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Department of Forestry and Environmental Science
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Panel of Reviewers
Senior Prof. D.M.H.S.K. Ranasinghe
Senior Prof. B.M.P. Singhakumara
Prof. H.S. Amarasekara
Prof. N.J.G.J. Bandara
Prof. S.M.C.U.P. Subasinghe
Prof. U.A.D.P. Gunawardane
Dr. P.K.P. Perera
Dr. D.T. Jayawardana
Dr. G.G.T. Chandrathilake
Dr. V.M. Jayasooriya
Dr. C.D.K. Pathirana
Dr. D. Rajapaksa
Dr. M. Munasinghe
Dr. K. Ranatunga
PREFACE

International Forestry and Environment Symposium organised by the Department of Forestry and Environmental Science, University of Sri Jayewardenepura has a long history which goes back to 1995, where the first event was held under the theme of “Forestry for Development”, at Coral Gardens Hotel, Hikkaduwa. Since this inaugural event, throughout the years, the symposium has obtained a wide recognition among academics and professionals in the forestry and environmental sectors, both Sri Lanka and overseas. Currently, the symposium is recognised as the oldest and most renowned forestry and environment symposium in South Asia, where the researchers, academia, professionals, policy makers, and the industries, annually publish, discuss and learn about the latest developments in forestry and environment sectors. Apart from furnishing a platform for sharing latest research outcomes related to forestry and environment sector, the International Forestry and Environment Symposium holds up in making a regional and national impact by sharing knowledge and ideas that covers a wide range of sub disciplines related to the fields of forestry and environmental sciences.

This year, the International Forestry and Environment Symposium celebrates its Silver Jubilee under the theme of “Post Covid 19: Environment and Society” presenting research findings under 10 major themes namely, Covid 19 on Society and Environment, Forest and Natural Resource Management, Biodiversity and Sustainable Tourism, Waste Management and Pollution Control, Environmental Engineering and Green Technology, Environmental Economics in Resource Management, Wood Science, Wood and Non- Wood Industry, Biomass and Sustainable Energy, Geology, Soil and Disaster Management, Climate Change and Water Resource Management. The symposium proceedings contain 101 abstracts of scientific studies from both local and international researchers.

The 25th International Forestry and Environment Symposium is supported by the generous financial assistance from Tokyo Cement Group and Control Union Inspections (Pvt) Ltd and University of Sri Jayewardenepura. The symposium organizing committee would like to express their sincere gratitude for these funding partners and sponsors for their support in making this event a reality. Further, we extend our gratitude towards all authors, reviewers, participants, and session chair persons, academic and non-academic staff members of the Department of Forestry and Environmental Science and the students for their persevering support in making this event a success.

Symposium Organising Committee
Department of Forestry and Environmental Science
22nd January 2021
Message from Dr. Anil Jasinghe, Secretary to the Ministry of Environment

It is my great pleasure to address at the opening of Silver Jubilee of International Forestry & Environment symposium 2020, under the umbrella theme of “Post COVID 19 – Environmental & Society” organised by the Department of Forestry & Environmental Science of University of Sri Jayewardenepura.

I would like to express my warmest gratitude, on behalf of the Ministry of Environment, Sri Lanka to the Department of Forestry & Environmental Science of University of Sri Jayewardenepura for organising and hosting the oldest Annual Forestry and Environment Research Conference in South Asia making a good platform for the researchers, academia, professionals, policy makers and the industry to network, share and disseminate their findings and experiences in the environmental management sector.

Department of Forestry and Environmental Science is the only one of its kind in Sri Lanka, which has been offering both undergraduate and postgraduate courses in Forestry and Environmental Science since 1983.

The Department has been able to reach wide horizons in training professionals who are contributing effectively to sustain the country’s development process. Around 500 students have been trained since 1983; many of them are employed in the Forestry and environmental sector in local institutions as well as in the international context.

A considerable number of students of the Department have been contributing to the national Environmental Management of the country. Majority of higher management of the Central Environmental Authority which is the major environmental regulatory authority of the country, are postgraduate holders of the Department of Forestry & Environmental Science. It’s a privilege for the Central Environmental Authority to have several special degree holders of the Department in the technical staff as young professionals, since they have been especially trained to contribute in multi-dimensions in environmental management.

There are several alumni of the Department serving at the Ministry of Environment as well as at the Geological Survey and Mines Bureau which is mainly involved in promoting the conservation and management of the mineral resources of the country.

I strongly believe that the department is able to complete its mission to assist in the sustainable management of natural resources and the environment through the commitment of students who have been serving in the different environmental management agencies all over the world.

University of Sri Jayewardenepura is a historic and unique education institution in South Asia. It was founded in 1873 by the erudite Buddhist monk Ven. Hikkaduwe Sri Sumangala Thera as the ‘Vidyodaya Privena’, a Buddhist Educational Institution. Since then the University has educated a wide range of notable alumni, including ministers and many heads of state departments and authorities, founders of reputed organisations, researchers, innovators and a vast number of professionals of diverse institutions around the world.
Research and innovation are the driving forces of any developing nation. The University is also in the forefront of research and innovation with over 25 nationally important research centres under the ‘Research Council’ and the ‘Invention, Innovation and Venture Creation Council’ with over 50 Entrepreneurs and stakeholders with over 15 patents.

Since the onset of the current epidemic in Sri Lanka, the Department of Immunology and Molecular Medicine of Faculty of Medical Sciences of the University has been supporting the Ministry of Health in sequencing the virus variants with the emergence of different types of novel SARS-CoV2 variants from several countries.

The very first ‘Forestry symposium’ by the Department of Forestry & Environmental Science was held at the Coral Gardens Hotel, Hikkaduwa, Sri Lanka under the theme of ‘Forestry for Development’ in 1995. 38 research papers have been presented by local researchers there.

Since 1995 the conference series has been covering a broad spectrum of relevant themes, methodologies, and research approaches including empirical, conceptual, review and case studies in the field of Forestry and Environmental Science.

These two days will offer a range of sessions designed to explore the delivery of effective and impactful research at the University and beyond.

I am sure that this international research conference would also promote scientific information interchange between researchers, scientists, academicians, developers, students, policy makers and practitioners working in and around the world.
Message from Senior Prof. Sudantha Liyanage  
Vice-Chancellor, University of Sri Jayewardenepura

It is with great pleasure that I write this message as the Vice-Chancellor to the proceedings of the 25th International Forestry and Environment Symposium 2020 organised by the Department of Forestry and Environmental Science, University of Sri Jayewardenepura as a Silver Jubilee Symposium. During the last ten years I have witnessed the progression and success of this symposium while I was in Office as the Dean, Faculty of Applied Sciences. I am delighted to see the profound influence this symposium has on the field Forestry and Environmental Science.

From its commencement, University of Sri Jayewardenepura has been guided by its motto “Vijja Uppatham Setta” (Among all that arise, knowledge is the greatest), taken from the Dhammapada. The vision of the University “Prosper lives through education” calls for an unwavering commitment to the well-being of people through education. Striving for the vision and the mission of the university includes searching for and testing new realities and disseminating knowledge, both existing and new, for the enhancement of society.

The Department of Forestry and Environmental Science is unique as it provides a platform for discussion and dissemination of knowledge exceeding researching and teaching on environmental discipline. This year too, this symposium has been organised with the theme of “Post Covid 19: Environment and Society” for the 25th consecutive year creating a great opportunity for researchers, academia, professionals, policy makers and the industry to network, discuss and learn about the improvements and needs in forestry, environment and development.

I would like to express my sincere gratitude to the organising committee of the Silver Jubilee Symposium of 25th International Forestry and Environment Symposium 2020 and I hope that this year too, this Symposium will be a great success.

Let us be partners in establishing a sustainable and innovative future for all.

Senior Professor Sudantha Liyanage  
Vice-Chancellor  
University of Sri Jayewardenepura
Message from Prof. Laleen Karunanayake, Dean,
Faculty of Applied Science,
University of Sri Jayewardenepura

It is crucial to maintain the sustainability in management of resources in order to safeguard the country’s ongoing social, economic and environmental well-being. The optimal management of resources is the base to accomplish development goals while reducing environmental impacts. To attain this, research and development plays a significant role, through innovation and introducing ways of optimally managing the natural resources.

International Forestry and Environment Symposium delivers a premier interdisciplinary platform for scientists, researchers, industrialists and policy makers to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered with the forestry and environmental sector alongside with the potential solutions that can be adapted for the sustainable management of forests and natural resources. This year’s theme of the symposium “Post Covid 19 on Environment and Society” will provide a much-needed national platform for disseminating knowledge on sustainable research and innovation among a diverse range of environmental practitioners.

I convey my heartiest congratulations to the organising committee and members of the Department of Forestry and Environmental Science for continually hosting this International Symposium for the 25th consecutive time, of which it is the only one of its kind in Sri Lanka.

As the Dean of the Faculty of Applied Sciences, of the University of Sri Jayewardenepura, I’m glad to be a part of my faculty’s involvement in making this event a success.

Professor Laleen Karunanayake
Dean
Faculty of Applied Sciences
University of Sri Jayewardenepura
Message by Prof. Hiran Amarasekera-Founder Chairman of the Symposium

It gives me great pleasure to witness the Silver Jubilee of the International Forestry and Environment Symposium which we began in 1995.

The only scientific gatherings back in 1995 was the SLAAS scientific sessions and few conferences. Therefore, to differentiate our gathering we opted to use the term symposium, which was a novel concept at the time. As such, we marked the first Research Symposium in Sri Lanka.

The period from 1995 to 1996 holds great significance. It is in 1995 that the Sri Lankan Forestry Sector Master Plan and the Forest Policy was developed and in 1996 that our department, the Department of Forestry and Environmental Science was originated. The department during the same period received funds under the Forest Resource Development project, and so, the idea of a symposium was conceptualised in order to best utilise these funds received. I take this opportunity to remember with gratitude Prof. H. G. Nandadasa, Prof. M. M. Karunanayake, Prof. Hemanthi Ranasinghe, Prof. Sydney Banyard and Late Mr. Thosapala Hewage for their assistance and guidance provided in initiating this symposium on a day like this, twenty-five years ago.

Prior to having this symposium, in Sri Lanka researchers presented their findings in the mere presence of fellow researchers, as such, they did not have a platform to reach out to and communicate with the industry and policy makers. For this reason, the symposium carried the slogan, “The Symposium where Researchers, Industry and Policy Makers meet”. Accordingly, the first symposium was hosted at the Coral Gardens, Hikkaduwa in December 1995.

The University of Sri Jayewardenepura was heavily involved in the Forestry Planning of Sri Lanka back then, and so, we were in contact with most of the stakeholders of the sector. As a result, most participants were prominent names of the time. This context, thereby, presented the opportunity for young researchers to share their findings, and for us to showcase them to local and international policy makers and industry representatives. I’m happy to note that the young and senior researchers who presented back then are prolific researchers in Sri Lanka today; and their students continue to utilise this forum to gain that same exposure.

Back in the day, we did not have event organisers, and so, the entire effort was primarily a result of the hard work of our students at the department with the help of staff members. The backdrop art was hand drawn by a traditional artist from my village, late Mr. Madalagama. The graphics, from the very beginning of the symposium up to now has been drawn by Mr. Tilak Dunusinghe from the “Professional One”. The first art that he drew for us in 1995, was drawn by hand, paint brush and spray gun, and from 1998 he has been doing this digitally via Photoshop. Likewise, our symposium has also evolved with the changing times over the years.
COVID-19 on Society and Environment
Danister L. Perera
National Expert Committee on Traditional Knowledge, Ministry of Environment.
*danisterp@gmail.com

According to official records the first case of Coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was identified in Wuhan, China, in December 2019. The World Health Organisation (WHO) declared the outbreak a Public Health Emergency of International Concern in January 2020 and a pandemic in March 2020. Recommended preventive measures of Covid-19 include staying at home, avoiding crowded places, social distancing, wearing face masks in public, ventilation and air-filtering, hand washing, practising good respiratory hygiene, disinfecting surfaces, and monitoring and self-isolation for persons exposed or symptomatic. Epicenter of the pandemic was switched from China to Europe and then to USA and Asia too with follow up waves that had different demographical effects from country to country and epidemiological paradigms with different variants and mutations. The COVID-19 pandemic further highlights the interrelations between the natural and societal systems where social inequalities, environmental factors such as air quality appear more likely to influence COVID-19 outcomes.

Governments had to face the challenge to achieve a balance between restrictions and normal life, the long-term responses to the pandemic that should consist of strict personal hygiene, effective contact tracing, quarantine and isolating. By the first quarter of last year, more than half the world's population was under some form of lockdown which had many negative impacts on society. The responses to the pandemic have resulted in global, social and economic disruption, including the largest global recession since the Great Depression of global economy. Many educational institutions have been partially or fully closed and system switched to on-line teaching. The large number of people working or learning from home via videoconferencing software led to several new terms and trends, including "Zoom fatigue", which created new mental problems for cyberpsychology. The term "doom scrolling" or “doomsurfing” became more widely used and society is overflooded with negative information affected to the mental health badly.

In some instances mass media created unnecessary panic situations by irresponsible reporting that gave highly unprofessional connotations to the society. There have been incidents of xenophobia and increasing levels of racist abuse and discrimination against particular ethnic groups and those perceived as being from areas with high infection rates. Society is misinformed by quacks and pseudo-healers with miracle cures and immune boosters backed with false information that has been spread through social media, text messaging, and mass media. This kind of misinformation created an infodemic and social media continuously carry out fact check and monitoring COVID-19 related information. The performing arts and cultural heritage sectors have been profoundly affected by the pandemic where, the religious bodies also cancelled religious ceremonies and imposed restrictions on seasonal pilgrims with social resistance due to disruption of traditional culture. The most sensitive cultural issue came up at national level was related to religious burial custom of Muslims was still debatable in ground water contamination with COVID dead bodies.
Within a short period, a large number of research publications came out and funding agencies backed more research projects to discover a medical solution while number of open access scientific papers and preprint server publication rate were increased. The COVID-19 pandemic has disrupted agricultural and food systems worldwide which caused hunger and undernourishment once again on the rise in the world. The pandemic has had many impacts on global health beyond those caused by the COVID-19 disease itself: negative impacts on mental health globally, with increased loneliness resulting from social distancing and depression and domestic violence from lockdowns. The COVID-19 pandemic has escalated into a “syndemic”, or a synergistic interaction between socio-economic, ecological and biological factors, resulting in adverse health outcomes. The worldwide disruption caused by the pandemic, resulted global reduction in human activity is coined as ‘anthropause’ and the considerable decline in travel traffic led to a large drop in air pollution and water pollution in many regions. Even though positive impacts on our environment, are likely to be temporary, this will benefit not only the environment, but also our society’s health and well-being.
Recent Technological Innovations to Maximise Resource Recovery from Landfill Waste Cells and Minimise Greenhouse Gas Emissions

J. Patrick A. Hettiaratchi

Department of Civil Engineering, Schulich School of Engineering, University of Calgary, Calgary, Alberta, Canada T2N 1N4
*jhettiar@ucalgary.ca

Over the last few decades, landfill design and operational practices have evolved. Current landfill waste cells include innovative features that eliminate most of the negative environmental impacts associated with waste disposal on land. Some of the historical and recent advances in waste cell design and operational practices that minimise greenhouse gas (GHG) emissions and maximise energy and resource recovery from waste cells accepting biodegradable organic waste are discussed. The emphasis is on innovative practices such as the design and operation of a waste cell as a landfill bioreactor with leachate recirculation to maximise landfill gas production and increase the rate of waste stabilisation, controlling fugitive GHG emissions during and after filling of the waste cell, and mining of waste cells to recover recyclables and reuse waste residue for energy recovery and other beneficial uses as well as for space recovery.

The early view of municipal solid waste (MSW) was pessimistic; waste is a liability to society and requires high level of resources to manage. Until recently, regulators and practitioners were happy to adopt a piece-meal approach to solve problems with the former practice of open dumping of MSW on land. Therefore, the dry-tomb landfilling approach was considered adequate to remedy the biggest threat of open dumps to environment and human health, which was the sub-surface release of leachate and potential groundwater contamination. However, with the realisation among experts and the general public that waste should be treated as a resource that needs to be utilised, recent research has focused on developing alternatives to dry-tomb landfilling, such as the operation of waste cells as landfill bioreactors. Landfill bioreactors enable maximisation of the energy and resource recovery potential of landfilled waste. Furthermore, operation of waste cells and landfill bioreactors enable finding a solution to GHG emission problems associated with MSW. Waste entombment in a conventional dry-tomb landfill slows down the process of biodegradation by minimising moisture entry, whereas landfill bioreactors speed up the biodegradation process by controlled input of moisture (i.e., by leachate recirculation) and increased cycling of nutrients and bacterial populations. By speeding up the waste biodegradation process, it is possible to generate large amounts of landfill biogas containing methane that can be collected and used as a renewable energy source. Unmitigated release of methane gas rich landfill biogas into the atmosphere is unacceptable because methane is 34 times more harmful as a GHG than carbon dioxide.
Apart from oceans and underground aquifers, fresh surface waters are the main resources of drinking water and high quality water for industrial uses in many parts of the world. Improving the water quality of freshwater resources is becoming a key challenge due to population growth, urban development, increased industrialisation and unsustainable use of natural water resources and contamination of those resources through the direct discharge of wastewater. Contamination of surface and groundwater resources by toxic and organic pollutants has becoming an important issue, because those pollutants even in low concentrations, cause significant damages to living organisms. Most of those pollutants are persistent and refractory and not be removed effectively by the conventional water and wastewater treatment plants. Therefore, the effective protection of natural water resources is only possible through the appropriate treatment of wastewater before discharging them into natural water bodies.

