Section 1

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Prof. Sumathipala,
Advisor,
Ministry of Mahaweli Development and Environment

and

Dr.N.D.R. Weerawardene
Additional Conservator General of Forests
Forest Department - Sri Lanka

Climate change is a major challenge faced by the world today, with the rise of global temperature, which has a direct link to human activities. With the projected increase in world population, it is crucial to adhere to sustainable production processes and consumption patterns in order to minimise the global average temperature increase. As a signatory to the Paris Agreement on Climate Change, and as a developing island nation that is vulnerable to natural disasters, Sri Lanka has to adopt appropriate measures to curb global warming and rapid climatic changes.

Sri Lanka's Blue-Green Economy incorporates the use of oceanic and terrestrial resources in an eco-friendly manner that heralds sustainable economic development. Achieving such an economy requires the development of strategies to manage ocean and land resources without over exploiting our natural capital and polluting the environment. The objective of managing natural resources – air, land, water, soil, plants, animals and minerals – in a sustainable manner is to provide a better quality of life for present and future generations.

The objective of this symposium is to provide a platform for researchers, engineers, and academicians, as well as industrial professionals, to present their research results and recommendations for future development activities for a Blue-Green Era where all Sri Lankans enjoy the fruits of development in a pleasant environment.

GREENING THE BLUE ECONOMY: SOUTH ASIA'S PERSPECTIVES FOR GOOD OCEAN GOVERNANCE

M. Imali Udeshika Manikarachchi[1*], Lawrence P. Hildebrand[2] and K.H.H Niroshana[3]

[1] Ocean University of Sri Lanka, NARA Road, Colombo 15, Sri Lanka.
[2] World Maritime University, Sweden.
[3] University of Ruhuna, Matara, Sri Lanka.

hashanniro@yahoo.com

The purpose of this work is to review the commitments of the coastal South Asian countries towards a sustainable Blue Economy in terms of national, regional and international initiatives. The Rio declaration and the Agenda 21 have embraced the importance of national and international level implementations of institutional frameworks, regulations and standards as roads to sustainable development. The Blue Economy concept, which is about building a sustainable ocean based economy, is quite new to South Asia, even though a number of maritime industries are currently practiced. South Asia being home to 1.7 billion people and one of the poorest regions in the world, its shared marine resources face challenges due to resource overexploitation, over population, habitat degradation and climate change. To join the regime of International Ocean Governance for a greener Blue economy, South Asia seeks solutions in terms of management plans, regulations and collaborative approaches. In this study, the national, regional and international perspectives of major coastal countries of the South Asian region, India, Bangladesh, Pakistan, Sri Lanka and Maldives are considered. In most South Asian countries at national levels, the constitution supports the provisions for safeguarding the natural environment as a whole. Initiatives in the context of Integrated Coastal Zone Management and Marine and Coastal Protected Areas have also been put in place. However, recent studies have revealed that concerns such as poor financial allocations, governance issues, duplication of responsibilities, un-harmonized policies, lack of coordination and evaluation capacities have hampered the performance of national initiatives. The secretariat of the South Asian Association for Regional Cooperation (SAARC) and the South Asia Cooperative Environment Program (SACEP) are the main organizations dealing with environmental issues at regional level. Other than that, The South Asian Seas Action Plan (SASAP) of the UNEP Regional Seas Program is operated under the SACEP and several other programs such as The South Asia Coral Reef Task Force (SACRTF), The Bay of Bengal Large Marine Ecosystem (BOBLME) Program and the Indian Ocean Tuna Commission (IOTC) dedicate their efforts for conservation and management of marine ecosystems and living resources.

Abstract No.01

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South Asian countries are parties to some major international environmental treaties. All the coastal States are signatories to the UNCLOS 1982, Part I, II and V of MARPOL, FAO CCRF, CBD, UNFCCC conventions while none or few countries have ratified important conventions such as HNS, OPRC, and Dumping. Since most coastal South Asian countries have mixed legal systems with common law system, the ratifications are not enforceable until the applicable domestic laws are enacted. When implementing their agreed international commitments, South Asian countries perform at both regional and local levels. All of them have declared national institutional structures to address environmental issues in a comprehensive way and some countries have well established specific legislations for mitigating marine environmental issues such as marine pollution. The study concludes that the framework for South Asian regional good Ocean Governance can be strengthened by establishing domestic integrated marine policies, strong political willingness, adequate quantitative research to formulate marine sector-wise national databases and uniform ratification of international agreements.

Abstract No. 02

VALUE ADDITION OF SRI LANKAN GEM ZIRCON VIA HEAT TREATMENT

W.G.C.N. Wewegedara[1*] and Prashan Fransis[1]

[1]Gem and Jewellery Research and Training Institute, Malabe, Sri Lanka.

chandimawgcn@gmail.com

A semiprecious gem variety called zircon is abundant in most gem bearing regions of Sri Lanka. Naturally zircon could be found in variety of colours but majority of stones found in brownish colours and do not fetch higher prices compared to their other colour varieties. Now most countries heat treat their inferior quality zircon and produce most sought after colours such as Emerald green, yellow and especially blue colour. So far heat treatment of zircon is not popular in Sri Lanka. As such the material sells in bulk quantities for a lower price tag. On the other hand, chemistry of Sri Lankan zircon is not identical to zircons from other countries. As such it is not possible to apply the same techniques directly to Lankan zircon, applied elsewhere. During this study heat treatment of Sri Lankan gem zircon carried out in both oxidizing and reducing conditions, incorporating gas and electrical furnace.

Low quality zircon samples from Rathnapura and Kawisigamuwa (E-166533/ N-256334) localities were collected and surfaces of the stones were cleaned. Thereafter each sample was sliced in to two parts and polished both sides of the slices. Heat treatment was carried out for one slice from each sample subjected to temperatures of $800^{0}C$ to $1300^{0}C$ for reddish brown zircon whereas $1600^{0}C$ to $1800^{0}C$ for greenish coloured zircon using gas and electric furnace. Different atmospheric conditions (reducing and oxidizing) were maintained and samples were Soaked for three hours. Treated and raw samples were visually observed under reflected and transmitted light for colour and clarity. EDXRF analysis was carried out for treated and non-treated samples to obtain the chemistry.

Reddish brown zircon turned yellowish at $900^{0}C$ within oxidizing atmosphere in 'Lakmini' furnace whereas the same variety turned into pale blue colour at $1100^{0}C$ subjected to strong reducing atmosphere. Greenish zircon turned into pale blue when treated at $1750^{0}C$ in reducing atmosphere. Chemistry was obtained for reddish brown zircon as ZrO_2, SiO_2, HfO_2, K_2O, CaO, Fe_2O_3, Cr_2O_3, CuO, NiO in concentrations of (all are % values) 66.2, 30.3, 2.62, 0.54, 0.19, 0.03, 0.01, 0.11, 0.01% respectively. In addition, the same constituents recorded in 64.7, 31.8, 2.33, 0.57, 0.27, 0.13, 0.01, 0.11, 0.02% values for greenish variety with the aid of EDXRF.

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Most sought after colours of zircon are obtained by means of heat treatment yet the clarity remains unattractive in most cases. Further studies are required to improve both colour and the clarity within low quality zircons found in Sri Lankan gem fields. Marked chemical changes were not observed through EDXRF analysis to separate heated stones from unheated zircon. Locality differences of zircon varieties found in different localities of Sri Lanka (e.g. Kavisigamuwa, Ratnapura) need to be studied in detail to decide the most appropriate conditions suitable for colour enhancement of the zircon. The study is still in progress. Finally, it could be concluded that Inferior quality zircon was yet another ideal gem stone variety that could turned into value added product by applying simple treatments. This is an instance where simple value addition processes could be used to harness the maximum earnings out of our gem resources.

A RISK-BASED APPROACH FOR THE SUSTAINABLE CATCHMENT MANAGEMENT IN BADULU OYA UPPER WATERSHED

W.G. Chathura Sanjeewa[1*], W.B.M.M.W Wijekoon[1]
Ruwan Liyanage[1] and Prasanna Pradeep[1]

[1]National Water Supply & Drainage Board, Galle Road, Ratmalana, Sri Lanka.

chatsanjwb@gmail.com

The World Health Organization (WHO) has identified, inadequate access to safe drinking water and sanitation as a leading cause of disease and death around the world. Though Sri Lankan population has a relatively good access to improved water supply and sanitation, health problems caused due to unsafe potable water have been increased over time in Sri Lanka as well. Illnesses and deaths from unsafe potable water can be prevented through simple, inexpensive measures. The WHO guidelines for drinking-water quality, aim to protect public health through the adoption of a Water Safety Plan. Catchment protection is a foremost fact in water management and safety plans since human activities in the catchment area can lead to water pollution and negatively impact public health. Proper watershed management could decrease the spreading of water borne diseases which saves money for medication and forms a healthy community. This study was conducted to assess the catchment area of Badulu oya which is the main water source in Badulla District. Watershed boundary, land / land cover use map, elevation model and the slope distribution of the catchment area were developed by using ArcGIS 10.1 software. Risk analysis was done by using weighted overlay in ArcGIS. Meteorological data were utilized for the risk analysis and results highlighted that the slope stability, unsafe sanitation and hygiene practices adopted by the people and improper waste disposal are the main issues in the watershed. Soil erosion is a serious concern since it deteriorates the quality of stream water by increasing turbidity. Moreover, Sediment attached pollutants also can be transported to the water. Awareness creation, adoption of soil conservation measures and strict implementation of laws and regulations are recommended to sustainable management of the watershed.

ADDRESSING FOOD INSECURITY BY CONSERVATION AND SUSTAINABLE USE OF BIODIVERSITY IN SRI LANKA

**W.L.G. Samarasinghe[1*], A.B. Sartaj[1], T.M.C.N. Tennakoon[1],
K.D.R.R. Silva[2] and D. Hunter[3]**

[1]Plant Genetic Resources Center, Gannoruwa, Peradeniya, Sri Lanka.
[2]Wayamba University of Sri Lanka.
[3]Bioversity International, Rome.

bfnprojectsrilanka@gmail.com

Global Hunger Index (GHI) for Sri Lanka for the year 2015 is 25.5 thus the International Food Policy Research Institute (IFPRI) categorizes Sri Lanka under the food insecurity level: serious. This issue of hidden hunger has proven to be budding concern that needs to be addressed nationally; majorly comprises the household food insecurity amongst the low-income population. Food insecurity is a multi-dimensional commodity where multi-sectorial intervening is required to enable reliable access to sufficient quantity of affordable, nutritious food. Biodiversity for Food and Nutrition (BFN) Project; mainstreaming biodiversity conservation and sustainable use for improved human nutrition and well-being is actively involved in addressing the prevailing concerns on nutrition through sustainable management and utilization of agro-biodiversity. With regard to the food insecurity persisting amongst the low-income proportion inhabiting the rural areas in Sri Lanka, the project completed baseline study for determination of the status of agro-biodiversity, dietary diversity, food security status of the households and associated traditional knowledge in the Gampola, Giribawa site representing the tank-based system in Sri Lanka. The food security status in the pilot site revealed the prevalence of food secure, food insecure without hunger, food insecure with moderate hunger and food insecure with severe hunger to be 40.0%, 57.4%, 7.1% and 1.4% respectively. Dietary diversity score of households 7.15 ± 1.11 out of 12. Prevalence of child under nutrition in food secure and food insecure households were 3.8% and 19.2% respectively. Collectively 40% of households were food secure and 60% of households were food insecure. Mother's and father's education level, household dietary diversity score and household income were seen to be positively associated with food insecurity. Insufficient knowledge and inappropriate practices related to agro-biodiversity use and household nutrition were identified from the baseline surveys. Loss of agro-biodiversity over time was evidently seen and traditional knowledge associated with local community is rapidly diminishing over generational lapses.

Abstract No. 04

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The BFN project, thus embarked on carrying out awareness programs, best practices, trainings and workshops at selected sites and nationally with sustainable development goals which address; achieving food security, improved nutrition & health and promoting effective utilization of agro-biodiversity & sustainable agriculture. Major projects include, nutritional composition analysis of 58 varieties/land races of 28 species of priority/local agricultural species with a national nutrition database. Establishment of school home gardens, model urban home gardens, food & diversity fairs to promote utilization of agro-biodiversity for human nutrition and establish marketing strategies for nutrient rich, under-utilized, traditional crop varieties including local root & tuber crops; development of demonstration model plots; traditional knowledge documentation and dissemination; production and marketing of novel value added products using under-utilized crops. Other activities include; popularization of use of nutritious herbal food and beverages; festival of under-utilized fruits; increasing local fruit and vegetable consumption of Sri Lankans through "*Helabojun*" sales centers.

Abstract No. 05

EFFECT OF SURFACE TEMPERATURE ON THE TEMPERATURE HOMEOSTASIS AND EMBRYONIC SURVIVAL OF A GROUND-NESTING SHOREBIRD ALONG A THERMAL GRADIENT ACROSS SRI LANKA

Shashiprabha Jayasinghe[1], Rashika W. Ranasinghe[1], Rasika Manjujeewa[2], Hiran Jayaweera[2], and Sampath S. Seneviratne[1]

[1] Avian Evolution Node, Department of Zoology and Environment Sciences, Faculty of Science, University of Colombo, Colombo 03. Sri Lanka.
[2] Department of Physics, Faculty of Science, University of Colombo, Colombo 03. Sri Lanka.

sam@sci.cmb.ac.lk

Urbanization and deforestation are two main reasons for the rapid rise in earth's surface temperature across the globe. Although the life on earth depends on earth's temperature for its survival, the life that associates with its surface, such as ground nesting shorebirds (Order Charadriiformes), could have a greater sensitivity to the alterations of the earth's surface temperature. Using an automated data logger critically evaluated the effect of ground temperature on temperature homeostasis of the egg of a ground-nesting shorebird (Red-wattled Lapwing (*Vanellus indicus*)) found in a wide range of environments, from city parks and parking lots to undisturbed forested wetlands, in varied ground temperature regimes. Measured the egg temperature (T_E; off the egg shell), ground temperature (T_G; 1cm below ground near the nest) and air temperature (T_A; 10cm above ground near the nest) in 5 minutes intervals for up to 72 hours in 29 eggs of 17 nests in six locations; Colombo, Mannar Island, Puttalum, Galle, Kandy, and Bibile. We observed the parent behavior from ~50m away from the nest using binoculars. We also measured the clutch size and the substrate of the nest. To set the thermal end points, a set of fertilized chicken eggs were incubated in an incubator under laboratory conditions at 42°C (high temperature), 22°C (low temperature) and 37°C (control).

The mean egg temperature under parental incubation (35.7°C $\pm$ 1.6) is significantly different from that of the absence of parental incubation (33.9°C $\pm$ 5.1; $t_{196} = 4.27$, $p < 0.05$). When the egg exposed to an extreme low temperatures ($<20°$C) or to an extreme high temperatures ($>42°$C), the survivorship of the developing embryo drops under laboratory conditions. The Colombo municipality area had the highest daytime temperatures ($T_G = 50.7$ °C, $T_A = 33.7$°C). Peradeniya University, another urban area had the second highest temperature ($T_G = 42.0$°C, $T_A = 30.8$°C).

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However the Mannar Island had mild temperatures and narrow daily temperature fluctuation when compared with urban areas. Mannar provides the optimum temperatures for embryo development (33–36°C), this may be probably a reason for many species of ground nesting birds to breed in large numbers in Mannar. The lowest temperatures were recorded in the foothills in Bibile ($T_G = 23.7°C$, $T_A = 24.5°C$). According to our data, lapwings did not breed in areas where T_G had dropped below 20°C. We also found that the bottom substrate of the nest (pebble, sand etc.) has a significant impact on the nest microclimate and embryonic survival ($F_{(2, 196)} = 268.5$, $p < 0.05$).

We found extremely high surface temperatures at urban areas when the habitat is altered with stone and pebbles (e.g. Nawala Wetland Park). Stone and pebbles had increased the nest temperature in natural nests as well. Grass and sand provided the optimum temperatures for the survival of embryos in the studied nests throughout the island. Urban landscapes showed high daily fluctuation in ground temperature, which resulted in nest failure due to exceeding of the tolerant range (33–40°C). Our findings exposed an overlooked aspect of the urban landscape that affects the wellbeing of the life associating with it, where future blue-green planning should pay a more careful attention.

THE FIRST RECORD ON BIODIVERSITY OF THE ARBORETUM OF SEETHAWAKA WET ZONE BOTANICAL GARDENS, SRI LANKA

Sudheera M.W. Ranwala[1*], I.A.D. Nadeesha Dilrukshi[1],
D. Siril A. Wijesundera[2] and A. M. Achala S. Attanayake[3]

[1]Department of Plant Sciences, University of Colombo, Colombo 03, Sri Lanka.
[2]National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka.
[3]Royal Botanic Gardens, Peradeniya, Sri Lanka.

ranwala@pts.cmb.ac.lk

Seethawaka Wet Zone Botanical Garden (SWBG) is a recent addition to the Botanic Garden Network of Sri Lanka. This paper documents flora and fauna in the arboretum area of SWBG for the first time and enumerated arborescent flora using thirteen 15m ×10m stands and determined the dominant woody species using the Important Value Index. To determine the seed rain during the year 2015 twenty seed traps (1m x1m) were randomly placed 0.75m above the floor and the richness and abundance of the seeds were recorded. Fauna was recorded through opportunistic surveys conducted during day and night. Composite samples of top soil obtained up to 10 cm depth from stands were also tested for pH, conductivity, total contents of nitrogen, phosphate and potassium using standard soil analytical methods to reveal the edaphic features of the site.

The arboretum canopy was 2-6m high with small gaps representing woody species of disturbed lowland rain forests. It accommodated 50 woody plant species belonging to 30 families, including 10 endemic and 05 threatened plant species (*Anodendron paniculatum, Diospyros walkeri, Persea macrantha, Hortonia angustifolia, Gyrinops walla*). The most dominant arborescent species that significantly contributed to the IVI were *Mallotus tetracoccus, Syzygium caryophyllatum* and *Litsea longifolia*. The undergrowth vegetation included small saplings of woody species, shrubs and few herbs and was dense in places which received ample sunlight through canopy gaps. These represented 43 species from 21 plant families into which 02 endemic and 02 threatened species (*Hypolytrum nemorum* sub sp. nemorum and *Carex indica*) were included. The preliminary investigation on lower plants included 09 species of ferns from 07 families and 20 species of macro-fungi species belonging to 16 families. The early establishment of invasive alien species *Alstonia macrophylla*, *Dillenia suffruticosa* and *Clidemia hirta* at few sites was noted as an emerging threat to the vegetation.

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The seed rain at SBWG varied seasonally exhibiting the highest input of seeds in April-June months followed by January-March > July-September > October-December. The relative contribution species was *Alstonia macrophylla > Mallotus tetracoccus> Syzigium caryophyllatum> Pagiantha dichotoma > Macaranga peltata.*

Fauna of SWBG included 67 bird species from 34 families including 8 endemic species. Out of them Punchi Binguharaya - Green Bee-eater, *Merops orientalis* was reported to be a threatened species. The fish species that inhabited aquatic habitats included 07 species belonging to 05 families and included 02 endemic and 02 threatened species (Uda handeya-, Day's killifish, *Aplocheilus dayi* and Gal weligouwa-Stone goby, *Sicyopterus griseus*). The mammals included 09 species belonging to 07 families. The threatened mammal species Sri Lanka Kalu-wandura-Purple-faced leaf monkey, (*Semnopithecus vetulus*) was included into this list. In addition, 12 species of reptiles from 8 families were also reported including 03 endemic species and 02 threatened species (Depath thudulla- Kelaarts earth snake, *Rhinophis homolepis* and Gatahombu katussa / Karamal bodiliya- Lyre head lizard / Hump snout lizard, *Lyriocephalus scutatus*).

The range of soil pH of the arboretum varied from 5.71 -6.87 while the conductivity ranged from 1.87- 3.94 reflecting a wide variation in mineral ions. The soil macronutrients contents varied (K>P>N) among stands. The total P range of arboretum soil was 106-260ppm, although very low value of 85ppm was also reported from one stand. The total potassium level varied from 105-817 ppm, but reported an exceptional value of 1173ppm in one stand while total N% varied between 0.12-0.25 excluding the stand which reported 0.07%. This would probably highlight minor topographic variations at the site and impact of soil on disturbances occurred at different scales during development of SWBG. In conclusion it is reported that the SWBG house a rich diversity of flora and fauna easily observable to the visitors. The arboretum vegetation exhibits a great potential to strengthen nature tourism in this area by serving as a representative sample of a disturbed lowland rain forest. Therefore, it is evident that the arboretum together with semi-natural landscapes enhances economic, aesthetic and ecological value of the SWBG.

