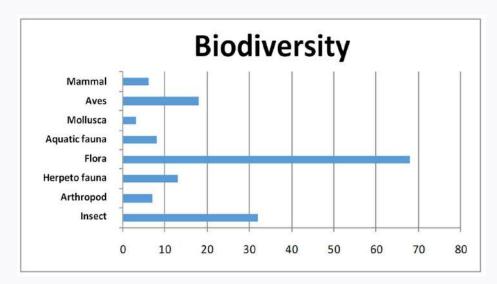


Fig.1 Biodiversity description during the survey at Winong Lake, Dec 2014-Apr 2015

#### **Local Conservation Practices**

To address the needs of local biodiversity conservation, some local community practices have begun. These include:

• Agroforestry to make a more sustainable management of the landscape and water rationing in which hillsides are planted with cassava and trees like teak and acacia while lower (foot) slopes are planted with corn and maize. Thus we see a multi-layers pattern on the landscape and more in tune with the landscape (Fig.2) and water supply control. Erosion is reduced especially through grass as a ground cover carpet. Along with fruit yielding trees, the overall approach seeks to combine a more planned crop and tree use with more sustainable economic returns.

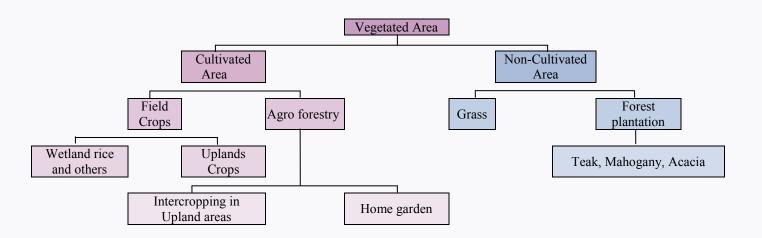


Fig.2 Vegetation Classification for Typical Village

#### • Save the Lake Program

A Community activity focusing on lake respect and protection took place on April 17, 2015. Some 2,000 participants gathered to demonstrate their respect and care of the lake. The diversity of this group was impressive in its inclusion of local students, local government, scouts, people, police and army. Cultural

dances symbolizing the removal of evil spirits that may harm the village and 'their' lake took place and was supported by both local and national media (Fig.3). A related cultural performance at which 3,000 local village people participated also took on 16 April 2015. The focus was on live involvement and cleaning the village (Fig.4).





Fig.3 The local community and students group conducted "save the lake" activities





**Fig.4** The local community conducted local culture performance in order to conserve their local culture and environment

#### Multi-level Eco-environmental Education Activities

To ensure that ecological awareness is propagated throughout the local society new efforts have been made to help bring the local people back to contact with Nature and its ecological resources especially biodiversity (Fig.5-6) illustrate the application of such activities at all levels in the educational system (Elementary, Junior, Senior High School) and local communities. The Candirejo Youth Project (2011-2012) which was backed by local

government helped to bring biodiversity close to the people.

## • Environment Program at Junior and Elementary School

Location at SMK Saptosari attended by 50 students. The objective is to increase the awareness the importance to save the forest in order to protect the lake. There is also a tree planting program near the school in order to enhance local biodiversity.





Fig.5 Discussion activities in class and tree planting



Fig.6 Local community learning about the lake and its biodiversity

#### Environment Education Program to Local Community

In the past, public awareness about the environment, especially biodiversity conservation is relatively low. This happens because often there was a widening field by people in the forests or by timber theft. Climate and soil in the location is also an obstacle to forest conservation. By supporting from EE2-NEWRI NTU Singapore, there are some programs created to village and its surrounding about how to improve an environment public awareness through Environmental education program. Different emphases are conducted for environmental education in various sectors:

a) Elementary and Junior Students: Environmental education at the school level will develop students' perceptions

- and values as well as encourage their active participation toward biodiversity conservation.
- b) Senior High Education: Environmental education at the higher education level is able to contribute in the deepening of knowledge and developing the necessary skills for the management and improvement of environmental quality that is conducive to the welfare/well-being of the Local community.
- c) Local Community Sector: Environmental education expect to inculcate awareness and understanding, as well as promote skills, commitments and actions among individuals and social groups for the protection and improvement of environmental quality for the benefit of present and future generations.

Learning lesson from Candirejo Project in 2011-2012, the Youth Organisation has a significant role in order to manage the local biodiversity resource management. This organisation is backed up by local government and local leader both formal and informal leader. The objective is to educate local community what is lake about and its biodiversity. There is information about physical, biological and social culture relate to Winong lake information.

#### Activities Organised by Local Government Village:

- Preparation of Village Forest Area of 65.044 ha
- Establishment of Community Forests Area: 796.6242 ha
- Establishment of Protected Forest in the Sacred Lake Conservation Area in *Padukuhan* (sub village) Wareng area of 4.2 ha
- Establishment of Forest Preserve in Lake Conservation Area
- Construction of the clean water problem solving
- Forest Conservation Reserve on the ground SG, Padukuhan Wareng
- Establishment of Horticultural Crops Plantation area of Organic Onion
- Food Security Program Lumbung Household Formation
- Biodiversity Conservation
- Greening the environment of the lake

#### Conservation in Local Belief Perception

The concept of conservation of Local community cannot be separated from the story of the (wayang) puppet story as a symbol of knowledge of the Java community to its environment. In adapting to its environment, the Java community develops ideas which refers to the balance, synchronization, harmony, and unity. About the climate environment, the Java community divides the climate into

four seasons, and each season is given symbol or symbols of Pancamahabhuta elements according to their natural phenomena, namely rendheng with symbol of Tirta (water), and Labuh with symbol of agni (fire), katiga with symbol of Maruta (wind), and Mareng with symbol of Bantala (ground). The above description shows that the human being is so close to the universe; so the human and the universe is a unity. Java community sees that the human (society), nature (the world), and a supernatural realm is not the three areas of relatively stand-alone and each has its own law, but is a unity. It can be connected with Koentjaraningrat opinion that: According to Agami Jawa conception, God is a whole in the natural world, which is denoted by a God creature so small that every time can be entered into the hearts of people; but God as lake as big and broad as the ocean, endless and stems like space, and consists of all the colors in the world. That is the view that is 'pantheistis' in Java community about God. According Zoetmulder, pantheistis view is that "everything is God" and "everything to the Lord".

## • Linking Conservation to local Beliefs and cultural stories

The existing beliefs and cultural stories held within Java Society based on the "Wayang" puppet story in which seasons and natural events feature strongly and remind people of Tirta (water), fire (agni), wind (Moruta) and earth or ground (Bantala) remind local people of their unity with society and nature. All these beliefs have their contribution to make to modern biodiversity conservation.

#### **CONCLUSIONS**

The Gunungkidul Strategic Assessment builds on two main conservation strategies:

1) Environmental Conservation Efforts by all

parties within government and local society to implement and apply a Biodiversity-focused Resource Management Policy.

2) CBBC: estblishment of Community-Based Biodiversity Conservation as an institutional strategy with linkages to all institutional sectors.

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# Exploration, conservation and phytochemical screening of unexplored flora of India

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Abstract-India is one among the eight mega biodiversity countries in the world having 22% of forest cover rich in medicinal plants. Among these, 70% are found in tropical and subtropical forests, while the remaining 30% are restricted to temperate and high altitude forests. According to Botanical Survey of India (BSI), 93% of medicinal plants are threatened, of which 335 have been Red Listed.

India has the world's second largest tribal population with 550 tribal communities. About 6,500 plants are used as folklore medicines whereas few hundred species are only under common usage. Species specific active principles have their own identity to cure a range of aliments used by various ethnic tribes. However, scientific exploration is not yet attempted on such species. In the present study, three important plants namely Allium stracheyi, Acacia nilotica and Naravelia zeylanica endemic to Himalaya, Eastern and Western Ghats respectively were chosen.

As per traditional ethnobotanical knowledge of Bhotiya, Malayali and Muthuvan tribes, these plants possess multiple medicinal applications. *In vitro* propagation studies reveal that MS media supplemented with IAA & BAP plant growth regulators induce callogenesis and NAA & BAP induce somatic

embryogenesis. Phytochemical screening revealed the presence of various phytochemical constituents besides antioxidants. The results indicated that these unexplored plant species were used by traditional communities for centuries. This study reveals the basic knowledge, biological potentials about these plant species to the world and the usage of appropriate tools to scale up our requirements in a sustainable manner.

**Keywords:** Medicinal and Aromatic Plants (MAPs), Conservation, in-vitro propagation, ethnobotanical knowledge, Tribes

#### I. INTRODUCTION

Plants have always played an integral role in the life of man from time immemorial. Plants have served and continue to serve mankind as a source of food, shelter and medicines besides cleaning the environment (Mukherjee and Rajasekaran 2010). The basic human needs increased multifold in the recent years, increasing demand of herbal medicines globally (Maikhuri *et al.* 2005). Hotspots like Himalaya, Western Ghats and Eastern Ghats are a treasure house for Medicinal and Aromatic Plants: MAPs (Rajasekaran 2000). According

to Nair and Shastry (1987) around 1750 plants in Indian sub-continent were red listed because of following reasons: Poor seed setting, germination and survival rate in nature and illegal collection/extraction from the wild leads to population reduction of many valuable species in natural habitats (Bhadula and Purohit 1994).

India is one among the eight mega biodiversity countries in the world having 22% of forest cover rich in medicinal plants. Among these, 70% are found in tropical and subtropical forests, while the remaining 30% are restricted to temperate and high altitude forests. According to Botanical Survey of India (BSI), India encompasses 17,500 plant species, of which around 8,000 plants were reported in Indian system of traditional medicine (Kalla and Joshi 2004). The use of plants in the different Indian systems of medicine is as follows: Ayurveda 2,000, Siddha 1,300, Unani 1,000, Homeopathy 800, Tibetan 500, Modern 200, and folk 6,500 (Pandey et al 2013). Out of 8,000 species, 600-700 species are heavily used and only 150 species with huge commercial usage and 95% of these plants are illegally collected from wild sources (Kalla and Joshi 2004). Each and every plant present in this globe has some medicinal value however the quantity and efficacies varies (Polunin and Stainton, 1984). Rest of the plants were known as two major categories: 1. Plants underutilised and 2. Unexplored. For this category scientific investigations are sporadic. Therefore in the present investigation keeping all these things in view from major three hot spots namely Himalaya, Western and Eastern Ghats geographical locations, three important plants namely Acacia nilotica, Allium strachevi and Naravelia zeylanica were chosen.

#### II. MATERIALS AND METHODS

Bhotiya, Malayali and Muthuvan tribes from Nanda Devi Biosphere, Jamunamadathur and Devikulum areas respectively were chosen.

#### **Plants**

Acacia nilotica (L.) Wild.ex. Delile subsp. indica (Benth.) Brenan, Allium stracheyi Baker, and Naravelia zeylanica L. (DC) belonging to Alliaceae, Fabaceae and Ranunculaceae respectively were chosen for the present investigation.

Ethnobotanical data survey was carried out by frequent visits to the tribal areas during different seasons of the year. The informants were selected based on the distribution of the people in the particular area. The informants were interviewed using the semi structured questions prepared with respect to the utilization of the plant. The questionnaires contains information such as their 1) Name, age, literate or illiterate 2) Occupation, traditional practices of plants they use, the disease they cured and, most importantly, the mode of use. They were questioned in the local languages/dialect.

#### Micro propagation

For all the plants MS (Murashige and Skoog, 1962) media was used with the supplementation of 3% (W/V) sucrose and gelled with 0.8% (w/v) agar, except Acacia nilotica, where woody plant media (WPM) was used. Plant growth regulators both Cytokinin and Auxin namely 6-Benzyl adenine (BAP), 2-Naphthalene acetic acid (NAA), 2, 4-Dicholorophenoxyacetic acid (2,4 D) and Indole-3-butyric acid (IBA) at different concentrations (0.5 mg<sup>-1</sup>,1.0 mg<sup>-1</sup>) either individually or in different combinations were added to the MS media. The pH was adjusted to 5.8 with NaOH or HCl and autoclaved at 121°C for 15 minutes.

Every six weeks sub culturing was carried out; five replicates were maintained for all the experiments.

#### Preparation of extracts

Air-dried leaves were packed into a soxhlet apparatus and extracted sequentially with petroleum ether (PE), benzene (BZ), chloroform (CF), ethanol (EA) and water (AQ). The organic extracts were dried in vacuum desiccator and the solvents were removed in vacuum (40°C). The extracts were dissolved in Di methylsulphoxide (DMSO), ethanol or H<sub>2</sub>O prior to analysis depending upon their solubility.

The extracts were subjected to further analysis and all the assays were done in triplicates.

#### Phytochemical analysis

The extracts were tested by different tests to determine the presence of various phytochemicals: Wagner for alkaloids, Foam test for Saponins and Ferric chloride, gelatin and Lead acetate for the presence of phenolic compounds and flavonoids. (Harborne, 1998)

#### **Determination of Total Phenolics**

The total phenolic content (TPC) of different extracts of A. nilotica was determined by the method of Folin–Ciocalteu reaction (Kujala et al., 2000), using gallic acid as standard. To the extract, Folin–Ciocalteu reagent and  $Na_2CO_3$  was added. After 20 min incubation at room temperature, the absorbance was measured at 730 nm.

#### **Determination of Total Flavonoids**

The total flavonoid content (TFC) of the different extracts of *A. nilotica* was determined by slightly modified method (Nieva Moreno et al., 2000). To the extract, potassium acetate and aluminium nitrate were added. After 40 min incubation at room temperature, the absorbance was measured at 415 nm using quercetin as standard.

## 1,1-Diphenyl-2-Picrylhydrazyl Free Radical Scavenging Activity (DPPH)

The ability of the extract to scavenge DPPH radicals was assessed as described by Ohinishi et al. (1994). To different concentrations of extract, 3 ml of freshly prepared ethanolic DPPH (0.1 mmol/ l) solution was added. After 30 minutes of incubation in dark, the absorbance was recorded at 517 nm. Results were expressed as percentage inhibition of DPPH.

% Inhibition =  $[(Abs_{control} - Abs_{sample})/Abs_{control})] \times 100$ 

The percentage inhibition was plotted against the sample extract concentration in order to calculate the  $IC_{50}$  values, which is the concentration (µg/ml) of extract that causes 50% loss of DPPH activity. Results were compared with the positive control, ascorbic acid.

#### Statistical analysis

All experiments were repeated at least three times. Results were reported as Mean ±SE. The statistical significance between antioxidant activity values of the extracts was evaluated with one way ANOVA between the groups followed by Holm-Sidaktest.P values less than 0.05 were considered statistically significant.

#### III. RESULTS

#### Ethanobotanicals of unexplored plants

Ethanobotanical usage of unexplored plants namely Acacia nilotica sub sp. Indica, Allium stracheyi and Naravelia zeylanica were collected from Malayali, Bhotiya and Muthuvan tribes respectively (Table 1). About 1,500 plants with varied medicinal uses are mentioned in the ancient texts with around 800 plants being used in the traditional medicine systems (Kamboj, 2000). Several works talk of an available link between both ancient and traditional medicine in India and elsewhere the forests and the

communities residing in these forests. Navaneethan et al. (2011) also relates to the cross-cultural ethnic knowledge of various tribal communities, but with regard to different places (pockets) whereas, the current study relates to the traditional ecological knowledge of different tribes from irrelevant areas.

Gireesha and Raju (2013) have reported only a few medicinal plants used by the tribal people and the local healers of BRTTR. People of India are known for their traditional and cultural practices. But, these traditional practices are on the verge of extinction and one of the

most important reasons being an inefficient transfer of knowledge to the next generations. Especially, when it comes to the traditional knowledge of Medicinal plants the healers do not reveal their traditional practices to other people fearing that, if done so, the potency of medicinal plants is lost. This belief has not only caused a decline in the traditional ecological knowledge of the people, but also a loss to the indigenous knowledge (Nautiyal et al., 2014). Therefore, this documentation is very useful in future usage. Invariably, the traditional ethanobotanical knowledge of all tribes is diminishing in the younger generation.

**Table 1** Ethanobotanical usage of *Acacia nilotica* subsp. *indica, Allium stracheyi* and *Naravelia zeylanica* 

	Acacia nilotica sub sp. Indica	Allium stracheyi	Naravelia zeylanica
Region	Eastern Ghat	Himalaya	Western Ghat
Tribes	Malayali	Bhotia	Muthuvan
Parts used	Leaves, bark, gum,	Bulbs, leaves as well	Leaves, stem and
	fruits	as whole plant	root
Ethnobotanical	Pneumonia, cold,	Jaundice, Wound	Skin Disease,
usage	urinary tract infections,	healing, Cold, cough,	arthritis,
	Treat cancer in mouth,	stomach problem	helminthiasis, colic
	bone and skin, diarrhea,		inflammation,
	hemorrhage, as a		leprosy, rheumathis,
	sedative in labor, as a		dermatopathy,
	cure for sore gum and		odontalgia, wound
	loose teeth and for		and ulcers
	diabetes, Ulcer		
Scientific	Anti Cancerous, Anti-	Anti-inflammatory,	Anti-microbial,
reports	inflammatory,	Hemolytic agent,	Immunomodulatory
	Hemolytic agent, Anti	Anti infection	activity, Anti-
	infection		inflammatory
Mode of	Twings used as	Battering to their kith	Leaves will be
common usage	traditional tooth brush	and kin	consumed during
			festivals

#### **Micropropagation**

Except A. nilotica other two plants have been red listed, therefore conservation strategy is very important. The micropropagation

studies details are listed (Table 2). In all the cases leaf and shoot meristematic tissue explants responded well. The response varied between 70-80%. In the case of A. stracheyi a response was observed up to 93.2%. In callogenesis

Table 2 Micropropagation of Acacia nilotica subsp. indica, Allium stracheyi and Naravelia zeylanica

	Acacia nilotica sub sp. indica*	Allium stracheyi	Naravelia zeylanica
Explant	Leaf	Leaf, Petiole	Leaf, Internodes
Callogenesis	IAA 1.0 + IBA 1.0	IAA 1.0 + 2,4-D 1.5	2,4 –D 2.5+ BAP 0.5
Somatic	IAA 4.0	IBA 5.0	2,4-D 3.0
embryogeneis			
Organogeneis – Shoot	BAP 2.0+ IAA 0.5	BAP 2.0 + IBA 1.0	BAP 2.0+ IAA 0.5
Organogeneis – Root	IAA 0.5	IAA $0.5 + NAA 0.5$	$^{1}/_{2}$ MS + IAA 0.5

<sup>\*</sup>WPM is used

callus color, texture of calli, width and weight were observed. Somatic embryogenesis time taken, number of embryos emerged, in case of organogenesis time taken, number of shoot, roots formed and its length were also recorded (data not shown).

In vitro micropropagation via callogenesiss, induction of somatic embryogenesis and organogenesis is essential for plant genetic resource management and has become increasingly

important for conservation of rare plant species (Iankova et al. 2001; Bhatia et al. 2002). Unfortunately, no serious attempts have been made to conserve this immense treasure of traditional knowledge of ethanobotincals associated with the indigenous people (Siva, et al. 2009). This is the first attempt to find the micropropagation protocol for *Acacia nilotica* subsp. *indica*, *Allium stracheyi* and *Naravelia zeylanica*.

**Table 3** Yield potentials of leaf extracts of *Acacia nilotica* subsp. indica, *Allium stracheyi* and Naravelia zeylanica

		% Yield	
Extract	Acacia nilotica sub sp. indica	Allium stracheyi	Naravelia zeylanica
PE	19.82	14.94	15.08
BEN	16.63	18.28	-
BUT	-	16.53	-
DCM	3.00	-	-
CF	3.61	-	23.60
EAC	-	2.66	6.20
ETH	35.07	11.56	15.41
ACT	-	-	9.01
AQ	15.63	29.54	20.22

PE: Petroleum ether; BEN: Benzene; BUT: Butanol; CF: Chloroform; DCM: Dichloromethane; EAC: Ethyl acetate; ETH: Ethanol; ACT: Acetone; AQ: Water

**Table 4** Qualitative analysis of crude extracts from the leaves of Acacia nilotica subsp. indica, Allium stracheyi and Naravelia zeylanica

Class of		Acacia	Acacia nilotica	ds qns	sub sp. indica			,	Allium s	Ilium stracheyi	ų			N	Naravelia zeylanica	zeylan	ica	
punodwoo	PE	PE BEN	DCM	CF	ЕТН	AQ	PE	BEN	CF ETH AQ PE BEN BUT EAC ETH AQ PE CF	EAC	ЕТН	AQ	PE	CF	EAC ETH ACT AQ	ЕТН	ACT	ΑQ
Alkaloid		-	-	+	+	-	ı	-	+	+	-	1	-	-	+	++	-	
Phytosterols	+	+	++	+	-	-	+	++	+	‡	-	-	+	+	++	+	-	_
Phenolics	+	+	+	‡	+++	+		-	+	+	+++	++	-	+	+	++	+	‡
Flavonoids	+	+	+	‡	+++	+	1	-	+	+	+++	+	-	-	+	++	+	+
Saponins				-	+	+		-	++	‡	+	++++		1		1		+++
Fixed oils	+	+	+	+	+	-	+	‡	++	+	1	++++	+	++	1	1	+	+
																		1

PE: Petroleum ether; BEN: Benzene; BUT: Butanol; CF: Chloroform; DCM: Dichloromethane; EAC: Ethyl acetate; ETH: Ethanol;

ACT: Acetone; AQ: Water

= not present, + = present, ++ = moderately present, +++ = highly present

Table 5 Total phenol content and total flavonoid content of crude extracts from the leaves of Acacia nilotica subsp. indica, Allium stracheyi and Naravelia zeylanica

	Total	Total Phenol Content (mg of GAE/g)	GAE/g)	Total Flavonoid C	Total Flavonoid Content (mg of Quercetin equivalents/g)	in equivalents/g)
Extract	Acacia nilotica sub sp. indica	Allium stracheyi	Naravelia zeylanica	Acacia nilotica sub sp. indica	Allium stracheyi	Naravelia zeylanica
PE	$51.17 \pm 0.25$	$28.03 \pm 0.17$	$9.3 \pm 0.31$	$8.49 \pm 1.63$	$7.52\pm0.71$	
BEN	$71.83 \pm 0.81$	$30.01 \pm 0.38$	ı	$4.90 \pm 0.57$	$12.43 \pm 1.26$	1
BUT	,	$65.73 \pm 0.62$	ı	ı	$4.21 \pm 0.21$	1
DCM	$98.0 \pm 69.96$		ı	$17.32 \pm 5.44$		1
CF	$181.82 \pm 1.19$		$10.2 \pm 0.56$	$3.59 \pm 0.33$		$10.2\pm0.53$
EAC	,	$79.31 \pm 0.85$	$18.6 \pm 0.73$	ı	$9.73 \pm 0.31$	$19.4 \pm 1.72$
ETH	$536.02 \pm 10.9$	$115.32 \pm 1.85$	$40.4 \pm 0.86$	$36.60 \pm 1.18$	$27.62 \pm 1.48$	43.4± 2.81
ACT	,	•	$11.2 \pm 0.52$	ı		$12.4 \pm 0.82$
AQ	$80.30 \pm 0.96$	$97.35 \pm 1.25$	$9.5 \pm 0.42$	$16.34 \pm 1.31$	$2.11 \pm 0.33$	$11.5 \pm 0.94$

PE: Petroleum ether; BEN: Benzene; BUT: Butanol; CF: Chloroform; DCM: Dichloromethane; EAC: Ethyl acetate; ETH: Ethanol;

ACT: Acetone; AQ: Water

#### Phytochemical analysis

It has been suggested that phytochemical extracts from plants holds promises to be used in allopathic medicine as they are potential sources of antiviral, antitumoral and antimicrobial agents (Nair, Kalariya & Chanda, 2005). The phytochemical screening of the extracts have shown the presence of alkaloids, flavonoids, phenolics, phytosterols, saponins and fixed oil. The yield potentials are listed in Table 3. Qualitative analysis of phtytochemicals from crude leaves extracts of *Acacia nilotica* subsp. *indica, Allium stracheyi* and *Naravelia zeylanica* (Table 4).

## Total Phenolic Content (TPC) and Total Flavonoid content (TFC)

The quantifications have revealed the amount of phenolics and flavonoids present (Table 5). Gallic acid was used as standard for quantifying phenolics (standard graph equation: y=.018 x-.0004,  $r^2=.999$ ). Quercetin was used as a standard for quantifying flavonoids (standard graph equation: y=.001x-.0002,  $r^2=.999$ ).

Values have been represented as mean ± Standard devation. In all the experimental plants ethanol extract was found to contain maximum flavonoids as well as maximum phenolics. Similar studies have revealed that four different varieties of *Allium cepa* contain total phenolics from 4.6 mg/gm to 74.1 mg/gm (Prakash et al., 2007). Similar studies of *Picrorhiza kurroa*, an important medicinal plant, have revealed the maximum total flavonoids content (Kalaivani et al. 2010a).

#### DPPH radical scavenging activity

DPPH radical scavenging activity IC<sub>50</sub> for crude leaves extracts of *Acacia nilotica* subsp. *indica*, *Allium stracheyi* and *Naravelia zeylanica* (Table 6). In all the cases ethnolic extract IC<sub>50</sub> value was observed effective. In biological systems, different reactive oxygen species might be generated which can have different kinds of target molecules including lipids, proteins and carbohydrates. These different kinds of target molecules are the results of various kinds of mechanisms. Thus it is very important to evaluate the antioxidant

**Table 6** DPPH radical scavenging assay of different crude extracts obtained from leaves of *A. nilotica, Allium stracheyi* and *Naraveloa zeylanica* 

		IC <sub>50</sub> (μg/ml)	
Extract	Acacia nilotica sub sp. indica	Allium stracheyi	Naravelia zeylanica
PE	>500	>500	218.3
BEN	>500	>500	-
BUT	-	>500	-
DCM	>500	-	-
CF	225.7	-	340.4
EAC	-	332.1	260.4
ETH	6.5	27.6	87.4
ACT	-	-	180.3
AQ	>500	>500	110.2

PE: Petroleum ether; BEN: Benzene; BUT: Butanol; CF: Chloroform; DCM: Dichloromethane; EAC: Ethyl acetate; ETH: Ethanol; ACT: Acetone; AQ: Water

potential of an antioxidant molecule by different antioxidant assays (Kalaivani et al., 2010b). Variations in antioxidant capacity of different extracts may be due to differences in their phytochemical profile such as phenolics, flavonoids, phytosterols, saponins and carotenoid (Kalaivani & Mathew, 2009).

#### **CONCLUSION**

In the present study, three important plants namely Allium stracheyi, Acacia nilotica and Naravelia zevlanica endemic to Himalaya, Eastern and Western Ghats respectively were chosen. As per traditional ethnobotanical knowledge of Malayali, Bhotiya and Muthuvan tribes, these plants possess multiple medicinal applications. In vitro propagation studies reveal that MS media supplemented with IAA & BAP plant growth regulators induce callogenesis and NAA & BAP induce somatic embryogenesis. The germplasm of these species can be conserved for future use. Phytochemical screening revealed the presence of various phytochemical constituents besides antioxidants. The results indicated that these unexplored plant species have been used by traditional communities for ages. This study reveals the basic knowledge, biological potentials about these plant species to the scientific, global community and the usage of appropriate tools to scale up our requirements in a sustainable manner.

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### Community empowerment in Mangunan-Girirejo Bantul through development of Gama Herbal Garden to increase economic value and conservation of medicinal plants

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Abstract-The markets of herbal products are increasing in Indonesia and even in the world market following increasing demand on herbal based health treatment. Gama Herbal Garden is a garden located in **Innovation Centre of Agro Technology UGM** in Mangunan-Girirejo Bantul Yogyakarta. Attempts are made to explore the possible economic development based on local natural resources and at the same time increasing the value of Gama Herbal Garden to support the conservation of the area. Human capacity development is the focus of this program targeting women farmers and administrator of Gama Herbal Park. The programs consist of education on identification and utilization of local herbal medicine to be used as self-medication, training on Good Agriculture and Collection Practices, product diversification, improving herbal material production facilities as well as exhibition of the product. Post harvesting training was also the focus of the programs due to the lack of information on the importance of product quality for industrial scale. Workshops and training on herbal

product diversification such as herbal drinks were introduced. Some products have been able to be produced by the farmers such as better quality of herbal materials (simplisia), herbal drinks, and plantation of medicinal plants. This program is in line with some parameters of SDGs including ensuring healthy lives, gender empowerment and protection as well as promoting sustainable use of terrestrial ecosystems. Further development and support are still needed to sustain production and creating integrated healthy and environmentally friendly livelihoods.

Keywords: human capacity development, healthy livelihood, Gama Herbal Garden, medicinal plants

#### I. INTRODUCTION

Herbal products such as herbal medicines, supplements and cosmetics have been widely accepted by society in developed as well as developing countries. The market of supplements and herbal medicines reached US\$93.15 billion by 2015 [1]. This was triggered in part by the increase in lifespan and awareness in maintaining health and livelihood in general with Europe ranking the highest as the market for herbal products. In 2015, as reported by Global Industry Analyst, the fastest growth was in Asia Pacific and reached 10.7% CAGR (Compounded Average Growth Rate). WHO showed the support for herbal medicine usage by recommended traditional medicines, including herbal ones to maintain community health, prevention and treatment of diseases especially chronic, degenerative diseases and cancer.

In Indonesia, the trend of back to nature impacts on the development of traditional medicine and herbal cosmetics industry each year. Data obtained from The Ministry of Health in 2013 stated that herbal medicine market reached US\$1.2 billion and tends to increase each year [2]. Support from government for herbal medicine development was implemented by Memorandum of Understanding (MoU) between Ministry of Cooperatives and Small Medium Enterprises, Ministry of Health and National Agency of Drugs and Foods Controls to increase capacity and monitoring development of SMEs which focus on herbal medicines, spa and herbal cosmetics on February 2, 2011. The support from Ministry of Health is also stated on Ministry of Health Regulation no.006/2012 about industry and business on traditional medicines which regulate the business and distribution of traditional medicine.

UGM has a park located in border of Mangunan and Girirejo villages Bantul Yogyakarta, the park is currently maintained by Centre for AgroTechnology Innovation. This land is developed as conservation area and used by local community for agroforestry based agriculture. The land is planted by eucalyptus, pine and rubber trees, which can be harvested for their essential oil production,

latex and wood to be sold or to be used to create handicraft and furniture to increase community income. In the conservation area there are many types of medicinal plants which grow wildly such as Andrographis paniculata, Curcuma domestica, Curcuma xanthorrhiza, Gynura procumbens, Phylantus nurii, Elephantopus scaber and Orthosiphon stamineus. In 2013, the small area of 0.5 ha was used to make a demonstration plot for local medicinal plant collection, namely Gama Herbal Garden.

Despite the routine use of this land to support the income of local community, the development of this land as Agro Techno Park has not yet been successful. There are many problems to face for its optimum uses without compromising the status of the land as a conservation area. Some of the problems are the lack of knowledge on how to conserve the forest. The communities are short of information on proper harvesting techniques and maintaining agroforestry. The 150 ha of the land has not been utilized optimally. Secondly, the local communities are not aware of the uses of local medicinal plants for maintaining their health. Thirdly, they lack techniques on medicinal plants' cultivation and post harvesting to produce standardized materials for industry. Currently, the herbal materials produced are still under market price due in part to their quality. Product diversification is also needed to increase the value of local products. Lastly, there is a need to increase the knowledge on business development for marketing their products.

Considering the potency and based on data on herbal product market development, universities play an important role in herbal medicine development, supplement as well as herbal drinks in better dosage form, safety, efficacy and quality. Gama Herbal Garden in the area of Mangunan-Girirejo villages could

be developed as the centre for developing product for maintaining health and supporting economy for local communities. The farmers, especially the women, who have high commitment are important assets need to be empowered to support the family income.

#### II. METHODOLOGY

- Training on medicinal plants' uses for maintaining health

Training was carried by workshops on determining variety of local medicinal plants and their uses to maintain health.

- Optimization and extension of herbal garden area

In order to fulfill the demand of herbal industry, the quantity of herbal medicine raw materials was increased by planting more cultivars in Gama Herbal Garden. Gynura procumbens is the main target for upscaling cultivation since it is the one needed by PT Phapros, the marketing partner. In 2015, more G. procumbens had been planted by intercropping/ "tumpang sari" system. Training on Good Agriculture and Collection Practices/GACP [3] was conducted for local farmers on UGM land and system contract farming was introduced. Parallel with supply demand, the variety of medicinal plants was increased by making "demplot" of local medicinal plants to conserve the biodiversity.

- Production of standardized herbal medicine raw materials

The cultivated medicinal plants were harvested as recommended by WHO guidelines. The harvested materials were further processed using standard protocols developed by the Indonesian Ministry of Health [4]. Briefly, the harvested raw materials were cleaned by running clean water and air dried under indirect sunlight. For processing rizhomes, the rizhomes must be sliced into recommended sizes prior to

drying. In some circumstances, the materials were dried in air circulated oven at 50°C. Benchmarking to Centre for Research and Development of Medicinal Plants and Traditional Medicines, Tawangmangu Indonesia was also conducted to increase the knowledge of local community on GACP.

#### - Product diversification

In order to optimize the potential use of herbal materials in local area, herbal based products were introduced in the program. One of the examples is introducing herbal drinks using local materials. Two types of herbal drinks are in the form of instant drink and "tea bag" form. The techniques include introduction of GMP in making and processing the products.

#### - Marketing

Products are marketed in collaboration with PT.GMUM to sell the herbal drinks and PT. Phapros for herbal materials. The products were also introduced to market by attending exhibition. Workshop on distribution license was also conducted.

#### - Strengthening enterprises

Capacity development of community on managing enterprises was conducted to sustain the production and existence of production units. This includes Good Manufacturing Practices, management of establishing enterprises and marketing strategies.

#### III. RESULTS AND DISCUSSION

In general the training, workshops and community empowerment processes in order to achieve the output of the programs were conducted based on co-creation, co-financing and win-win solution, considering the socioculture aspects, economic status and livelihood of the local communities. *Co-creation* means that the programs and solutions offered were based on community needs and designed

together with communities based on priority level. *Co-financing* was created based on the agreement that the funding needed to support the operational programs were shared by communities, local government, private sectors and universities. *Win-win solution* means that the output was expected to bring benefit to community, university, local government and the privates involved.

The workshops increase community knowledge on the uses of local medicinal plants in maintaining their health.





**Fig.1** Workshops and training on identification and uses of medicinal plants to maintain human health.

The workshops were conducted by training on identification and determining the types of medicinal plants grown in the local area. This was conducted by dialogue about what and how the communities normally use and do. Next, several plants were introduced and their uses for maintaining human health were explained. The activity was followed by hands on training on herbal medicine preparation methods (Fig.1).



**Fig.2** Cultivation of medicinal plants under shade (A) and semi open shade (B) with continuous supply of water irrigation (C & D).



**Fig.3** Intercropping system of medicinal plants with neem trees, prior (A) and after (B) and with pine tress, prior (C) and after (D) several months of growing.

#### Cultivation of medicinal plants

In this program the area of Gama Herbal Garden was extended to supply the demand of marketing partner. The local community was trained on cultivation, maintanance and post-harvesting techniques according to WHO guidelines. The cultivar was grown and maintaned using organic fertilizer (Fig.2). Shade was used to grow plants that are sentitive towards sunlight such as Piper crocatum and the semi open one was used for

those which are less sentive towards sunlight such as *G. procumbens*. Shading was reported to affect the content of bioactive compounds in medicinal plants. Growing *A. paniculata* under shade was reported to have more andrographolide content compare to non-shaded ones [5].

Water irrigation system was also built to maintain water supply during the dry season. In Gama Herbal Garden, the plantation was conducted using intercropping system, commonly called "Tumpang Sari" by local people. In this system the herbals were planted together with the deep-rooted plants, one of examples is neem plant (Azadirachta indica) (Fig.3), which also has bioactivity properties. A. indica was reported to contain biopesticide against two mosquitos Anopheles stephensi and Culex quinquefasciatus [6] as well as to Aedes aegypti in silver nanoparticle form [7]. Intercropping or agroforestry system has been reported to be able to promote cultivation and conserve medicinal and aromatic plants [8].

In addition to planting in Gama Herbal Garden, the local communities were trained to cultivate the medicinal plants in their own yard. Joint forest management and contract farming were applied to intensify the capacity of production and at the same time increase the efficiency of maintenance. This system was implemented based on win-win solution agreement between Management of Gama Herbal Garden as the core management and local communities as suppliers. The locals who have land and suitable for farming medicinal plants were asked to join and manage their own yard based on the training given. The products then were sold to Gama Herbal Garden management for further marketing.

Production of standardized herbal materials

In order to increase the value of medicinal plants, the herbal materials must be processed according to industrial standards. The process of production must meet the criteria of constant parameters as well as definitive qualitative and quantitative values to assure the quality, safety, efficacy and reproducibility of the materials [9]. In this



Fig.4 Hands on training on harvesting (A), handling herbal materials (B) and benchmarking local farmers to Centre for Research and Development of Medicinal Plants and Traditional Medicines, Tawangmangu Indonesia (C & D)

program, the farmer was introduced and trained on method of harvesting considering the season, age and part of intensify the productivity following GACP guidelines (Fig.4). Additionally, cleaning, drying method, packing, labeling, transportation and storage of raw material which could greatly affect the quality and therapeutic value of herbal medicines were explained. The quality of herbal materials was analysis according to standard of Indonesian Ministry of Health [4]. Hands on training was also conducted as well as benchmarking to nationally acknowledged herbal medicine development centre, Centre for Research and Development of Medicinal Plants and Traditional Medicines, Tawangmangu

Indonesia. This was intended to increase the knowledge and capacity of farmers in processing the medicinal plants and thus increase the value of herbal materials.

Herbal product diversification and marketing strategies

In Gama Herbal Garden, a number of varieties of medicinal plants were planted as "demplot". In addition to that locals have already planted their own medicinal plants



**Fig.5** Workshops on production of herbal drinks and marketing through exhibition.

such as turmeric, ginger, A. paniculata, O. stamineus, Caesalpinia sappan, Syzygium aromaticum. These commodities are important to be developed and utilized to increase the value of materials. Imogiri is famous of herbal drinks called "wedang uwuh" which are traditionally consumed by local people. However, most of the products are in raw material form. Raw material form has disadvantages in which it is bulky and the lifetime is relatively short. In this program, new forms of formulation were introduced which were in instant and tea bag form. Business of instant herbal based



**Fig.6** Upgrading production facilities in order to comply the requirement of herbal drinks production

drinks increases each year. Instant drinks not only function as normal drink but also were used to maintain health.

The workshops were conducted for local farmers as well as Gama Herbal Garden management staff. Based on questionnaire analysis conducted prior and after workshops, 68% of participants were able to produce the products by themselves. Their products were then introduced to public in exhibition to study the consumer acceptance of the products (Fig.5).

#### Strengthening enterprises

In order to sustain the production of herbal based products, a management and production unit was developed. Microenterprises, commonly called "Kelompok Usaha Bersama" consisting of several local farmers was established. The main workshop is in the Gama Herbal Garden secretariat which is also used as a training centre. Production facilities were upgraded to comply the requirement of the Ministry of Health standard for distribution licence (Fig.6). At the moment the business unit is still under development.

#### IV. CONCLUSION

The programs increased capacity of local farmers in production and utilizing of medicinal plants as an alternative source for increasing family income. The agroforestry system was found to effectively conserve the biodiversity of local medicinal plants. Further empowerment is needed to continue the production, increase the output and sustain the healthy livelihood of community.

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# Practices of mitigating biodiversity loss among indigenous people of Arunachal Pradesh

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Abstract-Contribution of indigenous communities all over the world in lessening biodiversity loss has been well recognized. Sustained Himalayan biodiversity in its pristine form exists as a great feature in Arunachalee tribes who live in tune with nature. Credit goes to their practices, strong beliefs, taboos, nature worship and their wisdom in replenishing biodiversity loss.

The Apatani tribe of Central Arunachal Pradesh, having 29,546 population limited only to 43 sq.km is an example of teaching value. Their practices based on their ancient wisdom is a developed rice cum fish cultivation with finger millet on the bunds over an area of 3,300 ha while around 1,000 ha is under rain-fed upland farming. They replenished their limited mountainous region by planting pine trees and thereby maintaining natural sources of water for the pisciculture. This wisdom has made them efficient natural resource managers with rich traditional knowledge that attracted the attention of UNESCO for consideration as a declared World Heritage Site.

No doubt, it's a great example of sharing knowledge, expertise, and technology with multi stakeholders, which is one of the main aims of RCEs. The example also can teach sustainable management of natural resources, replenishing the forests and halting biodiversity loss; one of the important sustainable development goals. This could be replicated in many parts of the land-locked valleys and remote hilly regions of the world.

RCE East Arunachal Pradesh has effectively transmitted these conservation strategies from one tribe to another.

Keywords: Himalayan State, tribes, wet rice culture, irrigation system, rich fish farming, sacred groves, totem, taboo

#### **INTRODUCTION**

The Himalayan State of Arunachal Pradesh has a 'highly precipitous and varied terrain' (Ramakrishnan, 1992). It is a land of lush green forests, deep river valleys and beautiful plateaus, unparalleled in the world for the concentration, isolation and diversity of tribal cultures it contains. It is home to 25 major and 100 minor tribes having unique cultural practices. The tribal community of the state largely depend upon diverse agriculture practices ranging from a variety of shifting agriculture systems, fallow systems and wet-rice cultivation (Ramakrishnan, 1992).

Ingenious systems of practice in farming of these tribal societies is often energy ecologically efficient. These also play important roles in lessening Biodiversity loss. Such practices are living examples of sustainable utilisation of the bio-resources endowed to the indigenous communities by Nature. In addition, tribal faith and belief play an important role in the conservation strategy. In every community there is a strong practice of and belief in taboos, nature worship and their associated wisdom. These practices since time immemorial helps towards replenishing the biodiversity loss that are the results of natural as well as anthropogenic activities.

#### 1. Agricultural practices in Apatani

The *Apatani* belong to the Tibeto-Mongoloid stock. They are very superstitious, nature worshippers and follow the *Donyipoloism*, believing the existence of Sun and Moon as supreme Gods. *Apatani's* settled in Ziro valley at an altitude above 1,600 m in Arunachal Pradesh, India. With a total population around 29,546 people (Census Report, 2011) the tribe live in sustainable villages made from wood and bamboo.

#### 1.1 Rice farming and irrigation system

Shifting or *Jhum* cultivation is one of the most prevalent land use systems and cause of forest degradation in the north-eastern region of India. However, shifting or Jhum cultivation is not practised by Apatanis. They have developed other important agro-system types, viz home gardens and wet rice cultivation. Apatani village ecosystem is an excellent example of economic sufficiency of a traditional agricultural society (Chaudhry et. al., 2011). With a highly developed valley cultivation of rice perfected over centuries Apatanis has often been suggested to be one of the relatively advanced tribal societies in the Northeastern region of India (Haimendorf, 1962). There are 16 varieties grown in wet-rice cultivation and are

classified as early or late harvesting varieties. *Pyare* rice is harvested during the last week of July, and *Emmo* in October. The terraced rice fields are classified as *Jebi, Ditor/Pitang* and *Miding*, depending on water-related properties. Jebi the marshy agricultural field normally kept without water during the fallow period is endowed with fine clay soil with higher water-retention capacity than *Ditor/Pitang* the land under water for three months during the fallow period. *Miding* (rice nursery) is the most fertile land and its water retention capacity is very high. Millet is cultivated on the bunds of plots.

The Apatani system of irrigation has been modified over many years through community involvement and equitable sharing of water resources. Water is tapped near the forest in the foothills of the valley and is channelled through major canals on either side of the valley. The water is distributed via numerous small canals so that every plot of land is well supplied with irrigated water for rice cultivation (Chandra et. al., 2008). This also ensures the draining back of surplus water to the main canal without the loss of any organic matter or soil. Terraces, made along the gradient, are connected using bamboo pipes of small circumference at the higher elevations where water intake is lower. In the lower valley, pine pipes of larger circumference are used. Water from the bamboo and pine pipes is not allowed to cascade from one plot to another; bamboo barriers are fixed on the upper elevations where the volume of water is smaller, with pine blocks at lower elevations where the volume of water is greater. Further, to contain losses of organic matter, bamboo traps or straw bedding are introduced into all plots. The dimensions of the bunds change from higher elevations towards the valley floor. The bunds are repaired every year before rice planting. Ploughing is not done in the rice plots so as to avoid soil loss; instead spades

are used to till the land before irrigation. The vision of the community is well reflected in the management and sharing of water as the entire community has a stake in it, and its equal distribution ensures collective survival and social cohesiveness within the community.

Recycling crop residues and use of organic wastes of the village for sustaining soil fertility practiced by the *Apatanis* is an effective way of restoring soil fertility. At harvesting, rice stems of up to 60-70 cm are left on the plot to decompose. After separation of the grain, the straw and spikes are spread on the plots to dry, and burned later. Weeds are also buried in the soil. Biodegradable wastes from the homesteads comprising vegetable, poultry and piggery waste are spread on the plot. The canal draining the village wastewater, which carries organic material, is also emptied on to the plots.

#### 1.2 Rice cum Fish farming

Rice cum fish farming by the Apatani involves a uniquely ingenious way of water and agricultural resource management. The level of water is maintained by opening and closing inlets and outlets called hubur made of bamboo. The preparation for rice cum fish farming starts after the final harvest of rice in November. Land preparation operations during December-January include installing inlets and outlets with bamboo pipes, raising and widening of bunds, and loosening and levelling the soil. Trenches about 50 cm deep are dug in the field to provide shelter to fish. The Apatanis prepare the fields with conventional daos (an implement for cutting) and spades. They consider these practices economically and ecologically viable.

Three strains of Common Carp fishes, (Cyprinus carpio specularis, C. carpio communis and C. carpio nudus) have been raised concurrently with paddy (Saikia and Das,

2004). These species are preferred for its high viability and feeding habit. Fingerlings are introduced during April and harvested in July, during the cropping phase of the early rice. About 2,500 fingerlings are reported to be used for one hector. This gives an average yield of 550 kg per hector annually (Tangjang and Nair, 2015). Fish feeds, primarily on natural food such as pteridophytic Azolla species, phytoplankton, zooplankton, periphyton, and benthos grown in the rice fields (Mustow, 2002). Fishes also eat harmful insects like water beetle, grasshopper and others. 'Lemna minor' and 'Azolla' are also eaten by fishes that originate in the root portion which fixes Nitrogen in the field. In turn, the waste material of fishes acts as manure to the plant (Ankita and Goswami, 2015). Fishes are caught from trenches during the harvest using the indigenous trap.

The rice cum fish farming system has become an important agro-cultural activity of the *Apatanis*. Indeed, the *Apatani* farmers do not have many options other than practicing this ingenious farming system due to scarcity of arable land resources.

#### 2. Sacred Groves

Sacred groves form an important part of the traditional resource conservation system in many parts of India. They can be called as stands of trees or patches of forest that the indigenous communities conserve mainly because of their religious beliefs and rituals that run through several generations (Gadgil and Vartak, 1975). They are the repositories of rare species and can be regarded as the remnants of the primary forest left untouched by the local communities due to the belief that deities reside in these trees or forests.

Many sacred groves have been recorded from Arunachal Pradesh of which that of *Apatanis* and Buddhists monasteries are

organised. In Apatani, each clan of the village has their own sacred groves. They are of two types, Ranthii and Lyago. Ranthii is a designated forest near the village where the rituals are performed. Lyagos are found in and around the village granaries, and is believed to be the dwelling place of the spirit called Subum Nyaro (Chaudhry and Murtem, 2015). Apatanis believe Subum Nyore to be the spirit of well-being. Rituals to appease Subum Nyore are performed in Lyago. No biotic interference is allowed and complete prohibition is practiced for collection of dead or living trees or plants. It is believed that if a person violates then a bad omen occurs to his family. Collection can be done only by the priest during a festival called Myoko.

The *Khamtis* inhabit the region around the Tengapani basin in Namsai district of Arunachal Pradesh. They are descendants of migrants who came from the Bor-Khampti region, the mountainous valley of the Irrawaddy. *Khamtis* are followers of Theravada Buddhism. Sacred Groves are maintained in and around the Monastery in the areas of *Khamptis*.

#### 3. Forest Management

Arunachal Pradesh has more than 82% forest cover. The tribal population of the state is mostly dependent on the wild bio-resources for food, herbal medicine and their routine household tools. For them the wild animal had been a main food source since ancient times. Forest products like bamboo, timber, cane are the only component of house construction. Many of the plant parts like leaf, bark and roots are used as herbal medicine. In spite of depending fully on the forest, they have various traditional ways of harnessing and protecting forest that helps in maintaining the biodiversity and ecosystem functionality of the region.

#### 3.1 Traditional Origanisation

Most of the tribes of Arunachal Pradesh have their own traditional methods for managing biodiversity. They reserve forests, streams and rivers on the basis of community and clan-wise use with certain rules and regulations restricting outsiders to collect any material from their areas. They also manage conservation through traditional reservation of biodiversity, traditional land holding, traditional practice of harnessing bio-resources and political organisation system (Borang, 2001). Legally, the traditional village council as the village authority under the Assam Frontier (Administrative of Justice) Regulation, 1945, has the power to watch and ward over the village and bio-resources. Even the Government has to obtain consent from the village council for implementing their activities like reservation of forests, establishment of sanctuaries and so on.

#### 3.2 Tribal culture and Ethos

The tribes of Arunachal Pradesh conserve their biodiversity through certain cultural ethos that have being practiced through the ages.

Totem: There is wide range of animistic conceptions associated with vegetation, animals, groves and ritual ceremonies. They believe in a supernatural power. Unnatural groves, big trees, large mountains are regarded as dwelling place of ancestral souls and supernatural power, and spirits. Such vegetation or structures are not disturbed and thus the natural habitat of animals is kept intact. Certain animals like Tigers, Elephants and Toads are believed to be ancestral brothers and well wishers of human being and killing such animals is avoided.

**Taboo:** In festivals and rites the tribal communities observe taboo. The duration varies from days to years during which they abstain from cutting, killing or hunting of certain plants and animals. This helps conservation of specific species.

#### 4. Pest Management

The farmers of tribal communities have preserved their ecologically based pest and disease control knowledge over the generations. Galo tribes occupying the southern part of Abor Hills are one that is known for this skill. In one of their practices they use the leaves of Pomelo (Citrus grandis) as an insecticidal repellent for the control of the rice pest Rice ear bug (Leptocorisa oratorius). Household ash is also used as a repellent to control pests and diseases of the cultivated crops. In a unique practice they wrap fermented rice in leaf, fixed on a stick and place in the Rice field. Insect lured with the smell of the fermented rice attacks this, thus leaving paddy grain alone. The method reduces the attack of pests on Paddy crops. A number of traditional traps are also used for control of rats in the rice fields. After harvest of rice crop, grains are stored in well protected indigenous Granary, which inhibits any pest and diseases of stored grains. Many insects are consumed as food by the tribe which not only serves as a measure of pest control but also a rich source of micronutrients and other therapeutic agents (Bora et. al., 2013).

#### **CONCLUSION**

There are many lessons that could be learned from some traditional societies, in terms of effective agro-ecosystems and landscape management itself. Learning from adaptive social evolution of land use practices of these societies could be an important lesson one could learn to cope with global change related uncertainties. A highly diversified landscape unit is likely to have a wide range of ecological niches conducive to enhancing biodiversity, and at the same time ensuring sustainability of the managed landscape itself.

Traditional wetland cultivators of rice such as the *Apatanis* provide, are examples of a high degree of ecological and economic efficiency from this system. In addition, they

have an indigenous set up of utilizing the limited space for rice fish farming. Arunachal's geographical patterns are diverse; therefore, one kind of farming system is not feasible for all the areas. However, the system with high viability and potential can be replicated in the areas with similar pattern of topography and climate anywhere in the world. Some of the possibilities exist for redeveloping this system so that the farmer is able to obtain better returns are: (a) transfer of technology from one tribe to another, (b) introduction of early maturing and improved varieties of rice to obtain two or even three harvests in a year, (c) Rainwater harvesting and storage in tanks to support the major water constraint outside the monsoon period.

The trial of Rice fish farming was introduced in a few other places of Arunachal Pradesh under government sponsored programme. Though it was not the replica of the *Apatani* system, it worked near to expectation which indicates the prospect of implementing the established *Apatani system* in other parts of the state.

The more recently evolved 'biosphere reserve' concept of UNESCO, indeed, a rediscovery of the concept of the 'sacred landscape' of traditional societies dating back to antiquity, is an attempt towards such an integrated management strategy to conserve natural resources for sustainable use. The efficient resource management practices, rich traditional knowledge and conservationist nature of Apatanis, attracted the attention of UNESCO for the Ziro valley being enlisted in the tentative list of World Heritage Site.

The diverse livelihood management practices, and traditional faith and belief of the indigenous communities of Arunachal Pradesh facilitate the region in retaining its biodiversity for decades to come. Their dependence on the bio-resources made themselves feel the essence of sustainable use long before it became internationally fashionable. The concept, that

the Biodiversity keeps the ecological processes in a balanced state which is necessary for human survival, has gained further momentum with the unique traditional practices of these indigenous communities.

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### Bazhu community conserved area: Eco-protection and sustainable development of a Tibetan village in northwestern Yunnan

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Abstract-The application of various community based resource management projects using the principles of Education for Sustainable Development in the village of Bazhu on the Tibetan Plateau provides a useful case study for the application of Education for Sustainable Development (ESD) in other areas. These programs seek to empower communities on an indivdual, institutional and societal level. Here, the situational context, inherent challenges and other factors that have made these projects successful are discussed.

Keywords: Education for Sustainable Development, Sustainable Resource Management, Tibetan Plateau

#### I. INTRODUCTION

The Tibetan Plateau is home to a unique range of ecosystems, ranging from alpine and cold temperate to subtropical, and as such, contains more than 20% of all of China's plant species, about one-third of its mammal and bird species and almost 100 endangered species. Due to its importance globally as one of the few remaining biodiversity hotspots in the world and as the source of Asia's major rivers, the protection of the unique environment, ecosystems, plants and animal

species on the Tibetan plateau is a matter of vital concern. Over recent decades, local communities have witnessed the deterioration of the plateau caused by the increasing number of outsiders looking to take advantage of the natural environment through activities such as mining, logging and tourism.

The deterioration of the local environment is of particular harm to the numerous communities who rely on surrounding natural resources for a large portion of their income. The Tibetan Plateau is an especially fragile ecosystem, and the degradation of its natural resources, including grasslands, meadows, and forests, undermines the livelihoods those who earn their living collecting the medicinal herbs and mushrooms found only on the Tibetan Plateau. Despite the fact that these communities possess a wealth of indigenous knowledge with tremendous value to community driven and sustainable resource management, their opinions often go unheard. At present, local communities are sometimes blamed for environmental degradation and even barred from local natural resources. A lot of potential at the local level goes untapped due to limited education, capacity and influence on decisionmaking processes. As a result, the rights of communities on the Tibetan Plateau are not protected, and they are increasingly vulnerable

to outside pressures and external threats looking to exploit their unique, natural resources. By practicing ESD programs with local communities for more than a decade, we report that the implementation of community-based resource management is an effective way to empower these communities to protect the resources that sustain their livelihoods. There is an urgent need to support community empowerment on the Tibetan Plateau so that communities are better equipped to participate in decisionmaking processes to ensure access, control and sustainable management of the natural resources they rely on for a living. Although the Shangri-la Institute for Sustainable Communities (SISC) and The Greater Shangri-La RCE (GSR) have implemented a series of ESD initiatives both on the Tibetan Plateau and the national level, in this paper, I will focus on how the program seeks to facilitate a learning process that helps Bazhu communities on an individual, institutional and societal level to meet their basic socio-economic needs, while conserving their environmental assets and preserving their cultural heritage.

Bazhu Village is a rural area on the edge of the Tibetan Plateau, with abundant natural resources, a variety of ecosystems and a rich cultural and biological diversity. However, there is only 2,400 mu (1.6 km²) of farmland in total in the village, or 1.75 mu (11.67 m²) per villager. Forest coverage is 98.2% or 86,814 mu (57.87 km²), among which, 37,143 mu is national-grade ecological protection forest, 22,264 mu (14.84 km²) is provincial grade and the rest is county grade. There are also 7,611 mu (5.07 km²) of grassland in the forest area. Experts have warned against over-development and exploitation of natural resources in this area.

"In the Bazhu Forest, there are many species of birds, but the number of each is not large. It is because of the limited natural and geological conditions, which are complex, allowing many different species of birds to survive. Each species needs a suitable space to live, however, so the numbers of each species are limited. Therefore, people must be very careful in developing the natural resources in this area."

"The development of natural resources, mining development in particular, will definitely damage the ecological environment in this area. Therefore, people must be very careful in opening it up, even for tourism"

Prof. Han Lianxian

For this reason, the village of Bazhu has been chosen as the site to establish a demonstration project of community empowerment and or community conserved area, that can be scaled up and replicated to other areas of the Tibetan Plateau, China and internationally. Due to its unique climate and location, the Bazhu forest is extremely important to ecological conservation. However it is also fragile; if damaged, it could only regenerate slowly, creating problems for future generations. Fortunately, this area is inhabited by ethnic minorities with strong religious beliefs, providing a foundation for self-managing communities. The strong faith of the villagers is reflected in their good deeds toward the forest and nature. Most villages in Tibet worship their local sacred mountains and so does Bazhu. There are 7 sacred mountains around the Village. The biggest one is Mount Benboshu. Different sacred mountains have different resident deities. The holy mountains are the taboo place of the deities and nobody is allowed to behave badly there. The villagers pray and make offerings on the mountains, but no loud noise, no collecting of firewood or dry leaves, no tree felling and no hunting is allowed. Even if there are dead trees on the sacred mountains, people should leave them alone. Thanks to the mountain deities, the

Bazhu villagers believe the deities would come to dine during the raining season from June to October. At this time, the forest should be kept quiet and intact, not even an axe should be allowed on any mountain. Otherwise, the mountain deities may be annoyed and in anger elicit landslides and rainstorms on the people as punishments. The faith in sacred mountains has deep roots in the minds of local people. They stand in awe and respect the holy mountains, which in turn bless them with a good environment and ecology. The Bazhu folks also believe that trees are sacred deities. especially those trees close to water sources and near their ancestor's houses. These holy trees give people clear spring water and good fortune for their families. The holy trees never falls. In Bazhu, along the brook and around the villages, holy trees are found everywhere. Some of these trees are walnut trees, hundreds of years old.

The Village made a rule in 1998 not to collect live wood as firewood. The villagers say trees are and should be loved and respected. Only dead wood could be used as firewood. The simple thought comes from their religion, Tibetan Buddhism. They serve their living Buddha (incarnate lama) in the local temple, pay respect to the monks and believe in the truth of Buddha's teaching.



Fig.1 Bazhu Elder Villager and Lama Initiate the Religious Ceremony

Even local officials would say that the official governance and religious practice are one. Thus government policies could be promoted among villagers in a religious way. Whenever there is a religious gathering in the village, the monks would come to the administration and ask if they could use the event to help promote government policies.

Bazhu villagers trust the mountain deities who would bless them for their good deeds in protecting the forest. The more and the better the work they do, the greater the blessing would be. Such thoughts of 'reaping what you sow' reflect the villagers' longtime practicing of their religion. From the outside, it may seem that they have indeed reaped fruitfully from their good deeds that they have sown. Starting from 2008, Yunnan Province has suffered from prolonged and severe droughts that have seriously harmed people's lives. However, Bazhu is as yet relatively untouched by climate change and still enjoys nature's blessings of spring water flows and timely rainfall. The villagers' life goes on as before and their incomes grow steadily. Now, wild mushrooms that grow on the mountain regularly yield about RMB300 per villager. While the neighboring villages are pressed hard to survive dry spells, Bazhu has been receiving national and provincial awards amounting RMB1000 per household a year since 2011, for their work in protecting the local forest ecology.

#### II. ISSUES

However, there are some concerns. The Community is being challenged by globalization:

High external demand for precious natural resources such as the Chinese yew (*Taxus* sp.) has placed great pressure on the Community and their ecological resources.

More and more outsiders are coming to the area to illegally fell these valuable trees. At the same time, internal self-control is being weakened under the influence of market drive. A Bazhu forest ranger reported; "Of course, we want to punish the illegal timber-thieves seriously. But we don't want to use too much force, either." Severe punishment may discourage future attempts by villagers taking the law into themselves, and scare off outside intruders. The forest rangers would have an easier job to do. However, if they were to impose the law too severely, they may trigger reprisals or worsen the situation for enforcement by creating a violent, tense atmosphere. The rangers patrol the forest every day. They are the first to deal with the law-breakers from the first moment they see trouble, so they are in a very dangerous position.

Religion is the foundation of Bazhu's traditional culture, but this foundation is being undercut by secularization. In Bazhu today, religion continues to play a positive role in supporting government policies and economic development. For example, a local monk has introduced edible roses into Bazhu's plantations by utilizing his networks in the provincial capital of Kunming. He not only helps the villagers grow their roses, but also participates in processing and trading. If religion becomes too involved with secular affairs, especially if it dips into the into the economic pie, it may be tarnished in people's eyes and thus lose some of its power in guiding people spiritually and ethically. Another concern with secularization is that more and more villagers are going out into cities as migrating workers, seeking higher education and for other purposes. They are bringing individualism, egoism and materialism back from the outside world, which in turn risks weakening traditional culture. This means that forest ecological management and conservation is facing the danger of waning interest.

The Bazhu forest not only produces wild mushrooms and medicinal plants to increase villagers' incomes, but it also yields subsidies from the government in the form of rewards to the community as ecological credits. If the government's subsidies keep coming, the community's work of forest conservation will continue. Otherwise, the villagers would be less passionate about such work.

Bazhu is still economically less advanced than other communities. The villagers have high expectations of improving their own lives by increasing their incomes. However, their resources do not at present permit them to achieve this easily. A crucial issue is how to process the natural resources that they do have to generate more added value.

Bazhu is now feeling the pressure from the outside world: increasing demands for their natural resources; the challenges to their traditional culture of respecting and living in harmony with nature; their reliance on the government's ecological subsidies; their expectation to improve living standard by increasing incomes.

#### III. SOLUTIONS

The proposed solution to this problem is to set up the Bazhu Community Conserved Area (CCA) or Community Nature Reserve (CNR).



Fig.2 Bazhu Community Learning Center (CLC)

To date, SISC has worked with several communities on the Tibetan Plateau to initiate a process of community empowerment. In Bazhu, a solid foundation has been established for nature conservation through projects such as "Water School China", "Community Integrated Nature Reserves" and in particular, the project "Education for Sustainable Development in the Tibetan Plateau" which was implemented from Feb 2008 - Dec 2011. The programme facilitated a learning process to enable local communities, while protecting the natural environment, to meet their socio-economic needs and to preserve their cultural heritage. This has included a range of training and capacity building initiatives including the development of nine Community Learning Centers (CLCs). The CLCs serve as platforms to promote community learning and action as well as collaboration between communities and other stakeholders. The action also played a role in facilitating stronger cooperation between local schools, communities, monasteries, nature reserves and local government agencies. In order to establish efficient and sustainable management of natural resources, the community wishes to make further efforts in individual and collective capacity building for lasting protection of bio-diversities for the community. To set up the Bazhu CCA or CNR is the best means to meet this purpose. Such a mechanism would support the community empowerment by exploring the ways to protect the community's bio-diversities and local traditional culture, to help increase the villagers' incomes and improve their livelihood, to benefit from ecological conservation and to open up the road to sustainability. The Bazhu CCA or CNR focus on public participation in conservation and functions as a platform of the community for bio-diversity protection and sustainability. On this platform, Bazhu networks with environment-friendly partners nationally and internationally, to share social learning and experiences.



Fig.3 Bazhu Handicraft Making Workshop

Regardless of the site be it a Bazhu village, or at any other project site, the philosophy and or the core strategy of SISC and GSR is to implement ESD practices at three levels: individual social learning and practices; collective empowerment to build a long-term mechanism in the community; broader social promotion and scaling up to a broad range of communities.

#### A. On an Individual Level

Knowledge, skills and values of the community have been enhanced through a programme of vocational and cultural training sessions.

#### B. On an Institutional Level

The community learning centre and training base in Bazhu village not only provides the CNR or CCA staff and groups such as the women's forest patrol and agricultural co-op with opportunities to develop decision-making and leadership skills, it is also as a platform for community members to take on the role of educators of sustainable development and by hosting important stakeholders, and sharing knowledge and experiences of how to be actively involved in the management of local nature resources.

#### C. On a Societal Level

The project supports community members to take a pro-active role in the broader environment. In order to gain support for the continued protection of this unique area on a larger scale and at a higher level, the project aims to participate in international initiatives such as the ICCA registry (Indigenous and Community Conserved Areas), UNESCO, IUCN, Global RCEs and the Earth Charter Initiative. Through national level partnerships with the State Forestry Administration, the Ministry of Environmental Protection, and the Ministry of Education, as well as local government partnerships including Provincial Forestry Bureaus, and Provincial Education Departments, government representatives have been given opportunities to share and enhance their experiences and knowledge through participation in regional workshops, meetings and national exchange workshops.

#### IV. CONCLUSIONS

In achieving status as a Priority Action Area of the Global Action Programme (GAP) on ESD and Sustainable Development Goals (SDG) by UNESCO, the Bazhu programme has proved to be a worthwhile case study for Greater Shangri-la RCE to replicate and expand to a wider area. The society is developing in both sustainable and unsustainable ways; positive and negative ways, and the near future will undoubtably contain more challenges. Therefore, strategic improvements should be discussed and developed not only by the local level but also at the national and global level.

## Assessing land use change and its impact on ecosystem services in northern Thailand

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Abstract-The sustainable development goals (SDGs) are being pursued by all the countries as priority actions to achieve by 2030. This study assessed land use change and its impact on ecosystem services, which is relevant to SDG 15 that aims to protect, restore and promote sustainable use of terrestrial ecosystems. Conducted in Wang thong watershed in Northern Thailand, we assessed the land use change and ecosystem services from 1989-2013 using GIS and projected the future land uses under different scenarios with varying options for enhancing ecosystem services. Integrated Valuation of **Ecosystem Services and Tradeoffs (InVEST)** model was used to map and quantify a set of ecosystem services. CLUMondo, a dynamic spatial model, was used to project future land uses for three policy scenarios. In business-as usual scenario, there is a general decrease in ecosystem services by the year 2033. In two other scenarios viz integrated land use and biodiversity conservation, ecosystem services will increase by about 6% and 20% repectively due to the effect of assumed respective land use policies. The study findings, which present a trend of ecosystem services and options for enhancing ecosystem services, can serve as the guideline for sustainable land use planning in the study

area and thus can be helpful in improving management of environmental resources of the watershed. Scenario results provide opportunities to implement appropriate land use options directly addressing SDG to protect ecosystems. Similarly, the comprehensive methodology used in the study can easily be replicated in assessing the ecosystem services of other watersheds or basins.