Advanced water treatment, in particular membrane technologies are well suited to address these issues, and in meeting the demands of high quality water for sensitive and advanced industrial uses such as food and beverage, pharmaceuticals and electronics. Membrane technologies are progressing fast in terms of enhanced performance and reduced cost. Membrane separations are also considered as green technologies, which are relatively simple in concept and operation, flexible, and compatible with integrated systems in many environments and can minimise the use of treatment chemicals, the production of residuals, and energy consumption. The possibility of combining membrane processes with other forms of technology like advanced oxidation process (AOP) or biological process in a hybrid fashion is also being explored, developed and applied in many wastewater treatment facilities. This talk will present research at Victoria University on membrane technology to treat challenging industrial and domestic wastewaters. For example, ceramic membranes were used with photocatalysis, ozonation and biological activated carbon (BAC) to provide treated water from municipal wastewater at lower cost and higher reliability compared to polymeric membranes. For the textile industry, application of photocatalytic ultrafiltration (UF) membranes showed an advanced capability to remove dye from challenging organic rich wastewater. Coupling of nanoparticles with membrane improves the filtration performance, anti fouling and antibacterial properties under UV irradiation compared to conventional polymeric membranes. Also includes recent research involving thin film nanocomposite membranes for enhanced separation performance during surface water treatment. Thus, membrane technology is not only play an increasingly large role on the field of water treatment but also produce considerable economic, social and environmental benefits.
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Agrochemical Usage and Farmers Perception on Selecting Pesticides in Upper Uma Oya Watershed in Sri Lanka

Sumudumali R.G.I.¹, Piyathilake I.D.U.H.¹, Randika J.L.P.C.¹, Jayawardana, J.M.C.K.², Malavipathirana S.², Udayakumara E.P.N.², Gunatilake S.K.²

¹Faculty of Graduate Studies, Sabaragamuwa University of Sri Lanka, Belihuloya, Sri Lanka
²Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka, Belihuloya, Sri Lanka
*iresha9301@gmail.com

Abstract

Understanding farmers’ behaviour in pesticide usage and selection is critical to enhancing the sustainability and health of the environment. Farmers indiscriminately use pesticides to reduce pest damages and to maximise the economic benefits. Intense application of pesticides subsequently affect the immediate environment. Uma Oya catchment is one of the main vegetables growing areas in Sri Lanka. Thus, this study was carried out to evaluate the farmers’ perceptions of pesticide usage and attitudes on the selection of pesticides. 61 respondents among farmers were randomly selected and interviewed using a pre-tested semi-structured questionnaire and key informant interviews covering two main seasons (Yala and Maha) of 2019/2020. The study has identified 43 commercial brands and 23 active ingredients of insecticides, 47 commercial brands 20 active ingredients of fungicides, 6 commercial brands 3 active ingredients of herbicides. The most frequently used pesticides are insecticides followed by fungicides. More than 50% of farmers used five insecticides (i.e. Abamectin, Carbosulfan, Chlorantraniliprole 20%+Thiamethoxam 20%, Profenofos), three fungicides (i.e. Chlorothalonil, Mancozeb, Propineb). Only three types of weedicides were found in this study (mainly Metribuzin). Most of these active ingredients were belong to the World Health Organisation (WHO) hazard classification class “U” which is unlikely to present an acute hazard. Insecticides Abamectin, Carbosulfan, Profenofos belongs to WHO hazard class II (Moderately hazardous) chemicals while fungicide Chlorothalonil belongs to hazard class III (Slightly hazardous) chemicals. Furthermore, the farmers were incapable of selecting proper pesticide for certain pest and selection of pesticide mainly based on the opinion of the pesticide retail shops or dealers (74%). Meanwhile, 3% of farmers selected pesticides with their-own knowledge. From the total, only 5% of farmers seek advice from agricultural instructors on pest management decisions. Only 28% of respondents had training on the correct use of pesticides and such training was conducted by private sector organisations involved in pesticide marketing. The present study indicates that pesticides application in the study area represents a potential risk for the environment, farmers and consumers. More investigations are needed to quantify pesticide residues on the waterways and need to determine the potential effect of those products on human and environmental health. Development of non-pesticide dependant crop management practices, training and educating farmers and retailers, proper disposal of pesticide waste, and sufficient supervision from authorities should be considered for improving the levels of knowledge and awareness of the dangers of pesticides to human health and environmental pollution.

Keywords: Farmers’ perceptions, Pesticide, Uma Oya watershed, Fungicides
Genetic Diversity and Beverage Quality of King Coconut Collected from Kurunegala District of Sri Lanka

Thamel K.M.M.1*, Meegahakumbura M.K.2, Dasanayaka P.N.1

1Department of Botany, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
2Coconut Research Institute, Sri Lanka
*madushanithamel@gmail.com

Abstract

King coconut (Cocos nucifera, var. Aurantiaca) has a globally increasing demand as a beverage and its productivity in Sri Lanka is relatively low when compared with its demand. Therefore the increase of production through breeding programmes has become essential. Revealing the genetic diversity of available King coconut germplasms in the country is important to use in breeding programmes. SSR is one of the most common marker type used in genetic diversity studies. The main objective of the study was to analyse the genetic diversity of 45 King coconut samples collected from extensive cultivations in Kurunegala district using SSR markers to form a co-collection having genetically diverse germplasms and to analyse some physical and chemical parameters of those King coconuts with a special focus on total sugar content in nut water. The diversity present within the forty-five King coconut samples collected from Pannala, Kalugamuwa and Makandura of Kurunegala district was evaluated incorporating two tall and two red dwarf coconut samples as standards using ten SSR markers. The constructed dendrogram based on 10 SSR loci comprised of an out group and a main cluster, the out group containing only two tall coconut standards and the main cluster containing all other analysed King coconut samples and the two red dwarf standards. Two red dwarf coconut standards were clustered in a separate subgroup within main cluster. Out of 45 King coconut samples 10, 19 and 4 King coconut samples collected from Kalugamuwa, Makandura and Pannala respectively were clustered within one sub group showing their genetic relatedness of analysed 10 SSR marker loci. All other King coconut samples were grouped to other 5 subgroups. Fruit size, colour of epicarp, nut water volume, pH, electrical conductivity and brix value of nut water were measured using standard methods and the total sugar content of nut water was measured using Phenol-Sulphuric method. In this analysis the highest sugar content and the lowest sugar content were observed in King coconut samples collected from Makandura and Pannala respectively. Conservation of genetically different King coconut individuals with favorable nut characteristics to use in future breeding programmes is recommended.

Keywords: King coconut, Genetic diversity, Breeding programmes, SSR markers, Nut water
Impact of Covid-19 on Herbal Sector; an Opportunity for Development of Traditional Medicinal and Aromatic Plants Based Natural Products for Rural and Societal Development

Chandrashekhar S.*, Bhandari A.

Herbal Research and Development Institute, Gopeshwar Uttarakhand, India*
*chandra.sanwal@gmail.com

Abstract

In the wake of novel Covid 19 pandemic the entire mankind is suffering as there is no proven medicine available as of now, therefore it would be good to take immunity booster medicine as a preventive medicine. As herbal products are considered safer than synthetic modern drugs all over the world. Hence with the Covid-19 outbreak, the use of herbs as herbal ingredients in the formulation of herbal medicines as well as other herbal products around the world is anticipated to increase significantly. This provides an opportunity for promoting MAPs sector for sustainable development. Looking at the importance of medicinal and aromatic plants based natural products for rural and societal development. Herbal Research and Development institute (HRDI) Gopeshwar, Uttarakhand, India made experimental studies on development of models of herbal gardens suited to various habitats of a region for developing range of herbal products. The results of experimental study demonstrated the development of concepts of innovative herbal gardens like aquatic herbal gardens, rock herbal gardens, orchid herbal gardens and ornamental herbal gardens besides the traditional home herbal gardens like demonstration herbal gardens, home herbal gardens etc. Also the results of field study based on primary and secondary data collecting traditional medicinal and aromatic plants led to the development of six categories of herbal products vis pharmaceuticals, nutraceuticals, cosmeceuticals, aromaceuticals, herbal disinfectants, repellents and culinary herbs based natural products. These herb based products have been displayed in “Herbal Museum” at Mandal, Gopeshwar. With the covid-19 outbreak the species which came into limelight are Tinospora cordifolia, Andrographis paniculata, Withania somnifera, Glycyrrhiza glabra, Ocimum sanctum, Asparagus racemosus, Adhatoda vasica etc. It is expected that the development of such herbal products would help in promoting awareness for cultivation, conservation of indigenous rare and endangered medicinal plants for rural and societal development across the world. Further there would be a need for research on herbal medicine on Covid19 like diseases; as traditional medicinal and aromatic plants based natural products would also help in treating such diseases and common health problems like colds etc.

Keywords: HRDI Gopeshwar, Herbal gardens, Herbal museum, Societal development, Covid 19
Extraction and Characterisation of Pectin from Lemon Peels and Its Food Application

Dhushane D.*, Mahendran T.

Eastern university, Chenkalady, Sri Lanka
*dhusha111@gmail.com

Abstract

Citrus fruits are major processed fruits in the world that results in generation of large quantities peels from the processing industries as become one of the main sources of the municipal solid wastes, which have been an increasingly tough environmental issue so can be suitably exploited for production of pectin. Pectin in a structural polysaccharide present in the primary cell wall and the middle lamella of plant tissues. Pectin is widely used in the food industry as a thickener, emulsifier, texturiser, stabiliser, and jelling agent in jams and jellies. Pectin was extracted using the method of acid hydrolysis followed by ethanol precipitation. The objective of this study was to evaluate the impact of different extraction conditions on the yield to characterise the lemon peels pectin. The influence of pH and extraction time were analysed to maximise the yield of pectin and they were characterised by assessing the physiochemical properties. The feasibility of utilising extracted pectin in food applications were evaluated. In this study, dried lemon fruit peels were treated separately with citric acid at 3, 3.5, 4 pH, for 30, 60, 120 min and the pectin obtained from these methods were compared in terms of yield and physicochemical properties. The yield of pectin ranged from (14.96-20.14%) on a dry weight basis. The results suggested that the highest pectin content is in the lemon peel extracted using 0.05 N citric acid at 80°C, 3 pH for 60 min. In addition, ash content, equivalent weight, methoxyl content and anhydrouronic acid of extracted pectin varied significantly (p>0.05) with the various extraction conditions. Based on the value of methoxyl content and the degree of esterification, lemon fruit peel pectin can be categorised as low methoxyl pectin. Sensory analysis revealed that there is no significant difference in colour, taste, aroma, spreadability and surface texture of two types of watermelon jam prepared using lemon peel and commercial pectin. Therefore, pectin which was extracted from lemon peels can be used as an effective food additive in watermelon jam production.

Keywords: Citric acid, Lemon peels, Methoxyl content, Pectin, Yield
The Importance of Non-Timber Forest Products in Livelihood Maintenance of Rural Communities of Mulatiyana Forest Reserve, Sri Lanka

Weththasinghe B.T.*, Caldera H.I.U.

1Department of Plant Sciences, University of Colombo, Colombo 03, Sri Lanka
*bhagyaweththasinghe@gmail.com

Abstract

Forests provide many products and ecosystem services for the wellbeing of people. However, increase in human population has caused an enormous pressure on the way of utilising forest resources. Several studies have claimed the use of Non-timber forest products (NTFPs) as a forest conservation strategy involving local communities. The NTFPs contribute in several ways to improve the livelihoods of populations living adjacent to forests; providing food, water, medicines, energy, other material inputs and a source of income. This enhances the value of the forest and encourages community-based forest conservation. A study was carried out in the Mulatiyana Forest Reserve; a lowland rain forest in Southern Province, Sri Lanka to obtain an overview of the current utilisation of NTFPs. Seventy-two individuals who use the forest on a regular basis and are residents within 1 km boundary of the forest participated in the survey. The study found that, utilisation of forest resources is restricted to age classes above 30 years. Thus, the interaction between the forest and the younger generation is rare. There is only 16% female representation among the users and therefore, promoting the use of NTFPs by females has the potential of supporting their families by improving their livelihood. A majority of the forest users (85%) have not attained the GCE O/Ls’ indicating their possible ineligibility to pursue a profession. More than half (58.4%) of the forest users are farmers. Forest products are extracted as input materials for farming activities and hence their livelihoods are strictly bound with the forest. Most of the forest extractions were carried out to fulfill their food and medicine requirements. Plants with timber value (Vitex altissima), medicine (Canarium zeylanicum, Dimocarpus longan, Coscinium fenestratum) or other importance (Gyrinops walla, Caryota urens, Caesalpinia bonduc) are illegally extracted from this forest. Controlled and well managed practices inside the forests under the inspection of relevant authorities are essential to achieve sustainable forest management. Forest officers and rangers are actively involved in protecting this reserve. Community around the forest also actively participate in such activities by informing the authorities of illegal actions. The NTFPs are an important resource for local inhabitants, which also encourages community-based forest conservation actions. Further attention should be given to this aspect in local forest policy implementation.

Keywords: Non-timber forest products, Community forestry, Sustainable forest management, Rural communities, Sri Lanka
Potential of Extra Income Generation for the Rural Sector by Medicinal Plant Cultivation

Munugoda K.D.¹, Subasinghe S.M.C.U.P.¹*, Hettiarchachi D.S.², Cooray A.T.³, Hapugoda M. D.⁴

¹Centre for Forestry and Environment, Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
²School of Science, Edith Cowan University, Australia
³Department of Chemistry, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
⁴Molecular Medicine Unit, University of Kelaniya, Dalugama, Sri Lanka

*upuls@sjp.ac.lk

Abstract

Sri Lanka is very rich in plant diversity ensuring the supply for resources for local folk remedies and ayurvedic treatments. Among those plants, some bear volatile oils in the leaves with the ability to repel mosquitoes. However, most such plants were underexploited and underutilised. Hence, this study aimed to compile information on plant species which are commonly found in homegardens in Kurunegala district of Sri Lanka and to find strategies to help rural economic development. For this purpose, indigenous knowledge was gathered through interviewing 50 traditional ayurvedic practitioners and 30 subject experts. This survey revealed the availability of 127 volatile oil-bearing plant species with mosquito repellent properties. Those plants were cross-referenced with the IUCN conservation status to eliminate the ones in the high risk categories. Finally, 29 plant species (Ocimum tenuiflorum Sub-type Rama, O. gratissimum, Hyptis suaveolens, Atalantia ceylanica, Citrus aurantifolia, Cinnamomum verum, Cymbopogon citratus, O. tenuiflorum Sub-type Krishna, Plectranthus barbatus, P. zatarhendi, Acronychia pedunculata, Ageratum conyzoides, Acorus calamus, Citrus madurensis, Eryngium foetidum, Citrus sinensis, Citrus reticulata, Aegle marmelos, Anisomeles indica, Vitex negundo, Tithonia diversifolia, Croton laccifer L., Toddalia asiatica, Piper betle, Clausena indica, Ruta chalepensis, Limonia acidissima, Michelia champaca and Evolvulus alsinoides) were identified out of 123, by following a weighted ranking system based on the priority given by both ayurvedic practitioners and subject experts. Identification of the availability and willingness to supply of those top ranked plant species was tested via a structured questionnaire survey conducted for 80 participants in four villages (Hulugalla, Randenigama, Porawewa and Papolegama) in two agro-ecological regions (IL1 and IL3) of Kurunegala district. Selected 20 households from each village had the land extent equal or greater than 1 acre (0.4 ha). According to the results, Citrus aurantifolia, Citrus sinensis, Citrus reticulata, Aegle marmelos and Ocimum tenuiflorum Sub-type Rama were the top 5 ranked plant species that were commonly available. Further, this study demonstrated that on an average a family could earn between Rs. 500.00 and Rs. 3,000.00 by selling 1 kg of air-dried leaves. Thus, encouragement of medicinal plant cultivation in rural areas will help to generate financial returns and to conserve these plants in the wild.

Keywords: Mosquito repellence, Volatile oils, Medicinal plants, Rural economy, Indigenous knowledge
An Assessment of the Impacts of *Elaeis guineensis* (Oil Palm) Cultivation on Ground Water Table in Sri Lanka

Dissanayaka D.M.C.P.*, Bandara W.A.R.T.W.

*Department of Zoology and Environmental Management, University of Kelaniya, Dalugama, Sri Lanka
*chathuripoornima1@gmail.com

Abstract

Oil palm is a profitable crop in the wet zone of Sri Lanka. It currently occupies the topmost position in the international vegetable oil market worldwide. However, after the expansion of Oil Palm, it shows severe problems in those areas such as declining ground water table. People faced lack of quality drinking water and they have complained about drying of their wells. But, the contribution of Oil palm to these problems is highly controversial. Some myths have arisen about negative impacts of this cultivation with lack of scientific details. Therefore, the main objective of this study is to assess the impacts of oil palm cultivation on ground water table and well water depth, relative to the land use of rubber plantations and natural forest in Sri Lanka. For that, study area was selected in the Nakiyadeniya oil palm estate which is located in Udugama, Galle district. Data were collected from May to October, 2019. Study area consists of 6 study sites such as 1 year old (OP1), 7 years old (OP7), 19 years old (OP19) oil palm cultivation, 14 years rubber cultivation (RB14), Kanneliya natural forest (NF) and an abandoned site (ABND) in Nakiyadeniya. Groundwater table was evaluated by measuring the well water depth which is the distance between the mouth of the well and the water level in the well, using a measuring tape. Monthly rainfall data from each study site were collected and the data was analysed using one-way ANOVA in minitab software. A face to face interviews with families from each study site using a pre-tested questionnaire survey was conducted to get the peoples' attitudes and experience about the oil palm cultivation. Random 20 households from each site except abandoned site as there were no households around, were selected as the respondents of the questionnaire. The data were analyzed using Excel software. 71% of the respondents are female and they employed as laborers in the Nakiyadeniya oil palm estate. 70% of the respondents are uneducated and 75% of them have been living there for 40 years in each site. 70% of the wells are older than 20 years, in each site. More than 50% of wells are deeper than 20 feet in each site.

70% of the respondents representing all the sites except NF stated that, their wells get dried in the dry season and the problem occurs only in the dry months of the year. More than 80% of the respondents, around OP19 and OP7 sites, said that although their wells are fully or half filled before 10 years, now they are filled only with less than quarter with water. 50% residents living around OP1 and RB14 sites, are also said that the water levels of their wells are decreasing. Percentages of well water reduction in OP19 and OP7 sites are higher than other sites. Further, average annual rainfall from 2010 to 2019 in the study area does not show gradual decline in any study site. Well water level of the houses located around the oil palm sites has decreased more than RB14 and NF sites. Least well water decline was recorded in the houses located around NF site. Finally it can be concluded that, there is a negative impact of oil palm cultivation on ground water table and well water depth.

*Keywords*: Oil palm cultivation, Impact assessment, Well water depth, Ground water table
Developing a Multiple Criteria Decision Making Model for Selecting the Best Roadside Tree Species in Different Urban Environmental Settings in Colombo District, Sri Lanka

Dissanayake C.T.M.1,2*, Bandara W.A.R.T.W.