SOCIAL WATER USE IN ASSESSING ENVIRONMENTAL FLOWS: A CASE STUDY IN DEDURU OYA BASIN

M.M.J.G.C.N. Jayasiri[1*], N.D.K. Dayawansa[2] and E.R.N. Gunawardena[2]

[1]Postgraduate Institute of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.
[2]Department of Agricultural Engineering, Faculty of Agriculture,
University of Peradeniya, Peradeniya, Sri Lanka.

nishanka.jayasiri@gmail.com

River ecosystems are interlinked with natural flow functions. Dam constructions can modify the natural flow patterns leading to unpredictable consequences on ecosystems including change of living pattern of riparian community who depends on river for their primary needs. Environmental Flow (EF) releases can restore or reverse the already occurred degradation. EF is defined as the quantity, quality and timing of water flows required for sustaining freshwater ecosystems and the human livelihoods and wellbeing that depend on these ecosystems. The water use of the riparian community for their livelihood, day to day life and customs or believes is described as social water use and has been identified as a component of EF. This study aims to identify the pattern of social water use in downstream of Deduru Oya reservoir and quantify the social water use focusing on basic water needs and livelihoods. At first, the riparian area was segmented in to three according to adjacent land use. The average width of living area of the regular river water users was identified during the preliminary survey as 1 km. Then riparian population was estimated within this 1 km buffer. A questionnaire survey was carried out within the riparian zone for a sample of 30% of the total population in each segment. The questionnaire focused on water uses, water sources, direct water uses from Deduru Oya, required minimum water heights of the river for each water use, frequency of using Deduru Oya, details on direct abstraction by pumping, timing of using water pumps and livelihood details. This study focused on bathing, domestic activities and subsistence agriculture as major water uses from Deduru Oya. Water discharge from the pump was calculated when people use water pumps to abstract water from river for household activities. Pumps used for brick industry and agricultural lands more than 0.25 Ac were ignored from calculations to avoid commercial water use. According to the survey, 25% of the population totally depends on Deduru Oya for irrigation and 18% of the population totally depends on Deduru Oya for bathing and domestic activities. According to the quantified water volumes, the dependency on Deduru Oya is comparatively high in dry months. It is 1650 m^3/day in February and 1700 m^3/day in August while 1480 m^3/day is the average. In many months water use is below the average.

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However, EFs are allocated to secure the water needs of ecosystems and in-stream living organisms. Though it is not possible to comment on the social water requirement of Sri Lankan rivers as a component of EF due to lack of studies, it is possible to have a high social water dependency in dry zone rivers comparative to the wet zone rivers due to irrigation water use and water shortages for domestic purposes specially in dry months. Since a considerable amount of the riparian community depends on river for their primary needs and subsistence agriculture, especially in water scarce months it is a requirement to release EF from the Deduru Oya reservoir. It is useful to consider the cultural water requirement such as water related religious activities, cultural beliefs and activities which are also components of social waster use.

WHAT IS MORE EFFECTIVE IN REDUCING DEFORESTATION: 'MANAGEMENT REGIME' OR 'OWNERSHIP TYPE'? A CROSS-COUNTRY DATA ANALYSIS FOR 1990-2015

D.V.P. Prasada

Department of Agricultural Economics and Business Management,
University of Peradeniya, Peradeniya, Sri Lanka.

pp16252@gmail.com

Even though greenhouse gas emissions still continue to increase, forest cover throughout the world is not declining due to the fact that deforestation rates have stalled for the last five years at the global level leading to the outcome that global forest cover has remained stable over this period. However, a closer look at the regional data shows that there are wide disparities in the deforestation rates across regions. For instance, the Asian (South and south East Asian) deforestation rates are considerably higher than the rest of the world. This is especially evident for the last five years during which the annual rates of deforestation for the rest of the world is approx. 0.3 percent of the existing forest area but the corresponding figure for Asia is 0.5 percent of the forest area. Using empirical panel data models, we investigated this divergence of deforestation rates (measured in ha per year) statistically using potential associative factors and relate it to management regime and ownership type. We used a panel data estimation controlling for country-specific fixed (i.e. time-invariant) effects to estimate the partial coefficients of each factor on deforestation rates. We used a model combining the following variables: the ratio of forest area to total land, total employment in forestry sector, reforestation rate, and total areas under public and private ownership and the area of forest under managed plantations. The results of the model indicated that while both public and private ownership significantly reduce deforestation rates and the level of reduction of deforestation rate in the case of private ownership is twice that of public ownership under the model assumption of country-specific unobservable factors correlated with explanatory variables.

WATER PRODUCTIVITY, LAND PRODUCTIVITY AND PROFITABILITY OF PADDY CULTIVATION UNDER AGRO WELLS, IN-STREAM AND IRRIGATION SCHEME WATER USERS IN *HAKWATUNA OYA* WATERSHED

N.G.R. Saumyarathna[1]*, E.R.N. Gunawardena[1] and N.D.K. Dayawansa[1]

[1]Postgraduate Institute of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.

ngrsaumyarathna@gmail.com

The *Hakwatuna Oya* major irrigated system, in Deduru Oya river basin provides irrigation water to 2,578 ha of land to cultivate paddy in both wet (*Maha*) and dry (*Yala*) seasons. In 1964, the catchment which feeds the reservoir, included 5,024 ha of natural forest owned by the state (part of *Kahalla-Pallekale* wildlife sanctuary) and 976 ha of privately owned lands by 136 settler farmers. By year 2000, the cultivated land in the catchment area has increased to 2126 ha which included encroachment of 1,137 ha. Presently, farmers in the command area are facing a water shortage to cultivate their paddy lands mostly in the "*Yala*" season. Ground water abstraction from agro wells constructed in newly developed cultivated lands in the catchment and the direct abstraction from three tributaries, which feeds the reservoir, are considered as some of the contributing factors to this water shortage.

With this background, a study was conducted to assess the water productivity, land productivity and profitability of cultivation of three types of water user groups, consisting of, i) farmers of *Hakwatuna* irrigation command, ii) agro-well farmers in the *Hakwatuna* catchment, and iii) farmers who abstract water from streams of the *Hakwatuna* catchment. Ten farmers from D-10 canal of the right bank and nine farmers from D-4 canal of the left bank of *Hakwatuna Oya* irrigation scheme were randomly selected to represent the farmers in the irrigation command. Nine in-stream users and ten agro well users were selected randomly from "*Halmillawewa*" GN division which has the highest number of agro wells and in-stream users. Cultivation activities of all these 38 farmers were closely monitored during the 2014-2015 *Maha* season.

The results show that in-stream and agro well users in the *Hakwatuna Oya* catchment were performing either equally or better compared to farmers in the irrigation command, who are the legitimate users of the water. This implies that encroaching new lands in the catchment and easy access to water resources on their own from streams and agro wells appears to be more attractive. Further, non-implementation of existing land and water regulations exacerbated by poverty could further accelerate the encroachment of natural forests.

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These encroachments lead to degradation of remaining natural forest and increase the already existing human-elephant conflict in this area. In addition, the degradation of catchment and water scarcity of *Hakwatuna Oya* irrigation scheme due to decreasing inflow as a result of water abstraction from streams and agro wells would have a serious impact of the long term sustainability of the *Hakwauna Oya* watershed, which encompasses the catchment, reservoir and the irrigation command. Therefore, policy makers need to take these trends in to serious consideration in developing long term strategy to protect the natural resources.

MACRO PROPAGATION OF *Eucalyptus microcorys*

A.L.M. Zuhry

Forest Department, Sampathpaya, Rajamalwatta, Battaramulla, Sri Lanka.

zuhry8@hotmail.com

Establishment of highly productive uniform forest plantations is essential to meet the demand for timber in sustainable forest management. *Eucalyptus microcorys* is one of the major upcountry plantation forest species in Sri Lanka. Timber of this species has a high demand due to the high density, the strength and the resistance to termite attacks. Seedlings, the planting materials that we use at present, yield less uniform (uneven) plantations because of their genetic diversity. Therefore, this experiment was conducted to identify the possibilities of obtaining clones from coppice shoots and nodal cuttings at Erabedda (Badulla) plant nursery in 2016. Two types of cuttings, nodal (2 nodes) cuttings obtained from one year old seedlings and coppice shoots (10- 15cm long) obtained from base of thinned trees (around ten years old),were used. Twenty cuttings each from both types were taken and established in the sand medium inside a completely closed propagator. Coppice shoots consisted of 15 mature and 5 fleshy herbaceous cuttings. Final reading was recorded after 59 days. Rooting was observed in 10 nodal cuttings (50%) and 13 mature coppice shoots (65%). All 5 herbaceous coppice shoot cuttings were removed in the early period of the experiment due to wilting and decaying. However, as far as only mature coppice shoots are considered the rooting percentage was 86.7. This is the first time rooting of *E. microcorys* shoots has been observed in Sri Lanka. Further studies have to be extended to evaluate the macro propagation of the species in commercial level to apply in establishment of highly productive plantations.

CLIMATE CHANGE VS. STATE SOVEREIGNTY: BALANCING THE CONFLICTING INTERESTS IN GLOBAL ENVIRONMENTAL DECISION MAKING

Anjani Leelarathna

Faculty of Law, University of Colombo, Colombo 03, Sri Lanka.

shanikaanjani@gmail.com

Climate change rapidly became one of the main global environmental issues with the rise of sea level, increased intensity of wind storms, changed rainfall patterns and other potential harm during the last couple of decades. The recognition of need for a worldwide environmental policy response to climate change issue has led to a separate dimension in International Law. There is a global concern to manage interdependence of countries where natural resource consumption harms spill across the national boundaries and affect neighboring countries or the shared resources of the global commons. The institutional response to climate change cannot be achieved without a structure of decision making that aligns with the emerging consensus around principle of State Sovereignty. Therefore, it is intended to evaluate the conflict between climate change issue and the principle of State Sovereignty in the light of the decisions of environmental law making panels and the right of individual states to use natural resources within their own jurisdiction. In the context of sustainable development, it is evident that the right of countries to control the use of natural resources has been reaffirmed at the United Nations Conference on Environment and Development, held in Rio de Janeiro in 1992. However, short term economic benefits may be achieved by anthropocentric decision making, but with the adverse effects on human health and ecosystem functions resulting from climate change may counterbalance such gains. Therefore, it can be concluded that nations can no longer ignore the alarming threat of climate change even though the individual states have sovereign right to exploitation or use of natural resources within their own jurisdiction. As a recommendation, to be more effective in global decision making, the panels such as The Intergovernmental Panel on Climate Change (IPCC), must focus on equity, sovereignty finance and transfer of technology and also to increase the regional level co- operation. The author has employed qualitative research methodology in this paper. Climate change will leave no corner of the planet unaffected, but the impacts will be unevenly distributed. Finally, decision making panels have to take adequate steps to smooth the function of decision making while preserving the rights of individual states in use of natural resources in order to have a balance between these two conflicting interests.

ACHIEVING LAND DEGRADATION NEUTRALITY FOR SUSTAINABLE DEVELOPMENT IN SRI LANKA

Champika S. Kariyawasam[1]*, Sujith S. Ratnayake[1] and I. J. K. Palugaswewa[1]

[1]Ministry of Mahaweli Development & Environment, Sampathpaya, Battarmulla, Sri Lanka.

champikakariyawasam@yahoo.com

Land degradation is the key constraint for managing land resources sustainable. The world leaders recognized the economic and social significance of sustainable land and soil management at the Rio+20 that stipulated to achieve a land-degradation neutral world in the context of sustainable development. The United Nations General Assembly adopted the 2030 Agenda for Sustainable Development which highlighted the importance of SDG target 15.3 on Land Degradation Neutrality (LDN). Attaining LDN will significantly contribute to sustainable development through rehabilitation, restoration, conservation and sustainable management of land resources. Establishment of national-level voluntary LDN targets is one of the key decisions taken at the 12th session of the COP of the UNCCD in 2015. Land Degradation is a global concern for sustainable development and it has close links with other environmental and sustainable development challenges, including poverty, food security, climate change and biodiversity loss. Consideration of synergies of the three Rio Conventions UNCCD, UNCBD and UNFCCC is important and the national priorities of thematic areas under these conventions should be recognized. In Sri Lankan context, LDN is not a new concept. According to the requirement of the UNCCD, Sri Lanka has compiled its National Action Program (NAP) to combat land degradation and desertification in line with the 10-year strategic plan and an Integrated Financing Strategy for sustainable land management to support country to mobilize necessary financial resources effectively and efficiently. Several green growth development strategies have been successfully employed to make the country green. Several Government and Non-governmental agencies, projects and programs are working on achieving LDN at national and local level.

ESTIMATION OF SOIL CARBON STOCKS OF TROPICAL RICE BASED CROPPING SYSTEMS: RICE-RICE, RICE-SOYA, RICE-ONION AND RICE-TOBACCO IN SRI LANKA

B.M.A.C.A. Perera[1], R.P.S.K. Rajapaksha[2],
E.M.H.G.S. Ekanayake[2] and R.R. Ratnayake[2]

[1]Faculty of Agriculture, Aquinas University College, Colombo 08, Sri Lanka.
[2]National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka.

renukar@ifs.ac.lk

Carbon sequestration increases soil fertility at the same time reduces global warming by storing atmospheric carbon in soils. This study aimed to investigate the variation of Soil Organic Carbon (SOC) fractions and carbon stocks as affected by crop rotation with upland crops in tropical rice based cropping systems in Sri Lanka. Total Organic Carbon (TOC), Microbial Biomass Carbon (MBC), Water Soluble Carbon (WSC), and $KMnO_4$ oxidizable Carbon were analyzed at 0-15 and 15-30 cm depths in Rice-Rice (RR), Rice-Soya (RS), Rice-Tobacco (RT) and Rice–Onion (RO) rotations. Soil pH and moisture were also analyzed. The data were analyzed as a completely randomized design (CRD) analysis of variance (ANOVA). Results showed that SOC fractions among the cropping systems varied significantly ($p<0.05$) showing high contents of Carbon in 0-15 than 15-30 cm depth except only for water soluble Carbon which showed a higher content in 15-30 cm depth. The top soil layer had higher amount of MBC than the deeper layer. Although it was not quantified comparatively high amount of organic matter remaining in RR as paddy stubble accounted for highest amount of TOC. RS also maintained a higher TOC content probably due to the organic residues collected in soil via leaf litter as all dry leaves have fallen on to the soil at the time of harvesting of soya. However, in RO no residues were added to the system and significantly lower organic Carbon content was reported. After 10 years of cultivation cropping system changes from RR to other annual crops such as RT and RO reduced the soil Carbon sequestration to a significant level. However, crop rotation changes from RR to upland soya maintained same level of C (65.18 t/ha) as in RR (63.48 t/ha). This indicated that Carbon sequestration capacity is species specific and differences are mainly due to remaining crop residues and specific soil tillage practices used for upland crops. The study confirmed that tropical rice based cropping systems have a great potential in storing and maintaining Carbon in soils.

GREEN IMPERIALISM: ETERNAL BATTLE OF THE SOUTH FOR EQUITY, JUSTICE AND FAIRNESS IN GLOBAL ENVIRONMENTAL GOVERNANCE

Kokila Konasinghe

Department of Public and International Law, Faculty of Law,
University of Colombo, Colombo 03, Sri Lanka.

kokila@law.cmb.ac.lk

The political tension between the North (the developed countries) and the South (the developing countries) is of prime concern to the global environmental decision-makers; it is also the underlying theme of this research. Therefore, it is important to establish at what levels the environmental governance system has failed to recognize, and address, the key factors that have resulted in the North-South polarization of environmental policy making. As Sands states, "the challenge for international environmental law in the world of sovereign states is to reconcile the fundamental independence of each state with the inherent and fundamental interdependence of the environment". Consequently, environmental policy making in many Southern states become subject to external influences which highlights the dangers of setting project norms based on international environmental standards rather than setting national and local environmental norms.

To this end, this paper explores three international environmental law principles, some of which have been incorporated into international instruments, while others have been created by customary international law: state sovereignty, the right to development and, common but differentiated responsibilities. Traditionally, international law ensures the right of all states to the political determination over their own environments, which implies paramount of the concept of non-intervention of one state in the internal affairs of another. Right to development emphasizes the importance of collective effort in achieving three pillars of sustainable development – economic development, social development and environmental protection. The common but differentiated responsibilities principle entails that the North should take the lead in implementing international environmental standards and policies for the reason that they are the main contributors of the global environmental crisis.

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Continued

In spite of these legal safeguards, however, the North- South disparity and the application of equity, fairness and justice have not yet been fully addressed in terms of Southern states' participation in the decision-making process. This paper suggests that the main reason for Southern environmental concerns not being heard is that they have not been effectively represented at the global level because of insufficient representation in decision-making process, ineffective implementation of global environmental standards, and the lack of local scientific knowledge and research. It seems clear that what is required is more equitable governance procedures and a better distribution of resources, which could be achieved by educating local scientists and creating research centers. Such innovations could be a progressive way to broaden Southern participation in the development of an equitable global environmental agenda.

GREEN APPAREL FACTORIES AND WORKER'S PERCEPTION: POST OCCUPANCY EVALUATION ON INDOOR ENVIRONMENT, BUILDING RELATED SICK SYMPTOMS AND PRODUCTIVITY

I. Rajapaksha

Department of Architecture, University of Moratuwa, Moratuwa, Sri Lanka.

indrika_rajapaksha@ymail.com

Buildings symbolize the single largest contributor to human created emissions and responsible for significant share of Greenhouse Gas emissions. Local building stock consumes 70% of the grid generated energy and with the ambitious GDP growth projections it is definite that the current national annual energy demand will increase in future. However, at COP 21 in Paris, our pledge for Intended Nationally Determined Contributions is reduction of 7% of GHG emissions by the year 2030. Thus, enforces a greater seriousness on mitigation of building related emissions. Green buildings are effective catalysts to promote sustainable built environments and several green rating systems are focused on resource efficiency, promotion of occupant's health, productivity and reduction of waste, pollution and environmental degradation. LEED the Leadership in Energy and Environmental Design of the U.S. Green Building Council is the most widely used and recognized green building rating system in the world.

There is an enduring trend for LEED green rating in the construction industry of Sri Lanka and pioneering buildings of this rating system in Sri Lanka are key players of the apparel industry and renowned as the flagship green garment factories in the global apparel sector. Thus the study focuses on the systematic evaluation of worker's satisfaction and perception of indoor working environment and emerging health issues through symptoms of Sick Building Syndrome in Platinum and Gold rated green apparel factories.

In this study worker's perception on working environment was assessed through a widely used structured questionnaire of Building User Survey (BUS). The questionnaire explores the working atmosphere through thermal and visual, comfort, perception of indoor air quality, worker's satisfaction and prevalence of sick building syndrome symptoms. Randomly selected sample of 150 machine operators participated in this survey. Results explicitly prove that the working environments of both green factories promote negative impacts on productivity and majority suffers from health issues originated from poor indoor environment conditions. Moreover, majority of workers are affected with building related sick symptoms such as fatigue, nausea, heavy head, dry throat and dry facial skin.

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Continued

Indoor environments of both green factories are not influential in the increase of productivity of its workers. Prevailing indoor environment decreases the productivity by 29% and 32% in Platinum and gold rated green factories respectively. Statistical analysis of the data proves a significant relationship between productivity and building related sick symptoms. These findings inform limitations of universal certifications in evaluating indoor environmental conditions. Moreover, establishes that the green factories in Sri Lanka do not support the worker's perception on working environment which in turn promotes negative impacts on productivity. Thus this research highlights far reaching implications and importance of national policies, guidelines and rating schemes to originate a precise green building certification approach for Sri Lanka.