Keywords: Land use change, Ecosystem services, InVEST, CLUEMondo models, northern Thailand

#### I. INTRODUCTION

In the past, Thailand has constantly enjoyed agricultural growth with a number of agricultural commodities for international export due to high technological practice including inputs mostly brought about by land use conversion and improved agricultural practices [1]. A substantial increase in agricultural areas occurred from forest conversion despite a national logging ban in all natural forest areas being implemented in 1989 [2]. In the recent past, agricultural land use conversion from the food crops for subsistence to commercial crops (particularly cash crops in agriculture) has been very rapid

[3], [4] largely due to policy and market support on these crops. Such increase has been a serious concern. The government started the "Rubber Cultivation for Raising the Sustainable Income to Farmers in the New Planting Area" scheme in 2004 by providing incentives eventually attracting many to convert their land to rubber.

With changing sectoral policy, like agricultural policy, there are changes in land use and land management to eventually maximize economic return [5] undermining ecosystem services. Recent studies have shown that an increase in agricultural land use can have direct negative consequences on ecosystem services or reduced productivity which may be considered as an ecosystem disservice [6]. There is a critical need to manage locations that are important for maintaining ecosystem services while maintaining demand for agricultural purpose [7]-[10]. Although a number of recent studies have quantified and mapped ecosystem services (e.g. [9]; [11] [13]), studies linking land use impacts on ecosystem services are scarce, especially in the tropics which serves as a major source of the world's biodiversity.

The Wang thong watershed in Northern Thailand has experienced significant land use change particularly due to the government induced policy encouraging rubber plantation. As a result, this had led to expansion in plantation of perennials, particularly rubber, replacing annual crops. The area also has experienced frequent a flooding problem with severe soil erosion. Hence, in order to better understand linkages and consequences of land use change on the ecosystem services, this study assessed the impact of land use on selected ecosystem services; namely water yield, sediment retention, carbon stock, and habitat quality in the Wang thong watershed.

#### II. STUDY AREA

The study area, Wang thong watershed, situated between  $16^{\circ}$  22' 10'' to  $17^{\circ}$  2' 38'' N latitude, and  $100^{\circ}$  36' 10'' to  $101^{\circ}$  3' 47" E longitude in Wang thong district of Phitsanulok province and Khao kho district of Phetchaboon province, covers 198,082 ha (Figure 1). The geological formation is composed of sedimentary rock and metamorphic rock [14] with an elevation ranging from 700 to 860 m.s.l. The climate is tropical and sub-tropical with three distinct seasons, namely winter (November-February), summer (March-May), and rainy (June-October). The average maximum temperature is 31°C and the annual rainfall is 1,481.60 mm. Forest covers more than half of the area. About a quarter of the area is under farming and rest of the area under perennials and forest plantation, urban and other land uses.

The watershed is inhabited by a total human population of 95,668 mostly engaged in farming. The soils in cultivated landscapes are light textured with less water holding capacity and thus subjected to high soil erosion resulting in reduced ecosystem value.

#### III. METHODOLOGY

We first detected the change in land use patterns across the study area using historic data and Geographic Information Systems (GIS) followed by assessment of selected ecosystem services to understand the impacts of land use on ecosystem services. Field survey of 60 farm households was conducted for understanding land use patterns before projecting land use options for enhancing ecosystem services. The methods for specific tasks involved in the study are described hereunder.

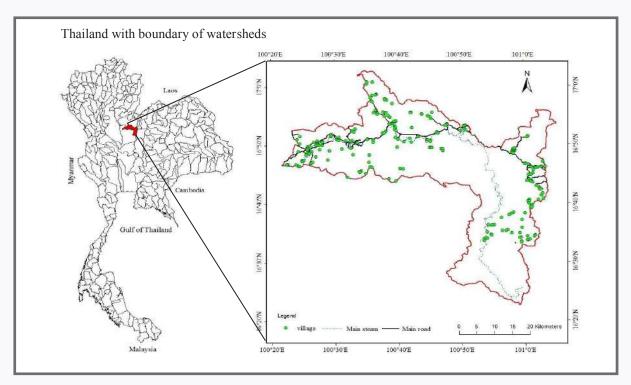


Fig.1 Location of the study area.

#### A. Assessing land use change

Land use change was analysed for four time periods (1989, 2000, 2007 and 2013). Year 2000 represents the immediate past before the major agricultural policy implemented to promote rubber plantation in the country.

The year 1989 was chosen to examine what was the land use type as it was the year when logging ban was implemented and 2013 to represent the current situation.

Land use map 1989 was interpreted from Landsat-5 Thematic Mapper (TM) satellite data for Path 129/Row 48 and 49 acquired on 25 March 1989 from the United States Geological Survey website (http://earthexplorer.usgs.gov/) by visual interpretation technique in ARCGIS 10.2 software (ESRI, 2013).

Land use maps for the year 2000, 2007, and 2013 were obtained from the Land Development Department of Thailand in digital format. The land use classes were regrouped for all the years into eleven major land use classes. Land use change was analysed in ARCGIS by creating land use change matrix.

#### B. Assessing ecosystem services

The Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST 3.0.1) tool was used to map and quantify a set of ecosystem services in this study. InVEST, a geospatial modeling framework tool, which quantifies and maps a range of ecosystem services and evaluates the impact of land use change on ecosystem services [13], [15], is widely used for assessing ecosystem services [16]. In this study, we analysed four selected ecosystem services, 1) water yield, 2) sediment retention, 3) carbon storage, and 4) habitat quality, representing supporting (sediment retention, habitat quality as a proxy of biodiversity), regulating (carbon sequestration), and provisioning (water yield) services.

#### 1) Water yield

Water yield is defined as the amount of water runoff from the landscape [17]. The water yield model, which runs on a gridded map, requires specific data input in the form of raster maps to estimate the quantity of water

runoff from each sub watershed. The model determines the amount of water running off each pixel as the precipitation less the fraction of the water that undergoes evapotranspiration.

#### 2) Sediment retention

Sedimentation is a natural process that contributes to healthy ecosystems, but too much may have severe consequences [16]. The sediment retention module in the InVEST uses the Universal Soil Loss Equation (USLE) [18] together with sediment approach for sediment deposition, both at grid cell scale.

#### 3) Carbon storage

Carbon stocks in different land covers were estimated using the InVEST model, that requires an estimate of the amount of carbon stored in the four basic carbon pools: aboveground and belowground biomass, dead organic matter and soil organic matter ([9], [13], [19], [20]). This is followed by production of carbon stocks map based on available coefficient on biomass carbon stocks per unit area in each land use type.

#### *4) Habitat quality*

Habitat quality is defined as the landscapes' ability to provide suitable conditions for the persistence of an organism [17]. The model uses a habitat-based approach, where habitat quality and rarity serve as a proxy for biodiversity. Consequently, habitats of high quality are considered intact with functioning within its range of historic variability [17], [21]. The habitat quality was estimated based on the relative impact of threats, sensitivity of habitat to threats, distance between habitats and sources of threats and location of protected areas.

#### C. State of ecosystem services

The status of ecosystem services and change was analyzed by combining four ecosystem services into very low, low,

moderate, high, and very high category.

#### D. Projecting future land use scenarios

The future land uses for the year 2033 were simulated using the CLUMondo model for three scenarios: 1) business as usual; 2) integrated land uses; 3) biodiversity conservation. The criteria considered the existing trend and most possible trend of the factors considered in simulation.

#### IV. RESULTS and DISCUSSION

#### A. Land use change

The major land use in the study area is the forest cover. The agricultural land use types consisted of cassava, paddy rice, sugarcane, corn, mixed orchard, and mixed perennials. The results show the trends of change; particularly plantation, which has increased from no area under plantation in 1989 to 7.02% of total study area in 2013 (Table 1). Due to the Royal Thai Government's reforestation promotion campaign, perennial crops, such as eucalyptus, bamboo, and rubber plantations were grown after 1989. Mixed orchard was also found to be increasing during the first period (1989 -2000), from 6,590 ha to 12,188 ha. The built-up area increased from 0.30% (1989), 0.82% (2000), 4.32% (2007) to 4.50% (2013).

#### B. Impact of land use on ecosystem services

The results showed that there was no area considered to have high overall ecosystem services (combined four services). Nearly 43% area has high degree of ecosystem service, whereas 23% moderate and another 35% area had low to very low (Figure 2).

Analysis of the land use distribution indicated that mostly the decrease in services occurred in agriculture areas suggesting that the increased agroforestry type plantations have direct negative effects on biodiversity and ecosystems services. There was a large amount

Table 1 Land use classification 1989, 2000, 2007 and 2013

	19	989	2	2000	2	017	2	103
Land use classes	Area	%	Area	%	Area	%	Area	. %
	(ha)		(ha)		(ha)		(ha)	
Abandoned area	8105	4.09	16656	8.41	16840	8.50	10273	5.19
Paddy field	9403	4.75	8229	4.15	6986	3.53	6838	3.45
Built up area	587	0.30	1620	0.82	8561	4.32	8922	4.50
Plantation	0	0.00	1459	0.74	2117	1.07	13903	7.02
Mixed orchard	6590	3.33	12188	6.15	8285	4.18	7450	3.76
Cassava/sugarcane	11885	6.00	3621	1.83	3592	1.81	4817	2.43
Corn	31045	15.67	28948	14.61	27012	13.64	23930	12.08
Deciduous forest	54456	27.49	64412	32.52	50947	25.72	46090	23.27
Evergreen forest	61415	31.00	50530	25.51	63131	31.87	59719	30.15
Forest plantation	12709	6.42	9442	4.77	8249	4.16	13600	6.87
Upland rice	1888	0.95	976	0.49	2361	1.19	2539	1.28
Total	198082	100	198082	100	198082	100	198082	100

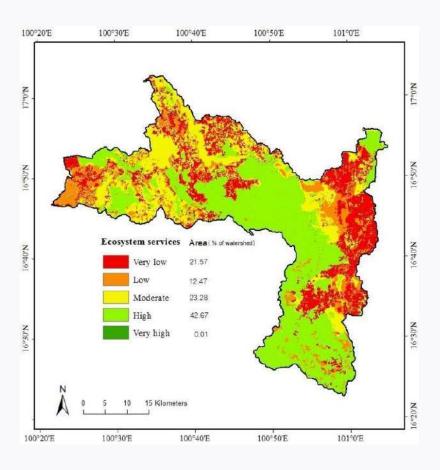


Fig.2 Ecosystem services status in the study area.

Table 2 Land use land cover (LULC) area and ecosystem services by year

Year	Land use class		% of ecosystem servi	ice in land use class	
		Water yield	Sediment retention	Carbon storage	Habitat quality
1989	Abandoned	7.3	0.4	1.5	0.0
	Paddy field	6.4	0.1	0.4	1.3
	Built up	15.5	0.0	0.1	0.0
	Plantation	0.0	0.0	0.0	0.0
	Mixed orchard	6.9	0.2	1.9	4.4
	Cassava/ sugarcane	9.4	0.2	0.5	1.7
	Corn	24.5	4.7	1.3	4.6
	Deciduous forest	16.1	46.3	35.4	34.3
	Evergreen forest	8.9	46.7	56.0	45.4
	Forest plantation	2.7	1.4	2.8	8.0
	Upland rice	2.3	0.0	0.1	0.3
2000	Abandoned	9.8	0.9	3.2	0.0
	Paddy field	4.5	0.0	0.3	1.1
	Built up	18.0	0.1	0.1	0.0
	Plantation	1.0	0.1	0.3	0.8
	Mixed orchard	9.2	0.4	3.6	7.6
	Cassava/ sugarcane	3.8	0.1	0.1	0.5
	Corn	21.1	4.3	1.2	4.1
	Deciduous forest	9.3	54.7	42.4	45.5
	Evergreen forest	6.9	38.4	46.6	34.6
	Forest plantation	15.0	1.0	2.1	5.7
	Upland rice	1.4	0.0	0.1	0.1
2007	Abandoned	14.2	0.9	3.2	0.0
	Paddy field	4.5	0.0	0.3	1.0
	Built up	15.7	0.3	0.6	0.0
	Plantation	2.5	0.1	0.4	1.3
	Mixed orchard	14.7	0.3	2.4	5.4
	Cassava/ sugarcane	3.9	0.1	0.1	0.5
	Corn	20.1	4.1	1.1	3.9
	Deciduous forest	13.9	44.2	32.9	36.9
	Evergreen forest	6.4	49.0	57.1	45.6
	Forest plantation	1.7	0.9	1.8	5.1
	Upland rice	2.4	0.1	0.1	0.3
2013	Abandoned	10.6	0.6	2.0	0.0
	Paddy field	4.1	0.0	0.3	0.9
	Built up	15.0	0.3	0.6	0.0
	Plantation	9.7	1.1	3.0	7.6
	Mixed orchard	14.5	0.3	2.2	4.6
	Cassava/ sugarcane	6.3	0.1	0.2	0.7
	Corn	17.9	3.9	1.0	3.4
	Deciduous forest	11.9	42.6	31.0	33.0
	Evergreen forest	5.2	49.4	56.4	41.2
	Forest plantation	2.1	1.6	3.2	8.3
		4.1	1.0	J.4	0.5

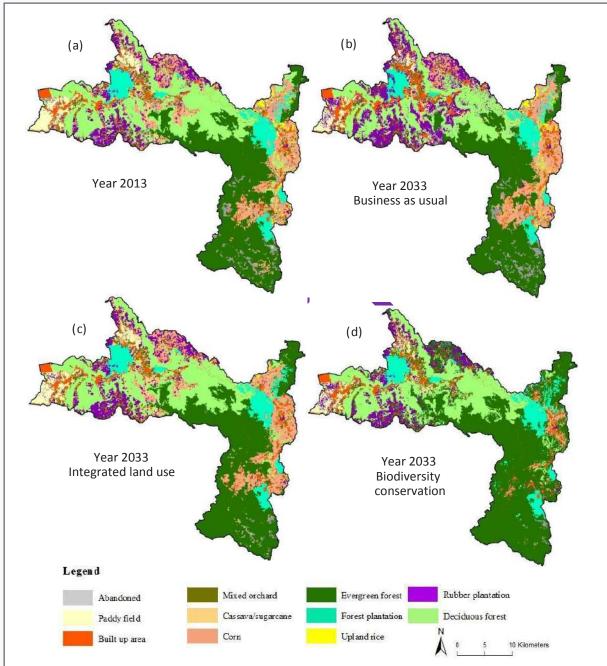
of variability in the distribution and change in ecosystem services between services and across the years of study (Table 2).

A number of studies reported native (in this case Evergreen and Deciduous) forest and pristine vegetation offer high ecosystem services [22], [23]. We also found that these forests provided better ecosystem services than crop lands.

#### C. Future land use

The spatial distribution under different land uses as projected by CLUMondo model for three different scenarios in 2033 are presented in Figure 3.

Scenario 1 presents the likely situation in absence of no protected area. The result of scenario 1 (business as usual) showed that in year 2033, there would be a substantial



**Fig.3** Projected land uses: a) Year 2013, b) 2033 for scenario 1: Business as usual; c) 2033 for scenario 2: Integrated land use; d) 2033 for scenario 3: Biodiversity conservation

increase in rubber plantation (from 7 to 13.3% of the study area), while forest areas will decrease (60.3 to 54.1%). Built-up area, which is at 4.5% will expand to 6.5%. The paddy area will slightly decrease. Likewise cassava/ sugarcane and corn also would decrease while abandoned area and upland rice may slightly increase.

In scenario 2 (Integrated land use), the forest area (deciduous, evergreen, forest plantation) increased to 64.5% of total area compared to the present situation of 60.3%, while agriculture area remained similar to that of the present situation. Only upland rice area was observed to slightly decrease as it causes high erosion and thus retaining less sediments. Abandoned area significantly decreased because this scenario does not allow the conversion of land in protected area.

In case of scenario 3 (Biodiversity conservation), there will be substantial increase of forest cover from current 60.3% of study area to 78.3%. This is because besides the coverage of protected area at present it also includes the area to be established forest for protecting ecosystem services based on the findings of assessing impact of land uses on ecosystem services.

#### D. Changes in the ecosystem services

The results of the scenario 1 showed trend of all four services had negative change as it showed slight declines in sediment retention and carbon stock and small declines in habitat quality, while the trend of water yield showed slight decrease.

In scenario 2, the trend showed improvement in all services. Water yield had slight decline, while rest of services had moderate increase. Scenario 3 showed dramatic increase in three services, although water yield had a small increase, the trend stillgoes in a positive way.

#### **V. CONCLUSIONS**

During 1989-2013, increase in rubber plantation mainly influenced by the government's rubber promotion scheme was the major land use change, whereas the area under paddy, cassava, sugarcane, corn, and deciduous forest have slightly decreased while built-up area and upland rice have increased.

No area in the watershed retain very high and intact ecosystem services. Only two-fifth of watershed is having high ecosystem services. Land use change has influenced overall ecosystem services during the study period, together with a variation in the spatial distribution and temporal change in those ecosystem services studied.

Under ongoing trend of land demand, forest cover may decline in next 20 years due to demand for agriculture conversion or lack of policy enforcement. Built up areas and the encroachment for rubber plantation will substantially expand while the ecosystem services at the watershed level will decline. Simulation results show that encouraging certain land use can enhance ecosystem services from 6 to 20% of current situation. This implies proper land use assignments are necessary to balance production and ecosystem services and thus achieve sustainable development goals.

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## Conversion of water hyacinth resource nuisance into high value-added carbonaceous materials using hydrothermal carbonization technology

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Abstract-In relevance to the 2030 Sustainable Development Agenda, water pollution management technology has been proposed through various mechanisms. Among various issues of water resource management, control of environmental nuisances, especially water hyacinth has become an important research topic in many countries because it is one of invasive plants which result in social and environmental problems, such as obstructing water transportation and decreasing of oxygen in water. This paper discusses with conversion of water hyacinth into high value-added carbonaceous materials using hydrothermal carbonization technology. In general, hydrothermal carbonization could be considered as an efficient technique for production of carbonaceous material because water under a regulated condition of high temperature and pressure could effectively

react with the lignocellulosic ingredient of water hyacinth to produce gaseous, liquid and solid products. As a main focus, solid products were characterized by FT-IR spectroscopy, scanning electron microscopy and specific surface area analyzer for confirmation of their usefulness for ecosystem control activities, which would support technical competency needs in the context of the Sustainable Development Goals.

Keywords: Water hyacinth, Hydrothermal treatment, Carbonization, Carbonaceous material

#### I. INTRODUCTION

Nowadays, water pollution management technology has been proposed through various mechanisms with regard to the 2030 Sustainable

Development Agenda. In many countries, emerging issues of water resource management have been recognized as research topics including control of environmental nuisances, especially water hyacinth and other fast growing plants [1-4]. Among those invasive plants, water hyacinth, which is one of perennial aquatic weeds, could be considered as biomass, which refers to organic compound materials. As a result, such biomass can be a sustainable source of chemicals or fuels. Because of its fast growing and excessive quantity, water hyacinth causes environmental problems, such as decreasing oxygen content in water resources, obstructing water transportation, and consequently harming the ecological system [1, 2].

Meanwhile, innovation of novel functional materials focusing on functionality, quality, cost and quality are important. Those novel materials could be applied to some new aspects including renewable energy and reduction of environmental burden. In order to utilize such biomass effectively, its conversion to other useful products is a crucially important research aspect. It has been recognized that hydrothermal technique is an effective method for converting organic compounds to various useful gases, liquid and solid products, such as hydrogen, glucose, porous carbon and other derivatives. Both quantity and quality of those products depend on the composition of biomass and operating condition [5-7]. In more specific viewpoint, hydrothermal carbonization could be considered as an efficient method for production of carbonaceous material because water molecules under a regulated condition of high temperature and pressure could effectively react with lignocellulosic ingredient of biomass to produce solid carbonaceous products. Therefore, as a linkage between the issue of environmental nuisance reduction and novel functional material production, this article addresses the conversion of water hyacinth into high

value-added carbonaceous materials using hydrothermal carbonization technology. In general, such carbonaceous solid products, which contain high carbon content, could be utilized in many applications, such as electrode material, catalyst and fertilizer [8, 9]. In this work, repetitive experiments were carried to investigate effect of treating temperature and time on hydrothermal treatment of dried water hyacinth powder to produce carbonaceous products, which were characterized by FT-IR spectroscopy, scanning electron microscopy and specific surface area analyzer for confirmation of their usefulness for ecosystem control activities, which would support technical competency needs in the context of the Sustainable Development Goals.

#### II. EXPERIMENTAL

Synthesis of carbonaceous material

Typical samples of water hyacinth were collected from a pond in Thammasat University, Rangsit, Patumtani, Thailand. For removing moisture content, samples of water hyacinth were dried at 105°C for 24 hours. The dried water hyacinth was cut into small pieces by a disk mill and then classified based on its size distribution as shown in Fig.1. It is noted that the ground water hyacinth powder possessed an average size of 585 µm with a standard deviation of 63 µm. In hydrothermal treatment process, 20 g of the ground water hyacinth powder and 40 cm<sup>3</sup> of de-ionized water were added into an autoclave reactor, which was heated in a temperature range of 160 to 220°C for 4, 8 and 12 hours. Next, autoclave reactor was quenched immediately by cold water to stop the reaction [9]. Solid product was separated and washed with de-ionized water until pH = 5. The received solid productwas dried again in the oven at 105°C for 24 hours. Finally the solid product was carbonized using a tubular

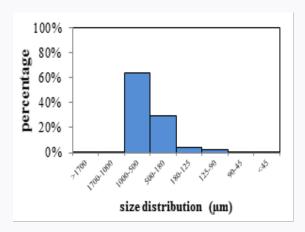


Fig.1 Size distribution of dried water hyacinth

horizontal furnace attemperature of 900°C under nitrogen atmosphere (99.999% purity, Linde) for 2 hours with a constant flow rate 100 cm³/min.

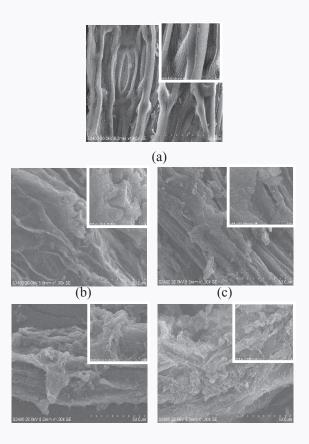
#### Characterization of carbonaceous material

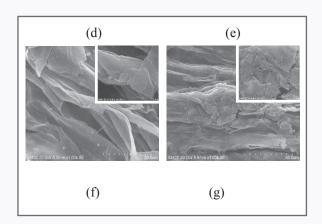
Morphology of hydrothermally carbonized product was examined by Scanning Electron Microscope (SEM, s3400H, Hitachi). The chemical composition and functionalities of such solid carbonaceous product were evaluated by Fourier transform infrared spectroscopy using ATR mode (FITR, Nicolet 6700, Thermo Scientific) scanning with in a wave number range of 500 to 4000 cm $^{-1}$ . Specific surface area and average pore diameter were measured by  $N_2$  sorption (Belsorp-Mini, Bel Japan) using BETanalysis.

#### III. RESULTS AND DISCUSSION

Based on the composition analysis, a typical sample of water hyacinth contained 38.4% cellulose, 10.3% hemicellulose, 18.5% lignin and 22.9% ash. These cellulosic contents within the water hyacinth sample would generally be present in the fibrous structure which could be clearly observed under a microscope. Within hydrothermal treatment process, water molecules with high internal

energy due to heat supply could react with those cellulosic contents, resulting in physicochemical change in its microscopic properties [9-12]. As shown in Fig.2 (a) it could be clearly observed that the microscopic structure of the dried water hyacinth powder is fibrous with few defects. Meanwhile, Fig.2 (b) to (e) reveal that there are significant difference in the microscopic appearance of the water hyacinth power which was treated hydrothermally at temperature range of 160 to 220°C, respectively. Similarly, effect of treating time of 4 and 12 hours at a constant treating temperature of 180°C are depicted in Fig.2(f) and (g). All insets with higher magnification would further confirm the remarkable change in their surface containing many defects which could be observed as irregular morphology. All of this visual evidence of clearly rough surface morphology could suggest that an increase in the treating temperature and treating time for the hydrothermal

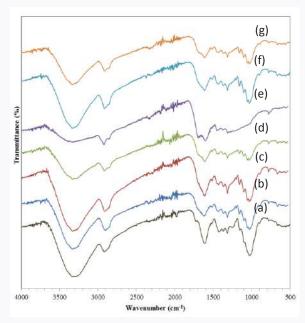




**Fig.2** SEM micrographs of **(a)** dried water hyacinth, **(b, c, d, e)** water hyacinth treated hydrothermally at 160, 180, 200 and 220°C for 8 hours, **(f and g)** water hyacinth treated hydrothermally 180°C for 4 and 12 hours

treatment of dried water hyacinth powder could lead to conversion of cellulosic content due to the hydrolysis reaction [7]. Sevilla and Fuerters reported that the hydrolysis of cellulose and hemicelluloses at a specific temperature above 210°C would result in formation of gas, liquid and solid products [9]. Meanwhile, other previous works confirming the formation hydrogen, glucose and carbon are available elsewhere [10, 12]. In this work, only the solid product which is called 'hydro-char' would be further analyzed and discussed.

For confirmation of the existence of functional groups attaching on the surface of hydrothermally treated water hyacinth powder or hydro-char, FT-IR analyses of those solid products were carried out. FT-IR spectra of carbonaceous samples depicted in **Fig.3** clearly suggest that functional groups of hydro-char are different from those of originally dried water hyacinth. Distinctive bands at wave number of 3700-3000 cm<sup>-1</sup> are attributed-OH stretching vibration [9, 10]. The 3500-2850 cm<sup>-1</sup>



**Fig.3** FT-IRspectra of **(a)** dried water hyacinth, **(b** to **e)** hydrothermally treated water hyacinth at temperature 160, 180, 200 and 220°C for 8 hours, **(f** and **g)** hydrothermally treated water hyacinth at temperature 180°C for 4 and 12 hours

bands were attributed to the presence of – CH vibration whereas the 1700 cm<sup>-1</sup> band would suggest the presence of C=O group on the surface of each sample. The appearance of the 1650 and 1200-950 cm-1bands would confirm the presence of C=C in aromatic ring of lignin and C-O in ester or ether, respectively [10]. Based on comparison of these FT-IR spectra, it could be noted that an increase in the treating temperature and treating time could result in drastic change in the presence of functional groups on the surface of hydrochar samples.

With an ultimate purpose for usage as electrode materials, all of hydro-char were further carbonized for removing un-desired contents of hydrogen, oxygen and other constituents. Because of the removal of some impurities, the carbonized hydro-char would possess a higher content of carbon with a higher purity and

**Table 1** Specific surface area, average pore diameter and total pore volume of typical samples prepared under different hydrothermal treating conditions

	BET of carbonized hydro-char							
Sample	Specific surface area (m²/g)	Average pore diameter (nm)	Total pore volume (cm³/g)					
C-HT160 °C 8 hours	564.5	3.4	0.481					
C-HT 180 °C 8 hours	635.8	2.8	0.437					
C-HT 200°C 8 hours	470.4	2.1	0.246					
C-HT 220 °C 8 hours	416.8	2.0	0.205					
C-HT 180 °C 4 hours	351.9	4.4	0.391					
C-HT 180 °C 12 hours	359.1	3.7	0.333					

\*HT = water hyacinth treated hydrothermally (hydro-char)

C = HT carbonized at  $900^{\circ}C$ 

improved surface properties. **Table 1** summarizes the BET analytical results including specific surface area, average pore diameter and total pore volume of each carbonized hydro-char sample. It was found that the hydro-char sample which was hydrothermally treated at 180 for 8 hours (C-HT 180°C, 8 hours) possesses the highest specific surface area of 635.8m²/g with average pore diameter of 2.8 nm. These characteristics would suggest that the carbonized hydro-char would have potential to be utilized

as carbonaceous powder for fabricating electrodes because of its high specific surface area [8].

Nevertheless, confirmation of their carbon content would be further conducted and discussed in the future. Therefore, this research attempt exhibit a potential of the conversion of water hyacinth by the hydrothermal carbonization method, as useful for ecosystem control activities by decreasing some environmental nuisance as well as providing functional carbonaceous material, which would support technical competency needs in the context of the SDGs.

#### IV. CONCLUSIONS

Hydrothermal treatment could be employed to convert dried water hyacinth powder to gas, liquid and solid products by hydrolysis which could break chemical bonds with in the cellulosic structure. Carbonization of hydrothermally treated hydro-char would further result in remarkable change of physicochemical properties, especially surface area of the carbonized hydrochar which would be confirmed by microscopic and spectroscopic analyses. Based on BET surface analyses, the carbonized hydro-char which was treated hydrothermally at 180°C for 8 hours could exert the best specific surface properties which would be appropriate for utilization as carbon electrodes. This contribution suggests that conversion of water hyacinth by the hydrothermal carbonization method would be useful for ecosystem control activities by reducing environmental nuisance associated with the invasive and explosive growth of this environmental problem. In addition, the method provides a high value-added carbonaceous material which would support technical competency needs in the context of the SDGs.

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# $\begin{array}{c} \mbox{Higher contribution of soil respiration } (R_s) \\ \mbox{to ecosystem respiration } (R_e) \mbox{ in mixed} \\ \mbox{deciduous forest compared to dry} \\ \mbox{dipterocarp forest} \end{array}$

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Abstract-Absorbing CO, from atmosphere into forest is an important ecosystem service from the global warming perspective. However, forest can be either a CO, source or sink. Soil respiration (Rs) or soil CO, emission which is a component of ecosystem respiration (Re) is one of the processes determining a sink-source capacity of a forest. In order to improve our understanding of forest carbon exchange, its source-sink capacity and its responses to climate change, enhancing accuracy in assessment of soil CO, emission in forest is required. This study aims to measure soil CO, by the newly established method using CO, profile gradient and to study variations in soil CO, effluxes in a dry dipterocarp forest (DDF) and a mixed deciduous forest (MDF). During the study periods in dry dipterocarp forest and in mixed deciduous forest for 181 days, we found that the average soil CO, efflux was 1.9±0.8 and

4.8±2.3 μmol m<sup>-2</sup> s<sup>-1</sup>, respectively. Accumulative soil CO, emissions of 2.6 kg CO, m-2 y-1 in DDF were much lower than those of MDF where these emissions reached 6.7 kg CO, m<sup>-2</sup> y<sup>-1</sup>. In line with this trend, Rs accounted for 44.6% of Re in DDF while reaching 70.9% of Re in MDF. The Rs values of MDF were about 2.6 times higher than those of DDF. This may indicate more active soil and forest floor process including a rapid turnover of carbon in mixed deciduous forest compared to dry dipterocarp forest. At both sites, Rs is strongly related to soil moisture:  $r^2 = 0.61$ , P<0.01, n = 150 in DDF and  $r^2 = 0.75$ , P<0.01, n = 136 in MDF. In addition, the soil CO, probes also enabled us to detect the behavior of soil CO<sub>2</sub> emissions during climate variability.

Keywords: soil respiration, ecosystem respiration, dry dipterocarp forest, mixed deciduous forest

#### I. INTRODUCTION

Ecosystem services are part of the 2030 Agenda for Sustainable Development and Sustainable Development Goals (SDGs) especially SDG 15 (managing sustainable forest, combating desertification, halting land degradation and biodiversity loss) [1]. An important ecosystem service is absorbing CO<sub>2</sub> from atmosphere into forests by photosynthesis process as a CO<sub>2</sub> sink. However, forests also release CO<sub>2</sub> to atmosphere by plant and soil respiration processes as a CO<sub>2</sub> source.

Soil respiration (Rs) or soil CO<sub>2</sub> emission which produces CO, by soil organisms and underground parts of plants in forests is an important component of ecosystem respiration (R<sub>a</sub>). Moreover, the amount of this CO, exchange is important in our understanding response of forest during climate variability such as the effects of heavy rainfall events and extended dry periods. Dynamically, soil CO<sub>2</sub> emissions occur during both non-steady state (with disturbances) and steady state (without disturbances) [2], and understanding the emissions during both states is crucial to help us quantify soil respiration. The fast response of CO<sub>2</sub> emission to these environmental changes and disturbances could be causes of uncertainty associated with CO, emission quantification [3]-[9]. Therefore, enhancing accuracy in assessment of soil CO, emission in forest is desired in order to improve our understanding of forest carbon exchange, its source-sink capacity and its responses to climate change/variability. Although, most of researchers in the past had used chamber method (conventional method) because it is economical and easy-to-use, some conventional methods could not detect phenomena of soil respiration responses during such disturbances.

On the other hand, soil gradient method using  $CO_2$  sensor as a newly established technique could improve the accuracy of the  $CO_2$  quantification together with capturing its

responses to disturbance including variability in climate [8]-[9]. The sensor method was found to yield a very close result to that obtained by chamber measurements [4]-[5], [8]. A good correlation between the two techniques was also reported [6]. Therefore, this study aims to measure soil CO, by the newly established method using CO, profile gradient (continuously and frequently recorded every 15 seconds and averaged every 15 minutes) and to study variations in soil CO, effluxes in a dry dipterocarp forest and a mixed deciduous forest. The monitoring using the soil CO, probes also enabled us to clearly see the behaviors of soil CO<sub>2</sub> emission during climate variability.

#### II. MATERIALS AND METHODS

#### A. Site Description

The study sites were located in a dry dipterocarp forest and a mixed deciduous forest. These are among the two of the AsiaFlux network's sites in Thailand. Both sites are tropical monsoon forest. The first study site was known as DFR site (a Dry Dipterocarp Forest Flux Ratchaburi), King Mongkut's University of Technology Thonburi (KMUTT), Ratchaburi Campus, Rang Bour, Chombueng, Ratchaburi, western Thailand (Latitude: 13° 35' 13.3" N, Longitude: 99° 30' 3.9" E). Another site was MKL site (Mae Klong Watershed Research Station), Thong PhaPhoom, Kanchanaburi, western Thailand (Latitude: 14° 34' 34.6" N, Longitude: 98° 50' 38.0" E). The DFR site had been kept as the dry dipterocarp forest for approximately 50 years but communities have exploited for timber and charcoal raw material harvests. As a result, most of trees in this forest were regenerated and ages of the trees were 6-7 years (measurement in 2011). The DFR site was situated at 118 m elevation. The vegetation type was a dry dipterocarp forest and the dominant species were Dipterocarpus intricate,

D. obtusifolius, D. tuberculatus, Shorea obtuse and S. siamensis [10]. The canopy was about 5-7 m height (measurement in 2009). Soil texture was a loamy sand soil [11]. The MKL site was in mixed deciduous forest which was mature forests (age was about 37 years in year 2015). It was situated at 231 m elevation. The vegetation type was tropical seasonal deciduous forest (mixed deciduous forest) and the dominant species were Shorea siamensis, Vitex peduncularis, Xylia xylocarpus. The canopy was about 30 m height (measurement in 2008). Soil texture was a sandy clay loam soil [12]-[13].

#### B. Soil CO, measurement by sensor method

Soil CO<sub>2</sub> concentrations were continuously measured by the soil CO2 sensors (GMP343, Vaisala Inc., Finland), which were horizontally buried along soil profiles at depths of 5 cm and 20 cm. The sensors scanned for concentration determination every second, recorded every 15 seconds and averaged every 15 minutes. These sensors were connected with a transmitter, a data logger and a computer for data records. In this study, three replications were made. The measurements at DFR site were commenced on the 1st to the 181st day of the year in 2011 for 181 days and MKL site were commenced on the 121st day in 2014 to the 120th day in 2015 for 365 days. In order to impartially compare, the results in two forests were determined at the same months during January to June for 181 days.

#### C. Measurements of Environmental parameters

Air temperature was measured by Vaisala sensors (HMP45C, Vaisala Inc., Finland). At the depths of 5 cm, soil temperature and soil moisture were continuously measured every 15 seconds and averaged every 15 minutes by custom-built thermocouple sensors and water content reflectometers (CS615, Campbell Scientific, Inc., USA), respectively. The water content reflectometers started to

collect the data at the same time as with CO<sub>2</sub> sensors

## D. Determination of the Soil Respirations $(R_o)$ and Ecosystem Respirations $(R_o)$

Soil  $CO_2$  emissions were calculated using data on the soil  $CO_2$  concentrations (µmol mol<sup>-1</sup> or µmol m<sup>-3</sup>) together with environmental factors. We followed the steps of the calculations from Tang et al [5]. The main equation of the soil  $CO_2$  effluxes (F, µmol m<sup>-2</sup> s<sup>-1</sup>) was determined as shown in the following Equation (1).

$$\mathbf{F} = -\mathbf{D}_{s} \frac{\partial \mathbf{C}}{\partial \mathbf{z}} \tag{1}$$

where F is soil  $CO_2$  efflux ( $\mu$ mol m<sup>-2</sup> s<sup>-1</sup>), Ds is  $CO_2$  diffusion coefficient (m<sup>2</sup> s<sup>-1</sup>), dC/dz is the vertical soil  $CO_2$  gradient, C is  $CO_2$  concentration ( $\mu$ mol m<sup>-3</sup>) and z is depth (m).

Moreover we determined forest ecosystem respiration ( $R_e$ ) in dry dipterocarp forest at DFR site from eddy covariance night time flux at the same period with their soil respiration which was 5.88 kg  $CO_2$  m<sup>-2</sup> y<sup>-1</sup>. Forest ecosystem respiration ( $R_e$ ) in mixed deciduous forest at MKL site which had been determined by [14] was 9.44 kg  $CO_2$  m<sup>-2</sup> y<sup>-1</sup>.

#### E. Data Analysis

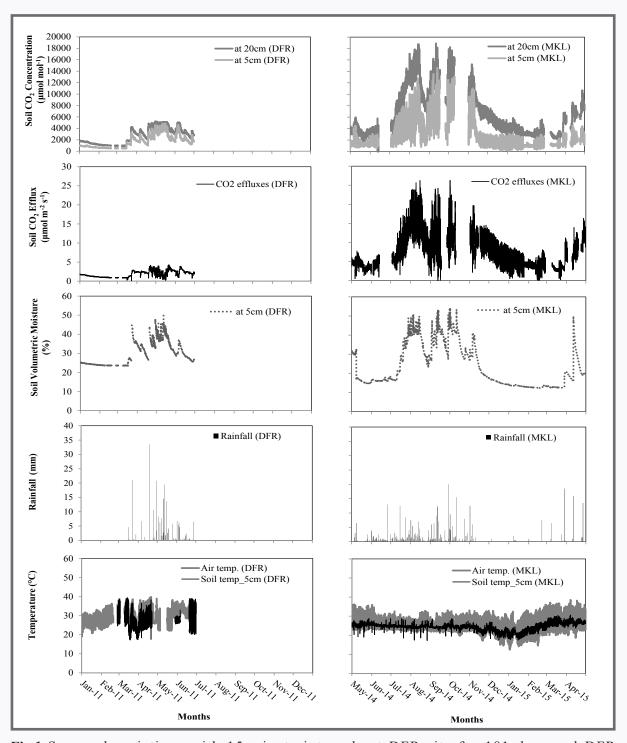
T-Test at significance level of 0.05 was applied to compare soil  $CO_2$  effluxes between a mixed deciduous forest and a dry dipterocarp forest. Percentage of CV (coefficient of variation) was applied to study variations of the soil  $CO_2$  effluxes. Linear Regression Analysis was applied to study relationships between the soil  $CO_2$  efflux with their soil temperature and moisture.

#### III. RESULTS AND DISCUSSIONS

## A. Soil CO<sub>2</sub> Concentration Measured by Soil CO<sub>2</sub> Probes in the Forests

Soil CO<sub>2</sub> concentrations were measured by burying of CO<sub>2</sub> probes in soil profiles at depths of 5 cm and 20 cm in dry dipterocarp forest at DFR site and mixed deciduous forest at MKL site. We found that soil CO<sub>2</sub> concentration at the depth 20 cm was higher than at the depth of 5 cm at both sites.

Comparing between both sites, we found that the averages of soil CO<sub>2</sub> concentration and their variations at the two depths in mixed deciduous forest at MKL site were higher than in dry dipterocarp forest at DFR site (as shown



**Fig.1** Seasonal variations with 15 minute-intervals at DFR site for 181 days and DFR site for 365 days; a) Soil CO<sub>2</sub> Concentration; b) Soil CO<sub>2</sub> Efflux; c) Soil Volumetric Moisture; d) Rainfall; and e) Soil Temperature

in Fig.1a). During January to June for 181 days, average soil  $CO_2$  concentrations at the depths of 5 cm and 20 cm in mixed deciduous forest were 1,543.9±728.1 µmol mol-1 (with variation of 47.2%, n=17,157) and 3,918.4±1,524.6 µmol mol-1 (variation of 38.9%, n=12,926), respectively. In dry dipterocarp forest, we found that average soil  $CO_2$  concentrations at the depths of 5 cm and 20 cm were 1,826.6±1,140.7 µmol mol<sup>-1</sup> (with variation of 62.4%, n=15,627) and 2,766.2±1,386.1 µmol mol<sup>-1</sup> (variation of 50.1%, n=15,627), respectively (as shown in Table 1).

#### B. Environmental parameters in the Forests

In this study, we measured soil moisture, soil temperature, air temperature and rainfall as seasonal scales (Fig.1c-e) which were used for assessing soil respiration (R<sub>s</sub>) afterwards. The results show that the total precipitation during January to June for 181 days in mixed deciduous forest was 349 mm (n=338) and dry dipterocarp forest was 427 mm (n=267). The rain events influenced the dynamics of their soil moistures and temperatures afterwards. In mixed deciduous forest, average soil volumetric moisture at depths of 5 cm was 20.8±6.9% (variation of 33.2%, n=17,298). The average temperatures in soil at depths of 5 cm and atmosphere were 24.8±2.3°C (variation of 9.3%, n=17,157) and  $25.9\pm4.5^{\circ}$ C (variation of 17.4%, n=17,376), respectively. In dry dipterocarp forest, we found that the average soil volumetric moisture content at depths of 5 cm was 29.6±5.8% (variation of 19.7%, n=15,315).

## C. Soil Respirations $(R_s)$ and Their Contributions to Ecosystem Respirations $(R_e)$

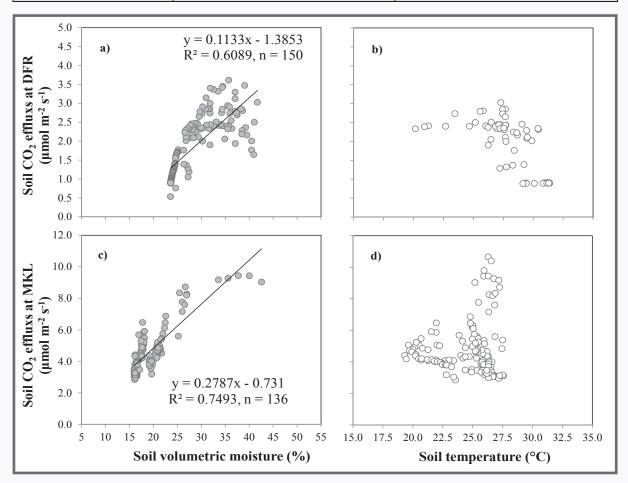
Assessing  $\mathrm{CO}_2$  emissions using soil  $\mathrm{CO}_2$  profile probes had been validated by comparing with the closed chamber method. There was no statistically significant difference between both methods [8]. In this study, soil  $\mathrm{CO}_2$  effluxes (or soil respiration rates) were

reported with 15-minute intervals (Fig.1b). During January to June, soil CO<sub>2</sub> effluxes in two forests was significantly different (p<0.05, n=11,845). However dynamics of soil CO<sub>2</sub> efflux at the both sites coincided with dynamics of their soil CO<sub>2</sub> concentration, soil moisture, temperature in soil and atmosphere, and rainfall.

In mixed deciduous forest at MKL site and dry dipterocarp forest at DFR site, the average soil CO, effluxes were 4.8±2.3 μmol  $m^{-2}$  s<sup>-1</sup> (variation of 46.7%, n=12,919) and  $1.9\pm0.8 \mu \text{mol m}^{-2} \text{ s}^{-1}$  (variation of 42.3%, n=15,626), respectively (Table 1). Their accumulative soil CO, emissions were 6.6 and 2.6 kg CO<sub>2</sub>m<sup>-2</sup> y<sup>-1</sup>, respectively. Their ecosystem respirations (Re) were 9.4 and 5.9 kg CO, m<sup>-2</sup> y<sup>-1</sup> therefore, the soil respirations (R<sub>s</sub>) accounted for 70.9% and 44.6% of the R<sub>s</sub>, respectively. In addition, R<sub>s</sub> in mixed deciduous forest contributed higher to R<sub>s</sub> than R<sub>s</sub> in dry dipterocarp forest of about 2.6 times. This may indicate more active soil and forest floor processes including a rapid turnover of carbon in mixed deciduous forest compared to dry dipterocarp forest.

Table 1 Variations in soil respiration (R<sub>s</sub>) and their environmental factors in dry dipterocarp forest and mixed deciduous forest

	Dry Dipterocarp Forest				Mixed Deciduous Forest							
Values	at DFR site (181 days)				at MKL site (181 days)							
	Max	Min	Mean	SD	%C V	n	Max	Min	Mean	SD	%CV	n
Soil CO <sub>2</sub> Concentration												
at depth of 5 cm (µmol m <sup>-3</sup> )	4887.3	506.4	1826.6	1140.7	62.4	15627	4573.4	138.4	1543.9	728.1	47.2	17157
at depth of 20 cm (µmol m <sup>-3</sup> )	5191.9	926.5	2766.2	1386.1	50.1	15627	10693.5	239.6	3918.4	1524.6	38.9	12926
Soil Volumetric Moisture (%)	49.8	23.6	29.6	5.8	19.7	15315	63.3	15.6	20.8	6.9	33.2	17298
Soil Temperature (°C)	39.4	17.2	27.3	4.1	15.1	5769	30.5	17.5	24.8	2.3	9.3	17157
Air Temperature (°C)	39.8	19.2	29.9	3.8	12.9	12825	38.4	12.4	25.9	4.5	17.4	17376
Rainfall (mm)	33.5	0.1	(Total =	= 427 mr	n)	267	18.50	0.50	(Total =	= 349 mr	n)	338
Soil CO <sub>2</sub> Efflux (μmol m <sup>-2</sup> s <sup>-1</sup> )	4.31	0.15	1.89	0.80	42.1	15626	16.29	0.02	4.82	2.25	46.7	12919



**Fig.2** Relationships between daily mean soil CO<sub>2</sub> effluxes with; a) soil moisture at DFR site, b) soil temperature at DFR site, c) soil moisture at MKL site, and d) soil temperature at MKL site

## D. Relationships between Soil Respiration $(R_S)$ with Moisture and Temperature in Soil

Daily mean soil respiration rates (or soil CO, effluxes) in dry dipterocarp forest and mixed deciduous forest were strongly correlated to soil moisture (r2=0.60, p<0.01, n= 150 and r2=0.75, p<0.01, n=136, respectively) but there was no clear relationships to soil temperatures as shown in Fig.2 c-d. Although soil respiration rates did not relate to soil temperature in seasonal scales, it may relate in diurnal scales (or 24-hour scales). These results indicated that soil respirations in two forests at seasonal scales were mainly controlled by soil moistures, similar to those reported by others [2], [5], [8]. Aside from moisture and temperature in soil, controlling factors of soil respirations were substrate supply and ecosystem productivity, soil pH, soil oxygen, nitrogen, and soil texture [2]. In this study, soil texture in mixed deciduous forest at MKL site had higher soil waterholding capacity than dry dipterocarp forest at DFR site which were a sandy clay loam soil and a loamy sand soil, respectively. Soil texture could influence soil respiration through its effects on soil porosity and moisture. In addition, above ground litterfall is another important factor influencing the CO, flux from the forest ecosystems [2]. In this study, the litterfall production in a mixed deciduous forest at MKL site (8.91 ton ha-1 y-1 of dry weight, measurement between June 2003 and May 2005 [14]) was higher than in the dry dipterocarp forest at DFR site (6.42 ton ha-1 y-1 of dry weight, measurement in 2009 [15]). Therefore soil respiration (R<sub>s</sub>) and their contributions to ecosystem respiration (R<sub>a</sub>) from the mixed deciduous forest were higher than from the dry dipterocarp forest.

#### IV. CONCLUSIONS

Measuring soil CO<sub>2</sub> by using CO<sub>2</sub> profile gradientin mixed deciduous forest and

dry dipterocarp forest for 181 days, we found that the average soil CO, efflux were 4.8±2.3 (n=12,919) and  $1.9\pm0.8$  (n=15,626)  $\mu$ mol  $m^{-2}s^{-1}$ , respectively. Their accumulative soil CO, emissions were 6.69 and 2.62 kg CO, m<sup>-2</sup> y<sup>-1</sup>, respectively. The R<sub>s</sub> accounted for 70.87% and 44.56% of the R<sub>e</sub>, respectively. R<sub>s</sub> in dry dipterocarp forest and mixed deciduous forest were strongly correlated to soil moisture (p<0.01). In addition, R<sub>s</sub> in mixed deciduous forest was about 2.6 times higher than in dry dipterocarp forest. This may indicate more active soil and forest floor processes. In addition, we found that there were higher temporal variations of soil CO, fluxes at mixed deciduous forest when compared to dry dipterocarp forest. This may be attributed to higher variations in rainfall which caused higher variations in soil moisture and in soil respiration.

#### **ACKNOWLEDGMENT**

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Session A.4: Multi-stakeholder Approaches



## Breakthrough from the conservation stewards program in southern Rakhine Yoma, Myanmar

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Abstract-The fences-and-fines approach to wildlife protection is now perceived by many to have failed in developing countries, including Myanmar. One alternative approach is a conservation stewards program where partial management responsibilities for natural resources have been assigned to local people under a community-based program. Friends of Wildlife, a local Conservation NGO and Indo-Myanmar Conservation, and an International Conservation NGO have been working with 24 households of 127 Chin communities, who are skilled hunters living near the Rakhine Yoma Elephant Sanctuary (RYES). There is no economic alternative so they hunt a wide range of species including gaurs, elephants, and all available vertebrates down to the endangered Rakhine forest turtle (Heosemys depressa). The program methods include negotiating incentive agreements, awareness raising, educational support, 30-year leases for land tenure and providing training courses like wildlife surveys, agricultural farming, and community forestry. Recognizable changes have been noted from the initial inactive to active participation in various activities. A total of 123 out of 127 persons engaged by RYES stopped poaching, participated in joint patrols and elephant surveys with RYES staff, and support anti-poaching efforts and human-elephant conflict mitigation as part of forest resource management. Changing the people's attitude to choose conservation and providing the techniques for their livelihoods to increase incomes could lead to the sustainable development of RYES areas. Overall, this approach has been successful though it took more than 7 years even for small communities to see strong results and suggestions to use this stewards program anywhere there is human-elephant conflict.

Keywords: Chin ethnic communities, humanelephant conflict, livelihood support, Rakhine Yoma

#### I. INTRODUCTION

Chin ethnic group is one of 53 Chin races that were formerly found in the southern part of Chin State, who moved to the southern Rakhine Yoma in the early 2000s after they poached out the large mammals in that area where Rakhine Yoma Elephant Sanctuary

(RYES) exist. Due to human population growth, forest clearing and intense hunting reduced region's biodiversity rapidly. The main groups responsible for major threats to the natural resources in RYES are the Chin tribes. Their traditional livelihood styles are shifting cultivation and hunting. To poach they use dogs and spears. Their dogs are very well trained and useful in harvesting numerous wildlife species including large mammals (e.g. gaur, sambar) and medium to small prey (e.g. tortoise, monitor lizard, porcupine). Gaur population numbers declined at increasingly rapid rates over the course of 20 years (Nature and Wildlife Conservation Division (NWCD) report 2005, Forest Department). But older Chin men nevertheless insist that the gaur population cannot disappear from the southern Rakhine Yoma on account of their hunting practices.

Lack of education, insufficient basic mechanical technology, and other such factors, the Chin have had very limited opportunities to obtain employment. Although some are able to secure jobs, their salary is very low, and generally insufficient even for basic needs. Accordingly, they are unable to survive in the city over medium to long term periods, primarily due to the high costs of living and health care. Although they have tried to settle in the towns and cities, about 70% of Chin returned to the Yoma where they resettle in the forest to poach wildlife and create taungya (shifting agriculture) plantations. This phenomenon is the norm among the Chin ethnic group. Poor civil practices, including bribery, corruption in some government agencies are widespread among Chin people around RYES in Southern Rakhine Yoma.

Conservation Stewardship Program offers incentives through a negotiated benefit packages to the communities to make them

responsible and choose conservation actions. Importantly, conservation agreement brings different stake holders like government, bilaterial agencies, private sector companies, foundations, individuals to a common platform and links them to people who own and use natural resources. A conservation agreement warrants people to impel the solution to conservation challenges. This way of approach assists in safeguarding biodiversity while upgrading the quality of life for local communities. Many communities in different parts of the world are using their land, water and other natural resources in unsustainable ways-simply because they have no other readily available economic alternatives.

Myanmar's Forest Department (FD) established the RYES in 1999 to protect one of three largest elephant populations in the country. RYES lie in Southern Rakhine Yoma where semi-evergreen, evergreen rain forest, dry upper mixed deciduous forest and bamboo forest are found. It supports an important population of critically endangered Arakan forest turtle (*Heosemys depressa*); as well as significant population of Asian elephant (*Elephas maximus*), Hoolock gibbon (*Hoolock hoolock*) and a number of regionally threatened species such as Phayre's langur, dhole, Malayan sun bear, Himalayan bear, leopard, cloud leopard and gaur.

There is therefore an opportunity to support Chin ethnic group in ways that reduce their need to poach while building working relationships with the sanctuary. In a country with no tradition of community-based conservation, this sets an important precedent. The key to designing conservation incentive agreements is to understand the economic drivers of poaching and to negotiate changes in community behavior that will offset or mitigate these drivers.

Without external intervention, the region's large mammals will be wiped out within a few years. This will not only terminate a vital income source but represent a globally significant loss of forest biodiversity. By transitioning the focal communities to more sustainable livelihoods based on agroforestry, security of tenure, and improved cash crops, the project will improve the quality of life and increase the self-reliance of these communities, and thereby eliminate a clear and present threat to one of Asia largest elephant populations.

#### II. METHODS

Several Action Steps were carried out in this project.

#### 1. Community Development Initiative

1.1 Annual Incentive agreement through engagement meetings

In 2007, using household survey results, we negotiated an incentive agreement with 24 Chin families for support of rice up to nine months a year, two local teachers, local agricultural extension officer to help the Chin increase rice yields, negotiate the establishment of a community forest and an incentive payment to participate in joint patrols with RYES staff. It aimed to immediately stop the unsustainable hunting of gaur and other large mammals and to increase relationships between the Chin and RYES, while setting the basis for improved food security and forest tenure.

This first agreement was signed by the Chin representatives and RYES staff in October 2007 with key objective of securing the participation of Chin villagers in surveys of the Arakan forest turtle. Chin hunters and RYES staff have identified and surveyed sites within RYES that hold concentrations of the turtle.

In 2008-2013, six more agreements were negotiated and signed based on the results and lessons learned of preceding ones; a last agreement was scheduled for 2014. It focused on sustainability of livelihood and children education. Negotiations have been led by co-author, U Myint Aung, who during his 25 years working for FD established a close relationship with the Chin. Specific issues addressing in the 2013 agreement were: improved data collection to document patrol routes and wildlife sightings; specific measures to take to ensure that dogs are kept out of the RYES; and use of these data in support of RYES planning and management.

All components in the second agreement are the same as the first except for educational support. They needed some supports for middle education students who will attend the 5-9 grade classes at Daung-chaung State Middle School and Gwa State High School. As stated in the incentive agreements, Chin sold their hunting-dogs. The supply of rice declines every year. Rice was provided for 7 months in 2010 and for 6 months in 2011. In 2012, it was provided for 5 months to ensure food security and terminated in 2013.

1.2 Setting up Village Conservation and Development Committee (VCDC)

In terms of institutional development, we set up a VCDC in Chin community. VCDC was made up of 7 individuals and selected by chin people. Their roles include managing and organising of more productive and sustainable of project activities (such as Community Forestry, livestock and agro-forestry), working with FD, RYES and FOW. We had defined the objectives and responsibilities of the VCDCs.

1.3 Community and Land Tenure certificates

In March 2009, the ceremony of land tenure certificate for forest plantation for 30 years was held at project site. This certificate was for the land of 50 acres planted last year in first year of this program. The secretary of Gwa Township Authorities, FD officer, Township Police officer, warden of RYES, Township Education officer and other village authorities attended and gave a speech. This is an important step for our project because other groups did not get this kind of legal certificate yet. This means that the landless Chin-hunters had the chance to live on this land for 30 years officially.

## 2. Capacity Building and Awareness Raising 2.1 Trainings and Activities

FOW and FD had been jointly implemented capacity building activities and trainings such as grassroots stakeholders on CF, civil society development and wildlife survey for Chin community. The objectives of these trainings are to build the capacity of grassroots stakeholders for their leadership skill, decision making skill, CF management, and other skills so they can actively contribute to the forest plantation and good relationships with local authorities. FOW also supported and trained Chin people in some simple wildlife surveys (e.g., turtle and elephants) including how to use GPS-receiver, record GPS location, habitat type, take photos, and operate camera traps.

## 2.2 Community participation to mitigate HEC

The community participation is a vital role in mitigation HEC. The object is to improve the capacity of villagers to cope with elephant damage. This was accomplished by helping communities share with each other methods that they currently use to mitigate elephant damage and by introducing to them new methods that have proved successful in other countries. FOW has tested these HEC prevention

methods in Shwe-U-Daung Wildlife Sanctuary in Mandalay Division. Methods that villages do not currently use include visual clearing, permanent watchtowers in fields and planting crops, such as sesame (*Sesamum indicum*), that the elephants do not like. FOW led villages who wished to do so to write action plans employing methods they would like to try or that are appropriate for them.

#### 3. Project supporting activities

#### 3.1 Forestry program

During the period of 2008-2014, the seeds of hardwood species such as Xylia spp. were distributed by the project for establishment of about 200 hectares of a community forestry plantation. The local community also planted 12 different crops inside the forest plantation for incomes. Securing this plantation signifies a real change in attitudes between the local authorities and Chin villagers. These were previously marked by fear. Relations are now friendly and provide the basis for further win-win opportunities to balance conservation and sustainable development.

In 2009 Forestry Minister's visit to Gwa Township, he appreciated project activities and objectives and promised to support the education in Chin state. Following his enjoyment on the project, many benefits appeared such as: 1) one donor for reconstruction of mobile school; 2) Arranging the National Registration Cards (NRC) for Chin people by Township Immigration Department with lower expense; 3) Upgrading mobile school to government primary school by Township Education Department.

In 2011, the project provided equipment and technical assistance to construct a nursery. The Chin planted and tended the seeds for six months and sold the seedlings to local people. Income from the nursery goes into a village welfare fund and is used to hire teachers and maintain the water pipeline.

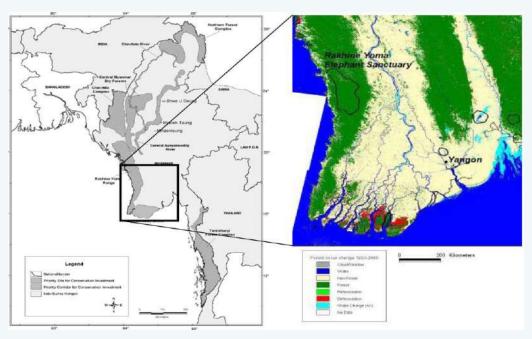


Fig.1 Location of Rakhine Yoma Elephant Sanctuary

#### 3.2 Income Generation

To reduce dependence on shifting cultivation, the project has supplied seeds for agro-forestry and cash crops that are not eaten by rats such as yam, ginger (for which there is a major export market), pineapple, banana, betel and lime. Four training courses on cash-crop plantation including production of biofertilizer were conducted during 2011-2013. Study tours for government agricultural research center and private farms were arranged for Chin Villagers. Starting in January 2014, with funding from the FAO's Forest and Farmers Facility (FFF), the Chin farmers could have access to major domestic markets for their products.

The supply of livestock farming began in March 2013. As a pilot work, FOW provided chickens for all families. The observation found that families derive income every 3-6 months by selling eggs and hatchlings.

This income generation would help the sustainability of this project to reduce dependency on forest resources, through diversification of livelihoods.

Based on the leadership of VCDCs and activities of Chin communities, the project continued to supply pigs to them in July 2013 and worked with VCDCs to implement and manage this livestock farming activities.

## 3.3 Environmental education and awareness

Environmental education activities such as school and village education program, erecting signboards and posters were carried out. School teachers, students, and local people from three villages are the target groups for these activities. Education teams conducted the education activities at 10 State High and Middle Schools in Gwa townships according to the requests of chairman, township authorities and township education officer. Education talks included the endangered and endemic species such as Arakan forest turtle, elephant, conservation of mangrove forests, clean environment such as avoiding plastic littering, water pollution, fish and poisoning. Litter bins for all 10 schools were support for cleaning

activities that will be accomplished by students.

Generally they lack a good toilet system. Therefore, the toilet equipment for all families and litter bins made of bamboo for plastic litter cleaning were arranged. Now they are following this practice such as using litter bins and toilet units.

#### III. RESULTS

The results show three different aspects: Biodiversity conservation practices; Socioeconomic practices; and Agroforestry practices in this conservation steward program.

#### 1. Biodiversity Conservation

As the Chin villagers themselves are skilled trackers, can recognize animal track and signs well, and have a thorough understanding of local wild flora and fauna, it was easy to train the people to do surveys of elephants and other large mammals. They also have become good patrollers for RYES together with better relationship between sanctuary and FD staff to monitor wildlife and deter hunters while at the same time establishing the basis of a costeffective monitoring system. Participation in anti-poaching and mitigation of human-elephant conflict (HEC) are active and as a very good result, the Chin people had already sold their hunting dogs and stopped hunting because the key to the survival of wildlife species in RYES is preventing the entry of hunting dogs. In addition, some wildlife appears to be relatively abundant and number of illegal poaching elephants is decreased year by year in RYES. In 2013, BBC team consisted of many scientists selected our project site for film making on wild elephant and other wildlife, and the team used Chin people which FOW supported as local field experts.

#### 2. Socio-economics

The Chin people's livelihood style started to change through improved capacity building in terms of knowledge, attitude, behavior, practice, project management, agroforestry, and communication and facilitation skills as well as awareness improvement on issues of sustainable natural resource management and environmental protection. Generation of income for Chin families already became different from the past and is now getting through CF establishment, crop plantation and livestock farming rather than illegal hunting wildlife in RYES. Better and sustainable education system for Chin children supported by this program and Basic Education Department put a stop to children becoming hunters in future and child labor in restaurants. Education is humanity's best hope and most effective means to achieve sustainable development (Educating for a Sustainable Future, UNESCO report, 1997).

#### 3. Agro-forestry

The Chin who never had any land got official permission to live there for 30 years through land tenure certificates by FD together with community forest plantation; high-value timber plantation and watershed plantation. Moreover, they are now familiar with agroforestry works as they became to know that sustainable agroforestry generates income and helps to protect the environment.

#### 4. Challenges

There were two major challenges: 1) the first one was all bamboo forest flowered and died in 2010-2011. Then many rats came out and destroyed the crops in southern Rakhine Yoma. It was a natural disaster. All Chin families loss their crops and money saved.

The second one happened in 2013-2015. Out of 24 families, totaling of 127 people, 4 chin people got punishment of one year in the jail. They were involved in hunting during project period although they hunted in other areas 120 miles far from project site especially in Ayeyarwady Region. Due to inflation rate becoming higher and higher year by year, they wanted more income to cover the cost of children's higher education.

#### IV. CONCLUSIONS

At present, most researches have focused on environmental conservation effects, while few researches have focused on the social and economic impacts of protected areas (Fortin and Gagnon, 1999, Badalamenti, 2000; Van Beukering, 2003). But in this program, we represent a coordinated effort on the small group of local people, Chin tribes, for their sustainable living in and around RYES. More diversified, sustainable and secure livelihood options with local authorities will reduce both poverty and pressure on the region's globally threatened wildlife. The key approaches and methods used in this project were: 1) supporting the negotiation of incentive agreements and training of joint patrols together with RYES staff to reduce poaching and HEC in RYES; 2) capacity building and awareness raising among local people on issues of sustainable natural resource management and environmental protection; 3) promoting the generation income for chin families through CF establishment and agroforestry practices and 4) supporting better and sustainable education system for Chin children.

The main lessons learned during the project were:

- Conservation-related activities should be strategic, and focused on selected community to achieve the most impact.
- Technical assistance is needed for project

- implementation, especially for livelihoodrelated and sustainable forest resource use, and agricultural practices.
- The program has to respond to newly emerging development pressures, especially to poaching and HEC in RYES.
- Monitoring should be done frequently especially on their income and household expenses. Because although they have had some improvement in their livelihood during project period, this has not kept pace with Myanmar's inflation rate.

Overall, we learnt that the approach has been successful though it took more than 7 years even for small communities to see strong results and we can use this stewardship program elsewhere where there are key biodiversity areas, and human-wildlife conflict sites.

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## Building teachers capacity in biodiversity: Enhancing teachers' awareness and knowledge of biodiversity across the Malaysian secondary school curriculum

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Abstract-The importance of biodiversity, or biological diversity, for sustainable development is the basis of the Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets adopted by the Convention on Biological Diversity (CBD) in 2010 and subsequently recognized by the UN in goal 15 of the SDGs. Schools play a key role in ensuring that biodiversity concepts are taught in the curriculum, but also that students develop values and increase their capacities to preserve biological diversity. Teachers play a vital role in developing students' values and increase their capacities to preserve biological diversity. However teachers should be knowledgeable about biodiversity and biodiversity related element and have skills in order to successfully integrate in teaching. This paper will describe a teachers' professional program with the aim of increasing their awareness and knowledge on biodiversity. This program was developed to assist secondary education teachers, from different subject areas, in embedding features of biodiversity across the school curriculum.

The main aim of the program is to reorient the learning experience and the skills teachers develop, so they can think and act in support of ways of integrating biodiversity in their subjects.