1Department of Zoology and Environmental Management, University of Kelaniya, Dalugama, Sri Lanka
2School of Technology, Sri Lanka Technological Campus, Padukka, Sri Lanka
*mahanamadissanayakec@gmail.com

Abstract

Roadside trees help to mitigate air pollution by serving as a sink for gaseous air pollutants. However, in Sri Lanka roadside tree selection mechanism remains uncertain due to the absence of selection criteria and lack of scientific research. The present study was designed with the objective of developing a multiple criteria decision making model which includes Air Pollution Tolerance Index (APTI) values, leaf carbon content, leaf area, canopy structure, plant type and economic value to select the most suitable tree species for road side planting. Five roadside tree species were selected; *Terminalia catappa* (Kottamba), *Cassia fistula* (Ehela), *Pongamia pinnata* (Karanda), *Madhuca longifolia* (Mee), and *Peltophorum pterocarpum* (Kaha Mara) as they are mostly abundant in roadsides of Colombo district. Air Pollution Tolerance Index (APTI) was calculated using four biochemical parameters; pH, ascorbic acid content, relative water content and total chlorophyll content on leaves. The study was conducted at two environmental settings identified as least polluted and highly polluted in Colombo, Sri Lanka. Environmental settings were identified based on SO\(_2\), NO\(_2\) and PM 2.5 level in ambient air. Five tree species with ten replicates at each site were evaluated using standard methods and the grades were allotted to develop the model. Standard One-way Analysis of Variance (ANOVA) followed by Tukey’s pairwise comparison was done to determine whether there is a significant difference in multiple criteria values between five selected roadside tree species for both sites separately. According to the multiple criteria decision making model *Pongamia pinnata* (Karanda) was recorded as the most suitable tree species for planting along road side in both environmental settings. The suitability for road side planting varied as follows in least polluted site; *Pongamia pinnata* (Karanda)>*Peltophorum pterocarpum* (Kaha Mara)>*Cassia fistula* (Ehela)>*Terminalia catappa* (Kottamba)>*Madhuca longifolia* (Mee). In highly polluted site the suitability pattern varied as follows; *Pongamia pinnata* (Karanda)>*Peltophorum pterocarpum* (Kaha Mara)>*Cassia fistula* (Ehela)>*Terminalia catappa* (Kottamba)>*Madhuca longifolia* (Mee). It is recommended to follow this procedure for other roadside tree species in the Colombo district and expand to other urban cities. Rather than selected biological and socioeconomic criteria in this study, other main criteria such as stem carbon content, leaf roughness, pest and disease resistance can be simultaneously incorporated into selection criteria.

Keywords: Air Pollution Tolerance Index, Road side trees, Air pollution, Multiple criteria decision making model
Development of Best Fit Models Based on Allometric Equations to Predict the Clear Bole Height Stem Carbon Content of *Rhizophora mucronata* in Kadolkele and Rekawa Mangrove Forests

Liyanage P.M., Wijeyaratne W.M.D.N.*

*University of Kelaniya, Dalugama, Sri Lanka
*dimuthu.wijeyaratne@kln.ac.lk

Abstract

Mangrove forests can play an important role in carbon removal as they are considered as one of the most carbon-dense ecosystems in the world. The objective of the present study was to develop allometric equations to estimate the stem carbon content of *Rhizophora mucronata* in Negombo and Rekawa mangrove forests. Kadolkele mangrove forest is a planted mangrove forest located in the wet zone and Rekawa mangrove forest is a natural mangrove forest located in the intermediate zone. Fortyfive trees of *R. mucronata* were selected from each mangrove forest. Stem core samples were obtained from each tree and their dry weights were measured. The organic carbon content of stem core samples was determined using loss on ignition method. This study used stem Diameter at Breast Height (DBH), Clear Bole Height of the stem (CBH), Crown Height (CH), Total Height (TH), Leaf Area (LA) of *R. mucronata* to develop allometric equations to estimate clear bole height stem carbon content. For each site, 75% of data were used for model construction and 25% were used in model validation. Stepwise regression model with backward elimination was used to develop the best fit model to predict the clear bole height stem carbon content. MINITAB 14 statistical software was used in statistical analysis. Results showed that clear bole height stem carbon content of *R. mucronata* can be determined using DBH. The best fit allometric equation of stem carbon content for *R. mucronata* in Rekawa was ln(c)=-1.686+1.997 ln DBH with a reliability of 80.60%. In Negombo, the best fit model was ln(c)=-3.125+2.522 ln DBH with a reliability of 77.9%. The common best fit model for *R. mucronata* (after the combination of two forests data sets) was ln(c)=-2.403+2.247 ln DBH with a reliability of 76.17%.

Keywords: Allometric equations, Mangroves, Stem carbon, Sri Lanka
The Efficacy of Uprooting Method to Control *Prosopis juliflora* in Bundala National Park of Sri Lanka

Rathnayake C.¹, Ranaweera B.¹*, Ratnayake R.H.M.K.¹, Suraweera P.A.C.N.B.²

¹Wayamba University, Makandura, Sri Lanka
²Czech University of Life Sciences, Prague, Czech Republic
*branaweera@gmail.com

**Abstract**

Invasive alien species (IAS) are species whose introduction and/or spread outside their natural past or present distribution threaten the biological diversity. *Prosopis juliflora* (Kalapu Andara; Family Fabaceae) is an invasive plant species spread in the Bundala National Park (BNP) of Sri Lanka, which has become a serious threat to the very existence of the park by restricting the growth of feeding plants for wild animals. The BNP has been declared a RAMSAR site and is well-known for water birds and in particular, migratory shorebirds. At present, its water bodies have been contaminated by extensive spreading of *P. juliflora*. Chemical and conventional methods of weed control are not permitted in national parks. Therefore, uprooting has been adopted to control the spread of *P. juliflora* within BNP. However, the success of uprooting method was not assessed. The present study investigated the growth behaviour of native flora in BNP following uprooting of *P. juliflora*. Data were collected from three ecosystems in BNP; ecosystem 1, 2 and 3 where *P. juliflora* has been removed by uprooting less than 1 year ago, 1-3 years ago and more than 3 years ago, respectively. Three transects of 100 m size were taken for each category to collect data on populations of *P. juliflora* and other plant species. Plant biodiversity indexes were calculated for the three eco-systems. Margalef’s Species Richness Index was not significantly different among three ecosystems indicating that the value of richness had not changed within the three year period following uprooting. A significant difference was found in Shannon’s Diversity Index and therefore, all three ecosystems had different community composition during the 3-year period after uprooting. According to the mean comparison of ecological indices, there was no significant difference in Margalef’s Richness Index between E2 and E3, although it was significantly lower than E1. The analysis of mean values of Evenness Index indicated a significant difference in E1 from E2 and E3. Both Simpson Dominance Index and Evenness Index had approached closer to 1 at E1 ecosystem. Uprooting did not have a sustainable effect to reduce *P. juliflora* population and / or to improve biodiversity in BNP. There is a high risk of reinvasion by *P. juliflora* from the third year onwards after uprooting. It was suggested to control the risk by complete removal of all vegetative parts of *P. juliflora* and suppression of emerging *P. juliflora* seedlings using suitable native plant species.

**Keywords:** Biodiversity indices, Bundala National Park, *Prosopis Juliflora*, Species diversity, Uprooting
Investigation of Solubility of Eppawala Rock Phosphate Using Jeevamrutham

Weerasooriya D.N.M.\textsuperscript{1*}, Udawatte C.P.\textsuperscript{2}, Yapa P.I.\textsuperscript{3}, Udayakumara E.P.N.\textsuperscript{2}

\textsuperscript{1}Faculty of Graduate Studies, Sabaragamuwa University, Belihuloya, Sri Lanka,
\textsuperscript{2}Faculty of Applied Sciences, Sabaragamuwa University, Belihuloya, Sri Lanka
\textsuperscript{3}Faculty of Agricultural Sciences, Sabaragamuwa University, Belihuloya, Sri Lanka
\textsuperscript{*}neleekha@gmail.com

Abstract

Phosphorus is one of the most essential nutrients for plant growth. It is usually supplied by phosphorus fertiliser. Rock Phosphate (RP) is the main source to produce phosphorus fertiliser. Sri Lanka has a good quality Apatite mineral deposit at Eppawala, which can be utilised as a source for phosphorus fertiliser after increasing its capacity for water solubility. Hazardous acids are commonly used in order to produce more soluble forms of phosphate fertiliser. However; it is not an economically feasible and environmentally friendly method in a country like Sri Lanka. Hence, use of biological process, as using microbes to increase the water solubility of RP is recommended. Jeevamrutham is an Indian traditional organic fertiliser that contains a mixture of microorganisms. This study investigates the suitability of Jeevamrutham which contains natural inoculums to increase the solubility of Eppawala RP. Five undisturbed forests (Sinharaja and Badagamuwa conservation forests, Nonperial Pine, Girandurukotte Teak, and Diyathalawa Turpentine plantations) were selected in order to obtain the soil samples (n=30) using simple random sampling as bio inoculums to prepare Jeevamrutham. Available phosphorus content of selected soil samples with (5 replicates of each) were determined using the Vandomolybdate method. Five different Jeevamrutham were prepared using the selected soil conditions. High-grade Eppawala rock phosphate (HERP) were treated by prepared Jeevamrutham. Available phosphorus content of each of the samples were determined using the Vandomolybdate method within 2 months in 7 days intervals. Randomised complete block design was used as an experimental design and data was analysed by using Two-way ANOVA and Turkey pairwise comparison tests. The results revealed that the all selected soil samples, which act as bio inoculum were contained higher available phosphorus than 1 ppm. Available phosphorus percentage was increased until 6 weeks for all treatments and then it had reduced gradually. Highest available phosphorus percentage was recorded in Pinus soil+Jeevamrutham treated HERP with 0.83% by mass after 6 weeks of treating. Teak soil+Jeevamrutham treated HERP showed high phosphorus percentage over a long period of time due to nature of the contained microorganisms. Thus, bio inoculum which grows in the Jeevamrutham supports to increase the water solubility of phosphorus in HERP.

Keywords: Available phosphorus, Jeevamrutham, HERP, Microorganisms
Seed Biology of Ten Common Roadside Sri Lankan Weed Species

Kumari L.R.L.S.1, Gunadasa D.M.N.H.1,2, Merritt D.J.3,4, Turner S.R.3,4, 
Gama Arachchige N.S.1,2*

1Department of Botany, University of Peradeniya, Peradeniya, Sri Lanka
2Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka
3Kings Park Science, Department of Biodiversity, Conservation and Attractions, Kings Park, Australia
4School of Biological Sciences, University of Western Australia, Perth, Australia
*surajithgan@gmail.com

Abstract

Weeds are undesirable in habitats where they grow and cause negative economic and environmental impacts. Understanding in weed seed germination is important to deploy control measures. This study was conducted to evaluate the effect of seed dormancy, smoke, KAR1, salinity and pH on germination of ten common roadside weed species in Sri Lanka. Freshly collected seeds of ten weed species were subjected to five treatments vis, (1) 0 and 500 ppm GA3; (2) Smoke solutions of 0%, 5%, 25%, 50%, 75%, and 100% strength; (3) 0 nM, 10 nM, 100 nM and 1 μM KAR1 solutions; (4) 0 nM, 25 mM, 50 mM, 75 mM, 100 mM, and 200 mM NaCl solutions; and (5) 4,5,6,7,8,9 and 10 pH buffer solutions. All the treatments were applied on 100 seeds (five replicates, 20 seeds each) and incubated at 25°C under 12/12 hrs light/dark for 4 weeks. Final germination percentages were calculated. Seeds of Bidens pilosa, Mikania micrantha, Rivina humilis, Tridax procumbens, and Vernonia cinerea were identified as non-dormant (germination>90%) and seeds of Ageratum conyzoides, Hyptis capitata, Oldenlandia herbacea, Ocimum tenuiflorum and Spilanthes iabadicensis were identified as dormant (germination<65%). GA3 improved germination of S. iabadicensis and KAR1 improved germination of A. conyzoides, H. capitata, O. herbacea, and S. iabadicensis. Smoke water did not improve seed germination of any of the species. Seven species (B. pilosa, M. micrantha, O. herbacea, O. tenuiflorum, R. humilis, and T. procumbens) exhibited a wide range of salinity tolerance (0-75 mM NaCl) with >50% germination. R. humilis exhibited a wide range of pH tolerance (pH 5-8) with >50% germination. Seed dormancy of four species were broken by GA3 and KAR1 treatments indicating physiological seed dormancy (PD). Due to unresponsiveness to dormancy breaking treatments, it can be assumed that seed of O. tenuiflorum possess deep-PD. The study confirmed that responsiveness to KAR1, smoke, salinity and pH is species specific and seed dormancy may lead to the formation of persistent soil weed seed banks. These traits may facilitate the weed seeds to compete with other species and dominate the vegetation.

Keywords: Karrikinolide (KAR1), pH, Smoke water, Salinity, Weed species
Species Distribution Models to Predict Suitable Habitats for Conservation of the Endangered *Lagenandra bogneri* (Araceae)

Madola G.K.I.S., Yakandawala K., Yakandawala D.M.D., Karunarathne S.B.

*Wayamba University, Makandura, Sri Lanka*
*University of Peradeniya, Peradeniya, Sri Lanka*
*CSIRO Agriculture and Food, Canberra, Australia*
*indrakeelamadola@gmail.com*

Abstract

The genus *Lagenandra* is represented by 16 species and is confined to Sri Lanka, India and Bangladesh. Out of those recorded species, Sri Lanka harbours eight species of which seven are endemic to the island. The species *Lagenandra bogneri*, is an endemic, listed under the endangered category during the National Red Listing, 2012. The plants show a restricted distribution in the wet zone of the country and according to the last revision of the flora in 1987, it has been recorded from the Sinharaja Man and Biosphere Reserve of the Rathnapura district and in an another unknown location. Hence, the objective of the present study was to identify the potential areas of occurrence or the suitable habitats for the introduction of the species which would enable the conservation of this endangered endemic species using distribution models. Extensive field visits were conducted in the wet zone exploring new locations in addition to the recorded, and GPS locations of the identified populations were logged. Using the location data coupled with spatial environmental covariates; namely climatic and topographic, species distribution was first modeled and mapped. Resulted maps revealed areas that have a high probability of occurrence of *L. bogneri*. Apart from the recorded location in and around Sinharaja reserve, the other location that was used for extracting data for modelling was from Morapitiya, Runakande forest reserve, a new record for the occurrence of the species. The resulting model identified three areas with high probability value for the possible occurrence of the species of which two lie within protected forest patches; Gilimale and Peak wilderness Forest Reserves (Ratnapura district), and two other possible areas outside of the protected areas of the same district. The information would provide insight for further exploration as well as possible habitats for introducing of this endangered species with narrow habitat requirements in view of conserving the plant in future.

**Keywords:** Conservation, Endangered species, Species distribution model, Biodiversity
Different Habitats, Distribution Range and Diversity of *Strobilanthes* Species in Sri Lanka

Renuka N.R.M.\(^1\), Wijesundara D.S.A.\(^2\), Bandaranayake P.C.G.\(^3\)

\(^1\)Department of Wildlife Conservation, Sri Lanka  
\(^2\)National Institute of Fundamental Studies, Sri Lanka  
\(^3\)Agriculture Biotechnology center, University of Peradeniya, Peradeniya, Sri Lanka  
\(^*\)nilanthi.dwc@gmail.com.

**Abstract**

*Strobilanthes* belongs to Family Acanthaceae, first described by Blume in 1826 from specimens collected in West Java. This is one of the largest genera in the flora of Sri Lanka and most interesting for its diversified habits, gregarious occurrence and elegant flowering. Approximately 450 *Strobilanthes* species are distributed in worldwide. Although a tentative list of 30 species of *Strobilanthes* occurring in Sri Lanka was provided by Wood in 1998 no updated report has subsequently been published. According to this study 33 species are currently known from Sri Lanka including one new species and out of them 27 species are endemic. Extensive plant explorations were conducted across the entire distribution range of the genus *Strobilanthes* in Sri Lanka covering 21 administrative districts from September 2005 to July 2020. The species of genus *Strobilanthes* grow from 100 m up to 2,800 m, in a very wide range of different habitats such as, dense aggregations along steep rocky slopes, along margins of grasslands, dense aggregations along slopes at lower altitudes, in plains, thick rainforest undergrowth, shaded places in ravines, open rocky cliffs, on the exposed rocks, along stream banks, evergreen forest margins, primary forests, scrambling shrub growing through other plants, moist rocks along streams. *S. gardneriana*, critically endangered possibly extinct species could be found from Hantana at 1,330 m elevation in 2020 after 1927 and critically endangered species, *S. rhytisperma* could also be found from Gendalala in 2019. Species distributions are wider with increasing altitude. Some species were not found in their type locality, such as *Strobilanthes laxa*, *Strobilanthes stenodonbuth* but they were found at other locations. The extended distributional record for many species of *Strobilanthes* could be found. The principle threats in the study area are urbanisation, cultivation, tourism activities, fire, overgrasping, pollution, road and dam constructions. In near future, plant diversity may decline and threatened species may disappear in the area if necessary conservation measures are not taken.

**Keywords:** Gregarious, Altitudes, Undergrowth, Locality, Exploration
Population Genetic Structure of Swallows within the Pacific Clade

Thakshila T.1*, Scordato E.2, Seneviratne S.1

1University of Colombo, Colombo 03, Sri Lanka
2California State Polytechnic University, Pomona, United States
*thilini.thakshila.tt@gmail.com

Abstract

Swallows are amongst the best-known families of birds to man in terms of their behaviour and ecology. They belong to family Hirundinidae in the genus Hirundo. Swallows have relatively conserved morphology due to their aerial insectivorous lifestyle. Therefore, fine morphological characters and genetic markers are needed to objectively evaluate the phylogenetic status of this group. We constructed both morphometric and phylogenetic analysis to determine the population sub structuring of Swallows in the Oriental region (commonly known as Pacific Swallows). Two mitochondrial gene regions; NADH dehydrogenase 2 (ND2) and cytochrome b (Cyt b) were considered separately and concatenated manner using PopArt (version 1.7). For each analysis 18 Sri Lankan Hill Swallow (Hirundo javanica domicola) sequences from six locations and 18 sequences from H.j. javanica (Western Malaysia, Japan, Borneo), H.j. tahitica (Papua New Guinea) and H.j. neoxena (Australia and New Zealand) were used. All haplotypes were mapped using median joining network algorithm with epsilon (ε) value of 0. Based on the haplotype network five main clusters could be identified. Higher number of single nucleotide polymorphic sites (SNPs) were present between those five clusters. Low level of gene flow between those clusters were identified, possibly due to geographical isolation. Results obtained from phenotypic and phylogenetic analysis further supported the obtained haplotype network indicating greater degree of isolation, hence limited gene flow. Three haplotypes within Sri Lanka, two haplotypes within Australia and New Zealand, one haplotype within Tahiti Island, two haplotypes within Fiji Islands, and six haplotypes within Borneo and Japan were obtained. Most parsimonies explanation to this would be higher level of gene flow within islands and low level of gene flow between distant geographic locations.