Abstract No. 16

SURVIVAL AND GROWTH PERFORMANCE OF NATIVE TREE SPECIES PLANTED IN HIGHLAND PINE PLANTATIONS IN SRI LANKA

S. H. Bandumala

Forest Research Institute, Kumbalpola, Boyagane, Sri Lanka.

shbandu@gmail.com

Pinus has been introduced to the country more than sixty years ago with the purpose of restoring degraded lands in the highlands and low country wet zone of the country. Despite various benefits provided by the pine plantations, there has been a growing resistance against those plantations due to some negative impacts on the environment, e.g. undesirable changes in the physical, chemical and biological conditions of the soil; impeding natural regeneration of indigenous tree species. Due to those negative environmental impacts, certain studies have been conducted to convert pine plantation into more environmental friendly mixed species forests. Previous studies have indicated that pine plantations can support the regeneration of indigenous tree species under their canopy and catalyze the natural regeneration processes. In the Wet Zone of Sri Lanka, plantation management techniques, such as thinning operations, have been found to create suitable micro climatic conditions for the growth of native tree species. Most of the attempts on conversion of highland pine have failed due to reasons such as fire, infertile soil, root competition and heavy shade inside the mature pine plantations. The objective of the present study was to identify the suitable tree species and management techniques to convert a mature pine plantation into a native, broad-leaved forest in the highlands of Sri Lanka. This study was carried out in an old pine plantation adjoining the town of Ella in the Badulla Forest Range. To provide different shade levels, rows of pine trees were removed to create 5m, 10m, 15m wide open belts within the study area. In one block, all pine trees were removed to receive full sunlight. The study tested fourteen tree species. Planting was done in November 2010 during the monsoonal rains. Seedlings of 1 ½ years were planted at 2.5m x 2.5m grid arrangement. Fire belts were opened and fallen pine needles were removed twice a year from the study area to reduce the fire hazard. Measurements were recorded biannually to study the growth performance of planted tree species in different shade levels.

Survival and growth data of tree seedlings were analyzed four years after planting separately for different thinning densities. The results revealed that high density thinning of pine trees (15m wide pine tree removal) tended to have positive effect on the growth and survival of planted tree seedlings than low density thinning (5m and 10m wide pine tree removal).

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Continued

Both survival and height growth of tree species revealed that *Calophyllum Inophyllum* (domba), *Madhuca longifolia* (mee), *Pericopsismooniana* (nadun), *Michelia champaca* (sapu) and *Calamus ovoideus* (rattan) were the most suitable tree species for conversion of pine plantation into indigenous tree forest. Those seedlings showed higher survival and seedling growth in 15m wide opening of pine, *Chloroxylon swietenia* (burutha), *Durio zibethinus* (duriyan), *Caryota urens* (kithul) and *Artocarpus heterophyllus* (kos) failed to grow under any shade treatments. Browsing of porcupine and barking deer are the major causal factors for failures of above.

It can be concluded that the overall performance of the planted tree species were greater in 15m wide pine tree removal treatment. The study revealed that that *Calophyllum inophyllum*, *Madhuca longifolia*, *Pericopsis mooniana*, *Michelia champaca* and *Calamus ovoideus* are the most suitable indegenous species for conversion of pine plantation into indigenous tree forest in highlands of the country. Proper species selection and their size at planting are the most important factors to be considered. A thorough approach to managing uncontrolled fires should also be established to mitigate the risk to the growth and survival of the trees.

DISTRIBUTION, CONSERVATION AND IDENTIFICATION OF *Strobilanthes* sp. IN SRI LANKA

R.M.R. Nilanthi

Department of Wildlife Conservation, Jayanthipura, Battaramulla, Sri Lanka.

nilanthi.dwc@gmail.com

Strobilanthes is the most species-rich genus (The name 'Nelu' is applied to the whole genus) coming under Family *Acanthaceae* which was first described by Blume (1826) from specimens collected in West Java. This is one of the largest genera in the flora of Sri Lanka and one of the most interesting. *Strobilanthes* is widely distributed over tropical south and south east Asia and individual species are restricted to isolated islands. 31 species have been reported in Sri Lanka and out of them 26 species are endemic. Shrubs of the genus *Stroblilanthes* dominate the montane forest understory in Sri Lanka.

The species of *Stroblilanthes* range in growth habit from short perennial herbs to densely branched, erect shrubs and many species are reported to be plietesial; plants which grow for several years before flowering, setting seed and dying. Some Nelu species are known only from collections made several years ago and they may have become already extinct as a result of their habitats being lost to agriculture. According to the Red List of 2012, out of the total of 21 threatened *Strobilanthes* species,1 is listed as Extinct (endemic), 6 are listed as Critically Endangered 'Possibly Extinct' (of this 5 are endemic), five are listed as Critically Endangered (all are endemic); eight are listed as Endangered (all are endemic); and one is listed as Vulnerable (endemic). Species delimitation remains problematic, essentially because many species are poorly known and rarely collected, mainly because of their seasonal flowering pattern. Nevertheless, new species have been described in the past decade and it is possible that others still remain to be discovered. There are some more varieties under few of those species. Also further taxonomic reviews may result in discovering of new species in future. Further, differentiating indistinct anatomical differences between closely related taxa needs highly trained taxonomists.

In the current study specimens of 15 *Strobilanthes* species were collected from the different locations of the island for both preparation of herbarium samples and extraction of DNA. Distribution maps were prepared using Arcview GIS. Herbarium samples were prepared and deposited in the national herbarium, Peradeniya. We used DNA barcoding for identification of 15 Nelu species present in Sri Lanka. Two universally accepted barcoding regions, rbcL and trnH-psbA were used for discrimination of species.

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A CTAB based extraction protocol was optimized to acquire good quality DNA from Nelu species rich in phenols and other secondary metabolites including indigo, those possibly affect quality and quantity of extracted DNA. PCR was done with high-fidelity Taq polymerase and amplified regions were gel-purified and sequenced from both directions. Cleaned DNA sequences were aligned with Clustal X program and the phylogenetic analysis was done with PHYLIP program. Our results showed that the DNA barcoding technology can effectively be used for discrimination of Nelu species in Sri Lanka. DNA barcoding together with morphological characterization can be used to resolve the phylogeny of the Genus *Strobilanthes.*

A PRELIMINARY STUDY ON FUNGAL SPOILAGE PREVENTION OF SOLAR COLLECTOR DRIED *Moringa oleifera* LEAVES USING HUMIDITY CONTROL

Kathirgamaraja Pradeep[1], Natheesan Ratnasegar[1], Vikum Sri Wijesinghe[2], Dumidu Thilakaratne[2], Kaushalya Bandara[3] and Upeka Premaratne[1]

[1]University of Moratuwa, Moratuwa, Sri Lanka.
[2]Millennnium Information Technologies, Malabe, Sri Lanka.
[3]Synopsys Sri Lanka, Colombo, Sri Lanka.

upeka@uom.lk

Moringa oleifera, commonly known as "Murunga" in Sri Lanka, is a valuable multi-purpose tree that grows in arid tropical climates. This tree is easily accessible at very low cost to rural populations as a rich source of nutrition and medicine. Its leaves contain proteins, essential amino acids, vitamins A and C, minerals and carbohydrates. The leaves are consumed directly with food, or as dried powder ingredient for making herbal tea. The medical properties of the leaves include anti-inflammatory, anti-fibrosis, anti-microbial, antioxidant, anti-hyperglycaemic, anti-tumour and cancer preventative properties. When direct solar drying is used, the process takes up to four days. Solar collectors can achieve this within a single day. Furthermore solar collectors prevent damage to the produce by ultraviolet radiation and contamination from dust and atmospheric pathogens. However, due to the high moisture content of Moringa leaves, persistent overcast conditions can lead to fungal spoilage of the collector dried batch due to symbiotic Fusarium and Aspergillus type fungi. In this study, humidity control is used to prevent such fungal spoilage. The currently implemented bang-bang controller is capable of maintaining the collector humidity 5% above the ambient humidity to minimize the possibility of fungal growth.

ESTABLISHING BASELINE DATA TO MONITOR VIABILITY OF THE NEWLY ESTABLISHED BEDDAGANA WETLAND PARK

Dishane Hewavithana[1*], Devaka Weerakoon[2], Mayuri Wijesinghe[2], and Nalinda Peries

[1] Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.
[2] Department of Zoology & Environment Sciences, University of Colombo, Sri Lanka.

dishanehewavithana@gmail.com

Urban wetlands are highly productive ecosystems, which are extremely sensitive to anthropogenic perturbations. This paper presents baseline data on two indicator taxa, the dragonflies and butterflies, which would be useful for monitoring ecosystem health of this newly established man-modified urban wetland prior to its opening for public visitation. Additionally, the status of invasive flora within the wetland is also assessed. The present survey was conducted from June 2015 to February 2016 and used three transects, established along the three existing bund roads. Sampling of dragonflies and butterflies was conducted over a total of 108 transect days which covered morning (0600 – 1000 hrs), afternoon (1200 – 0200 hrs) and evening (1600 – 1800 hrs). The presence and abundance of floral species nationally designated as invasives were also recorded.

A total of 30 dragonfly species representing five families i.e. Coenagrionidae (08 species), Gomphidae (01 species), Libellulidae (19 species), Platycnemididae (01 species) and Protoneuridae (01 species) were recorded. Among these were two endemics *Ictinogomphus rapax* and *Prodasineura sita,* three Vulnerable species (*Onychargia atrocyana, Aciagrion occidentale* and *Ceriagrion cerinorubellum*), and six Near Threatened species (*Diplacodes nebulosa*, *Hydrobasileus croceus*, *Lathrecista asiatica*, *Orthetrum luzonicum*, *Orthetrum pruinosum* and *Rhodothemis rufa*). The most common species present at the site includes *Neurothemis tullia*, *Urothemis signata* and *Crocothemis servilia* whilst sightings of *Brachydiplax sobrina, Hydrobasileus croceus* and *Prodasineura sita* were rare. The number of butterfly species was 42 belonging to five families (Hesperiidae (03), Lycaenidae (06), Nymphalidae (18), Papilionidae (06) and Pieridae (09). This included one endemic (*Appias galane*) and two Vulnerable species (*Ideopsis similis* and *Telicota ancilla*). The most commonly observed butterflies were *Neptis hylas, Pachliopta hector* and *Graphium agamemnon* whilst species such as *Euthalia aconthea* and *Telicota ancilla* were observed rarely. The mean species richness of the dragonflies per day was 23 (+3.65) whilst that for butterflies was 25 (+2.45). Potential indicator species for monitoring the wetland park include the dragonflies *Ictinogomphus rapax* and *Lathrecista asiatica* and the butterflies *Ideopsis similis* and *Graphium agamemnon*. The disappearance of any of the threatened species could also be taken to indicate deterioration of the habitat.

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With regard to invasive flora, a total of nine terrestrial, two aquatic and one semi aquatic species were recorded within the wetland along with three potentially invasive species. Although at present, their spread is at a minimum, there is potential for extensive spread of the aquatic weeds such as *Salvinia molesta* and *Eichhornia crassipes* which in turn may threaten the dragonfly populations unless timely action is taken. Also, further spreading of *Annona glabra* (Wel Aattha) in fringes of the wetland and along bunds, streamlets and canals would threaten these indicator groups as it would result in the homogenization of the wetland habitat. Possible indicator species include the dragonflies *Ictinogomphus rapax* and *Lathrecista asiatica* and the butterflies *Ideopsis similis* and *Graphium Agamemnon.* Butterflies since they are inhabitants of terrestrial vegetation, and prefer open sunlit areas colonized by native herbs which serve as host/feeding plants (e.g. *Derris trifoliata*, *Litsea glutinosa* and *Melastoma malabathricum*), would be further affected. The biotic wealth of this wetland park as indicated by the richness of dragonflies and butterflies highlights the importance of such modified urban habitats in serving as critical refuges for displaced animals.

EFFECTIVENESS OF ENVIRONMENTAL POLLUTION CONTROL MEASURES IMPLEMENTED IN METAL CRUSHING SITES AT KADUWELA MUNICIPALITY

**A.P.Weerakkody[1], T.K.Weerasinghe[2*], N.S.Gamage[1],
R.P.P. M. Dilrukshi[2] and K.G.N.H.Weerasinghe[2]**

[1]Central Environmental Authority, Battaramulla, Sri Lanka.
[2]Center for Environmental Studies and Sustainable Development,
The Open University of Sri Lanka, Nawala, Sri Lanka.

tkwee@ou.ac.lk

Metal Crushing industry plays a major role in supplying construction materials in Sri Lanka. Although it gives a better financial and social development to the nation, the caused environmental pollution significantly influence the future sustainability of the industry. Therefore, this study was aimed to evaluate the effectiveness of pollution control measures that are already implemented in *Welehandiya* area in Kaduwela Divisional Secretariat in Colombo District by the Central Environmental Authority (CEA). Since the noise pollution and the dust emission were identified as the major impact categories, the equivalent continuous sound pressure level and concentration of Suspended Particulate Matter (SPM) in ambient air were measured in the study area. As the measurements were done after the successful implementation of recommended pollution control measures, results revealed a substantial reduction of noise level and very slight reduction of SPM levels recorded. Finally, the recommended noise pollution control measures can be introduced to similar industries while dust emission control measures need to be improved innovatively. Further intensive studies are required to analyze the effectiveness and generalize the results in future.

CLIMATE CHANGE IMPACT ON THE DISTRIBUTION OF HIGHLAND ENDEMIC BIRDS IN SRI LANKA

Janaka N. Perera[1], Lal P. Muthuwatta[2] and Sampath Senevirathne[1]

[1] Avian Evolution Node, Department of Zoology, University of Colombo, Sri Lanka.
[2] International Water Management Institute (IWMI), Pelwatte, Battaramulla, Sri Lanka.

janakanirmala@gmail.com

Changing climate will have adverse effects on to islands rather than large landmasses. Both the physical and biological characters can be altered by the direct and indirect causes of climate change. Islands such as Sri Lanka, where much endemic biological diversity is trapped on a small piece of land are more prone to these adverse effects since there is no alternative refuge. In this study we have selected five endemic birds which are exclusively found in highlands of Sri Lanka and predict the climatic suitability for 2020, 2050 and 2080. We have used secondary data stored in Birdlife International database for species' occurrence data. Climatic data was downloaded from the Intergovernmental Panel on Climate Change Data center derived from the model UKMO:HADCM3, emissions scenario A1B for 4th Assessment Report. These climatic data were then derived in to 19 bioclimatic variables under the guidelines given by the United States Geological Survey (USGS). Elevation data was downloaded from the U.S. Geological Survey, Earth Resources Observation and Science Center and using elevation data layer, slope and aspect ratio layers were created. We used Maxent (Maximum Entropy) as the modeling algorithm to create the predictive models for the 5 species. The predictive environmental data layers: 19 bioclimatic layers, elevation, slope and aspect ratio were in 30 arc second resolution. We converted the result output from the Maxent to probability maps using GIS techniques. We used QGIS 2.8.2 as the GIS platform in this study. In the results, Sri Lanka Bush warbler showed an overall increase in area with more than 50% climatic suitability over the period from 2000 to 2080. Other four species showed a reduction in the area with more than 50% climatic suitability over time. The most significant reduction occurs in the Yellow-eared Bulbul (*Pycnonotus penicillatus*) where by 2050 the overall climatic suitability drops down to less than 30 %. Our predictions suggest that the highland endemic birds might be severely affected from the reduction of areas with suitable climate. Central hills of Sri Lanka are the only remaining refuge for these montane specialists. However these models do not consider the changes in vegetation occurring due to the change in climate or the changes in land use. Therefore, the actual effects might be much higher than these current predictions.

POSSIBILITY OF BIODIESEL PRODUCTION THROUGH SELECTED ALGAE SPECIES UNDER SRI LANKAN CONDITIONS

A.M. Gammanpila[1], C. P. Rupasinghe[2] and S. Subasinghe[3]

Faculty of Agriculture,University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka.

[1]shanigam@yahoo.com; [2]chintharupasinghe@ymail.com; [3]subasinghesiripala@yahoo.com

Microalgal biofuels are currently considered to be the most promising alternative for future renewable energy source. The key to economic algal biomass production is to optimize the growth conditions. The two robust microalgae strains; *Nannochloropsis* sp. and *Chlorella* sp. were cultivated in Guillard and Ryther`s modified F/2 media with different levels of Nitrate, Phosphate, salinity, light intensity and photo periods with the aim to obtain optimum conditions for biomass cultivation for biofuel production under Sri Lankan climatic conditions.

In general, there was a significant trend of increased percentage lipid content and decreased dry biomass weight with increasing N and P concentrations in the culture medium in both species. The best lipid productivity was achieved using KNO_3 or Urea as N source with 12.4 mg/L concentration and NaH_2PO_4 as P source in 1.3 mg/L concentration for *Nannochloropsis* sp. while $NaNO_3$ and KNO_3 in double of that N concentrtaion (24.8 mg/L) is well suited for highest lipid yield in *Chlorella vulgaris. Nannochloropsis* sp. reported a significantly higher lipid yield of 0.13 g/ L, when cultured at higher salinities of 30 and 35 ppt. Salinities lower than 10 ppt reported significantly higher lipid yield of 0.12 g/ L for *Chlorella* sp. Further, it was found that the amount of light intensity affect significantly to the lipid yield of micro algae. The optimum photo period for culturing *Chlorella vulgaris* and *Nannochloropsis* sp. for lipid production, is to cultivate them with a light-dark cycle of 16:8 hour with 5 Klux light intensity.

Finally, the free fatty acid value of the lipid extracted from these two species of microalgae found to be in the recommended range for biodiesel production. Therefore, it is clear that *Nannochloropsis* sp. and *Chlorella* sp. can be successfully cultivated in Sri Lanka to produce biodiesel where the prevailing natural environmental conditions are ideal for their optimal growth.

FACTORS AFFECTING PADDY FARMERS' CLIMATE CHANGE ADAPTATION RESPONSES: THE CASE OF PADDY FARMERS IN IBBAGAMUWA AREA

T. D. Udugama[1]

Department of Agricultural Economics and Business Management, Faculty of Agriculture, University of Peradeniya, Sri Lanka

thilangideepthi@gmail.com[1]

Global climate change is increasing at an alarming rate and has created numerous uncertainties regarding the livelihoods of farming communities all over the world. Total paddy production of Sri Lanka in 2012 declined by 10.72% compared to the highest ever production of 4.30 million MT in 2010, mainly due to insufficient water for cultivation during the *Yala* season as a result of delay in the onset of monsoon rains and the consequent delay in release of water for cultivation. That is why, adapting adaptation measures to mitigate the impacts of adverse climate change conditions to maintain consistency of paddy production. Even though farmers do some adaptation practices for the mitigation of climate change impacts, factors affecting paddy farmers' climate change adaptation responses in *Ibbagamuwa* area is still questionable. Therefore the objective of this study was to identify the factors affecting paddy farmers' climate change adaptation responses.

The study was conducted in Ibbagamuwa Divisional Secretariat Division which is moderately vulnerable to droughts and is located in the Intermediate zone in Sri Lanka. Semi-structured questionnaire was used to collect primary data by using stratified random sampling method interviewing 60 paddy farmers in Ibbagamuwa. The regression analysis was used to identify factors that are affecting on climate change where the dependent variable was the climate change adaptation responses of farmers. Degree of orientation of farmers, age, education level, mode of irrigation, number of labour use, land extent were used as independent variables of the regression model. Data analysis was conducted using the Statistical Package for Social Sciences 20 version (SPSS 20).

The results indicate that, the factors affecting on climate change adaptation responses is a function of degree of orientation, age of the farmer, land extent of farmer and cultivated variety were significantly affecting on climate change responses at *$p < 0.05$* level.

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Since, the climate change responses of farmers significantly affecting on yield performance, the required knowledge which is related to climate change responses should be provided by extension services and farmer training programmes. And also these factors can be considered positively when developing existing agricultural policy in Sri Lanka.

Section 2

Proceedings of International Research Symposium on

Valuation of Forest Ecosystems and their Services

18 October 2016

Colombo, Sri Lanka

Message from Emeritus Professor Nimal Gunatilleke Chairperson, REDD+ Academic and Research Forum

On behalf of the Academic and Research Forum of Sri Lanka's RED[...] my pleasure to write this message for the International Research Symposium on 'Valuation of Forest Ecosystems and their Services', which is an integral part of the Sri Lanka Next 'Blue-Green Era' Convention and Exhibition to be held from 17-19 October 2016.

Forest ecosystems and their biodiversity are economically portrayed as an essential component of our 'natural capital' and it is invested in processes that include all life support systems in the form of 'interest' on that capital. These ecosystem services provide both tangible and intangible benefit interests that need to be managed at a sustainable level. Maintaining their continuous flow ensures environmental quality and human well-being, including poverty alleviation. In common parlance this is known as 'health, wealth and happiness'.

This symposium attempts to bring the recent developments in valuing ecosystems and their services, in line with The Economics of Ecosystems and Biodiversity (TEEB, 2010) methodology – a global initiative bringing nature's values more visible in the economic landscape. TEEB has three core principles: i. *recognising* benefits provided by biodiversity and ecosystem services, ii. *demonstrating* their values, and iii. where appropriate, capturing those values in decision making at policy levels. The three keynote speakers and twelve national/ international scientists would be sharing their research on how forest ecosystems and their services could contribute/have contributed to the mainstream decision-making and economy of their respective nations.