Keywords: biodiversity, teachers' professional program, teachers awareness, teachers knowledge, capacity building

#### **INTRODUCTION**

Malaysia is widely known as the one of the world's mega diversity countries. Malaysia's ecosystem is full of variety of plants and animal. Biodiversity provides essential ecological services to the nation in order to ensure we are able to enjoy fresh air, clean water and healthy ecosystem. It is important to the Malaysia citizen to conserve the biodiversity in Malaysia.

According to Malaysia's National Policy on Biological Diversity principles, public awareness and education play an important role to ensure the conservation of biological diversity and the sustainable utilization of its components. Therefore, Malaysia's education system has seen biodiversity as an important element to be embedded across the curriculum. The importance of biodiversity, or biological diversity, for sustainable development is the basis of the Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets adopted by the Convention on Biological Diversity (CBD) in 2010 and subsequently recognized by the UN in goal 15 of the SDGs.

We all fully depend on biodiversity, which provides us with goods and services that support and sustain our lives. Biodiversity not only provides us with food, water, fertile soil, medicines, protection from storms and floods and recreation spaces, but also ensures us security and health and affects our social relations (see http://www.iucn.org). Although protecting biodiversity is key to human development, we often ignore how important it is for our personal health and the health of our economies. Human activities, magnified in recent years by population and economic growth and climate change, have led to a dramatic loss of biodiversity across the world.

#### The Teaching of Biodiversity in Schools

Schools play a key role in ensuring that biodiversity concepts are taught in the curriculum, but also that students develop values and increase their capacities to preserve biological diversity. In addition, there is a need for promoting whole-school approaches, so that actions to promote biodiversity are practiced on the school grounds (Mula and Munirah, 2016).

Teachers are powerful actors to reorient and transform students learning experiences toward sustainable development. An important prerequisite is that teachers should have sufficient knowledge, a good attitude and practices with regard to education for sustainable development. Furthermore, teachers need to be knowledgeable on the matters related to the content to be conveyed as learning depends on what teachers know (Acheson, 2003). However, the reality is that teachers may lack professional development opportunities to help them develop competences to re-think and change their teaching practice towards sustainable development. Exploratory study on teachers' knowledge about some concepts of education for sustainable development and teachers' attitudes showed that geography and science teachers achieve a moderately high level (Mohammad Zohir Ahmad, 2010).

## Positioning Biodiversity in the School Curriculum

Mohammad Zohir Ahmad et. al. (2016) show that it is feasible to integrate Biodiversity concepts across the secondary school curriculum. In fact, it is possible to integrate biodiversity concepts across many of the subjects taught at secondary school level specifically in Science and Geography, Languages (both English and Malay language) and Mathematics. In fact, it is possible to infuse biodiversity concepts in all subjects for all years from Form 1 to Form 5. Exceptions are for the subjects Biology, Physics and Chemistry which are only taught when students enter form 4 and form 5.

Moreover, it is also possible to inject biodiversity ideas in Forms 1 to Form 5 in Science, Geography, Malay language and English. In Mathematics however, the integration is more subtle whereby the concepts are implicitly instilled through teachers' verbal explanation of the pictures and diagrams and other visual forms of biodiversity concepts. Biodiversity concepts are discussed further in Form 4 Biology. This rather brief analysis of the curriculum shows

that it is possible to integrate Biodiversity concepts in the subjects taught in secondary schools as well as across the five years of secondary schools.

#### Teachers' Professional Program to Develop Awareness and Knowledge on Biodiversity

The quality of teachers in teaching biodiversity in long run will contribute to produce students with skills in dealing with issues related to biodiversity in particular as well as sustainable development in general. To improve the quality of teachers, especially those related to biodiversity, teacher professional development program in the form of training should be held. The training of teachers is one of the important strategies of education for sustainable development.

Teachers' professional program that was carried out aim to clarify concepts, themes and principles associated with biodiversity and how they can be integrated in all subject areas across the curriculum. The module proposes a transformative view of education in order to align the current curriculum with education movements such as environmental education, global citizenship education, health education or development education. The transformative view promote the concept of the teacher as an "expert" or "instructor" to a learning facilitator that engages students in critical and values reflection and challenges their own learning experience. See Figure 1 below:

#### From

Passing on knowledge

Teaching attitudes and values

Seeing people as the problem

Sending messages

#### To

Understanding and getting to the root of

issues

Encouraging values clarification

Seeing people as facilitators of change

Dialogue, negotiation and action

Fig.1 Educational shifts proposed by sustainability education

Source: Tilbury (2011)

Sustainability education is not just about teaching knowledge on sustainable development issues, such as biodiversity, but also helping the student to develop skills to respond to complex social, environmental, and economic complexities related to biodiversity that affect the quality of life on this planet. The focus is on the pedagogy and methodologies that should be used in the classroom. Therefore,

the teachers' professional program which has been planned provides key pedagogical principles that can be used in teaching and learning processes. The keys are as below:

- Futures thinking
- Critical reflective thinking
- Learning to act and change
- Systemic and integrative thinking
- Participation and participatory learning

#### Futures Thinking

According to Tilbury (2011), futures thinking can be defined as imaging or envisioning a better or preferred future. All educational levels as well as in social and business contexts are encouraged to use the futures thinking as a key pedagogical principle. Future thinking is also considered to be a pivotal component of ESD. However, various parties such as media, scientist and educator are always portraying the negative image of future particularly related to biodiversity such as the natural disaster, species extinction, and destruction of ecosystem. This action actually discourage the efforts to solve or reduce the problem or enhance conditions of well-being. Some other parts of the world today are facing extreme poverty, depletion of resources, war conflicts and species extinction which require immediate action. However, by having the basic knowledge about them, does not lead or encourage people to transform the situations (Tilbury and Cooke, 2015). Therefore, by applying the future thinking concept, the current generation can give hope and create positive future dreams together with the younger generations. In future thinking, one will try to gain knowledge, understand and analyses information about the future images and visions which will help to motivate proactive attitudes and actions for the positive future (Lehtonen, 2012). By envisioning a better future, we can established a link between long term goals and immediate actions, and motivate people to action by harnessing their deep aspirations; identifies relevance and meaning for different people; explores how to achieve change; offers direction and energy to take action and will results in ownership of visions, processes and outcomes (ARIES, 2009).

#### Critical Reflective Thinking

Another key skills in ESD is critical and reflective thinking. Critical reflective thinking is much deeper than simply being critical about certain issues and events (Mula and Munirah, 2016). By critical reflective thinking, students have to explore the root causes of unsustainability and identifying his/her own and others' underlying values, assumptions, perceptions and world views. Students learn and get involve in a process of deep questioning and learn how to make critical and meaningful questions (Mula and Munirah, 2016).

#### Learning to Act and Change

Learning to act refers to the application of knowledge and skills in the daily life of students developed through activities in and outside the classroom which enable students to identify their role in the society which involve personal and social action.

Students should be trained that they can effect change in their community and their personal lives as well. Therefore leaning will be active and will link to their social responsibility. Teaching and learning in school should provide opportunities to develop students' knowledge and skill for their future sustainable living.

According to Mula and Munirah (2016), exploring case studies with local community groups and business is an example of technique that can be used to encourage student to use the knowledge that they have gained into practical actions on sustainable development issues.

#### Systemic and Integrative Thinking

Systemic or integrative thinking is one component of a holistic approach which is one of the core competences in ESD for educators. By using systemic and integrative thinking, people can understand the "whole picture" and manage any situation which can be complicated (Mulá and Munirah, 2016). This involved the fundamental of systemic thinking which identify the relation of natural, social and economic systems as well as their functions; the mutually dependent relationship within the current generation and between generations, between human and environment as well as between rich and poor; their personal paradigm, cultural assumption and understanding of others; the link between sustainable futures and how we think, live and work; and their own thinking and action towards sustainable development (UNECE, 2012). Hence, systemic and integrative thinking will involve the students with case studies, project-based learning, stimulus activities, and the use of the school grounds as a learning resource.

#### Participation and Participatory Learning

Cognitive gains, action competence and community building are the outcomes from participation and participatory learning which provide tools for developing and sharing knowledge, skills and experiences (Reid et. al., 2008: 2). This implies that students becoming active participants and co-creators of knowledge and experiences, rather than passive consumers of content (Breiting et. al., 2005). Teachers act as facilitator and helpsstudents to search for meanings, construct new knowledge, think critically and create innovative solutions. This will develops students' leadership and negotiating skills, empower them to share knowledge and experiences and provides them the opportunity to become change agents (Mula and Munirah, 2016). There are various

way of teaching and learning methods that support participatory learning, such as group dialogue or discussion, problem trees, ranking activities.

#### The Module

The module used in this program will be developed based on the existing module i.e Curricula on Education for Sustainable Science for Secondary School Teachers (Mulà and Munirah, 2016). The module adopt key pedagogical principles for sustainability education that has been discussed above. The module also exposes teachers to arrange of pedagogical approaches and strategies that they can use in their own schools. These include participatory and student-centered teaching and learning methods as well as transformative, action, values and experiential learning, needed to reorient the curriculum experience towards sustainable development. The module helps students to engage more effectively with sustainability concerns. As Tilbury (2011) states, sustainability education engaged students in:

- learning to ask critical questions;
- learning to clarify their own values;
- learning to envision more positive and sustainable futures;
- learning to think systemically;
- learning to respond to applied learning; and,
- learning to explore the dialectic between tradition and innovation.

The reflection box provided in the module can be used by the teachers as a guideline to incorporate the sustainable development (biodiversity issue) key points in their teaching processes. The example of the reflection box is below:

#### **Reflection Box 2**

#### **Teaching for Biodiversity**

- 1. Think about your teaching practice and subjects you teach.
- **Learning content:** Think about the key issues in your discipline and how they might be linked with biodiversity.
- **Pedagogy and learning environments:** Think about the teaching methodologies that you use and the learning environments that you create for your students. Are they teacher-or student-centered? Do they promote participation and collaboration? Do you create spaces for students to explore, think critically and act towards the sustainability of biodiversity?
- Learning outcomes: Think about the skills (not knowledge) that your students develop throughout their learning journey. Do students develop skills such as critical and systemic thinking, futures thinking and collaborative decision-making?
- **Societal transformation:** Think about how your teaching can contribute to social change.

Do you provide opportunities for students to envision change, transform themselves, the school and their local communities?

Fig.2 Reflection Box 2 Teaching for Biodiversity

On the other hand, the module also exposes teachers to arrange of pedagogical approaches and strategies that they can use in their own schools. These include participatory and student-centered teaching and learning methods as well as transformative, action, values and experiential learning, needed to reorient the curriculum experience towards sustainable development. An excerpt from the program on biodiversity is given in Figure 3.

Teachers will be given various websites sources on biodiversity that consist of concepts, benefits and conservation measures. Various activities involving five key pedagogical principles as mentioned above will be carried out in the workshop such as group dialogue or discussion, problem trees, ranking activities, games, and so on.

#### Biodiversity

The importance of biodiversity, or biological diversity, for sustainable development is the basis of the Strategic Plan for Biodiversity2011-2020 and the Aichi Biodiversity Targets adopted by the Convention on Biological Diversity (CBD) in 2010 and subsequently recognised by the UN in goal 15 of the SDGs.

Biodiversity is the term used to describe the variety of life on Earth. It refers to the wide variety of ecosystems and living organisms, including animals, plants, their habitats and their genes. Our biological diversity has continuously evolved for billions of years and it has been shaped both by natural and human processes(https://www.cbd.int). We are all integral and fully depend on biodiversity, which provides us with good and services that support and sustain our lives. Biodiversity not only provides us with food, water, fertile soil, medicines, protection from storms and floods and recreation spaces, but also ensures us security and health and affects our social relations (see http://www.iucn.org).

Although protecting biodiversity is key to human development, we often ignore how important it is for our personal health and the health of our economies. Human activities, magnified in recent years by population and economic growth and climate change, have led to a dramatically loss of biodiversity across the world.

Schools play a key role in ensuring that biodiversity concepts are taught in the curriculum, but also that students develop values and increase their capacities to preserve biological diversity. In addition, there is a need for promoting whole-school approaches, so that actions to promote biodiversity are practiced on the school grounds (UNESCO, 2015).

#### **Biodiversity**

Of the 8,300 animal breeds known, 8% are extinct and 22% are at risk of extinction.

Of the over 80,000 tree species, less than 1% have been studied for potential use.

Fish provide 20% of animal protein to about 3 billion people. Only ten species provide about 30% of marine capture fisheries and ten species provide about 50% of aquaculture production.

Over 80% of the human diet is provided by plants. Only three cereal crops – rice, maize and wheat – provide 60% of energy intake.

80% of people living in rural areas in developing countries rely on traditional plant-based medicines for basic healthcare.

Source: http://www.un.org/sustainabledevelopment/

Fig.3 Keyfacts-Biodiversity

At the end of the module, the teacher should be able to understand concepts and themes related to biodiversity and how they can be integrated in subject areas; design and plan learning experiences related to biodiversity that involve interdisciplinary thinking and practice; and use a wide range of interactive and participatory teaching and learning strategies that empower students in futures thinking, critical discussions, values clarification and action learning.

#### **CONCLUSION**

This project is still in very early initial stage. Currently researchers are developing list of biodiversity issues and topics which can be integrated into existing school subjects and where teachers and pupils can connect with local issues they face in the communities. Future works need to be done in order to ensure biodiversity elements could be integrated in all subjects at all levels across the curriculum in secondary school in Malaysia. It is expected that teachers will have at least a basic knowledge on biodiversity and pedagogical skillsthat will help them to act as catalysts to lead a process of change the understanding and behavior of the school pupils and other teachers.

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## Analysis of biodiversity in the Malaysian secondary school curriculum

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Abstract-Biodiversity is important to people and the health of ecosystems. It became one of the ten key sustainable development issues in Education for Sustainable Development by UNESCO and in goal 15 of the Sustainable Development Goals (SDGs) by UNDP. Education is an important element and school becomes among the important place and plays a significant role to create awareness, knowledge and change attitudes towards the environment (biodiversity). This paper analyse instances of biodiversity in the Malaysian curriculum using a content analysis technique of documents focusing on the following subjects: Geography, Sciences, Languages (English and Malay) and Mathematics. The purpose of this paper is to identify "where & when" the biodiversity concept and issues are discussed in the existing secondary school curriculum. This brief analysis of the curriculum shows that elements of biodiversity are integrated either directly or indirectly in the subjects taught in secondary school curriculum in Malaysia. The curriculum emphasises on inquiry, discovery learning through experience and problem solving processes that utilised scientific and thinking skills. The curriculum also emphasises on active learning approaches.

Keywords: biodiversity, secondary school curriculum, subjects, integrated, Malaysia

#### I. INTRODUCTION

Biodiversity is important to people and the health of ecosystems. It became one of the ten key of sustainable development issues in Education for Sustainable Development by UNESCO and in goal 15 of the Sustainable Development Goals (SDGs) by UNDP. In other words, conserving biodiversity is key to achieving sustainable development (Durham Biodiversity Partnership, 2016). Education is essential for sustainable development. Citizens of the world need to learn their way to sustainability (UNESCO, 2012). School becomes among the important place and plays a significant role in the education of tomorrow's citizens. Introducing biodiversity in the curriculum will prepare students to take action throughout their lives to protect and restore biodiversity in their own communities and around the world (National Wildlife Federation, n.d.). Teaching and learning in schools depends on the curriculum provided, usually a national curriculum. This paper analyse instances of biodiversity concept in the Malaysian curriculum using a content analysis technique of documents focusing on the following subjects: Sciences, Geography, Languages (English and Malay) and Mathematics. As Haury (1998) pointed out, biodiversity is more than a biology or science topic, but is a concept that cuts across disciplinary boundaries, and it is an environmental issue with board ramifications for the quality of human life. The purpose of this paper is to identify "where & when" the biodiversity concept and issues are discussed in the existing secondary school curriculum.

#### Biodiversity in Malaysia

Biodiversity means the variety of living organisms on earth. The term derived from the combining of the genetic resources which are plants and animals, the variety of species and the habitats in which they live (MNRE, 2006). According to Convention on Biodiversity "Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity with in species, between species and of ecosystems." (United Nation, 1992: 3).

In general, biodiversity consists of genetic diversity, species diversity and ecosystem diversity. Biodiversity in Malaysia focuses on diversity of the species diversity and ecosystem diversity such as terrestrial tropical rainforest, the lake and river system and the coral reefs and marine. Malaysia is known as one of the richest countries in the world in terms of biodiversity per unit area with only 0.2% of the world land's mass. The diversity of flora and fauna has made Malaysia as one of the 12 mega-diversity countries in the world recognised by the Global Diversity Outlook in 2001 (MNRE, 2006).

Flora diversity are estimated about 15,000 species of vascular plants in Malaysia, with about 3000 in Peninsular Malaysia and 12,000 in Sabah and Sarawak. The fauna of

Malaysia consists of a huge variety of animals includes 307 known species of mammals, 30 of them are endemic to Malaysia, 785 species of birds, 242 species of amphibians and 567 species of reptile and 1951 species in aquatic ecosystems (MNRE, 2016).

Due to the importance of biodiversity to life in maintaining natural environment and the life-support systems especially in Malaysian context that give food, water and numerous economic benefits (MNRE, 2016) and the importance of education in providing knowledge and skills and develop positive attitudes and practices to the public, so studies on biodiversity in the current curriculum is important.

This study provides information on biodiversity in the curriculum. This information can be used as a guide towards strengthening the national curriculum in line with Action 1.2 for Target 1 Malaysian National Policy on Biological Diversity 2016-2025. Action 1.2 is nurturing participation amongst children and youth by strengthening biodiversity literacy in the formal curricular education that will inspire young Malaysians to discover, explore, and cherish the wonder of nature. This entails the greater emphasis on biodiversity within related subjects such as science, mathematics and geography as well as introducing biodiversityrelated examples in other subjects (MNRE, 2016). This study focuses on geography and science subjects. However, other subjects such as languages (Malay and English) and mathematics have also been studied. Biodiversity fits well with science and geography curricula, and with a creative thinking it can easily link in to all subjects (DCSF, 2010) where biology (science) and geography are widely believed can contribute in creating understanding about environmental issues such as loss of biodiversity (Dalelo, 2012).

#### Malaysian School Subject Syllabus

The curriculum in Malaysia is centralized and coordinated by the Curriculum Development Division (CDD), Ministry of Education. The CDD designs the syllabus and teachers' resource books for all school subjects for the preschool, primary and secondary schools. Two main materials published by CDD are the syllabus and curriculum specifications of each subject that are used as a guide and road map to teachers, students and textbook writers which dictate the content of students' textbooks, teachers' guides, teaching materials, and other matters related to the teaching and learning of the subject. The subject offerings, status at lower and secondary level; and time allotments for each subject are also determined by CDD. The current curriculum use the Integrated Curriculum for Secondary School (KBSM) where Science and Geography are compulsory subjects at the lower secondary (Form 1-3). Science subject is allocated 200 minutes per week while Geography subject is allocated 120 minutes per week. At the upper secondary (Form 4 and Form 5), Science remains a compulsory subject while Geography is an elective subject for Arts stream. According to Habibah Lateh and Vasugiammai (2011) only a few schools offer geography at this level. Malay Language (240 minutes per week), English Language (200 minutes per week) and Mathematics (200 minutes per week) are compulsory subjects at lower and upper secondary.

The aims of the science curriculum for secondary school are to provide students with the knowledge and skills in science and technology and enable them to solve problems and make decisions in everyday life based on scientific attitudes and noble values. Science curriculum emphasises on inquiry and problem solving processes that utilised scientific and thinking skills (MOE, 2002a). Scientific skills are important in any scientific investigation

such as conducting experiments and carrying out projects. The teaching and learning process 'should enable students to acquire knowledge, master skills and develop scientific attitudes and noble values in an integrated manner' (MOE, 2002a: 10). The science curriculum is organised around themes where each theme consists of various learning areas, each of which consists of a number of learning objectives. A learning objective has one or more learning outcomes. Learning outcomes are written in the form of measurable behavioural terms based on the hierarchy of the cognitive and affective domains (MOE, 2002a: 13). Topics and subtopics of lesson and textbooks are derived from learning objectives.

The Geography syllabus at secondary school was formulated based on three parts i.e. (A) Geography Skills, (B) Human and Physical Geography, and (C) Local Study. The study of biodiversity focus on Part B which is organised around eight themes. Each theme consists of various topics and subtopics. Geography curriculum enables students to understand the phenomenon of geographical focus to Malaysia and its relations with other countries in order to produce students who are knowledgeable, responsible, grateful and love the country. In the process of teaching and learning, emphasis should be given to the development of thinking skills and generic skills. Inquiry and discovery learning through experience is highly recommended.

Both English and Malay Language focus on language use, language skills and language system. Among the objectives enables learners to listen to, view, read and respond to different texts, and express ideas, opinions, thoughts and feelings imaginatively and creatively in spoken and written form; and show an awareness and appreciation of moral values and love towards the nation (MOE, 2003; KPM, 2003). In Malaysia, English is taught as a second language in schools. Learners are taught the English language to enable them

to use the language to further their studies and for work purposes (MOE, 2003: 1). One of the themes and topics that was stipulated in Form 1 to Form 5 English Language syllabus is environment. However, learners are not expected to deal with the topics in depth. This topic serve as the subject matter through which the three areas of language use are developed using meaningful tasks and activities (MOE, 2003: 8). While in Malay Language (national language) the knowledge covers various disciplines, such as science and geography that can be used to develop language knowledge and language skills (KPM, 2003). Teachers should take into account current issues (including biodiversity or biodiversity-related) in their teaching and learning.

Two of the objectives for secondary mathematics curriculum enable students to apply knowledge and the skills of mathematics in solving problems and making decisions and relate mathematics with other areas of knowledge (MOE, 2002c: 2). These objectives are in line with one of the elements emphasized in the syllabus ie mathematical connections. By making connections, students are able to see mathematics as an integrated whole and will be able to use mathematics contextually in different learning areas and in real life situations. (MOE, 2002c: 7). Biodiversity or biodiversityrelated provide opportunities for mathematical connections elements that could be taken into account and infused in the teaching and learning processes in the classroom. In teaching and learning teacher must incorporate various teaching strategies and approaches such as direct instruction, discovery learning, investigation, guided discovery or other methods (MOE, 2002c).

#### II. METHODOLOGY

This study employed a qualitative research approach through content analysis technique of documents. This technique is

purposely used to capture 'biodiversity' in the Malaysia existing curriculum. Bardach (2009:69) stated that documents are "anything that has to be read". In this study, documents that been analysed are the official curriculum documents prescribed by the Ministry of Education such as the syllabuses, the description of each subject syllabuses for Form 1, Form 2, Form 3, Form 4 and Form 5, and Teacher's GuideBook on Environmental Education Across the Curriculum for Secondary School. Following Yan Zhang and Wildemuth (2009), samples of documents for the qualitative content analysis consist of purposively selected texts which can address the research questions being investigated. The texts were read through several times to obtain a sense of the whole. The items that have been sought in the text is about biodiversity and biodiversity-related that meet the definition of biodiversity as discussed above.

#### III. RESULTS

#### Biodiversity in Science Curriculum

There are specific learning areas on biodiversity in the secondary school science curriculum. Science syllabus for Form 2 have specific learning area on biodiversity under the theme Man and the Variety of Living Things. Based on the learning objectives in this area, knowledge related to biodiversity that must be known to the students are variety of living organisms and their classification. The topic comprise two elements of biodiversity which are genetic diversity and species diversity. These topics provide instances for students to explain the diversity of living organisms in a habitat; classify various animals based on common characteristics; classify various plants based on common characteristics; and explain the importance of biodiversity to the environment (MOE, 2002b).

No specific learning area or topics on biodiversity per se in Form 1, Form 3, Form 4 and Form 5 Science Syllabus. It means that the term 'biodiversity' did not appear in the syllabus. In the upper secondary level, only Biology Form 4 has two specific topics of biodiversity under the learning area 1.0 Dynamic Ecosystem that is understanding the concept of biodiversity and appreciating biodiversity. Through understanding the concept of biodiversity students will be able to explain the meaning of biodiversity; explain the need for classification of organisms; state the five kingdoms used in the classification of organisms; identify the main characteristics of organisms in each kingdom; list examples of organisms in each kingdom; state the hierarchy in the classification of organisms, using examples; explain through examples, the method of naming organisms using the Linnaeus binomial system; and explain the importance of biodiversity. While through appreciating biodiversity students will be able to justify the importance of preservation and conservation of biodiversity; and preserve and conserve various living things around him/her (MOE, 2005).

Furthermore, there are many topics related to biodiversity in the Science syllabus for secondary school. In Form 1, in Learning Area 2 (The Variety of Resource on Earth) under the theme 'Introducing Science', knowing the different resources on earth (Learning objectives 2.1) and appreciating the importance of the variety of earth's resources

to man (Learning objectives 2.3) are related to biodiversity. This topic contain two elements of biodiversity which are species diversity and ecosystem diversity. Expected learning outcomes for knowing the different resources on earth are a student enable list the resources on earth needed to sustain life; list the resources on earth used in everyday life. Through appreciating the importance of the variety of earth's resources to man, a student will be able to explain the importance of variety of earth's resources to man; state the meaning of the preservation and conservation of resources on earth; state the importance of the preservation and conservation of resources on earth; practise reducing the use, reusing and recycling of materials (MOE, 2002a).

In Form 2 syllabus, there are six topics that related to biodiversity in Learning Area 2 Interdependence among Living Organisms and the Environment under the theme Man and the Variety of Living Things. The six topics are the interdependence among living organisms, the interaction between living organisms, food web, photosynthesis, the importance of conservation and preservation of living organisms, and the role of man in maintaining the balance in nature. The elements of biodiversity influence among the variety of living are species diversity and ecosystem diversity. Expected learning outcomes for each learning objective are shown in Table 1.

**Table 1** Topics related to biodiversity in the Science syllabus for Form 2

- 2.1 Analysing the interdependence among living organisms
- A student is able to state what species, population and community are; state what habitat and ecosystem are; identify various habitats in one ecosystem; explain through examples the interdependence among living organisms and the environment to create a balanced ecosystem.
- 2.2 Evaluating the interaction between living organisms

A student is able to list the types of interactions between living organisms; explain with examples the interactions between living organisms; justify the importance of interaction between living organisms and the environment; explain through examples the advantages and disadvantages of biological control in regulating the number of pest in certain areas.

2.3 Synthesizing food web

A student is able to explain what producers, consumers and decomposers are; combine a few food chains to construct a food web; identify the producer, consumer and decomposer in a food web; construct a pyramid number from a food chain; relate the food web and the pyramid number to energy flow; predict the consequences if a certain component of living organisms in the ecosystem is missing

2.4 Analysing photosynthesis

A student is able to state what photosynthesis is; state the factors required for photosynthesis; state the products of photosynthesis; control the variables that are required for photosynthesis; explain the role of photosynthesis in maintaining a balanced ecosystem.

2.5 Evaluating the importance of conservation and preservation of living organisms

A student is able to explain what conservation and preservation are; explain the steps taken to preserve and conserve living organisms; justify the importance of conservation and preservation of living organisms; support activities organised by various parties to preserve and conserve the living organisms.

2.6 Evaluating the role of man in maintaining the balance in nature

A student is able to explain the effects of human activities on the balance in nature; describe how man solves problems related to environment; justify that human need a stable, productive and balanced ecosystem.

Source: Ministry of Education Malaysia, (2002b)

In Form 5 syllabus, Learning Area of Microorganisms and Their Effects on Living Things under the theme Man and the Variety of Living Things, there are topics that related to biodiversity i.e. the classification of microorganisms, and useful of microorganisms. This topic debated species diversity as the biodiversity elements on living things. Through the classification of microorganisms students will be able to list the characteristics of various types of microorganisms; classify microorganisms into bacteria, fungi, protozoa, viruses and algae; and describe the characteristics of each group of microorganisms. While through knowledge about useful microorganisms students will be able to state examples of uses of microorganisms; explain with examples the roles of useful microorganisms; suggest potential uses of microorganisms in various fields (MOE, 2006).

Biology Form 4 Syllabus also has topics related to biodiversity of the Learning Area 1 Dynamic Ecosystem under theme 'Investigating the Relationship between Living Things and the Environment'. Living things and the environment can be categorised as ecosystem diversity. It includes the abiotic and biotic components of the environment; the processes of colonisation and succession in an ecosystem; and ideas on population ecology. In this Learning Area, students will able to identify, classify, explain the component of an ecosystem; processes that involve in ecosystem; determine the distribution of organisms based density, frequency and percentage; and correlate the change in population distribution of an organism with the changes in each of the abiotic factors (MOE, 2005).

#### Biodiversity in Geography Curriculum

The term 'biodiversity' did not appear in the Geography syllabus for Form 1 to Form 4. However, there are number of themes and specific topics related to biodiversity. Under the theme 'Natural Vegetation and Wildlife' in Form 1 syllabus, there are topics on type and distribution of natural vegetation (tropical rainforest, mangrove forest, coastal forest, and mountain forest) and wildlife, factors that affect a variety of natural vegetation growth (Malaysia and in other places such as Sahara, Siberia, Mediterranean and tropical monsoon), the importance of natural vegetation, the impact of human activities on the natural vegetation and wildlife, and preservation and conservation of natural vegetation and wildlife (MOE, 2001a). Natural vegetation and wildlife is an ecosystem diversity.

In Geography Form 2, there are few topics that relate to biodiversity elements. For example, in Dynamic Population theme, there is a topic that discuss the effect of dynamic population towards the environment. Under this topic, student analyse the impact of human activities towards the environment such as deforestation can be harmful towards the forest ecosystem and destroy the habitat for variety of species in the forest. This topic discussed two elements of biodiversity which are ecosystem diversity and species diversity (Kementerian Pelajaran Malaysia, 2001b).

While in Geography Form 3, there are themes and topics that contains the biodiversity elements. Although, the term 'biodiversity' does not appear in the syllabus, the concept of biodiversity has been taught in the subject. In theme 'Resource' there is a topic of 'Forest Resource'. Under that topic, the biodiversity elements can be classified as ecosystem diversity as forest known as the type of terrestrial ecosystem. Other than that, species diversity also can be found in the forest resources (Kementerian Pelajaran Malaysia, 2001c). There are variety of species that live in the forest.

In Geography Form 4, a specific elements of biodiversity has been discussed under theme 'Landform and Its Resources'. The biodiversity elements refer to the marine ecosystem. In this topic, students learn about

the life under the sea and discover that there are variety types of species in the marine ecosystem especially the coral reef species. The topic covers two elements of biodiversity which are ecosystem diversity and species diversity (Kementerian Pelajaran Malaysia, 2001d).

In Geography Form 5, there is a specific term related to biodiversity in the theme 'Resource' under topic of 'The Importance of Resources'. This topic elaborates the importance of variety of resources including the biological diversity (Kementerian Pelajaran Malaysia, 2001e). Through this topic, students learn about diversity of plants, wildlife and microorganisms in an area at a given time genetic diversity and species; ecotourism diversity and unique plant and wildlife; ecosystem balance - photosynthesis process, transpiration process and simplifying temperature; economic value - export: logs, rattan, resin and agar wood and direct consumption - animal

feed, protein sources, fruits and firewood. This shown that the biodiversity elements appear in the subject. This topic contains elements of biodiversity in ecosystem.

#### Biodiversity in English Curriculum

As for language curriculum such as English, the biodiversity elements do not directly appear in the curriculum at all levels. The concept of biodiversity can be integrated in the English subject by infusing the concept and element of biodiversity in the topic discuss in the subjects. Teacher's Guide Book on Environmental Education across the Curriculum for Secondary School (Kementerian Pendidikan Malaysia, 1998), suggested to include the biodiversity elements in English subject. Table 2 shows the example of biodiversity elements which appear in Teacher's Guide Book. Both topics can be categorised under species diversity in biodiversity elements.

Table 2 Topics related to biodiversity in the English syllabus for Form 1

Topic	Suggested Learning Activities	Learning Outcomes
Directions  Descriptions	Classify the flowers into two types which are: (a) flowering plants (b) non-flowering plants Collect information about the flowering plant and the animal exist in school environment	A student able to describe the features

Source: Kementerian Pendidikan Malaysia, 1998

#### Biodiversity in Malay Language Curriculum

The biodiversity elements in Malays language is not directly mention across the curriculum. The features of biodiversity can be embedded in the Malay language subject by specifically relating the contents of the learning materials towards biodiversity. Based on the

Teacher's Guide Book on Environmental Education across the Curriculum for Secondary School, Malay Language can be integrated with biodiversity (Table 3). The topics below contain two elements of biodiversity which are species diversity and ecosystem diversity.

Table 3 Topics related to biodiversity in the Malay language syllabus for Form 4

Topic	Suggested Learning Activities	Learning Outcomes
Listening Speaking	and Listen to the reading or watch videos about forest conservation Take note on the habitat, flora, fauna and ecosystem Write an essay about The	A student able to identify the types of forest in Malaysia; describe the habitat, flora, fauna and ecosystem in Malaysia.
Writing	Important of Environmental Conservation and Ecology	A student able to describe and elaborate about the environmental conservation and ecology; and know that there are different type of ecosystem on earth.

Source: Kementerian Pendidikan Malaysia, 1998

#### Biodiversity in Mathematics Curriculum

For Mathematics, there is no term of 'biodiversity' appears in the syllabus for Form 1 to Form 5. However, based on Teacher's Guide Book on Environmental Education across the Curriculum for Secondary School on Mathematics subject, biodiversity elements can

be embedded in the subject. Although the scope of biodiversity is not widely covered, the elements of biodiversity are still appeared in the subject across all levels. Table 4 shows example of biodiversity elements which are species diversity and genetic diversity that have been found in Teacher's Guide Book.

**Table 4** Topics related to biodiversity in Mathematics syllabus for Form 1

Topic	Suggested Learning Activities	Learning Outcomes
Addition	Total up the animal species in the forest	A student able to identify the types animal species in the forest
Fraction	Sum up the fractions of different	A student able to identify the various type of flowers.
Percentage	type of flower into one Divide fruit according to the fraction To count the percentage of reptile class in a zoo – (have shells, live in the water, do not have legs, extinction	A student able to discover the genetic diversity in reptile class in a zoo.

Source: Kementerian Pendidikan Malaysia, 1998

From the analysis, it can be summarized that the biodiversity elements in Malaysia secondary curriculum can be categorised as genetic diversity, species diversity and ecosystem diversity in which the living world is a complex combination of different levels in organism.

Only specific topics on biodiversity (Science Form 2 and Biology Form 4) discusses the genetic biodiversity (Table 5). Other related topics discuss species diversity and ecosystem diversity.

Table 5 Summarisation analysis of biodiversity elements in Geography and Science syllabus

Subject & Form	Genetic Diversity	Species Diversity	Ecosystem Diversity
Specific learning area on biodiversity F2	√		
Specific topics on biodiversity in Biology F4	$\sqrt{}$	,	$\sqrt{}$
Topics related to biodiversity in the Science syllabus for F1		√	$\sqrt{}$
Topics related to biodiversity in the Science syllabus for F2		$\sqrt{}$	$\sqrt{}$
Topics related to biodiversity in the Science syllabus for F5		√	
Topics related to biodiversity in the Biology syllabus for F4			$\sqrt{}$
Topics related to biodiversity in the Geography syllabus for F1			$\sqrt{}$
Topics related to biodiversity in the Geography syllabus for F2		$\sqrt{}$	$\sqrt{}$
Topics related to biodiversity in the Geography syllabus for F3		$\sqrt{}$	
Topics related to biodiversity in the Geography syllabus for F4		$\sqrt{}$	$\checkmark$
Topics related to biodiversity in the Geography syllabus for F5			$\sqrt{}$

#### IV. DISCUSSION

The findings from the study show many elements of biodiversity appear in almost all topics in both subjects Science and Geography which covered three types of diversity: genetic diversity, species diversity and ecosystem diversity. However, for other subjects such as Languages (English and Malay), and Mathematics, the biodiversity elements only appear in the topics as suggested in Teacher's Guide Book on Environmental Education across the Curriculum for Secondary School. This practice is almost the same with Ontario secondary school curriculum where biodiversity has been integrated in the mandatory subjects in Grade 9 Geography and Grade 10

Science. While in other subjects, biodiversity is used as the context for learning (Ontario Biodiversity Council, 2015). The Ontario secondary school uses The Standards for Environmental Education in the Curriculum (2008) to help curriculum writers to incorporate biodiversity across the curriculum, as well as in Malaysia which uses Teacher's Guide Book on Environmental Education across the Curriculum for Secondary School to integrate biodiversity in other subjects.

Biodiversity in Malaysia school curriculum is more than the teaching of species names. Students will be able to gain knowledge of complex interrelations and connections through classroom activities. Scientific skills (encompass science process skills and manipulative skills)

and thinking skills are utilised (Ministry of Education, 2002a; 2002b). The syllabus emphasised on active learning approaches (such as discussion; gather information from magazines, books and internet; collect and interpret data; experiments, role play, mind map, forum, project, draw a picture, game, campaign or competition, scrap book, field trips) and seek to engage the students in thinking critically (such as attributing, comparing and contrasting, grouping and classifying, sequencing, prioritising, analysing, detecting bias, evaluating, making conclusions) and creatively (generating ideas, relating, making inferences, predicting, making generalisations visualising, synthesising, making hypotheses, and making analogies) about key issues associated with biodiversity. Science process skills such as observing, classifying, measuring and using numbers, making inferences, predicting using space-time relationship, interpreting data, defining operationally, controlling variables, making hypothesis, experimenting and communicating also been emphasized. The syllabus also suggested to conduct a field study for some topics which in hands on approach that meet outdoor learning and experiential learning strategies. These strategies fulfil teaching and learning approaches and strategies widely accepted in sustainability education. East Lothian Council (no date) emphasised that a principal element of teaching biodiversity is getting children outside-the hands on approach. According to National Science Board (1991: 27), student will be able to appreciate and understand the natural world if they have the chance to work directly with natural resources by using their sense to observe and with the help of learning instrument to extend the ability of their senses. John Muir (in Goralnik and Nelson, 2011) asserted that if the people have exposure to the natural world, they will act on behalf of it. In line with this, Goralnik and Nelson (2011:4) expressed that

"the impact of individual's actions on natural world is influenced by the knowledge about (and/experience) the individual have which will affect the attitudes towards natural world".

#### V. CONCLUSION

The elements of biodiversity are integrated either directly or indirectly in the subjects taught in secondary school curriculum in Malaysia especially in Science and Geography. Only in Form 2 Science and Form 4 Biology have a specific topic on biodiversity, whereas Science and Geography syllabus in other Form discuss elements of the biodiversity without the term 'biodiversity'. Although there are no specific theme or topic that discuss element related to biodiversity in other subjects such Languages and Mathematics, it can be infused in some activities as suggested in the Teacher's Guide Book on Environmental Education across the Curriculum for Secondary School. The biodiversity elements in the syllabus meet the three types such as diversity, species diversity and ecosystem diversity. The curriculum emphasises on inquiry, discovery learning through experience and problem solving processes that utilised scientific and thinking skills. The curriculum also emphasised on active learning approaches that meet the widely accepted approach in sustainability education. It is hoped that the new curriculum that will be implemented in 2017 will emphasis on current issues related to biodiversity and to focus on action learning, experiential learning, problem based learning with values education, futures and critical reflective thinking which will provide students with are not only knowledgeable about biodiversity but also able to take the necessary action to ensure the preservation of biodiversity for their well-being in the future.

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# Collective initiative to protect biodiversity of Kodagu Sacred Grove

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Abstract-Indigenous communities in many parts of the world have protected forests and worshiped as local deities to protect them from different calamities. These forests patches are sacred forests or groves based on spiritual and cultural values. Kodagu district in Karnataka, India has over 1214 sacred groves locally called as Devarakadu and is located in the Western Ghats-a Biodiversity hotspot. These groves are unique and rich in biodiversity and every village has at least one sacred grove. Today, due to changes in forest structure, religious beliefs, and perception towards the groves, sacred groves face many threats. Realizing the importance of community participation and a more holistic view towards the protection of ten selected groves in Kodagu, Forest Department in collaboration with Centre for Environment Education (CEE), Forestry College, Kodagu Model Forest Trust initiated a project "Conservation **Education Programme for Sacred Groves".** 

Scientific inventory of flora and fauna along with the history, belief and myths of 10 selected groves in Kodagu are documented and published. Oriented teachers, students

and youths residing around the groves experienced and realized the sacred grove importance. Posters and wayside informative panels helped to spread the message of sacred grove protection among the community. Trail path, signages created inside the groves enables tourist to enrich their experiences. Sensitized students compiled interesting stories and facts from their grand-parents and parents about their nearby groves. This initiative helps the forest department to draw up an effective grove management plan, to mitigate the loss of biodiversity and manage forest sustainably and thereby addressing SDG Goal 15.

Keywords: Biodiversity, community conservation, scared groves of Kodagu, Sustainable development goals

#### I. INTRODUCTION

Sacred forests, often referred to as sacred groves, are sites that have cultural and religious beliefs. Since time immemorial indigenous communities all over the world have always worshiped nature and inherited from their ancestors. These patches or sections of a forest were believed to have spiritual beings residing there, and where everyday activities such as tree felling, gathering of wood, plants and leaves, hunting fishing, grazing of domestic animals, harvesting of crops, and building ordinary dwellings were prohibited (Hughes and Swan 1986). Sacred groves are distributed across many countries extending from Asia, Africa, Europe and America, but the present occurrence is mostly restricted in Africa and Asia. In India, sacred groves are recorded from North-east Himalayan region, Western Ghats, Eastern Ghats, Coastal region; Central Indian Plateau and Western desert (Rajasri Ray). A diverse range of ecosystems are preserved in grove tradition along with its regional and local identities as represented in name, practices and management of groves.

Sacred groves of India have Pre-Vedic origin. This age old tradition is still prevalent today and plays a vital role in the conservation of resources. They not only have cultural and spiritual value, but also act as reservoirs of the local diversity preserving unique flora and fauna. The level of disturbance varies across many sacred groves and from their proximity to villages. These groves also act as corridors and can reduce human wildlife interaction. The groves play an important role in water and soil conservation as well.

The earliest documentation in India on sacred groves is that of Brandis (1897), the first Inspector General of Forest. His observation on scared groves is more of a travelogue. The Scared Groves are known locally by many names in each state across India. In Kodagu,

located in Karnataka, India the sacred groves are known as "Devarakadu" (Gods forest). Kodugu district in Karnataka has 1,214 sacred groves covering an area of 2,250 (ha) with every village in Kodugu having at least one devarakadu or more than one in some cases (Kushalappa & Kushalappa 1996). In terms of density there is one Devarakadu for every 300 acres, possibly the highest in the world. The uniqueness of the grove is that each devarakadu has its own traditions and culture showcasing the cultural diversity. According to a study done, Kodagu can be regarded as a "Hotspot" of sacred grove tradition in the world (Kushallappa and Bhagwat, 2001.) All communities come together, offer their prayers and participate in the annual activities. This community participation symbolizes unity and harmony. Today, the sacred groves face many threats such as change in religious beliefs, forest structure, landscape and attitudes towards the groves. Hence, it is vital to motivate and include the community in preserving the sacred groves as common property resources (Kushalappa & S. Raghavendra, 2012).

In Kodagu the sacred groves are declared as Protected Forests and owned by the Forest Department. The groves are managed by the local communities. Incorporating the groves into conservation networks could help in the effectiveness of protected areas by covering a wider variety of habitats and by harnessing the support of local people. (Shonil A. Bhagwat, 1996).

#### II. METHODOLOGY

#### A. Inventory

The Sacred groves of Virajpettaluk of Kodagu were selected for the study and to execute the conservation education program. Ten sacred groves were selected from the Virajpet Taluk which was at variable distances from the protected area and from one another.

Coffee plantations are predominating,

from the perimeter of the protected area to the landscape between sacred groves. These ten scared groves were sampled for their biodiversity. Inventories were done for each grove by doing a rapid assessment of biodiversity in more than one taxon. The selected groves sampled were very variable in size and each grove had variations from the level of disturbance from high to low; some sacred groves were patchy. In each grove the forest structural studies were done. Four transects of 25 x 4 meters were laid and all trees above 30cm girth at breast were recorded. The dominant species were recorded. Regeneration studies were done at each grove. The flora included trees, shrubs, herbs and climbers. Birds, butterflies and mammals (mostly indirect evidence) were recorded. The forestry college, Ponnampete undertook the primary research for the project. To calculate species richness, the shannon diversity index was used.

#### **B.** Questionnaires

Semi structured interviews were conducted to assess the cultural and management approach for each of the selected sacred groves. In each grove the head/Committee leader was approached to carry out the questioning, seek permission for research and other devarakadu related activities.

The info graphic below indicates the flow of activities executed as part of this initiative resulting into collective efforts to document, protect and make sacred groves a learning centre for rural students.

#### C. Capacity Building

This approach was used to impart the knowledge and awareness of sacred groves such as its importance, biodiversity, ecological services, and ethical services to various stakeholders—forest department officials, teachers, students, and the community. The duration of the capacity building ranged from 3 hours to 8 hours and specific modules for each target group was developed and followed for the same.

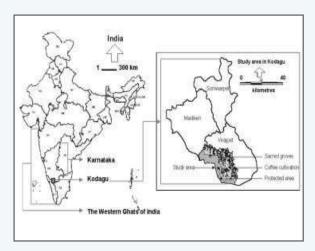


Fig.1 Map of Kodagu and study area



Fig.2 Enumeration of species



Fig.3 The flowchart of collective activities between multi stakeholders

#### D. Communication Materials

These materials act as triggers for people to understand the concepts and issues and are essential for awareness. As part of this initiative, a set of four posters were developed highlighting the importance of and need for protection of forest were developed and distributed to schools.

#### E. Outreach

Unless the community or the general public is made aware of the importance and relevance of groves, any conservation or protection efforts of sacred groves may not succeed. Thus, straightforward community outreach activities were initiated that included outdoor signage's appreciating the groves and informative signage on selected trees within each grove.

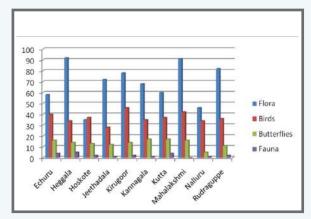
Discussions with community members who manage sacred groves were held for cross learning. School children collected interesting stories pertaining to local groves from their parents with the help of teachers.

Outdoor camps for school children at their nearby sacred groves provided better insights among the children about the ecological, ethical, social, biological diversity and cultural aspects of these groves. These learning's by the student were linked to their curriculum in the camps.

Trails laid out within the groves enable visitors to explore and experience sacred groves. News coverage of the activities in newspapers and fortnightly magazine helped to spread the message among the people.

#### III. RESULTS

Sacred groves assist as tools that document the management of biotic resources through people's participation. (Hashish Antheil et. al., 2015). It is vital to involve the different stakeholders of the community for developing new strategies and preservation of the sacred groves. The study shows that each sacred grove is unique in its forest structure with rich biological diversity and home to many endemic species. The graph below depicts the rich diversity in 10 selected groves.



**Fig.4** Number of species recorded in 10 Sacred Groves (broad categories)

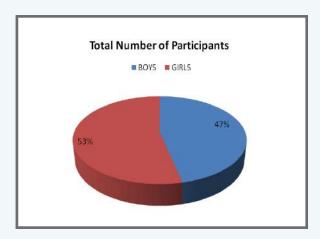


Fig.5 Total number of school children (301)

Analysis from the survey indicates that teachers can play a vital role in spreading the message importance of sacred among community through children. Teachers are able to make their school children understand the science aspect of the sacred groves and link it to the curriculum. This strengthens the communication approach tool of TCCPC (Teacher to Child, Child to Child, Child to Parent and Parents to Community). Teachers can promote awareness by informing students about issues, problems by informing students about effective problem strategies and discussing cognitive and motivation

characteristics of thinking. The twin benefits of this "consciousness raising" are: a) it transfers responsibility for monitoring learning from teachers to students themselves and b) it promotes positive self-perception effects and motivation among students (Scott G. Paris and Peter Winograd). The inquisitive learning among children about sacred groves has further increased and they are able to identify and talk about at least 10 floral and faunal species found in their neighbourhood groves. Of 301 students involved in this initiative, 53% were boys and 47% were girls.

Impressive outdoor signage on sacred groves makes a lasting impression among the community and more particularly tourist visitors. The signage developed and displayed near groves has reached hundreds of people.

#### IV. CONCLUSION

Conservation of any resources especially the sacred groves that are important as ecological, cultural, environmental services and that are managed by the community and owned legally by the forest department is an uphill task. These are also anthropogenic pressures on these groves such as encroachment and cultivation, habitation and fragmentation. The results from this project strongly advocate that improving knowledge and awareness about the importance of sacred grove among multi-stakeholders is vital for sacred groves conservation. It also helps active participation of people and thus helping cross learning. The inventory developed in the process brings a scientific and academic temper; documentation from the community about social aspects supports cultural dimension; outreach and communication tools developed supports the critical pedagogy; self-initiative by the forest department highlights their endeavour in engaging multi-stakeholders in protecting sacred groves. Probably this is a first of a kind initiative where multi-stakeholders are engaged in promoting conservation education on sacred groves. Such a unique initiative is showing positive results in strengthening the sacred grove conservation.

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# Adaptation to climate change through mangrove rehabilitation involving local community participation

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Abstract-Since 1990, the International Society for Mangrove Ecosystems (ISME) has been conducting mangrove restoration and rehabilitation projects in many counties such as Brazil, India, Indonesia, Kiribati, Malaysia, Pakistan, Samoa, Thailand, Tonga, Tuvalu and Vietnam. The UN-REDD Program Strategy (2011-2015) emphasized that efforts to reduce emissions from deforestation and forest degradation will only succeed with the meaningful engagement of stakeholders such as indigenous people and other forestdependent communities. At the UN Sustainable Development Summit on 25 September 2015, world leaders adopted the 2030 Agenda for Sustainable Development, which includes 17 Sustainable Development Goals (SDGs) to end poverty, fight inequality and injustice, and tackle climate change by 2030. Most of these UN documents emphasize the importance of community participation in the implementation of regional and national projects. When we implement our mangrove restoration and rehabilitation activities to address problems of climate change and forest degradation, we have always considered the involvement of local communities. However, we have encountered

many difficulties. For instance, in most island countries of the Pacific, local authorities have stronger political powers than the central government, i.e. an official from the central government has little jurisdiction over local activities. Political and social conditions vary from country to country, and from area to area. We have had good and bad experiences from our activities. Let us share some information on lessons learned and on the achievements of our projects that are relevant to the goals of sustainable development.

*Keywords*: mangrove rehabilitation, local community participation, adaptation to climate change, collaboration and sustainability

#### 1. Background

The International Society for Mangrove Ecosystems (ISME) is an international non-profit and non-governmental scientific society established in August 1990 with its headquarters in Okinawa, Japan. In 1992, ISME was certified a Foundation by the Japanese Law of Foundation and in 2003, the society was registered as a non-profit organization (NPO) under a new

Japanese law of promoting specified non-profit activities. Revised at the Eighth General Assembly in 2012, the Statutes of ISME stipulate that 'the Society shall collect, evaluate and disseminate information on mangrove ecosystems', and 'shall promote international cooperation'.

ISME has been carrying out its activities at the global level through application of knowledge to particular situations; training and education; and exchange of necessary information. Activities of the society have been supported through collaborations, and links with other organizations, universities, research institutes and local communities. Currently, the membership of ISME includes 40 institutions and over 1,150 individuals from 92 countries.

With more than 20 years of experience in project management and implementation in 20 countries, ISME has developed the following expertise:

- Rehabilitation of mangroves under different site conditions and climatic regimes with the involvement of local authorities and communities
- Conducting research, training and ecotours in support of conservation, and sustainable management and utilization of mangrove ecosystems
- Publication of books for education, and materials for enhancing public awareness on the socio-economic and environmental importance of mangroves

In this paper, three of our on-going projects are described with comparisons made based on performance indicators and the involvement of community participation. They are the mangrove rehabilitation project in Tarawa, Kiribati; the mangrove plantation

project in Gujarat, India; and the project on rehabilitation of degraded mangroves in Sabah, Malaysia.

#### 2. Project in Tarawa, Kiribati

Kiribati is one of several island countries in the Pacific facing the serious threat of sea-levelrise. Since 2004, ISME has been implementing mangrove rehabilitation project in Tarawa, Kiribati. The objective of this project is to introduce techniques of planting mangroves to the local communities and to plant mangroves together with school children for environmental education purpose. The project is financed by Cosmos Oil Co., Ltd., Japan with strong support from Ministry of Environment Lands and Agriculture Development and Ministry of Education, Youth and Sports of Kiribati.

With more than 10 years of experience inplanting mangroves on atolls and coral islands of Tonga, Kiribati and Tuvalu in the Pacific, ISME has successfully developed a unique silvicultural technique for establishing mangroves along the shores of sheltered lagoons of the islands. At Kiribati, site conditions are extremely harsh because of salt spray, low rainfall and absence of surface water. Kiribati has no rivers, the soil is mainly white coral sand which is nutrient poor and salt accumulates in the soil during prolonged dry season. The technique involves close-group planting of propagules of Rhizophora stylosa between mean water level andmean high water level. In successful sites, e.g. Ananau Causeway of Tarawa, survival can be 90% a year after planting and over 50% after 3 years. Height and diameter of seedlings can reach 1.2 m and 1.8 cm after 3 years, respectively. Propagules of R. stylosa are group-planted (three per group) at close spacing of 25 x 25 cm or 50 x 50 cm. An iron bar is often needed to create planting holes in the white coral sand.

When UN Secretary-General Ban Ki-moon planted *R. stylosa* at Tarawa in Kiribati during his visit on 5 September 2011, he adopted the same planting technique (Figure 1). About 800 local elementary school students and 230 environmental youth club members have participated in planting activities since 2005 (Figure 2). The mangrove plantations are also extended to the other islands such as in Abemama,

Butaritari and others using the same technique led by ISME and the Ministry of Environment Lands and Agriculture Development together with local communities. Currently, the massive effort of greening the bare white coral sand flats in Kiribati by school children and youth is yielding positive results (Figure 3), a move in the right direction towards addressing the problems of climate change.



**Fig.1** UN Secretary-General Ban Ki-moon planting mangrove propagules in Kiribati using the close-group planting technique.



**Fig.2** Teaching the school children in Kiribati the technique of group planting of *Rhizophora stylosa* propagules on the white coral sand under blistering heat.



**Fig.3** The amazing greening effort of the bare white coral sand flats in Kiribatiby the school children and youth is showing positive results. (background)

#### 3. Project in Gujarat, India

The objective of this project is to establish mangrove plantations on bare mudflats for coastal protection, to enhance mangrove biodiversity including habitats for endangered birds and to generate income for the local community. Located at the estuary of Sabarmati river near Vadgam, 80 ha of *Avicennia marina* plantation have been established each

year since 2009. The project is funded by Tokio Marine Nichido and Fire Insurance Co. Ltd., Japan. Planting and nursery work are carried out by the womenfolk (Figure 4) supervised by Daheda Sangh, a local NGO, in collaboration with Dr. A. Untawale (Chief Technical Advisor) and Dr. Bharat Jethva. Planting was moderately successful (Figure 5) and the second phase of this project will continue for nother five years (2014-2019).



**Fig.4** Line planting of *Avicennia marina* propagules in perfect synchrony on the barren mudflats (left) and raising seedlings in the nursery (right) by the womenfolk in colorful sari.



Fig.5 One-year-old seedlings of Avicennia marina

#### 4. Project in Sabah, Malaysia

Funded by Tokio Marine Nichido and Fire Insurance Co. Ltd., Japan, this project aims to rehabilitate 50 ha of degraded mangrove sites annually in Sabah. The project is carried out by the Sabah Forestry Department (SFD) with technical advice from ISME. At the end of the first phase of the SFD-ISME project (2011-2014), over 150 ha of degraded mangroves in 20 project sites located in five forest reserves of four forestry districts (Figure 6) were successfully planted. The forest reserves (FR) are Sungai Gum-Gum & Sungai Loboh FR and Sibyte FR in Sandakan; Padas Damit FR in Beaufort; Kuala Bonggaya & Kuala Labuk FR in Beluran and Sandakan; and Kuala Tingkayu FR in Kunak. The three major habitat types of the project were areas encroached by oil palm, degraded riverine mangroves and areas cleared for shrimp ponds.

Nearly 200,000 propagules, cuttings, seedlings and seeds belonging to 11 species were planted. Students and teachers from schools and universities of Japan, including staff members of Tokio Marine Nichido and Fire Insurance Co. from three countries participated in the planting activities. The second phase of this project will continue for another five years (2014-2019).

Project activities are implemented by a mangrove task force based in Sandakan and led by Dr. Joseph Tangah, the Project Leader (Figure 7). They work closely with the forestry staff in the districts and contractors of the project.

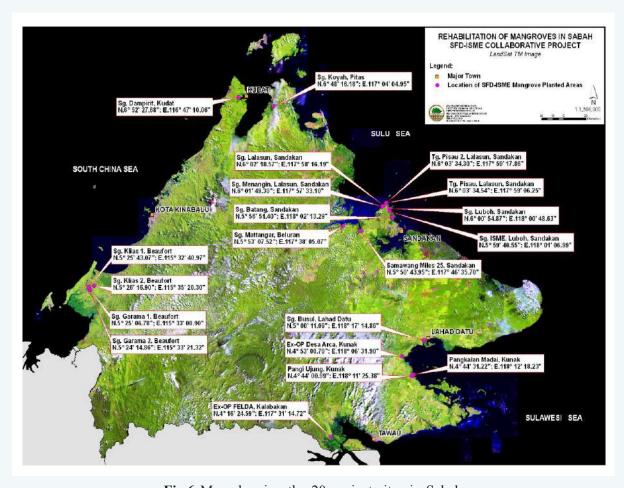


Fig.6 Map showing the 20 project sites in Sabah





Fig.7 The mangrove task force in Sandakan led by the Project Leader. (top) with the forestry staff in the districts and contractors of the project. (bottom row)

ISME and SFD officials visit the project sites twice a year during each meeting of the Project Steering Committee (Figure 8). The success of the project can been seen in Figures 9, 10 and 11. Wherever possible, other mangrove species such as *Nypa fruticans*,

Avicennia alba, Hibiscus tiliaceus and Aglaia cucullata are also planted (Figure 12). As part of the project, a river near Sandakan has been officially named after ISME and the first phase of the project ended with a publication of a book (Figure 13).



Fig.8 ISME and SFD officials visit project sites twice a year during each PSC Meeting.



Fig.9 Growth of Rhizophora seedlings at Sg. Lalasun near Sandakan from 2011-2013



Fig.10 Some saplings of Rhizophora mucronata started flowering three years after planting.



**Fig.11** One-year-old *Terminalia catappa* seedlings planted on the bunds were more than two meters tall.



Fig.12 Other mangrove species planted by the project.



**Fig.13** Ariver near Sandakan has been officially named after ISME (left) and the book to commemorate the first phase of the project. (right)

The project in Sabah is currently in its second phase (2014-2019) with more sites planted in the eastern, northern and northeastern coastal areas. They include Kunak and Kalabakan in the east coast, Kudat and Pitas in the north coast, and Sandakan in the northeast coast.

#### 5. Project Overview

Our three mangrove rehabilitation projects do have some differences:

#### **Tarawa**

**Objectives:** To establish mangrove vegetation on low-lying atolls in anticipation of problems associated with climate change i.e. sea-level rise, storm damage and coastal erosion

Forestry approach: Afforestation

*Habitat:* Nutrient poor and hyper-saline white coral sand flats with little freshwater inputs from the rain

Choice of species: Rhizophora stylosa

**Planting technique:** Close-group planting of propagules

*Implementation:* Planting by school children and youth

#### Gujarat

**Objectives:** To establish mangrove plantations for coastal protection, to create habitats for endangered birds and to generate income for the local community

Forestry approach: Afforestation

*Habitat:* Barren mudflats with strong tidal current during the high tide

Choice of species: Avicennia marina

**Planting technique:** Line planting of propagules and boosting up with nursery raised seedlings

*Implementation:* Planting and nursery work by womenfolk from nearby villages, supervised by Daheda Sangh, a local NGO

#### Sabah

**Objectives:** To rehabilitate mangrove forests encroached illegally by oil palm plantations and shrimp ponds, and to enhance ecosystem recovery

Forestry approach: Reforestation

*Habitats:* Cleared and bunded degraded mangrove sites

*Choice of species:* Rhizophora in tidal sites, Terminalia on bund tops, Rhizophora and Nypa in abandoned shrimp ponds

**Planting technique:** Line, random and cluster planting of propagules, seeds, seedlings and stem cuttings

*Implementation:* Planting by contractors, supervised by the Mangrove Task Force of SFD

#### 6. Project Performance

Based on 10 criteria (accessibility, collaboration, objectives, costs, publicity, capacity building, voluntary participation, community participation, conservation awareness and sustainability), we conducted a simple performance evaluation of our three projects (Table 1).

Tawara scores moderately in all criteria, except for accessibility due to its remoteness in the Pacific and difficulty in inter-island travel. Gujarat scores strongly in community participation and project costs, but weakly in publicity, capacity building and sustainability. It is very unlikely that the local NGO will be able to sustain the project after ISME. Sabah scores strongly in accessibility, collaboration, publicity, capacity building, voluntary participation and sustainability, but weak in community participation and project

costs. However, a substantial part of the project costs such as salaries, subsistence and transportation of project personnel are borne by SFD. Two four-wheel drive vehicles have been assigned to the project. Under the second phase of the project, SFD has allocated USD 156,000 in addition to the logistics and manpower provided.

#### 7. Conclusion

Ranking of the three projects based on overall performance is Sabah > Tarawa ~ Gujarat. We are of the view that one should not over-emphasize on the importance of community participation, as it is only one of the criteria used for project evaluation. There are other important criteria that one should consider e.g. effective collaboration, meeting project objectives, capability building and project sustainability. With government support, the ability of the collaborating agency to continue with the project without external funding and without the technical assistance from ISME is most crucial.

The following issues need to be addressed when initiating and implementing a mangrove rehabilitation project involving participation of the local community:

- Obtain the endorsement of the government
- Seek a competent person among the local community to manage the project activities
- Convey ideas to the local people through the head of the community
- ➤ Get the support and collaboration from the local community
- ➤ Provide information to the villagers to enhance their awareness of the project
- > Continue to support the community
- Maintain project motivation and that of the community

Table 1 Evaluation of the performance of ISME projects

Evaluation Criteria	Tarawa, Kiribati	Gujarat, India	Sabah, Malaysia
Accessibility	+	++	+++
Collaboration	++	++	+++
Objectives	+++	+++	+++
Costs	++	+++	+
Publicity	++	+	+++
Capacity Building	++	+	+++
Voluntary Participation	++	+	+++
Community Participation	++	+++	+
Conservation Awareness	++	++	++
Sustainability	++	+	+++
Overall Performance	20	19	25

Scores: + weak, ++ moderate, +++ strong, and high project cost-low score. Note: There is correlation between capacity building and project sustainability. Poor community participation did not adversely affect overall project performance. Everyone emphasizes on the importance of community participation but our experience shows that we cannot work easily with any local community because each village has different social and political conditions. Without proper analyses of these conditions, we cannot work well with the local community.

#### Acknowledgements

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#### **LEADearthSHIP**

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#### **Background**

It is a known maxim that for any nation to develop and progress, its youth citizenry has to stand strong and prosper. Equipped with the modern education and technological knowhow, today's youth has the utmost ability and potential to compete with any individual of any age group. They have the potential and charisma to effect change in the status quo of society. And for this reason precisely, maximum engagement of youth is being sought through thematic projects, aimed at providing the youth with tools to influence and catalyze the environment improvement through effective resource management initiatives, both at the local and global levels.

We live in the age of Information Super highway. With the advancement of technology and globalization, the medium of receiving as well as reaching out to people in different parts of the world is at tremendous rise. Contemporary age is that of transformation of minds, values, relationships, people, families, cultures, economics and most importantly environment. The Information Superhighway provides us with a window of opportunity to empower the youth to fashion a tomorrow based on ideas oriented and committed to making lives better on the planet-economically, socially, politically and environmentally.

With this view in mind 'LEADearthSHIP', a joint initiative of The Energy and Resources Institute (TERI) and Genpact, was conceived. It is a youth program for undergraduate and post graduate students from universities and institutions of repute in India and focuses on business and sustainability and aims to be the spring-board for future youth leaders in India who have their world views deeply rooted in sustainability, ethics and innovation.

Through LEADearthSHIP, we try to provide the participants with tools to influence and catalyze the improvement of rural and urban environment through effective resource allocation and management in the most judicious ways. This programme is based on the belief that it is not only important but also critical that young people of the country are engaged in ideation, innovation and action that would ensure holistic development of the nation.

The key idea of LEADearthSHIP is to develop competencies in young people that are relevant for creating an empowered workforce which would work towards building low carbon societies. This includes creating learning opportunities for students that complements and builds on the knowledge, skills and values acquired through education.

#### **Objectives of the Project**

- Prepare youth for leadership roles in their institutions, communities and cities through intensive training and imparting transversal skills.
- Facilitate understanding of innovation and cutting age sustainable practices by industry leaders as well as grassroots initiatives.
- Impart knowledge on the triple bottom line (people, planet, profit) of business and enable learning through the example of sustainability initiatives.
- Develop competencies in young people to integrate sustainability in thought and practice in any field and vocation.

The primary focus of LEADearthSHIP is on strengthening the following three dimensions:

- Emphasis on the 'individual' by imparting 21 century relevant skills
- Enhancing domain knowledge and competencies on leadership
- Sustainable development and exposure to real life examples of sustainability initiatives by businesses as well as civil society organizations through field visits.

Sustainable Development Goals are at the heart of LEADearthSHIP and rigorously follow Goal 3: Good health and well-being; LEADearthSHIP Quality education through non formal modes of education; Goal 6: Clean water and sanitation through projects which are based on WASH; and Goal 8: Decent work and economic growth through empowering women, of SDGs.

#### Structure of LEADearthSHIP Program

#### **LEADearth Fellowship**

The LEADearth Fellowship is the mainstay of LEADearthSHIP and provides the Fellows with resources and financial support to work on a key environmental or social project. They are mentored into relevant skillsets and domain knowledge and taken on field visits showcasing examples of sustainability initiatives by corporate houses and civil society organizations. The 30 Fellows, selected through a rigorous selection process from Delhi-NCR, are awarded the 'LEADearth Fellowship'. At least one student is selected from each of the core group of colleges for the fellowship program. Each applicant had to conceptualize a sustainability project/campaign in line with his/ her skills and expertise that would directly or indirectly impact the excluded and marginalized communities.

The first stage has applications from across India where 60 applicants are shortlisted for personal interviews based on written application out of which 30 students are selected as LEADearth Fellows through personal interviews.