Keywords: Haplotype network, Phylogenetic status, Geographical isolation
Foraging Behaviour of Sri Lanka Green Pigeon (*Treron pompadora*) in Tropical Wet Evergreen Forests of Sabaragamuwa Province, Sri Lanka

Chandrasiri S.1*, Liyanage M.2, Chandrasiri B.3

1University of Sri Jayewardenepura, Nugegoda, Sri Lanka
2Divisional hospital Kiriporuwa, Sri Lanka
3University of Ruhuna, Matara, Sri Lanka
*spchandrasiri@gmail.com

Abstract

Sri Lanka green pigeon (*Treron pompadora*) is endemic to Sri Lanka. It is a fairly common breeding resident distributed in lowlands to lower hills. The objective of this study is to determine foraging behaviour including searching behaviour, attack behaviour, foraging sites, food types and food handling techniques. The study was conducted in the Tropical Wet Evergreen Forests of Kiriporuwa (6°48’53” N, 80°14’13” E) in Sabaragamuwa Province, Sri Lanka. This study was conducted from January 2018 to August 2020. Data collection was carried out in three line transects (100×10 m) using binoculars (Nikon Monarch, 12×42, Japan) from 0630h to 1830h in two days per month. An ethogram was constructed by using observational data. The behaviours for searching food, attacking food, foraging site, food types and food handling techniques were categorized in 380 foraging observations. Diurnal time duration was divided into two-hour time periods. Direct foraging observations and faecal sample analysis methods were used to observe food consumption. Time allocation for foraging behaviour was maximum in 1630h-1830h time period. Flying was the major foraging site movement. Gleaning attack method was used to capture food. They highly utilised the trunks and main branches of trees as foraging substrates. They foraged in the middle position of the trees and moderate density foliage cover was preferred. They consumed fruit, flower buds, leaves and moss. The diet of Sri Lanka green pigeon was comprised with fruit of the Families of Myrtaceae, Salicaceae, Anacardiaceae, Fabaceae, Moraceae, Clusiaceae, Sapindaceae and Fabaceae. They consumed these fruits by using biting food handling technique. They have arboreal foraging behaviour with complete consumption of plant food. Therefore, it is important to protect the tropical wet evergreen forests to ensure the conservation of this endemic bird species

Keywords: Foraging, Sri Lanka Green Pigeon (*Treron pompadora*), Endemic bird, Tropical wet evergreen forests, Sabaragamuwa Province
Variability of Pathogenicity of Different Isolates of *Phellinus noxius*: The Causal Organism of the Brown Root Disease of Rubber in Sri Lanka

Silva M.K.R.¹*, Fernando T.H.P.S.¹, Wijesundara R.L.C.², Nanayakkara C.M.²

¹Rubber Research Institute, Dartonfield, Sri Lanka
²University of Colombo, Colombo 03, Sri Lanka
* keshanisilva@yahoo.com

Abstract

*Phellinus noxius* is the pathogen causing brown root disease: an emerging disease condition in Sri Lanka rubber industry, especially in dry and intermediate regions. The possibility of the pathogen to be mutated into more virulent forms can be considered as one of the factors influencing the increased frequency of its occurrence in the country during the recent past especially in certain parts of the country. Considering the diversity of soil and climatic conditions in which the pathogen has been reported and the large number of tree species it attacks, it is necessary to have an understanding whether there is any variation in pathogenicity within the population of the fungus. Ultimately, this heterogeneity in the pathogenicity of the pathogen population within the country would be helpful in the development of management strategies against the disease. The current study has evaluated the pathogenicity of 24 Sri Lankan isolates of *Phellinus noxius*. A pot trial was carried out by artificial inoculation of three months-old rubber seedlings with an inoculated mixture (with respective fungal isolates grown on MEA) of rice bran and saw dust. Forty seedlings were inoculated by each isolate, and another forty seedlings were kept as control without inoculation. Starting after four months of inoculation, ten destructive samplings were done at two months intervals to observe the pathogenicity levels of different pathogen isolates against rubber seedlings. Based on the underground signs and symptoms, a pathogenicity score was given of each uprooted plant as: 0 (no infection), 1 (mycelial crust without root decay), 2 (mycelial crust with root decay) and 3 (plant death). The pathogenicity levels recorded as ranks were subjected to Kruskal–Wallis analysis and subsequently to the Wilcoxon rank-sum test, as the scores obtained for the different isolates were significant. A variation of pathogenicity was observed among the 24 *Phellinus noxius* isolates. As all the isolates had initiated to show a stabilised pathogenicity value at three and half months of the inoculation, a cluster analysis was performed for the mean score values of pathogenicity rank at three and half months and the dendrogram showed that the test isolates were separated into two main clusters at the similarity level 0.8.

Keywords: Brown root disease, Rubber, Pathogenicity of isolates, Clustograms
Variability of *Trichoderma* Population Isolated from Rubber Growing Soils, Showing Antagonistic Ability against *Rigidoporus microporus*, the Cause of White Root Disease of Rubber


*Plant Pathology and Microbiology Department, Rubber Research Institute, Dartonfield, Sri Lanka
*srarojinifernando787@gmail.com

**Abstract**

Natural rubber (*Hevea brasiliensis*) is a very significant crop to the global economy. Loss of production of rubber plantations can be caused due to plant pathogens. *Rigidoporus microporus*, the causative agent of white root disease is abundant in rubber plantations of Sri Lanka. Since control of the disease by applying fungicide is expensive, fungal species can be used as a biological control agent against white root disease. *Trichoderma* isolates obtained from rubber growing soils were found antagonistic against *R. microporus*. An attempt was taken to isolate various antagonistic *Trichoderma* isolates from different rubber growing soils. Soil samples were collected from Kalutara, Rathnapura, Ampara and Vavuniya in Sri Lanka. Soil pH and moisture contents were measured using standard methods and fungi were isolated using the dilution plate technique. After preparing pure cultures, antagonistic ability against *R. microporus* was tested using dual plate culture test. More than 65% inhibition showing fungi were selected to observe the cultural and reproductive morphology. According to the results, the dual plate culture test indicated that five *Trichoderma* species were effective to show more than 65% inhibition against *R. microporus*. These included *T. hamatum*, *T. koningii*, *T. spirale*, *T. ghanense* and the teleomorph of *T. harzianum* (*Hypocrea lixii*) in DNA sequencing data after processing from Macrogen, Korea. *Hypocrea lixii* showed the maximum inhibition of 80% over the control in *R. microporus* followed by *T. koningii*. *Trichoderma* species were able to grow in rubber growing soils with a range of pH from 4.0 to 6.8. *Hypocrea lixii* were isolated from the dry zone where showed comparatively higher pH and lower moisture values than the wet zone. *T. spirale* and *T. hamatum* were observed in both dry and wet zones. The isolates produced irregular or circular colonies with filiform or entire types of margin showing maximum growth rate of 4.08 cm/day. Therefore, these antagonistic fungi show a potential to control *R. microporus* under field conditions too.

**Keywords**: Rubber plantation, White root disease, *Trichoderma* sp.
Variability of *Colletotrichum* Species Causing Colletotrichum Leaf Disease in two Main Rubber Growing Districts: Kalutara and Ampara in Sri Lanka

Aberathne A.H.M.N.R.¹, Fernando T.H.P.S.¹, Daranagama D.A.D.A.²

¹Plant Pathology and Microbiology Department, Rubber Research Institute, Dartonfield, Sri Lanka, ²Department of Plant and Molecular Biology, University of Kelaniya, Dalugama, Sri Lanka

*nadeeshaniaberathne@gmail.com*

**Abstract**

Colletotrichum Leaf Disease (CLD) caused by *Colletotrichum* sp. is one of the most destructive leaf diseases in natural rubber (*Hevea brasiliensis*). As the causative agent of CLD in rubber has been changed time to time, continuous characterisation of currently persisting species is critical. Disease samples were collected from two main rubber growing districts. The pathogen was isolated from the leaf lesions. Cultural and reproductive characters of each isolate were observed after 10 days of incubation. Conidia concentration of each isolate was compared using haemocytometer. Growth rates were measured on Potato Dextrose Agar (PDA) plates. Fungicide sensitivity was tested with different concentrations of carbendazim using poisoned food technique. Pathogenicity test was performed by using 10⁵ conidia/ml suspension. The disease index (DI) value for each leaf was calculated. All the isolated colonies showed approximately similar colours, shape and other morphological characters with slight differences. Conidia of all the isolates were aseptate with one cell, green colour, smooth-walled, cylindrical, rounded at both ends, guttulate and granular. All the isolates were pathogenic. Conidia production varied between 0-2.09×10⁷ spores/ml. All the isolates showed approximately similar growth rates. All the isolates were able to exhibited 100% inhibition between 0.1-20 ppm concentrations of carbendazim. All the non-wounded leaves treated with the spore suspensions of each isolate exhibited different levels of lesions except the control and one isolate (A5). All of them were susceptible for the disease showing highest DI value as 2.444 while A5 did not exhibit any lesion development on the leaves. However, lesions were appeared in A5 after 03 days of incubation when the leaves were artificially wounded. According to the study, getting an idea of morphology, growth rate, conidia concentration and pathogenicity can be used as good criteria for fast detection of the pathogen and molecular techniques are recommended for the confirmation of different species.

**Keywords:** Natural rubber, Colletotrichum leaf disease
Flood Disaster, Wetland Loss and Ecosystem Services: Community Perceptions-A Case Study from Muthurajawela Wetland Complex, Sri Lanka

Siriwardhana S.T.1*, Gunawardena A.2, Mallawatantri A.3, Wickramasinghe D.D.1

1Department of Zoology and Environment Sciences, University of Colombo, Colombo 03, Sri Lanka
2Central Environmental Authority, Sri Lanka
3International Union for Conservation of Nature, Sri Lanka
*sandanisiriwardane94@gmail.com

Abstract

Urban expansion and population growth are increasingly apparent in many parts of Sri Lanka with significant impacts on the environment. Urban areas often have little room for nature. Yet, remaining ecosystems or habitats extend valuable ecosystem services to the communities. Ecosystems, therefore present avenues to serve humanity and enhance community resilience to many stressors including natural disasters. This study focusses on Muthurajawela Marsh which is the largest coastal wetland in Sri Lanka. Even though this large wetland (3,068 ha in extent) provides provisional, regulatory, cultural and supportive services, how the residents value those services are largely not known. The present study examined how wetland loss has attributed to increased flood impacts as well as impairment of ecosystem services provided by the wetland to increase the resilience of the community. Loss of extent of the wetland was studied using Arc GIS software by providing thematic maps for the last eleven years (2008-2019). Here, we demarcated the study area considering the boundary of an administrative unit named Wattala. By 2019, Muthurajawela marsh has lost 35% of its wetland habitats in 2008. The area with the lowest loss of wetland habitats (35.5 ha loss) was Mahapamunugama with the least number of flood events (2) as well as a lower number of people affected (725). Conversely, the highest number of people affected (46,951) and the highest number of flood events (19) were reported in Kerawalapitiya where the wetland experienced the most severe loss of wetland habitats (86.7 ha loss). A rapid assessment of the social values of Ecosystem Services (ES) was carried out in both areas through a questionnaire survey. This assessment aimed at investigating how much ecosystem services help to strengthen the wellbeing of the local community in reality. Nineteen ecosystem services were apparent including the value of being a cultural heritage, aesthetic value, noise and visual buffering, providing habitats for biota and regulating the local climate in Mahapamunugama where the wetland is comparatively healthy and the communities were of high resilience. In contrast, where the wetland is highly disturbed (Kerawalapitiya), the number of ecosystem services provided was only eleven with lower mean social values. The results of the present study highlight the importance of the health of wetlands in flood attenuation and increased community resilience as a result of ecosystem services they provide to the residents.

Keywords: Ecosystem based disaster risk reduction (Eco-DRR), Ecosystem Services, Flood mitigating role of wetlands
Revealing the Outstanding Floristic Value of Hatton-Nallathanniya Area of the Adam’s Peak Wilderness, Sri Lanka

Gamhewa. H.1*, Kathriarachchi H.1, Attanayake A.2

1Department of Plant Sciences, University of Colombo, Colombo 03, Sri Lanka
2Department of National Botanic Gardens, Royal Botanic Gardens, Peradeniya, Sri Lanka
*hasankitg@gmail.com

Abstract

Adam’s Peak Wilderness is one of the three UNESCO world heritage sites in Sri Lanka having an enormous floral diversity. Scientific investigation of the floristic wealth of the Hatton-Nallathanniya area is a crucial prerequisite for its protection, conservation, and management as the most popular Sri Pada (Adam’s Peak) route; Hatton-Nallathanniya trail, which is subjected to continuous disturbances, lies through this area. Field survey was carried out from August to October, 2018 within an altitudinal range of 1224-1952 m in the Hatton-Nallathanniya area to achieve the following objectives; (1) to prepare an inventory and explore the floristic richness, (2) to study the relationship between altitude and endemic species, (3) to determine beta diversity (β) between sub-montane and upper-montane forest formations. The stratified random sampling method was used as the primary sampling method, while opportunistic sampling was also performed to get a superior representation of flora in the area. A total of 35 plots, each 10x10 m (0.55 ha) were sampled to enumerate tree and understory layers. The ground layer was sampled in four 1x1 m plots, randomly located within each of the 10x10 m plots. Objectives 2 and 3 were achieved only through plot data. To exhibit the altitudinal distribution pattern of endemic and non-endemic species, boxplots were obtained using R version 3.4.1 software, and Pearson’s correlation coefficient was used to ascertain the relationship between altitude and endemic species at 5% significance level. Jaccard similarity index (SJ) and Sorensen similarity index (Ss) were used to calculate β diversity between sub-montane and upper-montane forest formations. Based on the results, the number of plant species found either in the plots or in the general collection was 235, representing 135 genera and 55 families. Out of the total recorded plant species, 112 (48%) were endemic. A total of 107 (45%) plant species were nationally threatened, and 27 (11%) of the total species were globally threatened. Among the 112 endemic species, 68 (56%) species were listed as nationally threatened. The obtained p-value and Pearson’s correlation coefficient (r) were 0.04 and 0.4 accordingly, which indicates a moderate positive correlation between altitude and endemic plant species. SJ and Ss values were 0.29 and 0.45, respectively. Low similarity and high β diversity highlight the heterogeneity between two forest communities. Our findings provide insights for the effective conservation management and further protect the critical habitats of this fragile, biologically diverse ecosystem.

Keywords: Adam’s Peak Wilderness, Floristic richness, β Diversity, Endemic species, Altitude
Determination of Tolerance Limits of Dimethyl Sulfoxide (DMSO) on Selected Bacterial Strains for the Antimicrobial Assays of Natural Products

Wanigasekara D.*, Madhushanthi P., Liyanaarachchi C., Wijayaratne G., Napagoda M.

University of Ruhuna, Matara, Sri Lanka
*dharaninirasha@gmail.com

Abstract

Dimethyl sulfoxide (DMSO) is extensively used as a solvent in natural product chemistry to dissolve plant extracts. Although it serves as a universal solvent for many fields of science, the toxicity of certain concentrations of DMSO may interfere in antimicrobial assays of natural products by inhibiting the growth of bacteria. Therefore, the present study was carried out to investigate the maximum concentrations of DMSO which can be used to dissolve plant extracts for antimicrobial assays without any toxic effects on test microorganisms. Different concentrations of DMSO (5%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%) were tested against *Escherichia coli* (ATCC 25922), *Staphylococcus aureus* (ATCC 25923) and *Pseudomonas aeruginosa* (ATCC 27853) by broth dilution method. Sterile distilled water used to dilute DMSO was served as the negative control. The results indicated that bactericidal concentrations of DMSO are 80%, 50% and 30% for *E. coli*, *S. aureus* and *P. aeruginosa* respectively. Subsequently, the exact maximum concentrations of DMSO which the tested bacteria can tolerate were also determined by the same method. The obtained maximum DMSO tolerant concentrations were 70%, 40% and 25% for the test organisms accordingly. The results of the experiment suggests the optimal DMSO concentrations to be used to dissolve plant extracts in antimicrobial assays in commonly used bacteria, thus further tests to be undertaken to evaluate the DMSO tolerance limits of some other bacteria and yeast species.

Keywords: DMSO, Plant extracts, Antimicrobial
Antimicrobial Activity of *Mangifera zeylanica* Stem Bark from two Climatic Zones in Sri Lanka

Gunawardana S.L.A.\(^1\), Wickrama W.D.S.A.\(^2\), Kapuwella K.G.A.\(^2\), Siriwardhene M.A.\(^1\), Sirimuthu N.M.S.\(^3\), Gunasekara T.D.C.P.\(^2,4\)

\(^1\)Department of Pharmacy and Pharmaceutical Sciences, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
\(^2\)Department of Microbiology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
\(^3\)Department of Chemistry, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
\(^4\)Center for Plant Materials and Herbal Products Research, University of Sri Jayewardenepura, Nugegoda, Sri Lanka

*gunawardana.shehara@gmail.com*

Abstract

*Mangifera zeylanica* commonly known as ‘atamba’ is an endemic plant in Sri Lanka. In traditional medicine, the stem bark is used for its anti-inflammatory properties. The antimicrobial properties of leaf extracts have also been reported. This study investigates the antimicrobial properties of the stem bark obtained from Rambukkana (intermediate zone) and Neluwa (wet zone). Specimens of *M. zeylanica* stem bark was collected from the two locations, and the plants were authenticated at Bandaranayaka Memorial Ayurvedic Research Institute, Nawinna. The plant barks were separated into inner bark and outer bark, washed with distilled water and air dried. The dried bark was coarsely powdered and extracted into aqueous and methanol. The aqueous extract was freeze dried and the methanol extract was rotary evaporated. The obtained products were dissolved in sterile distilled water to prepare a dilution series of 100 mg mL\(^{-1}\), 50 mg mL\(^{-1}\), 25 mg mL\(^{-1}\) and 12.5 mg mL\(^{-1}\). The antimicrobial activity against *Staphylococcus aureus* (ATCC 25923), *Pseudomonas aeruginosa* (ATCC 27953), *Escherichia coli* (ATCC 25932) and *Candida albicans* (ATCC 10231) were determined using agar disc diffusion and agar well diffusion assay methods. The average zone of inhibition of the extracts were compared with the zone of inhibition obtained by the standard gentamicin discs (10 µg) for bacteria and ketoconazole discs (10 µg) for *C. albicans*. Methanol extracts of Rambukkana and Galle inner bark had antibacterial activity against *S. aureus* with an average zone of inhibition (ZOI) of 20.67 mm while none of the extracts had antimicrobial activity against *E. coli*. The highest ZOI against *P. aeruginosa* (15.33 mm) was found in aqueous extract of Rambukkana outer bark, while Galle outer bark gave a ZOI of (13.33 mm). Methanol extract of Rambukkana inner bark gave an average ZOI of 14.33 mm against *C. albicans* while methanol extract of Galle inner bark had an average ZOI of 11.5 mm. Irrespective of the climatic condition the methanol extract of inner bark of both Rambukkana and Galle samples have shown antimicrobial activity against *S. aureus*. The antimicrobial activity against *C. albicans* and *P. aeruginosa* were shown by Rambukkana outer and inner barks are comparable with the antimicrobial activity shown by the Galle outer and inner barks.