Currently, many districts in Sri Lanka are experiencing an unprecedented drought and extensive forest destruction due to human induced fires. It is indeed, timely to address the economic valuation of the island's forest ecosystem services that can contribute to better-informed decision-making and market-based mechanisms promoting conservation of biodiversity and their ecosystem processes that provide goods and service benefits for human well-being.

Keynote Address:

ASSESSMENT OF CARBON AND NON-CARBON BENEFITS OF TROPICAL HOMEGARDENS IN RELATION TO NATURAL FORESTS FOR REDD-RELATED ACTIVITIES IN SRI LANKA

Eskil I. Mattsson[1], M. I. Ostwald[2] and S. P. Nissanka[3]

[1] Centre for Environment and Sustainability, Chalmers University of Technology, 412 96 Göteborg, Sweden.
[2] Centre for Climate Science and Policy Research, Dept. of Thematic Studies/Environmental Change, Linköping University, 581 83 Norrköping, Sweden.
[3] Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.

[1] eskil.mattsson@chalmers.se, [2] madelene.ostwald@liu.se, [3] spn@pdn.ac.lk.

Sri Lanka's natural forests are rich in biological diversity and endemic species of flora and fauna and are critical for soil conservation, watershed and flood control. The conservation, protection and sustainable management of these forests have motivated Sri Lanka to engage in REDD+ activities through the UN-REDD program. Another important land use system for meeting climate change and development goals as well as for enhanced agricultural productivity is tropical homegardens. This ancient and locally adapted agroforestry system is presently estimated to occupy nearly 15 % of the land area in Sri Lanka and is described in the scientific literature to support ecosystem services and food security.

Several field campaigns were conducted in the recent past across Sri Lanka using both qualitative and quantitative methods to assess carbon and non-carbon benefits of natural forests and homegardens. Results showed that mean carbon stocks in the aboveground biomass across natural forest types in Sri Lanka range from 22-181 Mg C per ha with open forests having the lowest stock and lowland wet evergreen forests the highest carbon stock. The wide range in above ground carbon stocks between and among forest types reflects variations in species diversity, stand structure and age, tree density, environment and human disturbance. Estimates also showed that homegardens may contain a significant portion of the total above ground biomass carbon stock in the terrestrial system in Sri Lanka (wet zone: 87 Mg C ha-1; dry zone: 35 Mg C ha-1), increasing from almost one-sixth in 1992 to nearly one-fifth in 2010.

Keynote Address continued:

Policy measures could be formulated to allow degraded, logged, and secondary forests to regrow into a mature state, which could help maintain carbon stocks while sustaining ecosystem services and providing non-carbon benefits from forests. Another measure that could help decision makers to maintain and enhance carbon stocks while promoting ecosystem services, would be to promote establishment of homegardens through intensification or extensification on marginal lands and serve as important buffers for the remaining natural forests in areas that are experiencing pressure from increasing populations.

There are also multiple merits of homegardens in providing food security and environmental services, but a recent systematic review show that many studies are descriptive and only provide location-specific information on plant species, yield and management while making few comparisons with forests or other production systems, and even less is there empirical evidence and quantification of the food security benefits. Therefore, more scientific studies on valuation of overall ecosystem services especially on homegardens are needed taking a landscape approach to monitor the role of food security in relation to synergies and tradeoffs with climate and development goals while promoting the community based sustainable management and conservation.

MINI-HYDRO, AN INJURIOUS NOVEL THREAT TO HIGHLAND FOREST ECOSYSTEMS OF SRI LANKA

E.I.L. Silva[1] and E.N.S. Silva[2]

Water Resource Science and Technology Consultants,
77/2, Hettiyawatte, Elapitiwela, Ragama, Sri Lanka.

[1] eils.mecamp@gmail.com; [2] sandeep.drck@gmail.com

Small hydropower generation by arresting mountain streams is being viewed as an environmentally benign energy source, compared with large dams and fossil fuel combustion as it has no effects on global climate change. They can however, exert multiple negative effects locally, especially on riverine and riparian ecosystems, and eventually on aquatic biodiversity and human health of riparian communities, but reported studies on these aspects are hardly any. Ecological risk of cascade operation of small hydropower plants established on the highland tributaries poses adverse effects, as it leads to almost drying up of the natural stream channels during dry season whereas small hydropower plants affect not only fish but also the ecological integrity of lotic ecosystems and terrestrial landscape. Apparently, present knowledge and findings have fueled that principles of ecosystem science need to be fully integrated into water resources planning and management. Although the negative impacts of mini-hydropower plants on aquatic ecosystems are fairly well understood, the holistic long-term effects of clustering mini-hydropower plants on highland forest ecosystems are hardly investigated along with ongoing climate change scenarios.

The present study examined the hydrological network of Sri Lanka's mountain landscape and its associated mini-hydropower plants, to understand their effects on highland forest ecosystems. All potential sites in Sri Lanka's highlands have been either tapped or permitted to tap for small hydropower generation. About 170 km of stream channels have no water as the water flows through concrete canals, conduits, and penstocks, resulting in lessened ecological integrity between vegetation and water. The northern boundary of Sinharaja Rainforest has been encroached to construct the Koskulana mini-hydropower plant. Several kilometer-long headrace canals have been constructed removing canopy trees (e.g. Badulu Oya mini-hydropower project) whereas penstocks over one meter in diameter have been buried for several kilometers within restricted forests hindering the growth of deep-rooted trees as in Wellawaya mini-hydropower plant in the Kirindi Oya basin. Obviously, river bank vegetation between the diversion weir and tailrace outfall consisted of canopy trees and other terrestrial and semi-aquatic plants that disappeared due to the decline of lateral flows. When the diversion weir of the mini hydropower plant is placed upstream of a waterfall, as it has happened at Ethamala Ella on the Nilwala River, forest vegetation unique to the spray zone will be badly affected. These potentially negative impacts will certainly result in gradual decline of the remaining forest in the highland of Sri Lanka as global climate change is proactive in the Asia-Pacific region.

THE ECOLOGICAL AND ECONOMIC VALUE OF NATURAL FORESTS IN RELATION TO THE SRI LANKAN LEOPARD

Andrew M. Kittle[1], Anjali C. Watson[2], Samuel A. Cushman[3] and David W. Macdonald[4]

[1,2] The Wilderness & Wildlife Conservation Trust, 130 Reid Avenue, Colombo 04, Sri Lanka.
[3] U.S. Forest Service, Rocky Mountain Research Station, 2500 S., Pine Knoll Dr., Flagstaff, AZ 86001, USA.
[4] Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, Tubney House, Abingdon Road, Oxon OX13 5QL, UK.

[1,2] info@wwct.org, [3] sam.cushman@gmail.com, [4] david.macdonald@zoo.ox.ac.uk

The Sri Lankan leopard (*Panthera pardus kotiya*) is an endangered, endemic sub-species and the island's only apex predator. As a probable keystone species the leopard's ecological value in Sri Lanka is likely high. To best predict leopard presence in Sri Lanka we used multi-scale maximum entropy modelling to investigate the influence of a suite of relevant ecological, climatic and anthropogenic variables on observed leopard presence across the island.

Leopard presence was determined from >15 years of surveys, observations and verified reports. Independent variables emerged from known leopard ecology and previous research. Ecological factors included class- and landscape-level metrics of land cover composition and configuration; climatic metrics included altitude, rainfall and temperature; and anthropogenic metrics included road densities, landscape protection level and a selection of land use categorizations. All variables were derived from global and Sri Lankan GIS layers. We created 200 unique models, each composed of a random selection of 5 of the 31 appropriately scaled independent variables. Models were compared using Area Under Curve (AUC) values, and individual variables further evaluated by averaging the AUC values of all models which included each variable.

The most influential variable predicting leopard presence across Sri Lanka was the landscape proportion encompassed by level 1 Protected Areas (National Parks, Strict Natural Reserves and Sinharaja Forest Reserve). This variable was top ranked in all 9 analyses (no bias correction; bias correction using spatial rarefication at 4 spatial scales; and bias correction using Gaussian kernels at 4 spatial scales). The three forest composition and configuration metrics (Area weighted mean, Patch density and Cohesion of forest) were consistently ranked within the top 10 variables across analyses. Overall, area weighted mean of forest cover was the 2nd highest ranked variable, forest cohesion 3rd and patch density of forest 5th. This clearly indicates the influence of natural forest on Sri Lankan leopard distribution and underlines the value of these forests in ensuring the ecological integrity of the island's faunal assemblages. In addition to ecological value, the leopard represents considerable economic value with local non-use value (leopard tourism from local sources) estimated at >16 billion rupees. Overall this study highlights, through the lens of the island's top predator, the ecological and economic value of Sri Lanka's natural forests.

ASSESSMENT OF CANOPY DIEBACK IN HORTON PLAINS NATIONAL PARK USING MULTISPECTRAL SATELLITE DATA

Prabha Rupasinghe[1], Sisira Ediriweera[2] and Tithira Lakkana[3]

[1] Post Graduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka.
[2,3] Faculty of Science and Technology, Uva Wellassa University, Badulla, Sri Lanka.

[1] prabharupasinghe@yahoo.com [2] sisira@uwu.ac.lk,
[3] tithiralakkana@gmail.com

Satellite data play an important role in investigating the relationships between the spatial patterns of vegetation and environmental variables. The aim of this study was to investigate spatial distribution of canopy dieback using remotely sensed data in conjunction with field collected data in the upper montane forest. The study was conducted in the Horton Plains National Park (HPNP) in the southern part of the central hills of Sri Lanka. Ten meter resolution cloud and haze free ALOS (acquired in September 2009) and ASTER Global Digital Elevation Model (DEM) with 30 m resolution were used. ASTER DEM was resampled to 10 m spatial resolution in order to match with ALOS data. One hundred and thirty (130) field sampling plots were established and information on vegetation structure and species composition was collected. The centre of each plot was determined using a GPS unit (Global Positioning System-Garmin 12).

ALOS image was classified into four categories as dieback area, forested area without dieback, grassland and water. Topographic Wetness Index (TWI), slope and aspect products were generated using DEM. Results showed that dieback is reduced with the decrease of slope of the terrain. More canopy dieback affected areas were observed at the south facing slopes and less dieback is observed on the north facing slopes. It was noted that when TWI increased, canopy dieback is significantly reduced. Further results of our study indicated that 27% (area of 9.5 km^2) of the total forest reserve is subjected to the dieback.

Our findings showed that all the environmental variables considered, slope, aspect and TWI, have significant influence on the spatial distribution of forest dieback at HPNP. Furthermore, this study provides evidence that remote sensing and GIS based analyses are more capable and provide accurate results on investigating the tree mortality in forested areas.

PERFORMANCE OF COASTAL VEGETATION IN DISSIPATING THE ENERGY OF THE INCOMING FLOW

R.M.C.L. Bandara[1], E.A.D.D.D. Egodawatta[2], H.R. Abeywickrama[3], and S.S.L. Hettiarachchi[4]

[1,2,3,4] Department of Civil Engineering, University of Moratuwa, Sri Lanka.

[1] lakmalbandara87@gmail.com, [2] danudk@gmail.com, [3] hashan088@gmail.com, [4] sampens1955@hotmail.com

Several field investigations carried out in the aftermath of the Indian Ocean Tsunami disaster in 2004 reported significant reductions in inundation depths at locations where different types of coastal vegetation were present. Since most of the other geographical features such as seabed topography and environmental conditions could be assumed to be homogeneous for the surrounding coastline, it has been identified that the presence of vegetation has led to localized reductions in inundation depths at such locations. Coastal vegetation, which performs effectively in mitigating the impacts of the incoming waves, has been identified as a cost-effective and sustainable counter measure against coastal hazards. The resistance offered by vegetation barriers against the flow depends on the characteristics of the individual plant species and the characteristics of the vegetation as a whole and would ultimately be governed by the ability of the plants to resist the flow without being damaged or uprooted.

This study is mainly concerned with the influences of overall porosity and extent of the vegetation barriers on the performance of barriers against incoming flow. Small-scale physical model tests were carried out in a hydraulic flume to investigate the flow behavior through porous vegetation barriers from a viewpoint of hydraulics of flow through a porous barrier. Hydraulic flow parameters, which could be used for all practical applications of analyzing the flow through porous vegetation barriers, were investigated by analyzing the test results.

The results reveal the effectiveness of even shorter vegetation barriers in dissipating the energy of the incoming flow.

Keynote Address:

NATURAL CAPITAL, ECOSYSTEM SERVICES AND ROLE OF ENVIRONMENT VALUATION IN POLICY MAKING

Herath Gunatilake,

Environment and Safeguards Division, Sustainable Development and Climate Change Department, Asian Development Bank, Philippines

hgunatilake@adb.org,

The central development challenges of the 21st century is ending poverty and achieving sustainable levels of population and consumption, while securing the earth's life-support systems that underpin human well-being. Essential to meeting this challenge is incorporating the economic values of natural capital and ecosystem services into decision-making. In particular, greater recognition is needed regarding the interdependence of ecosystems and human well-being; as well as a better understanding regarding the role and mechanisms by which ecosystems support food, water and energy security, and mitigation and adaptation to climate change.

The keynote address (KA) will first review the progress in ecosystem services valuation, and will identify crucial gaps at this frontier, giving special emphasis on forest ecosystem services. Reflecting on "getting the ecosystem services values right", the presentation discusses the importance of marginal changes in values corresponding to policy changes against the total economic value. Given the overemphasis on terrestrial ecosystems in past valuation studies, it will highlight the need to focus on neglected ecosystems in valuation studies, as well as the need for more site specific studies that consider the local context and values. Moreover, the KA highlights the need to consider ecosystem disservices, and the impacts of environmental and climate catastrophes on the provision of ecosystem services; as well as the assessment of the costs and benefits of alternative uses of ecosystems.

In conclusion, the KA will consider reasons why ecosystem service information has yet to fundamentally change decision-making; and it will provide recommendations for strengthening this process. This will emphasize: 1) developing solid evidence linking decisions to impacts on natural capital and ecosystem services, and then to human well-being; 2) working closely with leaders in government, business, and civil society to develop the knowledge, tools, and practices necessary to integrate natural capital and ecosystem services into everyday decision-making; and 3) reforming institutions to change policy and practices to better align private short-term goals with societal long-term goals.

Keynote Address continued:

Within this context, using performance-based incentives such as ecosystem service payments and cost benefit analysis are emphasized as tools for operationalizing the incorporation of ecosystem service values in decision making. Finally the presentation will highlight ADB's recent initiatives on natural capital and ecosystem services including some examples from the Peoples Republic of China and other countries in Asia.

VALUING ECOSYSTEM SERVICES TOGETHER (VEST): A SOCIAL MARKETING STRATEGY FOR THE PROMOTION OF PES IN NORTHERN MINDANAO, PHILIPPINES

Evans Rosauro I Yonson

Xavier University, Ateneo de Cagayan, Cagayan de Oro, Philippines.

eyonson@xu.edu.ph

In December 2011, tropical storm Washi (local name Sendong) hit the cities of Cagayan de Oro and Iligan in the Philippines, leaving 10,000 residents homeless and close to 2,000 dead. One of the contributing factors to such devastation is the massive forest denudation in the twin peaks of Bukidnon, Mount Kitanglad and Mount Kalatungan.

A Xavier University-based initiative, called Valuing Ecosystem Services Together (VEST) was launched in November 2013, with the objectives of raising awareness, and creating ripples of positive change towards payment for ecosystem services (PES) in Cagayan de Oro. The sellers, an indigenous tribe of Mount Kalatungan in Talakag, Bukidnon have partnered with a local foundation to help them sell two services: flood control, and clean and potable water. Such services were identified by the seller's community development plan. A survey was done in five sectors, namely, corporations, cooperatives, churches, schools, and households.

VEST was conceptualized as a social marketing strategy for PES, where a slew of information, educational and communication efforts were done. The VEST brand was developed in partnership with the indigenous tribe, the Talaandigs. Traditional and modern media forms were utilized: radio plugs, television guestings, photographs and news articles, songs and MTVs, short documentary films, lectures, posters and flyers, social media, and Web sites.

These VEST efforts resulted in partnerships with corporations and a federation of cooperatives in Mindanao, the adopting of PES policies by local government units, the issuance of memorandum order endorsing the inclusion of VEST in the curriculum of higher education institutions in Northern Mindanao, and increased and new collaborations with the buyers, among others.

Future plans for VEST include the production of more information, educational and communication materials such as a full-length documentary film, a regular radio program, TV ads, increase and intensify partnerships with various sectors, such as water service and electric service companies, local government units, PES awards, and an annual public forum.

POTENTIAL INCOME FROM REDD+ ACTIVITIES FROM NEPAL'S TERAI ARC LANDSCAPES (TAL)

Basanta Gautam

Arbonaut Ltd., Latokartanontie 7 a, 00700 Helsinki, Finland.

basanta.gautam@arbonaut.com

Nepal is one of the first countries to receive REDD+ Readiness funds from the Forest Carbon Partnership Facility (FCPF) of the World Bank to conduct REDD+ Readiness activities. As a part of the readiness activities, Nepal developed Emission Reductions Programme Idea Note (ER-PIN) for 12 districts in Terai Arc Landscape (TAL). Nepal submitted its ER-PIN to the FCPF in March 2014. Nepal's ER-PIN was selected into the pipeline for result-based payment from carbon fund of the FCPF. Currently, Nepal is developing its Emission Reductions Project Document (ERPD) and is expected to be completed by the end of 2016. Aboveground forest carbon was estimated using a state of the art remote sensing technology combined with the field plots.

The analysis shows that during the 12-year period between 1999 and 2011, a total of 52,245,991 tCO_2e were emitted from the forest sector in the TAL, an average emission of 4,353,833 tCO_2e/year.

Based on the analysis of drivers of deforestation and forest degradation, five key activities and policy interventions are proposed to address those drivers and underlying causes of deforestation and forest degradation. These interventions are i) increasing supply, protecting and enhancing carbon stocks through sustainable management of forests (SMF), improved enforcement of laws, and maintenance of essential stewardship in protected areas, ii) expansion of biogas plants and cooking stoves, iii) integrated land use planning to reduce forest conversion while advancing needed infrastructure, iv) increasing supply by engaging the private sector to bring new forest production to degraded lands, and v) enhancing alternative livelihood opportunities to address underlying drivers. It is estimated that the emission reductions from aforementioned five REDD+ activities in TAL would result in a total of 14.0, 42.7 and 72.8 million tCO2e during next 5, 10 and 15 years, respectively. The result-based income from these emission reductions activities would make Nepal to be eligible to receive, USD 70 million, 213.5 million and 364 million, within the next 5, 10, 15 years, respectively. In addition to the carbon benefit, the proposed Emission Reductions Program area has many non-carbon benefits as well (e.g. biodiversity, ecosystem services, culture).

RECOGNIZING FOREST ECOSYSTEM SERVICES AND BENEFITS

Priyanie Amerasinghe[1], Matthew McCartney[2] and Sanjiv de Silva[3]

[1] International Water Management Institute, Delhi Office, India.
[2] International Water Management Institute, Laos Office, Lao PDR.
[3] International Water Management Institute, Head Quarters, Colombo, Sri Lanka.

[1] p.amerasinghe@cgiar.org, [2] m.mccartney@cgiar.org, [3] s.s.desilva@cgiar.org

Forest ecosystems provide a multitude of services and their valuation can be complex. The Total Economic Value (TEV) framework provides meaningful ways to embrace use and non-use values, which are classified as direct or indirect values, willingness to pay for conservation, knowledge of preservation of ecosystems for the future, and its utility value.

This paper examined examples of valuation of Forest Ecosystem Services (FES) from different settings in Asia, to understand the forest ecosystem flows, purpose of valuation, cost-effectiveness of investments in conservation, impact of natural disasters, trade-offs between management options of multiple ecosystem services, influence on policies that have shaped and encouraged wise-use of forest services for human well-being, effectiveness of awareness building and communication of ecosystem concepts for preservation.

The forest ecosystems studied were located in diverse settings, and spread over different climatic zones. The valuation depended on the characterization, degree of ecosystem flows into the landscape for supporting human well-being and availability and access to suitable data. While the market-based services dominated the valuation assessments, there was a gradual increase in the use of non-market services using indirect methods. In Nepal, a protected forest cover of 6,038 km^2 (Districts of Taplejung, Panchthar and Ilam) was valued at USD 125 million/yr with a significant contribution to agricultural production making a positive impact on human well-being. The baseline value for nine types of forest ecosystem services was estimated at USD 7.3 billion (2012) in Myanmar, with a projected valuation for 2031. In Indonesia, total economic value of mangrove forests (Indragiri estuary) was estimated at USD 11,823,848/yr, and USD 485,896/ha/yr. In the Uttarakhand (Himalayas), India, the average total value for ecosystem services (2,352,700 ha of forest cover) were estimated at USD 1150/ha/yr and USD 2.4 billion/yr. While the reasons for valuation were diverse, a noteworthy action was the implementation of an 'ecological cess', for environmental governance in Uttarakhand.