In the current session, a week long residential orientation program including sessions on sustainable development, leadership, CSR, conflict resolution, team work and project management brought top 10 projects from the pool of 30 projects was selected for funding and implementation and was further undertaken.

Through these projects implemented by the TERI-Genpact Fellows are expected to reach out to the following Target groups:

- Women/adolescent girls with low income backgrounds or low levels or no education
- Young people with physical disabilities

- Children with learning difficulties due to poor school infrastructure and low living standards
- Communities in rural or less serviced areas as well as slums in urban centers
- Youth having low social and economic status in urban areas

A few of the projects are as follows:

#### 1. Project Name: Solar Chirag

The main objective of the project is to impart skills of making solar-based lamps for marginalized women. It aims at training women and children in the slums of Delhi to make solar lamps using waste material like plastic bottles; bamboo sticks etc. through simple color coding. In slums, where electricity is hardly available, these lamps can help children in studying after dark and also can be used to light up the dark streets making the slum colonies safer. The project also aims to disseminate knowledge about solar energy use as well as channelizing the handmade, reasonably priced solar products into urban markets thereby focus is on creating women solar entrepreneurs.

#### 2. Project Name: Youth for SPLASH

The main objective is to spread awareness regarding Water Sanitation and Hygiene (WaSH) related issues and possible interventions by community themselves to reduce disease burden. SPLASH is an acronym for Strengthening People's Life: Accentuating on Sanitation and Hygiene. This project aims to develop and promote integrated participatory approaches by addressing water quality, sanitation facilities and hygiene behaviors to create healthy homes. It seeks to benefit more than 2,000 women and children in urban slums of Delhi. Through awareness campaigns, training programs, door to door interaction, mobilization of students from nearby schools and colleges and collaborating with

NGOs having similar goals, the project reaches out to 550 children in slums conducting sessions on WaSH. It also has an outreach of 1,000 youth through social media pages of youth for SPLASH on issues of water and sanitation.

#### 3. Project Name: Flashback

One of an unique kind, this project aims to bring back the values of sustainability which were a part of life two generations back and uplifting the situation at old age homes; by connecting children and youth to the elderly. It revolves around connecting the bridge between the generations to inculcate values of sustainability in the very existence of people, as it used to be two generations back. This is done through plantation drives at old age homes, plantation of organic kitchen gardens, collection of magazines, books, and to form a library in these homes. The project has been able to reach to more than 650 people up to now.

#### 4. Project Name: #Enviroz

The main aim is to create a platform for internship and employment opportunities in the field of environment and spread positive stories happing in the environmental arena. It aims at spreading positive news about the environment through online media platform which will also attract experienced and skilled manpower. The project has covered 50 inspiring stories of people working in this sector thereby, bringing a positive change in the society.

#### 5. Project Name: Directing Discourse

Keeping the SDG Goal 4 in mind, this project's main objective is to bring back the importance and cultural relevance of historical monuments in Delhi. It also aims to promote citizens to visit these places and make them 'cool' hangout zones. Delhi being one of the metropolitan cities with a high concentration of

heritage structures, which are currently being neglected and many have turned in dump yards and encroached by slum population, was the idea behind this project. The project aims to bringing awareness and importance about the places among the citizens and school and college trips were organized as part of the project to these locations to spread awareness.

#### Leadership Lecture and Project Launch

A series of workshops and talks by renowned leaders from the field of sustainability, youth activism, business and media, young visionaries and motivational speakers to interact with and inspire young minds was organized. With approximately 200 students attending from different colleges at one location, the event was able to initiate an engagement of 'thought leaders' from across the spectrum with the young minds.

#### YUVA Meet 2016

YUVA (Youth Unite for Voluntary Action) Meet, a special event of the Delhi Sustainable Development Summit (DSDS) was organized to bring together young people from various parts of the world so that the voice of the young can be heard at this major international forum. The 2-day youth conference that brings together young people from various parts of India and select countries abroad, has been held annually since 2009. Local participation from all across India and international participation from over more than twenty five nations have been witnessed.

As part of the YUVA Meet, a series of State Level Youth Seminars are organized which provide an opportunity for youth to enhance their understanding on issues concerning education and sustainable development. These meets have been successful in engaging the participants in diverse activities during as well as after the YUVA meet. In the last six years YUVA Meet has received support from Government of India,

Delhi Government, British Council, RCE Network, United Nations University IAS, Tetra Pak India Pvt. Ltd. and Dell Global Giving.

#### Campus Impact Challenge

The Campus Impact Challenge, is an inter college competition for colleges. The colleges are made to identify sustainability challenges in their respective campuses, design a campaign to transform the problem into an opportunity, implement it over a specified period and came up with collective social and environmental solutions. 15 colleges comprising of 25 members each were shortlisted from Delhi NCR based on their key sustainability challenge in the college campus. Each of these colleges implemented their Campus Impact Challenge idea and made a comprehensive report thereby, helping develop a green college footprint. Based on the reports, 11 colleges were shortlisted for the next level. A TERI-identified evaluator visited some of the shortlisted colleges to assess the impact of the campaign. Based on the evaluators' feedback, 8 campaigns are selected for the day long Campus Impact Meet for their final presentation. Top 3 campaigns will be awarded the 'Genpact Campus Impact Award'.

A few of the projects are as follows:

### 1. Project Credence (Belief to make something true):

The objectives of the project are to spread awareness regarding the discriminatory practices against girls in various communities. The focus area is nutrition and health services. Appropriate activities and interventions have been planned to work toward the abolishment of the traditional practices which are harmful to women. This will be done by conducting workshops about the pressing issues in the neighborhood communities. Social media will also be used extensively in order to increase the

outreach of the project. The expected impact will be a change in mindset of people and upliftment of women's status in the society.

### 2. Project The Shredders and Makers of Plastic crafts:

The project aims at spreading awareness regarding the environmental effects of mismanaged solid waste among the marginalized women living in the slums near the university campus. It is also to ensure its proper management through its recycling and treatment. The slum community is also involved with training sessions, to become social entrepreneurs. The main impact of the project was employment of the local women in rope making, along with reduction in plastic wastage. An initiative called 'THE LUNCHBOX', which involved women of the nearby slum areas making tiffins for the students of nearby college proved very successful and has been able to bring about a better change in the lives of these women who learnt to take a step for a better life.

### 3. Project TRAS-Think Responsible, Act Sustainable:

The objective of the project is to create awareness among the students regarding sustainable consumption by optimizing the usage of resources used in the institute and minimizing the waste generated. This was done through seminars and workshops to spread awareness. Optimization of resource usage was ensured through selfauditing and monitoring using a standardized checklist made for hotels and restaurants resource consumption. Waste minimization was achieved through waste segregation and weighing of waste produced by the institute and projecting it regularly on the notice board. The project was successful in reducing average plate waste from 19.55 kgs per day to 2.5 Kgs per day with 100 % food utilization of left- over food. Eleven liters of water was saved through decanters in the lunch service on a daily basis for servicing 32 covers.

8% energy reduction was also achieved.

#### 4. Project Be Desi, adopt a desi campaign:

Stray dogs are often considered a menace and they live in the most deplorable conditions. People in India prefer to pet the pedigree breed instead of the Desi breed (the Indian dog seen as a stray on the streets of India). Under the ABC programme, the dogs are picked up from a locality by the municipal corporation are then taken to an NGO (for animal welfare) where they are sterilized and given an anti-rabies vaccination and thereafter are dropped back in the same locality from where they were picked up. Delhi, alone, has a stray dog population of half a million. The project aims to improve the condition of stray dogs in the campus and in colleges around the University by providing food, water and shelterto the dogs. It also aims to exhibit people's participation in the ABC programme by making the college campus rabies free and creating an atmosphere where both dogs and humans co-exist in perfect harmony. Under the project, the dogs were sterilized and vaccinated directly through an NGO. The project has been successful in providing the dogs social acceptance and a healthy life by regularly feeding them and taking care of their medical problems. Till date, 14 Dogs in the campus have benefited directly and around 2,000 students and 200 staff of the college have been made part of the impact. This project also helped generate revenue for the underprivileged women by teaching the skill of making dog collars and leashes. As a result, there are 10 Self-employed women and Rs 16,800 revenue has been generated as of date from sale of 100 collars and 27 leashes.

### 5. Project Sanitation and Health: "The Need of the Hour":

The objective of the project is to work in the area of health and sanitation with adolescent girls in neighborhoods of the college campus. This was done through spreading awareness on menstruation related issues and safe sanitation practices in the community. Training was given to college students to take sessions in the neighboring slums with women and girls. The community was also sensitised on the benefits and importance of using toilets and also provided information on making use of government schemes to construct toilets at their homes.

### 6. Project Creating Auxiliary Nesting Habitat for Birds around the College Campus:

The objective of the project is to create auxiliary nesting habitats for birds around the college campus. This was done through educating students on the role and importance of birds in the environment. Awareness generation was undertaken about the loss of habitat of birds in Delhi and NCR region and the students were encouraged to learn about the flora and fauna on the campus. Bird houses, which were using sustainable materials, were placed around the campus as auxiliary nesting sites to help in attracting various bird species from around the area.

In addition to this, LEADearthSHIP went beyond the confines of text-based and a linear training process into versatile grounds of education, integrating internet and social media to channelize the potential of the youth. LEADearthSHIP already has a thriving presence on social media. However, to target youth in a more systematic and structured manner, a microsite is being developed devoted exclusively to the project.

Online Activities: A Facebook page (https://www.facebook.com/pages/LEADearthSHIP) and LEADearthSHIP blog allowing students to interact, express, study, ideate, relax, innovate, learn, network and channelize their potential has been created.

#### Output

- Ten sustainability projects were designed and implemented by the LEADearth Fellows
- A national level conference (YUVA Meet) with 250 youth from India and abroad was conducted.
- 15 Campus Impact campaigns were implemented with an exclusive microsite dedicated to the project.
- Through LEADearth Fellowship, TERI
  has been able to achieve a direct outreach
  of over 20,000 participants; and an
  indirect outreach of over 100,000.
- In future, TERI may expand the programme nationally, to create a chain of green colleges and thus expanding the concept of green footprint among the student fraternity.
- Through this programme, linkages between global values, leadership, initiatives and more were created.

## Integration of biodiversity conservation into school curriculum

Suranid Ong-la Chiang Rai Municipality, Chiang Rai, Thailand

Chiang Rai Municipality is located in Chiang Rai province, the northernmost province in Thailand, bordering to the Union of Myanmar and Laos PDR, in the plain of Kok river basin, covering 60.85 km/sq with over 73,838 people, and the density is 1,213 persons per sq.km. Fast growth of the city and its economic activity occurs due to the increasing border trade with Myanmar and China. Once we have AEC, the trade and economic growth will be growing even faster. Some research suggests that, Chiang Rai has a degree of risk due to climate change such as fluctuation of precipitation, hotter or cooler days, including season's variation (extended summer and shorter dry season) all of which affect the city in terms of urban livelihood, agriculture, and tourism.

Amid the rapid development toward ASEAN Economic Community, it has been a

challenge for Chiang Rai Municipality to develop the city as a sustainable center. The question is how to improve the infrastructure and economy of this growing city alongside the conservation and preservation of natural resources, environment, as well as local wisdom, customs, culture, and the charming "Lan-na" way of life.

These aforementioned are invaluable indigenous assets, as a strong foundation to be preserved. The concept of "A quality tree grown from a quality seed lasts gracefully and prospers" inspires the management of Chiang Rai City to nurture the young generation, considered as promising saplings of the city, to grow gracefully and become "the citizen of Chiang Rai" which cherishes its hometown and volunteers to protect this "wide variety of the assets" to last for future generations. Figures 2 to 14 illustrate the biodiversity based activities.



Fig.1 Location of Chieng Rai in the context of Thailand and Asia



Fig.2

In 2007, the students from Chiang Rai Municipality School 5 conducted the first survey of flora and fauna species supervised by the Provincial Office of Natural Resources and Environment in Doi Saken community forest areas as a part of the school subjects. In 2008, the Municipality and Thailand Environment Institute (TEI) conducted another survey of biodiversity at Doi Saken forest, which was funded by Keidenren Nature Conservation Fund (KNCF) Japan. Both surveys were initiated by students, community conservation groups, some related provincial government agencies, and extended their collaborations to other neighboring schools and community networks.



Fig.3

The Biodiversity Center was established in 2010 as an important outcome of the survey and conservation efforts initiated by students of Chiang Rai Municipality School 5 and community members at Doi Saken community forest. It aims to protect local flora and insect species, including serving as the biodiversity database sharing center among students, communities and outsiders. In the same year, Chiang Rai Municipality was invited to present its case in "City Biodiversity Summit 2010:COP 10" in Nagoya, Japan. Currently, the center is upscaling to Environmental Education Center,



Fig.4

which is looked after by the Chiang Rai Municipality School 6 and community members.

After that, the students from Chiang Rai Municipality School 1, 4, 5 and community members in Doi Prabaht have proceeded to set up a biodiversity inventory program at Doi Prabaht community forests to become long-term plan for biodiversity conservation as well as disseminate the survey report to the public. At the same time, The Chiang Rai Bird Watching Club has been established by the community and activist group of Doi Prabaht community in order to raise awareness and participation on biodiversity conservation.



Fig.5

Chiang Rai Municipality was awarded for "Good Practice" city for Urban Biodiversity Conservation and was invited to be present and receive this award in the event of World Habitat Day 2011 in Aguascalientes, Mexico on 3 October 2011.



Fig.6

Later, The Chiang Rai Municipality has designed and implemented a natural ecosystem to become a biodiversity learning site and environmental study center at Nong Pueng swamp. In this wetland ecosystem, the students survey aquatic plants and aquatic animals in Nong Pueng swamp as the "Two



Fig.7

Heart in One Tree Project "which is a joint exploration and conservation activity by students from Chiang Rai Municipality School 5 and community members focusing on large trees around Nong Pueng.

In 2014, Chiang Rai Municipality got ASEAN Award on Sustainable Urban Environment for its waste and green area management by ASEAN Working Group on Environmentally Sustainable Cities (AWGESC) which Nong Pueng swamp is the Environmental Learning Center "Wetland Ecosystems" under the public-private partnership project. The projects in Nong Pueng include "Two Heart in One Tree" Project, Miyawaki Method Reforestation Project and Plant Biodiversity Conservation Project.



Fig.8

The concept of "A quality tree grown from a quality seed lasts gracefully and prospers" inspires the management of Chiang Rai City to nurture the young generation, considered as promising saplings of the city, to grow gracefully and become "the citizens of Chiang Rai" which cherishes their hometown and volunteers to protect this "wide variety of the assets" to last for the future generations.

So far, we have been so proud that the "biodiversity" has been completely integrated in the 8 Subject Groups, and we still keep improving continuously of 2 learning levels, i.e. junior high school (Mattayom 1-3), and senior high school (Mattayom 4-6).

## Thai Language Subject Group

- Junior high school (Mattayom 1-3)
  - Summary and comparison of plants in the vicinity of Chiang Rai Municipality School 5
  - Moto, poem, and composition on impressive plants
  - Information review and report writings, and booklet marking
  - Plant-relating tales



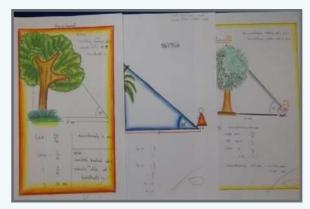
Fig.9

- Senior high school (Mattayom 4-6)
  - Summary and comparison of plants in the vicinity and inside of Chiang Rai Municipality School 5
  - Discussion on medical benefit of indigenous herbs
  - Plant taxonomy and/or grouping according to range, location, scientific name and family
  - Seminar on benefit of plants in the study area of Chiang Rai Municipality School 5
  - Poem composition on impressive plants

## **Mathematics Subject Group**

• Junior high school (Mattayom 1-3)

- Plant coordinate and geo-location
- Tree graphic and mapping
- Measurement and area calculation of the school study area
- Ratio, proportion, and chart & graph
- Tree height measurement using triangular shape
- In-school wood quantification



**Fig.10** 

- Senior high school (Mattayom 4-6)
  - Sets of plants
  - Tree height recording using trigonometric function
  - The statistical calculations to calculate average and median, norm of the height and canopy of trees

## Science Subject Group

- Junior high school (Mattayom 1-3)
  - Parts of plant
  - External structure of plants
  - Plant response to stimuli
  - Matter and its change
  - Preservation of plant (dried/preserved)
  - Factors on the growth of plants
- Senior high school (Mattayom 4-6)
  - Internal structure of plant

- Light intensity effects on the change and correlation among plant factors
- The correlation of living things and the effect of their physical surroundings on their life



Fig.11

## Social Studies, Religion, and Culture Subject Group

- Junior high school (Mattayom 1-3)
  - Local history and indigenous herb studies
  - Herbs in the Lord Buddha's life studies
  - Local demographic studies
  - Herbal plant growing studies
- Senior high school (Mattayom 4-6)
  - Local plant studies
  - Indigenous herbal plant and animal studies
  - Participation in local wisdom, culture and Thai wisdom conservation and studies

## Health Education and Physical Education

- Junior high school (Mattayom 1-3)
  - Herbal plant survey and glossary
  - Herbal plant growth and medical benefit of herbal plant studies



Fig.12

- Senior high school (Mattayom 4-6)
  - Application of herbal plants in disease treatment; matching the disease and the cure in respective curative herb
  - Herbal production and processing for promotion of the usage

## **Art Education**

- Junior high school (Mattayom 1-3)
  - Plant drawing
  - Thai musical learning through local northern songs and school musical poem improvisation
  - Dance and choreography in school botanical garden fair
  - Dress design using locally available materials
  - Art exhibition



**Fig.13** 

- Senior high school (Mattayom 4-6)
  - Botanical drawing and photography
  - Sketching and drawing parts of plant
  - Singing or music on nature and environment-related songs
  - Dress making using locally available materials

## Vocational and Technology Subject Group

- Junior high school (Mattayom 1-3)
  - Plant propagation studies
  - Plant information search and review
  - Plant presentation preparation



Fig.14

- Senior high school (Mattayom 4-6)
  - Plant propagation studies
  - Plant information search and review
  - Plant graphic design and e-book making
  - Plant glossary

## Foreign Language Subject Group

- Junior high school (Mattayom 1-3)
  - Scientific name and common name sign making for plans
  - Vocabularies on plant parts

- Senior high school (Mattayom 4-6)
  - Plant Leaflet production
  - Plant description composition



**Fig.15** 

## **Strategic Partners**

Strategic Partners that involved in development and implementation of this project by sector as follows:

- 1) Public sector has key role in providing academics as knowledge base and resources (except the budget), include a lecturer in training, a joint exhibition, supporting knowledge and join in as a working group for the exploration biodiversity. Include the agencies in national and provincial level such as the following:
- Office of Natural Resource and Environmental (ONEP)
- Department of Environmental Quality Promotion (DEQP),
- Protected Area Administration Regional 15, The Royal Forestry Department (RFD)
  - Chiang Rai Provincial Fisheries Office
  - Chiang Rai Provincial Agriculture Office
  - Chiang Rai Provincial Irrigation Office
  - Chiang Rai Office of Public Works and

Town & Country Planning

- **2)** Local Educational institution has key role in exploration, research the biodiversity in each area and being a consultant/resource person to the working group from:
- The Center for Natural Resources and Environmental Management (NREM Center) of Mae Fah Luang University
- Biodiversity Center of Chiang Rai Rajabhat University
- Rajamangala University of Technology Lanna Chiang Rai
- 3) Local, National, and International NGOs and Civil Society Organizations have a key role in development of project proposals, coordinate with funding sources and other agencies in national and local level with municipality including co-operation to drive the activities of the project including;
- Thailand Environment Institute Foundation (TEI)
- The National Municipal League of Thailand (NMT)
  - Chiang Saen Bird Club
- Network of 62 community leaders in Chiang Rai Municipality
- Eco Youth Volunteer Network of Chiang Rai Municipality
- International Union for Conservation of Nature (IUCN)
- Asia Pacific Adaptation Network (APAN)
  - World Wide Fund for Nature (WWF)
- **4) Private sector** has a key role in supporting the budget and knowledge via academics for the implementation including:
- Thailand Business Council for Sustainable Development (TBSCD)
  - Dusit Island Resort Chiang Rai
  - Chiang Rai Tourism Association

The outcomes of such integration of "Plant Biodiversity" into the 8 Subject Groups are as follow;

## 1. Learner

First-hand experience on hands-on learning, thinking, analyzing, problem-based solution finding, knowledge and links, knowledge aggregation, and applying the experience learned in one's school and person life. This leads to mental stability, gentleness, artistic appreciation, rationalization, mind openness, compassion towards both animals and plants in the vicinity, and the realization of the value of nature leading to awareness and participation in indigenous plant and animal genetic conservation.

## 2. Teacher

There are big changes ranging from classroom environment to outdoors learning, and more freedom given to the learners to create a product with more creativity, reduced lecture hours, teachers' role transformation to facilitators and counselor, focusing on handon experience maximizing local outdoor environment, and establishing a better relationship of teachers from different subjects based on integration of teaching.

## 3. School

Innovative and effective use of existing school environment for learning, as recognized and awarded by HRH Princess Maha Chakri Sirindhorn as, "the first-class school botanical garden" portraying the commitment on conservation of life and environment, engaged by youth and teachers' awareness, uplifting the image and academic quality of the schools under the municipality's supervision. The school also becomes greener, and more pleasant to learn in.

## 4. Community

Members can use the school's botanical garden as recreational area and life-leaning site, learning from school students' exhibition and publication in different occasions. This way the community members realize the value of biodiversity and nature, yielding collaboration in conserving local trees and better care for the respective community's environment.

Today, biodiversity conservation efforts led by the students are replicated in other landscapes in Chiang Rai Municipality areas. The students and their teachers are the main mechanism to push this conservation forward and promote its success to the public. Eight schools affiliated with Chiang Rai Municipality have adopted the biodiversity conservation initiatives and implemented their own environmental related projects in the schools.

In addition, environmental education and biodiversity conservation are officially integrated into eight thematic subjects of the Chiang Rai Municipality School 5 curriculum. The school may become a place for best practice of biodiversity conservation by the students with the support of the municipality, local communities and provincial government agencies.

One of the success factors is the participation from every sector and the strong sense of city communal ownership. It starts from the society's family and school, and expands to the community as a whole. The municipality has won honorable awards and that proves Chiang Rai Municipality has enhanced economic and social development in line with natural resource and environmental development, in accordance with sustainable development principles.

## Participatory mangrove conservation and restoration project for sustainable development: Grow, share, and protect the mangrove project

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Abstract-Mangrove ecosystems are specific and outstanding as connecting land and sea. Mangroves help to balance nature, absorb carbon dioxide and produce enormous amount of oxygen. It is recognized that mangroves are prosperous centers of biodiversity contributing to many aspects of human well-being.

Charoen Pokphand Foods PCL (CPF), who realizes the environmental, social, and economic importance of mangroves to the country, therefore, has initiated "Grow, Share, and Protect the Mangrove" project in 5 strategic areas; Rayong, Samut Sakhon, Chumphon, Songkla, and Phang Nga. The project partners consist of government, the private sector, and local communities.

It was learned from the project to use local knowledge to promote the survival rate of new planted mangroves in the shorelines with high erosion rate and disturbed by abundant wastes. Furthermore, the importance of area preparation by plantation of suitable plants was experienced. It is expected that this practical knowledge could be extended to the similar mangrove plantation areas. Throughout the course of the project the biodiversity information such as quantities of benthos, zooplankton, phytoplankton, land or ecotone and marine animals were

also estimated and recorded for resource management purposes.

It is anticipated that the project reinforces Thailand's Mangrove Management Master Plan. It is also remarkable that the mangrove conservation and restoration of the project supports the achievement of many of the United Nations Sustainable Development Goals (SDGs) particularly Goal 14; Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

"Grow, share, and protect the mangrove" project according to CPF's mangrove strategy

## 1. Principles and Reasons

From the past 1993 to 2013 under the "CPF which encourages Thai people to be part of a grow mangrove" Project, more than 300,000 mangrove trees were planted. In 2014, CPF expanded the project to be "Grow Share Protect the Mangrove" with the collaboration with Department of Marine and Coastal Resources (DMCR), Biodiversity-Based Economy Development Office (Public Organization) and Civic Network to support and promote the conservation of soil water forest and biodiversity under the concept

Grow = to promote conservationconsciousness, encourage knowledge accessibility in conjunction with the mangrove plantation

Share = to share experience and knowledge about participatory planting, taking care and managing

Protect = to protect mangrove with the collaborative civic network

The pilot project has been launched in the 5-year period (2014-2018) at 5 strategic areas.

## 2. Targets

By 2018, CPF will conserve and restore more than 2,000 rai (320 hectares) of mangrove and establish mangrove learning centers in 5 strategic areas: Rayong, Samut Sakhon, Chumphon, Songkhla, and Phang Nga.

## 3. Implementation

To achieve the targets for conserving and restoring mangroves with participatory activities and sustainability, follow these steps;

## 1. Defining the responsible persons

For launching the process according to strategic plan, define the responsible persons into 3 levels:

- 1.1 Board of directors
- 1.2 Local officers
- 1.3 Local community committee for driving the strategic plan

The result of strategic implementation throughout 3 years shows that defining the responsible persons can drive the activities following the action plan.

## 2. Reviewing mangrove strategies of relevant agencies

For driving the CPF mangrove project to the same direction as national strategy, CPF's

mangrove strategy is reinforced with 11<sup>th</sup> National Economic and Social Development Plan, National Policy, DMCR's Urgent Policy and National Mangrove Management Master Plan. The targets of national strategies are;

- 1.52 million rai (243,200 hectare) of Thailand mangrove area must be managed.
- Number of target groups and mangrove conservation and protection network should not be less than 100 groups per year. So, CPF's mangrove strategy will specify targets and KPIs accords with these national strategies.

## 3. Defining site selection criteria

For having appropriate areas to launch mangrove project, 6 site selection criteria are defined:

- 3.1 To be an ecologically important area that is included in the national strategic plan because it is a critical area with abundant biodiversity requiring remediation.
- 3.2 Not to be an area owned by a private sector, the access to the area for project implementation is not prohibited and the area should be governed by clear conservation and restoration policies.
- 3.3 There should be governmental agencies and strong civic network in the area to actively participate within the project and sustainably maintain the mangrove.
- 3.4 By using SWOT analysis, the result should indicate that there is an opportunity to successfully implement the project.
- 3.5 The results from the project implementation should have broad impacts on stakeholders.
- 3.6 The area should be suitable for mangrove plantation or governed by restoration policies such as the area with wind and wave protections or there is a chance higher than 60% to successfully planting mangrove.

## 4. Defining key performance indicators (KPIs)

For implementation to respond national

policy, biodiversity strategy and SDG goals, KPIs are defined to set the strategy, action plan and activities. These are:

- 4.1 Number of conserved and restored mangrove areas.
- 4.2 Number and biodiversity of species indicating richness of mangrove ecosystem.
  - 4.3 Number of civic networks
- 4.4 Number of groups and people who receive and exchange knowledge resulting from the project.
- 4.5 Quantity of reduced  $CO_2$  (tons of  $CO_2$ /year).

## 5. Action plan

From KPIs of conserving and restoring mangrove project, 4 strategies are defined;

Strategy 1 Create collaboration

Strategy 2 Knowledge accessibility

Strategy 3 Conservation and restoration

Strategy 4 Monitoring

## 6. Monitoring and evaluation for continuous development

Monitoring and evaluation strategy is identified because it is important to project implementation. This will monitor and evaluate at every level; board of directors, local officers and local community committee, any problems will be solved. Therefore continuous development should happen.

## 4. Project results

Project results in year 2015

1. Restored (new plantation) and conserved areas

In the second year of implementation; Actual restored areas: 40% (154 rai from 390 rai targeted areas) Actual conserved areas: 98% (2,025 rai from 2,065 rai targeted areas)

2. Biodiversity figures (Benthos, Zooplankton, Phytoplankton, Mangrove-dwelling and Marine

animals)

To cover biodiversity in the strategic areas, data of biodiversity figures (Benthos, Zooplankton, Phytoplankton, Mangrove-dwelling and Marine animals) are collected by Marine and Coastal Resources Research and Development Center from the Eastern Gulf of Thailand in 3 areas; Rayong, SamutSakhon and Chumphon. The reference areas are Panang Gulf Nakhon Si Thammarat Province, Sikao Canal Trang Province and Kung Kra Bend Chantaburi Province. The results showed that:

Benthos: Lower than criteria except in Chumphon

Zooplankton: Lower than criteria in all 3 areas

Phytoplankton, Mangrove-dwelling and Marine animals: Greater than criteria in all 3 areas

## 3. Number of mangrove local community committees

For operating in each area, local community committee is an importance working group structure because they will take the responsibility to operate the project for sustainable development. So the first 5 years of CPF mangrove strategy will support budgets, conduct knowledge sharing activities and build strength on the local community committee. In the last phase of CPF mangrove strategy, local mangrove protection fund will be established to operate continually for sustainability.

In year 2015, local community committee was appointed in 4 areas except Phang Nga Province which is in process.

## 4. Number of groups/persons attending the learning centers

Mangrove ecosystem learning centers are established in all 5 strategic areas. The target is set by increase 10% of visitors from year 2014 as baseline year.

## 5. Carbon absorption quantity

CPF mangrove project can behelping the world to reduce greenhouse gas emissions. So in the 5th year of strategy, CPF will measure carbon absorption quantity from trees. At this time trees cannot measure carbon absorption quantity because they must be older than 3 years with a height of 1.3 meters and circumference of 0.15 meters.

## 5. Example of participatory mangrove plantation activities

Samut Sakhon Province

Samut Sakhon province is the most affected by coastal erosion area because of huge waves and abundant wastes. So, mangrove planting in this area is troublesome. It shows that there cannot be planted any mangroves in this area in the past 10 years. In other words, it is 0% survival rate because of huge waves and abundant wastes. Moreover, bamboo revetments project for coastal erosion protection by government is not supported in this area. But because of local community attention, knowledge of techniques for planting, suitable plant species from department of marine and coastal resources and private sector supporting, the participation of these 3 sectors makes new planted mangroves to establish in the area to protect from coastal erosion. By using indigenous knowledge from artisanal fishery, bamboo and old fish net are used to build temporary barriers surrounding the mangrove area. The result showed that it can protect new planted mangroves by reducing or re-fusing waves and obstructing abundant wastes from coming into the planting area. And after a year has passed, it showed that survival rate of new planted mangroves was up to 65%.

## 6. Participation building for sustainable development

CPF and local community will participate to develop mangrove project by making incomes into the local community and parts of income will be contributed to the local mangrove protection fund. At the beginning, CPF will s upport local community committee and officers to make a study trip to observe the other strength local communities. After that local community committee and officers will use ideas to develop their mangrove area.

Each area must establish mangrove ecosystem learning center and has young local tour guides to share their knowledge about mangrove ecosystem to visitors. Furthermore, it will make young local tour guides love and care their mangrove area. And CPF will establish mangrove protection fund to community for develop the learning center to sustainability. This June 2015, the first learning center is planned to open for visiting at Rayong area.

Project development in each area from year 2015-2016

- Rayong: Klu tree plantation (the local community needs Klu leaves for making Klu tea)
- Samut Sakhon: Biochar production
- Chumphon: Chak sugar production
- Songkla: Tanod sugar production
- Phang Nga: Plantation of rare mangrove species

## 7. Success factors

From 3 years of strategic implementation showed that the key factors of achievement have 3 points;

- 1. Defining responsible persons
- 2. Setting goals and KPIs to make the same direction
- 3. Monitoring and evaluation for continuous development

## Reversing environmental damage through community focused sustainable livelihoods in Ban Don Bay, Surat Thani Province, southern Thailand

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Abstract-Wetlands International-Thailand Office (WI-TO) with the cooperation of local NGO's and government offices, funded by Mangrove for the Future Project (MFF) organized the large project named "Reversing **Environmental Damage through Community** Focused Sustainable Livelihoods in Ban Don Bay, Surat Thani Province, Southern Thailand". The objectives of the project were to conserve and restore mangroves in areas around Ban Don Bay; to develop and using financial innovation to manage and restore mangroves along with the vocational development of communities overseeing the resources, to promote cooperation among various sectors from the government, academic institutions, private organizations and communities in mangrove management and lastly to promote knowledge and skills in the management of mangroves and awareness among the people involved at local and national levels. Thus, they grow value and give importance to sustainable ecosystem conservation. The project was funded and operated from May 2009 to September 2011. Ban Don Bay is situated on the coast of the gulf of Thailand in Surat Thani Province. It covers approximately 145 kilometers of coastline which is divided among seven districts. Canals and rivers play an important part in carrying sediment into the coastal areas, thus making Ban Don Bay a muddy beach extending 1-3 kilometers into the sea, with certain parts becoming a river delta. The ecosystem of three water regimes makes the Ban Don Bay area abundant with mangroves and sea grass which is a significant habitat for marine life as well as an important fishing site for the surrounding communities. The mangrove areas of Ban Don Bay have degraded continuously as a result of marine animal farming, especially modern shrimp farming which began in 1995. Coastal marine life, which was a resource base and source of income for the communities surrounding Ban Don Bay, deteriorated. People who turned to modern shrimp farming faced losses. Some on them even lost their land to financial institutions. Thus, the project proceeded with the plans to restore degraded mangrove ecosystems, to establish mangrove complimentary livelihoods, to form a Mangrove Co-management group and to campaign on local and national awareness raising. From close operations

with various groups, the implementation of the concept of Bio-Rights, at least 72 ha. of mangroves have been conserved and restored. This activity has included restoration by planting mangrove trees in abandoned shrimp farms and diminishing mangrove forests, with conservation of young seedlings in the coastal areas of Liled village by using the process of consultation for the issuance of measures to control fishing methods, such as pushing boats, trawling and shell dredges boats, to keep the aforementioned from destroying voung mangrove seedlings over an area of 320 ha. Seedlings grew naturally during 1997-2006 for a total area of 432 ha and more seedlings grew during 2006-2010 for a total area of 80 ha. At the same time, public sea space was protected from occupation of groups of investors and influential individuals for cockle farming over an area exceeding 2,240 ha which will be beneficial for fishing communities in Liled village and nearby sub-districts. In terms of promoting improved quality of life, the project provides small circulating funds for livelihood promotion to six community organizations such as raising fish in floating baskets, fishery instrument production and seafood product processing. These activities generate income for member communities participating in the project. The aforementioned circulating funds will be repaid to the Bay Conservation Network in order to be further allocated to promote quality of life for other communities. Following the completion of the project, the Province of Surat Thani, then issued an order appointing a Ban Don Bay Coastal Resource Management Committee as a mechanism for participation from various sectors in conserving, restoring and resolving problems concerning coastal resource management in the Ban Don Bay area.

## I. INTRODUCTION

Ban Don Bay is situated on the coast of the gulf of Thailand in Surat Thani Province. It covers approximately 145 kilometers of coastline which is divided among seven districts (Fig.3): Tha Chana, Chaiya, Tha Chang, Punphin, Mueang Surat Thani, Kanchanadit and Don Sak. The west of Surat Thani is a high mountain sloping down toward the gulf of Thailand. The Tapi River originates from Khao Yai (Nakhon Si Thammarat Mountain Range), Thung Yai, Nakhon Si Thammarat, and passes the Chawang, Phrasaeng, Kiansa districts of Surat Thani then meeting Phumduang or the Khirirath River, which originates from Khao Sok in the Phuket Mountain Range, Punphin, Surat Thani, before flowing into the Gulf of Thailand at Ban Don Bay. There are also numerous canals such as the Phum Riang, Thakian, Chaiya, Huawua, Thapoon, Thathong, Nui, Kram and Don Sak canals.

These canals and rivers play an important part in carrying sediment into the coastal areas, thus making Ban Don Bay a muddy beach extending 1-3 kilometers into the sea, with certain parts becoming a river delta (Office of the National Environment Board, Ministry of science, Technology and Environment, 1992). The ecosystem of three waters (brackish waters) makes the Ban Don Bay area abundant with mangroves with certain areas being sea grass which is a significant habitat for marine life as well as an important fishing site for the surrounding communities in the Ban Don Bay area (Darunee Jiamjamrassil and Krisada Sutinun 2008).

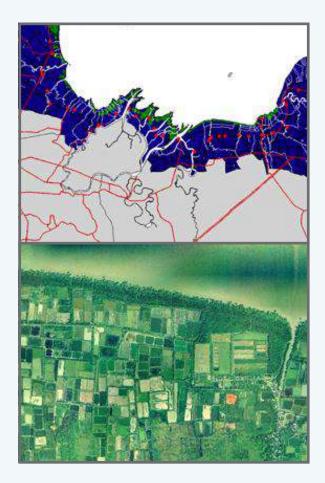
The mangrove areas of Ban Don Bay have changed consistently as a result of marine animal farming, especially modern shrimp farming which began in 1995. Although a lot of revenue had been generated for the country, the loss of mangrove forests has also been extensive. Modern shrimp farming without strict control of environmental measures led to

the drainage of bad water, chemicals and shrimp farm mud into natural rivers. This not only caused the canals to be shallow, but also affected the entire coastal ecosystem (Food and Agriculture Organization. 1985). Coastal marine life, which was a resource base and source of income for the communities surrounding Ban Don Bay, deteriorated. People who turned to modern shrimp farming faced losses. Some on them even lost their land to financial institutions because they had used the land as collateral for the loan they borrowed to invest in shrimp farming.

At the same time, the increased population, effective fishing equipment and diminishing resources have led to fierce competition for resources. In 2004, the Sea Food Bank Project, under the policy of asset-to-capital was a factor that stimulated widespread occupation of the Ban Don coastal areas. The aforementioned occupation reduced the fishing area for the local residents because fishing activities in the shell pens were not feasible, thereby reflecting the injustice of Ban Don Bay resource management. These problems are the inevitable and significant reasons for the inhibition of quality of life of local fishermen.

Under the financial support from Mangrove for The Future Project (MFF) administered by IUCN .Wetlands International-Thailand Office (WI-TO), with the cooperation of the Ban Don Bay Conservation Network (BDCN), the Regional Mangrove Management Office no. 4 (Surat Thani), and Surat Thani Provincial Fisheries Office (DOF), organized the project "Reversing Environmental Damage through Community Focused Sustainable Livelihoods in Ban Don Bay, Surat Thani Province, Southern Thailand" with the objectives of:

- 1) Conserving and restoring mangroves in areas around Ban Don Bay.
- 2) Developing and using financial innovation to manage and restore mangroves along with the vocational development of communities overseeing the resources.
- 3) Promoting cooperation among various sectors from the government, academic institutions, private organizations and communities in mangrove management.
- 4) Promoting knowledge and skills in the management of mangroves and awareness among the people involved at local and national levels, so they value and give importance to sustainable ecosystem conservation. The project was funded by Mangroves for the Future (MFF) and operated from May 2009-September 2011.



**Fig.1** Remote sensing and geographic Information System (GIS) of Ban Don Bay

## II. MATERIALS AND METHODS

## 1) Restore degraded mangrove ecosystems

1.1 Study and assess mangrove ecosystems conducted by mangrove experts in order to be aware of basic data involving geography, ecology, factors affecting mangrove restoration and recommendations for mangrove restoration techniques, as well as preparation of a geographic information system (GIS). The findings (Fig.1) of the aforementioned study were used in mangrove restoration project planning.

1.2 Hold training on capacity development and knowledge building regarding mangrove restoration for related community organizations and agencies conducted by mangrove experts with experience in mangrove restoration using various methods such as restoration based on silviculture principles, planting by Ecological Mangrove Restoration (EMR), exchanging knowledge and experiences with community

organizations so there is blending of academic knowledge and a local pool of knowledge on mangrove restoration and so community organizations can implement in their areas as suitable with the area and community needs.

1.3 Work in cooperation with seven community organizations receiving small circulating funds for livelihood promotion for mangrove restoration in line with the concept of Bio-Rights and to restore 453 rai of mangroves (1 ha = 6.25rai) in the Ban Don Bay area by mangrove restoration in abandoned shrimp farms (Fig.2), mangrove restoration in diminishing mangrove areas, planting supplementary mangroves with economic value and planting mangroves in order to protect erosion of the river banks. Apart from its main objective of increasing the mangrove areas, mangrove planting is also employed as an instrument for raising awareness among local residents and generating cooperation with various agencies.



Fig.2 Mangrove restorated in abandon shrimp pond at Takiean Thong district

1.4 Restore mangroves by natural sprouting. Due to an abundant supply of Sonneratia caseolaris (local name:Lampoo) seedlings, approximately 2,000 rai or approx. 320 ha. were available in Liled village, Phunphin. Nevertheless, these *Sonneratia caseolaris* seedlings tend to be affected by the use of fishing equipment, such

as push net fishing boats, trawlers and shell dredges. The project involved the communities to survey and establish boundaries to protect these seedlings and organizes discussion forums to hear public opinion from communities in order to establishing zoning in the Li Let coastline areas.

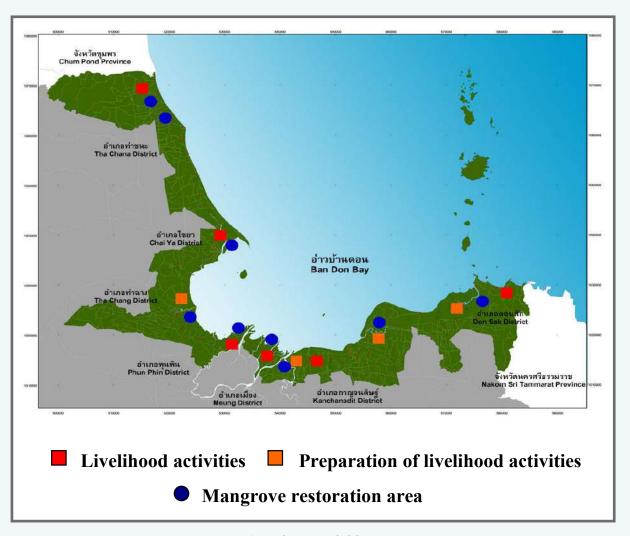
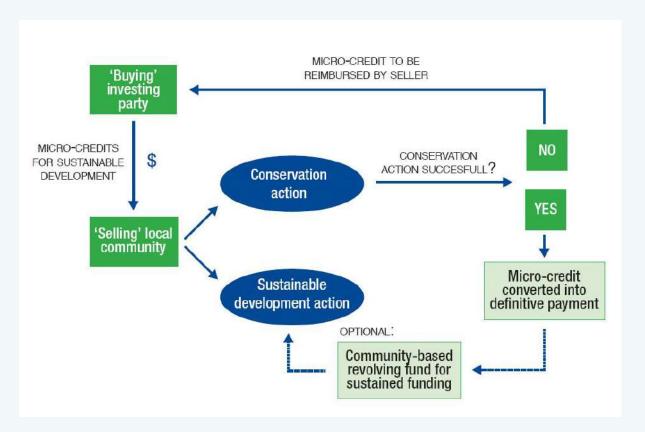


Fig.3 Project's activities area

## 2) Establishing mangrove complimentary livelihoods

2.1 Provide small circulating funds to support livelihood promotion to community organizations surrounding Ban Don Bay by implementing Bio-Rights (Pieter van Eijk and Ritesh Kuma, 2009) (Fig.4 & 5), which is a financial mechanism for improving quality of life and eradicating poverty along with the conservation of ecosystems and biodiversity. Over the past 10 years, the coastal resources of Ban Don Bay have been intensely degraded, especially through the loss of mangrove area and water pollution, which was caused by the expansion of shrimp aquaculture that currently covers up

to 25,000 rai. The result has been degradation of the coastal ecosystem and depletion of marine animals, which has reduced the quality of life and economy of fishing communities in Ban Don Bay. At the same time, the drop in shrimp prices, and shrimp diseases during 2001-2002, led to insolvency for many aquaculture families. In light of those circumstances, the project has focused both on restoring the ecosystem and supporting livelihoods of local communities. A close collaboration with the Ban Don Bay Conservation Network (BDCN) has facilitated the process under the Bio-rights concept, which provided support for livelihoods projects proposed by several communities.



**Fig.4** Simple schematisation of the Bio-rights approach. In case of successful conservation or restoration of ecosystem services by the local community, micro-credits can be converted into one-off definitive payments. Alternatively communities might be requested to reimburse their loan in a community-based fund, which ensures sustained cash availability beyond the project implementation lifetime. (dashed arrow)

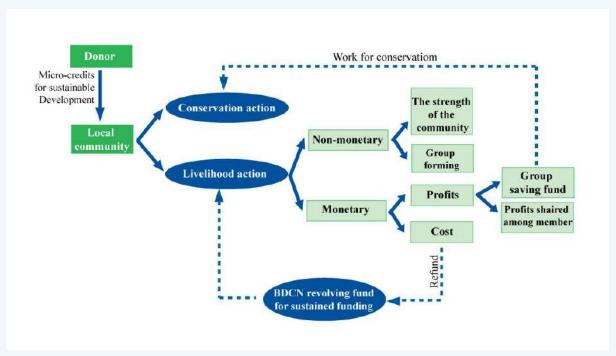


Fig.5 Bio-rights concept at Ban Don Bay, Surat Thani Province

The "Bio-rights" program to support livelihoods in Ban Don Bay, Surat Thani Province, is slightly different from those "Bio-rights" projects implemented in Indonesia, Malaysia, Costa Rica, and Mali because of differences in the social, cultural, and economic contexts of the area. Project staff, BDCN and local communities agreed in a meeting that the micro-credits for supporting livelihoods should be turned into "revolving funds". A group or community receiving a micro-credit has to clear the loan at the end of the contracting period to keep the funding sustainable. BDCN can rotate the funds to promote livelihoods in other communities, under the same stipulation that there be environmental conservation in those communities. For example, conservation, restoration and surveillance can be considered an activity that covers the interest payment on the loan.

Each step of the strategy to implement the program to support livelihoods stressed capacity building in communities through participation of its members. Local academics met to determine if the proposed projects and conditions in the communities would yield solutions alleviating income poverty, as well as human poverty, by building capacity and learning processes. Examples of human poverty are the lack of opportunity to access fundamental resources, the lack of power to fairly negotiate over natural resources management, and the lack of recognition for local knowledge.

2.2 Develop community capacity by organizing training in various areas related to and affecting current and future quality of, e.g. accounting administration, summary of lessons learned, preparation and adaptation to climate changes.

## 3.) Mangrove co-management

- 3.1 Support and push for the establishment of the Ban Don Bay Coastal Resource Management Committee to serve as a mechanism for building cooperation among the state sector, private organizations, NGOs and community organizations in the management, conservation, restoration and dispute resolution among groups of stakeholders.
- 3.2 Building capacity and strength for community organizations and the Ban Don Bay Conservation Network by promoting forums for exchanges among Ban Don Bay communities, providing training on community rights in resource management, following up on national policies and strategic plans related to regional natural resources and environmental management, and working with local administrative organizations to pass local mandates regarding natural resources and environmental management with participation from local communities.

## 4) Local and national awareness raising

- 4.1 Develop instruments for campaigns and dissemination of the value and significance of Ban Don Bay and conduct conservation activities under the project with target groups from the local level to the general public by newsletters, exhibitions, websites and Facebook.
- 4.2 Campaign, generate knowledge and understanding about coastal resource conservation and mangroves in the Ban Don Bay area at both the community and provincial levels (Fig.6), i.e. organizing discussion forums, youth camps, mangrove planting activities on important occasions, by closely coordinating the work with state agencies involved.

4.3 At the policy level, the project focuses on collecting data on the issues and situation in order to propose and drive for policy-related correction and management of marine and coastal resources with various agencies such as the Thai National Reform Committee and the Office of Natural Resources and Environmental Policy and Planning (ONEP).

4.4 Collect data, work performance and lessons learned from the project, e.g. application of Bio-rights mechanisms in order to promote improved quality of life in combination with

coastal resource restoration in the Ban Don Bay area, Surat Thani, for publication and presentation in academic conferences on various occasions.

4.5 Join with party organizations to hold a seminar with the agenda "Coastal Thailand in the New Decade of Sustainability" in order to be a forum for exchanging experiences among state agencies, NGOs, academic experts and communities in carrying out coastal resource conservation and restoration activities, integrating cooperation and managing disasters.



Fig.6 Training on 'Building Individual Capacity for Mangrove Restoration'

## III. RESULTS AND DISCUSSION

From close operations with the Ban Don Bay Conservation Network (BDCN), Regional Mangrove Management Office no. 4 (Surat Thani), and Surat Thani Provincial Fisheries Office (DOF), Surat Thani Natural Resource and Environment Office (MONRE), local administrative organizations (TAO) and community-base organizations (CBOs) from seven districts surrounding Ban Don Bay with the implementation of the concept of Bio-Rights, at least 450 rai or approx. 72 ha. of mangroves have been conserved and restored. This activity has included restoration by planting mangrove trees in abandoned shrimp farms and diminishing mangrove forests, for a total area of

450 rai with conservation of young seedlings in the coastal areas of Liled by using the process of consultation for the issuance of measures to control fishing instruments, such as pushing boats, trawling and shell dredges boats, to keep the aforementioned from destroying young mangrove seedlings over an area of 2,000 rai. Seedling grew during 1997-2006 for a total area of 2,700 rai (432 ha) and more seedlings grew during 2006-2010 for a total area of 500 rai (Fig.7 & 8). At the same time, public sea space was protected from occupation of groups of investors and influential individuals for cockle farming over an area exceeding 14,000 rai (2,240 ha). which will be beneficial for fishing communities in Liled and nearby sub-districts.



Fig.7 Mudflat at Leeled Sub-district

If the public sea status of the aforementioned area can be preserved, it will help preserve the sea as a source for fishing livelihood for the fishermen in addition to helping increase mangrove forested areas. The community has proposed the establishment of definite community boundaries, including local regulations at the community level. In terms of promoting improved quality of life, the project provided small circulating funds for livelihood promotion to six community organizations such as raising fish in floating baskets, fishery instrument production and seafood product processing. These activities generated income for member communities participating in the project. The aforementioned circulating funds would be repaid to the Ban Don Bay Conservation Network in order to be further allocated to promote quality of life for other communities. Nevertheless, because the establishment of rules, community regulations, including the establishment of boundaries, involves numerous stakeholders, so the project has arranged for hearings of public opinion of local residents in a total of four villages on two occasions. Furthermore, the meeting in each community had selected community leaders in order to participate in the process of providing suggestions for preventive actions against the occurrence of conflicts. In addition, the aforementioned issue was submitted to the collaborative meeting of committee of project directors by inviting related agencies, professionals and legal experts to attend and offer advice.



**Fig.8** Seedlings of Lampoo (Sonneratia caseolaris)

Bio-rights constitute a financial innovation for sustainable management of natural resources, the environment and biodiversity by placing importance on and relieving the issue of poverty among local residents. Wetlands International has applied the concept of Bio-rights to a variety of biodiversity conservation and poverty relief efforts in Indonesia, Mali and Malaysia by offering micro-credit fund to members in the communities participating in the project in order to develop environmentally friendly livelihoods and generate income for poverty-stricken people while communities carry out activities for the conservation and restoration of natural resources and the environment at the same time.

The "Bio-rights" program to support livelihoods in Ban Don Bay, Surat Thani Province, is slightly different from those "Biorights" projects implemented in Indonesia, Malaysia, Costa Rica, and Mali because of differences in the social, cultural, and economic contexts of the area. Project staff, BDCN and local communities agreed in a meeting that the micro-credits for supporting livelihoods should be turned into "revolving funds". A group or community receiving a micro-credit has to clear the loan at the end of the contracting period to keep the funding sustainable. BDCN can rotate the funds to promote livelihoods in other communities, under the same stipulation that there be environmental conservation in

those communities. For example, conservation, restoration and surveillance can be considered an activity that covers the interest payment on the loan. The project consideration process utilizes the principles of transparency and participation from all sectors. Committees have been established at district and network levels in order to screen projects proposed by groups/ communities for receiving budgetary support comprising project consideration committees at the district, network and provincial levels. Group/community members who have received budgetary support arranged joint consultation in order to select member representatives to take responsibility for the process of monetary reimbursement and accounting for the project based on the principles of joint responsibility.

Following the completion of the project, the Province of Surat Thani issued an order appointing a Ban Don Bay Coastal Resource Management Committee as a mechanism for participation from various sectors in conserving, restoring and resolving problems concerning coastal resource management in the Ban Don Bay area with support from the Thailand Research Fund (TRF) to make the multi-party resource management even more practical. At the same time, the Office of Natural Resources and Environmental Policy and Planning (ONEP), which is a state agency overseeing natural resource and environmental policies, is preparing to declare Ban Don Bay an environmentally protected area as a legal measure for the promotion and support of the sustainable conservation and management of coastal resources and mangroves in Ban Don Bay.

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# Exploring new approaches to climate change adaptation in Thailand: The case of the Phetchaburi and Prachuap Khiri Khan River Basins

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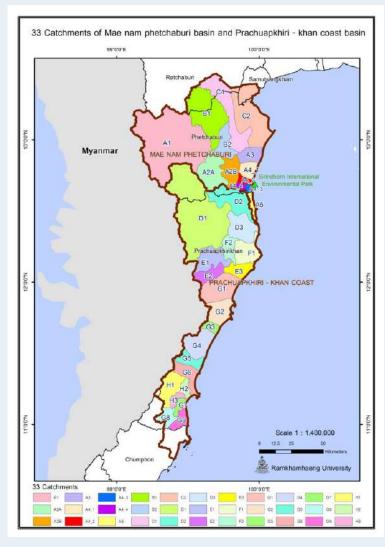
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Abstract-The Phetchaburi and Prachuab Khiri Khan River Basins of Thailand, in which the Sirindhorn International Environmental Park is located, are undergoing dramatic changes, including development pressures, a changing climate, and increasing needs of this limited resource. A comprehensive water resources management plan is needed to ensure the sustainability of the resource in the face of these mounting pressures. This study explored the current and future climate of the region, developing a set of climate data that were used in an integrated water resource management (IWRM) model of the region. The future climate data set was developed using a regional climate model, the Regional Climate Model version 4 (RegCM4), resolved at 25 km grid resolution over the CORDEX-SEA domain up to the year 2040. Regional climate modeling provides finer spatial scales than are currently available from Global Climate Models (GCMs). The downscaling applied in this study using RegCM4 made use of the Representative Concentration Pathways 4.5 and 8.5 (i.e. RCP 4.5 and RCP 8.5), under the framework of the Couple Model Intercomparison Project Phase 5 (CMIP5) of the World Climate Research Program, with the boundary forcing from the MPI-ESM-MR GCM. The future climate projection data from the RegCM4 model were then statistically downscaled to a 5-km resolution over the Phetchaburi and Prachuab Khiri Khan River Basins using an Artificial Neural Network (ANN). Future climate projections for the region suggest average temperatures will increase from by about 1.5°C by 2040 and 2°C by 2060, while rainfall is likely to decrease. The downscaled climate were applied to an integrated water resource planning model (IWRM) based on the Water Evaluation and Planning (WEAP) system, where the relationships between water supply, water demand, environmental requirements, and groundwater were developed, which will allow decision makers to explore alternative management options within the context of a changing climate, socio-economic, environmental, and other priorities.

*Keywords:* water resource, limited supplies, climate change prodictions, water futures, Phetchaburi, Thailand

## I. INTRODUCTION

The Phetchaburi and Prachuab Khiri Khan River Basins of Thailand, in which the Sirindhorn International Environment Park is located as illustrated in Fig.1, are undergoing dramatic changes, including development pressures, a changing climate, and increasing needs of a scarce water resource. A comprehensive water resources management plan is needed to ensure the sustainability of the resource in the face of these mounting pressures. This study explored the current and future climate of the region, developing a set of climate data, used in the development of an integrated water resource management (IWRM) assessment framework for regional stakeholders, which could be used to explore alternative development pathways and management options.



**Fig.1** Map showing the location of the Phetchaburi and Prachuab Khiri Khan River basins of Thailand and the location of the Sirindhorn International Environment Park

Global Climate Models or General Circulation Models (GCMs) are mathematical models that simulate the physical process of the atmosphere, ocean, cryosphere and land surface and are used, among other things, to simulate the response of the climate system to increasing concentrations of greenhouse gases in the atmosphere. GCMs have been continuously developed for the past 35 years or so, incorportating even increasingly complex components of the earth system. The history of modern climate change modeling can be traced back to the early 1980's, with climate modeling centers developing, running, and analyzing their model output, with little opportunity those outside the modeling community able to gain easy access to their model data. This was partly a consequence of relatively primitive computer networking and data transfer capabilities, along with the daunting task of collecting, storing, and transferring large amounts of model data (Meehl, 1985). In the mid 1990s, the Working Group on Coupled Models (WGCM) under the World Climate Research programme (WCRP) organized the first global climate model intercomparison exercise, Couple Model Intercomparison Project (CMIP) to be the standard of analyzing output from the coupled Atmosphere-Ocean General Circulation Models (AOGCMs). An important goal of the CMIP process is to make the multi-model output publically available in a standardized format.

GCMs simulate the climate system by dividing the land surface, sea-ice, and oceans into grids, with the atmospheric component including such variables as pressure, wind speed and direction, temperature, humidity, water vapor, precipitation and other variables, which are calculated on the three-dimensiononal grid of the earth over time. In general, the horizontal grid of a GCM size is on the order of 100 to 600 km., depending on the model and the moedeling experiment to be conducted.

A GCM also divides the atmosphere and oceans veritically, with from 10-20 layers over the land surface and as many as 30 layers for the oceans. The coarse resolution of GCMs's makes their output not readily suitable for the study of climate change impacts at the local or regional scales of a river basin such as the Phetchaburi and Prachuab Khiri Khan. The output from GCMs needs to be downscaled to finer spatial grid resolutions, which can be done using a variety of methods and techniques. In this study, the output from GCM was downscaled to finer grid resolution. The downscaled data set was applied to an integrated water resource systems model to assess the impacts of future climate change on the water resource in Phetchaburi and Prachuab Khiri Khan river basins.

### II. METHODOLOGICAL APPROACH

The methodological approach of this study to assess the impacts of a changing climate on the Phetchaburi and Prachuab Khiri Khan river basins comprises five major steps:

- 1. The acquisition of a 6-hourly global climate model dataset, the Max Plank Institute's Earth System Model at Medium Resolution (MPI-ESM\_MR), which provides boundary conditons to force a regional climate model over a large region of Thailand.
- 2. The setup and running of the regional regional climate model, REGional Climate Model version 4.3.5.7 (RegCM4, Giorgi 2012) at 25 km for both historical and future climate conditions, and the subsequent statistical downscaling using an Artificial Neural Network (ANN) algorithm of the RegCM4 output to a 5-km resolution in the area of Phetchaburi and Prachuab Khiri Khan river basins.

- 3. The processing of the climate model output into daily time series of precipitation and temperature for the historic period 1970 through 2005; and the future period 2006 through 2040. These data were processed to be compability with the Water Evaluation and Planning System (WEAP) decision support system.
- 4. The development of an integrated WEAP water planning model of the of Phetchaburi and Prachuab Khiri Khan river basins, which characterizes the water supply and demand across these basins, including the coastal Sirindhorn International Environmental Park. The model was developed and applied to address water management questions using the future climate forcing from the downscaling processes.
- 5. An assessment of the water management in the Sirindhorn International Environmental Park and adjacent areas was carried out by incorporated the impacts from future climate change as well as the increase in the future water demand.

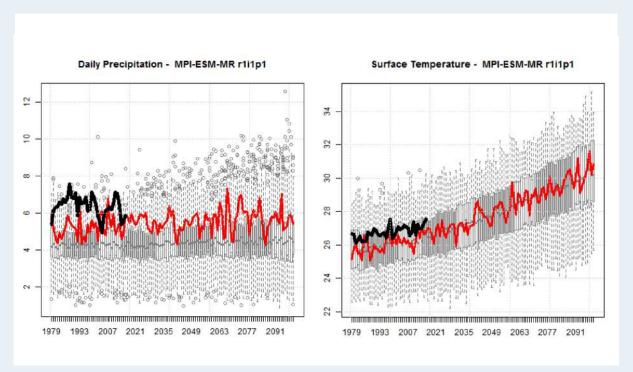
## The MPI-ESM-MR Global Climate Model

The MPI-ESM-MR GCM output applied in this study is among the new set of Earth System Models under the recent Coupled Model Intercomparison Project Phase 5 (CMIP5). For this study, we used data from the MPI-ESM-MR as the boundary forcing for the RegCM4 regional dynamical modeling, including two different future greenhouse gas concentration trajectories (Giorgetta 2012).

The greenhouse gases emission scenariso under the CMIP5 are known as Representative Concentration Pathways (RCPs), with the MPI-ESM-MR's RCP4.5 and RCP8.5 data used in this study for the regional downscaling. Since the GCM provides the lateral boundary conditions for the RCM within the region of interest, the GCM is the primary determinant of the climate charertics that are simulated at the regional scale.

Fig.2 summarizes in the gray box plot, the future projection of the full set of CMIP-5 models including the daily average preciption and annual average temperature over land for the Thailand region that includes the Petchaburi and Prachuap Khiri Khan River basins. The black line in the plots shows the historic estimate of those same variables based on the ERA-Interm data, which are a pseudo-observational product based on a global atmospheric reanalysis process of the European Centre for Medium-Range Weather Forecasts (ECMWF). The plots shows the variability of precipitation and the fact that GCMs generally under-estimate rainfall in the region, with the mean GCM estimate of about 4.3 mm/day, while the re-analysis suggests about 6 mm/day); while surface temperatures are about 25.8°C while the ERA-Interm estimate is slightly more warm, at about 26.3°C in the early 1980's. The red lines in both figures are the data from the MPI-ESM-MR and show similar inter-annual variaiblity with regards to rainfall, with a mean estimate of 5 mm/day, with no strong long-term trend. It is interesting to note that the re-analysis data suggests a warming trend in the region by about 1°C from 1979 to 2016, with the MPI-ESM-MR model

Representative Concentration Pathways (RCPs) are four greenhouse gas concentration trajectories adopted by the IPCC for its fifth Assessment Report (AR5) and describe possible climate futures which consider possible future greenhouse gases emissions, and include RCP2.6, RCP4.5, RCP6, and RCP8.5, named after a possible range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 W/m2, respectively).



**Fig.2** Daily average precipitation (left) and annual average temperature (right) averaged over Southern Thailand's land points from 102°E to 95°E and 5°N to 16°N for 1) the full set of RCP8.5 climate projections from the CMIP-5 archive (light gray box-plots), 2) the ERA-Interm estimate for the period 1979 through 2016 (heavy black line), and 3) the MPI-ESM-MR GCM

generally following this same trend, with an overall bias of about 0.5°C. The MPI-ESM-MR's model of surface temperature tracks along the ensemble meant for temperature is more wet than the ensemble mean with regards to precipitation.

## **Regional Downscaling**

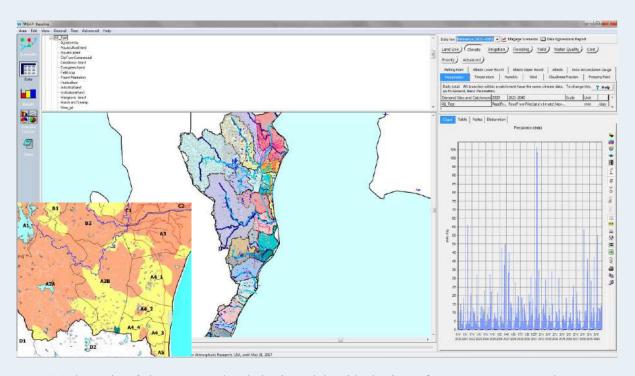
The downscaling process is a hybrid approach that combines both dynamical atmospheric modeling and statistical methods to derive high resolution, daily meterological data across Thailand. The statistical downscaling encompasses both experimental observations, relative to a specific location, or simulations, computed either by a large scale general circulation model (GCM) or a regional circulation model (RCM) (Valverde et al, 2014). The dynamical downscaling was accomplished

using the the REGional Climate Model version 4.3.5.7 (RegCM4), driven on its boundary by the MPI-ESM-MR. Downscaling was done at a 25 km  $\times$  25 km spartial resolution over the CORDEX-SEA domain covering 15.14°S-27.26°N, 89.26°E-146.96°E. The simulation was done on the Normal Mecator-domain cartographic projection using the MIT Emanual-Cumulus convection Scheme, Zeng Ocean model roughness formula 1-Ocean Flux scheme, Holslag PBL-Boundary layer scheme and Explicit moisture-Moisture scheme. This dynamical downscaling process is also a part of activities under the Southeast Asia Climate Downscaling Experiment/ CORDEX Southeat Asia (www.ukm.edu.my/ seaclid-cordex). The outputs from RegCM4 over the Petchaburi and Prachuap Khiri Khan River Basins were then further staticially downscaled to a 5 km × 5 km grid resolution using a multilayer perceptron, feedforward artificial neural network

(ANN). The supervised learning technique, Bayesian regularization back propagation was used to training the ANN. The predictors from RegCM4 output comprises 5 climate variables including precipitation, atmospheric pressure, maximum, minimum and mean temperature at the ground surface. The predictands are four meteorological variables including precipitation, maximum, minimum and mean temperature from the observation stations of Thai Meteorological Department. The daily predictors from 70 grids over the Phetchburi and Prachuab Khiri Khan river basins were trained with each daily predictand from each station. Predictands from 12 meteorological stations were applied for the training processes. The output from the ANN are then gridded onto the 5 km x 5 km domain using an inverse distance approach. The downscaled products cover two periods- a base line period, 1970-2005 and a future projeciton period, 2006-2040.

## The Integrated Water Resource Management Framework

The climate change impacts on watershed management are evaluated by using the Water Evaluation and Planning model (WEAP). The WEAP-Phetchaburi model has been configured to represent the Phetchaburi and Prachuab Khiri Khan provinces in Thailand, including their primary river systems. The model includes as inputs, daily climate data (i.e. air temperature, precipitation, wind speed and humidity); soil type and land use characteristics, reservoirs, diversions, and water demands. Several different datasets have been used to configure the model, including geographical information system (GIS) digital data, which includes river networks, canal networks, reservoir locations, land use, soil type, watershed boundaries, digital elevations, and groundwater well locations. The entire region have been represented in the model however,



**Fig.3** Schematic of the WEAP-Phetchaburi model, with the inset figure, a zoom over the eastern region of the study domain, highlighting the refined detail of the model and the location of the Sirindhorn International Environmental Park and the Phetchaburi water transmission project

this study have focused on the Phetchaburi province and particularly the region surrounding the Sirindhorn International Environmental Park.