**Keywords**: Antimicrobial, Methanol, Aqueous
Drought Tolerant Microorganisms to Promote the Growth of Finger Millet (*Eleusine coracana*) under Drought Conditions

Dharmarathne H.N.Y.¹, Undugoda L.J.S.¹,², Hennayake H.M.K.N.K.², Mapa M.H.M.M.N.², Imtiaz I.R.², Kodithuwakku K.V.A.T.², Wimalasekera R.¹*

¹Department of Botany, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
²Sara Bhumi Lanka Bio Products (Pvt) Ltd., Dambarawa Estate, Kandy, Sri Lanka
*rinukshi@sci.sjp.ac.lk

Abstract

Finger millet (*Eleusine coracana* (L.) Gaertn) is an important food crop mostly grown in semi-arid and arid regions of Sri Lanka under adverse soil and climatic conditions as rain fed crops. Although, finger millet performs better under extreme environmental conditions such as inadequate soil moisture levels, drought is identified as the major abiotic stress that leads to growth reductions and yield loss. Plant growth-promoting rhizobacteria and fungi are able to promote the growth of plants under stress conditions through the stress defensing capabilities. Therefore, this attempt was to introduce efficient microbial consortia with drought tolerant, Indole Acetic Acid (IAA)-producing, phosphate-dissolving and nitrogen-fixing capabilities which can enhance the growth and yield of finger millet cultivation under drought conditions. Plant growth-promoting bacteria and fungi were isolated from rhizospheres of finger millet plants growing in intermediate zone of Sri Lanka. The isolates were screened for their drought tolerance, nitrogen-fixing ability, phosphate-solubilising ability and IAA-producing ability in vitro. A phosphate-solubilising *Penicillium* sp., a phosphate-solubilising *Rhizomucor* sp., an IAA-producing *Rhizopus* sp., two IAA-producing *Rhizomucor* spp. and seven nitrogen-fixing bacterial species (unidentified) were isolated from the rhizosphere of drought tolerant finger millet plant samples. Rhizosphere of finger millet plants were inoculated with isolated drought tolerant plant growth-promoting bacteria and fungi under artificially created soil moisture deficit conditions. Inoculation of rhizosphere of finger millet plants with isolated crop specific beneficial microorganisms resulted in increased average shoot height, flag leaf width, root length, number of green leaves per plant and early inflorescence compared to the non-inoculated control finger millet plants. Treated 55% of finger millet plants bore panicles after 39 days of the first microbial application while only 25% of the non-treated finger millet plants bore panicles. The results suggest the beneficial effects of inoculating bacterial and fungal consortia towards drought tolerance in finger millet plants.

Keywords: Drought stress, Microbial consortia, Rhizosphere, Finger millet, Growth
Value Addition to Natural Rubber by Enhancing Electrical Conductivity through the Incorporation of Carbon Nanotubes

Mapalagama C.M.¹, Pamunuwa K.M.P.P.K.¹*, Abeyesinghe A.A.D.T.¹, Ekanayake S.A.¹, Sirimuthu N.M.S.¹, Fernando E.J.², Etampawala T.N.B.², Karunanayake L.², Kumarasinghe A.R.³

¹Department of Chemistry, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
²Department of Polymer Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
³Department of Physics, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*p.pamunuwa@gmail.com

Abstract

Rubber sector is the third largest export earner in Sri Lanka thus; natural rubber has acquired the status of a globally significant industrial raw material. Hence, value addition to natural rubber has become increasingly important in developing rubber products with enhanced properties in order to meet the industrial demand. This study was conducted with the aim of improving the electrical conductivity of natural rubber latex through the incorporation of carbon nanotubes (CNT). Electrically conductive rubber materials are important to shield devices from electromagnetic radiation by discharging electrical charges which are accumulated when rubber is used in contact with electro sensitive material. Commercial applications of conductive rubber include; conductive tyres and gloves, stretchable conductors and antistatic coatings. In this study, CNT were synthesised using a chemical method and characterised using Raman spectrometer, UV visible spectrophotometer, XRD analysis, TEM and FT-IR spectrometry. Produced CNT were used as a conductive filler in preparing rubber nanocomposites. A series of rubber compounds were formed by varying the phr of CNT from 0-5. The electrical conductivity of these samples was determined using the Four-point probe conductivity meter and an increase in conductivity was observed compared with the control rubber sample. The electrical conductivity of pristine rubber was found to be 4.58×10⁻⁶ S/m. Addition of CNT showed a thousand fold improvement (2.49×10⁻³ S/m). This value lies in the antistatic range thereby proving its ability to neutralise the accumulated static charges. In addition to electrical conductivity, thermal conductivity and mechanical properties such as tensile strength, young’s modulus, elongation at break, hardness of CNT incorporated latex samples were measured and a significant improvement was observed in these properties. Results of this work give a promising insight towards the development of a novel rubber material with improved electrical and mechanical properties. Therefore, it can be concluded that the incorporation of CNT would be a value addition to natural rubber thus paving the way for the development of a highly profitable export material which will be beneficial for the local economy.

Keywords: Natural rubber latex, Carbon nanotubes, Electrical conductivity
Performance Evaluation of Coconut \((Cocos nucifera \text{ L.})\) Nurseries in Kurunegala District of Sri Lanka


1Department of Plantation Management, Wayamba University, Makandura, Sri Lanka
*gajawyb@yahoo.com

Abstract

Coconut \((Cocos nucifera \text{ L.})\) is the most widely cultivated plantation crop in Sri Lanka, occupying about 416,000 ha of the total cultivated area. Success of establishment of coconut plantation starts with the production of good quality planting materials. Providing high quality seedlings for coconut cultivation has become a challenge to the development of coconut industry in Sri Lanka. Kurunegala is identified as the main coconut growing district in Sri Lanka and 21 established nurseries fulfill the seedlings requirement. These nurseries are categorised in to four categories as Coconut Research Institute Recommended Nurseries (CRIRN), Coconut Cultivation Board Seedling Nurseries (CCBSN), Coconut Cultivation Board Model Garden Nurseries (CCBMGN) and Private Nurseries (PVTN). Formulating a strategic plan for development of high quality seedlings is vital. This study was conducted with the general objective of evaluating the performance of coconut nurseries. This was fulfilled with the specific objectives of identifying the key variables associated with nursery performances in different nurseries and to develop an index (Coconut Nursery Performance Index, CNPI) to quantify the performance and finally rank the estates. In order to investigate the performance of coconut nurseries in Kurunegala district, ten (10) variables were identified namely cost of Production (COP), out turn percentage, land area, labour units, managers’ educational qualifications, managers’ experience, degree of mechanisation, availability of irrigation technology, distance from main road, and infrastructure. Data were collected using a semi-structured pretested questionnaire from 21 nurseries in Kurunegala district. The developed index (CNPI) was used to quantify the performance of the different categories of coconut nurseries. According to the developed performance index, nursery categories CRIN, PVTN, CCBN and CMGN showed the percentages of performance as 22%, 20%, 29% and 29% respectively in Kurunegala district. The lowest COP was recorded in Ibbagamuwa nursery and the highest COP was recorded in Kumari nursery. Lower trend was observed in purchasing coconut seedlings from PVTN. Higher out turn percentage was found in Dodangaslanda, Nikaweratiya and Ibbagamuwa nurseries. In contrast, the lowest out turn percentage was recorded in Melsiripura nursery. It is highlighted that the high education level and experience of managers, availability of new irrigation technology and availability of infrastructures, land area, degree of mechanisation and sufficient labours has significantly contributed in achieving higher performances in coconut nurseries.

Keywords: Coconut, Coconut nurseries, Cost of production, Out- turn, Performance index
Intercropping Agarwood Producing Species with Rubber for Sustaining Income

Dilrukshi P.G.T.1, Subasinghe S.M.C.U.P.1*, Nayanankantha N.M.C.2, Senevirathna A.M.W.K.3, Watawala W.K.S.W.2

1Centre for Forestry and Environment, Department of Forestry and Environmental Science
University of Sri Jayewardenepura, Nugegoda, Sri Lanka
2Department of Plant Science, Rubber Research Institute, Agalawatte, Sri Lanka
3Department of Export Agriculture, University of Uva Wellassa, Badulla, Sri Lanka
*upuls@sjp.ac.lk

Abstract

Sri Lankan rubber industry contributes to country’s economy in significant manner. Anyhow the natural rubber industry has now faced a threat due to the low price. As a solution, financially profitable other species can be intercropped with rubber to maintain sustainable income of the growers. Since agarwood has a very high demand and value in perfume and incense industry, it is worth to assess the feasibility of growing this crop with rubber. Therefore, the current study was conducted for the first time to test the potential of growing three agarwood producing species with young rubber under two intercropping systems, of which rubber is grown as a single row with 12 m and double row with 18 m spacing. The field trial was established using Aquilaria crassna, A. subintegra and the native species Gyrinops walla of family Thymalaeaceae in 2 ha land belongs Rubber Research Institute, Agalawatte in low country wet zone. A. crassna and A. subintegra seeds were imported from Vietnam and Thailand respectively while G. walla seeds were locally collected. All seeds were germinated in a nursery to raise seedlings. Then, one and three rows of agarwood species were planted at 3 m distance between rubber in single and double row systems, respectively. Tree height and stem diameter (30 cm above the ground) were measured at monthly intervals for all agarwood species (152 trees) while those of rubber (174 trees) were measured at six months and two months intervals respectively. Data collected for 4 years were analysed by one-way ANOVA and Student’s t-test. According to the results, G. walla recorded significantly lower height (F=168.58; p=0.000) and diameter (F=77.49; p=0.000) compared to both Aquilaria species in two selected intercropping systems. However, neither its height nor diameter was significantly different between two planting systems of rubber. Only A. subintegra in double row system was significantly taller than A. subintegra in single row and A. crassna in double row. Further diameter was not significantly different between Aquilaria species or planting system. However, the highest average tree height and stem diameter were recorded by A. subintegra in double row system and A. crassna in single row system respectively. Though diameter of rubber plants was not significantly different in two intercropping systems (t=-1.73; p=0.085), height in single row system was significantly taller (t=-3.71; p=0.000). The findings concluded that the growth performance of G. walla, the native species is comparatively lower than that of both Aquilaria species. Further, A. crassna and A. subintegra showed better height growth performances in single row and double row systems respectively.

Keywords: Agarwood rubber intercropping, Aquilaria species, Gyrinops walla, Single row, Double row system
Abstract

Gyrinops walla Gaertn. is endemic to Sri Lanka and naturally populated in the forests and homegardens of lower elevations of the southwest region. It produces a highly valuable fragrant agarwood resin in stems and roots due to a self-defense mechanism, mainly to protect from fungal attacks, by activating secondary metabolic network. This study identified the fungal diversity in agarwood formed stem tissues and associated soils of G. walla trees by analysing genomic DNA of fungal isolates. Sampling of agarwood tissues and soil samples was made in G. walla growing in three different areas of the low country wet zone of Sri Lanka, vis. Neboda and Yagirala of Western Province and Rakwana of Sabaragamuwa Province. Solvent extraction was employed to extract the resin contents of agarwood samples. Surface sterilised tissues were subjected to grow, isolation and identification of fungal isolates. Soil samples were subjected to standard dilution series of plate count technique to isolate the fungi in soil samples. Morphological and molecular data were used to identify fungal isolates from infected tissues and soil samples. Phylogenetic trees were constructed to examine the relationships between the isolates sequence data and reference sequences in GenBank software. Results revealed that the agarwood resin contents of the tissue samples varied from 0.58±0.03% to 3.57±0.24%. Isolates from infected tissues of G. walla were identified as Aspergillus aculeatus, A. flavus, A. niger, A. sojae, Botryosphaeria laricina, Colletotrichum gloeosporioides, Endomelanconiopsis endophytica, Fusarium falciforme, F. proliferatum, F. solani, Nodulisporium indicum and Trichoderma harzianum. The number of fungal colony-forming units (cfug⁻¹) were estimated in the soil as 2-5×10⁸ g⁻¹ at the reproductive stage of the G. walla trees. Among them, Ambifimbra verrucaris, A. flavus, A. niger, A. pseudonomius, A. terreus, F. falciforme, F. solani, Penicillium citrinum and P. reperi were common according to the BLAST analysis. The results confirmed that the infected tissues and soil of G. walla in the natural environment harbors multiple fungal taxa that exist in a complex system leading to agarwood production in the tree stem.

Keywords: Gyrinops walla, Agarwood, Fungal community, Soil, PCR
Potential of Smallholder Rubber Farming Based Agro-tourism-A Case Study in Moneragala District in Sri Lanka

Gunaratne P.K.K.S.¹, Tennakoon T.M.S.P.K.², Edirisighe J.C.³

¹Rubber Research Institute, Ratmalana, Sri Lanka
²Department of Geography, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
³Department of Agribusiness Management, Wayamba University, Makandura, Sri Lanka
*kapila.s.gunarathne@gmail.com

Abstract

Globally, tourism is rated as the fastest-growing industry and agro-tourism is an emerging, sustainable and very prospective sub-sector of tourism in the world which is still at the infant stage in Sri Lanka. This study was carried out to assess the possibilities of the Rubber farming based Agro-Tourism (RAT) in the smallholder rubber sector in Moneragala. The study covered 222 rubber smallholdings in eight rubber growing Divisional Secretariat (DS) Divisions and was conducted in 2019 through a questionnaire survey, focus group discussions and field level observations. Stratified random sampling technique was applied for the household survey. Data were analysed through descriptive and Spearman correlation analysis. Rubber Agro-tourism Potential Index (RAPI) was developed to measure the resource availability in rubber smallholdings to optimise the conditions in need for the development of RAT. The 18 potential rubber farming practices which can be offered to a tourist were identified. Based on the RAPI, Badalkumbura DS division was the most potential resourceful area for development of RAT in Moneragala. The younger farmers are more aware of the agro-tourism. Age (r=0.7578), education level (r=0.6110) and farming experience (r=0.7370) of rubber farmers showed significant relationship with attitude for establishing RAT with 0.05 significant level, while rubber extent and memberships of the societies were not significant. Comparatively, more positive impacts of RAT were highlighted by rubber farmers. Lack of practical exposure to RAT and low level of different language skills were identified as major constraints by the farmers. Findings indicate that smallholder rubber farming based agro-tourism is a potential area to develop in the years to come. This study will enhance the benefits of agro-tourism as a sustainable rural development strategy in Moneragala district.

Keywords: Agro-tourism, Rubber smallholders, Rubber agro-tourism, Potential index
Study of Major Reef Fish Families and Their Feeding Types with Relation to Different Size Variations in three Major Coral Reefs in Southern Province of Sri Lanka

Bandara G.\textsuperscript{1}\textsuperscript{*}, Gunasinghe V.\textsuperscript{2}

\textsuperscript{1}Department of Fisheries and Marine Sciences, Ocean University, Mattakkuliya, Sri Lanka
\textsuperscript{2}Department of Coastal and Marine Resource Management, Ocean University, Mattakkuliya, Sri Lanka
*gayarandy2010@gmail.com

Abstract

Reef fish are vital for reef health as their feeding types disturb the benthic environment. Studies on reef fishes have been supported to conserve and manage both reef fishes and the reef environment. But studies on reef fish are rarely conducted in Sri Lanka. The present study was conducted at the Paraiwella, Polhena, and Hikkaduwa coral reefs in Southern Province in Sri Lanka to study the prominent reef fish families, their feeding habits, and size variations. The Stationary Point Count method (SPC) with 5 m radius water column was used for surveying the reefs. Data were collected between September 2018 to February 2019. Reef fish families, their feeding habits (herbivores, carnivores and omnivores) and their size classes (Small, Medium, and Large) were observed. Reef fish were identified using existing field guides. Twenty-five families were recorded, and among them, four families (Acanthuridae, Pomacentridae, Labridae, and Monodactylidae) showed dominance throughout the reefs. The diversity of reef fish between the three reefs were significantly different (One-way ANOVA, p<0.05). Paraiwella had the highest diversity of reef fish, followed by Polhena and Hikkaduwa reefs. The partial ban of the Paraiwella reef can be a reason for this high diversity. But the highest abundance of fish was recorded in the Hikkaduwa reef. Omnivore was the feeding type of more than 50% of fish followed by herbivores and carnivores. Medium Medium-size fish were the most abundant. As there were some breeding grounds among the reefs, small size fish were the second most abundant. Since this was a preliminary study, continuous studies are recommended to be carried out around Sri Lankan waters spatially and temporally.

Keywords: Reef fish, Stationary point count, Feeding type, Size variation, Sri Lanka
Knowledge, Perceptions and Practices of Undergraduates on the Use of Native flora in Landscaping: A Case Study from a State University in Sri Lanka

Ranasinghe L., Yakandawala K.*, Udayanga L.

Wayamba University, Makandura, Sri Lanka
*yakandawalakapila@gmail.com

Abstract

A plant is considered native if it has occurred naturally in a particular region, without any human introduction. Native species are usually valued above exotics by environmentalists as they are less costly to maintain as they have evolved and adapted to local environmental conditions with minimum inputs. Hence they are recommended to be used in landscaping and restoration projects. Despite their functional values, native ornamental plants are not readily available in the Sri Lankan market as opposed to exotics. Further, according to previous studies, the use of natives in landscaping is not a familiar concept in the country, and the present demand for natives is deficient. Hence, the need to educate the general public on the use of natives and its role in improving biodiversity through landscaping is timely. Therefore, this study was focused to assess the awareness, knowledge, and attitudes of the undergraduates on the use of native plants for landscaping. The study was carried out at the Faculty of Agriculture, the Wayamba University of Sri Lanka, using a structured interviewer administrated questionnaire (n=164) using simple random sampling. The association between native plant knowledge and demographic factors was measured by the Pearson chi-square test where the knowledge level of the undergraduates denoted a significant association with the age (p<0.001), province of residence (p=0.004), and the academic year (p<0.001). A notably higher percentage of undergraduates had a moderate level of knowledge on natives (78.0%), while 3.0% of students were characterised by a very high knowledge level. The native ornamentals are not used by any respondents at the home garden level. However, medicinal and fruit plant usage is established among undergraduates (57.3%), and 22.6% purchased native plants from the local market. Though native ornamentals are not popular among local community, at present, the hotel industry is keen on the use of native plants for sustainable tourism and ecofriendly services. A majority (80.5%) of the participants showed a highly favorable level of attitudes towards natives and medicinal value (Ranked score out of 5 (RS=4.2), drought tolerance (RS=3.7), erosion control potential (RS=3.6), and enhancement of pollinator interactions (RS=3.6) was recognised as the most preferred inherent characteristics. In conclusion, though the knowledge level and use of native fruit and medicinal plants among undergraduates are satisfactory, it is vital to educate them on the potential of native ornamental plants for promoting the concept of using natives in the landscape industry in Sri Lanka as ambassadors to disseminate the knowledge among the general public.