IDENTIFICATION AND VALUATION OF DIRECT ECOSYSTEM SERVICES FROM PROTECTED FOREST AREAS IN BANGLADESH: A CASE STUDY

Mohammed Jashimuddin[1], Samiul Islam[2] and Tapan Kumar Nath[3]

[1,2] Institute of Forestry and Environmental Sciences, University of Chittagong, Bangladesh.
[3] School of Biosciences, University of Nottingham, Malaysia Campus, Semenyih, Selangor, Malaysia.

[1] mjashimuddin2001@yahoo.co.uk, [2] samictg10208009@gmail.com,
[3] tapankumarn@yahoo.com

Forest resources collection is the major livelihood option for majority of the people living in or around the Chunati Wildlife Sanctuary (CWS) providing direct ecosystem services to them on one hand, and degrading the forests and biodiversity on the other. This study aimed to identify the nature, type and amount of forest resources collected by different resource collectors, and to quantify them and evaluate their value.

Market based approach was used to estimate the value of the collected resources by interviewing the resource collectors and cross checking the selling price of that particular resource from the adjacent local markets. A total of 28 forest trails (out of 56 used by local communities as entry or exit points for forest resource collection) were selected randomly for this study.

The study showed that 481 resource collectors per day enter the CWS through surveyed trails before noon and get back before evening. Of them 104 (22%) were female. Higher numbers of resource collectors harvested fuel wood (30%), followed by NTFPs: fruits (13%), timber (11%), agricultural products (11%), bamboos or bamboo shoots (10%), sungrass (10%), etc. The mode of carrying forest resources was by shoulder load (63%) followed by head load (30%). Among the resource collectors 84% are adults and the rest 16% are minors. The resource collectors on average spend 5.71 hours in the forest to collect resources and travel 6.41 km on each visit within the CWS. The average value of the resources gathered by each collector on each visit is BDT 301 (USD 3.84), which may be calculated as BDT 289,562 (USD 3,697.16) for the whole of CWS per day. This may again be calculated as BDT 104.24 million (USD 1.33 million) per year.

The findings of this study will be useful to-managers and policy makers for valuation of total ecosystem services provided by CWS, and it gives a better insight to the problem of forest degradation in Bangladesh, particularly in the CWS.

Keynote Address:

INCORPORATING ECOSYSTEM SERVICES AND BIODIVERSITY BENEFITS INTO DECISION MAKING THROUGH ECONOMIC INCENTIVES AND REDUCING ENVIRONMENTALLY HARMFUL SUBSIDIES DUE TO GOVERNMENTAL OR INSTITUTIONAL INACTION

Madhu Verma

Centre for Ecological Service Management (CESM),
Indian Institute of forest Management,
Bopal, India.

mverma@iifm.ac.in

The decision making process of the government and the institutional actions have been based on a narrow knowledge base about the immense biodiversity benefits from forest ecosystems, which many a times has led to policy, institutional and market failures. Though the policies have good intentions they result in bad outcomes in terms of weak or absent market and institutional mechanisms, due to insufficient information on which they have been formulated.

This address is thus an attempt to equip the policy makers with the information regarding the value of various ecosystem services of forests, such that the system of compensation and rewards can be institutionalized to compensate for losses on account of forest diversion, reward the states (of India) conserving large forest areas on account of policy directives, and incentivize the stakeholders who are engaged in the conservation process. The states that have been practicing green growth approach, but lack its reflection in the accounting system, are devoid of their due recognition. The address thus provides a connection between the economic value of forest biodiversity and how the values so obtained from various quantitative, qualitative and biophysical assessment methods are taken forward and captured in the decision-making process by introduction of various instruments.

Keynote Address continued:

This address also demonstrates the internalization mechanism through three live examples from various studies undertaken by the author in India. The first example talks about charging the **Net Present Value** (NPV) of forests due to diversion for non-forestry purposes, which is an attempt not only to compensate for loss of ecosystem services from forest diversion, but also to act as a deterrent for demand for forest land in the future. The second example of **forest fiscal federalism** where the states are incentivized for bearing the cost of conservation of forests and providing large amount of public benefits, forgo development of the state and lose considerable revenues despite possessing the 'rich forest resource'. The third example **demonstrates** the **multiplier effect of investment in natural capital**, the Tiger Reserves of India where the conservation of habitats of umbrella species has led to multiple times benefits in terms of ecosystem services from these habitats.

BIOFILM BIOFERTILIZERS FOR INCORPORATING BIODIVERSITY BENEFITS AND REDUCING ENVIRONMENTALLY HARMFUL SUBSIDIES IN AGRICULTURE

Gamini Seneviratne[1] and Wijepala P.C[2]

[1, 2] Microbial Biotechnology Unit, National Institute of Fundamental Studies,
Kandy, Sri Lanka

[1] gaminis@ifs.ac.lk;　[2] piyumichathurika8136@gmail.com

Any natural ecosystem (e.g. a forest) is composed of a food web-based network of interactions of organisms. Nutrients in natural ecosystems are conserved by cycling them in the producers-consumers-decomposers loops in these systems. Thus, food web-based network of interactions of microbes, flora and fauna is the key to ecosystem sustainability. As long as all the interactions are intact, the ecosystem is equilibrated and sustainable.

There are some microbes and insect fauna, which contribute to the structure or stratification of plants within a forest ecosystem by consuming seedlings of the same species that grow at high densities on the forest floor thereby thinning them. This allows seedlings of other species too to emerge in the same manner, leading to a remarkable diversity in the seedling stratum in natural forests. In forest conversion to conventional agriculture, stress factors, like forest clearing, tillage and chemical inputs, reduce biodiversity of the functional flora, fauna and microbes. Most of the negatively affected biodiversity enter into an inactive or dormant phase to bypass the stress factors, by forming 'seeds', which are stored in the soil seed bank. Then, the natural food web collapses in agroecosystems. In the absence of other plants in conventional croplands, those forest structuring and diversifying remnant microbes and insects start feeding on our crops. This is how pathogens and pests originate in agroecosystems. Eventually, all the above anthropogenic activities lead to collapse the sustainability of the agroecosystems.

To address the above, beneficial biofilms have been formulated to be used in agriculture as biofertilizers that are called biofilm biofertilizers (BFBFs). The BFBFs render numerous biochemical and physiological benefits to plant growth, and to improve soil quality. Thereby, the application of environmentally harmful, subsidized chemical fertilizer (CF) NPK use could be reduced by 50% in various crops. The role of BFBFs is to reinstate the sustainability of degraded agroecosystems through breaking dormancy of the soil microbial seed bank, thereby restoring microbial diversity and ecosystem functioning. As such, this contributes to a more eco-friendly agriculture with an array of benefits to our health, economics and to the environment.

VALUING ECOSYSTEM BENEFITS THROUGH REFORESTATION OF DEGRADED RAIN FOREST PATCHES IN SRI LANKA WHILST HELPING TO MITIGATE CLIMATE CHANGE

Lakmini Senadheera[1], W.M.P.B.S. Wahala[2] and Shermila Weragoda[3]

[1,3] Conservation Carbon Company, Colombo-05, Sri Lanka.
[2] Department of Tourism Management, Sabaragamuwa University of Sri Lanka.

[1] lakmini@susutainablefuturegroup.com, [2] sampathwahala@yahoo.co.uk
[3] shermila@carbonconsultco.com

Sri Lanka is one of the most vulnerable countries for climate change risks in many ways and there is growing acceptance that the environmental benefits of forests extend beyond traditional ecological benefits to address the mitigation of climate change.

The Hiniduma Bio-link Project owned and maintained by Conservation Carbon Company in Sri Lanka offers value-added carbon credits for socially and environmentally conscious organisations and individuals. It is a reforestation project to establish a biodiversity corridor between two large protected remnant Sri Lankan rainforest patches – Sinharaja and Kanneliya.

The Bio-link Project accomplishes this through the reforestation of traditional farmers' home-gardens in the lowland wet zone region through analog forestry. New trees were distributed among smallholder farmers who currently have their own land use practices of traditional tea planting, small rubber plantations, and coffee and paddy cultivation. Along with the baseline biomass estimation of the selected pilot project, the carbon savings from the newly planted trees were calculated. The expected sequestration potential per hectare is 152.14 tCO_2/ha after a 20% deduction for unexpected losses. The ecosystem services provided by the project will be sold as Plan Vivo Certificates, which represent long-term carbon sequestration. Crediting period of the project is 15 years. A baseline survey was conducted in each land and the base-load was calculated to be 299.47 tCO_2/ha. The certificates registered under the Plan Vivo registry for CO_2 sequestrated from the newly planted trees are eligible to be sold as Voluntary Carbon Credits in the international market.

Hiniduma Bio-link Project, as a case study of a successful Sri Lankan carbon mitigation reforestation project, going beyond carbon benefits, has identified other market based approaches to evaluate payments for ecosystem services.

MIKOKO PAMOJA: A SMALL SCALE MANGROVE REDD+ PROJECT IN KENYA

J Kairo and M. Czarchur

[1] Blue Carbon Unit, Kenya Marine and Fisheries Research Institute, Kenya.
[2] Bangor University, Bangor, United Kingdom.

gkairo@yahoo.com and mollyczachur@gmail.com

Carbon sequestration is higher in mangrove forests than any terrestrial natural forest. When degraded, this ecosystem can release large amounts of carbon to the atmosphere and cease to perform vital services. At the mangrove REDD+ project in Kenya, known as Mikoko Pamoja, we investigated how we could protect mangroves whilst achieving community development. Based on years of research, 117 ha of mangrove forest were protected in Gazi bay in 2013. Twenty plots of 10m × 10m were monitored for forest condition, including forest cover, stem density and the pattern of natural regeneration. Mangrove fauna, particularly crabs and molluscs, were monitored in triple replicated quadrats of 1m × 1m. Community impact of Mikoko Pamoja was assessed against national standards for water and education, and by effectiveness of the first growth *Casuarina* woods established to control leakage.

Between initiation of project in 2013 and now, the overall condition of the mangrove forest has improved. The stocking density of stems increased from 3,931.81 to 5,640 ± 660 stems ha^{-1}. Natural regeneration decreased from 39,632 to 24,090 trees ha^{-1}, indicative of a less degraded forest. *Uca* and sesarmid burrows existed in a 1:0.54 ratio. During the same period, through avoided deforestation, reforestation of 117 ha, increased surveillance and educating the community, over 9,000 tCO$_2$ was sequestered, generating USD 36,278 to the local community. This has directly benefitted the quality and supply of water in Gazi and Makongeni villages, and the local schools have received over 700 books. Mikoko Pamoja contributes to global action for sustainable development, and is being upscaled across the WIO region.

Livelihood projects such as aquaculture, ecotourism and beekeeping have been introduced to the community in order to control carbon leakage in Mikoko Pamoja designated areas. Mikoko Pamoja has therefore been a successful example of community-led blue carbon project designed in similar principles to REDD+. Success of Mikoko Pamoja is being upscaled to other parts of Kenya (in Vanga) as well as across the Western Indian Ocean countries of Tanzania, Mozambique and Madagascar.

ASSESSMENT OF LAND COVER CHANGES AND ITS IMPLICATIONS FOR CARBON STOCK OF A CONSERVATION AREA OF SOUTHWEST, NIGERIA

Oluwole John Pelemo[1], C. F. Agbor[2], Maureen O. Ogoliegbune[3], T. Oshati[4], and I. S. Adamu [5]

[1,2,3,5] Remote sensing and GIS Section, Forestry Research Institute, Nigeria.
[4] National Productivity Centre, Ibadan, Nigeria.

[1] pelemo03@yahoo.com, [2] chukwuka_friday@yahoo.com, [3] mogoliegbune@gmail.com,
[4] oshatiti@yahoo.com, and [5] lollysbergtally15@gmail.com

This study presents the methodology applied for estimation of forest woody biomass and its carbon content according to main tree parameters on the forest stand scale, at the Old Oyo National Park, Nigeria. In 32 sample plots, tree species >20cm DBH and their respective heights were recorded. Ground-based and remote sensing measurements of tree attributes were converted into carbon estimates using allometric relationships and also remote sensing measurement using normalized-difference vegetation index (NDVI) and soil adjusted vegetation index (SAVI).

Four habitats were identified in the study area: dense forest, light forest, savanna/rock outcrop and water. Over a period of thirteen years, the land cover of dense forest decreased from 1,296.192 ha to 916.88 ha, *i.e.* from 51.6 to 36.5 %. Concurrently, savanna/rock outcrop increased from 364.994 ha to 699.592 ha, i.e. 14.53 - 27.9%. The probability/transition matrix that dense forest would change to light forest was 0.3226 and to savanna was 0.1913. The accuracy level and Cohen's Kappa estimate of Old Oyo National Park were 90% and K = 85.08%, respectively. The above-ground biomass was 11,785.49 metric tons/ha, CO_2 emitted 30,949.94 metric tons/ha. Tree carbon was estimated at 2,193,699.51 metric tons/ha, and CO_2 sequestered was 22,253,949.58 tCO_2-e/ha. The regression analyses on CO_2 sequestered and CO_2 emitted showed R2 was 0.6358, while the correlation coefficient ranged from 0.80 to 1. Also, NDVI and SAVI of each of the sample plots were determined. The regression analysis on NDVI and AGB showed that R^2 was 0.7342 while the correlation ranged from 0.11 to 1. Correlation between AGB and SAVI ranged between 0.08 and 1.00, showing a strong association.

This study considered the environmental, economic and political values of woody biomass estimation of the country's forest biomass resources. The estimation is important for strategic planning of the use of forest resources. It then becomes expedient to apply adaptation measures, substantial planting of trees, and urgent development of forest and game reserves to mitigate the environmental hazards.

SUCCESS OF FOREST RESTORATION:
A CASE STUDY AT LOWER HANTANA, SRI LANKA

Jayamini Jayawardhane[1] and AMTA Gunaratne[2]

[1, 2] Department of Botany, University of Peradeniya, Sri Lanka.

[1] jayaminiJayawardhane1@gmail.com, [2] thilankag@pdn.ac.lk

Assessing the recruitment of woody species in restoration trials is crucial to understand the increases in biodiversity due to restoration efforts. The aim of our study was to investigate the success of restoration in a *Pinus caribaea* Morelet plantation at lower Hantana, Sri Lanka, 11 years after the commencement of a restoration trial. A pine stand with enrichment planting (RP) and an unrestored pine stand (UP) were selected for the study. In both sites fifteen plots, each of size 5m x 5m, were established randomly. In order to determine the species richness and diversity of woody species, saplings (>50 - 300 cm in height) and trees (>3 m in height) in all the plots were tagged, identified and counted.

A total of 309 and 97 individuals were recorded in the RP and UP stands in 2015, respectively (RP; saplings= 235, trees= 74: UP; saplings= 12, trees= 85). Both sites were dominated by the invasive species *Alstonia macrophylla* Walla.ex G. Don (RP= 188; UP= 80). Six families, 8 genera, 8 species in the UP stand and 18 families, 22 genera, 22 species in the RP stand were recorded during the study. Species diversity was higher in RP than in the UP (Shannon Weiner Indices in RP= 1.53 and UP= 0.69). Native species were higher in RP (23.3%) than in the UP (15.46%). Zoochory was observed in both stands (RP= 36.89%; UP= 17.53%). Moreover, the stratification of plants was more in the RP than UP stand. Fires were not observed in the RP stand even during the dry seasons after restoration trail began.

Our study concludes that the species richness and diversity of woody species is greater in the RP than UP stand indicating the success of the restoration trail. Moreover the study stresses the importance of converting monoculture pine stands to mixed species stands using broad leaved species in mountainous region of Sri Lanka, in order to improve ecosystem services provided by them.

VALUE OF FOREST ECOSYSTEMS IN THE NATIONAL ECONOMY OF BANGLADESH: CHALLENGES AND PROSPECTS

Marufa Akther[1], Nikhil Chakma[2], Mariam Akhter[3] and Matieu Henry[4]

[1] Bangladesh Forest Department, Dhaka, Bangladesh.
[2,3,4] Food and Agriculture Organization of the United Nations, Dhaka, Bangladesh.

[1] marufaakther@gmail.com, [2] Nikhil.Chakma@fao.org
[3] Mariam.Akhter@fao.org, [4] Matieu.Henry@fao.org

Forest ecosystem services (FES) are an important contributor to the local and national economy. The true value of FES is poorly reflected in the national economy of Bangladesh, because many services are non-traded and thereby a market value in financial terms is not readily available to be included in GDP calculations. It is imperative that the total value of the forest ecosystem is well understood to appreciate the effort to sustainably manage them. The objectives of this paper is to review the current status, gaps and challenges for evaluating the FES as a contributor to the national economy.

For this we reviewed, mentions of the forestry sector in the GDP analysis. Experts were consulted to list the major undervalued services from various forest ecosystems in Bangladesh and to identify the valuation tools and techniques appropriate for these services. Only the agricultural census from the Bangladesh Bureau of Statistics has information on the contribution of forest ecosystems to the country. According to the latest survey, direct forest services, mainly through traded timber, fuelwood, and bamboo contribute about 1.42 % to the national economy. Indirect services (provisioning and regulating) are largely absent from calculations. In Bangladesh it was identified that forests play a crucial role for ecosystem functioning through land stabilization, fertility enhancement, carbon sequestration, adaptation and resilience to climate change, regulation of water cycle and local climate, mitigation of impacts from storms and cyclones. Many of them quite recently recognized as unique to Bangladesh. Hence, economic evaluation of many of these services will require new, adaptive or mixed techniques.

Our assessment clearly shows a large gap in ecosystem services valuation effort in Bangladesh, and we identified that FES are most important to the country. This should help researchers, academia and professional institutes to prioritize their FES valuation efforts. We propose that a general framework should be developed to include non-traded ecosystem services into the national GDP calculations. Currently, only about 0.6% of the National GDP is invested in the forestry sector through various programs, including coastal forest plantation, conservation of Sundarbans, ecotourism and social forestry. This disproportionately lowers the services provided by the sector. With increasing demand for land and forest products from the growing population pressure, without adequate investment the sustainability of these services will be at risk. Awareness of forest ecosystem services should promote public sector investment towards managing the forest ecosystems of Bangladesh.

TRADE-OFFS BETWEEN FOREST ECOSYSTEM SERVICES AND FUELWOOD CONSUMPTION OF THE BRICK MAKING INDUSTRY IN BANGLADESH

K. M. Nazmul Islam[1], Anatoli Poultouchidou[2], Matieu Henry[3]

[1] Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong-4331, Bangladesh.
[2,3] Food and Agriculture Organization of the United Nations, Dhaka, Bangladesh.

[1] nazmul@ifescu.ac.bd, [2] Anatoli.Poultouchidou@fao.org, and [3] Matieu.Henry@fao.org

Brick manufacturing industry (BMI) is a small-scale and disorganized industry, concentrated in the rural and peri-urban areas of Bangladesh that makes bricks by burning locally available clay using mostly coal and fuelwood. The estimated number of BMIs in Bangladesh is around 5000. Most of them use traditional fixed-chimney kilns (FCK), and are blamed as the largest stationary source of the GHGs emission of the country. Moreover, since the country's BMI is based on traditional FCK that use fuelwood, this may result in potential deforestation and loss of carbon sequestration services.

The objective of this study is to assess the trade-offs between forest carbon sequestration ecosystem services, and fuelwood consumption of the BMI in Bangladesh. Quantify the deforestation and GHG emissions from BMI in Bangladesh, and compare it with carbon sequestration ecosystem services in an equivalent deforested area. Fuelwood consumption data is collected using interviews, and compared with national statistics. Harvested biomass (m^3) is computed using country specific wood density values from annual fuelwood consumption data (tDM/yr). IPCC methodological approach is used for annual GHGs estimations from BMI industry. Total GHGs emission from the BMI of Bangladesh is compared with the loss of carbon sequestration services of equivalent forest areas in the major forest ecosystem types of Bangladesh, *viz.*, mangroves, Sal forests, hill forests and homestead forests.

This study highlights that the carbon sequestration services lost is notable in the different forest ecosystems. It is particularly relevant to support the sustainable management of tree and forest resources in Bangladesh.