The WEAP model simulates the main components of both the natural and managed components of the hydrologic cycle, e.g. overland flow, percolation, evapotranspiration, groundwater recharge, river flows; reservoir storage and operations, hydropower generation, irrigation diversions, water demands and deliveries for human uses (municipal, industrial, environmental, and agriculture). The WEAP-Phetchaburi model includes the main rivers of the Phetchaburi and Prachuab Khiri Khan provinces of Thailand, with

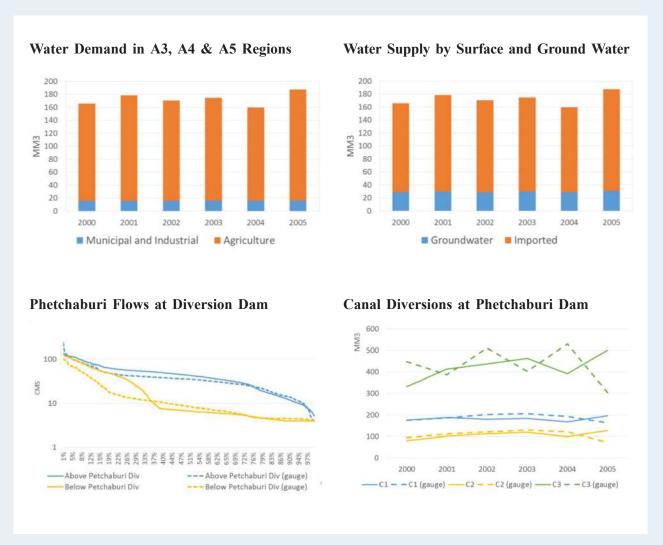
Fig.3 showing the extent and inter-connectedness of the model. The water systems are connected through a series of both natural rivers and manmade canals, whose inflows originate from 60 WEAP catchment objects covering roughly 12,000 km² of land area, with an average size of 200 km², a median area of 80 km², and maximum size of 2000 km². Each catchment is broken into representative land use/land cover classes described including forests, grasslands, agriculture, and urban. The catchments were defined by important hydrologic and water infrastructure attributes, such as tributary rivers, reservoirs, diversions, and agricultural areas (Table 1).

Table 1 Characteristics of the WEAP model for the Phetchaburi River

Spatial Domain and	Model covers the Phetchaburi and Prachuapkhrii Regions, and includes the
characteristics.	31 largest rivers, 17 reservoirs, 11 municipal demands, and 50 sub-basins,
	of which 20 include irrigation (field crop, perennial, aquaculture, paddy
	field). The major canals that deliver water to the eastern coast are included.
Time Horizon	Model runs on a daily timestep and uses the historic period 1999 to 2005 for
	calibration and validation; the future period is 2020 to 2040.
Modeled	Model simulates the hydrologic cycle, generating streamflow to the river
Components	and canal networks. Demand includes environmental, municipal and
	agricultural demands. Groundwater and surface water are primary supplies
	to region.

Fig.4 shows results from model calibration and summarizes important attributes of the WEAP-Phetchaburi model for the historic period 2000 through 2005, with 1999 used as a spin-up year to stabilize the hydrologic processes such as soil moisture. Fig. 4 includes municipal-industrial and irrigation demands for zones A3, A4 and A5 (see Fig. 3 to identify those zones) and the source of supply for those same zones. The figure shows that agricultural use and imported water dominate the water systems of the region. Fig. 4 also shows the simulated flows for the Phetchaburi River above and below the Phetchaburi Dam diversion plotted as a frequency distribution (bottom left), and the diversion from

the three primary canals (see Fig. 3). We estimate that the total water demand in the Phetchaburi and Prachuab Khiri Khan Provinces, with a total population of about 1,000,000 and an agricultural area under irrigation of more than 350,000 ha. We estimate total water demand in the region of between 7,000 MM3 and 10,000 MM3. A comprehensive analysis of this region was beyond the scope of this study, and so we focused our analysis on the southern coastal region of the Phetchaburi province that includes the Sirindhorn International Environmental Park. We estimate annual water use in this region of about 170 MM³ or just about 2% of the total water demand for the two provinces.



**Fig.4** Results of model calibration for the historic period 2000 through 2005, showing the agriculture demand and supply for the A3 and A4 coastal region (top), the flows at Phetchaburi (bottom-left) and the groundwater storage in the A4 region

A water management policy framework was used to develop a set of future scenarios based on a set of underling principles. The first principle is that the framework should distinguish between a set of underlying assumptions that are used to establish Business-As-Usual (BAU) scenarios and a set of policy interventions that form the basis of a set of water management policy scenarios. The BAU scenarios define the baseline and future assumptions that are predominantly outside the control of water managers, such as the future climate conditions and the regional population growth; and include the policies that have

historically been in place. A second principle is that the policy scenarios should be plausible, policy-oriented narratives that account for the unique perspectives and characteristics of the region and its culture. For Thailand, this means that they should consider priorities of development, the importance of tourism and cultural heritage, and the significance of agriculture and environmental protection. The final principle for this analysis is that the policy scenarios should be quantifiable. That is, policy interventions that can only be characterized in a qualitative sense relative to their impacts on the water system are not explicitly considered

(e.g., the role of environmental education in primary and secondary school, as example).

Taking the above principles into account, the BAU and an Environmental Policy scenario

were developed to demonstrate the utility of the WEAP model as a tool for integrated water resources management, and are summarized in Fig.5.

## **Illustrative Water Management Policy Scenario**

## Regional Environmental Conservation

- 1. Double the instream flow requirement below the Petchaburi River to maintain higher flows down river.
- 2. Do not allow Khangkachan Reservoir to fall below a minimum height.
- 3. Ensure groundwater levels do not fall below minimum threshold to reduce salinity threat.



### **BAU Scenario - Assumptions**

1. Without Climate Change: Historical climate repeats

### **BAU Scenario - Assumptions**

- 1. With Future Climate Change (RCP4.5 and RCP8.5).
- 2. Regional population and tourism grows by UN estimate, with a growth rate of less than 1%.
- 3. Minimum flow requirements below the Petraburi Dam Diversion have highest priority.
- 4. Irrigated agriculture and municipal water supplies to Eastern region have equal priority, but secondary to Petchaburi river.
- 5. Irrigation preference is first from Petchaburi canal, then groundwater, and finally local sources.
- 6. Hydropower is a secondary benefit (serves agriculture and flood protection).
- 7. Irrigators closer to the canal source possess a "Positional Advantage" to the canal water
- 8. A minimum canal flow of 1.5 cms to the Southern Region must be met.

Fig.5 Baseline assumptions and two select, future water management policy scenarios

The BAU scenario assumes current water use and supply sources continue along the same trajectory that includes regional population growth and tourism visit estimates, while the land in agriculture and the current infrastructure and their operations remain the same. Water use per-capita also remains constant throughout the future period, which have considered to be 2020 through 2040 for this analysis. The policy scenario that we have developed for this report focuses on environmental enhancement of the

Phetchaburi river system. Ideally, policy scenarios would be developed within a participatory environment that would gather input from stakeholders in an iterative fashion. Unfortunately, this brief project did not have the benefit of such direct input. The Environmental scenario that was developed, looks to enhance the environmental flows of the Phetchaburi river, recognizing that more than 60% of the flow at the Phetchaburi dam is annually diverted primarily to serve irrigated agricultural interests.

This Environmental policy scenario assumes a doubling of instream flows below the Phetchaburi diversion and a reduction in releases from the Khangkachan Reservoir to maintain storage. Releases from the reservoir are restricted by halving the buffer coefficient, which determines the amount of water that can be released as portion of what is stored. Performance metrics for this scenario include, 1) the amount of water delivered through the canals to regions A3, A4, and A5; 2) the amount of groundwater used in the region and groundwater levels; and 3) reservoir storage and hydropower production at the Khangkachan Reservoir. The BAU and Environmental policy scenarios are summarized in Fig.4.

### III. RESULTS

We present results for the future climate projections of the region from the RegCM4 regional climate modeling experiment, forced on the boundaries by the MPI-ESM-MR GCM model. We also present the analysis of the Integrated Water Resource Management model on the water supply and demand of the study area.

## **Climate Projections**

The climate projection of the two river basins the downscaling of MPI-ESM-MR can be summarized as follows and changes are summarized in Fig.6 and 7:

- The projection of annual average daily mean temperature of both basins show an increasing trend. The projected temperature under RCP8.5 is higher than RCP4.5.

- The projected temperature from the downscaling process is able to capture the variation of temperature over the baseline period or 1971-2005.
- Over the period 2031-2040, the daily mean temperature of both basins under RCP4.5 and RCP8.5 is about 0.84°C and 0.96°C higher than the baseline period respectively. The higher change from RCP8.5 resulted from higher driving force of greenhouse gas concentration in the atmosphere.
- The increase in daily mean temperature over the period 2036-2040 of Phetchaburi and Prachuab Khiri Khan river basins under RCP4.5 and RCP8.5 compared to the baseline period are illustrated in Fig.5.
- Over the period 2036-2040, the annual average precipitation from RCP4.5 and RCP8.5 are projected to decrease from the baseline period as illustrated in Fig.6. The change in precipitation is not as pronounced as the change in annual average daily mean temperature.
- Over the period 2031-2040, the annual average precipitation projection from RCP8.5 is lower than the RCP4.5 when compared to the baseline period.
- Over the projection period or 2006-2040, the annual average precipitation change from RCP4.5 is in the range of -9.3-+7.2% compared to the baseline while the RCP8.5 is the range of -10.2--4.6%.

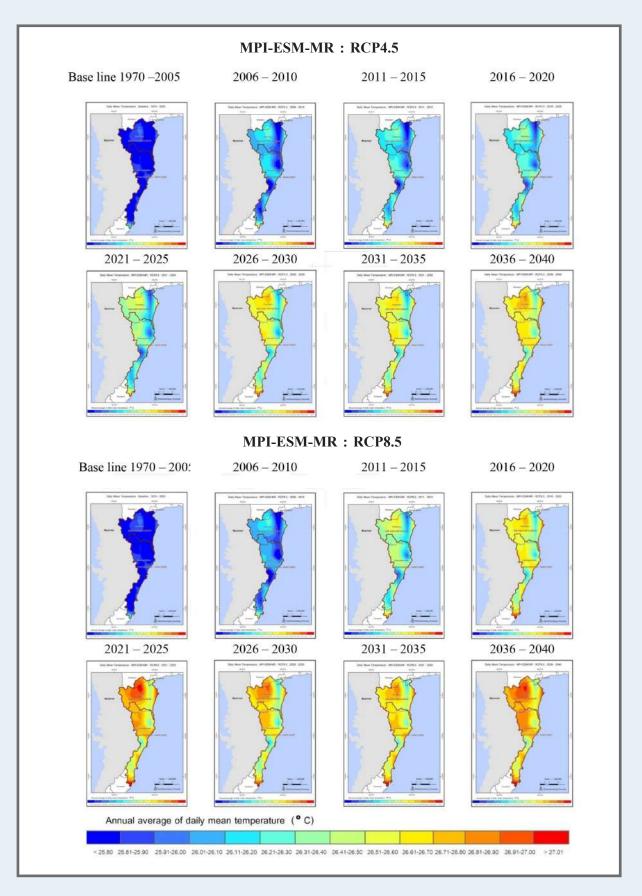


Fig.6 Mean temperature projection from the downscaling of MPI-ESM-MR

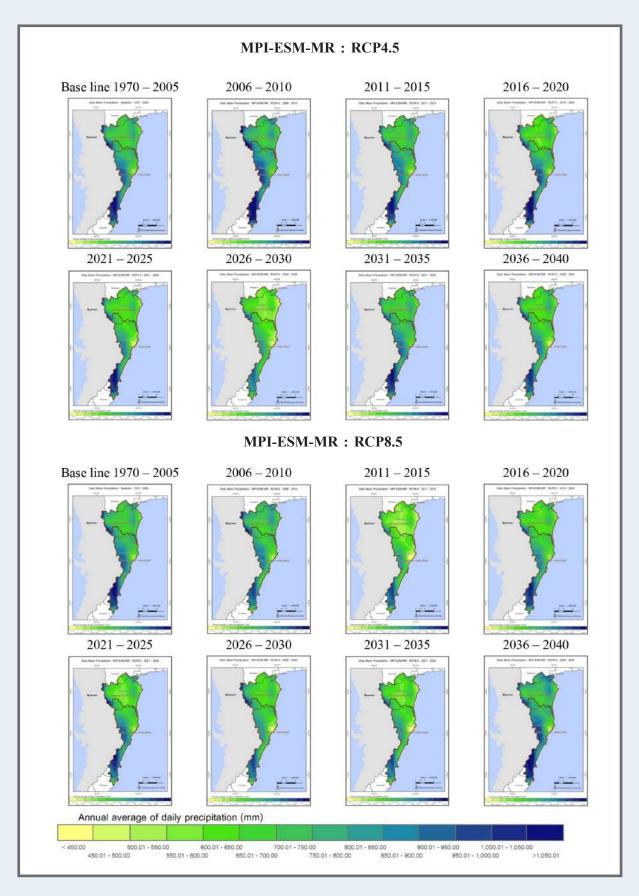


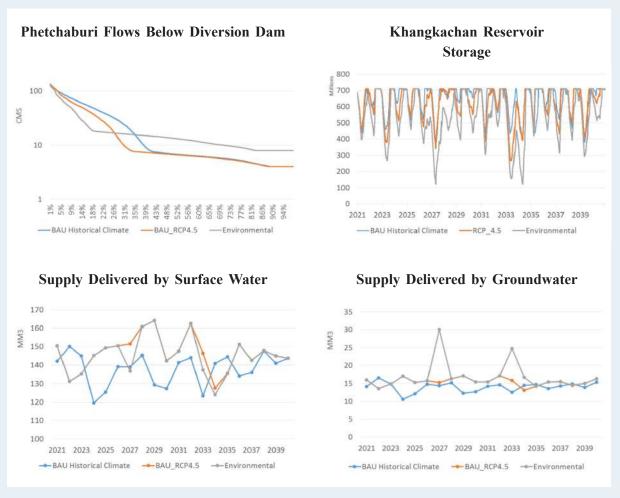
Fig.7 Annual precipitation projection from the downscaling of MPI-ESM-MR: RCP4.5

## Analysis of the BAU and Environmental Protection Scenario

The *Environmental* protection policy scenario was used to demonstrate the utility of the WEAP model to explore the impact of various water management policies on the water supply and demand of the region and other water resource metrics, such as groundwater storage, water delivery by source, and reservoir storage. Fig.8 shows a select set of results for the BAU scenario both with and without climate change (BAU and BAU-RCP4.5) and the Environmental policy scenario (note: for this summary report, the RCP8.5 results are not shown but are available within the WEAP modeling framework). The RCP4.5 scenario represents the mid-range future climate change projection, with a global average increase in temperature of about 1.5°C between 2045 and 2065. The RCP4.5 scenario that we are using for this region of Thailand, shows a modest increase in temperature of 0.7°C by 2040 and is about 6.5% drier over the 20 year period of 2020 to 2040 when compared with the historic period of 1980 to 2000. Fig.8 shows a comparison among the scenarios for several water resource metrics. Comparing the BAU and BAU-RCP4.5 shows that diversions below the Phetchaburi diversion dam decrease under the climate change scenario for flows above about 10 cms or the 40<sup>th</sup> percentile ranking. For lower flows, the climate change impact is not large since these are managed flows, and thus maintained through releases from the Khangkachan Reservoir. Fig.8 shows the daily time series of storage in the reservoir, where it is evident that during periods of lower precipitation, greater reservoir releases are made in support of increasing demands and Phetchaburi diversion flows requirements. The Environmental policy scenario forces an increase in water delivery below the Petchaburi diversion, reflected in the increase flows from the about the 15th percentile level. Fig.8 includes

the delivery of water to the eastern region including all uses (agriculture, municipal, and tourist) for the period 2020 to 2040 by surface water (Lower Left) and groundwater (Lower Right). Note that climate change, reflected within both the BAU-RCP4.5 and Environmental policy scenarios, increases both surface and groundwater delivery, with a total increase in water demand for the region of about 7% when compared to the BAU scenario that is based on the historic climate. This increase in demand places greater pressure on the Khangkachan Reservoir, which is drawn down further to serve both water use needs and meet environmental flows below the Petchaburi diversion dam.

Fig.9 shows that in addition to increased pressure on surface water reflected in less storage in the Khangkachan reservoir, the climate change signal also manifests itself on the regional groundwater, creating a draw-down in stored water until 2035. After 2035, groundwater rebounds, as there is a wet period within the RCP4.5 climate scenario in 2034 and 2035 that are 10% and 20% greater than the long-term mean, which were preceded by two of the driest years in the sequence-2032 and 2033-with 20% and 5% less rainfall, respectively. Fig.9 also shows the monthly mean Khangkachan Reservoir storage and shows that the climate change signal reflected in the drying associated with the RCP4.5 climate scenario slightly reduces the mean monthly storage. The Environmental policy scenario reflects a greater reduction in reservoir storage to meet the increasing water demands and the increased environmental flow requirements below the Petchaburi diversion dam. In the Environmental policy scenario, 3 of the 20 years require supplemental groundwater be used to maintain levels of water use in the A3, A4, and A5 region, as there simply is not enough surface water to support both the environmental requirements and the growing demands.



**Fig.8** Future BAU and Policy scenario results, showing supply delivered by Surface Water (top left) and groundwater (bottom right) from the Phetchaburi River to the eastern region. Flows below the diversion (top right) and groundwater storage on the eastern coastal plains (bottom right)

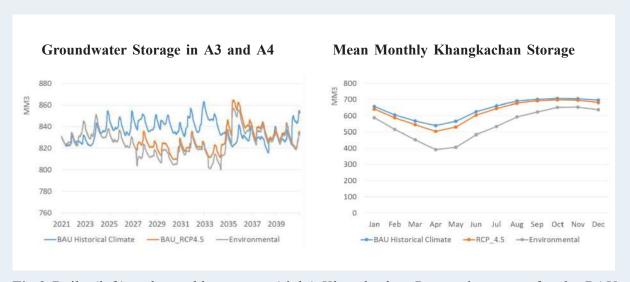


Fig.9 Daily (left) and monthly average (right) Khangkachan Reservoir storage for the BAU scenario with historic climate, BAU with future climate, and the Environment

### IV. CONCLUSIONS, LESSON AND FUTURE RECOMMENDATIONS

The outputs from the RegCM4 and ANN downscaling process were used to drive a daily, integrated water resources management model based on the Water Evaluation and Planning (WEAP) decision support system. This modeling framework facilitates the integration of physically based hydrologic modeling along with water management elements that explored the implications of climate change on the managed water resource systems of the region. While the model was developed for the entire Phetchaburi and Prachuab Khiri Khan Provinces, the analysis focused in on the southeastern region of the Phetchaburi province that includes the Sirindhorn International Environmental Park. The analysis shows that the region's agriculture sector is highly dependent on surface water supplies from the Phetchaburi and Huai Mae Prachan Rivers through a large man-made diversion. Paddy fields, aquaculture, field crops, and perennial crops are grown in the region, largely supported by these diversions, with agricultural water use nearly 10 times larger than municipal, industrial, and tourism water use.

We explored the future water use in this region with this model, driven by the climate change scenarios developed by the climate team. This future climate scenario suggests regional warming of about 1°C during the period, with drier conditions from 2020 through 2035 leading to increased water use of about 6%, also driven by a modestly growing population of less than 1%. The extended dry period results in drawdown of the surface reservoirs in the region. After 2035, the climate scenarios has a wet period, which leads to a recovery of both the surface and groundwater systems. The model was also used to demonstrate how water resource management policy scenarios

could be developed and deployed, and then used to explore tradeoffs among various water management strategies. The scenario developed for this study focused on environmental protections that included increasing the instream flow requirements of the Phetchaburi River, which currently sees more than 60% of its flows diverted for irrigated agriculture.

We created an Environmental policy scenario that doubled the flow requirement below the diversion, and that limited the amount of water that could be released from surface water reservoirs. The results showed that the regional water demands for both people and agriculture sector could still be met, but not without the agricultural sector occasionally tapping into the regional groundwater system as a substitute for surface water. This would imply the need to develop groundwater pumping capacity for the agriculture sector, which currently relies almost exclusively on surface water. Municipal water supplies, meanwhile, are primarily supplied via groundwater. Future studies could explore the feasibility and cost of the agriculture sector using groundwater as a supplemental supply to ensure that their water supply remains reliable and robust.

Highlights and lessons learned from the study can be summarized as followed:

- The waters systems of the region have. been developed such that agriculture depends on surface water supplies and municipal and industrial uses are primarily from groundwater.
- Regions in the Phetchaburi Province that are dominated by sandy loam soils show very low runoff coefficients and thus very little surface water. However, these infiltration rates support an active alluvial groundwater system, and these groundwater basins are very efficient and reliable in terms of supplying municipal and industrial water supplies.

- In regions with more clay-dominated soils, irrigated agriculture dominates the land uses, and includes rice paddies and aquaculture systems. These regions do not have well developed groundwater systems and must rely on surface water imports from the large, regional river systems.
- We estimate that in the southeastern coastal region of the Phetchaburi province, that agricultural water use is 10 times larger than municipal and industrial water use.
- The future climate change scenario shows warming and drying, but the water systems-including surface and groundwater storage-exhibited robustness and resilience to these climate trends, although the climate scenario exhibited an increase in precipitation towards the end of the 20-year period, and the surface and groundwater storages recovered.
- Future work should explore longer simulations that carry the analysis towards the end of the 21st century, as the analysis does suggest that climatic shifts that move the system into a different climate regime could lead to vulnerabilities of the water system. Surface and groundwater systems could need to be managed in a more holistic-conjunctive manner.
- Future research should explore the potential vulnerability of the coastal aquifers to sea-level rise and salt-water intrusion. Field studies suggest that the water table in the coastal region is high enough to counter salt-water intrusion, but increased water demands or extended dry periods might lead to lower water tables and salt water intrusion.
- Cost-benefit analysis with regards to agricultures use of groundwater could

- be explored. What are the practical implications of this sector using more groundwater and what the costs and benefits? Would there be a significant energy cost to the greater use of groundwater in the region (i.e. the water-energy-food nexus would be something to explore).
- Further studies in the region would benefit tremendously by engaging local stakeholders on the issue they are facing. A shared vision planning process, that included climate scientists, water resource specialists, models, agricultural interests, municipal and industrial water experts would make the water planning process more meaningful.

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# Integrated watershed ecosystem management: A case study of forest and water resources in the Bangtranoi and Huaisai watersheds within Sirindhorn International Environmental Park and adjacent areas

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Abstract-The aims of this study were: 1) gathering watershed resource information particularly on land use, soil, forest, water and socio-economics: 2) study integrated linkage relationship of watershed ecosystem and adjacent area and 3) formulation of guidelines for sustainable integrated watershed management with people participation. Studies of land use change, soil characteristics, soil erosion, forest resources (types, density, volume and biodiversity), stream flow and water quality and socio-economics in Bangtranoi (BTN) and Huaisai (HS) watershed were conducted. The results showed that the change of land use from 2009 to 2015 in both watersheds was mostly a change to village and community areas whereas forest and agriculture area showed decreases. The soil infiltration of BTN and HS showed very high rates with 31.52 and 30.91 cm./hr, respectively while, total N, Avail. P, Exch. K, Exch. Ca and OM were very low levels. On site soil erosion in BTN and HS was 20.29 and 7.18 tons/ha/yr., respectively. Furthermore, stream flow and water quality in both watersheds were

investigated. Annual stream flow in BTN was 9.69 Million Cubic Meters (MCM) (16.35% of annual rainfall) which was higher than HS with just 2.63 MCM (14.32% of annual rainfall). The water quality of both watersheds was classified as type 3 of surface water quality standards. Forest types including the remaining forest of Dry Dipterocarp and mixed deciduous forest with crown cover 25% in BTN and 34% in HS. Some 123-150 tree species were found in both sites such as Shorea siamensis Miq., Lagerstroemia calyculata Kurz. and Pterocarpus macrocarpus Kurz. Socio-economic features of both watersheds were similar and the local people displayed a good understanding in fundamental forest law and natural resource conservation. Nevertheless, the response levels of people participation was found to be at a low to moderate level in both watersheds.

Keywords: watershed ecosystem, integrated management, Phetchaburi Province

#### I. INTRODUCTION

Watershed management is fast becoming a top if not the top environmental and ecological challenge in global terms. Many international statements and reports (e.g. from and at UNO, UNDP, UNEP, UNESCO levels) make statements which point the resolution of watershed and water management issues firmly towards the local and community level.

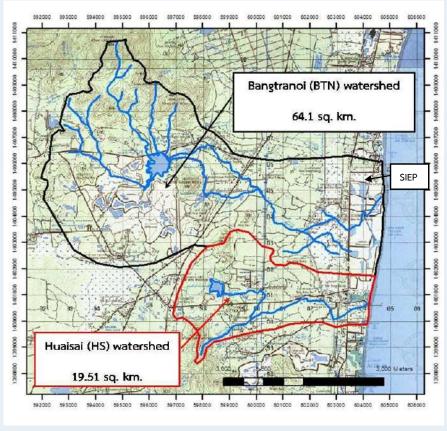
In the spirit and objectives of the International Conference on Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals (SDGs): Policy and Practice to be held at the Sirindhorn International Environmental Park in Cha-am, Phetchaburi Province in June 2016, we focus in this paper on a local Province, that of Phetchaburi and make use of the current challenges facing the Cha-am District of this Province where water

supply demands are growing more pressing as socio-economic, demographic, ecological and climate changes combine to magnify the importance of an ecologically sound approach to integrated watershed management.

The local changes of expansion in village number and size are occurring along with dramatic growth in the popularity of the district in terms of tourism: demands on and for safe and reliable water supplies are growing and warrant addressing in an integrated manner.

#### **Objectives**

- 1. Gathering watershed resource information:-land use, soil, forest, water, and socio-economics within 2 watersheds which cover Sirindhorn International Environmental Park (SIEP) and adjacent area
- 2. Study integrated linkage relationships of 2 watershed ecosystems and adjacent area



**Fig.1** Study site included 2 watershed areas covering SIEP and adjacent area in Cha-am District, Phetchaburi Province, Thailand

3. Formulation of guidelines for sustainable integrated watershed management with people participation

#### II. STUDY AREA

The study area is located in Cha-am District, Phetchaburi Province covering the study sites of 2 watershed areas: Bangtranoi and Huaisai with an area 64.1 and 19.51 sq. km. respectively, in which the Sirindhorn International Environmental Park (SIEP) and its vicinity area are included (Fig.1).

#### III. MATERIALS AND METHODS

#### 3.1 Land use change analysis

To work out the land use change of the study watershed (BTN and HS watershed),

land use classification mapping for the periods from 2009 to 2015 by the Land Development Department (LDD, 2015) was used. The classified images were converted to ArcGIS files format for investigating the change of land use detection and calculated land use change areas from 2009 to 2015 using the raster calculation technique in the spatial analyst module. In addition, a field survey was used.

#### 3.2 Soil resource analysis

Totally 10 disturbed and undisturbed soil samples were collected based on land use types and soil series (Fig.2). Soil texture, bulk density and chemical properties (soil fertility) was analyzed in a laboratory, whereas, infiltration rate data was collected during the field survey. Furthermore, on-site soil erosion was calculated using USLE equation and GIS technique.

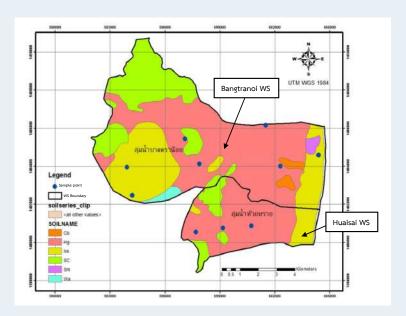


Fig.2 Soil sampling location

Key: Slope complex (Sc), Nhong Kae (Nk), Hup Ka Pong (Hg), Chonburi (Cb), Samutprakarn (Sm), Watana (Wa)

#### 3.3 Forest resource survey

Forest inventory techniques were used to measure forest resource involving 235 temporary field sampling plots. The plots are circular; a 17.85, 12.62 and 5.64 meter radius were used to measure forest types, stand

density (trees, saplings, seedlings, and bamboos), stand volume, and biodiversity. 15 permanent plots (20 x 40 m<sup>2</sup>) were used to study canopy crown cover, plant profile, and ecological features (Table 1) and comparison with the study by Faculty of Forestry, Kasetsart University (2008).

**Table 1** Forest sample plots in each forest type

Forest type	Temporary plot	Permanent plot
Mix deciduous and	170	7
Dry dipterocarp forest		
Reforestation	35	4
Beach forest	25	2
Mangrove forest	5	2
Total	235	15

#### 3.4 Water resource analysis

#### 3.4.1 Streamflow analysis

Rainfall and discharge data were collected from 11 hydrologic stations surrounding the study area. Simple linear regression was applied for streamflow calculation then water demand of each watershed and wet flow and dry flow were analyzed.

#### 3.4.2 Water quality analysis

Water samples from 9 stations were collected and analyzed for water quality (air and water temperature, electrical conductivity (EC), salinity, pH, dissolved oxygen (DO), biological oxygen demand (BOD), suspended solids (SS), total dissolved solids (TDS), hardness, fat, grease, and oil, nitrate, phosphate, total coliform bacteria and fecal coliform bacteria) then compared with surface water quality standard (Pollution Control Department, 1994) (Fig. 3).



2. Pond in SIEP



4. Khao Kapuk Reservoir



1. Watershed outlet (in SIEP)



3. Huai Sai Reservoir



5. Huai Ta Paad Reservoir

Fig.3 Water sample collection sites

#### 3.5 Socio-economic analysis

#### 3.5.1 Population targets and sampling

The population targets in BTN watershed was 7 villages with totally 1,432 households while, 3 villages in HS with totally 770 households; 96 households of BTN and HS watershed were sampled. Sampling methods were based on Yamane (1973).

#### 3.5.2 Data collection

Interviews of the heads of sampled households was conducted by using questionnaire divided into four parts: Part I: Population characteristics and sanitation, Part II: Utilization

of natural resources and environment, Part III: Understanding of social forest law and conservation and Part IV: People participation in natural resource conservation.

#### IV. Results and discussion

#### 4.1 Land use change

As shown in Fig.4 and Table 2, BTN watershed, land use mostly changes to villages and communities whereas forest and agricultural lands showed a slight decrease. For HS watershed, villages and communities also had significant increases while agricultural and miscellaneous areas recorded a dramatic decrease.

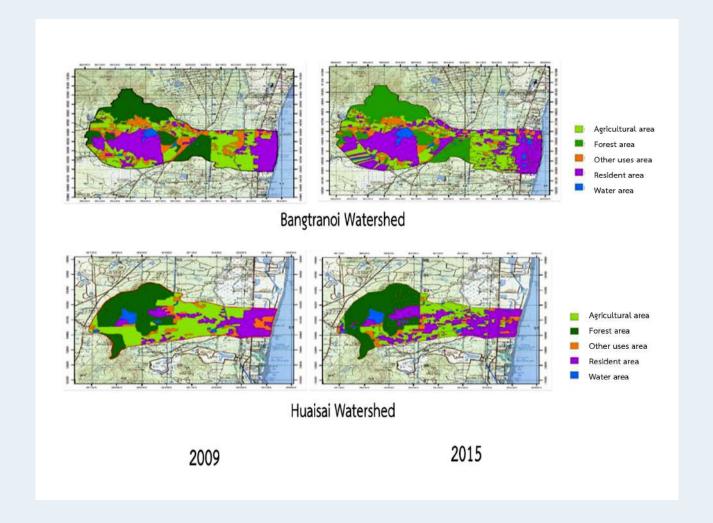


Fig.4 Land use change of the study watersheds (for the years 2009 and 2015)

**Table 2** Land use change patterns comparing the year 2009 with 2015 for Bangtranoi (BTN) and Huaisai (HS) Watersheds

	Bangtran	oi (sq.km.)	Huaisai	(sq.km.)
Land use type	2009	2015	2009	2015
Agriculture	19.50	17.61	7.06	4.66
Forest	16.54	16.07	6.41	6.64
Communities	17.49	21.55	3.86	6.04
Water bodies	1.32	2.94	0.71	0.99
Miscellaneous	9.25	5.93	1.47	1.18
Total	64.10	64.10	19.51	19.51

Footnote: % (change) is shown below the 2015 figures.

#### 4.2 Soil resources

The soil texture was classified as sandy loam in BTN and sand in HS. Soil infiltration showed very high rate for BTN and HS with an average of 31.52 and 30.91 cm/hr, respectively. Soil fertility focused on N, P, K

and Ca which were under the low rate while Mg showed a high rate in both BTN and HS (Table 3). On site soil erosion was classified as moderate rate for BTN (20.29 tons/ha/yr) whereas low rate was defined for HS (7.18 tons/ha/yr) (Table 4).

Table 3 Soil properties in Bangtranoi (BTN) and Huaisai (HS) Watershed

Soil properties	Unit	Waters	shed	Average	Rate
Son properties	Omt	BTN	HS	Average	Kate
Physical properties					
Soil texture	-	Sandy loam	Sand	-	-
Bulk density	gm/cm <sup>3</sup>	1.33	1.39	1.35	-
Infiltration rate	cm/hr	31.52	30.91	31.22	Very high
Chemical properties					
рН	-	5.6	5.3	5.5	Strongly acid
OM	%	1.2	0.73	1.1	Low
N	mg/kg	0.06	0.037	0.05	Low
Р	mg/kg	6.6	11	8	Low
K	mg/kg	81	48	71	Low
Ca	mg/kg	375	118	298	Low
Mg	mg/kg	124	19	92	High
Natural soil fertility	-	Low	Low	Low	Low

OM = Organic matter

Table 4 On-site soil erosion rate in Bangtranoi (BTN) and Huaisai (HS) Watershed

Factor	Unit	Water	shed	Average
T uctor		BTN	HS	Tiverage
R-factor		144.266	140.191	142.229
K-factor		0.196	0.168	0.182
LS-factor		6.71	3.176	4.943
C-factor		0.133	0.121	0.127
P-factor		0.802	0.791	0.797
A	Tons/ha/yr	20.286	7.178	13.723
A	Tons/rai/yr	3.246	1.149	2.198
Rate		Moderate	Low	Moderate

#### 4.3 Forest resource

Remaining forests covered approximately 25 and 34% for BTN and HS watershed, respectively. Forest types were mixed deciduous with dry dipterocarp forest, reforestation, beach, and mangrove forest and approximately 150 tree species were identified and can be characterized as follows (Table 5):

Mixed deciduous forest had an average crown cover of 40-50%; 123 species were found. *Shorea siamensis* Miq., *Lagerstroemia calyculata* Kurz. and *Pterocarpus macrocarpus* Kurz. are dominant species. Average stand density was 368 trees/hectare; average tree volume was 38.59 m³/ha and index of diversity was 22.28. A comparison with the previous study conducted in 2007 (Kasetsart University Report) found that the forest condition and ecology showed little change between 2007 and 2015.

**Table 5** Species, stand density, stand volume and Fisher's index of diversity in Bangtranoi (BTN) and Huaisai (HS) Watershed

Forest types		Tree	S	apling	S	eeding	Tree volume	Diversity index
	Species	Density (number/ha)	Species	Density (number/ha)	Species	Density (number/ha)	(cu.m./ha)	
Deciduous	123	368	116	563	92	1,273	38.59	22.28
Reforestation	70	296	77	437	41	1,100	37.21	18.88
Beach	35	253	34	628	16	1,082	39.47	9.77
Mangrove	5	765	2	8,000	3	36,000	79.83	0.89

#### 4.4 Water resources

Annual stream flow in BTN watershed was 9.69 Million Cubic Meters (MCM) (16.35% of annual rainfall) which was higher than HS watershed with only 2.63 MCM (14.32% of annual rainfall) (Table 6). In the dry season (December to April) MCM values were 1.09 and 0.30 or 11.25 and 11.41% of total flow of BTN and HS watersheds respectively. In the wet season (May to November) MCM values were 8.60 and 2.34 or 88.75 and 88.59% of total flow of BTN and HS watershed, respectively.

Most of water quality parameters in wet season (August 2015) of BTN and HS watershed was higher than dry season (April 2015) while, BOD, DO, TDS, Nitrate, Phosphate, TCB, and FCB in wet season were higher than dry season in BTN watershed. Besides, TCB and FCB in both BTN and HS watershed showed higher TCB (415 and 170 MPN/100 ml) and FCB (182.5 and 130 MPN/100 ml.) respectively in wet season. This may be caused by livestock activities along the stream channel.

However, this work found that both BTN and HS watershed water quality were in surface water quality standard value type 3 (Table 7 and Table 8).

#### 4.5 Socio-economic features

In the case of socio-economic aspects at BTN and HS watershed, it was found that the population characteristics of both study sites were similar. In addition, sanitation problems in waste water and garbage management still occurred in some areas. For utilization of water resources, there were no problems for drinking water in terms of both quantity and quality but samples in both watersheds have often faced a water shortage for household consumption in the dry period, especially in HS watershed. With respect to understanding, there was encouraging evidence of good understanding of fundamental forest law and natural resource conservation. Respondents in BTN and HS showed moderate to low participation respectively in action activities.

**Table 6** Annual stream flow amount in dry and wet season of Bangtranoi Watershed and Huaisai Watershed, Phetchaburi Province

				Discl	narge	
Season	Month	Rainfall	Bangt	ranoi	Hua	isai
		(mm)	MCM	mm	MCM	mm
	December	7.10	0.06	1.38	0.02	1.21
	January	15.30	0.09	1.26	0.02	1.11
	February	13.40	0.08	5.11	0.02	4.47
Dry period	March	48.50	0.32	8.66	0.09	7.59
	April	44.10	0.55	0.92	0.15	0.80
	Total	128.40	1.09	17.33	0.30	15.18
	Totai		(11.25%)		(11.41%)	
	May	107.70	1.32	20.94	0.36	18.34
	June	77.90	0.92	14.69	0.25	12.86
	July	98.80	1.03	16.41	0.28	14.37
Wet period	August	66.00	0.98	15.61	0.27	13.67
	September	118.00	1.65	26.16	0.45	22.91
	October	254.10	2.00	31.73	0.54	27.78
	November	90.50	0.70	11.07	0.19	9.70
	Total	813.00	8.60	136.61	2.33	119.63
			(88.75%)		(88.59%)	
	Annual	941.40	9.69	153.94	2.64	134.81
	% of rainfall	100.00	-	16.35	-	14.32

							Δ.	Parameter							
Location	Air temperature	Air temperature Water temperature	Hd	SOT	EC	Salinity	00	BOD	SS	Fat, oil & Grease	Hardness	N-NO <sub>3</sub>	Phosphate	Total coliform	Fecal coliform
	(°C)	(%)		(mg./L.)	( <b>µ</b> s/cm.)	(ppt)	(mg./L)	(mg./L)	(mg./L)	(mg./L.)	(mg./l. CaCO <sub>3</sub> )	(mg./l. N)	(mg./l. P)	(MPN/100 mL)	(MPN/100 ml.)
Outlet	25.85	30.04	7.87	39800.00	51.94	34.02	5.63	3.10	48.00	5.40	5900.00	76.0	0.32	14.00	9.30
Pond in Siep	27.45	34.97	8.15	577.00	1.04	0.00	4.92	8.70	27.00	1.40	105.00	76.0	0.61	11.00	4.50
Pond in Huai Chay	30.86	30.18	8.34	343.00	0.41	0.00	5.34	10.00	00.09	1.30	108.00	0.89	0.50	23.00	23.00
Pond in Khao Ka Puk	33.25	30.96	8.08	342.00	0.42	0.00	8.59	8.00	25.00	3.40	122.00	0.89	0.50	23.00	13.00
Reserevoir Huai Ta Pae	32.64	30.75	7.95	330.00	0.47	0.00	5.68	7.70	33.00	2.40	132.00	0.93	0.39	40.00	22.00
Reserevoir Thung Khal	34.57	32.76	8.38	302.00	0.46	0.00	10.49	4.30	38.00	4.00	136.00	0.81	0.50	95.00	49.00
Reserevoir Huai Hai Tay	32.99	31.87	7.75	295.00	0.47	0.00	6.87	3.60	18.00	1.00	156.00	0.93	0.37	49.00	33.00
Reserevoir Huai Sai Ngam	36.53	30.52	7.92	374.00	0.57	0.00	9.13	3.90	8.00	4.80	212.00	0.85	0.31	7.80	7.80
Hup Pa Pong Reserevoir	36.16	33.41	7.77	440.00	0.35	0.00	7.78	4.90	360.00	6.50	92.00	0.81	1.06	46.00	17.00
Water quality standard value		5/	59		1		4.00	2				5		20,000	4,000

Table 8 Water quality in rainy season (August, 2015)

							ď	Parameter							
Location	Air temperature	Air temperature Water temperature	듄	<u>\$</u>	Я	Salinity	8	BoD	SS	Fat, oil & Grease	Hardness	N-NO,	Phosphate	Total coliform	Fecal coliform
	്ര	്ര		(mg./t.)	(Hs/cm)	(bbt)	(mg./L)	(mg/L)	(mg/L)	(mg/L)	(mg/l. CaCO <sub>s</sub> )	(mg./LN)	(mg./l. P)	(MPN/100 ml.)	(MPN/100 ml
Outlet	28.89	28.84	7.78	42000.00	53.71	35.39	2.13	8.60	14.00	2.30	6300.00	2.60	0.32	920.00	350.00
Pond in Siep	32.50	30.61	9:26	944.00	1.55	0.00	14.19	22:00	36.00	3.80	132.00	2.38	080	220.00	140:00
Pond in Huai Chay	33.00	32.61	9.01	515.00	09'0	0.00	11.01	24.00	140.00	2.40	120.00	0.87	1.37	170.00	130.00
Pond in Khao Ka Puk	33.00	32.16	8.79	360.00	0.49	0.00	7.93	18.00	26.00	1.60	118.00	0.79	0.99	280.00	110.00
Reserevoir Huai Ta Pae	34.50	33,25	8.77	384.00	0.52	0.00	29:6	23.00	24.00	1.00	122.00	92.0	1.17	240.00	130.00
Reserevoir Thung Khal	35.00	32.80	8.77	304.00	0.49	0.00	9.63	16.00	26.00	6.40	130.00	0.73	1.72	220.00	95.00
Reserevoir Huai Hai Tay	35.00	29.01	8.52	268.00	0.49	0.00	6.25	9.00	84.00	7.70	160.00	0.73	0.99	170.00	49.00
Reserevoir Huai Sai Ngam	32.50	30,71	8.64	270.00	0.50	0.00	9.94	2.00	4.00	2.20	176.00	0.76	0.97	220.00	140.00
Hup Pa Pong Reserevoir	30.00	32.03	8.22	852.00	91'0	0.00	6.42	30.00	120.00	4.00	42.00	2.38	2.01	130.00	49.00
Water quality standard value		<sup>7</sup> 29	59				4.00	2				Ŋ		20,000	4,000

Table 7 Water quality in dry season (April, 2015)

#### V. CONCLUSION

From the results of each resource studied in BTN and HS watersheds, we found that in terms of forestry, remaining forest cover was only 25-34%. Forest fires occurred in dry season every year contributing to lower forest quality. SIEP and adjacent area were in rainshadow, with infertile soil. The reduced annual rainfall (941.4 mm) results in less annual stream flow (which represented only 14-16% of the annual rainfall). This situation will cause a water shortage in dry season (dry-flow only 11% of total stream flow). Encouragingly, water quality was still in type 3 of surface water standard and therefore suitable for household water consumption.

In terms of socio-economic involvement, the people in both watersheds showed moderate to low participation in action activities. Therefore, there was a greater need to encourage people participation in watershed management.

#### VI. RECOMMENDATIONS

Both BTN and HS watersheds would benefit from integrated watershed management in the following ways:

1. Providing opportunities to increase forest cover up to 40% of each watershed area especially on the hilly sites, where agricultural locations have poor soil and where misused land could be returned to forest areas.

- 2. Prevent forest fire in dry season based on people participation.
- 3. Increase water flow (during dry season/ dry flow) and retention by constructing check dams along the stream flow from the mountain in order to delay time of water flow to the sea. The optimal level of dry flow of both watersheds should be at least 20% of total flow.
- 4. Needs more people participation in watershed management by SIEP activities as follows:
  - provide training course in watershed management
  - provide study tour visit to other watersheds which has high people participation in watershed management and other King Bhumibol initiated projects.

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# Estimation of ecosystem water use efficiency using eddy covariance technique in dry dipterocarp forest of northern Thailand

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Abstract-Deforestation of northern Thailand has caused a major change in the hydrometeorological process at the ecosystem level. Water use efficiency (WUE) is an important ecophysiological index that changes consistently with the relationship between water and terrestrial carbon cycles. The focus of this paper was: (1) apply eddy covariance technique to estimate the ecosystem water used efficiency in dry dipterocarp forest in northern Thailand; and (2) to understand the seasonal variability of WUE in relation to meteorological conditions. CO, and water vapor fluxes were measured by the eddy covariance method during the period 2013-2015 over the dry dipterocarp forest Phayao site, Thailand (DPT). The seasonal variations of gross primary productivity (GPP), evapotranspiration (ET) and ecosystem WUE were analyzed. The annual average of ecosystem WUE ranged from 1.39 to 3.39 g Ckg-1H,O. The net radiation strongly dominated monthly scale GPP and ET. The

major driver of seasonally in WUE was soil water content while water vapor pressure deficit was the control factor in dry the season.

Keywords: dry dipterocarp forest, gross primary productivity, evapotranspiration, water use efficiency, eddy covariance technique

#### I. INTRODUCTION

The global rate of deforestation during 1990 to 2000 represented a loss about 16 million hectares per year [1]; primary forest in the tropics accounts for much of this. Mountainous headwater catchments often display considerable variability in ecosystem services such as water resources and water supply for human use which is scarce under deforestation in northern Thailand. In these activities, most of the major change in hydro-meteorological process is in the forest ecosystems. Water use efficiency (WUE) is an

important ecophysiological index that changes consistently with the relationship between water and terrestrial carbon cycles. Understanding the role of WUE at the canopy level in the forest ecosystem began in last century, and those results could play a more significant role in mountainous headwater catchments management practices. The development of flux-monitoring procedures including eddy covariance method to estimate the WUE in the forest has become popular. WUE in stand forest in flat terrain were dependent on atmospheric vapor pressure deficit (VPD) [2] and light intensity; these findings were consistent with those of Ouyand et al [3] who reported that the daily change in WUE at the canopy level were strongly influenced by VPD. In contrast, Judd, et al. (1995) found that the WUE was only weakly dependent on the levels of solar radiation and water dissipation. Inadequate information is available for forested watersheds. Therefore our main objectives were: (1) to estimate the ecosystem water used efficiency by using eddy covariance method in dry dipterocarp forest in northern Thailand; and (2) to understand the seasonal variability of WUE in relation to meteorological conditions.

#### II. MATERIALS AND METHODS

#### A. Site Description

The study was conducted in dry dipterocarp forest at the Phayao Site (DPT), Phayao Province, Thailand (19°02′ 14.38′′ N, 99°54′ 10.96′′ E; elevation 512 m). The experimental station is located at the University of Phayao near eastern site of Rongkhamloung Forest Park, close to the middle Ing river basin of the northern part of Thailand. The DPT site has a sloping terrain; the forest area covered 80 ha of upland dry dipterocarp vegetation. Five species were dominant. They were: Shorea obtuse Wall, Shorea siamensis Miq, Dipterocarpus tuberculatus Roxb, Dipterocarpus obtusifolius and Quercus sp. The canopy height

was approximately 15 m (measured in 2013). A tropical monsoon climate here brings a mean annual temperature of 26 deg C (max 35.72 deg C; min 16.94 and mean annual precipitation of 1,262 mm as reported by TMD for the period 1998-2007). Soil textures were sandy loam at 0-10 cm depth and a sandy clay loam below 11 and down to 40 cm in depth.

### B. Measurement of CO<sub>2</sub> and water vapor fluxes and microclimate variables

CO, and water vapor fluxes were measured at 42 m height from the ground surface by open path eddy covariance system including a infrared CO2/H2O vapor analyzer (IRGA, model EC150 Campbell Scientific Inc., USA) and a 3-D sonic anemometer-thermometer (model CSAT3, Campbell Scientific Inc., USA). The sampling frequency was 10 Hz, averaging time in 30 min data recording by datalogger (model CR1000, Campbell Scientific Inc., USA). Micrometeorological variables, such as air temperature, relative humidity, wind speed and direction, barometric pressure and precipitation all in a single device were measured by a weather transmitter at 36 m height (model WXT520, Campbell Scientific Inc., USA). Net radiation by 4-Componennt net radiometer was installed at 36 m height (model NR01-L, Campbell Scientific Inc., USA), leaf area index (LAI) was measured by plant canopy analyzer(LAI-2200, LI-COR, Lincoln, Nebraska, USA) and the position of soil temperature (thermocouple probe) and soil water content at 5 cm, 15 cm and 50 cm depth respectively (CS616, water content reflectometer, Campbell Scientific, Inc., Logan, Utah, USA). Data were sampled at 1min and 30 min frequency and recorded using a datalogger (CR1000, Campbell Scientific, Inc., Logan, Utah, USA).

#### C. Flux calculation, WUE and data processing

The fluxes of  $CO_2$ ,  $(F_{\varpi})$  latent heat  $(\lambda E)$  and ecosystem water use efficiency (WUE) were determined [5] as:

$$F_c = \rho(\overline{w'c'}) \tag{1}$$

$$\lambda E = \lambda \rho (\overline{w'q'}) \tag{2}$$

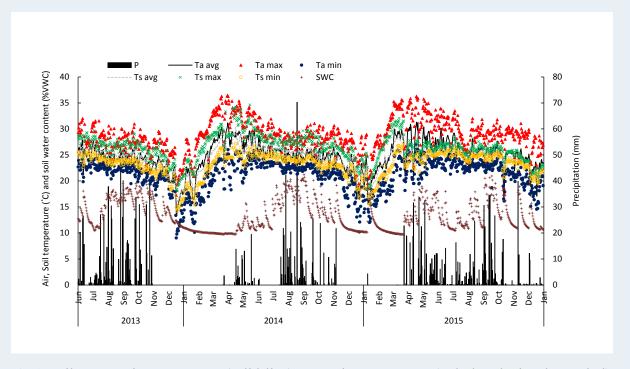
$$WUE = \frac{GPP}{ET} \tag{3}$$

were  $\rho$  is air density, w' is the instantaneous deviation vertical wind velocity, c is the instantaneous deviation of CO, concentration,  $\lambda \rho$  is the latent heat of vaporization, q' is the instantaneous deviation of water vapor density from the mean, GPP is gross primary productivity and ET is evapotranspiration. Data acquisition for flux measurements was done with EddyPro express software (open source version 6.0.0, LI-COR Bioscience 2010). Raw data were processed to half-hourly averages with the EddyPro software. In this study, fluxes data uses a double rotation with 30 min block averaging. Spikes were removed by statistical tests embed in the software [6, 7]. Corrections for density fluctuations [8] were applied during post-processing to the half-hourly averaged data. Spectral correction was followed those described by [9]. Periods with low turbulence conditions were excluded based on friction velocity (u\*<0.05 m/s) by ejection data were small turbulence (applying appropriate corrections for site-specific parameter). The amounts of ET half-hourly dataset were applied from Eqs (2) using specific heat of vaporization [10] and gaps were filled using the mean diurnal variation (MDV) and nonlinear regression method, respectively [11].

#### III. RESULTS AND DISCUSSIONS

#### A.Climate conditions

The seasonal patterns of climatic variables and soil water content are shown in Fig.1. The results of daily air and soil temperatures, precipitation and soil water content during June 2013 to December 2015 are shown in Fig.2. Daily air and soil temperatures varied between 9.04 to 36.45°C and 14.15 to 34.62°C respectively. The highest air and soil temperatures were observed in March, April and May, while the lowest air and soil temperatures were observed in December and January. Both were following the seasonal changes respectively. The average of air temperature (24.68±3.82°C) and soil temperature (24.47±2.58°C) were similar; moreover the most values of minimum of soil temperature was higher than minimum of air temperature throughout the year. However the fluctuation of air temperature was higher than soil temperature was of around 5% during study period. As a general pattern, rainfall in this upland dipterocarp forest started during May and endured until October, thus characterizing a rainy season. During this season the rainfall was>100 mm. The rest of the year was a dry season. The total precipitation in 2013, 2014 and 2015 were 816, 968 and 927 mm respectively.



**Fig.1** Daily mean air temperature (solid line), max air temperature (red closed triangle symbol), min air temperature (blue closed circle symbol) and, daily sum rainfall (solid bar in unit of mm) measured at 36 m height from the soil surface. Daily mean soil temperature (grey square dot line), max soil temperature (green cross symbol), min soil temperature (orange open circle symbol) and daily mean soil water content (brown plus symbol) in unit of% VWC at 5 cm depth during the study period. Note that Ta, Ts, P and SWC represented air temperature, soil temperature, precipitation and soil water content respectively

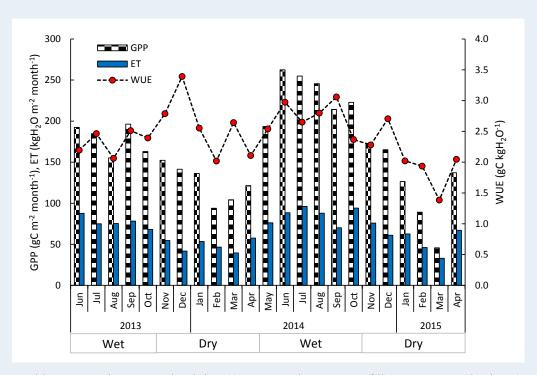
The pattern of soil water content (SWC) in general changed corresponding to the precipitation. During the dry season (November-April) the mean SWC ranged between 10-14% VWC in addition to wet season were about 12-18% VWC. The annual mean of SWC was 13.47±3.02%VWC and maximum (25.08%VWC) occurred in November 2015 because we found that the rainfall lasted for 2 hours (6.00-8.00 pm) consecutively in that day (27.68 mm), while the minimum was found in April 2014 (9.67% VWC) when the dry period started.

#### B. Monthly variations of GPP, ET and WUE

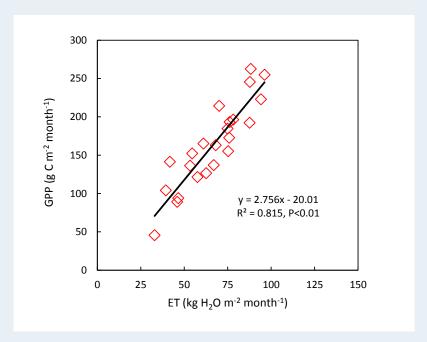
Figure 2 shows the monthly patterns of gross primary productivity (GPP) during the study period which varied between 46 to 262 g

C m<sup>-2</sup> month<sup>-1</sup> (164±55 g C m<sup>-2</sup> month<sup>-1</sup>) and maximum was founded in wet season such as in June in 2014, while minimum was occurred in March in 2015, during dry season. These patterns were correlated significantly (R<sup>2</sup>=0.81, P<0.01) with evapotranspiration (ET) (Fig.3). The monthly of ET was ranged between 33 to 96 kg H<sub>2</sub>O m<sup>-2</sup> month<sup>-1</sup> (67±18 kg H<sub>2</sub>O m<sup>-2</sup> month-1) in addition high ET was found in wet season (May to October) and the rest was found in dry season (November to April). High ecosystem water use efficiency (WUE) occurred during transition from wet to dry and varied between 1.39 to 3.39 g C kg<sup>-1</sup> H<sub>2</sub>O during study period. The annual WUE was 2.43±0.44 g C kg-1 H<sub>2</sub>O. This study was consistent that of a warm-temperate mixed plantation in north China reported by Tong, et al. (2014), who found that WUE ranged from 1.72 to 2.41 g C kg<sup>-1</sup> H<sub>2</sub>O and the average during 5-years was 1.90 g C kg<sup>-1</sup> H<sub>2</sub>O. Tong, et. al., suggest that soil water

content was the dominant factor contributing to WUE.



**Fig.2** Monthly gross primary productivity (GPP; grey bar pattern fill), evapotranspiration (ET; blue solid fill) and ecosystem water use efficiency (WUE; red circles line) during study period in dry dipterocarp forest



**Fig.3** Relationship between monthly gross primary productivity (GPP) and evapotranspiration (ET) during study period (2013-2015) in dry dipterocarp forest

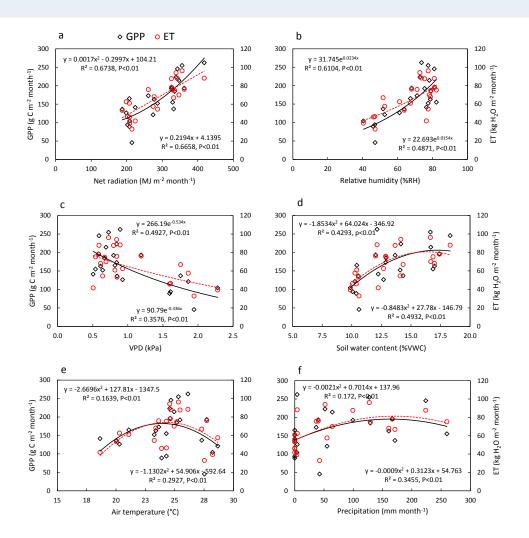
### C. Impact of climatic variation on the relationships between variations of GPP, ET and WUE

The monthly patterns of total GPP and ET had similar relationships with net radiation, relative humidity (% RH), soil water content (SWC), vapor pressure deficit (VPD), air temperature and precipitation (Fig.4). GPP and ET had strongly significant relationships with net radiation (P<0.01) and dominated both by about 70% (Fig.4a) and the rest had positive relationships with% RH, SWC, air temperature and precipitation (Fig.4b, 4d, 4f) respectively. However the reduction in GPP and ET was obvious when higher temperature occurs (Fig.4e). Furthermore, under high VPD condition, the GPP and ET declined (Fig.4c), because the maximum photosynthesis in dry dipterocarp forest flux site at the Ratchaburi site Thailand (DFR site) occurred under with VPD. The exponential relationship between GPP, ET and VPD in such periods coincided with less rainfall and SWC (<10%VWC) (Fig.1) and are in phase with the results reported by Tong, et al. (2014). Moreover in the dry season, WUE in dry dipterocarp forest decreased significantly with an increase of VPD (P<0.01) while in wet season this was not important (Fig.5). Typically, the VPD involved photosynthesis and respiration

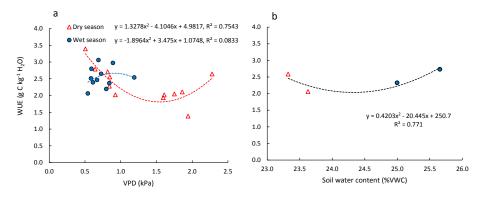
processes; if VPD was very high (lower air humidity) that means we have extensive dry conditions and thus a response by the plant stomata, which were closed and less transpiration and soil evaporation occurs. With lower stomatal conductance the net photosynthesis rate drops steeply but the on-going needs of evapotranspiration ensures that water loss continues. This leads to a reduction in WUE (Fig.5a). During the study period (2013 to 2015) the seasonal average WUE in DDF was negatively related to lower soil water content in the dry season. This returned to a positive relationship in the wet season (Fig.5b).

#### D. Conclusions

The major aim of the study was to apply eddy covariance technique to estimate the ecosystem WUE in dry dipterocarp forest in northern Thailand. It was found that WUE at above canopy ranged from 1.39 to 3.39 g C kg<sup>-1</sup> H<sub>2</sub>O. The technique here can be useful. The monthly and seasonal variability of GPP and ET had similar relationships to net radiation (70%). VPD was driver of WUE in dry season, while soil water content was the main factor to control WUE throughout the year. It is hoped that these findings will contribute to improving forest management practices.



**Fig.4** Relationship of monthly gross primary productivity (GPP), evapotranspiration (ET) with (a) monthly mean net radiation, (b) relative humidity, (c) water vapor pressure deficit, (d) soil water content, (e) air temperature and (f) monthly total precipitation during study period (2013-2015) in dry dipterocarp forest



**Fig.5** Relationship of ecosystem water use efficiency (WUE) with (a) monthly mean water vapor pressure deficit (VPD) and (b) seasonal mean soil water content. Note that dry season represent November to April and wet season represent May to October during study period (2013-2015) in dry dipterocarp forest

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# Teak plantation phenology changes and its relationships to climate variability in Lampang Province, North Thailand

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Abstract-Vegetation phenology is sensitive to climate variability, and understanding changes in phenology are necessary to infer the response of forest towards climatic variability. In this study, time series of Normalized Difference Vegetation Index (NDVI) extracted from Moderate Resolution Imaging Spectroradiometer (MODIS) from 2009 to 2012 was used to investigate changes of teak plantation phenology in Lampang Province. The NDVI was validated by Leaf Area Index (LAI) and the negative logarithm of the ratio of daily downward solar radiation on the forest floor to that above the canopy (NLR).

The results show that NDVI was significantly correlated with LAI (r=0.81), and NLR (r=0.77). Analysis from phenology metrics shows that length of growing season ranged between 264-324 days, starting from March to May and ending in January to March of the following year. In 2010, the starting of this growing season was delayed and the length of season was shorter than other years. NDVI was negatively correlated to maximum temperature (r=-0.85, p<0.0001),

whereas positively correlated to precipitation (r=0.51, p<0.0001) during the period from April to May. During the end of season (October to December), NDVI had significant and positive relationship with minimum temperature and precipitation (r=0.81, r=0.64), respectively.

This study demonstrates that NDVI extracted from satellite is able to capture the teak plantation phenology and provide spatial and temporal information for long term monitoring. The significant correlation between NDVI and climate factors in this study implies that future variability in meteorological variables under climate change would affect the forest ecosystem.

Keywords: climate variability, phenology, teak plantation, NDVI

#### I. INTRODUCTION

Teak is one of the most well known timbers of the world. Teak normally grows within a latitudinal range of 16° to 20°N and a longitudinal range of 97° to 101°E. Teak

forest is found in mixed deciduous forest throughout the North of Thailand and it covers about 25,000 km² [1]. The optimum condition for growing teak is where the range of annual rainfall is approximately 1,250-1,650 mm with the marked dry season of 3-5 months. Teak seedlings grown under the high constant soil moisture (near the saturation point) for eight weeks were about five times greater, in terms of dry matter production, than those grown under the severe soil moisture stress (near the wilting point) [1]. The critical maximum and minimum day/night temperature for growth and development of teak seedlings were about 36°/31° and 21°/16°C, respectively [2].

According to the model projections by Gopalakrishnan et. al. [3], 30% of teak grids in India are vulnerable to climate change under both A2 and B2 scenarios (scenario A2: atmospheric CO, concentration reaches 740 ppm by 2085; B2 scenario: CO<sub>2</sub> concentration reaches 575 ppm by 2085), the future climate may not be optimal for teak at these grids due to changes of sunlight, water and CO<sub>2</sub>. This suggests that teak plantations in Thailand may be vulnerable to changing climate. Therefore, monitoring teak plantation dynamics and understanding its relationship with climate variability is becoming important which should be considered for long-term teak plantation programs.

Vegetation phenology is the study of the timing of periodic biological events in the plant as influenced by the environment [3]. Long-term monitoring phenological patterns on trees provide information to indicate how plants have responded to variations in climatic conditions, which links to biodiversity and ecosystem services [4].

In Thailand, minimum and maximum temperatures have been increasing continuously during the last 60 years [5]. Extreme climate phenomena such as El Nino in 1997-1998 and 2009-2010 have become more frequent and severe. Many areas in the North of Thailand

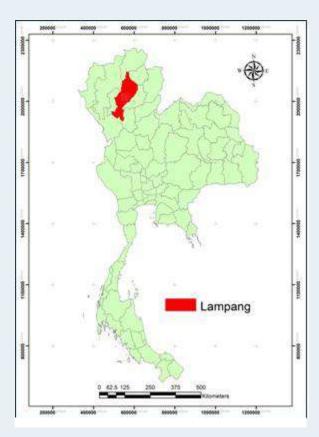
were affected by drought during summer to early rainy season in 2010 [5]. Other researches have shown that temperature extreme indices have significantly increased in Northern Thailand during 1960-2010, and climate projections indicate that summer days are expected to increase significantly in the future [6]. Annual rainfall is projected to increase by 9.65% in the period of 2011-2099 compared to the period 1960-2010 [6]. However, the impacts of projected climate changes on the vegetation of the tropic zones, particularly Southeast Asia, are currently poorly understood [7]. Therefore, there is an urgent need to take into account such impacts in order to determine the effects of climate factors on forest phenology including teak plantation.

Satellite imagery provides consistent and repeatable measurements at a spatial and temporal scale of vegetation dynamics [8], [9], [10]. Among remotely sensed surface parameter, Normalized Difference Vegetation Index (NDVI) has been widely used as an indicator of vegetation growth status, special density distribution and phenology [11], [9], [12], [13]. In terms of forest ecosystem and biodiversity research in Thailand, there is a need to increase our understanding of how the vegetation responds to climate variability in the spatial and temporal scale. This research paper is the first step trying to fill the knowledge gap and to quantify the response of vegetation dynamics to climate variability, by using teak plantation as a case study.

#### II. MATERIALS AND METHODS

#### A. Study Area

Lampang is situated in Northern Thailand with an area of 12,534 square kilometers. Lampang is located on a plateau with an altitude of 268.80 meters above sea level (Fig.1). In Lampang, the maximum summer temperature was 41.5°C, while the minimum winter temperature was 10.5°C. The average



**Fig.1** Location of teak plantation in Lampang Province

annual rainfall was 1,098 mm. Teak plantation is widely distributed in Lampang. Based on topography, precipitation and temperature, Lampang is the geographic representation of Thai provenances for field trials of teak genetics [14], therefore it was selected for this study.

#### B. Data Used

MODIS Data: Surface Reflectance MOD09Q1 of MODIS product providing Bands 1 (Red) and Band 2 (NIR) at 250-meter resolution and MOD09A1 at 500 meter resolution in an 8-day period were used in this study. Cloud cover is present in MOD09Q1 images, which limits the potential of images for ground information extraction. Removing cloud and replacing cloud contaminated pixels is necessary in phenology data extraction. All series of 184 images was applied with cloud removal method, developed by Hoan and

Tateishi [15] to provide free cloud data sets for further analysis on teak plantation phenology.

- 2) Meteorological Records: Climate data used in this study was obtained for the period of 2009-2012 from Thai Meteorological Department. The 4-year variation (2009-2012) of the following climatic factors was analyzed:
  - Maximum and minimum temperature: the daily maximum and minimum temperatures was averaged and aggregated for an 8-day period.
  - Accumulated precipitation: the total precipitation was computed for each 8-day period.