Keywords: Attitudes, Knowledge, Landscaping, Native plants
Wet Climate Drives Melanistic Giant Squirrel *Ratufa macroura melanochora* in Wet Zone of Sri Lanka

Pathirana K., Seneviratne S.S.*

Department of Zoology and Environment Sciences, University of Colombo, Colombo 03, Sri Lanka
*sam@sci.cmb.ac.lk

Abstract

The species; *Ratufa macroura* exists in three different coat colorations. *R. m. melanochora* in Sri Lankan wet forests has morphologically diverged from the *R. m. macroura* in the intermediate zone and *R. m. dandolena* shared between Sri Lankan Dry zone and Mainland India. This study investigated the correlation of geo-climatic parameters with the morphometry and colorimetry of *R. m. melanochora*; the level of divergence of *R. m. melanochora* in morphological and vocal aspects from the other two subspecies; and the exact phylogenetic position of the Wet zone melanistic *R. macroura*. We studied 18 live and fresh specimens of *R. macroura* and 56 preserved museum skins housed at the National Museum, Colombo. We collected blood or fur samples, morphometric and anatomical data, and hair samples. Colorimetric data were obtained using an Ocean Optics portable spectrometer. Both morphometric and pelage-associated characters showed clinal variation with the rainfall and biogeographic distance. Squirrels in wetter areas have dark and long fur while fur length increased with the increasing biogeographic distance from the mainland. Hence the wet zone Giant Squirrels are larger and darker than the other two forms. The conducted multivariate analysis (PCA) to determine differences among three populations showed no clear clustering in both skin and skull morphometric values. The dorsal and ventral coat color gets darker as the cline moves from dry zone to wet zone, which makes the extreme wet zone individuals black in dorsal coloration. The spectral data of *R. m. melanochora* displayed the highest absorbance. The microscopic structure of hair changes distinctly with densely packed melanin granules and fizzy hair with an oval-shaped cross-section, which may be an adaptation to the humid environment that, in-turn may assist in thermoregulation. Other than above mentioned phenotypic characters, *R. m. melanochora* is vocally distinct with chatter calls with higher repertoire, lower pulse frequency, lower pulse duration, and lower amplitudes. The genetic divergence of *R. m. melanochora*, however, is not clear from the rest of the *R. macroura* in Sri Lanka. In minimum spanning networks inferred for cytochrome-b and 12s regions of the genus, the *R. macroura* population in Sri Lanka share the same haplotype cluster. According to the concatenated and coalescent analyses of cytochrome-b and 12s genes, *R. m. melanochora* shares the subspecies status with *R. m. macroura* and *R. m. dandolena*. This shows that *R. m. melanochora* is not genetically distinct as claimed by studied gene regions. This proves that the melanistic form of Sri Lankan Grizzled Giant Squirrel is a unique evolutionary entity shaped by a wet climate in its isolated island habitat.

Keywords: Melanism, Climate, Ratufa, Wet forest, Sri Lanka
Resolving the Phylogenetic Status of *Dicrurus paradiseus* Allospecies Cluster in Sri Lanka

Weerakkody S.¹, Goodale E.², Seneviratne S.¹*

¹Department of Zoology and Environment Sciences, University of Colombo, Colombo 03, Sri Lanka
²College of Forestry, Guangxi University, Nanning, Guangxi, PR China
*sam@sci.cmb.ac.lk

Abstract

The advancement of modern molecular phylogenetic techniques allows the recognition of evolutionary relationships and the objective assessment of whether taxa should be considered as separate species. Here we studied the phylogenetic status of *Dicrurus paradiseus* allospecies complex in Sri Lanka to understand the phylogenetic relationships in a phenotypically conservative but vocally complex group of tropical songbirds. Two forms of *D. paradiseus* are found in Sri Lanka; *D. paradiseus lophorinus* (or *D. lophorinus* to some authors) found in the wet zone of the country, and *D. p. ceylonicus*, which inhibits the dry zone. Using wild-caught drongos and museum specimens across the range of *D. paradiseus*, we examined the phylogenetic relationships among these two taxa and their relative placement in the family Dicruridae. The relevant sequences of 16 species of the family Dicruridae were downloaded from GenBank to construct the phylogenetic tree along with the sequences of Sri Lankan Drongos. The phylogenetic relationship was tested using two nuclear (Myo 2, Cmos) and two mitochondrial (ND2, Cytb) markers from five individuals of *D. p. ceylonicus* and eight individuals of *D. p. lophorinus*, we analysed the phylogeny using a Bayesian inference coalescent-based species tree estimation method. The phylogenetic tree revealed that *D. p. lophorinus* and *D. p. ceylonicus* are paraphyletic with the posterior probability (pp) of 1 and showed a recent divergence. *D. annectans, D. p. ceylonicus* and *D. p. lophorinus* separated from the rest of the species in family Dicruridae by forming a single separate clade in the phylogenetic tree and the posterior probability (pp) of each split in this clade accounts as 1. Based on the phylogenetic analysis, we can conclude that *D. p. lophorinus* can be treated as a separate species when comparing the splitting patterns of the rest of the species in family Dicruridae.

Keywords: *Dicrurus paradiseus*, Allospecies, Phylogeny, Speciation
Foraging Habitat Utilisation of the Lesser Adjutant Stork around Maduru Oya Reservoir

De Silva P.C.W.U., Mahaulpatha W.A.D.*, Dilrangi K.H.

Department of Zoology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*mahaulpatha@sjp.ac.lk

Abstract

The Lesser Adjutant Stork (*Leptoptilos javanicus*) is a globally threatened bird species, a rare resident bird in Sri Lanka. The present study is aimed to determine foraging habitat variables associated with Lesser Adjutant Storks and to propose management implications based on the information gathered to conserve Lesser Adjutant Storks. Major habitat types were identified using field observations and preferred foraging habitat variables of Lesser Adjutant Storks were obtained at the locations where birds were observed from January to December 2019 around Maduru Oya Reservoir for three consecutive days per month (0600h to 1800h) laying three fixed line transects of 5km in each habitat type. The target species used two foraging grounds; seasonal grasslands that are adjacent to the major water body and seasonal pools that appear in the rainy season well away from the major water body. The most preferred seasonal grasslands comprised with high percentages of open water cover (57.00±10.14%) and with a grass cover of 57.66±44.45%. Percentage of sand cover was relatively low (9.81±12.92 %) and average soil penetration was 5.87±5.78 cm while DO in the water was 5.98±0.33 mg/L. Fish availability in the seasonal grasslands was 3.47±3.17 per sweep, frog availability was 1.14±3.73 per square meter and the soil invertebrate availability was 4.29±3.54 per sample. In the second preferred foraging ground, seasonal pools were characterised with high percentages of open water cover (74.00±22.57%) and less grass cover (5.75±8.16 %) with a sand cover of 2.75±4.44%. Average soil penetration was 12.32±6.79 cm and DO in the water was 4.01±1.31 mg L⁻¹. Fish availability in seasonal pools were 2.60±3.00 per sweep of 0.06 m³, frog availability was 6.05±5.95 per square meter and soil invertebrate availability was 3.95±3.75 per sample. Availability of open water and mudflats which determine the food availability of the habitat are important to compensate the energy requirements of Lesser Adjutant Storks. As wading birds require an area to rest amidst foraging, availability of sand cover is of similar importance to make the foraging ground more suitable. This study proves that this vulnerable bird species utilises both fresh water lakes and the surrounding grasslands and seasonal pools for its survival. Thus, it is of major importance to conserve both these habitat types for the conservation of this rare bird species.

**Keywords:** Maduru Oya National Park, Threatened bird species, Wetland birds, Conservation
Habitat Utilisation of Waterbirds in and around Maduru Oya Reservoir

Dilrangi K.H., De Silva P.C.W.U., Mahaulpatha W.A.D.*

Department of Zoology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*mahaulpatha@sjp.ac.lk

Abstract

Wetlands are important bird habitats and waterbirds use them for feeding, resting, breeding and other social interactions. This study was conducted to determine the most important habitat types utilized by waterbirds to exhibit different behaviors, in and around Maduru Oya Reservoir in Maduru Oya National Park from January to December 2019. Bird survey was carried out using the point count method. A common ethogram was constructed to identify the behavior categories of waterbirds. Behavioral data were collected under the main categories of feeding, resting, breeding and comfort activities in three time slots per day; morning (0600-1000h), mid-day (1000-1400h) and evening (1400-1800h). Eight habitat types utilized by waterbirds in and around the reservoir were identified based on field observations; open water, grass, mud, rock, invasive plants, non-vegetative cover, dead trees/logs and trees. Percentage cover of each habitat type was estimated by laying quadrates in a systematic arrangement along three 300 m long fixed line transects once a month. Behavior at the first sight and the habitat type used by waterbirds to exhibit the particular behavior were recorded to determine the habitat utilization. Resting was the behavior category shown by highest number of waterbirds followed by feeding, breeding and comfort activities. Availability of habitat types varied greatly among the months. Percentage cover of grass had increased gradually from March to September with the highest in September (69.27%) while open water was the most prominent habitat type in rest of months. Open water cover was highest in December (91.14%). No invasive plant cover was observed from June to September. Rock cover was increasing from April to September with the highest in September (10.41%). The most utilized habitat type was trees (12982) while the most under-utilized habitat type being invasive plants (363). Significantly high number of individuals used areas of grass, open water and mud for feeding and exposed rocks, dead trees and logs for resting (One Way ANOVA, p<0.05). Ludwigia sp. was the most prominent invasive plant used by waterbirds for resting. Breeding was observed only on the trees. Present study revealed the importance of preserving this large reservoir as an important habitat for the conservation of water birds.

Keywords: Water bird assemblage, Aquatic avifauna, Wetlands, Conservation, Maduru Oya National Park
Phylogenetic Affinities of an Endemic Cloud Forest Avian Relict: Sri Lanka Bush Warbler 
(*Elaphornis palliseri*)

Krishan T.*, Weerakkody S., Senevirathne S.

*Department of Zoology and Environment Sciences, University of Colombo, Colombo 03, Sri Lanka
* ktharindukrishan@gmail.com

Abstract

The endemic Sri Lanka Bush Warbler (*Elaphornis palliseri*) is a unique entity among avifauna of Sri Lanka due to it being an elusive montane relict and being ecologically and evolutionary isolated in the central highlands. This species is the only member of its genus *Elaphornis* as well. However, the phylogenetic affinities of Sri Lanka Bush Warbler remained unresolved over two centuries. This study therefore was aimed at resolving the phylogenetic affinities of this elusive bird using two molecular markers; nuclear Ornithine decarboxylase (ODC) and mitochondrial Cytochrome b (Cytb). Both Bayesian inference and Maximum Likelihood estimation methods were performed to generate best estimated phylogenies. Sri Lanka Bush Warbler manifests its phylogenetic affinities immediately with two Grassbird species (Posterior Probability: 0.87); Bristled Grassbird (*Chaetornis striata*) and Broad-tailed Grassbird (*Schoenicola platyurus*) which are endemic to the Central and Northern regions in India respectively. Together these three species share their affinities with an Afrotropical basal species (Posterior Probability: 0.9); Fan-tailed Grassbird (*Schoenicola brevirostris*). Based on this resolved phylogeny, we identified Sri Lanka Bush Warbler as an Afrotropical avian remnant isolated in the tropical wet zone mountain massif in Sri Lanka, which is an atypical phenomenon as most of the Sri Lankan bird lineages show Oriental affinities.

*Keywords:* Sri Lanka Bush Warbler, Phylogeny, Affinities, Afrotropical, *Elaphornis*
An Investigation of Factors Affecting the Willingness to Pay for Conservation of Mangroves in Negombo Lagoon: A Case Study of North Pitipana in Negombo

Gamage G.R.S.D.*, Upali M.M.R.

Department of Environmental Management, Rajarata University, Mihinthale, Sri Lanka
*grsdgamage@gmail.com

Abstract

Sri Lanka has wide array of coastal wetland ecosystem that harbors significant mangroves diversity. Negombo is very rich of mangrove ecosystem within the lagoon. Mangroves in Negombo lagoon provide variety of eco system services to surrounding community. The overall aim of this research was to an investigation of factors affecting the willingness to pay for conservation of mangroves in Negombo lagoon. Specific objectives were identify the eco system services and service providers and beneficiaries, identify the threats of Negombo lagoon and analyse and evaluate the factors that affect for wiliness to pay for conservation of mangroves in Negombo lagoon. In order to achieve the objectives of this study, required data were collected both from primary sources through questionnaire survey, key informant interviews and field observations. Secondary data were collected from reports, books and research articles. The sample size was 30 households at North Pitipana in Negombo and selected through convenient sampling method. Data was analysed by using SPSS software. The large extent of mangrove ecosystems around the Negombo lagoon have been indiscriminately exploited. Changes and modification are highly affected to exploiting for area of Negombo lagoon. Negombo faces unbearable threats towards mangrove ecosystem by fishery activities and shrimp farming and also development activities make it an extremely vulnerable ecosystem. According to the multiple regression analysis the researcher identified awareness of mangroves (Sig: 0.039) and monthly income (Sig: 0.000) has a positive and significant impacts on willingness to pay for conservation of mangroves in Negombo lagoon. Willingness to pay value estimated through householder’s monthly income. Most of householders have a monthly income of less than 40,000 rupees. Majority of among them are fishermen. Their daily income level is lower. According to the monthly income of householders, estimated that 150 rupees for the average value of willingness to pay. People who awareness about valuation of mangroves endeavor to protect mangroves in Negombo lagoon. This study will contribute to the society and decision makers to conserve mangroves in Negombo lagoon.

Keywords: Mangroves, Negombo Lagoon, Conservation, Payment for eco system services, Willingness to Pay
Breeding Biology of Dull-blue Flycatcher (*Eumyias sordidus*) in Tropical Montane Cloud Forests of Sri Lanka

Dharmarathne W.D.S.C., Mahaulpatha W.A.D.*

*Department of Zoology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*mahaulpatha@sjp.ac.lk

Abstract

Breeding biology of Dull-blue flycatcher (*Eumyias sordidus*) was studied in tropical montane cloud forests of Horton Plains National Park. The study was conducted from March 2016 to December 2018 during the breeding season and each visit five to ten days observations were made. Nests were searched using pole and mirror method. Binocular (NikonTM-Monarch, 10×42) was used to study bird behaviours. Incubation patterns such as on-bout and off-bout duration, nest trips rate and nest attentiveness were studied. Nestling diet was observed using a spotting scope (Nikon MonarchTM, 20-60×82 ED), hidden camera (SJCAM, M20) and faecal sample analysis. Total of 32 breeding pairs were observed during the study period. They laid a single egg 2 to 3 days after completing the nest construction, and another egg was laid within 24 hrs. The mean clutch size was 2±0.54 eggs (n=32), mean egg mass was 2.51±0.04 g (n=15), mean egg length was 21.29±0.32 mm (n=15) and mean egg width was 15.20±0.39 mm (n=15). The average incubation period was 20.1±2.2 days (n=16) and the average nesting period was 14±3.1 days (n=15). During the incubation period, on-bout duration (18.38±6.38 min) and nest attentiveness (78.02±7.51%) was higher in the evening period. Off-bout duration (36.54±6.52 min) was higher in the dawn period. Nest trips rate (6.02±0.67 h⁻¹) was higher in the mid-day. During the nestling period, on-bout duration (4.13±2.08 min) and nest attentiveness (70.83±12.42%) was higher in the morning period. Off-bout duration (3.56±1.42 min) and feeding trips rate (9.47±1.19 h⁻¹) was higher during the mid-day. They have selected ten Orders of invertebrates, one amphibian and two plant species to feed their nestlings. Both sexes participated in incubation and brood rearing. *E. sordidus* were monogamous and single-brooded although some pairs made re-nesting attempts after first nests failed. The overall nest success was 90.62%. Jungle crows were the main nest predators of *E. sordidus*. Therefore, control measures need to be conducted to minimise the disturbances to warrant the protection of future generations of *E. sordidus*.

Keywords: Breeding biology, Conservation, Tropical Montane Cloud Forests, *Eumyias sordidus*
Floristic Survey in Dombagaskanda Forest Reserve in Kalutara District, Sri Lanka

Jayaratne V.C.P., Singhakumara B.M.P.*

Department of Forestry & Environmental Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*balangodasinghe@gmail.com

Abstract

Dombagaskanda (aka Bodhinagala) forest reserve which is a lowland tropical rainforest found in Kalutara District of Sri Lanka and it’s the nearest tropical rain forest that can be reached from the city of Colombo. Bodhinagala forest hermitage and monastery has been in the heart of the forest from 1950s. People visit the monastery and this creates disturbance and anthropogenic pressure to the forest. For conservation and to develop sustainable management strategies for the forest, the floristic composition and richness of the forest needs to be understood. This study was carried out to investigate the plant associations and communities in Dombagaskanda forest reserve, to examine the floristic composition and diversity of the forest reserve along the topographic gradient and to record the endemic and threatened plant species of the forest reserve. Plots of size 20×20 m, 5×5 m and 1×1 m were laid down to record woody perennials of diameter≥5 cm, saplings of height≥1m and seedlings of height<1 m respectively. A total of 18 plots were sampled, 6 each for ridge, mid slope and valley of the forest in purposively selected undisturbed areas of the forest. A total of 98 species belonging to 55 families and 76 genera were recorded. Out of the species recorded, 41(43%) are endemic species, 53 (57%) are indigenous species, two species are invasive and one is exotic (3%). Eighteen globally threatened species and 33 nationally threatened species were recorded. According to the relative density values, the most common species is Horsfieldya iryagedhi and the most common family is Myristicaceae in ridge, mid slope and valley of the forest reserve. The most dominant family in all three altitudes is also Myristicaceae and the most dominant species in ridge and mid slope is Horsfieldya iryagedhi and in the valley Artocarpus nobilis is dominant. When the Shannon's diversity indices are considered, there is no significant difference (p>0.05) in diversity, evenness and dominance in ridge, mid slope and valley of the forest. The data found out through this study can be used to understand the importance of conserving this rainforest and to develop conservation strategies and more studies on soil and disturbed areas of the forest would be of vital importance.

Keywords: Dombagaskanda, Threatened species, Endemic species, Valley, Dominant species
Investigating the Assemblage and Activity Patterns of Mesomammals of Order: Canivora in Maduru Oya National Park Using Camera Trap

Jayasekara E.G.D.P., Mahaulpatha W.A.D.*

Department of Zoology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka

Abstract

Mesomammals of Order: Canivora represent an influential guild of forest vertebrates in the dry zone forests of Sri Lanka. This study was conducted to investigate the carnivorous mesomammal species assemblage and activity patterns in Maduru Oya National Park (MONP). Camera traps are increasingly used to study species activity patterns and temporal overlap among sympatric species as well as other heterospecific groups. In this study, camera trap surveys were conducted from January 2019 to May 2020 using 47 camera stations with a cumulative sampling effort of 1,410 trap days. Camera station locations were spatially arranged in a semi-random approach and camera locations were changed after operating 24 hours for a period of <30 days to increase the spatial coverage. Camera traps were stationed to represent all the habitat types present in MONP. Time stamp data on captured photos/videos were used to analyse mesomammal activity patterns. Nine of the 12 mesomammal carnivores present in the country were recorded in MONP. With a capture frequency of 184 and a recording rate of 13.05 (per 100 camera-trap days) Ruddy mongoose (*Herpestes smithii*) was the most abundant species recorded followed by Ring-tailed civet (*Viverricula indica*). Eurasian otter (*Lutra lutra*) and Rusty-spotted Cat (*Prionailurus rubiginosus*) were the rarest species with a recording rate of 0.14. Based on the activity pattern analysis, Sri Lankan Jackal (*Canis aureus naria*) and all mongoose species displayed diurnal activity patterns. Golden palm civet (*Paradoxurus zeylonensis*) and Ring-tailed civet were highly nocturnal. Fishing cat (*Prionailurus viverrinus*) with a relatively high recording rate of 4.33 was observed to be displaying some plasticity in its activity patterns being active in both nocturnal and diurnal hours. It would reduce overlapping of activity with other species such as Ring-tailed civet. The study reveals the coexistence of mesomammal carnivores in MONP and the temporal variation in activity patterns of different carnivore species. MONP can be identified as an important protected area for the mesomammal carnivores of the island due to the availability of suitable habitats to provide habitation to a considerable amount of species present in the county.