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Message from the Coordinator
Dr. Termey Pradeep Kumara
General Manager /CEO
Marine Environment Protection Authority

Oceans cover more than two third of earth's surface, approximately 71%. Oceans divide as well as connect continents. They are a highly important component of the earth system supporting its existence. Ocean is considered as the heart of the earth as it transport heat from tropics to polar region and regulates the weather and produces almost half of the Oxygen we breathe and while functioning as a great Carbon sinker. Oceans provide food and support 90% of world trade, communication, industries, and support sectors such as fisheries and tourism by providing more than 170 million jobs and high bio diverse natural environment.

Oceans are currently facing critical threat levels due to human induced causes. Though they contain 96% of the earth's living space and 80% of living organisms, 60% of the world's marine ecosystems are degraded or are unsustainably used. Four major threats world's oceans facing are marine pollution, invasive species, unplanned development and resource extinction through unsustainable harvesting. As the cumulative effect of ocean land and atmospheric depletion, mean sea surface temperature (SST) has increased by 0.7^0C over the last century. Warm Ocean temperatures trigger anomalies in monsoonal pattern, frequent cyclones and tornadoes. Further, Oceans will be 150% more acidic by year 2100 and estimated amount of 90% of coral reefs will be threatened by year 2030 mainly due to human induced and environmentally induced causes.

In order to control and mitigate Ocean ecosystem degradation, steps to develop more awareness in the general public, new research based on Ocean ecosystem management, site/area specific coastal and ocean management programs and marine spatial planning for the sustainable use of ocean and coastal resources are proposed worldwide. While UN based institutes and programs, other international agreements and protocols and environmental organizations work for this common goal, the country has taken steps in the same direction to ensure a sustainable development in coastal and marine environment within its jurisdiction at local level. Sri Lanka NEXT program and affiliated '*International research symposium on blue green economy and environment*' and one of its sub theme '*Sustainable coast and Ocean environment*' the results of such effort taken by Sri Lanka to ensure a sustainable Coastal and Marine ecosystem for our future generations.

MIXED LAYER VARIABILITY ALONG THE EAST COAST OF SRI LANKA DURING NOVEMBER 2014 AND 2015

Akila Harishchandra[1]*, S.U. P Jinadasa[1] and K. Arulananthan [1]

[1]National Institute of Oceanography and Marine Science, National Aquatic Resources Research and Development Agency, Crow Island, Colombo 15.

akila.uor@gmail.com

The open ocean where salinity, temperature, and density are almost vertically uniform is called as the mixed layer. It transfers mass, momentum and energy into the sub surface layers, hence make a source for almost all ocean motions. By using collected Conductivity Temperature and Depth (CTD) profiles by the ship board CTD of R/V Samudrikka, Mixed Layer Depth (MLD) was calculated for oceanic area adjacent to East coast Sri Lanka during 2014 and 2015. Resulted Sea Surface Salinity (SSS) map of the survey area showed low salinity (27 PSU) water mass floated at the top 15m of the near shore area. Calculated MLD was shallow (<15m) at this low saline water mass, vice versa. SSS was significantly positive correlated (p<0.05,r=0.824) with the MLD distribution. Wind stress (WS) was ranged between $0.015Nm^{-2}$ to $0.045Nm^{-2}$ during the whole survey area, it has impacted on the MLD significantly positive manner (P<0.05, r=0.715). Sea Surface Height (SSH) which the last parameter analyzed for this study was varied between 1.05m at the near shore area and 0.55m at off shore sampling area. It was significantly but negatively (P<0.05, r=-0.797) impacted on the MLD distribution over the sampling period. Low saline water mass floats on the sea surface, thus could make a possible barrier for surface turbulences to mix the ocean water, hence the mixed layer tends to shoal. The resulted shallow MLD in this study was associated with the near shore low salinity water mass, following the above mechanism. Simultaneously, Surface floating low saline water increase the SSH and shoal MLD, hence SSH was negatively correlated with MLD. WS is a general factor which contributes to deepen the MLD (higher WS deepen the MLD, vice versa) as seen in this study. This study concludes that the observed low saline water mass at the east coast of Sri Lanka attributes to the fresh water tongue which has been transported by East India Coastal Currents (EICC) and it hugged the East coast of Sri Lanka during November 2014 and 2015. Furthermore, the MLD of the associated ocean area tends to shoal simultaneously. More studies using in-situ and model observations are suggested to understand the climatology of MLD of Indian Ocean around Sri Lanka.

Keywords: *Conductivity Temperature and Depth (CTD), Sea Surface Salinity (SSS), Wind stress (WS), Mixed Layer Depth (MLD), Sri Lanka*

STUDY ON INDUCED BREEDING IN GUPPY, *Poecilia reticulate* BY GNRH HORMONE INJECTION

M.N. Samarasinghe[1]

[1] Marine Environment Protection Authority, No.758, Baseline Road, Colombo 09

[1]m88samarasinghe@gmail.com

Guppy, *Poecilia reticulate* is the one of most popular and easiest ornamental fish species to keep in aquaria as they are easy to breed, hardy, tolerate wide range of temperatures, salinity, pH and hardness.

However, induced breeding of Guppy is still not done in Sri Lanka. Guppies engage in the internal fertilization. They are livebearers. The females' eggs are fertilized while in their follicles and they hatch out from them just before the birth. The anal fin of the male fish is used to inseminate the female fish. Once inseminated, the female fish store sperm in her body for several months. It can be produced multiple broods without the need for further fertilization.

The main objective of this study was to evaluate the success of induced breeding of Guppy rather than the natural breeding. Hormones are given to fish body through intramuscular or intraperitoneal injection. Intramuscular injection is given in to the area between the dorsal fin base and the lateral line. Intraperitoneal injection is given at the base of the pectoral or pelvic fin.

Gonadotropin Releasing Hormone (GnRH) was used for induced breeding through intramuscular injection. An attempt has been made to determine the effect of GnRH on the fecundity and gestation period of female Guppy .0.0025 mg GnRH was used for inject to one female fish. Ten Females for five male fish were taken for the experiment. Same sample size was taken as control. Ten female were injected on 6th of May 2013. The results revealed that injected female fish laid about ten off-springs within a week. As well as naturally breeding female fish laid about ten off-springs within three weeks indicating the possibility of the usage of induced breeding for improved breeding.

Key words: *Guppy, Induced breeding, Gonadotropin Releasing Hormone (GnRH), Sri Lanka*

TEMPORAL VARIATION OF WATER QUALITY IN ANDAGALAWELLA SITE IN KIRINDA, HAMBANTHOTA DISTRICT

W.K. Suwandhahannadi[1*], M.T.K.Delpachitra[1]

[1] Marine Environment Protection Authority, No.758, Baseline Road, Colombo 09

[1*]Wathsala05kk@yahoo.com; [2]Madhurathilina@gmail.com

Coastal areas of Sri Lanka are facing with environmental problems due to undesirable pollution of its waters from various wastes. The objective of this research study was to determine the present status of water quality in Andagalawella site in Kirinda, Hambanthota. The study was carried from 2014 to 2015. Sampling was done on a monthly basis in five sub sites in the selected area. Temperature, pH, Turbidity, Conductivity and Salinity were determined as onsite parameters. Salinity (9.25 ± 10.42 ppt) and turbidity (20.61 ± 16.69 NTU) values showed a huge variation most probably due to fresh water influsk in 2014 as one branch of Yoda Ela in Tissamaharama reach to the sea near to that site bringing high volumes of freshwater yield from heavy rains and releases from irrigation system in the area. But in 2015, fresh water influx was same within whole year resulting low mean and SD values of salinity (1.72 ± 2.53 ppt) in relation to 2014. However the whole profile of the water quality was not possible due to the unavailability of water quality parameters heavy metal concentration, NO3-, PO4- and bacteriological parameters. Further studies are recommended obtain a complete water quality profile that is an essential part to draft highly needed policy development.

Key Words: *Turbidity, Conductivity, Salinity, heavy metal, NO_3^- and PO_4^-*

THE STATUS OF INTER AND INTRA LEVEL VARIATIONS IN COASTAL DEBRIS OF WESTERN PROVINCE, SRI LANKA

G.M.A.D.N. Muhandiram[1]

[1] Marine Environment Protection Authority, No.758, Baseline Road, Colombo 09

[1] dinushi.mepa@gmail.com

Marine environment pollution has become a global issue at present, and has become a great challenge due to the increasing accumulation rate of debris along coastal and marine ecosystems. In dealing with the scenario of high anthropogenic pressure on marine and coastal debris in Sri Lanka, Marine Environment Protection Authority (MEPA) conducts coastal cleanups each year aiming both purposes of awareness and survey. The coastline of Sri Lanka extends up to 1,710 km in total, from which 1,017 km are accessible. The coastal belt consists of 14 coastal districts fall in 5 coastal provinces. Western Province of Sri Lanka stretches through 120 km of coastline which accounts for 7.02% of the entire coastal length and consists of Colombo, Kaluthara and Gampaha coastal districts.

In 2015, MEPA conducted its National Coastal Cleanup covering approximately 1000 km of the coastline around Sri Lanka covering almost 98.3% of the total accessible coastline. The total accessible coastline was divided in to 2 kilometer segments and each segment was considered as a site. A debris survey was conducted in some selected sites of each district and the debris collected at each site was separated in to categories, number of pieces collected in each category was counted and their weight was measured separately. In Western Province, the National Coastal Cleanup was conducted in 44 sites along 94.5 km of the coastline and the debris survey was conducted in 20 sites.

Total volume of 102,415 kg of trash was recorded from the 1000 km of coastline cleaned around the country and the "trash to distance ratio" or the "amount of trash collected per one kilometer of cleaned coastline" was highest in the Southern Province (121.66 kg/km). Total trash amount recorded from Western Province was 7.24% of the national total, but it recorded the third highest trash to distance ratio (114.99 kg/km) of all provinces. Within its districts, Gampaha recorded the highest ratio and Kaluthara, the lowest. However, all 3 district values of Western Province were higher than even of some provincial values such as Eastern and Northwestern.

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The most abundant trash type recorded in Western Province was plastic waste and it accounted for 39.93% of total provincial waste. As a whole, metal, plastic, polythene and glass dominated the national waste categorization and they also accounted for more than 65% of the total provincial waste of Western Province. But this abundance patterns changed drastically within its three districts from 31% to 98%. Therefore, a need for a 'district specific' coastal and marine waste minimization strategy coupled with proper detailed analysis of waste generation is proposed to ensure the sustainable conservation of coastal and marine environment within the Western Province of Sri Lanka.

Key words: *Coastal cleanup, Western province, Debris, Plastic*

BASELINE STUDY TO DETERMINE GLOBALLY KNOWN MARINE INVASIVE ALIEN SPECIES IN SOUTHERN COAST OF THE SRI LANKA

M.M. Subasinghe[1*], P.B. Terney Pradeep Kumara[1], L.L.R.B. De Silva[1], A.J.M. Gunasekara[1], Y.P. Kumara[1], G.M.A.D.N. Muhandiram[1] and H.P.A. Chathurangi[1]

[1] Marine Environment Protection Authority, No 758, Baseline Road, Sri Lanka

[1]madhumihirani@yahoo.com

Marine Invasive Alien Species (IAS) is one of the major treat for the marine biodiversity, aquaculture and fisheries activities, tourist industry and human health. Many alien species are transferred within marine ecosystems through the ballast water transported during commercial shipping operations and hull fouling. The world's busiest international shipping lanes or the sea lines of communications (SLOC's) as popularly known by seafarers pass through the Southern coast of Sri Lanka. Moreover the west coast of Sri Lanka receives a vast amount of debris though currents floating across Gulf of Mannar and the Arabian Sea. Although there is a huge increase in shipping activities during recent years, the country is lacking information regarding not only IAS but also highly needed baseline data in the marine environment of Sri Lanka.

The study was carried out to identify native species, species that may have been introduced and also to investigate the globally known marine invasive species in the proposed study area. Biological baseline survey was carried out to gather baseline information mainly targeting the native fauna and possible invasions and also physical and chemical characteristics of the selected sites in Hikkaduwa to Dikowita. Three fishery harbors (Dickovita, Hikkaduwa and Beruwala) and two coral reefs (Hikkaduwa and Barbarian) were selected from Southern coast of Sri Lanka. Sampling and observations were conducted for phytoplankton, zooplankton, mobile and sessile fauna, and hard substrate organisms and identified to the nearest possible taxonomic level using standard idetification guides and keys. In Dickovita fishery harbour; 23 zooplankton, 23 phytoplankton, 14 fish species, 2 invertibrates, 15 molluscan species, 1 barnacle species, 4 algae species and 6 macrobenthos were recorded. In Beruwala fishery harbour; 25 zooplankton, 17 phytoplankton, 8 fish species, 4 invertibrates, 17 molluscan species, 4 barnacle species, 7 algae species and 7 macrobenthos were recorded, and in the Barbarian reef 19 zooplankton, 17 phytoplankton, 31 fish species, 2 invertibrates, 11 molluscan species, 2 sea grass species, 17 algae species and 4 macrobenthos were recorded. Hikkaduwa fishery harbour recporeded 15 zooplankton, 19 phytoplankton, 10 fish species, 2 invertibrates, 8 molluscan species, 1 barnacle species, 5 algae species and 2 macrobenthos and in the hikkaduwa reef 18 zooplankton,

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30 fish species, 2 invertibrates, 7 molluscan species, 1 algae species and 10 macrobenthos were recorded. Among the recorded species 4 globally known invasive species (1 barnacle species and 3 mollusk sppecies) were recorded. They were Eastern oyster (*Crassostrea virginica),* Australian acorn barnacles (*Eliminus modestus),* Hooded oyster *(Saccostrea cucullata)* and Common periwinkle (*Littorina littorea*). Although globally known invasive species were recorded in Sri Lankan waters, their invasiveness in the Sri Lanka had not been studied yet to determine their invasive status or pattern making it difficult to understand their potential threats.

Key words: *Marine Invasive Species, Sri Lanka, Base line study*

COMPARISON OF WATER QUALITY STATUS AROUND THE EXPLORATORY DRILLING LOCATIONS IN GULF OF MANNAR: BEFORE AND AFTER DRILLING

S.A.M. Azmy[1*], K.A.W.S. Weerasekara [1], N.D. Hettige[1], B.R.C. Mendis[1] and D.D.D. Weragodatenna[2]

[1]Environmental Studies Division, [2]Information Technology Division,
National Aquatic Resources Research and Development Agency (NARA),
Crow Island, Colombo 15, Sri Lanka.

[1*]azmyahamed@yahoo.com

The study intended to carry out environmental monitoring for the exploratory petroleum drilling operations proposed in the Gulf of Mannar during pre and post drilling operations. Objective of this study was to carry out baseline studies during pre and post drilling phases to determine the impact of the marine environment.

The study was carried out from January to December 2013 including pre and post drilling operations in Gulf of Mannar. Water sampling was conducted at different depths at five locations in the open sea including the drilling locations. In-situ analysis were carried out for the determination of pH, which was measured using a pH meter, conductivity, total dissolved solids (TDS) and salinity were measured using a portable multi range conductivity meter, and turbidity was measured using portable meter. In addition, Biological Oxygen Demand (BOD) was measured using BOD sensors.

Furthermore, the collected samples were analyzed in accordance with the Standard Methods for Examination of Water and Waste Water (APHA 21st edition) for nutrients and significant trace elements namely Cadmium (Cd) Copper (Cu) Manganese (Mn), Zinc (Zn), Lead (Pb), Nickel (Ni), Barium (Ba), Chromium (Cr) and Mercury (Hg) were also measured.

Overall water quality of the pre drilling and post drilling locations respectively are as follows; Dissolved Oxygen (7.26 ± 0.7 mg/l) (5.95 ± 0.45 mg/l), BOD (24.73 ± 2.55 mg/l) (26.85 ± 3.11 mg/l), EC (53.49 ± 0.24 mS/cm) (52.44 ± 0.18 mS/cm), pH (8.9 ± 0.10) (8.26 ± 0.04), Turbidity (1.37 ± 0.68 NTU) (1.51 ± 1.00 NTU), Phosphate (0.54 ± 0.18 mg/l) (2.36 ± 1.87 mg/l) Nitrate -N (0.73 ± 0.19 mg/l) (0.03 ± 0.03 mg/l) and Salinity (35.40 ± 0.17 ppt) (34.57 ± 0.08 ppt) .

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Results revealed that recorded average turbidity values, BOD and Phosphate concentrations in after drilling operations were slightly higher than before drilling operations. However, there were no distinct changes detected for targeted trace elements at all selected locations before and after drilling operations.

Key words: *Water quality, Trace elements, Gulf of Mannar, Petroleum drilling*

MICROBIAL ABUNDANCE REFERENCE TO THE *E.coli* IN THE WATER COLUMN AT CASURINA REEF, JAFFNA NOTHERN, SRI LANKA

D.M.R. Sankalpa[1*], S. Kuganathan[2], A.C. Thavaranjith[3]

[1]Casurina, Karainagar, Jaffna
[2]Department of Fisheries, University of Jaffna, Jaffna, Sri Lanka
[3]Department of Botany, University of Jaffna, Jaffna, Sri Lanka

[1]rajjadissanayake@gmail.com

Coral reefs ecosystems are sensitive to global changes in climate and human activities. The relationship between microbial activity and chemical substances available in the water column due to sensitive process from climate to human activity is not very clear. This area of research is needed to understand the ecosystem processes for conservation initiatives. Therefore this study aims to identify the current status of shallow coral reef Casurina at Karainagar Jaffna North Sri Lanka (9°46'19.75″N, 79°53'33.47″E) from August 2015 to of April 2016, with reference to *E.coli* as an indicator, activity and quality of water in reef water. Chemical conditions of sea water were measured, following parameters were used to assess viz. Dissolved Oxygen (DO), Temperature (T), Salinity (S), Depth (D), (pH) . *E.coli* and Total Bacterial abundance was measured using direct counting method. Also culture experiments to show the microbes' selective agar plates (Endo Agar for *E.coli* and, Nutrient Agar for total bacteria). Results disclosed that water quality (DO=9.78 ± 0.31 ppm, T=29.53 ± 1.76°C, S=34.5 ± 3.42ppt, D=0.56 ± 0.08 m, pH=8.10 ± 0.12) and microbial abundance (MA) (mean Total MA= 6.81×106 ml^{-1}, mean *E.coli* abundance = 3.96×106 ml^{-1} at Casurina reef were within the range of suitable condition for growth of corals and other associated organisms. Continuous monitoring is essential to describe the situations with relation to changes of climate of human activity.

Keyword: *coral, seawater, Casurina, E.coli, water column*

COASTAL ZONE POLLUTION CONTROL BY UTILIZUNG FISH WASTE TO PRODUCE FISH MEAL IN PALLIMUNAI, MANNAR

S. Kishoran[1] and K.P.A.M.K.Luxmini[2]

[1]Post Graduate Institute of Science, University of Peradeniya, Sri Lanka
[2] Marine Environment Protection Authority, No.758, Baseline Road, Colombo 09;

[2]kliuxmini@gmail.com

Dry fish marketing is very popular in Mannar district and many people involved in this sector. Still the waste produce from this sector considerably responsible to deteriorate the costal environment and it reduce the aesthetic value of the coastal region impacting environmental, social and cultural values of the area. The objective of the study was to reduce the pollution by effectively utilizing the waste to produce fish meal that is with a higher economic value. Results of this research revealed that Fish meal could be produce in mass quantities from fish waste freely available in this area. Nutrition composition of this fish meal were protein 60-70%, lipid 5-15%, CHO 1-4%, fiber 1-3% and ash 10-20%. The present study could be directly used to eliminate the coastal environmental pollution in a more productive and sustainable manner. Since the aquaculture industries are increasing in our country and in Sri Lanka, this product could be easily marketed if a continue supply is guaranteed. In addition to that, this project would provide alternative employment opportunities to coastal communities in this region by which enhancing their livelihood and economic status.

Keywords: *Coastal, fish waste, Fish meal, Pollution, Nutrition*

ESTIMATION OF WASTE WATER & SOLID WASTE GENERATED WITHIN THE GALLE FISHERY HARBOR

A.A.D. Alwis[1]

[1] Marine Environment Protection Authority, No.758, Baseline Road, Colombo 09

[1]anuradhaalwis.103@gmail.com

Fishery harbor is a complex system of activities which are potential waste generators and thus considered as a hot spot of coastal pollution. Pollution of harbor waters due to dumping of untreated sewage in contiguous waters and the harbor basin is often the most common causes for seafood-related diseases and epidemics. Harbor water quality is heavily influenced by human activity not only within the harbor complex but also in the surrounding environment as well. As the fishery harbor and its contiguous waters are part of the coastal zone, pollution of the harbor directly affects the coastal zone and vice versa.