In general the growing season of teak plantation starts in March or April and ends in January or February of following year [16], therefore whole year meteorological data was used in this study. The nearest meteorological station to study site of teak plantation in Lampang province was used for analyzing correlation between NDVI and climate variables (air temperature and precipitation).

3) Observation Data: The observation data for validation of the NDVI pattern in this study were collected from teak plantation in Mae Mo, Lampang province, Northern Thailand (18°25'N, 99°43'E, 380 meter above sea level) by Yoshifuji et al. [16].

Observation data were collected from previous research including the negative logarithm of the ratio of daily downward solar radiation on the forest floor to that above the canopy (NLR) and Leaf Area Index (LAI, m<sup>2</sup>m<sup>-2</sup>) [17], [18]. The collected data are daily data and in this study, they were aggrerated to 8 days temporal resolution for comparing to teak plantation NDVI (Fig.5).

#### C. Methodology

1) Time Series Analysis for Phenological Metrics of Teak Plantation: At a pixel scale (250 x 250 meter), 46 points NDVI time series revealed seasonal growth of teak plantation in each year. Savitsky-Golay as discussed by

Jonsson and Eklundh in TIMESATsoftware packagewas used to fit the curve of time series data following second order polynomial and to extract the following phenological metrics [19], [20], [21], [22].

Start of growing season (SOS): This is defined as the dates of leaf unfolding, this study considered SOS as a date when NDVI increases to 5% of the amplitude during the beginning period of the NDVI time series. For the series of NDVI in a given NDVI and NDVI is the maximum of NDVI and NDVI is minimum of NDVI in the first half of the year. NDVI start was calculated as follows;

$$VI_{end} = NDVI_{min} + (NDVI_{max} - NDVI_{min}) \times 0.05$$

 End of the season (EOS): This is defined as the dates leaf discoloration and leaf fall at the end of season. This study considered EOS as a date when NDVI decreases to 5% of the amplitude during the ending period of the NDVI time series. NDVI<sub>end</sub> was calculated as follows;

$$NDVI_{start} = NDVI_{min} + (NDVI_{max} - NDVI_{min}) \times 0.05$$

- Length of the growing season (LOS) is the number of days of growth from the start to the end of this season.

The results of 5% changing in NDVI value from minimum for SOS and EOS agreed to the transition date of LAI index and NLR, therefore this threshold has been applied for extracting seasonality data such as start, end of the season and the length of the season in this study.

2) Relationship between NDVI and Climate Factors: Daily data at the meteorological station in Lampang Province were aggregated to an 8 day period by calculating average for temperature and accumulated precipitation. Base on the distribution of data, the non-

parametric Spearman was applied to check the correlation coefficient between NDVI and climate factors [23].

#### III. RESULTS AND DISCUSSION

#### A. NDVI Time Series of Teak Plantation

The variation of NDVI, precipitation, minimum and maximum temperature at Teak plantation are shown in Fig.2, 3 and 4 respectively. Rainy season starts between March to May, the same time as the teak leaf starts to bud reflecting the gradual increase of NDVI values. Rainy season ends between October and November, corresponding to the decrease of NDVI values in this period of time (Fig.2).

During April which is the hottest month, NDVI value was lowest, indicating the leafless period of teak plantation. NDVI values increased from 0.35-0.40 to 0.75-0.80 during May to October, and then it decreased in November and December (Fig.3, 4). Growing season ended in January, February or March in different areas.

The linear correlation between NDVI with LAI and NLR was found, confirming the cloud free data set. It was found that NDVI was significantly correlated with LAI (r=0.81, p<0.0001), and NLR (r=0.77, p<0.0001) (Fig.6). This correlation is consistent with other previous reports. For example, the relationship between NDVI and field measured LAI in deciduous forests were reported by Madugundu et al. [24]. In their study, NDVI was strongly correlated with LAI (r2=0.68, p≤ 0.05) but showed evidence of saturation above a biomass of 100 g/m<sup>2</sup> and an LAI of 2 m<sup>2</sup>/m<sup>2</sup> [25]. Potithep et. al. [23] has also found that NDVI changes in relation to the seasonal variations of LAI [26]. These results indicate that the preprocessing NDVI derived from satellite is sufficient to capture the teak forest phenology.

#### B. Phenological Metrics of Teak Plantation

Based on the phenological metrics extracted from TIMESAT program, SOSs varied among these three years, which started at 96, 152 and 80 day of year (DOY) in 2009, 2010 and 2011, respectively (Table 1). SOS in 2010 was delayed compared to other years. El Niño in 2010 may contribute to this change in phenology (Fig.3, 4).

**Table 1** Phenological Metrics of Teak Plantation Period 2009-2012

Year	SOS (DOY)	EOS (DOY)	LOS (Day)
2009-2010	96 (April)	60 (March)	324 days
2010-2011	152 (May)	63 (March)	264 days
2011-2012	80 (March)	22 (Jan)	295 days

On the other hand, EOSs in 2009, 2010 and 2011 were on 60, 63 and 22 DOY, respectively. As a result of the changes in SOS and EOS, LOS in 2010 with El Niño was about 264 days; shorter than in 2009 and 2011 by about 60 and 31 days, respectively. In general, analysis from phenology metrics shows that LOS of teak plantation ranged between 264 and 324 days. SOS occurred from March to May while EOS occurred in January or March of the following year.

The patterns of teak forest phenology extracted from MODIS NDVI are consistent with those previously reported. Yoshifuji et al. [14] concluded that canopy duration of tropical seasonal forest is about 300-320 days.

#### C. NDVI and Its Response to Climate Variables

The Spearman correlation coefficient between NDVI (8 day period, 250 m resolution) and climate factors was calculated. Results indicate that NDVI was significantly and negatively correlated with maximum temperature (r=-0.85, p<0.0001), positively correlated with precipitation (r=0.51, p<0.0001) in the period of April-May (Fig.7). During EOS (October to December), NDVI had a significant and positive

relationship with minimum temperature and precipitation (r=0.81 and r=0.64, p<0.0001, respectively) (Fig.8). These results imply that growing season might start when temperature decreases with precipitation increases during April to May. Thus, the results suggest that climate variables such as precipitation and temperature were the main controlling factors for NDVI, corresponding to plant phenology. However, more analysis on this relationship is needed to be conducted at teak plantations with different topographic and climate conditions, in order to test the hypothesis that precipitation and temperature control teak phenology and obtain further understanding on phenology and climate variation, especially under the context of climate changes.

#### IV. CONCLUSIONS

In this study, four years time series of MODIS NDVI image were processed with cloud removal in order to investigate the phenological variations driven by climate variability. From the results, we concluded that:

- Processed MODIS NDVI was able to capture the changes of phenology of a teak plantation in this study.
- The SOS of teak plantation was delayed in El Nino year, with significant effects on the variations of LOS during four years in this study.
- Teak forests NDVI have a stronger relationship to maximum and minimum temperature than precipitation.
- retrics (such as comparison with photographs and field sensor data) in relation to meteorological variables is required for further understanding of the relationships between teak plantation phenology and climate variation, especially under the context of climate change.

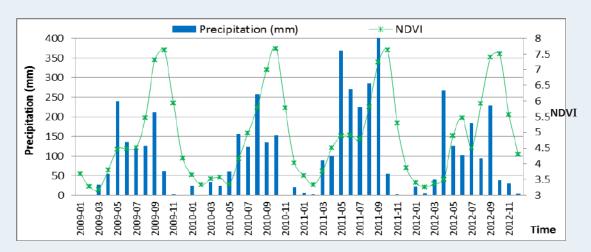


Fig.2 Time series of NDVI (green line) and precipitation (blue bar) of Teak plantation period 2009-2012

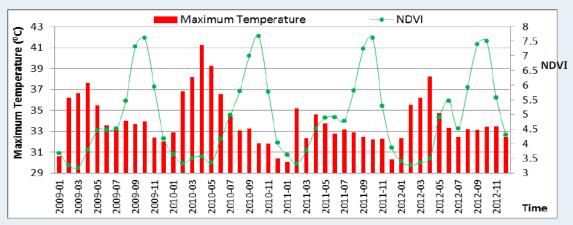
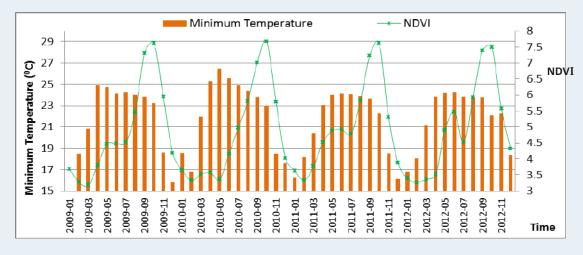
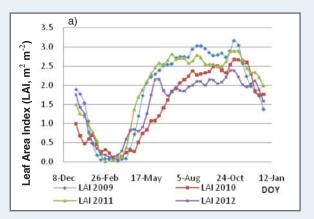
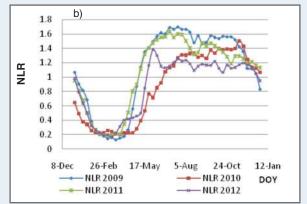


Fig.3 Time series of NDVI (green line) and maximum temperature (red bar) of Teak plantation period 2009-2012

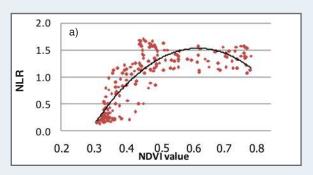


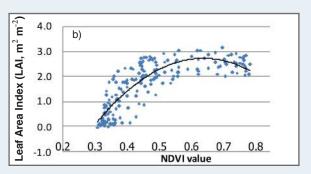
**Fig.4** Time series of NDVI (green line) and minimum temperature (orange bar) of Teak plantation period 2009-2012



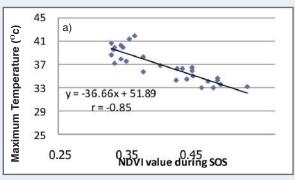


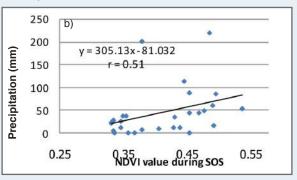
**Fig.5** The observation data of teak forest a) Leaf Area Index (LAI, m<sup>2</sup>m<sup>-2</sup>); b) the negative logarithm of the ratio of daily downward solar radiation on the forest floor to that above the canopy (NLR)



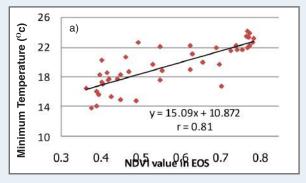


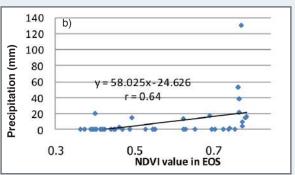
**Fig.6** Scatter plot describing the correlation between a) NDVI and NLR (r=0.77); b) NDVI and LAI (r=0.81)





**Fig.7** Scatter plot describing the correlation between a) maximum temperature with NDVI; b) precipitation with NDVI during the start of growing season (April-May)





**Fig.8** Scatter plot describing the correlation between a) minimum temperature with NDVI; b) precipitation with NDVI during the end of growing season (October-December)

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# Plant diversity and carbon storages in deciduous forests at the Huai Hong Khrai Royal Development Study Center, northern Thailand

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Abstract-Assessment of plant diversity and carbon storages in dry dipterocarp (DDF) and mixed deciduous (MDF) forests at Huai Hong Khrai Royal Development Study Center, Chiang Mai, northern Thailand, was carried out in 2011 using 47 plots, each of size 40×40 m, for vegetation study in areas of sandstone, shale and volcanic rock. Integrated watershed management has practiced here for 32 years since Center establishment in 1984 by the King's initiation and recommendations. A total of 186 species (140 genera, 63 families) existed in these forests: MDF, 119-125 species and DDF, 60-115 species. Shannon-Wiener Index of species diversity was higher in MDF (5.65) than DDF (3.17 to 4.76). Tree density in MDF varied in a range of 2,618-3,973 tree ha-1 while DDF had 3,019-3,706 tree ha-1. Different soils affected plant growth, biomass production, and carbon storages in biomass and soil. Soils varied from shallow with fragmented rocks (Order Entisols),

moderately deep (Inceptisols) and deep (Ultisols, Alfisols/Oxisols). Plant biomass amounts were higher in MDF (177.19-195.83 Mg ha<sup>-1</sup>) than DDF (84.18-95.38 Mg ha<sup>-1</sup>), and biomass carbon amounts in MDF and DDF were measured at 87.36-96.56 Mg ha<sup>-1</sup> and 41.79-47.12 Mg ha<sup>-1</sup>, respectively, whereas soil carbon storages were 49.86-65.56 Mg ha<sup>-1</sup> and 12.27-31.45 Mg ha<sup>-1</sup>. Ecosystem carbon storages were measured to be 139.82-152.92 Mg ha<sup>-1</sup> in MDF and 54.06-78.57 Mg ha<sup>-1</sup> in DDF.

*Keywords*: carbon storage, deciduous forests, plant diversity

#### I. INTRODUCTION

Huai Hong Khrai Royal Development Study (HHKRDS) Center is designed as a center of study, experiment and research on integrated watershed management. Initiated by the King on his recommendations to find out suitable development approaches for northern Thailand so as to extend knowledge to farmers in surrounding villages of this northern region. Before 1984, this watershed was very poor covered by degraded forests. The forests have protected the watershed upstream, and downstream areas are agriculture and fisheries. Reforestation by planting multi-purposed species is practiced yielding pole wood, fuel wood and fruits, and soil-water conservation to increase site moisture. Fifteen water reservoirs are made over the area, and check dams are placed along streams help to settle sediments, retain moisture, and encourage wildlife. Fish are taken from water reservoirs, whereas agriculture and pasture, and mushroom culture are carried out in the lower watershed area. Each year, many visitors, either Thais or foreigners, come here to learn integrated natural resource management.

DDF and MDF cover various soils and parent rocks. Different soil types influence the variation of plant communities: species composition, richness and diversity, plant growth and production. Other factors such as rainfall amount, topography, altitude, and microclimate are also important factors. Soils under sub-type DDF varied from Order Entisols (shallow) to Inceptisols (moderately deep) and Ultisols (deep) as in [1]. Four dipterocarps are dominant species in DDF: Teng (Shorea obtusa), Rang (S. siamensis), Hiang (Dipterocarpus obtusifolius) and Pluang (D. tuberculatus), while species in MDF include teak (Tectona grandis). Carbon sequestration by forests as the carbon sink is an important process of reducing carbon dioxide and global warming. [2], [3].

This research aimed to provide the overall assessment of plant species diversity and carbon storages in two deciduous forests, 26 years after Center establishment.

#### II. MATERIALS AND METHODS

#### 1. Study area

The HHKRDS Center is about 27 km north of Chiang Mai city. It covers an area of 1,360 ha (8,500 rai) and altitude range of 350-591 m above m.s.l. Average annual rainfall, maximum and minimum air temperatures, and water evaporation have been reported as 1,328.9 mm, 32.2°C and 18.9°C, and 1,222.6 mm per year, respectively.

#### 2. Plant community study

A plant community analysis was used for vegetation study. The 47 plots, each of size 40 x 40 m (0.16 ha), were used and arranged randomly over the forest. Stem girths at 1.3 m above ground and tree heights of all species were measured. Plant data were calculated for the parameters: frequency, density, dominance, importance value index and Shannon-Wiener Index of species diversity, as in [4]. Forest condition index (FCI) was calculated using the following equation, as in [5].

FCI = 
$$\Sigma$$
 n<sub>1</sub>.10<sup>-4</sup> + n<sub>2</sub>.10<sup>-3</sup> + n<sub>3</sub>.10<sup>-2</sup> + n<sub>4</sub>.10<sup>-1</sup> + 1(n<sup>5</sup>) + 2(n<sub>6</sub>) + .....

#### When

 $n_1$  = number of trees having girth <25 cm

 $n_2$  = number of trees having girth 25 to <50 cm

 $n_3$  = number of trees having girth 50 to <75 cm

 $n_4$  = number of trees having girth 75 to <100 cm

 $n_s$  = number of trees having girth 100 to < 200 cm

 $n_6$  = number of trees having girth 200 to < 300 cm

#### 3. Plant biomass estimation

Data of stem girth and tree heights of tree species were used for the calculation of plant biomass by these equations, as found in [6].  $W_S = 189 (D_2H)^{0.902}$   $W_B = 0.125Ws^{1.204}$  $1/WL = (11.4/Ws^{0.90}) + 0.172$ 

Where

 $W_S$  = stem biomass in kilogram  $W_B$  = branch biomass in kilogram  $W_L$  = leaf biomass in kilogram

Units of stem diameter (D) and tree height (H) were in meter. Root biomass was calculated using this equation, as found in [7].

 $W_R = 0.026 (D^2H)^{0.775}$ 

Units were in kilograms for root biomass  $(W_R)$ , centimeters for stem diameter (D), and meters for tree height (H).

#### 4. Carbon in plant biomass

Carbon amounts in tree biomass were calculated by multiplying biomass with average carbon contents in plant tissues, as in [8]. The carbon contents in stem, branch, leaf and root of 62 species in Thailand were reported to be 49.90%, 48.70%, 48.30% and 48.20%, respectively.

#### III. RESULTS AND DISCUSSION

1. Species richness and composition in relation to parent rock

#### 1.1 DDF

**Sandstone:** A total of 60 species representing (50 genera and 31 families) existed in the forest, and most areas were dominated by Hiang. Species with 100% frequency were Hiang, G. usitata, Teng, Pluang and Rang. Average density was 3,706 trees ha<sup>-1</sup>. Hiang had the highest density, followed by Teng, *G. usitata, M. scutellatum,* Rang and Pluang. Hiang had also the highest dominance, followed

by *G. usitata*, Pluang, Teng and Rang. Hiang had the highest IVI (23.19%), followed by *G. usitata*, Teng, Pluang and Rang.

**Volcanic rocks:** A total of 115 species (representing 88 genera and 47 families) were found. Most of the area was dominated by Teng and Rang. Teng had 100% frequency. Species with >80% frequencies were Pluang, Rang, *Dalbergia assamica, Gardenia obtusifolia* and *Semecarpus albescens*. Hiang had 8% frequency. Average density was 3,019 trees ha<sup>-1</sup>. Teng had the highest density, followed by Rang, *X. xylocarpa* and Pluang. Teng had the highest dominance, followed by Rang, Pluang and *X. xylocarpa*. Teng had the highest IVI (19.65%), followed by Rang and Pluang.

#### 1.2 MDF

Sandstone: A total of 125 species (representing 99 genera and 40 families) were observed. Dominant trees were teak, *X. xylocarpa*, *Terminalia mucronata* and *Lagerstroemia duperreana*. Tree species which had 100% frequency were *X. xylocarpa*, *Irvingia malayana*. Teak had 80% frequency. Average density was 3,973 trees ha<sup>-1</sup>. *X. xylocarpa* had the highest density, followed by *L. duperreana*, *H. cordifolia* and *D. assamica*. A bamboo, *Dendrocalamus membraneceus* had the highest dominance, followed by *I. malayana*, *X. xylocarpa*, and teak. The bamboo had also the highest IVI (9.03%), followed by *X. xylocarpa*, *I. malyana*, *T. mucronata*, teak.

**Shale:** A total of 119 species (representing 96 genera and 45 families) were found. Most areas were dominated by the bamboo. Other dominant trees were teak, *X. xylocarpa*, *L. duperreana* and *T. mucronata*. These dominant species had low frequencies, 20-60% that implied a distribution in patches. Average density was 2,618 trees ha<sup>-1</sup>. *X. xylocarpa* had the highest density, followed by *L. duperreana*,

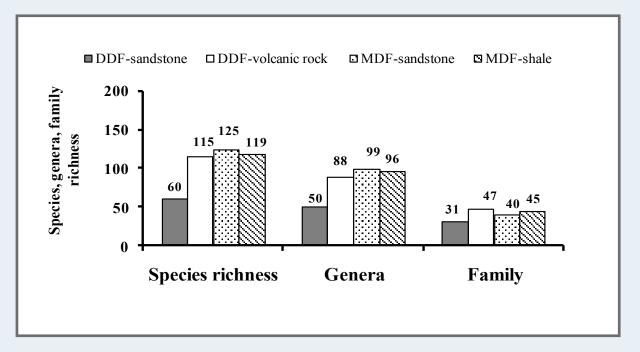


Fig.1 Species, genera and family richness of plants in DDF and MDF

teak, *S. oleosa* and *T. mucronata*. The bamboo had the highest dominance, followed by teak, *X. xylocarpa*, and *T. mucronata*. The bamboo had also the highest IVI (19.179%), followed by teak, *Sterculia pexa*. Species, genera and family richness of plants in DDF and MDF are shown in Fig.1.

#### 2. Species diversity and forest conditions

#### 2.1 Species diversity

Shannon-Wiener Index (SWI) of species diversity was determined by the concept of heterogeneity. In DDF, species richness on sandstone (60 species) was lower than volcanic rock (115 species). SWI values on sandstone and volcanic rock were calculated to be 3.17 and 4.76, respectively. In MDF, species richness on sandstone (125 species) was higher than shale (119 species), and SWI on these rocks was the same; 5.65.

#### 2.2 Forest conditions:

Number of trees having different stemgirths was used for FCI calculation. In DDF on sandstone, number of trees with girths of <25, 26-50, 51-75, 76-100 and >100 cm within a plot were 395, 111, 32, 6 and 0.8, respectively, and FCI was calculated to be 1.87. On volcanic rock, they were in the order of 338, 108, 29, 5.5 and 3.33, and FCI was 4.31. In MDF on sandstone, number of trees were 529, 63, 24, 8 and 7.2, respectively, FCI was 8.40. On shale, they were 342, 22, 15, 6.8 and 12.4, FCI was 13.3.

#### 3. Plant biomass in DDF and MDF

Amounts of plant biomass in DDF were lower than MDF. The DDF on sandstone and volcanic rock had amounts of 84.18 and 95.38 Mg ha-1, respectively, while MDF had higher biomass both on sandstone (195.83 Mg ha<sup>-1</sup>) and shale (177.16 Mg ha<sup>-1</sup>) (Table 1, Fig.2), Biomass allocation was the highest in stem, followed by branch, root and leaf.

Table 1 Average amounts of plant biomass in DDF and MDF

Forest	Parent rock	Carbon in biomass (Mg ha <sup>-1</sup> )									
type		St	em	Branch		Leaf		Root		Total	
DDF	Sandstone (n =12)	54.75	+ 8.61	15.77	+ 2.41	2.09	+ 0.42	11.57	+ 2.0	84.18	+ 13.25
	%	65.10		18.70		2.50		13.70			
	Volcanic rocks (n = 24)	61.43	+ 19.0	19.78	+ 7.81	1.98	+ 0.55	12.19	+ 3.35	95.38	+ 30.12
	%	64.40		20.70		2.10		12.80			
MDF	Sandstone (n = 5)	111.97	+ 25.74	52.05	+ 21.60	2.36	+ 1.22	29.45	+ 6.73	195.83	+ 51.00
	%	57.20		26.60		1.20		15.00			
	Shale (n = 5)	103.07	+ 18.73	43.55	+ 9.97	2.52	+ 1.36	28.02	+ 5.55	177.16	+ 34.16
	%	58.20		24.60		1.40		15.80			

#### A. DDF

**Sandstone:** Hiang had the highest biomass (39.18 Mg ha<sup>-1</sup>, 46.50% of the total), followed by *G. usitata* (12.05), *D. tuberculatus* (8.43), *S. obtusa* (6.87), *S. siamensis* (6.51), *D. oloverli* (1.59) and *Aporosa villosa* (1.0).

**Volcanic rocks:** Teng had the highest amount (32.39 Mg ha<sup>-1</sup>, 34.0%), followed by Rang (20.50), Pluang (6.14), *X. xylocarpa* (5.11), *D. assamica* (2.86), *T. alata* (2.45) and Hiang (2.42).

#### B. MDF

**Sandstone:** *I. malayana* had the highest value (57.43 Mg ha<sup>-1</sup>, 29.30% of the total), followed by *X. xylocarpa* (21.29), *T. mucronata* (19.19), teak (12.74), *C. formosum* (6.40), *S. pinnata* (6.24) and *L. duperreana* (6.21).

**Shale:** Teak had the highest value (45.0 Mg ha<sup>-1</sup>, 25.40% of the total), followed by *T. mucronata* (21.16), *X. xylocarpa* (18.20), *P. macrocarpus* (9.24), *S. oleosa* (8.31), *L. duperreana* (5.55).

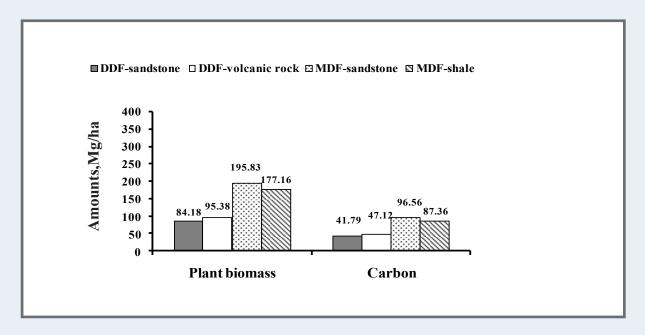


Fig.2 Amounts of plant biomass and stored carbon in the DDF and MDF

#### 4. Carbon storages in DDF and MDF

#### 4.1 Biomass carbon

In Table 2 and Fig.2, carbon amounts in plant biomass of DDF were lower than MDF. DDF on sandstone and volcanic rock had amounts of 41.79 and 47.12 Mg ha<sup>-1</sup>, respectively. Amounts in MDF sandstone (96.56 Mg ha<sup>-1</sup>) and shale (87.36 Mg ha<sup>-1</sup>) were higher than DDF. Carbon allocated in various plant organs was in the same trend as the biomass.

#### A. DDF

**Sandstone:** Hiang had the highest carbon storage (19.36 Mg ha<sup>-1</sup>), followed by *G. usitata* (5.96), *D. tuberculatus* (4.17), *S. obtusa* (3.39), *S. siamensis* (3.21) and *D. oliverli* (0.79).

**Volcanic rocks:** Teng had the highest amount (16.0 Mg ha-1), followed by Rang (10.13), Pluang (3.0), *X. xylocarpa* (2.53), *D. assamica* (1.41), *T. alata* (1.21) and Hiang (1.20).

#### B. MDF

**Sandstone:** *I. malayana* had the highest amount (28.31 Mg ha<sup>-1</sup>), followed by *X. xylocarpa* (10.50), *T. mucronata* (9.46), teak (6.28), *C. formosum* (3.16), *S. pinnata* (3.08) and *L.* 

duperreana (3.06).

**Shale:** Teak had the highest amount (22.19 Mg ha<sup>-1</sup>), followed by *T. mucronata* (10.43), *X. xylocarpa* (8.97), *P. macrocarpus* (4.56), S. oleosa (4.10), *L. duperreana* (2.74) and S. pinnata (2.57).

Khamyong *et. al.* (2014) reported that annual carbon storages in DDF and MDF-DDF in the Center were 1.65 and 2.58 Mg ha<sup>-1</sup> yr<sup>-1</sup>, respectively. In other areas, DDF had carbon of 52.63 Mg ha<sup>-1</sup> (Wattanasuksakul, 2012) and 62.0 Mg ha<sup>-1</sup> (Pongkhamphanh, 2015). The highest amount of biomass carbon was found in the upper montane forest, 347.91 Mg ha<sup>-1</sup>, as in [12].

#### 4.2 Soil carbon storages

Soil features influence plant growth and production. In Table 3, soil depths and types were different among forest types. DDF soil on sandstone had intermediate deep, Order Ultisols while that on volcanic rock was shallow, Order Entisols/Inceptisols. MDF soil on sandstone was deep, Ultisols, shallow on shale, Inceptisols, and deeper on shale/limestone, Alfisols/Vertisols. Thus, carbon storages in soils varied between 12.27 and 65.56 Mg ha<sup>-1</sup>.

**Table 2** Average carbon amounts in plant biomass in DDF and MDF

Fore	st Parent rock		Carbon in biomass (Mg ha <sup>-1</sup> )									
type	<b>;</b>	St	Stem		Branch		Leaf		Root		Total	
DDF	Sandstone (n =12)	27.44	+ 4.13	7.71	+ 1.13	1.03	<u>+</u> 0.19	5.60	+0.92	41.79	+ 6.28	
	Volcanic rocks (n = 24)	30.66	+ 9.50	9.63	+3.81	0.97	<u>+</u> 0.27	5.87	+1.63	47.12	+14.88	
MDI	Sandstone $(n = 5)$	55.88	+ 12.81	25.34	<u>+</u> 10.50	1.16	+0.59	14.17	+3.24	96.56	+25.13	
	Shale (n = 5)	51.43	+ 9.34	21.21	+4.66	1.23	+ 66	13.48	+2.67	87.36	+16.83	

Table 3 Average carbon amounts in soils under DDF and MDF

Forest	Parent rock	Soil depth	Soil Order	Organic carbon
type				(Mg ha <sup>-1</sup> )
DDF	1. Sandstone	Intermediate deep, 80/100 cm	Ultisols	12.27
	2. Volcanic rocks	Very shallow, 30 cm depth	Entisols/Inceptisols	31.45
MDF	1. Sandstone	Deep, 1-2 m depth	Ultisols	49.86
	2.1 Shale	Shallow, 50 cm depth	Inceptisols	52.46
	2.2 Shale/limestone	Deep, 2 m depth	Alfisols/Vertisols	65.56

#### 4.3 Ecosystem carbon storages

Table 4 shows amounts of carbon storages in plant biomass and soil. Total amounts in DDF varied from 54.06 to 78.57 Mg ha<sup>-1</sup>, while MDF had higher, 139.82 to 152.92 Mg ha<sup>-1</sup>. In DDF, percentages of carbon in plant were 60.0 to 77.3%, while MDF had

57.10 to 65.79%. In soil, DDF had values of 22.70 to 40.0%, while MDF had 34.10 to 42.90%. The higher percentages of carbon storage in plant were observed in forest with poor soil, but the storages in plant and soil were nearly the same for forest that had deep fertile soils.

Table 4 Carbon storages in plant and soil in DDF and MDF

Forest				Carbon amounts					
type	Parent rock	Pla	Plant		oil	Total			
		Mg ha <sup>-1</sup>	Mg ha <sup>-1</sup> %		%	Mg ha <sup>-1</sup>	%		
DDF	1. Sandstone	41.79	77.30	12.27	22.70	54.06	100		
	2. Volcanic rocks	47.12	60.00	31.45	40.00	78.57	100		
MDF	1. Sandstone	96.56	65.90	49.86	34.10	146.42	100		
	2.1 Shale	87.36	62.90	52.46	37.50	139.82	100		
	2.2 Shale/limestone	87.36	57.10	65.56	42.90	152.92	100		

## 5. Research application and relevance to sustainable development goals

This research was taken in a restored watershed managed by HHKRDS Center to assess conditions of plant species diversity and carbon storages in two deciduous forests. The forests have recovered from 1984, the beginning of Center establishment. Carbon storages in forests are increasing year by year with plant

growth. It is useful data as a guideline for management and study of community forests in the north. The watershed increases potential of water supply to streams which is useful for agriculture in lower land areas as well as providing non-wood forest products for food and sufficient economic livelihoods of villagers. Thus this conservation of forest biodiversity is relevant to the sustainable development goals.

#### IV. CONCLUSION

Two deciduous forests were poor before Center establishment, and have become recovered forests. Integrated watershed management can protect forest biodiversity and improve forest conditions. Plant species richness and diversity were different between these forests. They were also different with DDF on sandstone and volcanic rock. They were nearly the same for MDF on sandstone and shale. The MDF condition was better than DDF. Carbon storages in DDF ecosystem were lower than MDF. DDF on sandstone had the lowest storage whereas MDF on shale/ limestone had the highest. Forest condition and soil fertility are important factors influencing carbon storage in forests. Forest management is significant for improving the forest condition as well as soil fertility.

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## Changes in temperature and precipitation and their extreme indices over dry zone area in central Myanmar

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Abstract-The Dry zone is situated in central part of Myanmar in Magway, Mandalay, and lower Sagaing regions and covers 10 percent of country. This area is an arid to semi-arid zone with low rainfall, intense heat and degraded soil conditions. The dry zone is one of the most vulnerable areas to climate change impacts as compared to other parts of the country affecting ecosystem services and communities living in this region. The main objective of this study was to improve our understanding of the long term variations and extreme changes in temperature and precipitation in this dry zone region. Such information is necessary for quantifying the impacts of climate change. Temperature and precipitation data over 41-year period

(1975-2015) from five selected meteorological stations (Mandalay, Monywa, Meikthila, Minbu, Pyinmana) as proxies for changes in this region were analyzed. The results indicated the increase in maximum temperature by 0.25°C~0.35°C/decade and minimum temperature by 0.04°C~0.27°C/decade. Between 1975 and 2015, most of the temperature extremes showed significant warming trends. Trends in annual total precipitation and number of heavy precipitation days indicate a slight increase with 2~28 mm/decade and 0.25~0.97 mm/ decade, respectively. Therefore, it is evident that significant changes in climate patterns and extreme climate parameters have occurred in this area. This information could be applied

for evaluating the impacts of climate variable on local community, ecosystems and biodiversity.

*Keywords:* Climate extremes, Dry zone, Precipitation, Temperature, Myanmar

#### I. INTRODUCTION

Extreme weather and climate events have a negative impact on ecosystems, economies, and communities in a variety of ways [1]. Due to increasing trends of several climate extreme events such as cyclones, intense rainfall, floods, droughts, and landslides, the agricultural production, water resources and environment are under threat [2]. Many parts of the world have been experienced climate extremes during the last century [3]. In recent years developing countries including Myanmar are more vulnerable than developed countries in terms of climate risk index due to exceptional catastrophes and low-income. According to the Global Climate Risk Index (2016), Myanmar is the second highest vulnerability country in terms of climate extreme events and socio-economic losses during the past 20 years [4]. Several researches have been conducted in understanding of the trends in climate extremes on global and regional scale (e.g., [5]-[10]). However, long term climate data for the Southeast Asia and Asia-Pacific region is limited, especially at the country level [11]. Manton et al. [8] selected 6 synoptic stations in Myanmar and reported the overall warming trend in the region with increased in hot days and warm nights as well as a decrease in cold days and cold nights. In addition, the frequency of precipitation has declined but with statistical insignificance.

The aim of this study is to evaluate trends and extreme indices over 41 years of daily temperature and precipitation in a dry zone region in Myanmar, in order to improve our understanding of the long term variations

and extreme changes in this area. The results would benefit both future evaluation of the impacts of climate change as well as for identifying appropriate measures for adaptation.

#### II. MATERIAL AND METHODS

#### A. Study Area

Dry zone is located in central part of Myanmar in Magway, Mandalay, and lower Sagaing regions. The area covers about 10 percent of country with a population of about 12 million. Livelihoods in this area mainly depend on the south-west monsoon. Average annual rainfall in dry zone is the lowest (500-1,000 mm/year) and the variation of seasonal temperature is highest ranging from a minimum of 10-15°C to a maximum of 40-43°C within the country. Thus, this region is characterized by low rainfall, intense heat, degraded soil conditions, and lack of significant surface water availability which affect the ecosystem services of the local communities [13]. Moreover severe drought has been experienced in 2005 and drought has become more frequent in this region [13]. Considering the data availability, this study focused on five major cities of central dry zone, namely, Mandalay, Minbu, Meikthila, Monywa, and Pyinmana, as shown in Fig.1.

#### B. Data Collection

Long term time series data of daily maximum temperature (°C), minimum temperature (°C), and daily precipitation (mm) of five stations were collected from the Department of Meteorology and Hydrology (DMH), Nay Pyi Taw, Myanmar for the period of 1975 to 2015. The location details of these five stations are shown in Table 1. Minbu Station had a data gap between 1975 to 1980.

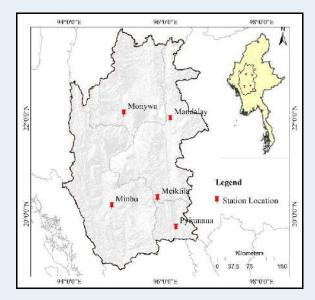


Fig.1 Location map of the study areas located in Myanmar's central dry zone

**Table 1** Detailed information for meteorological stations

Station Name	Station Code (WMO Standard)	Latitude (DD)	Longitude (DD)	Elevation (m)	Data Availability
Mandalay	48042	21.98	96.10	78	1975-2015
Meikthila	48053	20.33	95.83	214	1975-2015
Minbu	48064	20.17	94.88	51	1975-2015
Monywa	48037	22.10	95.13	81	1975-2015
Pyinmana	48074	19.72	96.22	95	1975-2015

#### C. Data Quality and Homogeneity Checks

Data quality control and homogeneity are necessary for statistical analysis as climatic trends are very sensitive to errant values and outliers from numerous sources [14, 15]. Prior to analysis of climate data, it is important to remove the data errors and outliers in standard methodological manner [14]. In this study, the basic quality control and temporal outliers check were carried out for all data sets using [14, 15]. During the basic quality control checking, the following errors such as missing value, negative precipitation value (human typing error), daily maximum temperature is less than or equal to daily

minimum temperature, and daily maximum or minimum temperature is greater than 70°C were detected [16]. All errors from basic quality control were assigned as no data. The temporal outliers check for a specific station is based on the premise that an individual monthly value should be statistically "similar" to the values of the same month from the other years. Outliers were identified by utilizing the sample distribution for each month of individual station. Extreme values are flagged out based on limited determination from a multiple of the interquartile range calculated for each station and each month using Eq (1). This procedure is common in exploratory data analysis procedures. An outlier is flagged using the formula [15];

Xij-q50j>f\*IRj Eq (1)

where,

Xijis the observed values on i date in j month.

q50j is the median (or the 50th percentile) in j month.

f is the multiplication factor (f = 5).

*IRj* is interquartile range (75th percentile minus 25th percentile) in *j* month.

After data have been passed the quality control, the temporal homogeneity test was carried out using RHtestsV4 software developed by Climate Research Division of Atmospheric Science and Technology Branch of Canada [17]. This method detects and adjusts for the multiple change points based on the pernalized maximal T test and penalized maximal F test

which are embedded in a recursive testing algorithm.

#### D. Calculating Extreme Indices

Expert Team on Climate Change Detection, Monitoring, and Indices (ETCCDMI) has defined a core set of 27 extreme indices for temperature and precipitation with user friendly R-based software, RClimDex. All of the extreme indices (seven for temperature and nine for precipitation, Table 2) are computed from the daily observation of temperature and precipitation using RClimDex software [18]. These indices are recommended by the Climate Variability and Predictability (CLIVAR) as well as adopted by the IPCC AR4.

Table 2 List of temperature and precipitation indices in this study

ID	Indicator	Definitions	Units
Tmaxmean	Mean max temp	Annual mean maximum temperature	°C
Tminmean	Mean min temp	Annual mean minimum temperature	°C
SU33/32	Summer days	Annual count when TX(daily maximum)>33/32 °C	Days
TN10p	Cool nights	Percentage of days when TN<10 <sup>th</sup> percentile	Days
TX10p	Cool days	Percentage of days when TX<10 <sup>th</sup> percentile	Days
TN90p	Warm nights	Percentage of days when TN>90 <sup>th</sup> percentile	Days
TX90p	Warm days	Percentage of days when TX>90 <sup>th</sup> percentile	Days
R10	Heavy precipitation days	Annual count of days when PRCP>=10mm	Days
R20	Very heavy precipitation days	Annual count of days when PRCP>=20 mm	Days
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (RR>=1mm)	mm
RX1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	mm
RX5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	mm

R95p	Very wet days	Annual total PRCP when RR>95 <sup>th</sup> percentile	mm
R99p	Extremely wet days	Annual total PRCP when RR>99 <sup>th</sup> percentile	mm
CDD	Consecutive dry days	Maximum number of consecutives days with RR<1mm	Days
CWD	Consecutive wet days	Maximum number of consecutives days with RR>=1mm	Days

#### E. Anomaly and Trend Identification

To evaluate the variation of climate pattern, anomalies based on the difference between mean temperature in each year and the long-term average for the period 1975-2015 are calculated. The observed mean annual maximum temperatures (Tmaxmean) or annual minimum temperature (Tminmean) were then plotted in time series.

The statistical significance of the trends was calculated using ordinary least square method. The Thiel-Sen nonparametric method is used to estimate the slope of linear trends [19]. This method is frequently applied in previous climatological studies (e.g. [20, 21]) and which outperforms the least squares regression in computing the magnitude of linear trends when the sample size is large [22]. The 95% significant levels were used to consider a trend to be statistically significant. The slope estimates of N pairs of data are first computed by;

$$Q_i = \frac{x_j - x_k}{j - k}$$
 For  $i = 1, ..., NEq(2)$ 

Where,

xj and xk are data values at times j and k (j>k), respectively. The median of these N values of Qi is the Sen's estimator of slope.

#### III. RESULTS AND DISCUSSION

#### A. Anomaly and Trend Analysis

1) Mean Maximum Temperature: The overall trend of mean maximum temperature anomalies at four stations in Mandalay, Meikthila, Monywa, and Pyinmana increased throughout the latter half of observed periods in all stations except Minbu. The anomalies in Minbu were varied, moving between positive and negative ones. Most of the station reaches the highest anomalies about +1.5°C versus the normal value. The mean maximum temperature in dry zone area started to increase since 1977. The continuous positive anomalies started from 1993 ranging from a minimum of +0.01°C (2001) to a maximum of +1.12°C (2010). The significant positive anomalies can be observed in 2009, 1998, 2005, 2014, 2012, and 1979 (descending order of anomalies value) (Fig.2) and almost all the years correspond with the declining phase of strong El Niño events [23]. During the 21st century, temperatures have continued to increase from 2003 to 2015 except in 2007 and 2011, which experienced the La Niña events [23].

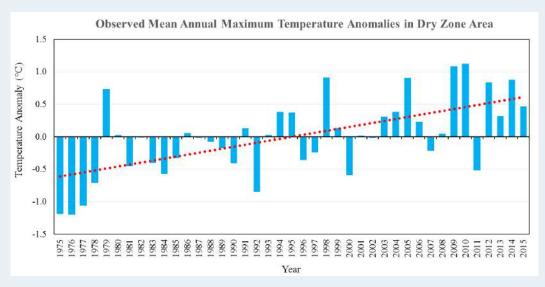


Fig.2 Observed mean annual maximum temperature anomalies in dry zone area

2) Mean Minimum Temperature: The mean minimum temperature anomalies for all stations demonstrated an overall increasing trend with values becoming positive after 1990s. However, the nature of the anomaly are not consistent among stations, both positive and negative anomalies were found. On average, dry zone area shows the continuous

positive anomalies from 2001 to 2014 with the range +0.01°C (2001) to +1.01°C (2005). Generally, it can be expected that warm periods started after 2000 (Fig.3). During the warm periods, the significant positive anomalies were detected in 2005 and 2010 which coincided with El Niño events.

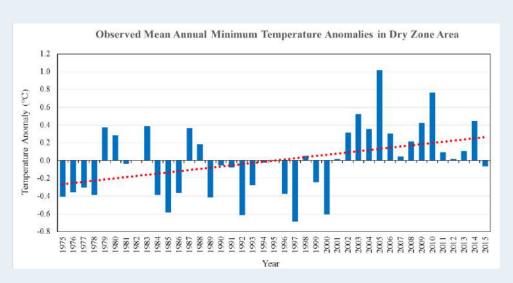


Fig.3 Observed mean annual minimum temperature anomalies in dry zone area

3) Annual Total Precipitation: The trends of annual total precipitation illustrates the increasing trend but is not significant for all stations. The highest precipitation were found in El Niño year 2006 and 2010 and La Niña year 2011. This could be explained

by the fact that precipitation pattern in dry zone area cannot be interpreted directly based on the links with El Niño and La Niña during the study period 1975-2015 (Fig.4). More detailed investigations are needed to explain the precipitation trends.

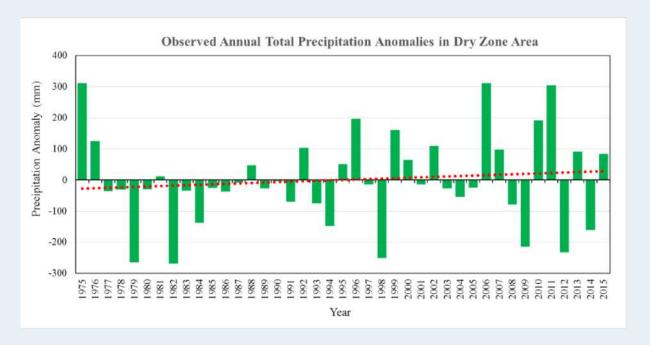
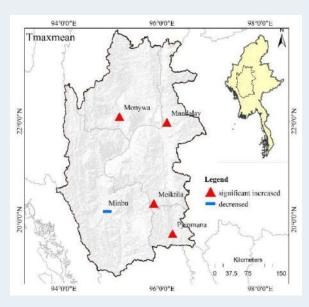


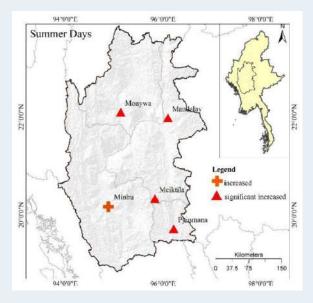
Fig.4 Observed annual total precipitation anomalies in dry zone area

#### **B.** Extreme Indices

1) Maximum and Minimum Temperature: There are significant increases in average maximum temperature (Tmaxmean), average minimum temperature (Tminmean), summer days (SU33/32), warm days (TX90P), and warm nights (TN90P) in all selected stations. Cold days (TX10P) significantly decreasing in three (Mandalay, Monywa, Pyinmana) of five stations. Fig.5 shows the trends in frequency of mean maximum temperature, Fig.6 shows the trends in the frequency of days with maximum temperature above 33/32°C (summer days) and Fig.7 shows the trends in frequency of days with maximum temperature above the 90th percentile (warm days). In each figure, an increase is represented by (+) sign and decrease is (-) sign, a significant increase with (() symbol and significant decreases with (+) symbol, respectively.

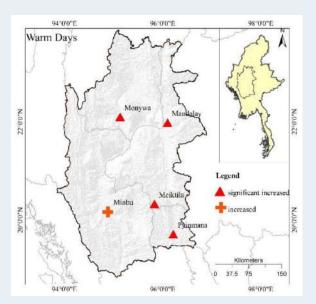


**Fig.5** Trends in mean maximum temperature in dry zone area for the period 1975-2015



**Fig.6** Trends in frequency of days with maximum temperature above 33/32°C in dry zone area for the period 1975-2015.

Table 3 shows in detail the calculated values used to determine the direction and significance of the trends in extreme temperature for each of the five stations in dry zone area. The stations which showed a statistically significant trend at the 95% significance level are highlighted grey.



**Fig.7** Trends in frequency of days with maximum temperature above the 90<sup>th</sup> percentile (warm days) in dry zone area for the period 1975-2015.

In dry zone area, four of five stations showed statistically significant increase in maximum temperature, summer days, and warm nights while increase in minimum temperature and warm days. Only one station, Minbu, shows decreasing trend in maximum temperature with 0.02°C/decade. This could be considered as the effect from data missing during 1975 to 1980. (See Section II, B).

**Table 3** Trends in extreme temperature for the period 1975-2015

Temperature Indicies								
Station	Tmaxmean (°C/decade)	Tminmean (°C/decade)	SU33/SU32 (Days/decade)	TX10P (Days/decade)	TN10P (Days/decade)	TX90P (Days/decade)	TN90P (Days/decade)	
Mandalay	0.35	0.27	12.04	-2.11	-2.76	3.34	2.13	
Monywa	0.48	0.12	14.26	-2.53	-0.09	4.51	1.07	
Meikthila	0.25	0.13	13.26	-0.72	-1.23	2.99	2.25	
Minbu Pyinmana	-0.02 0.30	0.14 0.04	0.30 19.15	0.98	0.88 0.17	0.91 3.85	3.52 0.58	

 $Note: \ Tmaxmean = mean \ maximum \ temperature, \quad Tminmean = mean \ minimum \ temperature,$ 

SU33/SU22 = annual number of days when daily maximum temperature >33 C or 32 C,

TX10P = Number of cool days, TN10P = Numer of cool nights, TX90P = Number of warm days,

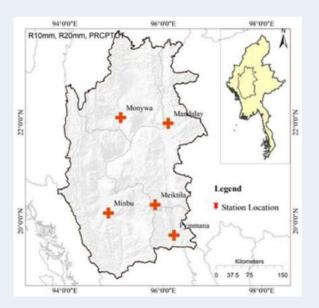
TN90P = Number of warm nights, (-) is decreasing trend,

Stastically significance trend are set grey color at the 95% significance level

2) Annual Total Precipitation: All the stations in dry zone area shows the increasing trends in the number of heavy precipitation days (annual count of days when precipitation >= 10 mm), number of very heavy precipitation days (annual count of days when precipitation >= 20 mm), and annual total precipitation (Fig.8).

The results from monthly maximum 1 day precipitation amount (RX1day) and monthly maximum consecutive 5 day precipitation amount (RX5day), very wet days (RX95P), and extremely wet days (RX99P) indicate the increasing trends of these indices in Mandalay, Meikthila, and Monywa while decreasing in Minbu and Pyinmana. Both consecutive dry days (CDD) and consecutive wet days (CWD) were increased in Mandalay and Minbu whereas decreased in Meikthila and Pyinmana.

Table 4 shows in detail the calculated values used to determine the direction and significance of the trends in extreme precipitation for each of five stations in dry zone area. The



**Fig.8** Trends in number of heavy precipitation days, very heavy precipitation days and annual total precipitation in dry zone area for the period 1975-2015

stations which showed a statistically significant trend at the 95% significance level are highlighted in grey.

**Table 4** Trends in extreme precipitation for the period 1975-2015

		Precipitation Indicies											
Station	PRCPTOT (mm/decade)	R10mm (Days/decade)	R15mm (Days/decade)	RX1day (mm/decade)	RX5day (mm/decade)	R95P (mm/decade)	R99P (mm/decade)	CDD (Days/decade)	CWD (Days/decade)				
Mandalay	28.20	0.40	0.71	8.99	15.49	28.30	26.94	1.84	0.46				
Monywa	17.50	0.25	0.66	1.28	2.95	9.15	5.55	-3.41	0.34				
Meikthila	28.88	0.97	0.32	2.09	10.71	11.56	1.95	-2.98	-0.09				
Minbu	11.53	0.81	0.18	-0.78	-3.43	-2.19	-20.74	0.65	0.24				
Pyinmana	2.48	0.37	0.58	-6.06	-3.83	-6.84	-9.02	-3.02	-1.00				

Note: PRCPTOT = annual total precipitation, R10mm = annual number of days when precipitation >= 10 mm,

R20mm = annual number of days when precipitation >= 15 mm, RXI day = maximum 1 day precipitation amount,

RX5day = maximum consecutive 5 day precipitation amount, R95P = very wet days precipitation amount,

 $R99P = extreme \ wet \ days \ precipitation \ amount, \ CDD = consecutive \ dry \ days, \ CWD = consecutive \ wet \ days,$ 

(-) is decreasing trend

Stastically significance trend are set grey color at the 95% significance level

#### IV. CONCLUSIONS

This study has presented continuous positive anomalies in both mean maximum and minimum temperature between the years 1975 to 2015. The increase of maximum temperature, minimum temperature, summer days, and warm days were between 0.25~0.35°C/decade, 0.04~0.27°C/decade, 12~19 days/decade, and 1~5 days/decade, respectively. Both decreasing and increasing trends in number of cool days and cool nights were observed.

On the other hand, trends in annual total precipitation and number of heavy precipitation days indicate a slightly increase in the range of 2~29 mm/decade and 0.25~0.97 mm/decade, respectively. Most of the stations describe decreasing trends in extreme wet days and consecutive dry days.

This study provides evidence on the pattern of climate change in the dry region as well as the possible impacts on various aspects of which the impacts on forest ecosystems in Myanmar are under investigation by the authors.

#### **ACKNOWLEDGMENT**

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### Responses of litter fall and carbon exchange to El Niño in a secondary dry dipterocarp forest, western Thailand

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Abstract-Severe and frequent climate extremes are expected under climate change. Understandings of the responses of ecosystems to such changes are thus crucial for early warning and appropriate impact managements. This study analyzes the amount and dynamics of litter fall and carbon exchange in secondary dry dipterocarp forest during 2009-2016, during which two El Niño years were observed (2009-2010 and 2015-2016). The litter was collected using litter traps and carbon exchanges above forest canopy were measured by using eddy

covariance technique. During El Niño years, less rainfall and lower soil moisture and higher maximum temperatures compared to normal years were observed. The litter fall occurred mainly during the dry season (November to April of the following year). The total litter fall for the whole dry season were 0.43-0.60 kg m<sup>-2</sup>. During the normal year, the ratios between monthly to total litter fall were highest during February-March with the value of 0.3-0.5. However, during the El Niño years, this was peaked in January with the value of around 0.6.

Thus, El Niño induced early and shortened the litter fall period. The gross primary production (GPP) was considerably decreased during El Niño years compared to those during the normal year. The net ecosystem exchange (NEE) were -26.34 to -309.53 gC m<sup>-2</sup> during El Niño and -327.89 to -391.25 gC m<sup>-2</sup> during the normal years. The high NEE and low GPP/RE indicate the net carbon loss during the El Niño. The less rainfall for extended period of time, low soil moisture and high soil temperature are the important factors controlling litter fall timing and carbon exchange. From these results it could be concluded that the extreme climatic events such as El Niño could induce early litter fall and reduce the potential of carbon uptake.

*Keywords:* Litter fall, carbon exchange, El Niño, secondary dry dipterocarp forest

#### I. INTRODUCTION

Extreme climate variability such as El Niño has been found in higher frequency due to climate change [1]. As atmospheric carbon dioxide concentration (C<sub>2</sub>) is the largest contributor to global warming and climate change, forest ecosystems play an important role in controlling Ca through tree photosynthesis and respiration [2]. Thus understanding the response of forest to climate extremes are important for both mitigation of atmospheric CO, and adaptation to climate change of the forest [3]. The importance of managing sustainable forest under climate change is highlighted as one of the 2030 Agendas for Sustainable Development and Sustainable Development Goals (SDG15) [4].

El Niño is the phenomenon with apparent increasing sea surface temperature (SST) in tropical Pacific Ocean to west coast of South America that links to atmospheric major change by transportation of heat in ocean into the atmosphere. During the events, the rainfall location is shifted and drier conditions occurred in South eastern regions. The last El Niño occurred during 2009-2010 [5, 6, 7] and since February 2015 we have been in the period of one of the strongest El Niño. In Thailand, a new maximum temperature of 44.6°C has been recorded [8]. Moreover, long-term trends and variability of precipitation during 1955-2014 illustrated that Thailand had a lower amount of precipitation during El Niño years [9].

The El Niño affects carbon exchange of a forest because the changing rainfall pattern and rising temperature over forests is tightly associated with CO, uptake. Moreover, the El Niño also influences forest fires that enhances the release of massive CO, into atmosphere [6]. Although the understanding of carbon exchange and how increasing temperature affects its process are relatively well understood in the temperate forest, our knowledge in tropical dry deciduous forest is poor [10]. In the tropics, 48.5% of seasonally dry tropical forests have been cleared for agriculture or other land uses and this causes the expansion of secondary forests [11, 12]. In the tropical to subtropical regions of Southeast Asia, a dry dipterocarp forest is one of the dominant forest types with unique forest characteristics and high diversity of several endemic species [13]. Understanding carbon dynamics and the relationship with climate extreme is thus crucial.

The study of biological cycle timing and its relationship to climate factors that is called "phenology" is crucial for understanding of carbon dynamics in forest [14, 15]. The phenological shift might be attributed to climate change. More work is thus needed to know how a phenological response is being affected by climate change [14]. This study investigated the phenological shift through

litter fall and carbon exchange under extreme climate variability in secondary Dry Dipterocarp Forest (DDF). The aim of the study is to better understand the litter fall timing and its relationship to carbon exchange, and their response to climate variability during El Niño events.

#### II. MATERIALS AND METHODS

#### A. Site Description

The study site was located in King Mongkut's University of Technology Thonburi, Ratchaburi campus, Rang Bour, Chombueng district, Ratchaburi province, western Thailand (Latitude: 13°35′ 13.3″ N, Longitude: 99°30′ 3.9″ E, elevation of 118 m). Total area covers 90 ha. The average tree height was 6-7 m. The dominant species are in the Dipterocarpaceae such as *Dipterocarpus obtusifolius, D. tuberculatus, Shorea obtusa* and *S. siamensis*. Previously, this forest had been exploited by nearby communities for timber, charcoal or other products. Since 2005, this forest has been conserved and trees could be regenerating as a secondary forest.

#### B. Climate conditions

The air temperature and rainfall were measured by Vaisalasenser (Vaisala Inc. Model HMP45C) and tipping bucket rain gauge (model TE525, Cambell Scientific, Inc.). These were connected with data logger (CR1000, Cambell Scientific, Inc.). Soil temperature was measured at a depth of 5 cm with two averaging soil thermocouple probes (TCAV, Campbell Scientific, Inc., USA). Soil moisture was measured at the same level with two averaging Soil Water Content Reflectometers (CS615, Campbell Scientific, Inc.). The moisture sensor was converted from volumetric water content to percent water-filled pore space (%WFPS) by equation;

%WFPS = [(SWC/BD)/(1-(BD/PD))]

where SWC is the soil water content, BD is the bulk density (1.42 g cm<sup>-3</sup>) and PD is the particle density (2.68 g cm<sup>-3</sup>) [16].

Statistical analysis was performed with R 3.1.2 Software, t-test was used to compare climate condition and its effects to phenology between normal and El Niño years.

## C. Litter fall collection and carbon content

Long-term monthly litter fall production was collected by thirteen litter traps with size of 1 m<sup>-2</sup> during 2009-April 2016. The litter was dried at 80°C and weighed. The data in dry season (November to April of the following year) was extracted to calculate normalized litter fall by using the ratios between monthly litter falls to total litter fall in dry season. Statistical data analysis was performed with R 3.1.2 Software. Tukey's HSD test was performed to identify significant differences of litter fall in each month. The carbon stock was calculated by multiplying the 0.50 conversion factors to biomass of litter fall [17].

#### D. Carbon exchange measurement

Carbon exchanges above forest canopy were measured at 10 m by using eddy covariance technique. The CO, was estimated by an openpath infrared CO<sub>2</sub>/H<sub>2</sub>O analyzer (LI-7500, LI-COR, Lincoln, USA). Wind velocity and the speed of sound were measured with threedimensional sonic anemometer-thermometer (CSAT3, Cambell Scientific, Inc.). Data processing in quality control and half-hourly average of NEE were analyzed by using EddyPro software. Then, the outlier with the range outside of mean 1.96 standard deviations was excluded in post-processing [18]. The monthly pattern of gross primary production (GPP) and ecosystem respiration (RE) was calculated by using biometric terms as

#### NEE = RE - GPP

where RE is estimated basing on the amount of CO<sub>2</sub> released during the night time [19, 20].

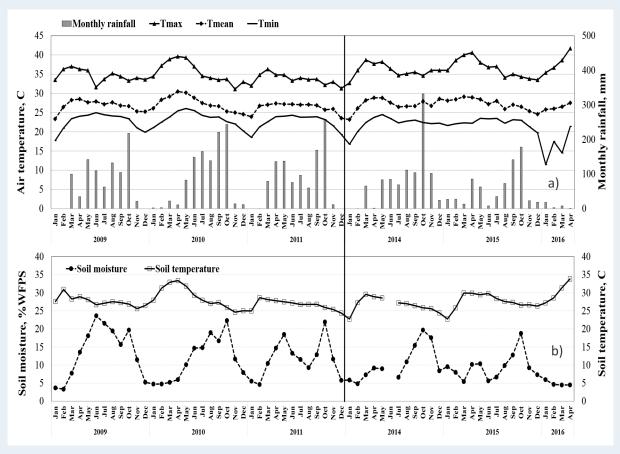
#### III. RESULTS AND DISCUSSIONS

#### A. Climate conditions

The climate trend between 2009-2011 and 2014-April 2016 was shown in Fig.1. During these periods two El Niño events were observed. NOAA [8] reported that the El Niño occurred since July 2009 to May 2010 and February 2015-the present (April 2016), consistent with the observed drought at the study forest site.

The maximum temperatures during the study period were 39.6, 40.6 and 41.7°C in 2010, 2015 and 2016 in April and these were 37.0 and 36.3°C in 2009, 2011 in March.

During the dry season (November to April of the following year), long drought was found due to less rainfall (<5 mm) for whole season during 2009-2010 and 2015-2016. The sums of rainfall were 59.10±9.83 and 71.40±9.22 mm, respectively. These ere 240.70 55.51 and 279.40±37.32 mm during 2010-2011 and 2014-2015, respectively (rainfall in normal year was significant higher than El Niño year, p<0.02).



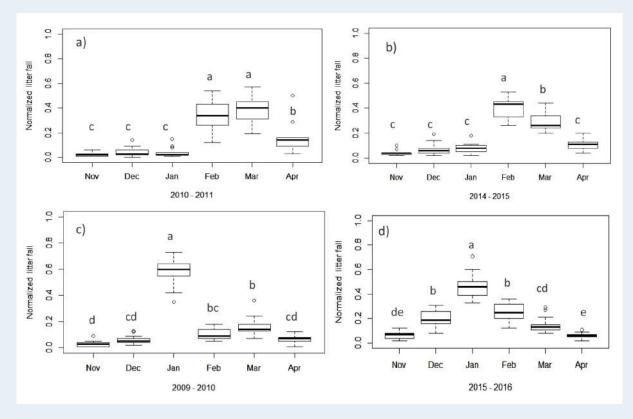
**Fig.1** Climate conditions a) monthly air temperature consisted of maximum air temperature (Tmax), mean temperature (Tmean), minimum temperature (Tmin) and monthly rainfall b) monthly soil moisture and soil temperature

Consistently, soil moisture during 2009-2010 and 2015-2016 were 6.23±2.61 and 6.02±1.93% WFPS. These were lower than normal years which were 9.15±3.84 and 9.85±4.12% WFPS, respectively. The soil temperature was significantly higher during El Niño; 29.6±3.36 and 29.00±2.99°C than during the normal years; 26.54±1.84 and 26.41±2.92°C (p<0.01 and 0.02 for soil moisture and soil temperature, respectively).

According to the climate conditions, the study of El Niño impacts on responses of litter fall and carbon exchange in dry season was divided into 4 periods; the extreme period during 2009-2010 (1st El Niño) and 2015-2016 (2nd El Niño), the normal period during 2010-2011 and 2014-2015. For the dry season during 2014-2015, although El Niño started on February 2015 [8] but there was a lot of rainfall in April 2015, so a drought was not found.

#### B. Shift of litter fall timing

In this secondary forest, the litter fall during the study period ranged from 0.43 to 0.60 kg m<sup>-2</sup>. We found that the litter fall occurred about one month earlier and the peaks were higher during El Niño years than during the normal years. Without El Niño in 2010-2011 and 2014-2015, the litter fall peaked during February to March. Meanwhile, during the El Niño years in 2009-2010 and 2015-2016, the litter fall occurred mainly in January. The highest normalized litter fall were 0.58 and 0.47 during El Niño years while these were 0.39 and 0.41 in the normal years (Fig.2). Casco et. al., (2015) reported that several droughts led to high litter fall production [21]. The declined soil moisture during high soil temperature affected litter fall production more than rising air temperature and there was a time lag for a month. A previous study



**Fig.2** Timing of litter fall production in dry season during the period without El Niño a) 2010-2011 b) 2014-2015 and during with El Niño c) 2009-2010 d) 2015-2016, different letters indicate significant differences by Tukey's HSD test at p=0.05; n=11

reported that the litter fall had a significant positive correlation with soil moisture and a significant negative correlation with soil temperature [16].

C. Effects of El Niño on Carbon exchange and carbon contents in litter fall

The potential carbon uptake in the whole dry season was reduced during El Niño in 2009-2010 and 2015-2016. The GPP were 432.87 and 719.67 g Cm<sup>-2</sup> during El Niño and 1,030.80 and 1,021.22 g Cm<sup>-2</sup> during the normal years (Table 1). Therefore, the GPP seems to be quite sensitive to El Niño as it

**Table 1** Summary of carbon contents in litter fall and total carbon exchange during dry season in secondary dry dipterocarp forest

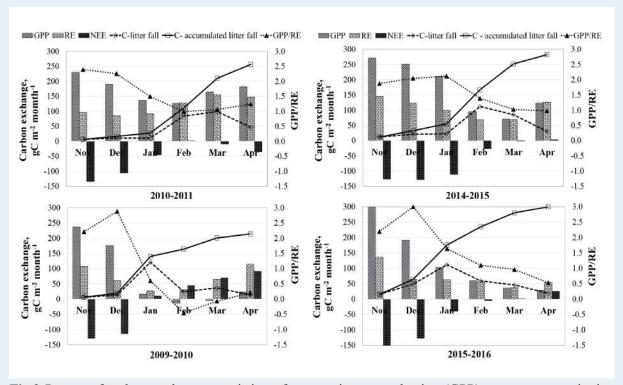
year	Events	Total carbon content in litter fall, gC m <sup>-2</sup>	Total GPP, gC m <sup>-2</sup>	Total RE, gC m <sup>-2</sup>	Total NEE, gC m <sup>-2</sup>	Total GPP/RE
2009-2010	El Niño	213.83	432.87	406.53	-26.34	1.06
2010-2011	normal	256.36	1030.80	702.91	-327.89	1.47
2014-2015	normal	282.15	1021.22	629.97	-391.25	1.62
2015-2016	El Niño	299.56	719.67	410.15	-309.53	1.75

decreased drastically during El Niño compared to the normal years. Furthermore, the carbon uptake reduced rapidly during El Niño events and during the peaking time of litter fall. The uptake of carbon was decreased by 600 g Cm<sup>-2</sup> in the 1<sup>st</sup> El Niño and 300 g Cm<sup>-2</sup> in the 2<sup>nd</sup> El Niño compared to the normal years (Fig.3). The RE were also low during El Niño which were 406.53 and 410.15 g Cm<sup>-2</sup>, compared to 702.91 and 629.97 g Cm<sup>-2</sup> during normal years.