Keywords: Activity patterns, Dry zone, Camera trapping, Species abundance, Species co-occurrence
Morphology and Morphometrics of Egg Masses of Fall Armyworm, *Spodoptera frugiperda* (Lepidoptera, Noctuidea) in Sri Lanka

Kasige R.H.*, Pallewatta N., Dangalle C.D.

Department of Zoology and Environment Sciences, University of Colombo, Colombo 03, Sri Lanka

* r_heshani@yahoo.com

Abstract

Morphological and morphometric studies on the life cycle stages of a species, specifically the egg stage, provide a sufficient guide in identifying the species from its initial stage. This study was aimed at egg mass characterisation of The Fall Armyworm (*Spodoptera frugiperda*) (FAW); an economically important pest worldwide. Eggs were reared in the laboratory and measurements such as the position of the egg mass, colour, shape, arrangement, number of egg masses per plant and clutch size were obtained. A total of 36 egg masses were studied. Spherical shaped, cream coloured eggs were deposited very closely like a string of beads in flat, single or double layered masses. Majority of the egg masses (72.2%) were single layered. Eggs were firmly attached to the leaf with a sticky substance. Most of the egg masses were found on the underside of Maize leaf blades which is a well-known adaptation of most insect herbivores like lepidopterans. Egg masses were covered with hair-like strands which can be attributed as a mechanism to avoid desiccation. However, 47.22% of the egg masses were partially covered with hairs while only 11.11% of the egg masses were covered fully which also included all egg masses obtained from field. The presence of ridges and transverse lines in eggs were noticeable Noctuid characters in eggs. A considerable variation was observed in number of egg masses laid by a female and its clutch size, which are measures of fitness of adult females. The clutch size varied from 9-200 eggs with an average of 73 eggs but varied from 100-500 eggs in field conditions in previous records. Newly hatched females deposited larger number of eggs but the older females deposited few or no eggs. Thus, the age of the adults also affected their fecundity. The average diameter of an egg was 0.43 mm and the egg stage duration varied with temperature and humidity of the external environment such as having 3-5 days under laboratory conditions. This study provides a baseline for future studies of this pest moth identification and characterisation using morphological and morphometric measurements of the egg stages. The study recommends, sensitising farmers and making them aware of life history characteristics of FAW, thus early detection can be led to early eradication of this pest species, before the emergence of the highly destructive larval stage.

Keywords: *Spodoptera frugiperda*, Fall Armyworm, Egg mass, Morphometrics, Sri Lanka
Diversity and Infestation Level of Nest-dwelling Ectoparasite in Five Types of Bird Nests in Sri Lanka

Kulatunga V.S., Perera I.C., Dayawansa P.N.*

Department of Zoology and Environment Sciences, University of Colombo, Colombo 03, Sri Lanka
*nihal.dayawansa@sci.cmb.ac.lk

Abstract

Nest-dwelling ectoparasites represent a part of nidofaunal community and bird nests play a role as a miniature ecosystem by providing food, refuge and a suitable microclimatic condition for these ectoparasites to successfully reproduce their generations. This study focused on the nest-dwelling ectoparasite infestation in relation to five types of bird nests (Cup, Pendulum, Dome, Platform and Cavity) which were represented by eighteen common bird species in Sri Lanka. During the study 180 individual nests were sampled. Ectoparasites were collected using a portable electric mini vacuum cleaner. A total of 1,506 nest-dwelling ectoparasites were extracted from the nest sample collection by saltwater filtration method. They were represented by hematophagous mesostigmatic mites (Order Mesostigmata), snout mites (Family Bdellidae), beetle mites (Family Oribatulidae), dust mites (Family Glycyphagidae) and one type of bird louse Columbicola columbae. When considering the parasitic infestation in relation to the nest type, cup shaped nests showed the highest percentage of infestation (31.70%) and the lowest percentage of infestation was seen among cavity nests (9.30%). The percentage of ectoparasitic infestation in nest types can be organised in descending order: Cup nests (31.70%), Dome nests (29.46%), Pendulum nests (15.98%), Platform nests (13.56%) and Cavity nests (9.30%). The infestation of cup nests, dome nests and pendulum nests were dominated by dust mites while the platform nests were dominated by hematophagous mesostigmatic mites. Since birds use diverse strategies to reduce the infestation of nest-ectoparasites due to their wide-ranging effects on birds with consequences on their morphology, physiology and behaviour this basic study provides an idea on the effect of nest type as another strategy to reduce the nest-ectoparasite infestation. Further studies should be carried out to investigate the influence of nest type and nest material to reduce the nest-ectoparasite infestation by avifauna.

Keywords: Bird nests, Nest-Ectoparasites, Nest types, Parasitic infestation
Assessment of the Blue Carbon Stocks Including Mangroves, Sea Grasses and Salt Marshes in Puttalam, North West Sri Lanka

Gobisankar S.*, Ranasinghe. D.M.S.H.K.

Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*gobishankarsathiyamohan@gmail.com

Abstract

Blue Carbon is the carbon stored in mangroves, tidal salt marshes, and seagrass meadows within the soil, the living biomass above ground (leaves, branches, stems), the living biomass below ground (roots), and the non-living biomass (litter and dead wood). These ecosystems remove carbon from the atmosphere and oceans, storing it in plants and sediment, where it is known as “blue carbon.” In fact, coastal ecosystems are some of the most carbon-rich ecosystems on Earth. But they are also the most threatened. And once they are degraded or destroyed, their blue carbon stores are released as carbon dioxide and contribute to global climate change. Therefore, the main objective of the study is the assessment of the blue carbon stocks including mangroves, sea grass beds and salt marshes. Puttalam Lagoon and the Ocean in North West Sri Lanka were selected for the study as all three ecosystems are available in this area. This area is located in the dry zone having average temperature of 29-32°C and average annual rainfall 100-110 cm. With regards to the mangroves, both naturally grown mangroves and planted mangroves of 25 years age were sampled in Soththupitya and Anawasala areas located surrounding the Puttalam Lagoon. Sea grass beds and salt marshes were sampled in Anawasala area. With regards to the mangroves, belt transects from the shore towards the land were taken. Nested circular plots having 7 m radius were established, large trees were sampled for diameter and height. Small trees (<5 cm dbh) were sampled in 2 m radius. Litter, pneumatophores and seedlings were sampled in plots of 30×30 cm area. Soil samples were taken at depths; 0-30 cm, 30-60 cm, 60-100 cm for the measurement of bulk density and carbon content. In total 13 plots were sampled for natural mangroves while 8 plots were sampled for planted ones. With regards to sea grass beds and salt marshes, belt transects were set up along the coastline and 1×1 m plots sampled. 15 plots were sampled for sea grasses while 37 plots were sampled for salt marshes using destructive sampling. The collected soil and vegetation samples were taken to the laboratory in clean polythene bags, oven dried to a constant weight. Based on published literature, the carbon content of the plant matter taken as 35% of the dry weight. In mangroves, allometric equations developed in the published literature were used to assess the aboveground and below ground biomass using diameter as the variable. The total organic carbon in the collected soil samples were done using Loss on Ignition Method. According to the results, the carbon content of the natural mangrove ecosystem including plant parts and the soil is 377.17 t/ha. The planted mangroves recorded a lesser amount of 228.66 t/ha. The carbon content in the salt marshes was 18.24 t/ha while the figure for sea grasses was 65.87 t/ha.

Keywords: Blue carbon, Salt marshes, Sea grasses, Mangroves, Carbon content
Fish Waste of *Anguilla nebulosa*, *Anguilla bicolor*, *Carcharhinus* sp. and *Netuma thallasina* for Production of Fish Oil

Zabith S.H.M.1*, Pathirana H.M.K.K.2

1Institute of Chemistry, Rajagiriya, Sri Lanka  
2University of Ruhuna, Matara, Sri Lanka  
*zabithhameed@gmail.com*

Abstract

Fish waste is currently used in certain countries to produce fish oil. In Sri Lanka, most of the fish processing industries discard fish waste and it has caused a huge environmental problem. In addition to that Sri Lanka does not produce fish oil and it is imported. Therefore the objective of the present study was to use fish wastes to produce good quality fish oil by using solventless microwave extraction which is a green method. For *Anguilla nebulosa*, *Anguilla bicolor* (eel) and *Netuma thallasina* (Giant Marine Catfish) skin, viscera, flesh and head region were used and for *Carcharhinus* sp. (Shark), liver was used. The best heating conditions were identified by using different temperatures and different heating periods. The best conditions for catfish and shark were 2 min. at 90°C and for eel it was 4 min. at 130°C. Crude oil was obtained by filtering the extracts using a clean cotton cloth and then centrifuging at 2,800 rpm for 10 min. Crude oils were refined by treating with 2% (w/w) bentonite for 30 min. The yield of oils from eel, catfish and shark were 8.4%, 14.1% and 63.2%, respectively. Quality of fish oils were determined by measuring the peroxide value, saponification value, iodine value and free fatty acid level (FFA) by following AOCS methods. Except the free fatty acid level, other parameters of all three fish species agreed with the recommended levels. FFA level of eel (0.25%) and shark (0.56%) agreed with the recommended level (1-7%), but the value for catfish was high (8.3%). Bentonite treatment reduced it to an acceptable level (0.23%). Above treatment increased the peroxide value to 12.4 (mEq/kg) but it was less than the recommended maximum. Fatty acid profiles were studied for eel and catfish oils. Monounsaturated fatty acids were found in the highest amounts (40.6-49.8%). Catfish oil is a better source for PUFA (9.2%) and DHA (2.2%) than the eel oil (PUFA, 0.9%; DHA, 0.8%). Fish oils from wastes of above three fish species are good sources for monounsaturated fatty acids. Oil from the wastes of catfish is a good source for PUFA especially for docosahexaenoic acid (DHA). The approach of producing fish oil from fish waste will solve the environmental problems caused by fish waste and also help to improve the economy of the country.

Keywords: Fish oil, Fish waste, Microwave-assisted extraction, Bentonite
Coir Fibre Ret Liquor Treatment by Fenton Oxidation and Coagulation

Siriwardhane U.*, Cooray A.

Department of Chemistry, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*upesha.siriwardhane@gmail.com

Abstract

Coir fibre is extracted from the mesocarp of the coconut fruit through a process called retting, in which the coconut husks are immersed in water to loosen the fibres. In the retting process, a considerable amount of organic matter is leached out to the surrounding water. The resulted water is called "coir fibre ret liquor", which creates adverse effects on the environment. The main objective of this study was to reduce the Chemical Oxygen Demand (COD) value of the ret liquor using the Fenton process and to optimise the reaction parameters used. A laboratory prepared ret liquor sample was used in the experiments and the COD values were measured using the open reflux method. The sample had an average COD value of 1,934 ppm. The Fenton process was employed to treat the sample and the parameters used in the Fenton process, Fe(II) concentration and H₂O₂ concentration were optimised. The obtained results indicate that when 1.00 mL of 10% of H₂O₂ and 1.00 mL of 0.1 M Fe(II) solutions which have initial weight ratio of, H₂O₂/Fe(II) 10.8 were used to treat 100 mL of ret liquor sample at pH=3, about 94% of total COD removal could be obtained, and the final COD of the sample was 64 ppm at the end of five hours. Within the first hour of the treatment colour removal, more than 80% of COD removal, and a large amount of Fe(II) consumption were observed. It was identified that the COD reduction of the sample mainly occurred through ferrous coagulation and by Fenton reactions. In the sample that was treated with optimised amount of Fenton reagent 53% of COD was removed through ferrous coagulation. The results obtained for Fe(II) control samples suggested that the COD of ret liquor also can be reduced using ferrous salt. When samples were treated with 10.00 mL of 0.1 M Fe(II) solution 93% COD reduction was obtained.

Keywords: Fenton, Coagulation
Hotel Sewage Sludge Derived Biochar as an Adsorbent for Aqueous Cadmium Removal

Mudiyanselage R.B. 1*, Mantilaka P. 2, Senarathne T. 2

1University of Ruhuna, Matara, Sri Lanka
2University of Peradeniya, Peradeniya, Sri Lanka
*anjnadananjind@gmail.com

Abstract

The hotel industry is considered to be one of the main sources of sewage sludge. Sewage sludge (by-products) of wastewater treatment is considered as water, inorganic and organic materials removed from wastewater. These by-products coming from various sources through physical, chemical, and/or biological treatments. Cadmium is a non-essential heavy metal available in water sources accumulated through both natural phenomena and anthropogenic activities. Direct and indirect accumulation of Cadmium in tissues through food and drinking water causing various diseases and disorders. Thus, developed biochar from hotel sewage sludge Sri Lanka and its applicability to remove aqueous Cadmium ions was studied. In this study, the biochar was synthesised pyrolysing the sewage sludge in a muffle furnace at 450°C. To maintain an oxygen-free atmosphere during the process, nitrogen was supplied to the system at a 200 mL/min flow rate. The temperature increase rate was set at 17°C/min. The pH, EC, total solid (TS), total fixed solid (TFS), and total volatile solids (TVS) were determined in sewage sludge. Then the synthesised biochar was characterised by X-ray diffraction (XRD), particle size analyser, and scanning electron microscopy (SEM). Furthermore, the Cadmium removal efficiency of synthesised biochar was tested with different concentrations of Cadmium solutions, pH levels, adsorbent dosages, and contact times. Atomic adsorption spectroscopy was used to analyse the Cadmium concentrations in water samples. The results were, pH (5.46), EC (1270 µs/cm), TS (55 mg/mL), TFS (14 mg/mL) and TVS (41 mg/mL). The maximum Cadmium removal percentage of 100% was obtained with 8 pH, 50 mL of 25 mg/L Cadmium solution, and 0.150 g of the synthesised biochar. Adsorption data were fitted with the Langmuir adsorption isotherm model and adsorption kinetics were fitted with a pseudo-second-order model with R² = 0.9924. The study presents a viable option for removing Cadmium ions in water to desirable levels as a means for controlling Cadmium related health issues while sustainably controlling the sewage sludge.

Keywords: Adsorption, Biochar, Heavy metal, Sewage sludge
Abstract

The textile and apparel industry is Sri Lanka’s largest manufacturing sector, accounting for 44 percent of total exports in 2018. Sri Lanka takes pride in leading sustainable apparel manufacturing in the region. This industrial sector is a key contributor to generating income for local communities, especially for women. However, the traditional lifecycle of the industry is centered around the "Take/ Make/ Use/ Dispose" model. This linear approach utilises excessive amounts of resources, including water and energy during its manufacturing process that creates negative environmental and social impacts. Furthermore, there is limited consideration on the possibility of valorising the products at the end of their lifecycle which leads to large volumes of waste ending up in open dumps. Previous studies have uncovered opportunities for integrating circular economic principles into the manufacturing sector. However, there is limited research on best practices that could enable textile manufacturers to ‘close the loop’. The aim of this study, therefore, is to evaluate best practices in waste and water management in the Sri Lankan textile industry using a circular economy as a theoretical framework. The study investigates best practices in 7 large-scale textile companies in Sri Lanka. This study adopted a mixed-method approach which included a questionnaire survey and in-depth interviews with sustainability personnel of the companies. Data were cross-checked with reports submitted to organisations such as the Central Environment Authority, Global Reporting Initiative and the UN Global Compact. Data were analysed using a thematic analysis to identify the best practices. The findings show that the best practices include recycling and upcycling textile waste, co-processing waste, utilising sludge from wastewater treatment to make bricks, rainwater harvesting for washing and gardening, water intensity reductions and sustainable procurement. As such, the key findings highlight that through a number of initiatives and best practices, the selected companies actively promote the circular economy and try to integrate sustainability into their business strategy. The authors highlight the importance of improving data availability and transparency. It is also recommended to establish Zero Emission Export Processing Zones in Sri Lanka. Furthermore, sharing these findings could assist small and medium textile companies in the country and in the region to evaluate their current practices, and in so doing, identify best practices that they could implement in transitioning to a circular economy.

Keywords: Textile industry, Circular economy, Wastewater, Sri Lanka
Pyrene Degradation Ability of Phyllosphere *Bacillus* Species Bacteria Inhabiting the Urban Areas in Sri Lanka


1 Faculty of Graduate Studies, University of Sri Jayewardenepura
2 Department of Biosystems Technology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
3 Department of Zoology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
* lankaundugoda@sjp.ac.lk

Abstract

Polyaromatic Hydrocarbons (PAHs) are a diverse group of ubiquitous hydrophobic organic contaminants which have a wide range of diversity around seventeen polycyclic aromatic hydrocarbons and these compounds are released from the incomplete combustion of organic matter, emissions from automobile exhausts, stationary matter and domestic matter, area source matter such as forest fires and agricultural burning and also in food. Out of many polyaromatic hydrocarbons, pyrene is concerned as a major environment pollutant. Pyrene is composed with three fused benzene rings. Remediation of pyrene from the environment is essential because of their toxic affect to the health. Out of many remediation methods bioremediation is the most eco-friendly and effective method which can be used to convert toxic substances to nontoxic substances. There are many phyllosphere microorganisms which have the capability in pyrene like polyaromatic air pollutant degradation. Therefore this attempt is to isolate, select and identify the efficient pyrene degrading bacteria. Bacteria were isolated using leaf samples of *Ixora chinensis*, *Ervatamia divaricate*, *Plumeria sp.* *Hibiscus rosa-sinensis* and *Amaranthus cruentus* collected from Panchikawatta, Orugodawatta, Pettah, Maradana, Colombo Fort and Sapugaskanda oil refineries like polluted areas in Sri Lanka. Pyrene degradation ability of isolated phyllosphere bacteria was primarily screened using plate assay method. Subsequently, pyrene degradation ability of each bacterial species was further analysed using the UV-Vis spectrophotometer and High-performance liquid chromatography (HPLC).

The selected bacterial isolates were identified up to species level through PCR amplification of a fragment of 16S rRNA gene and sequencing the amplified fragments using the primers 1492R (GGTACCTTGTTACGACTT) and 27F (AGAGTTTGATCMTGGCTCAG). Four *Bacillus* species *Bacillus* sp. P2B-02, *Bacillus velezensis*, *Bacillus* sp.1 and *Bacillus megaterium* were able to degrade more than 90% of pyrene. Out of these bacteria, *Bacillus* P2B-02 (Accession no: MN190154) and *Bacillus megaterium* (Accession no: MN190174.1) were the most efficient bacterial species which was highly capable in degradation of pyrene with 100% of degradation. The results of the present study clearly clarify the potential use of the phyllosphere *Bacillus* species in remediating environment contaminants such as pyrene. The *Bacillus* species could be beneficial as potential biological agent in bioremediation for polluted environments with pyrene like polyaromatic hydrocarbons.