In present study, waste audit was carried out to quantify the amounts and types of waste being generated. Main objective of the study was to estimate the waste water and solid waste generated within the Galle fishery harbor. Survey was carried out one month period & data were collected on a daily basis. Different types of waste in the harbor as waste oil , noxious liquid substances, black and Gray water, noxious solid part of fish, noxious solid polythene ,noxious solid plastic, noxious solid papers, biodegradable substance, recyclable and reusable waste, fiber glass , Styrofoam, timber & other composite, rubber , other garbage were estimated.

Result revealed that fiber glass was collected in large quantities (93%) followed by fish waste parts (3.48%) & Styrofoam (3.40%) and were the most prominent solid waste types. Large amount of Styrofoam, polythene, plastic, timber, and fiber glass were observed dumping daily. Pet bottles, polythene and bio degradable substances were not being fluctuated highly. Among the liquid waste, noxious liquid volume was highest (68.05%) while grey water was the lowest (12.41%).

Key words: *Fishery harbor, Waste audit, Waste type , noxious substance*

ANALYZING OF MONTHLY GARBAGE DISPOSAL QUANTITIES FROM SHIPS REACHING PORT OF COLOMBO

T.D. Ramasinghe[1]

[1] Marine Environment Protection Authority, No.758, Baseline Road, Colombo 09

[1] ramasinghe.tharindu@gmail.com

The port of Colombo is the largest commercial port of Sri Lanka and it serves as an important terminal in central Indian Ocean region due to its strategic location in the Indian Ocean. Annually, more than thousand ships reach Colombo harbor. Garbage released from these ships is just as deadly to marine life as oil or chemicals. The MARPOL, Annex V seeks to eliminate and reduce the amount of garbage that is discharged into the sea from ships. Under the revised MARPOL Annex V, garbage is categorized as incinerator ash, food waste, cargo residues, paper products, glass, metal, floating dunnage, lining or packaging material and plastics. The effectiveness of ships to comply with the discharge requirements of MARPOL depends largely upon the availability of adequate port reception facilities. Hence, Marine Environment Protection Authority, Sri Lanka (MEPA) has established a facility called Waste Reception Service (WRS) with effect from 1st July 2016.

The present study records the garbage disposal categories according to MARPOL, Annex V from 91 ships within the month of July 2016. Garbage that was collected from each ship was categorized and quantified at the time of inspection. Then quantities of garbage belonging to each category were recorded and then garbage was sent to appropriate disposal sites under continuous and strict monitoring.

At the end of July 2016, 96.78 m^3 of plastic, 6.1 m^3 of floating dunnage and packaging material, 33.79 m^3 of ground down paper products, 44.46 m^3 Cargo residues, 52.04 m^3 of food waste, 0.53 m^3 of incinerator ash, 2.76 m^3 of cooking oil and 75.28 m^3 of other waste were collected. Plastic was the dominant type of garbage collected from ships. However there is a high tendency of this garbage to enter into the land environment due to the absence of a continuous monitoring system in the area falls beyond the jurisdiction of MEPA. Hence a well-planned systematic monitoring process is needed with the collaboration of all the agencies involved in environmental management and shipping sectors.

Key words: *Port of Colombo, Garbage categorization, MARPOL convention, Waste oil reception service (WRS)*

ANALYSIS OF WATER QUALITY VARIATION AND ITS POLLUTION SOURCES IN ARUGAM BAY RECREATIONAL AREA

K. Sivakumar[1]

[1] Marine Environment Protection Authority, No.758, Baseline Road, Colombo 09.

[1]agrosiva23@gmail.com

Maintaining and protecting the quality of the recreational water is an important environmental health and resource management issue. Marine water quality monitoring is essential in identifying the risks in recreational waters and public health and plays an important role in determining the degree of pollution from land-based sources as well as from the sea based sources. Present study was undertaken with the view of assessing marine water quality of Arugam bay beach and its suitability for recreational activities. In addition, an attempt was made to suggest recommendations to mitigate the pollution levels. Water quality monitoring was conducted in 09 sampling points along the Arugambay coastal stretch representing bathing, surfing and fishery boat parking sites. Research was carried out monthly for a period of 03 months period from February to April, 2015.

Marine water quality results revealed that, average pH (8.15± 0.1) and temperatures (30.9± 1.92 0C) were within the recommended ranges for recreational sites and turbidity value (9.52± 0.58 NTU) was below the maximum permissible limit. Recorded average pH values are indicated slightly alkaline conditions and turbidity values of bathing site are higher than surfing and fishery sites, most probably due to the high density of sea bathers and re-suspension of micro particles due to excess disturbances. Mean Dissolved oxygen (7.51± 0.32 mg/l) was above the minimum recommended criteria whereas mean Nitrate (0.068± 0.075 mg/l) and Phosphate concentrations (2.97± 4.35 mg/l) exceed the recommended values. Substances carried to Arugam bay lagoon (fertilizers and detergents), sewage and storm water runoff nearby settlement area can be considered as the most acceptable cause which influence on Nitrate and Phosphate concentrations in water. Average values of Total Dissolved Solids, Electrical Conductivity and salinity were 27.14± 1.69ppt, 55.32± 3.58mS/cm and 32.24± 0.61PSU respectively.

Further, mean total Coliform (9± 9MPN/100ml) and *Escherichia coli* concentrations (6± 7MPN/100ml) were within maximum threshold limits. Total Coliform and *Escherichia coli* concentration are high in bathing site than surfing and fishery sites.

Continued

Further studies are needed to determine oil and heavy metal concentration and long term monitoring programs are essential to obtain clear picture of the pollution status of Arugambay and its suitability for recreational activities.

Keywords: *Marine water quality, recreational site, bathing site, pollution*

MONITORING OF MONTHLY OIL DISPOSAL QUANTITIES FROM SHIPS REACHING PORT OF COLOMBO

K.H.K. Prabasara[1*] and L.L.R.B. De Silva[1]

[1] Marine Environment Protection Authority, No.758, Baseline Road, Colombo 09

[1]kasunyou@live.co.uk

Colombo harbor is the major commercial port of Sri Lanka. More than thousand ships reach the port of Colombo annually. These ships carry considerable amount of waste oil and they are disposed at the closest harbor within the navigational pathway. Both, unmixed waste oil and oil water mixtures released from ships are referred as waste oil. Oil tankers transport some 2,900 million tons of crude oil and oil products year around the world by the sea. Many innovations introduced by MARPOL on allowable discharges of bilge water through the oily water separator and the oil discharge and monitoring system have contributed greatly to a noticeable decrease in pollution of the Marine environment. In Sri Lankan context, waste oil disposed by these ships is collected by service providers registered by under Marine Environment Protection Authority (MEPA). They collect waste oil by road tankers at the harbor and transport them to their oil refinery yards, the process involve in a considerable amount of oil pollution. However, there was no sufficient inspection for this waste oil collection, transportation and disposal process. Hence, an improved Waste Reception Service (WRS) was introduced by MEPA on 1st July 2016 to perform a complete monitoring on garbage and ship oil collection and disposal.

The present study records the waste oil disposal quantities from 47 ships within the month of July 2016 and the volume ratios between oil and water. Then a specialized instrument called the sampler was used to collect the waste oil from road tankers. Subsequently, the oil samples were transferred into 10ml centrifuge tubes and they were centrifuged at 5000 rpm for 10 minutes. Then oil/ water volumes were recorded for each waste oil sample. These data were extrapolated for original collected sample and the percentages of oil and water in waste oil samples were calculated.

According to the results of the study, within the month of July 1513.95m^3 of oil was collected from 47 ships. The waste oil composition of these ships was 1150.85 m^3 of pure oil and 135.91 m^3 of sea water. Therefore, findings of the present study reveal that ships call the port of Colombo carry large quantities of waste oil and are received at the Colombo port.

Continue

This waste oil has a high potential to contaminate the land environment if the proposed WRS mechanism is not executed with the help of all the stakeholders. Thus, it is essential to carry out continuous monitoring, stakeholder involvement, proper implementation of existing regulations and execute available legal tools where necessary.

Key words: *Port of Colombo, MARPOL convention, Ship waste oil, oil/ water mixtures, Waste Reception Service (WRS).*

ANALYTICAL INVESTIGATION OF POLLUTANTS IN BATHEEGAMA LAGOON, MATARA

M.A. Dilhani[1], S.L. Wickramasinghe[1], K.L.N. Dilini[1]and J.M.A Shanika[1]

[1] Marine Environment Protection Authority, No.758, Baseline Road, Colombo 09

[1]maanushadilhani@gmail.com

This paper reviews the pollution aspect of environmental management and monitoring of the lagoons for its sustainable development. Batheegama lagoon is an ecologically valuable coastal ecosystem in the Matara district and it is located close to Dickwella urban area in Matara district. Therefore this study is most important to assess the current situation of the lagoon. The water quality assessment at the principal locations of the lagoon was performed that Assessment was undertaken according to different physical and chemical parameters including Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Electric Conductivity (EC), turbidity and acidity from three sampling site (S1 to S3) for over three months.

The results indicated that physical and chemical parameters were different among sites. Average temperature levels of all three sites of the lagoon remained between 26.9 0C and 25.7 ^{0}C. The highest temperature value was recorded in the site 3 (26.90C) & the lowest temperature value was recorded in site 1. (25.7^{0}C). Average pH levels of all three sites of the lagoon fluctuated and remained between 5.77 and 7.74. The highest pH value was recorded in the site 1 (7.44) & the lowest pH value was recorded in site 3. (5.77) showing a slight acidic level.

Compared to other two sites, site 2 was having the lowest average conductivity and highest average turbidity and high level of average COD & BOD values compared most probably due to the fermentation of location with coconut husks, a leading income source for local women in the area. The highest average BOD & COD were recorded from site 3 connected to the release of clinical waste from the nearby hospital. Average turbidity, BOD and COD values are very low and pH and average conductivity is high at site 1 due to its high mixing with sea water. It is evident that the water quality of Batheegama lagoon is anthropogenic activities while highly threated due to the pollution from clinical waste indicating the need of a well-planned management options to secure its natural conditions.

Keywords : *Batheegama Lagoon, Water Pollution, Water Quality*

HUMAN AND ENVIRONMENTAL STRESS ON SOUTHERN CORAL REEFS OF SRI LANKA

S.M.D. Athukorala[1] and P.B. Terney Pradeep Kumara[1]

[1] Department of Oceanography and Marine Geology, University of Ruhuna, Wellamadama, Matara, Sri Lanka.

[1] smdathukorala@gmail.com; [2] terneypradeep@yahoo.co.uk

Southern coral reefs have been facing severe degradation problems due to human and environmental stressors. This study describes the reef related impacts by assessing substrate composition and spatial physico-chemical parameters between selected coral reef areas in Southern coast namely Hikkaduwa, Rumassala, Weligama, Mirissa, Polhena and Dondra during September to November 2014. Line Intercept Transect method (LIT) was used to estimate the coral and sessile benthic cover categories. Physico-chemical parameters were Concentration of Nitrate, Phosphate, Temperature, pH, Salinity, Conductivity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Dissolved oxygen (DO) and Biological Oxygen Demand (BOD).

The highest mean coral cover was observed at Weligama (32.66%±20.62) followed by Mirissa (23.97%±9.14), Polhena (21.57%±9.04), Hikkaduwa (19.68%±4.42), Dondra (17.31%±9.06) and Rumassala (12.5%±6.45). Significant differences between sampling sites were observed for percentages of sessile benthic categories and for all measured physico-chemical parameters. Dendrogram of physico-chemical parameters between selected sites illustrates that Dondra is completely separate from all the other sites when Polhena, Hikkaduwa, Rumassala and Weligama, and Mirissa grouped together. Weligama showed the lowest BOD level (2.41 mg/L±0.33) and comparatively lower nutrient levels. Live coral coverage at Weligama is the highest among surveyed sites. Destructive fishing practices such as use of moxy nets, iron rods and high ornamental fishing pressure, anchoring of fishing boats cause severe damage to the reef. Excessive overgrowth of calcareous *Halimeda* sp. and *Caulerpa* sp. would also be a threat. The reef was dominated by branching *Acropora* sp.and *Montipora* sp. The lowest TSS amount (0.07g/L) and lower nutrient levels were observed at Mirissa which is characterized with newly recruiting coral species. Polhena reef area is highly vulnerable for recreational visitor pressure due to coral trampling and the collection of corals as souvenirs and high turbidity level due to Nilwala river plume. The bottom substrate of Hikkaduwa National Park was dominated by dead coral reef and sand/silt coverage.

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It experiences the highest BOD level (3.98 mg/L±0.09) among surveyed sites. Coral trampling, boating activities and high siltation were observed as threats to the reef area. The highest siltation was observed at Rumassla with the highest TDS concentration (0.57g/L±0.08). *Acropora* sp. *Montipora* sp. and *Galaxea* sp. were dominant coral species. Dondra showed the highest Nitrate level (0.62 mg/L±0.06) and Phosphate level (0.03 mg/L). Dense bed of seagrass, *Thalassia hemprichii* and highly colonized sea urchins *Diadema* sp. also indicated high nutrient loading confirmed by higher number of sewage and domestic waste disposal directly to the coastal waters. By considering all surveyed sites southern coastal water was characterized significantly by high level of nitrate levels (0.27-0.71 mg/L), Phosphate levels (0.0115-0.0283 mg/L), high amount of TDS (32.7-49.29 g/L), TSS (0.062-0.63 g/L) and high BOD (2-4.06 mg/L) which were greater than the critical levels highlighting the excess stress levels exists impacting the healthiness of reefs in Southern coast of Sri Lanka.

Keywords: *Coral reefs, Human and environmental stress, Sri Lanka*

ZONING OF POLHENA PUBLIC BATHING AREA ON THE BASIS OF THE DISTRIBUTION OF BENTHIC COMPONENTS IN ORDER TO ACHIEVE BETTER MANAGEMENT GOALS

S.L.Wickramasinghe[1], P.B. Terney Pradeep Kumara[1], Mahesh Jayaweera[2], J.M.A. Shanika[1]

[1] Marine Environment Protection Authority, No.758, Baseline Road, Colombo 09; [2] University of Moratuwa, Katubedda, Sri Lanka.

[1]sandunlakmalw@gmail.com

Polhena is a well-known fringing coral reef and reef lagoon located within 2 km from Matara city having high economic and ecological importance while heavily exploited by the holiday makers and fishermen on the other hand. Many of local and foreign visitors visit Polhena because the area is blessed with immaculate stretches of coral reef, enriched with high biodiversity. Over the past decades, the fringing reef cover of Polhena is being damaged by many tourists without any control. The whole reef area was selected for sampling and divided into three zones according to its geological location where zone number one on the most eastward side and number three on the most westward side of the reef. The Lowest tidal day of every month from February to December 2013 was selected as the sampling day and random sampling method was used using 30m×30m quadrate and line Intercept Transects (LIT) method for the assessment of benthic organism (Coral). Their population density and abundance estimations were calculated. GPS readings of every sampling location were recorded. The biodiversity was calculated using Shannon-Weiner index. Our results indicate that the Zone number 1 and 3 were high in biodiversity, Shannon-Weiner index values were 1.9 and 1.6 respectively while the zone number 2 was low in biodiversity. Therefore zone number 2was selected to open for recreational activities such as swimming, snorkelling. Zone number 1 and 3 were selected to declare as restricted zones prohibiting any sort of activities including recreational and fisheries.

It was understood that zoning of a degraded reef is at its utmost importance to ensure this ecosystem sustainability while protecting its biological and ecological importance. However it is proposed that the importance of the in cooperation of Polhena reef zonation using its water quality parameters (including *E coli* levels) to the present reef zonation as it certainly assures the sustainability of the ecosystem while securing the sound health conditions of the reef users as well.

Key Words: *Benthic component, Biodiversity, Zoning*

IMPLEMENTATION OF INTERNATIONAL CONVENTION RELATING TO SHIP BASED MARINE POLLUTION IN SRI LANKA

W.J.R.N. Priyadarshani[1*], P.B. Terney Pradeep Kumara[1] and A.J.M. Gunasekara[1]

[1] Marine Environment Protection Authority, No.758, Baseline Road, Colombo 09

[1]nayani17mepa@gmail.com

International shipping transports more than 80 percent of global trade to peoples and communities all over the world and is the most efficient and cost-effective and environmentally safe methods of international transportation for most goods. The environmental impacts generated by shipping operations have increasingly become a burning issue discussed heavily at environmental forums. Marine pollution from ships may occur from accidental oil spills, exhaust gas emissions (air pollution), disposes of solid wastes, sewage, chemicals and other waste materials and introduction of Alien Invasive Species (AIS) from ballast water discharges. International Maritime Organization (IMO) which is under the United Nations creates a regulatory framework for the shipping industry that is fair and effective, universally adopted and implemented mainly under three categories; maritime safety, prevention of marine pollution and liability & compensation, especially in relation to damage caused by pollution. Sri Lanka ensures a fast growing shipping sector by expanding harbor facilities and policy changes. Expansion of the shipping sector cause high risk of environmental pollution, highlighting the country as one of the IMO membership countries, the importance of giving effect to the marine pollution related conventions at its earliest.

The main objective of this study is to evaluate the present status of the implementation of IMO international conventions related to marine pollution and liability & compensation in Sri Lanka. Marine Pollution Prevention Act no. 35 of 2008 (MPPA) was analyzed in order to identify the legislations which are included in the act as per the regulations of international conventions which were ratified in Sri Lanka. Sri Lanka has become a party to following International Conventions related to marine pollution and liability and compensation as follows. International Convention on the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto and by the Protocol of 1997 (MARPOL73/78) Annex I to V, International Convention on Civil Liability for Oil Pollution Damage (CLC), 1969 and 1992 Protocol to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (FUND 1992).

Continued

Although the country has legislation to directly deal with ship based marine pollution, MPPA has incorporated some provisions of the above conventions. However by today, it is very clear that the country has is no comprehensive legislation to give full effect to the above conventions. The comprehensive policies and legislation mechanism should be introduced to give full effect to IMO marine environment related legislations and its efficient enforcement of these legislations within the country ensuring the optimal development of the shipping sector, protection of the marine environment and maritime related industries.

Key words: *International Convention, International Maritime Organization, Ship based Marine Pollution*

HYDROCARBON EXPLORATION IN SRI LANKA: INTERVENTION TO MITIGATE IMPACTS ON FISHERIES INDUSTRY

J.M.P.K Jayasinghe[1], and D.G.N.D Gamage[1*]

[1] Department of Aquaculture and Fisheries, Faculty of Livestock, Fisheries and Nutrition, Wayamba University of Sri Lanka, Makandura, Gonawila.

angelnadee89@gmail.com

The fisheries industry plays an important role in the economy of Sri Lanka by providing direct and indirect employment opportunities for 560,000 and livelihood for 2.6 million people, Generation of income, foreign exchange earnings and provision of reasonably priced protein for the rural and urban masses in the country are other main benefits. This sector contributes around 1.8% to the GDP and serves as the cheapest source of animal protein, Fish and fishery products fulfill 53% of the protein requirement of the people. Daily per capita fish consumption of the country has achieved about 44.6g (16.3 kg/ year) which is expected to be increased up to 60g/day (22kg/ year) to fulfill the recommendations of the Medical Research Institute of Sri Lanka. The greatest portion of the total fish production comes from the marine sector which contributes more than 87%. Off shore fishery contributes 35% whereas coastal fishery contributes 52%. Government of Sri Lanka has identified commercially exploitable oil and gas reserves in the Cauvery and Mannar basin areas within the territory in Sri Lanka.

The aim of this study is to assess the present status of fisheries and potential impacts of oil exploration activities on the fishery resource with the view of identifying possible interventions to minimize adverse impacts. The present study was based on available information literature surveys and personal interviews.

The Cauvery is divided into five exploration blocks and Mannar basin is divided into nine exploration blocks by the government of Sri Lanka. Exploration activities such as seismic exploration, well drilling, and structural emplacement directly interfere with the fishery resources as well as fishing communities. Exploration activities can restrict the available areas for fishing, obstruct navigational paths of the fishing vessels and obstruct fish migration. Disturbance to fish breeding grounds due to sound waves are evident. Leakages from drilling equipment, ballast water discharges from dredging vessels, accidental oil spills, oil leakages from the ships, sewage and bilge water can lead to the chemical pollution of the marine environment and creating to health hazards to both fishery community and fishes.