The total NEE for whole season were -26.34 and -309.53 g Cm<sup>-2</sup> during the 1<sup>st</sup> and 2<sup>nd</sup> El Niño events, respectively. These were -327.89 and -391.25 g Cm<sup>-2</sup> in normal years (Fig.3 and Table 1). Interestingly, the NEE was considerably positive during the El Niño especially during the 1<sup>st</sup> El Niño. About 1.38-91.50 g CM<sup>-2</sup> month<sup>-1</sup> was emitted between January to April (Fig.3). The results of NEE were consistent with the GPP/RE. The GPP/RE

of more than 1 indicates that the forest is a net carbon sink [22]. During four study periods, GPP/RE had increased continuously between 1.06 and 1.75. It means that this forest is a carbon sink for whole dry season and the potential to be a carbon sink has continuously increased. Comparing GPP/RE in each month shows that this forest was a sink for carbon every month during the normal year (Except on April 2015, GPP/RE was 0.98, this might be because of El Niño impact during the end of period). During El Niño, the GPP/RE was 0.46-0.96 between February to April and March to April in the 1st and 2nd events, respectively. So, that El Niño induced carbon loss was obvious.

The low soil moisture due to reduced rainfall had an important role to control the GPP during El Niño events. The soil moisture was quite different between these two events.



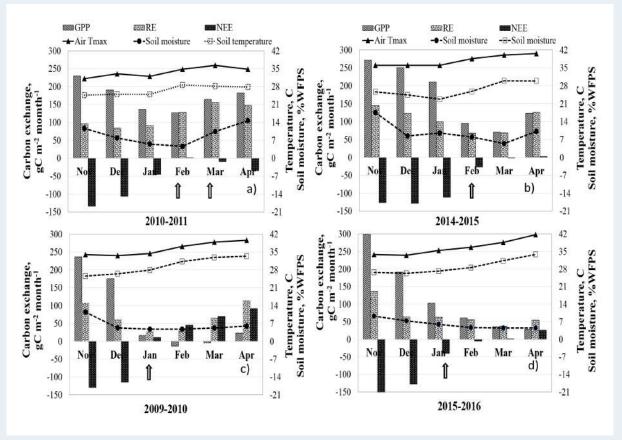
**Fig.3** Pattern of carbon exchange consisting of gross primary production (GPP), ecosystem respiration (RE) and net ecosystem exchange (NEE) and carbon content in monthly litter fall (c-litter fall) and accumulated litter fall

During the El Niño events, the soil moisture was reduced to very low level, consistent with that of the GPP that was reduced and remained low until the end of period. Conversely in normal events, soil moisture as well as GPP remained fairly high. During strong El Niño, soil temperature increased gradually since the beginning of season until the end of the season. The air maximum temperature trends were similar with those of soil moisture. So, soil temperature and maximum temperature might be the important factors controlling the GPP, especially at the end of period. Previous study reported that the start of foliage season had negative correlation with maximum temperature but it had positive correlation with rainfall [23]. Moreover, the phenology of leaf flushing of deciduous species was triggered by increase in water storage in soil [24]. Therefore, the GPP reduction found in this study might be because of late start of growing season due to the long drought.

Implications of the timing of the litter fall production could be linked to forest management, such as alerts or warning of forest fires potential. Due to 87% of litter fall of this forest was leaf litter [16] and its heating value is high (4,564 Kcal/Kg) [25], the shift in litter fall timing in the forest could have significant implications on fire management under climate variability. For example, according to the shift of litter fall production, the forest fire perhaps warning should be given a month earlier in this forest.

#### IV. CONCLUSIONS

The extended drought was found during the El Niño events and this lead to lower soil moisture, and a higher temperature than usual. The El Niño induced early litter fall for a month and caused a sharp decrease of the GPP during the dry season. Furthermore,



**Fig.4** Pattern of carbon exchange consisted of gross primary production (GPP), ecosystem respiration (RE) and net ecosystem exchange (NEE) and climate condition contained maximum air temperature (Tmax), soil moisture and soil temperature in dry season during without El Niño a) 2010-2011 b) 2014-2015 and during within El Niño c) 2009-2010 d) 2015-2016 and the arrow indicated the timing of highest litter fall

net carbon release was observed during these extreme events. Enhanced awareness of increased fire risk potentials due to induced leaf litter fall associated with El Niño events has important implications for forest management in dry dipterocarp forests.

#### **ACKNOWLEDGMENT**

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# Community based adaptation (CBA) to climate change through organic agriculture: Case study of Samroung commune, Cambodia

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Abstract-Organic farming is one of applicable strategies to climate change adaptation for small-scale farmers. It plays a concrete and sustainable role to reduce the emissions of greenhouse gasses (GHG) that are the significant driver for climate change. This study discusses the potential of organic agricultural practices to mitigate the vulnerability of climate change to small-scale farmers in Samroung Commune, Kampong Cham Province, Cambodia through community based adaptation (CBA) approach. The study aims to share the lessons learnt from promoting sustainable agriculture practices through CBA, which could be able to enhance farmers or communities' ability to climate change adaptation. During project implementation, farmers in the project site had practiced organic farming; as a result, the diversity of income sources is increased due to various agricultural

practices. The flexibility to cope with climate change is advanced. This leads to higher economic returns due to high yields and environmental stability with ecological balance. Moreover, the cyclic use of plant and animal residues in order to return nutrients to the soils through composting would minimize the use of non-renewable resources and reduce GHG emission. The project addresses the Sustainable Development Goals target 2.4 in terms of ensuring sustainable food production systems that strengthen the capacity of small scale farmers for adaptation to climate change. The lessons learnt from this project had disseminated in the community and district levels. The data and information drawn from this project is documented and distributed to the relevant parties as an example for sustainable resource management for climate change adaptation.

## *Keywords*: Climate change, Organic agriculture, Community based adaptation, Cambodia

#### I. INTRODUCTION

Generally, climate is one of the main determinants of agricultural production and climate alteration might cause variability in agricultural production. Agriculture is proved to be one of the most adaptable human activities to varied climate conditions [1]. However, agriculture which it is practiced today across most of the world is not part of the solution to mitigate the climate change; it is, instead, part of the problem. Rather than mitigating climate change, it is a main producer of greenhouse gas emissions both directly through conventional farming practices that deplete soil carbon stocks while emitting nitrous oxide (N<sub>2</sub>O), and indirectly through land-use change. Additionally, the intensification of livestock production and rice paddy agriculture has exacerbated release of the greenhouse gas methane (CH4). According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), greenhouse gas (GHG) emissions from the agricultural sector account for 10-12% or 5.1-6.1 Gt of the total anthropogenic annual emissions of CO<sub>2</sub> equivalent. However, this accounting includes only direct agricultural emissions; emissions due to the production of agricultural inputs such as nitrogen fertilizers, synthetic pesticides and fossil fuels used for agricultural machinery and irrigation are not calculated [2].

Shifting agriculture from a source of carbon pollution to a potential carbon sink is the best way to reduce greenhouse gas emission. Agriculture that reduces carbon is also agriculture that addresses our planetary water crisis, extreme poverty, and food insecurity while protecting and enhancing the environment now and for future generations. Hence, practicing organic agriculture is improving the resources rather than

destroying or depleting its and it is aligned with forms of agro-ecology practiced by farmers concerned with food sovereignty over the world [3] & [4]. Changing farming practices to organic, regenerative and agro-ecological systems can increase soil organic carbon stocks, decrease greenhouse gas emissions [5], maintain yields [6] & [7], improve water retention and plant uptake, improve farm profitability, and revitalize traditional farming communities while ensuring biodiversity and resilience of ecosystem services [8] & [9]. Moreover, organic farming has been adapted for many climate zones and local conditions; as a result, much and detailed situation-specific information on organic farming is available, and it is not only a specific agricultural production system, but it is also a systemic and encompassing approach to sustainable livelihoods [10].

Poor and vulnerable people are particularly affected by climate change impacts, such as floods, droughts and other extreme weather events. Community-based adaptation (CBA) can offer a cost-effective, sound way totackle the impact of climate change by capturing the wealth of knowledge and experience that communities have on dealing with climate variability and change [11]. CBA is a communityled process which it is based on communities' priorities, needs, knowledge, and capacities that should empower people to plan for and cope with the impacts of climate change. CBA needs to start with communities' expressed needs and perceptions, and to have poverty reduction and livelihood benefits, as well as reducing vulnerability to climate change and disasters. CBA may start by identifying communities in poor countries that are most vulnerable to climate change, or these communities may themselves ask for assistance [12]. In recent years, CBA has shown that it can also operate at scale but with communities remaining central to planning and action, for example through mainstreaming into government processes. Many of the participatory tools/

approaches used in CBA such as mental models, seasonal calendars, timelines, community mapping and modeling, transect walks, ranking, dream maps and drawings, theatre, poems, songs, participatory video, stakeholder analysis and key information discussion [13].

Hence, for on the ground level, community-based adaptation (CBA) is one of the tools to address Sustainable Development Goals (SDGs), particulary target 2.4, to ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extream weather, draught, flodding and other disasters and that progressively improve land and soil quality [14].

Cambodia is one of the most vulnerable countries in the regions among South-East Asia countries and climate change would be expected to affect this poor country significantly. Ministry of Environment, Cambodia [15] states that Cambodia faces many challenges in managing its resources sustainably while ensuring secure and productive livelihoods for its population. Cambodia Community Based Adaptation Programme (CCBAP) has been designed to implement the understanding of climate change for the present and future risks. As a result, the CCBAP takes into account flooding and droughts, which have been identified as the most serious risk to communities, and integrates adaptation strategies in the short term with vulnerability reduction and risk management in the future. It has been predicted that Cambodia will experience higher annual rainfall, with prolonging dry period in the rainy season and longer dry season and a more intensive wet season [16]. Among several projects for mitigating climate change vulnerability or climate change adaptation in Cambodia, the project titled

"Promoting Sustainable Agriculture in Samroung Commune, Prey Chhor District, Kampong Cham Province, Cambodia" was implemented by Institute of Environmental Rehabilitation and Conservation (ERECON) since April 2011-March 2016. The project has promoted organic agricultural practices for sustainable development and one of its objectives is to mitigate the vulnerability of climate change to small-scale farmers in Samroung Commune through community based adaptation (CBA) approach. The case study aims to share the lessons learnt from promoting sustainable agriculture practices through CBA, which could be able to enhance farmers or communities' ability to climate change adaptation in the project area.

#### II. METHODOLOGY

The 5-year project, financially supported by Japan International Cooperation Agency (JICA), was conducted in 11 villages of Samroung commune, Prey Chhor District, Kampong Cham Province in order to promote sustainable agricultural practice in this area. Samroung Commune is one of the third biggest producers of agricultural products among 10 districts of Kampong Cham to supply the local market in the district [17], most of farmers grow rice and vegetables and use a lot of chemical pesticide and fertilizer [18].

The Community Based Adaptation (CBA) approach to promote organic farming by cyclic use of natural resources was conducted in the project area in order to enhance farmers or communities' ability to climate change adaptation as well as to mitigate the vulnerability of climate change. The questionnaire survey was designed to conduct baseline survey with 450 farmers in July-August 2011 before starting the project and in February, 2016 terminating the project. The numbers of participatory learning workshops and technical trainings for producing and practicing

organic agriculture were delivered to the local farmers in the targeted area.

#### III. ACHIEVEMENTS AND LESSONS LEARNT FROM THE PROJECT

#### 1. Improvement of socio-economic benefits

This project has provided a number of socio-economic benefits to the 11 targeted villages. For instance, the construction of the pellet compost centre (Figure 1) at the commune level has urged farmers to produce more compost, granular compost and other organic fertilizers and pesticide. It helps farmers to reduce the expense of buying chemical fertilizer or pesticide compare to before implementing this project (Figure 2).

Moreover, the beneficiary including women-headed families could have more chance to attend workshops and training to increase adaptive capacities to cope with climate constraints occurring in their area (Figure 3).

However, Figure 4 shows that the average amount of chemical used by farmers after project implementation is slightly increased compare to when the project started. According to the interview with the beneficiary, this is because some farmers extend their farmland and they could not produce enough amount of compost to apply in their farmland. Because of this reason, they have to purchase chemical fertilizer to use together with compost to secure their crops yield.

In terms of average annual incomes as shown in Figure 5, before implementing the project in 2011, farmers could earn 920 USD and 560 USD per year from agricultural activities and non-agricultural activities, respectively, whereas after terminating the project in 2016, the farmers could be able to earn their average annual incomes up to 1,190 USD and 1,430 USD per year from agricultural



Fig.1 Farmers monthly meeting and discussion at Pellet Compost Centre at Samroung Commune

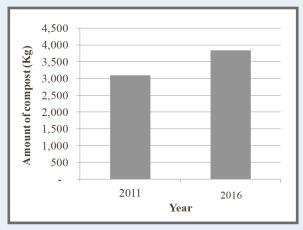
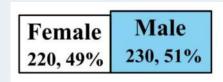


Fig.2 Average amount of compost used by farmers before and after project implementation



#### Total number of farmers = 550

Fig.3 Number and gender of farmers associated in the project

and non-agricultural activities, respectively. This change is a result from various agricultural activities that were generated from the project. Additionally, the income is increased due to good agricultural practices which produce high crop yields, decrease expenses for agrochemical products. Moreover, the cyclic use of

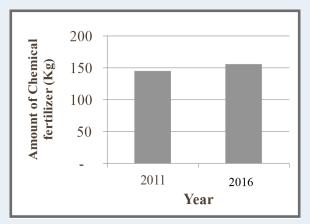


Fig.4 Average amount of chemical fertilizer used by farmers before and after project implementation

plant and animal residues in order to return nutrients to the soils through composting would minimize the use of non-renewable resources and reduce GHG emission. The achievement from this project would expectedly contribute to increase job opportunities and partly reduce labour migration from this commune to the city and neighbouring countries.

#### 2. Capacity Building Improvement

Numbers of capacity building workshops and technical trainings had been provided for local farmers to promote organic agriculture in the project area by encouraging them to apply compost or using cyclic use of plant and animal residues to increase nutrient in the soil in order to improve the environment and reduce CO, emissions. Moreover, the training on organic agriculture was not only conducted and practiced in the project area, but also in other countries. Farmers from Samroung commune were invited to join the technical training in Thailand and Japan during 2012 to 2014 in order to gain more knowledge and experiences related to organic agriculture and sustainable resource utilization.

Currently, farmers at the target area in Samroung Commune, Kampong Cham Province are producing organic vegetables to

supply to the local market; as a result, more income is generated (Figure 5). Moreover, they are producing organic agricultural products such as compost, granular compost and biopesticide for using in their farms. Also, they have shared the experiences and knowledge what they have learnt with other farmers who are not the members of the project. Aside from these, farmers are aware of selecting suitable crop varieties to grow in rainy and dry season and change the way of growing crops to those more adaptable to the climate change condition.

## 3. Raising Climate Change Awareness through organic farming

Workshops for raising climate change awareness through organic farming have been conducted in the target area in order to increase the knowledge on climate change at village and commune level.

The benefits from climate change awareness by promoting organic agriculture would mainstream concepts of climate change adaptation to local farmers as well as the commune authorities in the project site. Therefore, the commune authorities and project beneficiaries could understand what the main impacts of climate change are and which intervention options are available in the commune and should be taken in consideration. More importantly, the

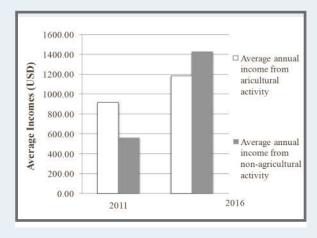


Fig.5 Changes of farmer's average annual incomes

commune authorities and local farmers would gain more experiences in conducting organic agriculture for adapting to climate change within their commune. The community would have more understanding on its impacts on their livelihoods and seek more prevention and adaptive options to help them reduce the vulnerabilities by drought and flood.

## 4. Dissemination of Lessons Learnt from the Project

Lessons learnt from the project were disseminated through various chanels including news letters on "Sustainable Agriculture" which was published once a year from 2013 to 2016, pamphlets and handouts related to organic agriculture and sustainable farming practices were also produced and disseminated in the project area and nearby communes from 2012 to 2016.

There were annual project evaluation meetings held once or twice a year both in Japan and in Cambodia. The participants in projects evaluation meeting learnt the progress of the project and gave comments and suggestions for project improvement.

Moreover, the farmers who actively participated in the project were able to be trainers for farmers from other province. On 2014 and 2015, farmers from Snoul Commune, Kratie province visited Samroung Commune to learn organic farming practices and climate change adaptation to practice in their farms.

## IV. CONCLUSIONS AND RECOMMENDATIONS

Community Based Adaptation (CBA) to Climate Change through organic agriculture is a very useful approach to reduce greenhouse gas emission. The approach also addresses Sustainable Development Goals target 2.4 in term of ensuring sustainable food production

systems that strengthen the capacity of small scale farmers for adaptation to climate change. The project has built the capacity of farmers through a series of workshops and technical



**Fig.6** Observing organic farming practice on October 2012, Thailand



**Fig.7** Observing organic farming practice on June 2013, Japan



**Fig.8** Observing bio-fertilizer making on December 2014, Thailand



Fig.9 Farmers' compost boxes at Samroung Commune



Fig.10 Organic agricultural practices in Samroung Commune

training including organic agricultural practices, raising climate change awareness, and producing organic agricultural products such as biopesticide, bio-fertilizer and so on. As a result, farmers could sustain their livelihoods and generate more income through farming activities. In order to create an enabling environment for climate change adaptation, it is important to firstly create the communities determination, and secondly create integrated participatory approach to foster adaptation processes. Therefore, enhancing the participatory integrated approach in project design and implementation is essential to achieve sustainable community based adaptation in the long term.

**Table 1** Workshop for sustainable agriculture based on cyclic use of natural resources

Year	2011- 2012	2012- 2013	2013- 2014	2014- 2015	2015- 2016	
Number of workshops	20	5	5	6	3	
Number of participants	747	190	158	318	61	
Total	1,474					

The farmers in the targeted villages have changed their agricultural practices from using a huge amount of agro-chemicals to organic farming and the change in agricultural practices has been also replicated to the other villages, so the emission of greenhouse gas from agricultural farming should be reduced in the area. Furthermore, the flexibility to cope with climate change is advanced. This leads to higher economic and environmental stability with more ecological balance. Aside from being resilience to climate change, the farmers who undertake to increase soil organic carbon by applying compost could achieve far greater success in CO, sequestration under suitable management.

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## Multi-sectoral governance council: A scaling-up approach in disaster preparedness and management

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#### I. ABSTRACT AND OVERVIEW

Civil society involvement in governance has been viewed as instrumental for sustainable and inclusive local development. For participatory governance to work, others outside of the Local Government Unit (LGU) must share in the responsibilities of governance. This is done with the formation of Multi-Sectoral Governance Council (MSGC), which provides a platform for involvement in the strategy formulation and implementation of programs/services.

In Mandaue City, the LGU and MSGC acknowledged that the challenges in developing the city are not only problems of the government but of the community as a whole. They have come to realize that everyone is part of the problem and the solution. Policies and projects implemented should be responsive and inclusive given the platform to dialogue with various sectoral representatives.

For Disaster Preparedness and Management strategy to move forward and produce results, it must do parallel activities of disseminating information to securing people's buy-in and involving them in concrete programs like post disaster recovery and rehabilitation. This is done through the formation of VACs (Vision Aligned Circles) which are small ad hoc work groups in departments and service sectors. They identify specific and realistic activities and work on it within a time frame of six months.

Presently, they focused their attention on preventive (preparedness training and capability-building), management and post disaster rehabilitation. These are assessed by the Multi-Sectoral Governance Council and will be the basis for fine-tuning development interventions. Activities were facilitated through the use of Geographic Information System data like Vulnerability Assessment maps, Topographic maps, Population and Health information and occurrence of critical incidents like typhoons, earthquakes, flooding

and fires. Related data were also accessed from PAG-ASA (Weather Bureau), NAMRIA for Landsatt maps and Google earth.

Cascading these activities to the barangay (village) level was also made with the formation and strengthening of Barangay Disaster Risk Reduction and Management Councils and regular assessment of DRRM related activities. Community residents were also able to maximally use GIS materials as basis in coming up with action plans and identify anchor persons for early warning, recovery and retrieval, rehabilitation and camp management.

#### II. RATIONALE

Almost 2 billion people currently live in urban regions of the developing world. This will double over the next 30 years, at which urban dwellers will account for nearly half of the global population (Metha & Buendia, 2004). An indicator of poverty and marginalization is the expansion of slum dwelling and precarious settlement in vulnerable areas like river banks, coastal zones, low-lying and sloping zones which are susceptible to flooding and landslides. Limited access to basic services and minimal involvement in governance are signs of marginalization from local governance. With worsening environmental changes, there is a concerted effort to involve this sector through institutional mechanisms like membership in development councils and related communitybased people's organizations. A new paradigm is also developing wherein civil society involvement in governance is viewed as instrumental for sustainable and inclusive local development.

#### III. THEORETICAL FRAMEWORK

The Good Governance Framework has three spheres - the State, Civil Society and the Private Sector. These different spheres overlap. The greater interplay there is between spheres of governance, the greater is the interaction between the State, the private sector and civil society (Brillantes, et. al., 2004).

The participatory dimension of civil society is operationalized through project functions and tasks like participation in project implementation, provision of benefits and services and in the overall direction setting of the local government unit.

The Local Government Code of 1991 (Republic Act No.7160) is very strong on people's participation. This was also reinforced in Executive order No.72, with provisions calling for the creation of multi-sectoral local planning teams that would prepare local development plans and the devolution of some of the review powers of Housing & Land Use Regulatory Board to the local government unit. Pertinent provisions in the creation of DRRM Councils down to the barangay level also support this enabling mechanism for people's participation.

#### IV. THE MANDAUE CITY CASE

(please see Appendix 1 for Research Methodology)

The process of providing avenues of participation of private sector and Civil Society can be achieved through Performance Governance System (PGS). The Performance Governance System (PGS) was originally meant to respond to governance gaps/needs of all sectors in the local government unit. It is a framework that aids in the management of the LGU's strategy. This was adapted for public sector institutions and incorporate it principles of good governance: fairness, transparency and accountability (ISA, 2015). Many municipal systems examine administrative performance while the present emphasis is on government processes to respond to service users and eventually their involvement in governance.

The objective of the PGS is to transform the LGU into a well-governed institution that produces breakthrough results. It begins by enabling the LGU to define its aspirations as articulated in its vision statement (Eizmendi, F., 2015). This defines its aspirations in a 3-5 time frame and becomes the basis for creating a strategy map. For participatory governance to work, others outside of the Local Government Unit (LGU) must share in the responsibilities of governance. This is done with the formation of Multi-Sectoral Governance Council (MSGC), which provides a platform for involvement in the strategy formulation and implementation of programs/services. It also acts as a monitoring and advisory body. Its primary role is to assess the implementation status of the initiatives on a regular basis.

The Local Government Unit and MSGC acknowledged that the challenges in developing the city are not only problems of the government but of the community as a whole. They have come to realize that everyone is part of the problem and the solution. Policies and projects implemented should be responsive and inclusive given the platform to dialogue with various sectoral representatives (Cortes, J, 2015). This is done through the formation of VACs (Vision Aligned Circles) which are small ad hoc work groups in departments and service sectors. It was an avenue for employees to know that they, too, have significant role to play in achieving the city's goals. Each team was assigned to handle a particular strategic initiative. The timeline set for each initiative varies from 6 to 12 months, depending on the nature of the initiative. The VAC undergo a bi-annual public revalidation (assessment) to present their accomplishments to external stakeholders.

Through the #iammandaue Transformation Program, the city's governance charter is being cascaded to the different departments in the local government. The emphasis was on the value of identity for the vision and the strategy to work.

The learning process was made through plays/simulation exercises. It allowed VACs to examine their dynamics as a unit. The importance that communication and teamwork for synergy was expressed by VAC members themselves.

For Disaster Preparedness and Management strategy to move forward and produce results, it must do parallel activities of disseminating information to securing people's buy-in and involving them in concrete programs like post disaster recovery and rehabilitation. They identify specific and realistic activities and work on it within a time frame of six months. Presently, they focused their attention of preventive (preparedness training and capability-building), management and post disaster rehabilitation.

Activities were cascaded at the barangay level through the formation of BRRMCs (Barangay Risk Reduction and Management Councils) and the activation of volunteers to anchor early warning, rescue/recovery and recovery. This was also facilitated through the use of Geographic Information System (GIS) data. This was made to assess and determine natural and man-made hazards and identify critical factors affecting vulnerability of community residents. It was envisioned that results of mapping out of vulnerability levels for each barangay will be made during the next six months. This participatory modelling/ mapping is integrated in the DRRM planning and training sessions.

Materials like vulnerability, topographic and population maps were used as planning tools during city and barangay discussions. Basic data like morbidity, mortality, dengue and HIV-AIDS prevalence were accessed from the City Health Department. Critical incidents data like flooding, typhoons and fires were

also accessed from line departments of the city. Related data were also accessed from PAG-ASA (Weather Bureau), NAMRIA for Landsatt maps and Google earth.

Specifically, population trends, ID of potential pollutants from industries and food processors; water source pollution and salt water intrusion; morbidity and mortality; dengue and HIV-AIDS tracking and other materials were also used in these consultative and planning sessions. Scenario-building or modelling (Using STELLA software) is presently ongoing for pilot areas with population density, health incidence and public health intervention as main variables. Within the next two months results of this modelling process will be shared to all stakeholders.

Another innovative strategy is the initiative of CSWDO and Bidlisiw, a partner NGO in responding to affected families in the biggest fire in the city was pilot tested in Barangay Mantuyong and Guizo. Development workers from CSWDO, and Bidlisiw came up with an initiative focusing on post-disaster psycho-social support. Selected mothers, youth and children undertook courses on coping, social support and social resiliency (see Appendix 2: Child-centered DRR).

#### V. SUMMARY AND CONCLUSIONS

Good Governance can only be achieved through active participation of civil society/people's organizations and the private sector. On the area of Disaster Preparedness and Response, community residents should play vital roles in early warning, rescue and rehabilitation. The Local Government unit should recognize this potent force in stakeholder participation. Community organizers and facilitators with its advocacy on environmental sustainability and disaster mitigation should use

this avenue in pursuing its development agenda of empowerment and participation.

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#### **Appendix 1: Research Methodology**

This is a case study. The researcher was involved in the formation of MSGC as representative of the social service sector. Analyzing secondary data VAC records for sectors on Health, Social Welfare and Bantay Mandaue (CDRRMC) and proceedings of barangay DRRMC formation were made in 2015 and first six months of 2016. Detailed documentation on Child-centered DRR was also made and converted into CDs. Requests can be made to Dave Mariquit, MCC-ICT Chair

Materials like maps, health data and others are available upon request. Modelling/scenario-building was made through the use of STELLA software. Variables like population, dengue incidence and community's health IEC and related development intervention were used in these exercises and pilot-tested in four barangays (communities).

# Appendix 2: Child-centered DRR for Barangays Mantuyong and Guizo

(facilitated by CSWDO, Bidlisiw and MCC social work interns)

Child-centered DRR Toolkit (HVCA-Hazard, Vulnerability & Capacity Assessment)

Child Friendly DRR is meant to:

1. Build capacities in DRR

- 2. Enable children to analyze and monitor risks, vulnerabilities, and capacities in their communities
- 3. Help children plan for DRR activities they can initiate or participate in their communities.
- 4. Provide a space for children to contribute their perspectives to DRR in their communities.
- 5. Link children HVCA findings appropriately to local disaster management governance and planning.

Key elements for carrying out effective training with children:

- 1. Child protection: ensure the training environment is safe (physically, and emotionally); ensuring trainer/s are trusted to work with children; parental consent for children's participation in training activities is obtained.
- 2. Child participation: ensure activities enable children's views to be shared; children's views are respected by trainer and fellow participants; no child is excluded from participation in the group; children's individual sharing of opinions must also be kept confidential.
- 3. Child engagement: ensure training activities are fun, interactive and age-appropriate.

Child centered DRR training using the HVCA

#### **Objectives:**

- 1. Define the concepts of hazard, vulnerability, capacity, risk and risk reduction (through the use of community vulnerability maps).
- 2. ID and rank hazards, vulnerabilities, capacities and risks in their community.

- 3. Analyze their community's disaster history and seasonal disaster calendar.
- 4. ID and analyze disaster causes & risks (including climate change).
- 5. Link identified vulnerabilities to opportunities for capacities and resources that can reduce risk.
- 6. Plan for disaster preparedness, prevention & mitigation activities.

#### **Contents:**

- 1. Icebreakers, hopes, Fears & expectations, Ground Rules (through the use of "Mandala")
  - 2. Community maps
  - 3. Better understanding of our risks
  - 4. Hazard Identification
  - 5. Disaster History
- 6. Hazard Ranking and Disaster causes & Impacts
- 7. Vulnerability ID and Transforming vulnerabilities into capacities and identifying prevention, preparation & mitigation activities.
  - 8. Conclusion & evaluation

Specimen 1: Icebreaker 3: Our feelings in the event of emergencies & disasters

During this activity, participants discuss the different feelings they might have in the event of a disaster, sometimes feelings that cannot be controlled, including fear, anger, crying, anxiety and despair. Learning how to manage these feelings is important in an emergency or disaster so that we can act appropriately. Disasters can scare us, our families and out neighbors, but solidarity and teamwork should be cultivated so that we can support each other.

#### **Process:**

- 1. Explain to the group that during this activity, we talk and reflect on our individual and family feelings during disasters or emergencies that have occurred in our community.
- 2. Divide the children into groups of 3-4 each
- 3. Each one receive a photocopy copy of "mandala" (their choice) with crayons and markers. Together, they color their choices and their feelings as expressed in the colors chosen indicating their feelings about what happened.
- 4. Ask each child/minor to present their pictures/mandalas describing what they have drawn and sharing their feelings about what has happened. During presentations, the facilitator should emphasize the importance of listening to each other and respecting each others' feelings, creating an environment of safety among the children.
- 5. After all the presentation, discuss together its importance to their lives. To share their feelings about disasters (to understand that they are not alone, to be able to heal, to be able to prepare ourselves better for future risks); discuss who they can share their feelings about disasters with friends and trusted adults in the community such as school teachers, counselors or religious leaders, and discuss how being more prepared for disasters and understanding our capacities and vulnerabilities in the event of a disaster can help them be better prepared and less scared.

Acronyms: NAMRIA - National Mapping Resource

CSWDO - City Social Welfare Office

LGU - Local Government Unit
DRRM - Disaster Risk Reduction and

Mitigation PGS - Performance Governance System

GIS - Geographic Information System VAC - Vision Aligned Circles

- Multi-Sectoral Governance

Council

**MSGC** 

# Policy to action: Low carbon education for RCE Iskandar

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Abstract-Iskandar Malaysia is an economic development region in the southern part of Malaysia, which is close to Singapore. Drastic changes in terms of physical development are taking place in Iskandar Malaysia but the agencies involved in the projects are committed to ensure that the development is sustainable. Education for Sustainable Development (ESD) movement started in this region since the establishment of Iskandar Regional Development Agency (IRDA) with units like Social Development Unit and Environment Division. Universiti Teknologi Malaysia (UTM) together with some universities and research institutes in Japan and IRDA have drawn a policy on low carbon for this region entitled, "Low Carbon Society Blueprint for Iskandar Malaysia 2025" which was endorsed by the Prime Minister of Malaysia in 2013. In 2014, UTM and IRDA established RCE Iskandar as more stakeholders work together to realize the policy. In 2016, all the 5 local authorities in RCE Iskandar adopted the policy and put them into action at micro levels. This paper presents low carbon education in RCE Iskandar, from how it started in 2011 with Johor State **Education Department, 4 District Education** Offices, 226 primary schools and 44 secondary schools through a few actions written in the

policy to realize a Low Carbon Society for RCE Iskandar. These actions included Stakeholders Engagement, Teacher Training, Iskandar Malaysia Ecolife Challenge, Problem-Based Learning for Low Carbon Society and Low Carbon Society for School Science Clubs, all helping to realize a Low Carbon Society for RCE Iskandar. The paper concludes that these actions contribute to raising awareness and practices among school students and teachers.

**Keywords:** Environmental Education, Low Carbon Society, Policy

#### I. INTRODUCTION

Iskandar Malaysia is the first of five Economic Regions created by the Malaysian Government with the purpose of focusing and spear-heading Malaysia's economy. Iskandar Malaysia (IM), formerly known as Iskandar Development Region (IDR) and South Johor Economic Region (SJER) is the main southern development corridor in Johor, Malaysia which was established on 8 November 2006 [1]. Iskandar Malaysia (IM) is a visionary economic region in Johor that was established as one of the catalyst development corridors to spur growth of the Malaysian economy [2]. Such very rapid development is due to several

factors, notably the completion of the Comprehensive Development Plan 2006-2025 (CDP), 24 blueprints and the Iskandar Regional Development Authority (IRDA) created through an Act of Parliament (Act 664), which is solidly guiding the development [1]. The economic region's transformation from mainly manufacturing, agriculture and food processing to advanced services and high value-added industries is rapid by world standards, and is seen today as one of the fastest growing regions not only in Malaysia but in East Asia [1]. With such rapid land use and other developments, driven by a major influx of Foreign Direct Investments and significant local investments, it became even more critical that such developments are closely monitored so that the plans, policy and programs stated in the CDP are carried out in a sustainable manner. IM's transformation clearly adheres to its vision of a 'Strong and Sustainable Metropolis of International Standing'. Therefore, a few steps were taken to ensure the sustainability of the development in IM such as the instalment of an Environment Division in IRDA, the production of the Low Carbon Society Blueprint for Iskandar Malaysia 2025 and finally all the efforts taken have established RCE Iskandar in 27 November 2014.

In 2012, the Low Carbon Society Blueprint for Iskandar Malaysia 2025 (LCSBPIM) was produced and endorsed by the Malaysian Prime Minister [3]. The blueprint was edited to the third edition in 2014 [4]. In the blueprint, 12 actions were drawn under triple bottom pillars namely Green Economy, Green Community and Green Environment. Under the Green Community comes two actions which are Low Carbon Lifestyle, and Community Engagement & Consensus Building. There are five sub-actions under the Low Carbon Lifestyle action where "Awareness through Education" is the core of this paper since one of the measures of this sub-action is to enhance school children awareness

through various programs drawn in the blueprint. The programs are Low Carbon Society (LCS) education across curriculum, school clubs for LCS & 3R (Reduce, Reuse, Recycle) programs, Children Eco-life Challenge project, interschool 3R project competitions, 3R measures at schools, LCS measures at schools, collaboration with relevant government agencies & NGOs, and students to collect reusable & recyclable wastes from home and neighbourhood. The details of the programs can be found in the Road Map [3]. This paper illustrates how the blueprint was drawn up and later put into action.

#### II. DRAFTING THE BLUEPRINT

In order to draw a Low Carbon blueprint for a sustainably developed IM, an international research project sponsored by Japan International Cooperation Agency (JICA) and Japan Science and Technology Agency (JST) were started in 2010 [2]. The project combined researchers from Malaysia and Japan to draw policies, actions, measures and programs to ensure IM achieve the reduction of carbon by year 2025, in line with Malaysia's voluntary commitment to reduce the country's carbon intensity by 40% by year 2020 (based on 2005 levels). The collaborative effort involved a big group of Malaysian researchers from Universiti Teknologi Malaysia (UTM) and IRDA, and Japanese counterparts from Kyoto University, Okayama University and National Institute for Environmental Studies. The project started in July 2011 and this five-year long project has achieved all the objectives of the project before the end of the project.

The research project began with a pilot study in IM and showcased best practice in LCS for Asian Regions. It was a hands-on project where researchers and government officials of Asian countries work together in implementing research outputs within the cities or regions involved, leading to the eventual

establishment of an Asian Low Carbon Society network. The Project consisted of 5 research groups, namely: (1) Scenario Integration and Land Use Planning, (2) Consensus Building and Education, (3) Energy System, (4) Solid Waste management and (5) Air Quality and Transport.

"Low Carbon Society Blueprint for Iskandar Malaysia 2025" is a written document that represents comprehensive climate change mitigation policies and detailed strategies to guide the development of Iskandar Malaysia towards "Strong and Sustainable Metropolis of International Standing". The document is the product of 'science-policy' partnership, the partnership among afore mentioned Japanese research institutes, UTM and IRDA. The overall process began with the information gathering, analysis and contextual appraisal of current development, carbon emission and policy scenarios in IM. This allowed the setting of IM's LCS goals and carbon emission reduction target in 2025. Stakeholder participation in the preparation of the document was a major activity through a series of Focus Group Discussions (FGD) and workshops where proposed actions, measures and programs were scrutinized and stakeholders' opinions were collected and fed back into the policy formulation process.

The blueprint incorporates various related national policies, and the other 24 Iskandar Malaysia Blueprints and Comprehensive Development Plan (CDP [1] & CDPii [5]) in transforming IM into a low carbon metropolis. The blueprint discusses and provides complex technical details of carbon mitigation options with specific measures and programmes. It is aimed to guide the implementation of 12 low carbon society policy actions in Iskandar Malaysia through 281 programs that would bring a reduction of 58% of GHG emission intensity and a 40% emission reduction from 2025 BaU (business as usual) compared with

2005 as base year.

Specifically for the low carbon education component, the Consensus Building and Education group was responsible in drafting Action 6 (Low Carbon Lifestyle) and Action 7 (Consensus Building & Community Engagement) of the blueprint. LCS Education is a measure under Action 6. The researchers first engaged with an officer from the Johor State Education Department (JPNJ) to bring the idea of low carbon education into schools in 2011. JPNJ was very keen to bring the new idea into schools. As a result, a focus group discussion was conducted among 33 selected principals and headmasters from the secondary and primary schools in the region of IM. They were introduced to the idea of LCS and were asked to share what measures that schools have taken and are willing to commit if LCS is to be implemented in schools in IM. The details of all the measures can be found in [6].

In September 2012, a group of researchers from UTM, JPNJ and IRDA visited Tokyo and Kyoto to learn about LCS good practices under a technical tour of the research project. In this visit, engagement with the Ministry of Environment and education boards took place to enable Malaysian delegates to learn how policy impacts the environmental education in Japan. Visits to some selected secondary schools, primary schools, nursery, ecology centers and non-profit organization (NPO) provided some ideas of the best practices that can be carried out in IM. The practices were studied and at the end a few measures were introduced to the IM's blueprint.

#### III. POLICY INTO ACTION

Following the global launching of the blueprint at COP18 Doha in November 2012, the Environment Division in IRDA, tasked with the strategic environmental planning and management of IM, focused on the

implementation of the blueprint. Hence, IRDA produced an implementation plan entitled "Iskandar Malaysia Actions for a Low Carbon Future" [7] in 2013 and was launched at COP19 in Warsaw, Poland. This is the first of a series that details 10 out of the 281 programs of the LCSBPIM and shows how actions supported by science can be used to ensure reduction in carbon emission. The document identifies 10 programs which were to be completed by end of 2015. These included the Eco-life Challenge Schools Project which was learnt from KIKO Network, an NPO in Kyoto, during the technical tour in Japan. Later "Low Carbon Society Blueprint for Iskandar Malaysia 2025 with 10 Implementation Plans" [4] was produced to serve as a complementary document or blueprint that guides the implementation of policy actions by outlining implementation programs according to the given priority, timeline and related implementation agencies.

#### A. Eco-life Challenge Schools Project

This project was implemented as a competition to inculcate low carbon awareness among all primary school students in IM. The competition organized in IM is the Iskandar Malaysia Ecolife Challenge. There were two stages of the competition. In the first stage, all the primary 6 students were given a workbook designed by UTM researchers. The workbook aimed to instill low carbon awareness through household accounting and other self-reflective activities. The schools also competed in recycling items collection and electricity and water saving projects as mentioned in the previous section. The second stage of the competition required the students to present their understanding and practice of low carbon orally. The finalists were selected based on the workbook completion and achievement of the projects. A total of 15 finalists were selected to the second stage of the competition and the winners went for a study trip in Kyoto, Japan.

In 2013, Iskandar Malaysia Ecolife Challenge project involved only 23 schools as pilot schools. It was expanded to 80 schools in 2014 and in 2015, it involves all 226 primary schools in IM and a total of 27,626 primary 6 students. The competition also involved at least 300 teachers. Thus the dissemination of low carbon awareness can be multiplied by this competition. The research results show that the students have increased their practices on LCS after the project [10]. The details of the project has been reported in [8]-[10].

#### B. Teacher Training

Recognising the important role of educator in promoting climate change education, teacher training was also included as a part of the Eco-life Challenge Schools Project. One or 2 teachers from each participating school joined the training which was given prior to the competition. They were introduced to the ideas of climate change, global warming, greenhouse gases and LCS. The teachers were given a questionnaire before the training to measure their knowledge (awareness), attitude and practices on LCS. At the end of the project implementation, the teachers were asked to fill in the same questionnaire. Research results showed that there was an increase in all three aspects measured [10].

# C. Problem-Based Learning for Low Carbon Society

After the success of disseminating low carbon awareness at primary school level, in 2016, RCE Iskandar continues to work on the secondary school students' awareness. In a new JICA funded project, Kyoto Environment Activities Association collaborates with UTM to introduce LCS through the use of Problem-Based Learning (PBL) in two pilot schools selected by JPNJ. 12 teachers from these two schools who teach Science, Mathematics and Living Skills subjects were trained to use PBL by experts from UTM. They were guided to

implement PBL to a class of Form 2 students from each school. Issues related to LCS were given to the students and, in groups, they must identify the underlying problems, learn about LCS, collect relevant data and then propose solutions to the problems identified in the issues.

## D. Low Carbon Projects through Schools' Science Clubs

In another attempt to introduce LCS to secondary school students, 44 secondary schools were selected to be involved in a project initiated by the Johor Bahru District Education Office (PPD JB). This project is a collaborative effort between PPD JB and UTM. The awareness is disseminated through school's Science Club. Advisory teachers were gathered by PPD JB for a training on LCS and they were asked to guide students in producing scrapbooks on LCS.

#### IV. CONCLUSIONS

This paper presents the process of drawing up a Low Carbon Society Blueprint as a policy endorsed by the PM and successfully adopted by IRDA to address climate change through creating low carbon society (of relevance to Sustainable Development Goals, target 13.2 [13]), and putting it into action. The activities discussed in this paper particularly focus on children and youth, targeting to educate them to lead a sustainable lifestyle (sustainable consumption and sustainable waste management, targets 12.5, 12.8 [13]). The activities also aim to educate, raise awareness and build capacity on climate change mitigation and adaptation (target 13.3 [13]).

Both Ecolife & Challenge Schools project and its accompanying teacher training has shown that it can increase students' and teachers' awareness on climate change and global warming. Respondents also reported to

have increased low carbon behaviour (addressing climate change issue through daily routine). The growth from 23 pilot schools to all 226 primary schools in IM with the collaboration with JPNJ and district education offices has proven the project's potential to be replicated in other regions in Malaysia due to its centralized education system. Replication of such projects in areas other than in Malaysia might yield success given that it originated from Kyoto, Japan but was successfully adapted to the Malaysian education culture.

As PBL is an innovative teaching approach to integrate low carbon education (for sustainable development) through interdisciplinary practices, it is in line with the objective of UNESCO's Climate Change Education for Sustainable Development [11]. PBL was shown to be promising approach to inculcate the concept of sustainable development and have deep impact on students [12]. PBL has built teachers' capacity to provide quality education for students (student-centered learning). Through real life low carbon-or climate-related issues given to them, students acquire knowledge and skills required to promote sustainable development specifically on sustainable lifestyles (in relevance to Sustainable Development Goals, target 4.7 [13]). However, the study on its impact to students' and teachers' awareness of low carbon (climate change/global warming) is still in progress to date.

In the Malaysian context, environmental education (or climate change education) is embedded across curriculum (not a stand-alone subject), hence largely depends on the teachers to use their discretion in instilling climate-related knowledge and awareness. Hence, one of the lessons learned through these projects are the importance of capacity building among teachers.

In terms of resource management, knowledge and material developed in these projects can be shared among educators in Malaysia due to the nature of its centralized education system. Adaptation to local culture must be emphasized should the materials be used in regions other than Malaysia.

With the positive results shown from the researches carried out concurrent with the projects, it is suggested that the projects encourage attitude and behaviour changes needed from a new generation of climate change-aware citizens.

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# Education for sustainable development to develop a climate smart and disaster resilient community in the Indian Himalayan region

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#### INTRODUCTION

Climate change is happening at a much faster rate than expected. It has also been recognized that climate change exacerbates underlying vulnerabilities of the communities to the hazards they normally experience as well as generate new hazards which a community may have no experience of handling. Climate change adaptation and disaster risk reduction go hand in hand; both aim to reduce the impacts of threats by anticipating risks and uncertainties and addressing vulnerabilities. Scaling up of Disaster Resilience and Relief (DRR) activities and interventions will contribute significantly to climate change adaptation.

Indian Himalayan Region (IHR) extends up to 12 states-Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Tripura and the hilly districts of Assam and West Bengal-covering 121 districts of the total 686 (as of 2016) districts of India. IHR comprises of 16% of the country's geographical area. The region supports 47,076,046 people constituting 3.88% of India's population (2011 census).

IHR represents a fragile ecosystem attributed to altitude, deep slopes, geological, edaphic and biotic factors limiting its capacity to withstand even small degrees of fluctuation. For centuries, the ecological balance of the mountain ecosystem was sustained supporting incredible biodiversity in the region.

The Himalayan Region represents a self-sustaining economy. Inhabitants are dependent on flora, fauna, and other natural resources native to the Himalayas for their life and livelihoods.

Since the past century, the Himalayas have undergone major changes. Population explosion, influx of tourism and incoming urbanization have resulted in the over-exploitation of natural resources, reduced forest cover, increased soil erosion and silting of water bodies, drying-up of rivers and streams and loss of biodiversity. Tourism has emerged as a major industry in the region resulting in development of roads and rampant infrastructure development. All these variables have been significant in contributing to the already occurring climate change at an unprecedented rate.

The rise in temperature is triggering melting of the glaciers at an alarming rate. The melting glaciers mean floods and fast run-offs in the rivers in the short term and droughts and water scarcity in the long term. Furthermore, rising temperature affects soil moisture and making it drier, which directly impacts on the food production, increasing food insecurity particularly for the marginalized population. The loss of biodiversity, forest cover and natural resources will further exacerbate the situation.

Climate change combined with other variables is aggravating the susceptibility of Himalayas to natural calamities. Intensity and frequency of extreme weather events like Glacial Lake Outburst Floods (GLOF), flash floods, landslides, mudflow and cloudburst has increased exponentially. Extreme weather events combining with exacerbating vulnerabilities and limited capacities of the Himalayan communities have given rise to catastrophes in the Himalayas.

The pressing need of the hour is to empower mountain communities to respond to disaster and climate change risks through improved systems, resources and skills.

CEE Himalaya (Himalaya Initiative of the Centre for Environment Education, India) has been working in the IHR for more than past 15 years with the aim to increase awareness and understanding to mountain communities about environmental issues in the IHR and to build climate smart and disaster resilient mountain communities. CEE Himalaya focuses on DRR, conservation and management of natural resources, sustainable livelihoods, and capacity building through education for sustainable development (ESD).

Under the Indian Himalayas Climate Adaptation Programme (IHCAP) of Swiss Agency for Development and Cooperation (SDC), CEE Himalaya was awarded two mandates for capacity building of mountain communities and other related stakeholders on climate change adaptation and disaster risk reduction in IHR.

Under IHCAP CEE Himalaya with TTP (The Third Pole) organized four workshops for the media – print, television and radio to be held at Shimla in Himachal Pradesh, Namchi in Sikkim, Srinagar, Jammu & Kashmir and Jorhat and Majuli in Assam. These media workshops provided the participants with an opportunity to interact with experts on climate change, science communication, government and media to help them understand the science and social aspects of climate change, existing policy framework and scope for implementation and the ways for effective reporting.

The objectives of the media capacity building workshops were:-

- to sensitize journalists on climate change issues globally viz-a-viz Himalayan region
- apprise them on existing policies and programmes for climate change mitigation and adaptation
- orient them to effective reporting on climate change issues, case studies and sustainable development for the mountain communities

The attempt was made to cover the entire Himalayan Range-Western, Central and the Eastern. Sikkim being strategically important for India lying astride the shortest route from India to Tibet, it was decided to conduct a workshop in Sikkim also. The first workshop took place in Shimla, Himachal Pradesh from 30 July to 1 August 2014 themed on biodiversity conservation; the second in Namchi, South Sikkim from 18 to 20 November 2014 focused on watershed management in Sikkim; the third in Srinagar, Jammu and Kashmir from 6 to 8

Table 1 Summary and number of participants of the four media workshops

Media Workshop Location	Duration	Participants		
		Journalists	Resource Persons & Organizers	Workshop Theme
Shimla, Himachal Pradesh	30 July to 1 Aug 2014	18	16	Impact of CC on Agriculture, Forests, Biodiversity, Food Security, Livelihood
Namchi, South Sikkim	17-19 November 2014	25	12	Watershed management and reviving the water streams
Srinagar, Jammu & Kashmir	6-8 April 2015	17	11	The devastating J&K Floods
Jorhat & Majuli Islands, Assam	2-5 November 2015	14	12	Climate change impacts on agriculture, tea and fish; Floods, soil erosion in Brahmaputra basin and livelihood in Majuli Islands

April 2015 discussed the role of climate change (CC) in natural disasters, and the last one in the series took place in Jorhat and Majuli, Assam from 2 to 5 November 2015 highlighting climate change impacts and adaptation measures in the eastern Himalayas, with a special focus on the Brahmaputra basin. Overall 75 journalists from print, television, radio and online media and 51 resource persons and organizers attended the workshops.

For each workshop 2 reports have been prepared, one the proceedings and second the journalist report. The proceedings have documented the workshops as they ran whereas the journalist reports provide the best of the deliberations made and discussions held. Both the reports of each workshop are kept stand alone and for this purpose there are overlaps in the two reports like the introduction of the workshop, list of participants, programme schedule, feedback and so on.

#### Two manuals have been developed:

## 1. Himalayas, Climate Change and the Media: A Trainers' Manual

- To facilitate organizations/agencies like CEE in conducting workshops of the kind.
- To provide trainers with competencies that will enable them to effectively mentor journalist participants in understanding climate change and selecting issues for news report/feature.

# 2. Himalayas, Climate Change and the Media: A Manual for Journalists

- To guide other journalists around the corner who were unable to attend the workshops.
- To help journalists cover climate change and adaptation issues in the Himalayas with more accuracy and understanding.

#### **Key Achievements of the Workshops:**

- 74 media personnel were trained through 4 media workshops on climate change and sustainable development issues, global initiatives on handling these challenges and get oriented on reporting these issues effectively resulting in community awareness, advocacy and policy influence.
- To date more than 50 press & electronic reporting/case studies appeared in the media.
- Increase in the amount of media coverage given to climate change issues.
- Compiled a database of journalists trained and stories they have published so far.

# SCIENCE EXPRESS CLIMATE ACTION SPECIAL (SECAS) TRAIN AND THE MULTIMEDIA MOBILE/PORTABLE EXHIBITION IN THE INDIAN HIMALAYAN REGION

CEE Himalaya and SDC again came together to support the Science Express Climate Action Special (SECAS), an initiative of CEE, Ministry of Environment, Forest and Climate Change (MoEF & CC), Department of Science and Technology (DST) and Indian Railways. SECAS is an exhibition on wheels mounted on 16 AC coaches flagged off on 15th October 2015 and was running in 21 states till May 2016. The objective of this collaboration was to support SECAS activities in the Indian Himalayan Region and to enhance awareness of students/general public on climate change, adaptation and mitigation.

During its journey, SECAS visited six stations in three states of Indian Himalayan Region, namely Amb Andura (9-10 November 2015) and Churaru Takarla (12-13 November 2015) in Himachal Pradesh (HP), Udhampur

(17-20 November 2015) and Samba (21-23 November 2015) in Jammu & Kashmir (J&K) and Haridwar (30 November 2015 to 2 December 2015) and Lalkuan (3-5 December 2015) in Uttarkhand. Since these stations lie in the mountain terrains and the train only halted for 2 or 3 days at each station making it difficult for the majority of people in the region to visit the train. Also the train has limited accessibility as it cannot cover the entire mountain terrains of the Indian Himalayan Region. Therefore CEE Himalaya and SDC decided to conduct activities at the platforms and in the cities of the stations where the train halted and also in Shimla in HP and Jammu in J&K where the train did not visit.

For delivering an effective and motivational programme, a facilitator's workshop was conducted wherein the volunteers and CEE Himalaya Team were detailed about the train and their roles during in conducting various activities. Two volunteers from each of the cities of Churaru Takarla, Amb Andura, Udhampur, Samba, Lalkaun and Haridwar were trained in the workshop. It was a two-day workshop to support them to prepare for these activities and also provide them the necessary literature and a kit.

To support the activities at the platform and in the cities a science kit was developed for each volunteer. Science kits contained following items: couple of glasses (made of glass), flask (should be filled with hot water before the experiments), big glass air tight container, packet of balloons, a transparent big air filled ball, small packet of thermocol balls, a stirrer glass rod, an ink dropper, 2-3 small plastic balls (hollow from inside), 3-4 meters of wire (malleable which can be folded), a cello tape and a brown tape roll, a small bottle of potassium permanganate, an ice box, 2 permanent markers, a globe and map of the World, a clinical thermometer, a laboratory

thermometer, a set of 4 small plastic containers (small ones used to keep salt or pepper), candle and match box, torchlight, ropes and ladders game done in big size on canvas; dice; messages printed and laminated, small size 'standees' rolled, a few chart papers, a bundle of string, scissors, box of office pins/stapler and so on.

PRE-TRAIN ACTIVITIES IN THE CITIES OF CHURARU TAKARLA AND AMB ANDURA IN HIMACHAL PRADESH (HP), UDHAMPUR AND SAMBA IN JAMMU & KASHMIR AND LALKAUN AND HARIDWAR IN UTTARKHAND

Prior to the arrival of SECAS, CEE Himalaya Team visited various schools and cities of Churaru Takarla and Amb Andura in Himachal Pradesh (HP), Udhampur and Samba in Jammu & Kashmir and Lalkaun and Haridwar in Uttarkhand to increase the awareness of students and residents about SECAS and to motivate them to visit the train. Drawing, Poster Making, Extempore, Speech, Discussion, Debates, Essay Writing, Quiz, Idea Activity, Mini Science Experiments, Activities on Basic Science and Mathematics Concepts, Spread the word, Check your Emissions, Take your pick, Ropes and ladder games, Display of Standees and discussion based on them, short plays were conducted with students and teachers

Other than students and teachers, activities were also conducted at Ganga Ghats, villages reaching out to farmers, street vendors, sadhus and so on. 4,927 students, 194 teachers, 15 Sadhus, 10 street vendors, 260 pilgrims, 55 farmers and 216 general public were addressed through various events/activities.

**Street vendors:** A small discussion was held with street vendors at one of the Ghats in Haridwar on impact of climate change in

Haridwar, Clean Ganga Mission and the impact of these on their livelihoods. It was found that during Ganga cleaning the holy water is stopped for a certain stretch and due to this many tourists did not visit that particular stretch thereby impacting the livelihood of the vendors in that particular stretch.

Farmers: climate change has its most powerful effects on food crop agriculture; the impacts go beyond crop failure to economics. To document this, discussions were organized with farmers at Rishikesh, Haridwar and Lalkaun about the changes in climate of that particular region, effect on crops, productivity and their livelihoods, and what adaptation are being taken to deal with it.

Pilgrims: Haridwar and Rishikesh being the holy places are packed with pilgrims from all around the country therefore discussions were also held at significant pilgrimage sites on Clean Ganga-Nirmal Ganga. Also pilgrims were addressed on the importance of climate change and how our indigenous practices are helpful in mitigating climate change.

**Sadhus (Sage/Hermits/Priests):** Sadhus provided information on the changes in climate over a period of time and its impact on the Holy River Ganga. The linkages between the religious practices and climate change were also very well documented by Sadhus.

#### **PLATFORM ACTIVITIES**

Activities were conducted at platforms of Churaru Takarla, Amb Andura, Udhampur, Samba, Lalkaun and Haridwar on Climate change, its issues and impacts in the IHR were discussed with students and teachers. Some mini science experiments were also displayed to students to show them different phenomenon occurring in our ecosystem and how these get

affected by slight changes. Standees containing some questions on environment were also used to stimulate discussion among students and to impart knowledge on the same. Students were given opportunities to display their thoughts through drawings, slogans, debates, speech and so on. Some basic concepts of Science and Mathematics were also imparted using puzzles, experiments and board games.

#### POST TRAIN ACTIVITIES IN JAMMU, J&K AND SHIMLA, HP

1. Workshop for Equipping Educators on Climate Change and Orientation for Media on Climate Change Reporting: - In collaboration with the Centre for Environment Education and Training, Jammu and Kashmir, and the Press Club of Jammu, the two daylong workshops were held on 14 December (for educators) and 15 December (for the media) in Jammu. 100 teachers and 25 media persons were addressed through the two workshops. The events were also graced by the presence of State Minister of Education, Shrimati Priya Sethi, Shri Bali Bhagat, State Minister for Social Welfare, Forest, Ecology and Environment, OP Sharma, IFS and Director of the Department of Environment, Ecology and Remote Sensing and other eminent personalities from the administration, thus conveying the message not only to the teachers but also to the administrators directly responsible for formulating and implementing policies related climate change, adaptation and mitigation.

2. Science Exhibition at State Level Children's Science Congress at Rampur, Shimla from 14th-17th December 2015:- HP State Council for Science, Technology and Environment invited CEE Himalaya to display our standees, science kit and other IEC material on climate change at the exhibition. Therefore CEE Himalaya participated in the event and took the opportunity

to aware students and teachers on the issues of climate change globally as well as specific to Indian Himalayan Region. 3,367 students and 73 teachers were addressed through the event. Information on Globe, North Pole & South Pole, Equators, Jet Wave, Equinox Line, Earth Rotation and Revolution, Earth's Axis & Tilt, Seasons change, Climate change and its Impact on Earth, Information on Science Laws like-Bernoulli's Law, Centre of Mass, Centre of Gravity and so on was imparted to students using science kits and display of standees. The exhibition stall of CEE Himalaya was one of the best stalls at the Children's Science Congress and it was deeply appreciated by Hon. Chief Secretary Mr. P.C. Dhiman.

#### IMPACT OF THE PROJECT

The project had a strong impact in the Indian Himalayan Region. The activities conducted in the cities before and during the arrival of the SECAS motivated the students, teachers and general public to visit the SECAS in large numbers. In many areas Science Express had visited before but still the majority of the people had no idea about the train and the train was not visited by many people earlier. Because of the activities conducted in and around cities and in the schools and colleges, the turn over at the respective stations was huge. Students, teachers and general public now have developed insights into the issue of climate change and the necessity to address it. They have learned about the 100 handprint actions through which they can reduce their foot print and increase their hand print in daily lives by lowering the consumption of water, switching off lights while moving out of the room, not using plastics, use of bicycle and so on.

The project also addressed other stakeholders which are mostly left untouched. The issue of climate change was also seen

through the lens of Sadhus, street vendors, pilgrims, farmers and so on.

The mountain areas for the reasons of their difficult landscape cannot be visited by the Train. Portable/mobile multimedia exhibitions cater to these places. The content of the SECAS Train was tailor made to fit in a 4-wheel drive vehicle. Using ESD for creating awareness on climate change and disaster risk reduction will go a long way in having climate smart and disaster resilient communities.

Table 2 Reach out Summary

Location		Activities	Activities conducted		
	Pre-train	Platform	Post-train	Quiz, Speech, Group Discussion, Mini Science	
Amb Andaura	Could not be conducted	795	-	Experiments, Activities on Basic Science and mathematics concepts  Display of Standees on Climate Change related messages and discussion based on them, Showing of previous video on Biodiversity Special Train-2012.  Drawing, Poster Making, Speech, Discussion, Idea Activity, theme based lectures, meeting,	
Churarau Takarla	due to Diwali Holidays in schools	548	-		
Udhampur	1320	2580	-		
Samba	1293	No proper platform at Samba Station.	-		
Haridwar	1857	2424	2/12/	interaction with and address by our resource persons and subject experts, Discussion on	
Lalkuan	1277	6270		water shed management and information	
New Jalpaiguri	3417	972	-	about environmental activities, rope & ladder game, Story Telling, Quiz, Speech, Group Discussion, Mini Science Experiments	
Students' Science Congress, Rampur, Himachal Pradesh	-	-	3440	Equinox Line, Earth Rotation and Revolution, Earth's Axis & Tilt, Seasons change, Climate change and its Impact on Earth, Information on Science Laws like- Bernoulli's Law, Centre of Mass, Centre of Gravity etc., Display of Standees and Discussion on them.	
Jammu	-	-	100	Equipped educators on climate change	
	-	-	25	Orientation of media for climate change reporting	
Total	9,164	13,589	3565	26,318 including students, teachers, Sadhus, street vendors, pilgrims ,farmers and general public	

These interventions have been helpful in achieving SDGs 13&15. The mobile/ portable exhibition has been very effective in creating awareness, empowering communities for making suitable climate change adaptation. The exhibition has also helped the policy makers and planners to have appropriate policies and planning. The exhibition creates platforms for discussion, interaction amongst different stakeholders. At each location of the exhibition we get to know many new things from the local community and

these newly learnt ideas are added to the exhibition. The local community feels part of the exhibition and when their contribution is included in the exhibition they appreciate it. Thus the exhibition keeps growing, becoming more participatory and community generated. This also facilitates exchange of adaptation and management practices between communities. Overall the exhibition has proved very effective, generated huge interest and resulted into immense benefits towards Climate Change adaptation.

# Conference outcomes: a synthesis of themes and innovations

Prof. Gordon S. Maxwell

When yet another book, document, Proceedings or Report appears readers typically ask, what's new? Will this publication herald new knowledge; will it shine a fresh light through the environmental challenges facing at least some corners of planet Earth?

To such questions of doubt and disbelief I give an unequivocal, positive reply: yes! Why the certainty, the confidence? Let me explain. Major non-Asian documents continue to call for specific case studies which show that climate change can be tackled and that biodiversity does contribute to sustaining ecosystems. The UK National Ecosystem Assessment: Technical Report (2010) (UKNEA) and the UN Framework Convention on Climate Change (UNFCCC) (2017) are good examples of such documents. In addition, bold claims that developing countries lack resources, policies and institutions to pursue forest sustainability and thus carbon capture and storage appear in the western literature (e.g. Nijnik, 2010).

Papers which provide data (case studies) on the values and benefits of biodiversity are in short supply (UKNEA, 2010). Disturbingly, a review of carbon capture and storage in Forests by Nijnik (2010) which was replete with 'should' and 'could' be's and statements like, "the role of forestry to mitigate climate change comes with a great deal of uncertainty" (Nijnik, 2010, P.226) only serve to deflect confidence and finance away from forest

ecosystem investment. Clearly, documents such as these Euro-centric publications on the contribution of biodiversity to Ecosystem services cannot be used as models for solving issues in the context of Asia. Our International Conference on Climate change, biodiversity and Ecosystem Services for sustainable development (ICCCBE, 2016) excitingly does provide a number of welcome and much needed case studies. This was a bravely conceived Conference yielding an inspiring and pleasing outcome; a fitting celebration of HRH Princess Maha Chakri Sirindhorn's 5th Cycle Birthday Anniversary. Contained within this Conference book are case studies that may well be helpful to and welcomed by countries such as the UK, where ecology has a long and respected history. European countries and the U.S. should also gain motivation from this same Thai publication.

The Conference addressed three interrelated challenges to genuine sustainable development. These were: biodiversity, ecosystem services and climate change. Perhaps the best way to conserve biodiversity is to identify how biodiversity is connected to ecosystem function. To demonstrate how fully functioning ecosystems are of real economic value to human activity we need to explain and, if possible, quantify the ecosystem services they provide. Armed with this knowledge, we are in a strong position to justify our growing concerns about climate change, for this change may seriously negatively impact on biodiversity and ecosystem function.

The literature that is attracted by the conceptual magnet of climate change comes from a staggering range of Scientific Journals and a host of expanding web pages. It is way beyond the scope of these Proceedings to even begin to encompass this literature here. Against this background, the contributions embedded within these ICCBE Conference Proceedings, provide a new relevance and importance. A key aspect of the work reported here is the fact that they are products of scientific endeavor in (so-called) "developing" countries. They herald a welcome contribution to genuine global efforts on climate change and all it brings in its wake. As this synthesis outlines the scope and topic diversity of the papers encapsulated in our book of Proceedings, some mention may be made to indicate how these clearly Asian endeavours can enrich those of Euro-American sources which, at present, tend to dominate the debate and content of discourse on climate change.

Wisely, the Conference attempted to organize the 36 papers selected for publication into five broad categories, viz –

- 1. Management
- 2. Policy
- 3. Practice
- 4. Multi-stakeholder approaches

Within Biodiversity
Conservation
and Ecosystem Services

5. Climate Change adaptation; adaptive learning, form Policy to Practice.

This categorization was useful but not at all inflexible: it allowed for the often complex interactions between these overlapping categories. Thus realism and pragmatism survived.

Sustainable development means many things to many people. Close to the heart of the concept sits the wise use of ecosystems. Thus what appears to be, on the face value of the 36 papers contained in this book, a huge diversity of topics and viewpoints, face alone

can be misleading: they are, in fact, all connected to the same *heart*. And more: they all seek to sustain the same *heart*. To reflect the thematic interconnections of all papers no pre-set sequence is followed in this synthesis. Rather, this synthesis chapter is certainly a synthesis and aims to create a free-flowing feeling for the body of topics which collectively embrace the heart of the Conference; and make a useful contribution to the aims of the UN Agenda 2030.

Bulia Pulu describes a system of traditional eco-agri-economics followed by the Apatani people of the Indian Himalayan State of Arunachal Pradesh which comes close to a sustainable anthropocentric ecosystem. The title of the paper, "Practices of mitigating biodiversity loss" among the Apatani only conveys part of this case study of sustainability in action. The UKNEA: TR makes the claim that much of the work on the relationships between biodiversity and ecosystem function has limitations in terms of understanding real-world ecosystems (Chap 4, P.66 in UKNEA, 2010). This could and perhaps should be described as a Euro-centric viewpoint; a view that would gain much from a study the Bulia Pulu paper. Yes, the Himalayan agro-ecosystem is based on rice but this cropping also embraces fish farming, forest and water management, bio-insecticidal pest control and culturally based eco-aware community rules and rituals. On close inspection, this long-established integrated 'biosphere reserve' (a UNESCO concept) system could be seen as a living, present day Asian version of the long-vanished English 17 Century crop rotation (four-course) agro-ecosystem. Bulia Pulu is correct when she concludes that, there are many lessons that could be learned (in fact, re-learned!) from traditional societies in terms of agro-ecosystems and land management.

Another lesson shines from Bulia Pulu's paper. This is the lesson of writing style:

the paper is a refreshing contrast with the ambiguous, jargon-laden often incomprehensible ecology that fills far too many international Journals today.

The more technically focused paper by Phan Kieu Diem et al. takes us to how one of the world's best known timber trees, Teak, may be responding to more variable temperatures and rainfall. In short, to climate change. As field ecologists know, studies of vegetation phenology are demanding jobs. To gain adequate data on a scale relevant to large forest ecosystems, is usually beyond the scope of foresters alone. The case study by the Phan Kieu Diem team pioneers the application of Moderate Resolution Imaging Spectroradiometers (MODIS) to teak leaf unfolding and eventual discoloration. The findings neatly demonstrated that teak forests respond more strongly to temperature extremes than precipitation. This useful work has ecological implications. It could invite opportunities to diversify the forest ecology by making more use of *non*-teak tree species which help mitigate forest air temperatures and enhance growth conditions for teak plantations.

Phongkhamphan et al. contribute an important study of connections between biodiversity declines in dry dipterocarp forest (DDF) and water storage. In these iconic DDE's of northern Thailand, the subtle connections between tree biodiversity and soil water holding capacity do need highlighting. Short term gains in total tree biomass due to reduced interspecific tree completion for precious soil water must not hide the long term importance of retaining good biodiversity. Research such as this is strongly needed and could be seen to contrast with the overemphasis on biodiversity for human well-being (e.g. attractiveness) that surfaces in the Woodlands chapter (8) of the UKNEATR. Calls to "monetize" (P.265, UKNEATR) biodiversity in

these European documents are welcome. However, to ensure that such calls are placed on solid ecology, studies like those of the *Phongkhamphan* team are essential. Indeed, they serve to remind those in advocating ecosystem conservation and eco-restoration, that these activities must be based on solid science as well as hard-to-measure human values like attractiveness.

Boonyawat et al. provide us with an impressive and realistic case study of why local people must be part of any rural water resource management system. Based in Phetchaburi Province they show that even modest increases in village development can contribute to significant changes in water supplies. With climate change moving in the direction of erratic rainfall, the Boonyawat team show that water supplies are best tackled at the ecosystem level. Water resource management on a provincial scale was also the focus of a data-rich paper by a big team of researchers led by Jerasorn Santisirisomboon. This team attempted to apply a Regional Climate Model (RegCM4) to the Phetchaburi and Prachuab Khiri Khan River Basins of Thailand and thus include the SIEP. Like the Boonyawat et al. group the Jerasorn Santisirisomboon team, climate change with a trend towards slight warming and drying was predicted by the model. Also in concert with Boonyawat's group, the wisdom of a holistic ecosystem approach to address anticipated climate change was advocated. To reinforce the need to use water in a more sustainable manner, local stakeholders provincial citizens - need to be deeply involved. One emergent theme here being that in this 21st Century we need to see people as part of ecosystems. In this way, a watershed ecosystem management approach would ensure that forests, soils, streams and people become components of an integrated ecosystem. With this approach, they are totally in phase with Bulia Palu's account of the Himalayan eco-agro-economic

long-established traditional system. Beyond, the Boonyawat group have produced a case study that contains lessons for those in 'developed' countries which also report the impacts of unexpected and sometimes extreme rainfall events. On close inspection the important factors which lie behind such impacts are ecological. Ecological Impact Assessments (Eco-IA) were neglected and land use issues such as road and housing estate development ignored landscaped and the importance of woodlands (to use a UK term for forests).

Puji Astuti et al. in Indonesia and Gopi Ragupathi in India take us to papers which show how the medicinal worth of plants can help to make biodiversity too valuable to loose. Today, with some recently re-activated economic trends which place dollars before ecology surfacing in the U.S., case studies demonstrating bio-medical values are timely. Short-sighted, dollar-driven businessman thinking is out of place when these subtle values of biodiversity are presented. Medicinal crops like Gloriosa superba from India present much needed alternatives to the huge number of synthetic drugs which all too often rule pharmacy in the market and are associated with many adverse reactions and side effects. In the "west", illness linked to life styles of 'developed' countries such as rheumatism and gout could benefit from G. superba's natural chemistry. Glorisoa's biochemical biodiversity is too good to loose.

Rajasekaran et al. provide a stimulating paper on exploration, conservation and phytochemical screening of India's huge and impressive but still incompletely explored flora. The paper focused on three biomedically important plants from India's mega biodiversity bank and neatly demonstrated how the 550 tribal communities that make up India as a nation, may make wise use of their plant medicinal resources. For a sustainable future

based on these *non*-industrial pharmacies – natural plant bioresources – this is a very important contribution to helping the local communities to avoid the pharmaceutical trap of expensive synthetic medicines which rule the 'west'. Additionally and importantly, the *Rajasekaran* team have pioneered a way forward in ethnobotanically apt methods for biodiversity wise use.

Many papers make compelling arguments in favour of community level and multi-sector activities to foster effective action on biodiversity retention and climate change adaptation. Two illustrate this them nicely: one comes from Indonesia, the other from the Philippines. Others extend and deepen this theme.

Agus Suyanto takes us to the challenging Karst landscapes and their ecosystems and shows that action on biodiversity conservation and respect at the community level, with its sensitivities to local belief systems, can produce positive results. These case studies can remind those in so called advanced and 'developed' societies that aspects of 'Eastern' belief systems have a basis in respect for natural resources.

Huberto C. Zanoria and his five coauthors from Cebu, Philippines, also remind readers of the importance of directly involving all sectors of society in addressing pressing environmental matters. In short, any Government must be integrated with the people; their needs and aspirations. This paper and similar research signals that we may, in future, benefit from more studies on how policy can be better formulated to enhance biodiversity conservation. Disasters like typhoons may magnify the needs but putting environmental sustainability on a long-term ecological (scientific) footing requires people will-power. Phang, Wong and Ho of Malaysia in phase with several other papers in this book, place a strong emphasis on the power of society wide education, in the broadest sense of the team, to transform policy into reality. Citing an innovative economic development region in southern Malaysia, Iskandar Malaysia, they show how low carbon thought and action can embrace society: sustainable thinking becomes a household norm. With strong endorsement at the highest level of government (Prime Minister), the effect of having climate change education embedded across school curricula enables adaptation to living a low carbon life style to reach all citizens.

Gangwar takes the same theme as he provides us with the humbling practical realities of handling climate extremes (serious change) in the Himalayan region of India. Here brave and effective efforts were made to spread the word on actions like minimum use of water and electricity and rejecting plastic. A mobile multimedia coach train worked to spread education for all (47 million) people of the Indian Himalayan Region (IHR).

The theme of community power and participation is powerful. Beyond S.E. Asia and Northern India we find it strongly in evidence again in the Asia-Pacific where Baba et al. report on mangrove rehabilitation in two Oceans (Pacific and Indian) and three seas (Arabian, South China and Sulu). Impressively, the Baba team pioneer a solution to establishing a mangrove ecosystem on the hardest of substrata; where white coral sand meets the Pacific at Kiribati. In the Gujarat region of India, this team selected the versatile Avicennia marina to help stabilize bare mudflats and create helpful habitats for endangered birds: in this we witness a welcome reminder that biodiversity can include both species and habitat (eco-diversity). The work also includes Sabah and the Sulu and South China Seas.

Here an ambitious 11 species mangrove biodiversity project is in place. Clearly, The ISME is truly international.

Noparat Bamroongrugsa amplifies the theme and wisdom of well structured community input again with an impressive case study of mangrove eco-economics in action. His paper takes us to Ban Don Bay in the Surat Thani Province of southern Thailand. This scheme features a Bio-rights model based on financial innovation and education at the local community level.

San Win et al., compile a data rich account of mangrove forest decline in Myanmar and clearly illustrate, once again, the urgent need for and wisdom of the sort of multisector, community supported 'Bio-rights' model, described by Naparat Bamroongrugsa. With the crying need for solid eco-economic action, the many different institutions currently operating along Myanmar's long mangrove supporting coastline, may have a chance to retain and regain their biodiverse ecological capital.

Although terrestrial studies outnumber those from coastal ecosystems, the book keeps the mangrove biodiversity theme very much in focus with the confirmation of a unique new natural mangrove hybrid of Rhizophora. Suchitra Changtragoon et al. use advanced molecular genetic technology to confirm the morphological attributes of this hybrid. Moreover, this discovery by Sonjai Havanond, in The Sirindhorn International Environmental Park (SIEP) confirms the importance of ecosystem parks like SIEP as genetic reserve banks, which allow the expression of genetic gymnastics. The hybrid vigour displayed by the natural hybrid present mangrove ecorestoration ecologists with new and robust genetic material. Discoveries of genetic novelty like this new Rhizophora hybrid gain status and value in the

context of raising sea levels; one of the outcomes of climate change: the hybrid outgrows its parental types in biomass formation, including prop root production. Mangrove biodiversity such as this present candidate species for coastal protection at sites where rapid, vigorous growth is needed.

The issue of biodiversity is never simple. There are those who look upon single species stands as undesirable. Such observers may decry a coastal protection or eco-repair site using one mangrove species, such as the vigorous Rhizophora hybrid. But as Maxwell contends in his perspectives on mangrove biodiversity paper, this issue is far from simple. Even a single species mangrove ecosystem as exists with Avicennia marina in New Zealand or Kandelia candel in Japan, mangroves provide habitat biodiversity for mangy non-mangrove species. From this habitat diversity flows ecological opportunity for a rich animal biodiversity. Thus low mangrove tree diversity is merely the beginning of the full story; in time the developing ecosystem can mature to offer an impressive range of 'goods and services'. As indicated above within the Baba et al. paper, this dimension of habitat biodiversity is an essential part of a holistic philosophy of biodiversity.

Nirunrut Pomoim et al. used an innovative maximum entropy (MaxEnt) model to forecast the expected and potential distribution of the commercially valued hydrophyte, the Water Onion (Crinum thaianum) in Thailand. They clearly demonstrated that the conservation status of this much desired endemic species was close to that of critically endangered. The most important abiotic factors favouring this sediment-loving aquatic species were annual precipitation and waterlogged, fresh water sediment. Sadly, excessive dredging – the core negative factor in Crinum thaianum's demise – was contributing to a conservation threshold

challenge where propagation by ecologically sound farming must urgently replace water onion collection from its vanishing natural habitats.

Amita Kanaujia provides a colourful, illustrated case study of active, down to earth, positive whole community mass awareness biodiversity building in India's Uttar Pradesh province. Biodiversity conservation was presented as happy activity in which young people of all ages and educational stages contribute their active conservation to adults. In short, the classroom moved out to embrace the community. The need for science to get directly involved with community conservation action, rather than retain distance from society was evident throughout Amita Kanaujia's case study. Such an approach gave new realism and life to such 'Green Calendar" events as World Sparrow Day, Vulture Awareness Day and Biodiversity Festivals. The account of a Nature ('Prakriti' in Hindi) bus and its 17,000 km journey of biodiversity promotion is inspirational. The bus drove home its mobile message: conservation on wheels.

Wande Gongba takes us to the Tibetan Plateau and reports how Buddhist people of the Bazhu Village on the edge of the diverse yet fragile biodiversity hot spot are working to sustain the ecosystems which underpin their life style. Despite the sometimes negative attractions of globalization and its demands for exotic precious plants like the Chinese yew (Taxus sp.) and market driven secularization and materialism, the Bazhu community are showing signs of resisting these outside influences. As was the case with some other studies reported in this Conference book, such as Noparat Bamroongrugsa in southern Thailand, finding how to generate a money incentive within the ecological activity greatly enhances success in biodiversity wise use. The southern Thai model advocated a 'Bio-rights' model

while Wande Gongba's Tibetan scheme featured RMB awards per household. Both Thai and Tibetan schemes gained their energy for success sensitive and respected community involvement.

Sunsanee Arunyawat and Rajendra Shrestha examine the impacts of rural land use change in northern Thailand on the landscapes ability to sustain ecosystem services. To approach this complex assessment they use two models: one was an Integrated Valuation of Ecosystem Services and Tradeoffs model (InVEST); the other a prediction model to help forecast trends in land use changes (CLU Mondo model). A field survey of 60 farm households provided a foundation on which to base the modeling. Using the year 2013 as a base line, the research projected future land use patterns to 2033. A business as usual scenario in which changes such as further rubber plantations continue, would result in declines in much needed ecosystem services like water yield, carbon storage and, importantly, declines in habitat quality – a proxy for biodiversity. A convincing case was made for either an integrated land use or biodiversity conservation land use scenario. Only these could ensure a sustained access to essential ecosystem services and to achieve sustainable development goals (SDGs). The business as usual scenario did not present a picture of sustainable development for the 96,000 people within the 198,000 ha of Phitsanulok and Phetchaboon provinces of northern Thailand.

Payyappallimana and Subramanian of UNU present a convincing and timely call for linking biodiversity and ecosystems to human health. In this they elevate the more regional calls for community based biodiversity awareness and involvement to the level of sustained health at the global level. With this comes the co-lateral wisdom of placing biodiversity as central in enabling ecosystems to continue to

provide interconnected provisioning, regulating, supporting and cultural services. Within this theme ecosystems are integrated with Human wellbeing in a "Health Synthesis", a synthesis in which affordable traditional medicine, agrobiodiversity and nutritional security unite. The Payyappallimana and Subramanian paper is far more than a generalized call for action. Much needed specifics decorate the message too. These include the One Health philosophy of an ethno-veterinary care of livestock to reduce antibiotic use and resistance; a factor of relevance to both humans and their livestock. Another timely example is the call to bring ecosystem resources into the professional realm of Health Ministries and departments. Collectively, this paper is a much needed affirmation that ecosystem respect and valuation is in no way a peripheral activity or added luxury to economic development: in contrast, human health and quality of life are directly linked to the diverse services that ecosystems provide.

Thantorn Vanavanichkul et al. bring us an innovative method of converting a well-known and troublesome aquatic plant pest into a useful industrial product. This win-win method converts water hyancith biomass into a valuable carbonaceous product (carbon electrodes) using hydrothermal carbonization technology. Thus in an innovative way the Thantorn Vanavanichkul team offer society an enticing way to convert an environmental nuisance into an economic asset; a scheme that neatly address the technical competency needs of SDGs.

Apaporn Bulsathaporn et al. used sensitive soil CO<sub>2</sub> detection sensors to obtain new, much needed data on how soils under different forest types release rather different amounts of CO<sub>2</sub>. Working in western Thailand's tropical monsoon forests, the team compared dry dipterocarp (DDF) with mixed deciduous forest (MDF) and showed that soil respiration

(Rs) accounted for 70.9% of ecosystem respiration (Re) in MDF but only 44.6% in DDF. Probing deeper, *Apaporn Bulsathaporn's* team also showed that Rs was strongly related to soil moisture and perhaps not surprisingly, to forest age or maturation. This work, like that of *Phan Kieu Diem* with teak forests, serves to highlight that further research on how climate change in terms of water and temperature dynamics, impacts on forest ecology grows in importance.

Htet Eain Khant et al. provide a case study in active conservation stewardship development – a seven year determined effort – in the southern Rakhine Yoma region of Myanmar, which, once again, demonstrates that success in biodiversity conservation comes from bottom up. The study reports how the active elephant hunting Chin ethnic groups can become the key components of biodiversity stewardship when livelihood tools like ecologically based agroforestry are fully in focus.

Biodiversity as a component of school curricula received the attention of two papers from Malaysia and one from Thailand. For Malaysia, Munirah Ghazali et al. emphasized the core role of teacher confidence in integrating thinking about biodiversity's many faces into and across all subjects. Mohammad Zohir Ahmad and colleagues analysed where biodiversity as a cross-curriculum concept occurred. Both of these Malaysian teams showed that biodiversity was an ideal concept and very relevant for a country so well blessed with biological diversity. The Thai study by Suranid Ong-la was an ambitious school with community, all embracing thematic integration of biodiversity as the heart that drives life of Chiang Rai Municipality. Here, biodiversity embraced Thai language, maths, science, social studies, religion, culture, health, art and foreign language: truly an holistic approach. School

became catalysts for community linkages.

The paper entitled, "LEADearthShip" by *Monmi Barua* of the Energy and Resources Institute (TERI) based in Delhi, India takes the application of the sustainability concept completely down to earth. *Monmi Barua's* approach is a heart-felt call to action for the youth to look sustainable behaviour firmly in the face and to devise ways of helping the poor of Delhi's slums; to own solar-lamps and facilitate educational activity in their simple dwellings and build nesting habitats for birds. These are but two examples of how the energy of youth can become tools for a more pleasant and sustainable standard of living.

Santosh Sutar et al. show how reactivated sacred groves can do much to enhance the wise use (conservation) of biodiversity. This case study is in phase with the paper by Bulia Pulu on the Apatani people of the Indian Himalayan region. Santosh Sutar and colleagues report that the site of their study, the Kodagu district in Karnataka (India) has over 1,214 sacred groves. All of these groves have demonstrated the positive potential of such pockets of biodiversity to become a TCCPC focus for a sustainable use of ecological resources: TCCPC represents, Teacher to child, Child to child, Child to parent and Parents to community. Although expressed in different terms, TCCPC broadly equates to people first multi-sectoral governance, as described by Huberto C. Zanoria et al. for Cebu in the Philippines.

The papers by *Phan Kieu Diem et al.*, *Phongkhamphan et al.* and *Montri Sanwangsri et al.* all take us to the forest ecosystems of northern Thailand. As mentioned, *Phan Kieu Diem's* group show that the iconic timber tree, Teak is more responsive to temperature extremes than precipitation. Both *Phongkhamphan's* and *Montri Sanwangsri's* groups show us, using some impressively detailed microecology, that

parameters like ecosystem water use efficiency (WUE) are becoming top considerations. Dominant trends emerging in climate change adaptation such as erratic and declining water supplies from climate based precipitation, are challenging foresters and environmental scientists to place a much stronger emphasis on water: the ecological basis of the hydrological cycle is fast becoming the top issue. In short, forest resources need the help of "big eye" ecologists.

Any doubts that forests may not be effective agents for carbon storage are dispelled by *Soontorn Khamyong et al.* study of mixed deciduous forests (MDF) in the far north of Thailand. This team from Chiang Mai University showed that even on relatively poor sandstone, MDF showed good ecosystem carbon storages capturing 152.92 Mg ha<sup>-1</sup>. Encouragingly, these forests were quite new, being reforestation as integrated watershed management sites initiated by the King in 1984.

Another e.g. of the down to earth community based level of ecological upscaling of interactions between agro-ecosystems and economic activity:

Nareth Nut, Jeeranuch Sakkamduang and Machito Mihara outline how organic agriculture can bring better ecology, enhanced income and a more sustainable lifestyle to a commune in Cambodia. Described as community based adaptation (CBA) the approach features using compost and the cyclic (in biogeochemical terms) application of plant and animal residues as workable alternatives to non-renewable resources, like expensive agro-chemicals. The scheme is grass roots action at its best and illustrates the advantages of enabling local University people, such as Nareth Nut from Cambodia's Royal University of Agriculture to work in unison with ERECON's Jeeranuch

Sakkamduang and Machito Mihara from the Tokyo University of Agriculture.

Clearly, as mentioned above the many case studies and topics attracted to this International Conference, although diverse in scope and geographic setting, are but different shades of meaning united by a core concept of finding ways and means to look climate change in the eye and counter its environmental challenges.

Herein lie the inspirational strengths and motivating goals of ICCCBE, June 2016.

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### 9<sup>th</sup> Asia-Pacific RCE Meeting 30 June 2016 Sirindhorn International Environmental Park

The Sirindhorn International Environmental Park and RCE Cha-am hosted the 9th Asia-Pacific RCE Meeting on 30 June 2016 along with the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) Capacity Building Workshop on Policy Support Tools on 1-2 July 2016. Before that the RCE members participated in and were involved in the academic roles, by way of presenting case studies, at the International Conference on Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals: Policy and Practice in Celebration of HRH Princess Maha Chakri Sirindhorn's 5th Cycle Birthday Anniversary held during 27 to 29 of June 2017. Knowledge sharing, and learning of the pertinent issues including Ecosystem Services which enhanced the clear understanding of Ecosystem Services that helped the RCE participants proceed to the IPBES Workshop. All events were very successful due to the immense cooperation of the Asia-Pacific RCE Community, UNU-IAS and all the co-organizers.

#### The 9th Asia-Pacific RCE Meeting

RCE Cha-am and UNU-IAS hosted the 9th Asia-Pacific RCE Meeting on 30 June 2016, at the Sirindhorn International Environmental Park. The meeting was aimed to introduce new RCEs in Asia-Pacific, to inform and report to the RCE members the progress of the RCE network and to exchange the ideas and opinion and share their experiences during the discussion for further cooperation.

#### **Achievement:**

There were 26 RCEs and RCE candidates from Asia-Pacific countries – namely Japan, Indonesia, Mexico, New Zealand, India, China, Malaysia, Philippines, Cambodia, Vietnam and Thailand – that attended the Meeting along with delegates from UNU-IAS, GIZ, UNESCO, and USAID.

The meeting introduced new RCEs in Asia-Pacific, informed and reported to the RCE members the progress of the Global RCE network. The achievements of the 8th Asia-Pacific RCE Conference was informed as well as the UNU-IAS ESD strategic directions and strategy/roadmap for the RCE community/ and the progress on Global Action Programme (GAP) on ESD/and updates of Asia-Pacific RCE collaborative activities. The evaluation of multi-stakeholder initiatives was also discussed in the meeting.

Break-out sessions were divided into three groups, namely School and Youth, Community, and Higher Education.

Each group developed working drafts of the Asia-Pacific regional action plan and the result on cooperation among the network is to be followed up after the meeting. The action plan drafts were presented at the plenary session.

# The Intergovermental Platform on Biodiversity and Ecosystem Services (IPBES) Capacity Building Workshop on Policy Support Tools 1-2 July 2016 Sirindhorn International Environmental Park

The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) Capacity Building Workshop on Policy Support Tools

RCE Cha-am in collaboration with UNU-IAS hosted the IPBES Capacity Building Workshop on Policy Support Tools during 1-2 July 2016, at the Sirindhorn International Environmental Park. The Workshop was aimed to introduce the IPBES and explain the goals and the IPBES functions, to identify the policy relevant tools/ methodologies, facilitate their use and promote and catalyse their further development. As well, group works on ValuES projects/the potential areas of engagement with IPBES and the linkage with task forces were carried out and presentation on the discussion summary were made at the plenary session.

#### **Achievement:**

22 RCEs and RCE candidates from Asia-Pacific countries which are Japan, Indonesia, Mexico, New Zealand, India, China, Malaysia, Philippines, Cambodia, Vietnam and Thailand attended the Meeting along with delegates from UNU-IAS, and USAID. Specialists from IPBES, UNU-IAS, GIZ, UNDP, and UNESCO delivered presentation and also facilitated the workshop.

A summary of the workshop presentations and discussions were made on the IPBES functions in terms of assessment, knowledge generation, capacity building and policy support tools vis-à-vis the ecosystem functions namely provisioning, regulating, cultural, supporting, and perhaps also inspirational. These functions are contributing to human well-being. There are challenges that must be addressed including the issue of biodiversity and ecosystems services assessment, valuation of benefits and their nonlinear and temporal nature. Assessment and decision making tools are available such as Cost-Benefit Analysis (CBA), Scenario Analysis, and Multiple Criteria Decision Analysis (MCDA). RCEs can be a strategic partner of the IPBES Secretariat, and in this regard efforts must be made to incorporate IPBES task forces' ambitions into the RCE action plans.

# The Sirindhorn International Environmental Park (SIEP)



#### **Background**

In 2000, the Border Patrol Police Bureau in conjunction with Huai Sai Royal Development Study Centre and the Mrigadayavan Palace Foundation under the Patronage of HRH Princess Bejaratana Rajasuda Sirisobhabannavadi founded an environmental park at Rama VI Camp in Cha-am District, Phetchaburi Province and presented it to HRH Princess Maha Chakri Sirindhorn on the occasion of her fourth cycle birthday anniversary in 2003. The Princess gave it the name of "the Sirindhorn International Environmental Park (SIEP)". The Park was designed in accordance with the Princess's initiatives to suit the royal activities conducted during her stay at Rama VI Camp. The Park was designed as a living nature museum and a means to publicize the Princess's noble involvement and ingenuity in the conservation of nature, environment, history as well as art and culture for both Thais and foreigners. The Sirindhorn International Environmental Park has become a special site for the study of the rehabilitation of mangrove, beach and mixed deciduous forests as well as habitats for an impressive variety of fauna. In addition, the Park is valuable for the promotion of ecotourism and historical tourism in Thailand and across the world.

Currently, the Sirindhorn International Environmental Park has demonstrated its potential as a center of training, disseminating and demonstration on the integration of scientific knowledge and technology with the conservation of energy, natural resources, environment and Thai wisdom to students, the public as well as interested Thai and foreign visitors. The Park's buildings and location are advantageous to achieving its primary missions within the management of the Sirindhorn International Environmental Park Foundation under the Patronage of HRH Princess Maha Chakri Sirindhorn.

#### Vision

The Sirindhorn International Environmental Park was founded as learning and training centre on the rehabilitation and conservation of natural resources, environment and energy that is consistent with the international standards and the royal initiatives of HRH Princess Maha Chakri Sirindhorn. The Park aims to generate innovations that integrate scientific knowledge and technology with local wisdom. The Park also encourages the application of the philosophy of sufficiency economy to sustainable community development efforts through collaboration with its domestic and overseas research and knowledge development networks.

#### Missions

- 1. To develop SIEP into a model for the rehabilitation and conservation of natural resources, environment and energy and the promotion of renewal energy utilization under the royal initiatives of HRH Princess Maha Chakri Sirindhorn. To advance SIEP into an internationally renowned ecological learning centre.
- 2. To promote and support study and research collaboration with domestic and overseas

networks on the integration of scientific knowledge, technology, innovation with local wisdom.

- 3. To develop up-to-date forms of dissemination, learning and training activities that are in keeping with the international standards and far-reaching benefits for various target groups.
- 4. To promote the establishment of prototype communities for the application of the sufficiency economy philosophy to their livelihood through collaboration with nearby royal projects and local community networks.
- 5. To develop SIEP into an organization with good governance and proactive management strategies.

#### Learning resources on energy

#### > Energy for Environment Centre

The Energy for Environment Centre operates with the support of the Energy Conservation Promotion Fund under the Energy Policy and Planning Office, the Ministry of Energy. The Centre hosts the energy for environment exhibition and aims to further develop as a center for the dissemination of knowledge on energy saving, and as a training camp on energy-saving and renewable energy technologies. The Centre's energy for environment exhibition is divided into three major themes as follows:

The Exhibition in Honor of the Royal Family is organized to publicize the royal projects established under the royal initiatives of His Majesty King Bhumibol Adulyadej, Her Majesty Queen Sirikit, HRH the Princess Mother and HRH Princess Maha Chakri Sirindhorn on the theme of "Royal Activities on Environment and Energy".

The Energy for Environment Exhibition presents three groups of information on energy issues. Different presentation formats such as

replicas, models, demonstrations and experiments are employed in each section.

The Sufficiency Economy Philosophy Exhibition was funded by the Crown Property Bureau and presents the royal initiatives of His Majesty King Bhumibol Adulyadej on the use of the sufficiency economy principles as a guideline for living.

In addition, the Energy and Environment Library was founded as a source for research in energy information and dissemination of learning media on energy and other fields of knowledge, including the environment, science and agriculture.

#### > Energy for community environment park

Energy demonstration and innovation systems were installed with the objectives of providing a prototype model that a community can implement in real life and extending such knowledge to other local communities across the country. The demonstration systems installed at the Energy for Environment Centre include a solar drying system, a biogas system, wind turbines and hydroelectric generator models and so on.

# > Learning source on renewable solar and wind energy

Solar cell and wind power electrical generation systems are installed on the compound of the Sirindhorn International Environmental Park with the primary objectives of establishing a learning and demonstration source on the use of clean, environmentally friendly renewable sources of energy and promoting utilization of solar cell and wind power electrical generation technology in real life. Such renewable sources of energy help reduce dependency on fossil fuel for electricity generation.

#### Learning resources on the environment

#### > The Princess Mangrove Plantation

This plantation is located in the mangrove forest areas that have been rehabilitated under the royal initiative that HRH Princess Maha Chakri Sirindhorn gave on August 14, 1994, which can be summarized as follows, "To secure suitable sites and management system for experiments on the propagation and rehabilitation of local mangrove forests so that the areas "ecology can be restored to its natural state". On August 17, 1994, the Princess planted mangrove saplings at the opening of Bang Tra Noi and Bang Tra Yai canals. She also gave additional initiatives to the Park's personnel to study and seek appropriate techniques to help these saplings survive and to continue with the propagation project. Today, SIEP's mangrove forests have become one of Thailand's major learning resources on mangrove forest ecology and rehabilitation.

#### > Integrated Constructed Wetland Wastewater Treatment System

The integrated constructed wetland wastewater treatment system at the Sirindhorn International Environmental Park was designed to treat 200 cubic meters of household wastewater per day. The system is an extension of the wastewater treatment technology initially developed at Laem Phak Bia Environmental Research and Development Project which is based on the idea of using natural processes to assist nature. This technology puts the microorganisms, plant plankton and green algae in wastewater to work with other key environmental factors, such as sunlight and wind, in treating organic contaminants in wastewater until the treated water meets the required water quality criteria and can be released into a natural water source.

#### > Learning centre and demonstration plots on alkaline soil treatment under the sufficiency economy principle

Since the soil salinity at Sirindhorn International Environmental Park was very high, at 29 dS/m (deciSiemens per meter), the problem was corrected with the use of the royally-initiated formula of organic fertilizer, cultivation of plants that can be ploughed over and used as fertilizer and addition of gypsum to soil surface.

After such treatments, the area's soil salinity dropped to 12-15 dS/m and can be used for vegetable growing. Since then the site has become a learning source for coastal saline soil improvement.

#### **Services**

#### > Accommodation

The Park offers environmentally friendly accommodation with energy-saving design and partial solar-powered electricity for up to 212 participants in energy and environmental conservation camps, meeting/conference attendants and tourists who want to have close contact with nature.

#### **▶** Meeting/conference rooms

The Park offers different meeting/conference rooms for 20 to 200 participants. The rooms can be adjusted to suit a variety of meeting arrangement and are equipped with video/audio equipment, amenities and services under the concept of green meetings.

#### > Venue for outdoor activities

The Park's magnificent greeneries are inspired by a living nature museum design

which aims to provide a pleasant and lively atmosphere for visitors. It offers venues for the organizing of outdoor activities that is fully equipped with all facilities for approximately 250 participants.

#### > Catering services

The Park offers a wide range of food menus and services to meet all needs. Its main dishes and desserts are a combination of conventional food menus and the traditional cuisine of Phetchaburi Province. Food and beverage for refreshment breaks served on table, in buffet style or in boxes are also available. The Park's kitchen gives special attention to the environmental impact of it services and uses environmentally friendly packaging.

#### > Souvenir shop

The Park's souvenir shop sells products of unique designs provided by the royal projects located in the areas of Phetchaburi and Prachuab Khiri Khan Provinces. It encourages the use of raw materials obtained locally and sustainably to produce the many agricultural products, handicrafts, herbal products and processed foods that are on sale at the shop.

The shop also offers the Park's own souvenir products, food and beverage for visitors.

#### **Activities**

#### > Study visit

The Park organizes dissemination activities to spread knowledge about the conservation of energy, natural resources and environment through media exhibitions, nature classrooms and demonstration of how these conservation measures work.

#### > Release of aquatic animals

This activity is organized to raise participants' awareness of the importance of environmental conservation and to increase the biodiversity of aquatic animals. Participants are invited to take part in the releasing of aquatic animals back to their natural habitats.

#### > Mobile energy exhibition

The traveling energy exhibitions are organized with the objectives of disseminating knowledge about energy and the environment to communities, educational institutions and organizations and increasing interested individuals' opportunity to access worthy learning sources.

#### > Training

The Park offers training camps on conservation of energy, natural resources and the environment under its specially designed program that include a wide range of activities from academic knowledge dissemination to recreational and hands on activities. Training participants will be able to have an enjoyable experience while learning. (A minimum period of two days and one night is advocated).

#### > Meeting and conference

The Park can organize meeting or conference functions that match service users' specific objectives in an environmentally friendly manner. Special consideration is given to the impacts of such services to the environment as part of the effort to mitigate environmental problems and to provide participants with practical guidelines for real life implementation.



#### National Research Council of Thailand

The major missions of the Office of the National Research Council of Thailand (NRCT) are as follows: to propose policies and strategies, development measure and guidelines, to promote, support, monitor and evaluate all research of the country; to set research standards as well as develop information technology database of the national research. Its goal is to produce a great deal of research with benefits to the development of The Kingdom of Thailand.

#### Vision

"The NRCT is the principal organization which guides the development of the country and public policy by using research, including the integration and the administration of national research budget leading up to concrete utilization."

#### **Strategies**

- 1. Steering and encouraging government and private agencies to apply national research policy and strategy concretely;
- 2. Integrating, administrating, monitoring, and evaluating of research plans and budget of

the country systematically and continuously;

- 3. Driving the utilization of national and international research results and body of knowledge for developing the country, and raising capability of commercial and industrial competition;
- 4. Strengthening sustainable cooperation between the Thailand Research Organizations Network (TRON) and national and international research networks to produce qualified research personnel;
- 5. Developing national research standards or operational guidelines in conformity with international standards, together with moving ahead extensive utilization of research standards in collaboration with the research community;
- 6. Developing and augmenting the use of research information system of the country and internationally in an, up to date manner, and to link with the ASEAN community;
- 7. Developing the NRCT to be a fully qualified organization, making research plans and integrating work performance in compliance with the digital policy of the government, together with accelerating the NRCT's personnel development to leadership and expertise in research systems.



#### **About UNU-IAS**

The United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS) is a leading research and teaching institute based in Tokyo, Japan. Its mission is to advance efforts towards a more sustainable future, through policy-oriented research and capacity development focused on sustainability and its social, economic and environmental dimensions. UNU-IAS serves the international community through innovative contributions to high-level policymaking and debates, addressing priority issues for the UN system.

The activities of the institute are in three thematic areas: sustainable societies, natural capital and biodiversity, and global change and resilience. UNU-IAS applies advanced research methodologies and innovative approaches to challenge conventional thinking and develop creative solutions to emerging issues of global concern in these areas. The institute's research, education and training combine expertise from a wide range of areas related to sustainability, and engage a global network of scholars and partner institutions.

Through postgraduate teaching UNU-IAS develops international leaders with the interdisciplinary understanding and technical skills needed to advance creative solutions to problems of sustainability. The institute offers master's and doctoral degrees, postdoctoral fellowships and innovative short courses, in close collaboration with leading universities in Japan and other countries.

An Institute of the United Nations University

UNU-IAS is one of 13 institutes and programmes, located in 12 different countries, which together comprise the United Nations University (UNU)—a global think tank and postgraduate teaching organization, headquartered in Tokyo.

The mission of UNU is to contribute, through collaborative research and education, to efforts to resolve the pressing global problems of human survival, development and welfare that are the concern of the United Nations, its Peoples and Member States.



































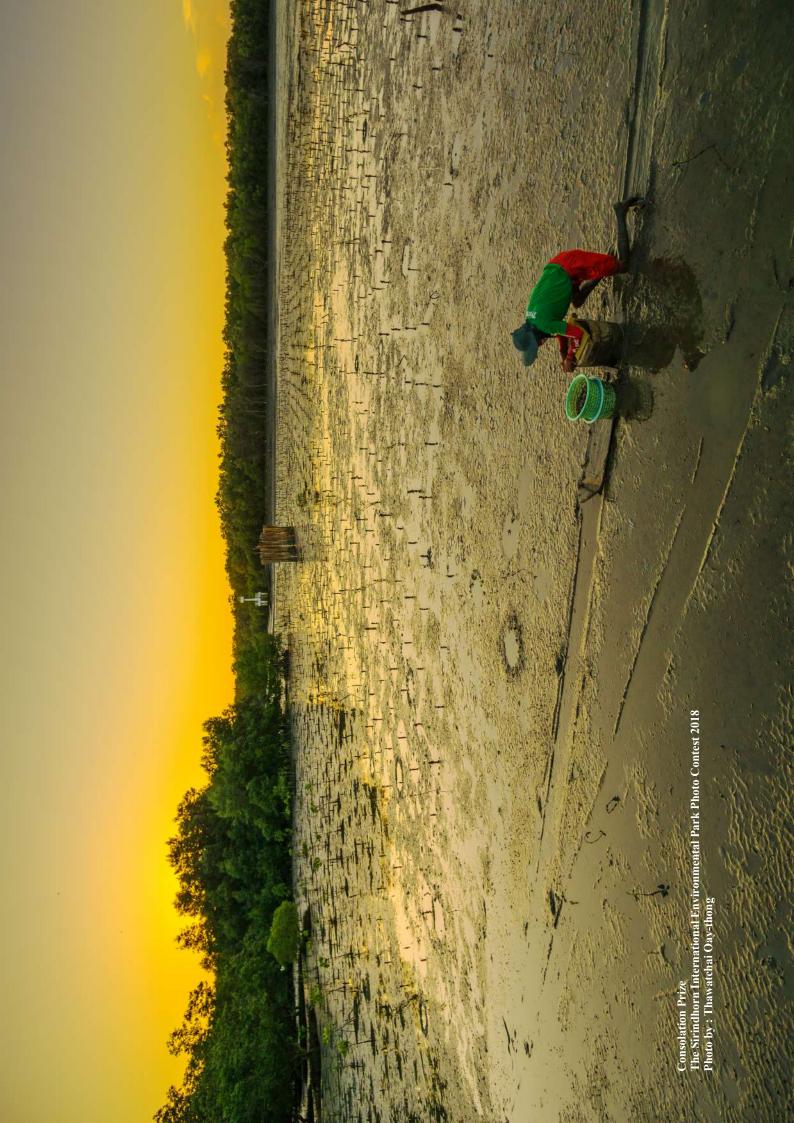






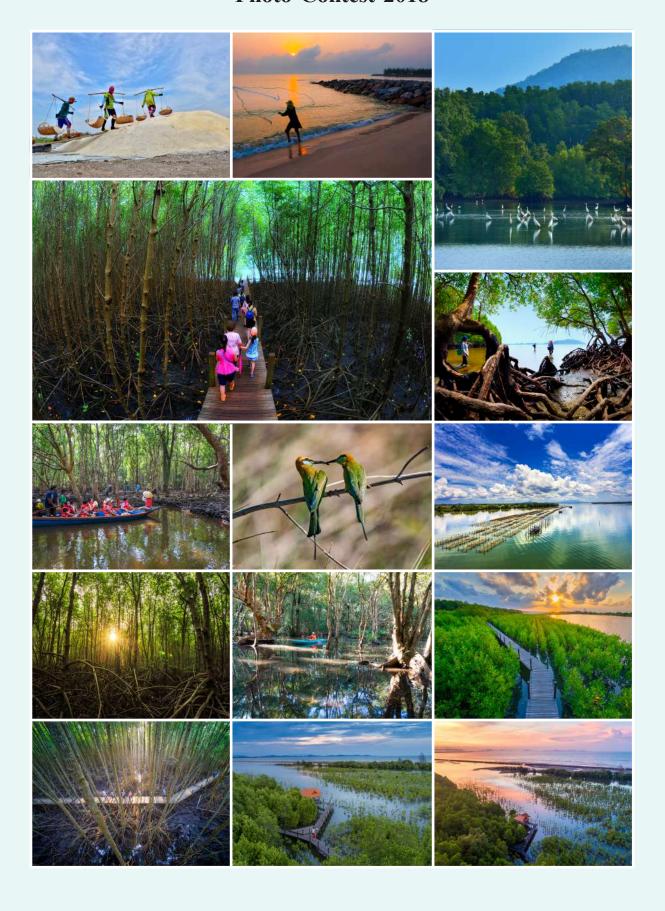


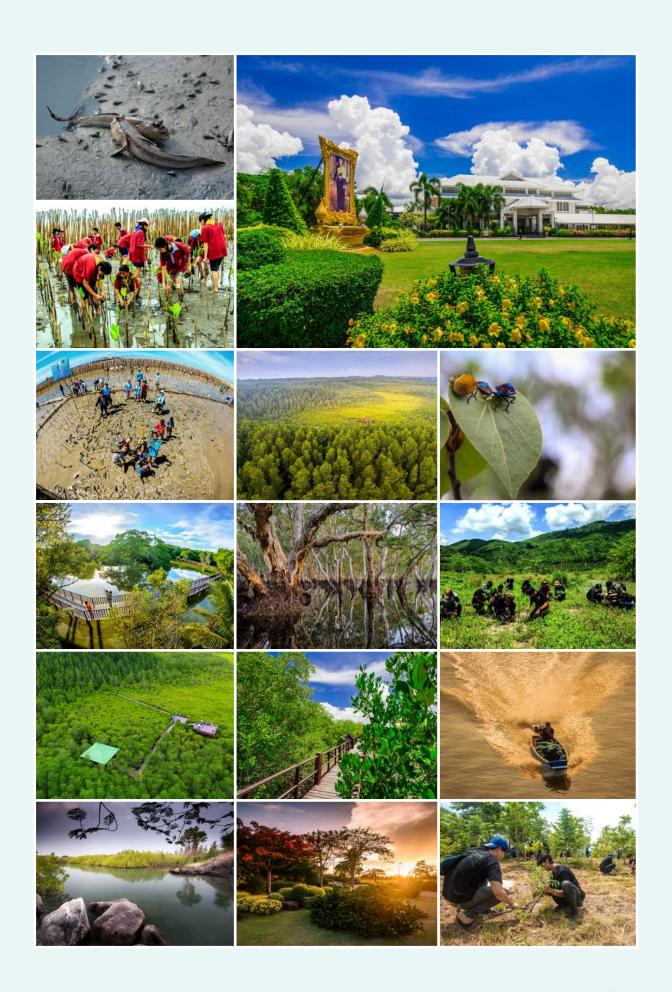




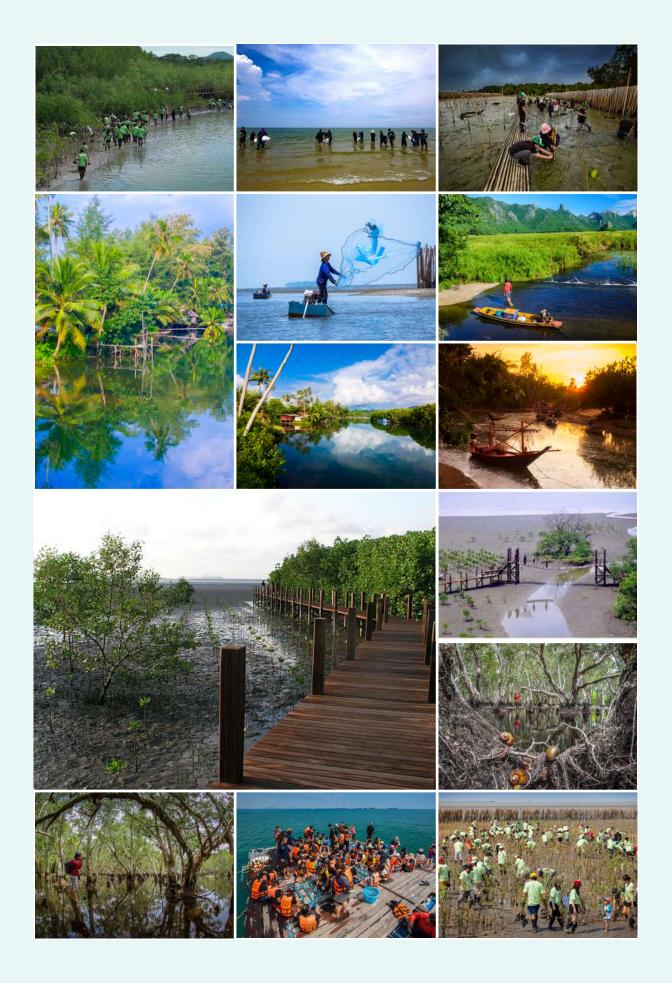


### Photos from the Sirindhorn International Environmental Park Photo Contest 2018

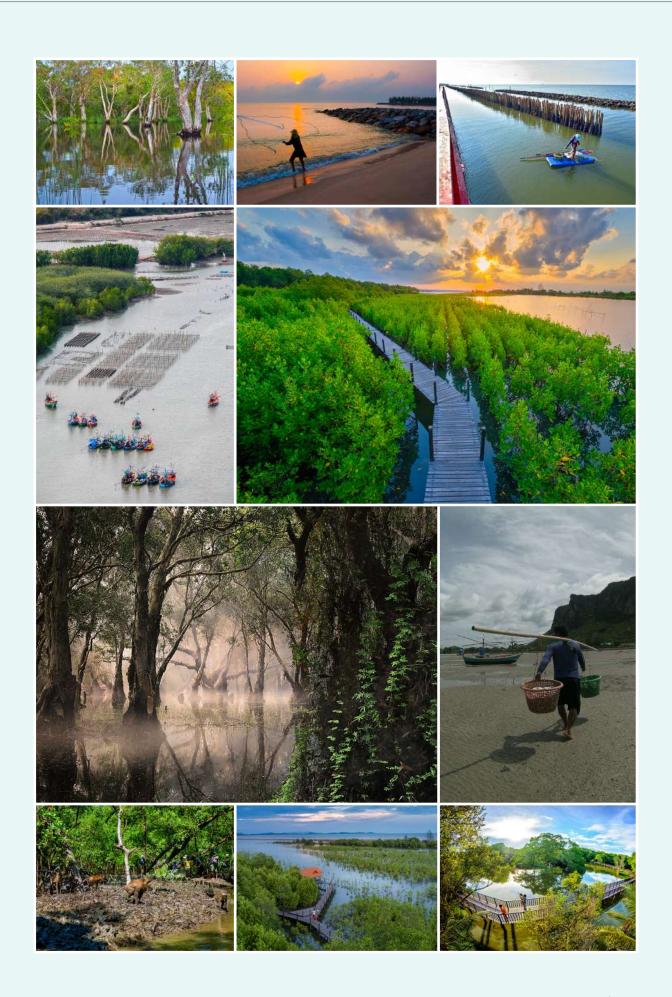




Proceedings of the International Conference on Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals (SDGs): Policy and Practice 27-29 June 2016, Cha-am, Phetchaburi, Thailand



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## **APPENDICES**



#### **PROGRAMME**

International Conference on Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals: Policy and Practice

27-29 June 2016

Sirindhorn International Environmental Park, Cha-am, Phetchaburi Province, Thailand

Monday, 27 June 2016

Session I: Plenary Opening Ceremony

- Opening Sumet Tantivejkul, Chairman of the Sirindhorn International Environmental Park Foundation under the Patronage of HRH Princess Maha Chakri Sirindhorn
- Royal Message HRH Princess Maha Chakri Sirindhorn
- Keynote presentation on "Perspectives on the 2030 Development Agenda and Sustainable Development Goals" – Mario Tabucanon, United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS)

Session II: Plenary Keynote Presentation I

- "Thailand's policy management on climate change"— Asdaporn Krairapanond, Deputy Secretary General, Office of Natural Resources and Environmental Policy and Plannning (ONEP), Ministry of Natural Resources and Environment, Thailand
- "Key issues of biodiversity and ecosystem services" Jeffrey McNeely, Senior Advisor on Biodiversity and Climate Change, Society for Conservation Biology
- "Adaptive watershed management for mitigating and corresponding to climate change impact"— Nipon Thangtham, Advisor to Forestry Research Center, Faculty of Forestry, Kasetsart University, Thailand

Session III: Parallel Session I

- (A) Watershed Vulnerability and Adaptation Assessment (VAA) The Watershed-based Adaptation to Climate Change (WACC) Experience & Next Steps
- (B) Biodiversity Conservation Management (I)
- (C) Biodiversity Conservation and Ecosystem Services Policy

Session IV: Parallel Session II

- (A) The Regional Watershed VAA Guidelines: Learning from on-the-ground experience in Asia
- (B) Biodiversity Conservation Management (II)
- (C) Ecosystem Services Management

#### All Day Poster Presentation

Welcome Dinner at Energy for Environment Center, Sirindhorn International Environmental Park

Tuesday, 28 June 2016

Session V: Plenary Keynote Presentation II

- "1.5 Degree Climate Stabilization: Needs for Science-Policy-Society interfacing"— Shobhakar Dhakal, Associate Professor, Asian Institute of Technoloy (AIT)
- "Sustainable biodiversity conservation and payment for ecosystem services: From theory to practice"— Fanie Bekker, Transboundary Director, WWF Greater Mekong CarBi Programme
- "Gender integration for improved ecosystems resilience" Maeve Nightingale, Mangroves for the Future (MFF)
- "Implementing the Sustainable Development Goals in Japan and designing collaborative activities by the G7 members"— Moeko Yoshitomi, Global Environment Bureau, Ministry of the Environment, Japan

#### Session VI: Parallel Session III

- (A) Climate Change Adaptation Adaptive Learning From Policy to Practice (I)
- (B) Climate Change Adaptation Adaptive Learning From Policy to Practice (II)
- (C) Biodiversity Conservation Practice
- (D) Ecosystem Services Practice

#### Session VII: Parallel Session IV

- (A) Regional Experience in Climate Change Vulnerability Assessment and Climate Change Adaptation
- (B) Climate Change Adaptation Adaptive Learning From Policy to Practice (III)
- (C) Biodiversity Conservation Multi-stakeholder Approaches
- (D) Biodiversity and Ecosystem Services-Multi-stakeholder Approaches

#### Session VIII: Plenary Closing

- Reflections on the Conference
- Cha-am Statement on Climate Change, Biodiversity and Ecosystem Services for the SDGs
- Closing Remarks

#### All Day Poster Presentation

Wednesday, 29 June 2016 Field visits: Two routes

- 1. Chang Hua Man Royal Project Khao Kling Agricultural Prison Kaeng Krachan National Park
- 2. King's Royally Initiated Laem Phak Bia Environmental Research and Development Project (LERD) Sea Farm Royal Project initiated by HM Queen Sirikit

#### 9th Asia Pacific RCE Meeting 30 June 2016

The 9th Asia Pacific Regional Center of Expertise (AP RCE) Meeting was held on the 30th of June 2016, hosted by RCE Cha-am at the Sirindhorn International Environmental Park (SIEP) in Cha-am, Phetchaburi Province. Thailand. Together with the International Conference on Climate Change, Biodiversity and Ecosystems Services (ICCBES) for Sustainable Development Goals: Policy and Practice on June 27-29 and the Intergovernmental Platform on Biodiversity and Ecosystems Services (IPBES) Capacity Building Workshop on Policy Support Tools on July 1-2, as its back-to-back events, the 9th AP RCE Meeting was rendered more significant as it was within the celebration of the 5th Cycle Birthday Anniversary of HRH Princess Maha Chakri Sirindhorn.

#### **Opening Programme**

The meeting started off with an opening remark by Dr. Munirah Ghazali, overall meeting facilitator. Dr. Sonjai Havanond, the Director of SIEP welcomed the participants. Dr. Havanond briefly emphasized that SIEP, the lead stakeholder of RCE Cha-am, needs the cooperation of the RCEs to implement its programmes, especially those related to the implementation of the Sufficiency Economy Philosophy of His Majesty the King of Thailand.

Dr. Mario Tabucanon, speaking on behalf of the Global RCE Service Centre, reminded members of the RCE community's support to the Global Action Programme (GAP) on Education for Sustainable Development (ESD) and of the implementation of the Sustainable Development Goals (SDGs) expressed during the 9th Global RCE Conference in Okayama, Japan. GAP and SDGs were therefore the focal discussions of the meeting.

It was reported that the Global RCE

community had grown to 146 members. With this, the network had to be strong and robust in its operation and in the conduct of its activities. This could be well-effected through self-assessment of RCEs. The output of the regional meeting was important since the outcome will be presented and followed up during the 10<sup>th</sup> Global RCE Conference in Yogyakarta. It was announced that Dr. Kiran Chhokar had been appointed as a new regional adviser of AP RCEs as of January 2016.

#### **Introduction of Participants**

The newly acknowledged RCEs in the Asia-Pacific region that were represented at the meeting were duly recognized. Participants made their self-introduction.

#### Review of the 8th AP RCE Meeting

Mr. Bernabe Mijares Jr. of RCE Bohol presented the highlights of the 8th AP RCE Meeting, held in the University of the Philippines, Cebu Campus, Cebu City on March 6-7, 2015 and in Bohol Island State University, Tagbilaran City, Bohol on March 8, 2015. The highlights of the review included the discussion on the strategic roadmap for promoting ESD beyond 2014 with ways for making substantial contributions to the Global Action Program on ESD.

#### Progress of the Global RCE Network

Ms. Kyoko Shiota of UNU-IAS reported on the progress of the Global RCE Network. The presentation mainly comprised two parts: (1) development of RCE Network and (2) overview of RCE-related activities, implemented since April 2015. The first part focused on the recognition of new RCEs in Asia-Pacific, Africa and the Middle East and the Americas. The addition of these newly acknowledged networks rendered a total of 146 RCEs

worldwide. Moreover, the projects submitted by the RCEs that were given awards of recognition were also highlighted. The second part of the report was a presentation of the events globally, both past and forthcoming, with data on dates of implementation, brief description of events and the initiating RCEs.

Ms. Shiota also discussed features of the Global RCE Portal, accessing Facebook for RCEs, RCE Bulletin and how to submit articles and RCE-related publications, specifically Policy Briefs which would entail co-authorship of experts from UNU-IAS, linking projects of RCEs with policies. She announced that one publication on health is underway and those who were interested were encouraged to submit their manuscripts.

#### Strategic Direction and Strategy: Roadmap for the RCE Community and the Progress on the Global Action Programme (GAP) on ESD

The Decade of Education for Sustainable Development (DESD) officially ended in December 2014. Thereafter the successor programme has been the Global Action Programme (GAP) on Education for Sustainable Development (ESD), hence, discussion on the strategic direction, strategies and roadmap for the RCEs should align with GAP on ESD implementation.

The overall goal of the GAP is to generate and scale-up action at all levels and in areas of education and learning to accelerate progress towards sustainable development. From this the GAP is achieved mainly by the objectives of re-orienting education and learning (that is, integrating ESD in the education agenda) and strengthening education and learning in all agendas, programmes and activities that promote sustainable development. Simply put, the GAP is education-learning

related which requires a whole institution approach.

There are five specific priority areas identified under the GAP, namely (1) advancing policy, (2) transforming learning and training environments, (3) building capacities of educators and trainers, (4) empowering and mobilizing youth, and (5) accelerating sustainable solutions at the local level. It was emphasized that it is in priority area 5 that the RCE network could specifically contribute to the GAP implementation.

ESD is essential in the 2030 Agenda and Sustainable Development Goals (SDGs) implementation. There are 17 goals with 169 targets and over a hundred indicators. An element of UNU-IAS' strategic vision relative to the SDGs is to bridge the gap between learning and sustainable development through research and actions that advance knowledge across geographic, knowledge and sectoral boundaries. There is a synergy between the UNU-IAS acknowledged network of higher education institutions called ProSPER. Net and RCE and that it should be recognized that the SDGs and targets are interlinked. The roadmap for RCEs involves three strategies, namely (1) strengthening governance to better coordinate ESD/SD learning and actions within the RCE community, (2) enhancing the capacity and development of local and regional stakeholders to contribute to both local and global sustainable development initiatives, and (3) strengthening the impact of actions related to SD/ESD by linking local and regional SD and ESD debates and processes with international platforms.

#### **Updates on AP RCE Collaborative Activities**

Update on the collaborative activity between RCE Penang and RCE Tongyeong was reported by both Dr. Munirah and Ms. Won J. Byun. Ms. Byun interacted with the participants virtually since she could not be physically present, as she was attending to another joint project with RCE Greater Western Sydney.

A video presentation on the Sejahtera Project of RCE Tongyeong was aired. Therein, it was explained what Sejahtera Project is, how other RCEs participated and could continue to participate with it and how RCE personnel and researchers could avail of the facility. Dr. Munirah informed the body that personnel from RCE Penang will visit Sejahtera Center.

Ms. Byun further shared another undertaking for participants to possibly join. It was the International ESD Forum open to everyone who was interested but teachers were favorably encouraged to join since the themes would emphasize on schools. Ms. Byun expressed optimism that the conference will be a success.

RCE Okayama representatives informed the participants on the Okayama Award. While flyers were distributed for detailed information, it was emphasized that those joining were required to present the project. There was only one award but which could be given to up to two groups. The deadline of the application was on July 29, 2016.

Dr. Chhokar talked about the Mahatma Gandhi Institute of Education for Peace (MGIEP) and Sustainable Development. She announced that the institute invites participants to its peer to peer learning that focuses on digital learning. Accordingly, their projects were always linked with the curriculum. One that had already been done was about migration.

The Sirindhorn International Environmental Park (SIEP) for its part played a video presentation to inform participants of the nature of their existence and their activities, including those that foster collaboration. Finally, a represe-

ntative from UNESCO Bangkok talked about their programs and expressed interest to know more about what RCEs do for possible networking. They were currently collecting in Asia-Pacific good practices on community-based action for publication and dissemination and would encourage collaboration on this undertaking.

Dr. Tabucanon pointed out that UNESCO ASPNet may be a good start to connect with schools which are closer in location to the individual RCEs. He further suggested that projects be developed around ESD so as to mobilize these schools to work with RCEs.

#### Introduction to Break-out Session

The primary aim of the sessions was to come up with an action plan at the regional level. Actions and action points applicable to all RCEs within the region would be identified from the action plan template distributed beforehand to individual RCEs and from the discussion. They would then be linked to the priority areas and presented during the plenary for comments as a regional action plan using the existing template. The draft regional action plan would then be circulated to the individual RCEs for further comments and therefrom be put together in a format for the Asia-Pacific Regional RCE discussion at the 10th Global RCE Conference. The following were the groups for the break-out sessions: Higher Education; Schools and Youth; and Community.

#### **Evaluating ESD in RCEs: The Start-up Tools**

The afternoon session of the conference took off with a discussion on evaluating ESD in the RCEs by Dr. Unnikrishnan Payyappallimana of UNU-IAS. In his presentation, he emphasized that the assessment is a self-reflection, that is, it is the RCE that is assessing itself, its collective identity.

Dr. Payyappallimana shared that the specific objectives of evaluating ESD in RCEs are (1) to collectively learn through an appreciative review of an RCE, (2) to improve transformative learning and sustainability and (3) to strengthen work of the RCEs as a networked community. There are six areas to be evaluated each with specific questions to be addressed. These areas are (1) RCE coordination and networking, (2) activities and their effects, (3) transformation and sustainability, (4) strategic areas and linkages, (5) Global Service Center and its role, and (6) value creation assessment.

After his presentation, Dr. Payyappallimana opened the floor for discussion by asking suggestions for the improvement of the instrument and for the manner of conducting the assessment. The following summary points of the interaction:

#### Issues deliberated included the following:

- The assessment model is an "Open Framework."
- Questions are not definitive. Participants can suggest questions that are not reflected. Are they the right questions? Can they be simplified?
- Does the evaluation require that old RCEs go back to the year of implementation for evaluation?
- What if there is a disparity of the reality of the past and the present? How is it reconciled?
- Is it a general agreement that assessment is required for RCEs?
- RCEs can do the evaluation beyond what is suggested. The RCEs are in the right position to determine their assessment.

- Learning experience is that people may have different perceptions about RCEs.
- The evaluation is not by stakeholders. It is by the whole RCE.
- There is no regular format for the conduct of self-evaluation.
- Old RCEs can go back and look afresh at what they have done since the beginning or go back at least 3 years.

During the assessment session, the following RCEs expressed interest in conducting self-assessment:

- 1. Srinagar (Abdhesh Gangwar)
- 2. Northern Mindanao (Dexter Lo)
- 3. Bangalore (Santosh Sutar)
- 4. Kodagu (Santosh Sutar)
- 5. Bohol (Bernabe Mijares)
- 6. Iskandar (Wai Yoke Wong)
- 7. East Arunachal Pradesh (Bulia Pulu)
- 8. Delhi (Monmi)
- 9. Greater Phnom Penh (Nareth Nut)
- 10. Penang (Munirah Ghazali)
- 11. Borderlands Mexico-USA (RCE Candidate Carolina Lopez)

After the discussion and interaction on the evaluation of RCEs, the meeting proceeded with the awarding of certificates of honor and appreciation to the plenary speakers, moderators and presenters. Then there was a video presentation of RCE Yogyakarta as initial information and partial acquaintance of the venue of the 10th Global RCE Conference.

#### Reporting of the Break-out Session

Dr. Chhokar presided over the plenary that heard the presentation of output of the

break-out sessions. The following reflect the groups with corresponding discussion and suggestions from the rest of the participants:

Group	Discussion	Questions/Suggestions
School and Youth	<ul> <li>Health education through school</li> <li>DRRM youth education for preventive action</li> <li>Program may be more than 1 year</li> <li>WASH or Health Technology</li> </ul>	<ul> <li>How do interested RCEs support the plan?</li> <li>Compile the output as an open document until the end of July so any RCE can access them to be transformed into a document of the Global RCE Network.</li> <li>Annual report is not enough. Pass the document in English and have it published.</li> <li>Is there a plan for a database or a network center for the many IECs?</li> <li>It can also be a description material. Any RCE may do the action plan</li> </ul>
Community	- There was no further discussion	- Coordinate with the first group with DRRM action plan.
Higher Education	- There was no further discussion	- Steering committee will be created for the implementation of the offering of a curriculum.

Each group produced a working draft of the Asia-Pacific regional action plan on their respective theme. These drafts would be further developed.

## Orientation of the Workshop for the following day

After the plenary discussion, Dr. Unni proceeded to orient the participants of the

workshop which was to be conducted in the following day. He introduced Ms. Suneetha Subramanian of UNU-IAS, an expert on the values of ecosystems, as the overall facilitator, and Ms. Maria Fernanda as a co-facilitator and resource speaker on a GIZ project. In preparation for the workshop, Dr. Unni advised that participants reflect on the ecosystem services that their RCEs were doing.

#### **Closing Session**

Dr. Sonjai Havanond of RCE Cha-am was pleased with the many joint project ideas expressed and the ideas that were conceptualized. He expounded that projects were not only for a specific RCE area but for the wider RCE community in Asia-Pacific for capacity building, learning and education. Further, he emphasized that the meeting and the preceding conference enhanced understanding, especially local knowledge, as well as the local people but qualified that scientific knowledge itself is difficult to understand and to be implemented in the local level. He concluded in saying that he hoped that the participants were happy and that he was willing to assist the participants in any of their needs.

Dr. Mario Tabucanon described the day as very productive. He said that they had accomplished a lot of what they aimed at. Then he highlighted the takeaways, those that the participants learn and should bring back to their respective stations. These were the following:

- Deepen understanding of the RCE movement;
- See the direction/pathway forward through the roadmap developed for the RCE community; It is the basis for developing the action plans;
- Follow through many things for the first round of the action plan;
- Put the draft action plan for circulation to all RCEs;
- Welcome suggestions to enhance the action plan;
- Refine plans before the 10<sup>th</sup> Global RCE Conference;

- Attach action plan of the individual RCEs to the regional action plan; and
- The assessment is very important. Take time to digest the issues.

Dr. Tabucanon thanked RCE Yogyakarta for the hosting of the upcoming 10<sup>th</sup> Global RCE Conference. He noted that finalization of the programme was underway. He also announced that the submission of proposal for the next AP RCE Meeting was already opened. He reminded that the hosting of the meeting and conference was voluntary and that it was best that RCEs consult their stakeholders for the holding of the event.

Dr. Tabucanon also thanked RCE Cha-am for graciously hosting the meeting. He noted that it was the second time that it had hosted which he described as an excellent contribution to the community. Finally, he thanked all RCEs which attended, through their representatives, the 9th AP RCE Conference.

#### **Group Photo**

The 9<sup>th</sup> AP RCE Conference in SIEP, Cha-am, and Phetchaburi, Thailand culminated with a group photo.

Prepared by:

BERNABE M. MIJARES JR.

Director of RCE Bohol in BISU

Edited by:

The Global RCE Service Centre



## In Celebration of Her Royal Highness Princess Maha Chakri Sirindhorn's 5th Cycle Birthday Anniversary

#### The International Conference

On

Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals: Policy and Practice

#### 27-29 June 2016

The Sirindhorn International Environmental Park, Cha-am, Phetchaburi, Thailand

#### **Honorary Advisory Committee**

Dr. Sumet Tantivejkul Chairperson
Prof. Sanit Aksornkoae Deputy Chairperson
Dr. Pornchai Rujiprapa Member
Prof. Mario T. Tabucanon Member

#### **Organizing Committee**

Dr. Monthip Sriratana Tabucanon Representative of Office of the Royal Development Projects Board Representative of Ministry of Natural Resources and Environment	Chairperson Member Member Member
Representative of National Research Council of Thailand	Member
Representative of Office of the Higher Education Commission	Member
Representative of Asian Institute of Technology	Member
Representative of Special Training Division, Rama VI Camp,	Member
Border Patrol Police Bureau	Mombor
Representative of Phetchaburi Provincial Office	Member Member
Representative of the King's Royally Initiated Laem Phak Bia	Member
Environmental Research and Development Project	Member
Representative of Huai Sai Royal Development Study Center Representative of Mrigadayavan Palace Foundation	Member
	Member
Representative of Thailand Environment Institute Representative of Biodiversity-Based Economy Development Office	Member
	Member
Prof. Sansanee Chaiyaroj Prof. Somsak Panha	Member
	Member
Prof. Yongyut Trisurat	
Assoc. Prof. Kansri Boonprakob	Member
Dr. Nawarat Krairapanond	Member
Dr. Sirin Kaewla-aid	Member
Dr. Chamniern Vorratnchaiphan	Member
Dr. Sonjai Havanond	Member and Secretary
Mr. Siripong Indramongkol	Member and Assistant Secretary
Mr. Thanakorn Palachai	Member and Assistant Secretary
Ms. Areeporn Sittiyanpaiboon	Member and Assistant Secretary
Mr. Thanavit Chaiyapa	Member and Assistant Secretary











REGIONAL CENTRE OF EXPERTISE ON EDUCATION FOR SUSTAINABLE DEVELOPMENT

ACKNOWLEDGED BY







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# In Celebration of HRH Princess Maha Chakri Sirindhorn's 5th Cycle Birthday Anniversary

International Conference on Climate Change, Biodiversity and Ecosystem Services for the Sustainable Development Goals:

Policy and Practice 2016



The Sirindhorn International Environmental Park Foundation under the Patronage of HRH Princess Maha Chakri Sirindhorn