Continued

To mitigate the socio- economic impacts and environmental problems due to oil exploration including, drilling of oil wells, structural emplacement, decommissioning or well abandonment, reduction in fishery resources, restrictions in fishing, fishers are to be compensated. In addition, a strict compliance to environmental regulations and continuous monitoring of fishing activities and fishery resources are suggested.

Key words: *Hydrocarbon exploration, Fishery resource, Environmental impacts, Cauvery basin, Mannar basin*

DO COUNTRIES REDUCE THE DEPENDENCE ON CAPTURE FISHERY AS THEY DEVELOP? STATISTICAL EVIDENCE FROM CROSS-COUNTRY DATA FROM 1990-2015

D. V. P. Prasada

Department of Agricultural Economics and Business Management, University of Peradeniya, Peradeniya , Sri Lanka.

pp16252@gmail.com

The fisheries sector is fundamentally important to a blue-green economic paradigm. Conventional livestock production as a means of meeting the animal protein requirement of the global population has many limitations with respect to its environmental footprint. The fishery sector, on the other hand, can be developed to have clear advantages in terms of environmental sustainability. The capture fishery is the dominant type of fishery activity in many countries. Based on the cross national data, the median annual volume of the capture fishery for the period from 1990 to 2015 is 32,361 mt while the median value for culture (aquaculture) fishery is 1,810 mt. This observation is robust to even considering the country-specific median values (i.e. median across 25 years): the country specific median for capture fishery is 33,210.mt and the country specific median for culture fishery is 2,117 mt. Only 41 countries (including the land-locked countries) have a culture fishery that dominates capture fishery and in terms of country-year observations in the panel data set, this fraction is approximately 12 percent of all observations. Based on the statistical estimation of a panel data model, we find that there is a paradox that with economic development, countries become more focused on culture fishery than capture fishery. This finding gives rise to certain policy implications on how a country, especially a low-income country, plans the resources and priorities in the fishery sector. If culture fishery associates with high income, then it makes sense for country on the path of rapid development to use resources in a way that prioritizes the culture fishery adequately.

Key Words*: Fisheries sector, capture fisheries*

IMPACTS OF NUTRIENT LOADING FOLLOWED BY MACROALGAL INVASION ON CORAL REEFS AT PIGEON ISLAND MARINE NATIONAL PARK, SRI LANKA.

P.A.K.N. Dissanayake[1], P.B. Terney Pradeep Kumara[1,2] and K.H.H Niroshana[1]

[1]Department of Oceanography & Marine Geology, University of Ruhuna, Matara, Sri Lanka
[2]Marine Environment Protection Authority, No.758, Baseline Road, Colombo 09, Sri Lanka

[1*]kushlanidissanayake@gmail.com

Pigeon Island (PI) is designated as a Marine Protected Area (MPA) in order to protect its fringing reef and terrestrial habitats under the Fauna and Flora ordinance. It harbors over 100 species of corals and 300 coral reef fishes and some of them are endemic and protected under IUCN red list. The island is a tourism destination enabling snorkeling, diving, bathing activities. According to the annual reports of Department of Wildlife Conservation 2012, the revenue earned by the visitors is about 2.1% as a percentage compared with the total income of other National Parks and placed 07th based on the income generated. At present the reef is degrading due to combined effects emanated from natural and anthropogenic influences. Invasion of macro-algae, Crown of thorn star fish (COTs) and corallimorpharians, thermal stress, coral diseases, impacts from tourism activities such as coral trampling, boat maneuvering, non-sustainable fishing methods, haphazard waste disposal, and agricultural run-off hamper the reef health. Therefore, from a conservation point of view, understanding the dynamics of the environment is indispensable to make informed decisions. The main objective of the present study is to elucidate the temporal changes and trends of nutrient loading in the park environment and to propose relevant remedial measures to ensure the reef health. Field works were conducted from September 2014 to March 2016. Nitrate and Phosphate concentrations were assessed at 6 locations (S1-S6) around the main Pigeon Island. Percentage cover of macro-algae was estimated with 15m Line Intercept Transect (LIT) at 14 sampling sites (T_1-T_{14}) along two depth contours; 1-2m and 3-5m.

Highest nutrient level is recorded in the bathing area and the values are above the optimum standards according to GBRMPA 2010; 2µgL-1 and 4µgL-1 for Nitrate and Phosphate respectively. A shift in algae growth was observed from West (highest algae growth) to East direction in the Southern flank of the island. It may be due to the current pattern around the island. Impact of human activities, effluent discharges of nearby hotels and industries, discharge of Irakkandi lagoon are possible causes for this situation. Intermittent outbreaks of COTS (*Acanthater planci*) also gave evidences for the potential nutrient enrichment.

Continued

The survival of the reef is in danger due to the ongoing nutrient loading followed by uncontrolled macro-algae blooming. Illegal fishing practices enhance the severity of the condition by removing the natural predators. Hence, prompt attention and management intervention of the park authority is necessary to safeguard the reef. Understanding the root causes of the situation is paramount to make sound decisions. Further research on modeling the hydrodynamics specifically with the current pattern during various seasons are proposed to obtain a clear overview of the PI marine environment.

Key words: C*oral, macro algal invasion, nutrient loading, LIT, COT, Pigeon Island, Sri Lanka*
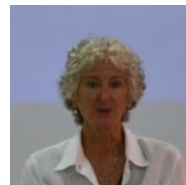
Section 4

Special Session on Community Forestry

19 October 2016

Colombo, Sri Lanka

Message from the coordinator - Community Forestry

Dr. Nora N. Devoe
Advisor, Forest Department

Community forestry struck root in Sri Lanka in the 1980s. Experimentation and experience have led to revisions in forest policy, administration, and approach at the field level. Efficacy in reaching the core aim of forest stewardship through community participation has been demonstrated.

Meanwhile, demand for land for settlement, agriculture, and other economic purposes continues to intensify. Forest cover in Sri Lanka was estimated at 84% in 1884, dropping to about 20% by 2005. The period 1992-1996 evidenced particularly rapid loss. Indications are that the deforestation rate has slowed significantly, but pressure for social and economic development continues unabated.

While registering some notable achievements, community forestry in Sri Lanka has unrealised potential to contribute to sustainable rural livelihoods. A significant proportion of Sri Lanka's greenhouse gas emissions are from land-use land-cover change, and forestry presents great mitigation potential. Linking expanded rural livelihoods to the protection and enhancement of forest cover by working with communities in appropriate programs will enable Sri Lanka to fulfil its Strategy for Sustainable Development and advance toward its Millennium Development Goal to "ensure environmental sustainability".

The purpose of this special session is to consider routes to maximising community forestry's contribution to the blue-green economy. The current Australian-funded phase of the Forest Department's community forestry program is drawing to a close. The Government of Sri Lanka will carry forward the community forestry program. It is timely now to critically examine current practice in community forestry, reflecting upon professional experience and research, to revise and strengthen implementation.

Keynote Address

COMMUNITY-BASED FOREST MANAGEMENT IN SRI LANKA: APPROACHING A GREEN ECONOMY AND ENVIRONMENT

Prof. Mangala De Zoysa

Department of Agricultural Economics & Extension, Faculty of Agriculture, University of Ruhuna

mangalaxyz@yahoo.com

Community-based forest management in Sri Lanka encompasses community-owned forests and agro-forests as well as government-owned forests managed by communities. Communities also manage forest-based enterprises, which are community-scale economic activities based on wood and non-wood commercial forest products and provision of ecosystem services. The ideal characteristics of a green economy, low carbon, resource-efficient and socially inclusive, are embodied in community-managed forests. This study reviews the literature and analyzes the community-based forest management approach for the green economy of Sri Lanka in terms of: contribution to the green economy and environment; issues and challenges; and strategies to promote the contribution.

Community-based-forest-management contributions to the green economy and environment include: a foundation for grassroots democracy; support for environmental justice; granted lands as acts of social justice; social stability of rural communities; employment generation and livelihood development with community-based forest enterprises and out-grower schemes purchasing the forest products and paying market prices; creation of markets for ecosystem services and payments for these services; sustainable production practices combined with broad distribution of benefits, and production of timber and wood products. Environmental contributions include biodiversity conservation and adaptation to climatic shifts and erratic climate events. Community-based forest management protects and restores forest ecosystems while creating green employment.

The issues and challenges are recognized as: engagement of communities to defend their rights and manage forests collectively; protection of forest ecosystems for cultural survival and social well-being; changes in the forest resource base; lack of secure tenure or access rights to forest resources; weak community governance; discriminatory market policies and poor market links.

Keynote Address Continued

Among strategies to promote the contribution are: incorporation of ethical criteria and bio-cultural heritage in forest management; greater land tenure security; change in the political and economic environment to restore governability to local communities; multi-functional rather than monoculture forests for community-managed forest ecosystems; technological advances towards a green bio-economy within the community-based forest enterprises; creation of an enabling business environment through direct subsidization; commercialization of forest-based enterprises while acknowledging the potential of the local community; removal of regulatory barriers and support of community rights to manage forest-based enterprises; and transformation of communities into key partners of forest-based industrial development.

Key words: *Community-based forest management, Green economy, Forest-based enterprises, Ecosystem services*

"COMMUNITY FORESTRY" – A STRATEGY AND A TOOL FOR SOCIAL EQUILIBRIUM AND COMMUNITY REINTEGRATION IN SRI LANKAN RURAL SOCIETY

Prof. K. Karunathilake,

Department of Sociology, University of Kelaniya, Kelaniya, Sri Lanka.

KKaru@kln.ac.lk

Sri Lanka Community Forestry Program (SLCFP) has evolved significantly since its inception in 2003. A qualitative study of community commitment to project activities and forest conservation was conducted at 20 of the 167 SLCFP sites, implemented during 2013-16. Data-gathering and analysis followed the case study method using observation, focus group discussions, and key-informant interviews as data-collecting techniques.

The rural communities in dry and intermediate zones in Sri Lanka are highly dependent upon agriculture, primarily as a subsistence economy for their domestic use. *Chena* [*Hena*] or shifting cultivation is one of the key agricultural patterns in village subsistence economy and is a practice central to many social and cultural factors of villagers' lives. Thus, *Hena* cultivation has very strong roots in the livelihoods and lifeways of villagers. The Colonial Administration banned *Hena* cultivation in 1896 with the introduction of the Waste Lands Ordinance, but it was continued under government permits as an integral part of village social and cultural life. Subsequently, the Forest Department (FD) has continued demarcation of forest boundaries for forest protection. At the same time, villagers' attitudes and patterns of economic activities have changed recently towards more commercial agriculture. These changes have had an enormous impact in *Hena* cultivation too and some villagers have used large forest areas for cultivation. Therefore, the forest degradation and deforestation level has increased substantially. The FD and other government administrators have faced many issues and challenges in controlling forest degradation and deforestation in the dry and intermediate zones of Sri Lanka.

The study found that the SLCFP has become a strategy and a tool for enhancing social equilibrium and reintegration in different ways among communities that became detached from their environments. The program provides them a platform to enjoy their historic nostalgia of *Hena* cultivation, continue some commercially viable crops/plants and get a good seasonal income, but within the limits of reforestation and forest enrichment activities. Within the SLCFP, villagers plan their home garden and income-generation activities, and improve community infrastructure. The SLCFP is increasing community sentiments towards forest conservation, reforestation, and environmental safeguards.

Key Words: *Community forestry, Social equilibrium, Re-integration, Hena cultivation*

IS COMMUNITY FORESTRY ACHIEVING ITS OBJECTIVES WITH REGARD TO CONSERVATION OF FOREST RESOURCES ?

Gamini Hitinayake[1] and Mike Nurse[2]

[1]Faculty of Agriculture, University of Peradeniya, Peradeniya
[2] Native Title Services, Victoria, Australia

gaminisbh@gmail.com and michaelcnurse@yahoo.co.uk

Sri Lanka has a long history of community involvement in many of its reforestation and forest conservation projects. These projects have delivered important benefits to the forestry sector, including increasing forest cover, institutional development and betterment of livelihoods of poor farmers who participated in these projects. The objective of this paper is to draw from these projects some key lessons learnt that might be useful to consider for making future projects more successful.

It has been proved that the best approach to conserve the natural forest would be by the co-management of forest resources with the forest users. Most community forestry projects done in Sri Lanka have avoided the option of co-management of natural forests. Instead, they have embarked on options such as farmer woodlot schemes, buffer zone development and alternative livelihood development. Such indirect activities have not yielded the expected results in terms of conserving natural forests.

It is a fact that many forest areas in Sri Lanka require active management urgently to restore the productive capacity. There is a high possibility that it can be achieved through community forestry. Sri Lanka has a rich history of forest utilization and management by local communities. They have practiced collective gathering of, and sharing of benefits from, forest products, and maintain a strong traditional belief system based upon reverence towards their forests. Most forest fringes are inhabited by communities who subsist upon low levels of income earned through insecure livelihood activities. Although their dependency on forest for livelihood is low at present, they will be willing to join as local partners to manage these forests if co-management is going to bring improvements to their livelihoods. When the community has a strong sense of its relationship to the resource, including some established social rules for resource management, then the opportunity to establish private communal ownership may be good.

Considering the above scenarios, it is important to develop a protocol for co-management of natural forests. This must consider both the policies and ideologies of the Forest Department, together with the local community and resource context.

Key words: *Community forestry, Lessons learnt, Co-management of forests, Forest fringe communities, Livelihood development*

ASSESSMENT OF DEGRADATION STATUS OF THE COMMUNITY-MANAGED DEGRADED FOREST LANDS IN SRI LANKA: PRELIMINARY ANALYSIS

RMD Alawathugoda[1] and Stephen Balharrie[2]

Forest Department, Sri Lanka

[1] deepani.alawathugoda@gmail.com, [2] sbalharrie99@hotmail.com

In the past, forest management and protection in Sri Lanka has largely focused on strict government control. However, with the appreciation of the relevance and importance of community involvement in forest management, various approaches to community-based forest management have been introduced. A monitoring and evaluation study was initiated to measure changes in forest condition over time in areas selected to be managed under the Community Forest Management (CFM) Program.

To assess changes in biodiversity, forest structure and biomass over time, 554 permanent sample plots (PSP) were established in 51 community forest areas in 2013, and vegetation data are being collected annually. Selected sites are situated within five main agro-climatic zones (ACZ); low country dry (19 sites), low country intermediate (10 sites), mid-country intermediate (18 sites), upcountry intermediate (3 sites) and upcountry wet (1 site). Using the baseline data collected in 2013, tree density, aboveground biomass (AGB), regeneration and species richness at plot and site levels were calculated. A combined index with regard to both stem density and AGB was formulated for each site to classify them into degradation levels. Sites were classified as critically, highly, moderately and lightly degraded, and numbers of sites within each category are 31, 17, 3, and 0, respectively.

Average stem density and AGB of the sites vary considerably, ranging from 82-1092 stems/ha, and 4-187 Mg/ha, respectively. On average across each climatic zone, the largest biomass is recorded for the low country intermediate zone sites, while the highest tree density is recorded in the upcountry wet zone site. Average density and AGB of a site is expected to increase if the site is recovering with time. Percentage change will be analyzed with respect to the relevant climatic zone over time. The relative contribution of pioneer, intermediate, climax and invasive species will be estimated to monitor changes in species composition. Regeneration will also be monitored.

Key words: *Community forestry, Biomass, Degraded forest, Species composition*

PAST EXPERIENCE AND FUTURE PROGRAMMING IN THE SRI LANKA COMMUNITY FORESTRY PROGRAM

Kalana Cooray[1] and **Nora Devoe**[2]

[1]UNDP Programme Associate, Sri Lanka Community Forestry Program
[2]Advisor, Forest Department, Battaramulla

Kalana.Cooray@UNDP.org and Sylvacare@hotmail.com

With Australian government funding, the Sri Lanka Community Forestry Program (SLCFP) became operational in 2012. This external funding will cease in December 2016, but the Forest Department will continue community forestry activities. To inform future community forestry programming, we examine the SLCFP Extension Officers' perspectives on Program results.

From the SLCFP goal and objective statements, these five criteria were extracted for judging "success" of the Program interventions: improve natural resource management, support livelihoods and reduce poverty, reduce deforestation and forest degradation, involve communities in forest management, and build Forest Department capacity in community forestry. Extension Officers' (N=30) evaluations of the Program's interventions, importance rankings of factors thought to contribute to success, and rankings of priority and likely success of potential future community forestry activities were gathered in a questionnaire (individual responses) and at a de-briefing workshop (group discussion) in August, 2016.

These scores and ranks were compared qualitatively with the perspectives of other stakeholders collected separately in semi-structured interviews and focus groups (Karunathilake in prep). A simple form of content analysis, in which frequency of mention was tabulated from transcripts of interviews and discussions with community members, was used to examine congruence of assessments between the two groups. Additional data on Program outcomes taken from quarterly and annual monitoring and evaluation reports were also compared with the perceptions of Program participants.

The perspectives of the Extension Officers were aligned with those of other stakeholders around the Program's most successful aspect, livelihood development. Participation and poverty reduction were emphasised throughout the Program. Among natural resources activities, enrichment planting and creation of farmer's woodlots were seen to deliver the greatest benefits. As expected, perspectives on success of past interventions correlated with Extension Officers' prioritisations for future activities. Promoting community-based monitoring and evaluation of natural forest condition and structuring future Program interventions to more directly link improved forest condition with livelihood benefits may enhance future Program performance around natural forest outcomes.

Key Words: *Community forestry, Program evaluation, Stakeholder perspectives, Program planning*

ECOLOGICAL RESTORATION OF DIYAKOTHAKANDA

Prof. Lakdas D. Fernando[1], **Dineth Danushka**[2]

Wildlife & Nature Protection Society

[1]lakdasf@gmail.com, [2]danushkabutterfly@gmail.com

Diyakothakanda is a steep hill slope in the Low Country rain forest area. The site is totally denuded land subjected to manmade forest fires, erosion due to long-term exposure, and heavy runoff. Exposed rocks throughout the site are evidence of prolonged erosion.

The main goal of this project is the increase in biodiversity of the area through ecological restoration, re-installing the original assemblage of the forest structure to the site. Using principles of relay floristics, sun-loving, fast-growing pioneer species such as *Macaranga pelata* and *Macaranga indica* are to be planted on the site to provide the necessary shade to eliminate the layer of bracken and to promote suitable environmental conditions for the establishment of later successional and primary rainforest trees. Eight-thousand mixed-species pioneer seedlings are being grown in polythene pots in a village nursery to be ready for planting in November 2016. These seedlings will cover 25% of the total project site of 2 hectares. The growth of these pioneers will be carefully monitored. They will be weeded as needed. A further 16,000 plants to cover the entire area is planned for November 2017.

The community has established and staffs the nursery. Planting and monitoring activities will be with the participation of the community and five area schools. The project is developing capacity in environmental conservation among school children in the selected schools and has built awareness in the village community of the need for environmental conservation in general and the need to protect and conserve forests within the village in particular. This project serves as a model for forest restoration.

Keywords: *Ecological restoration, Pioneers, Primary species, Rainforest, Community*

PRACTICING SUSTAINABILITY: PRINCIPLES FOR NON-TIMBER FOREST PRODUCTS

Nora N. Devoe

Advisor, Sri Lanka Forest Department

sylvacare@hotmail.com

While there is no universal definition, most natural resource managers agree that sustainability has socio-cultural, economic, and ecological dimensions. This paper considers the broad attributes of sustainability but focuses on the ecological basis for sustainable management of non-timber forest products. This review of principles follows Peters (1994) and is intended for application by Extension Officers and other field personnel within the Sri Lanka Community Forestry Program to support expanded options for sustainable, forest-based livelihoods within that program.

Population biology is the core of the approach to the question of how we can remove products, whether they be fruits and seeds, plant exudates, or vegetative structures, on an on-going basis without diminishing supply. The steps in the process are species selection, forest inventory, yield estimates, regeneration surveys, harvest assessments, and harvest adjustments. A regular flow of diagnostic information about the ecological response of the species or resources to varying degrees of exploitation enables on-going adjustment to maintain population structures. Tending and enrichment can be used to protect and augment populations of economic species.

Almost any form of resource harvest affects the structure and function of tropical plant populations. If nothing is done to mitigate the impacts, continued harvesting will deplete the resource. If practiced on a sustainable basis, the exploitation of non-timber forest products provides a way to use tropical forests for profit while conserving their biological diversity and ecosystem functions. Expanded, sustainable, forest-based livelihoods improve prospects for forest retention and protection.

Key words: *Sustainability, Non-timber forest products, Silviculture, Population biology*