*Keywords:* Phyllosphere, Aromatic hydrocarbon, Bioremediation, Pyrene, *Bacillus* species
Estimation of Methane and Carbon Dioxide Gas Emissions from a Municipal Solid Waste (MSW) Open Dumpsite in the Tropical Climate

Herath P.L.*, Jayawardana D.T., Bandara N.J.G.J.

Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*priyathpriyara@gmail.com

Abstract

Rapid urbanisation and economic growth have led to accelerating the municipal solid waste generation. Open solid waste dumpsites are a primary anthropogenic source of greenhouse gases, mainly Carbon dioxide (CO$_2$) and methane (CH$_4$). However, minimal studies are available on quantification of the emissions, particularly in Sri Lanka. Therefore the present study aims to estimate CH$_4$ and CO$_2$ flux rate from the open dumpsite in Karadiyana, Sri Lanka which has been functioning for over 30 years. The dumpsite under study was split into eight different cells according to the surface variations. The gas emissions are estimated using the standard static flux chamber technique. Chamber volume and surface coverages were 0.1 m$^3$ and 0.2 m$^2$, respectively. The total sample size is 140, with three replicates at each sample location. Moisture and organic content of the surface layer were measured, and necessary surrounding environmental conditions such as atmospheric pressure, temperature, and relative humidity were measured with the sampling. Results indicate that the flux rates are highest in trench areas where leachate is flowing (36,854 and 139,657 mg m$^{-2}$ h$^{-1}$) while it is lowest in the cell of mixed waste covered with a layer of compacted soil (110 and 400 mg m$^{-2}$ h$^{-1}$). High values were also reported from the cell of old mixed waste saturated with water/vegetation grow on the waste (14,659 and 58,817 mg m$^{-2}$ h$^{-1}$) and the cell with slightly degraded organic waste/ wet (9,864 and 60,716 mg m$^{-2}$ h$^{-1}$). Low values were reported from cells of New wet organic waste (6,687 and 52,652 mg m$^{-2}$ h$^{-1}$), highly thick (around 5 m) organic waste covering the old mixed waste (5,627 and 2,433 mg m$^{-2}$ h$^{-1}$), Old mixed waste covered by vegetation (2,382 and 4,943 mg m$^{-2}$ h$^{-1}$) and Old mixed waste/ recently mixed (656 and 400 mg m$^{-2}$ h$^{-1}$). The flux rate of CH$_4$ and CO$_2$ of each cell were mentioned, respectively. The moisture content of the surface layer has shown a positive correlation with both CH$_4$ (0.82) and CO$_2$ (0.66) flux rate. Meanwhile, Organic content is also positively correlated with CH$_4$ (0.59) and CO$_2$ (0.49). Wet conditions create an anaerobic environment and lead to fermentation, acetogenesis, and methanogenesis. These processes produced a considerable amount of both types of gases, and the results obtained in this study showed a positive correlation (0.85) between CH$_4$ and CO$_2$ emission rates. Compacted soil layers trap the gases and decrease the emission rate.

Keywords: Emission, Greenhouse gases, Calculation, Waste

Abeywickrama H.G.K.*, Jayaratne K.P.S.C.

Department of Physics, University of Colombo, Clombo 03, Sri Lanka
*kavindi.abeywickrama@gmail.com

Abstract

Currently, there is no system in Sri Lanka for real-time measurement and transmission of data of environmental Greenhouse gases (GHG). Due to global warming and other harmful effects, these data are essential to implement environmental-control measures in a country. This study is aiming at designing a cost-effective device capable of measuring and transmitting the real-time data of components of GHG vis. CO₂, NO₂, CH₄, together with relative humidity and temperature. The proposed system consists of gas sensors (MICS-6814, MG-811, MQ4, DHT11), Real-Time Clock (RTC+storage) and Wi-Fi/GSM modules and a data logger feeding to a processing interface for visualisation and presentation. The prototype capable of measuring all of the above parameters was built, and its transducers are calibrated. The instrument was tested for its robustness in real climate conditions and feasibility of long-distance transmission of data from a base station to the server. It is planned to reproduce five more similar instruments to take simultaneous measurements of greenhouse gases percentages in different places in the country.

Keywords: Measurement of Greenhouse Gases, Greenhouse Gas Sensors
Mechanochemical Conversion of Ilmenite to Synthetic Rutile: A Green Technology


Department of Applied Earth Sciences, Uva Wellassa University, Badulla, Sri Lanka
*chandimasubasinghe00@gmail.com

Abstract

Titanium minerals such as ilmenite (FeTiO$_3$), leucoxene (altered ilmenite) and rutile (TiO$_2$) are economically imported in the global heavy mineral market. In this regard, high quality ilmenite, leucoxene, and rutile concentrates can be directly used as feedstock for TiO$_2$ pigment production. However, lower quality ilmenite requires prior processing to titanium slag or synthetic rutile. Chemical routes such as Sulphate and Chloride processes are traditionally followed to prepare synthetic rutile from ilmenite. However, chemical methods yield environmentally unfriendly by-products such as iron(III) chloride and acidic iron(II) sulphate. Consequently, the current study is focussed on upgrading Sri Lankan ilmenite using crystalline vein graphite and commercially available sulphur as reducing agents. In this mechanochemical method, the ball milling induced Sulphurisation and carbothermic reductions were examined using X-ray diffraction (XRD), X-ray fluorescence (XRF), Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM) and particle size analysis. XRF results suggest that raw ilmenite was characterised by over 95% of FeTiO$_3$, ~2% of SiO$_2$, ~1% of Al$_2$O$_3$ and the rest compensated by other minor elements. Ilmenite was mixed with a combination of sulphur and vein graphite in three ratios by weight as 1:1, 2:1 and 4:1. These mixtures were uniquely milled for 4 hours and 6 hours each. The reduction in the intensity of sulphur and graphite peaks and the broadening of ilmenite peaks in XRD spectra obtained after milling. It indicates a possible dissolution of sulphur and graphite into the ilmenite structure through cleavage planes. The incorporation of additives into the ilmenite structure was confirmed using the SEM images. Pseudorutile peaks observed in the XRD spectra of milled samples. Each sample was separately annealed at 800$^\circ$ C, 1,000$^\circ$ C and 1,200$^\circ$ C respectively. Consequently, the effective temperature was determined to be 1,000$^\circ$ C. Each ratio produced similar results and the optimum ratio was obtained at 4:1. The pseudorutile peaks were disappeared whereas, brookite and rutile peaks appeared in the XRD spectra of the annealed samples. It was concluded that mechanical attrition applies beneficial outcome on the diminishing temperatures of ilmenite reduction. Consequently, this environmentally friendly method could be applied to convert ilmenite to synthetic rutile.

Keywords: Ball milling and isothermal annealing, Ilmenite, Sulphur and vein graphite, Environmentally friendly
Water Hardness Removal by Coconut Shell Activated Charcoal

Rajapaksha R.A.J.J.¹*, Pallege P.T.S.², Coswatte A.C.W.W.M.C.L.K.¹

¹Department of Animal Science, Uva Wellassa University, Badulla, Sri Lanka
²Department of Applied Earth Sciences, Uva Wellassa University, Badulla, Sri Lanka
*jayanirajapaksha94@gmail.com

Abstract

Excess water hardness is a problem in many parts of the world including Sri Lanka. It is a measure of the quantity of divalent ions such as Calcium and Magnesium. The long-term consumption of hard water has directly been associated with a number of challenges including the Chronic Kidney Disease (CKD) in Sri Lanka. Therefore, removal of water hardness has become a challenging issue for all communities especially in underdeveloped areas, who mostly rely on groundwater sources. Thus, it is important to reveal water softening applications with the aim of providing safe drinking water by introducing the low-cost natural materials. The most common means of reducing water hardness rely on reverse osmosis or ion-exchange resin but according to the traditional knowledge in Sri Lanka, coconut shell activated charcoal has been used to purify well water. The present study was aimed to check the truthiness and the most suitable amount of activated charcoal to reduce water hardness as the shells of the Cocos nucifera is a cheap and easily available source to produce activated charcoal in Sri Lanka. Activated charcoal of the coconut shell was prepared by heating at 350º C by 15 minutes at Muffle furnace. Natural hard water samples were collected from three selected water sources near the research site in Badulla with the 300 mg/L hardness. Three replicates were done for each dosage of 15 g, 20 g and 25 g activated charcoal with the controller and water hardness was determined by the EDTA titrations. All the data were analysed using the one way anova. According to the results there was a significant difference between initial water hardness (300mg/L) and final water hardness of samples within the two hours time period. Water hardness removal efficiency was calculated, and it was between 40%-50% within that time period. When increasing the weight of the coconut charcoal the water hardness removal efficiency was increased by 2% respectively Water hardness removal efficiency became into the range between 50%-60%, within the increasing time period up to four hours in each sample. Therefore, it is a more effective water softening natural material that can be easily used in day to day life and it is one of the best alternatives which can be used as an efficient purifier of water with low cost.

Keywords: Activated Charcoal, Water Softening, Water Hardness Removal Efficiency, Coconut shell
Influence of Street Tree Canopy on the Microclimate of Urban Eco-Space

Bandara R.¹*, Rupasinghe H.², Halwatura R.², Jayasinghe G.¹

¹Faculty of Agriculture, University of Ruhuna, Matara, Sri Lanka
²Faculty of Engineering, University of Moratuwa, Katubadda, Sri Lanka
*ranahansibandara@gmail.com

Abstract

Rapid population and urban growth increase the vulnerability of tropical cities to climate change. Substantial modifications in urban eco-space with current development trends and urbanisation create Urban Heat Island (UHI) effect. UHIs represent dense urban areas within cities where the temperature is recorded to be higher than those located in suburbia. UHI induces through low albedo surfaces, building geometry and loss of green infrastructure in urban setting, causes a huge influence on the quality of life of urban dwellers. Expanding urban forest through street tree planting is considered as one of the most cost-effective means of mitigating the urban heat island effect and associated expenditures for air conditioning. This study evaluates (a) the relationship between the radiation cut off by street tree canopy and the changes in ambient temperature and the RH in Colombo Metropolitan Region (CMR) (b) the street tree species with the highest thermal and RH benefit from the abundant street trees in CMR (c) the average ambient temperature and RH benefit to the urban environment from street trees through a simulation study using ENVI-met 4.4 software version. Hence, the study comprises with a field assessment along six main selected streets in Colombo city and a computer-based simulation study using ENVI-met 4.4. The ambient temperature change and the RH change under the street tree canopies in the CMR has a positive correlation with the amount of radiation cut off from the tree canopy. From the studied street tree species *Mesua ferrea* recorded the highest thermal and RH benefits and those were 3.8° C and 7.2%, respectively. Simulation study indicated that by increasing the street tree canopy by 2, 3 and 4 folds than existing, the modelled area of CMR (Wellawatta city) can receive a thermal benefit of 1.280° C, 1.37° C, 1.63° C and a RH benefit of 1.99%, 2.77%, 3.94%, respectively. Hence, the average ambient temperature drop and RH increase from a single tree to a wider area (Wellawatta city) was 0.53° C and 1.34%, respectively. Consequently, by enhancing urban forest cover through strategic establishment of street trees urban environment and outdoor thermal comfort of tropical Sri Lanka can be enhanced effectively.

Keywords: ENVI-Met, Street trees, Urbanisation, Urban Heat Island (UHI).

Puthumailolan K.¹, Pathmanathan S.¹*, Saravanjan S.², Christie T.A.¹

¹Department of Botany, University of Jaffna, Sri Lanka
²National Water Supply and Drainage Board, Vavuniya, Sri Lanka
*sevvel@univ.jfn.ac.lk

Abstract

A continuing worldwide problem for drinking water is the presence of microorganisms particularly algae in water sources. This algal population density is varying with seasonal changes and the quality of water is significantly reduced by algae especially Cyanobacteria which has the capability of producing toxins. In this study, the analysed water samples were collected from Peraru water reservoir located in Vavuniya. The impact of the seasonal changes on the algal population, detection of algal toxin and the different toxic removal approaches were also investigated. This study was conducted during the period of October 2019 to February 2020. A total of seventeen algal taxa were identified from the selected areas and 11 taxa belonged to green algae, 6 taxa belonged to blue green algae (Cyanobacteria) and diatoms. Among them, Microcystis sp. was found to be 17%. It was also found in the study that, the total population density of algae increased in summer and decreased in rainy season. Aerated water of the water treatment plant from the water reservoir contains 0.2 ng mL⁻¹ concentration of microcystin toxin. In the water treatment plant, initially the concentration of the microcystin toxin was reduced from 0.2 ng mL⁻¹ to 0.14 ng mL⁻¹ by coagulation/flocculation. After that, the toxin concentration reduced from 0.14 ng mL⁻¹ to 0.116 ng mL⁻¹ by Granular Activated Carbon (GAC) treatment. So that, the water treatment plant removes 42% of total toxin from the initial concentration. According to the WHO guidelines, 1 µg L⁻¹ microcystin toxin is safe for the person who drinks 2 liters of water per day. Therefore this water treatment plant achieves this guideline efficiently.

Keywords: Algae, Microcystis sp, Microcystin toxin, Algal population density, Granular activated carbon
Green Approach to Develop Antimicrobial Fabric using *Garcinia zeylanica* and Tea Waste Extract

Alwis M.K.S.C.¹, Bogahawatte L.B.A.E.², Gunasekara T.D.P.C.²,³, Jayaweera P.M.¹, Kumarasinghe K.G.U.R.¹*

¹Department of Chemistry, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
²Department of Microbiology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
³Center for plant materials and herbal products, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*upulk@sjp.ac.lk

Abstract

Recently, there is an upsurging interest in textile industry towards production of antimicrobial fabrics due to their potential for reducing the transmission of infections. These products are of greater interest in sportswear industry and medical/healthcare industry due to the high moisture content that aggravate the microbial growth in sportswear and high exposure to pathogenic microorganisms in hospital settings. Fabric provides a hospitable growth surface to microorganisms resulting in irritation of the skin, development of body odor and finally deterioration of the fabric. The main objective of this study was to develop an antimicrobial fabric using a natural origin in a sustainable manner. Natural antimicrobial agents are important in terms of their bio-compatibility, eco-friendliness and low or zero toxicity to human body. *Garcinia zeylanica* which is an endemic plant to Sri Lanka and tea dust are two natural resources that can be easily found in the country. Aqueous and ethanolic crude extracts of these were characterised using UV-Vis spectra and, FTIR spectroscopic techniques and Total Phenolic content studies. Aqueous and ethanolic extracts of *G. zeylanica* showed inhibition of 120.5 mm and 140.5 mm against *Escherichia coli* respectively and inhibitions of 140.5 mm and 170.5 mm against *Staphylococcus aureus* respectively. Aqueous and ethanolic extracts of tea dust showed inhibition of 100.5 mm and 130.5 mm against *S. aureus* respectively. Optimisation of the dyeing pH and temperature were carried out and on cotton, nylon and polyester fabric in order to compare the effect of dyeing on natural fibers vs synthetic fibers. Using aqueous and ethanolic solutions of concentration of 5% by weight of the solvent the pre-mordanted fabric (by ferrous sulphate) were dyed, under the optimised conditions. The antimicrobial activity of aqueous and ethanolic extracts of *G. zeylanica* and tea dust were investigated using well-diffusion assay whereas the antimicrobial activity of dyed fabric were investigated via disc-diffusion assay. Aqueous and ethanolic extracts of *G. zeylanica* and tea dust showed pronounced inhibition against *S. aureus* and *E. coli* while no antifungal activity was observed against *Candida albicans*. Polyester fabric dyed from ethanolic extract of *G. zeylanica* and tea dust showed inhibition of 90.5 mm and 120.5 mm against *S. aureus* respectively, when a discs of 6 mm were used. Hence, it can be concluded *G. zeylanica* and tea dust can be used to give fabric an antimicrobial finish naturally.

**Keywords:** Green approach, *Garcinia zeylanica*, Tea waste, Antimicrobial, Fabric, Ferrous sulphate, *Staphylococcus aureus*, *Escherichia coli*
Microwave Assisted Solvent-Free Green Approach to Synthesis of Oxindole Derivatives using Surface Modified Silica from Rice Husk Waste


1Department of Chemistry, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
2Department of Microbiology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
3Center for Plant Materials and Herbal Products Research, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*shymwijekoon226@gmail.com

Abstract

Designing new synthetic schemes for synthesis of biomedical significant compounds in environmentally benign manner is an emerging challenge. Microwave assisted solvent-free synthetic methodology for drug synthesis address our future challenges by maximising atom economy and minimising by-product formation. Oxindole nucleus is a ubiquitous pharmacopore found in variety of pharmaceutical active compounds having extensive range of biological applications. There are different types of methodologies for synthesis of 3-benzylidene-indolin-2-ones by modifying oxindole nucleus with different functional groups. Major disadvantage associated with the above methods is usage of environmentally hazardous solvents. The present study introduce a novel green approach to synthesise 3-benzylidene-indolin-2-ones from naturally occurring aldehydes in solvent free conditions under microwave irradiation. (3-Aminopropyl) triethoxysilane (APTES) modified silica was used as the catalyst for the above reaction. Silica was extracted from rice husk waste collected from Polonnaruwa, Sri Lanka. Further it was activated using concentrated hydrochloric acid. APTES was immobilised on activated rice husk silica to attached amino functionality on the silica surface. Surface amino functionality of the APTES-Silica facilitate the reaction between oxindole and aldehydes. The reaction afforded targeted compounds in high yield within 12 minutes under the microwave irradiation. Percentage yield of the compounds A, B and C was 91%, 87%, 88% respectively. The silica supported catalyst was characterised by thermogravimetric analysis (TGA) and showed a similar weight loss as reported in the literature. Synthesised compounds were characterised by Fourier-Transform Infrared Spectroscopy (FTIR), Nuclear Magnetic Resonance Spectroscopy¹H NMR) and melting point analysis. Melting points of the compounds A, B and C were 174° C, 178° C and 205° C respectively. FTIR spectra showed that the characteristic peaks for the main functional groups present in the compounds.¹H NMR spectra of the resulting compounds confirmed that the expected products were successfully synthesised. Microwave assisted synthesis is a rapid efficient and environmentally safe green method in the synthesis of 3-benzylidene-indolin-2-ones derivatives. Further silica obtained from rice husk waste can be effectively modified to use as a solid catalyst in the synthesis of biologically important compounds of medicinal interest.

Keywords: Microwave assisted, Solvent free, APTES-Silica, Oxindole, 3-Benzylidene-Indolin-2-Ones
Removal of Drinking Water Taste and Odour Causing Compounds using Modified Sand Filter; Green Solution via Biotechnology

Ganegoda S.*, Pathmalal M.M.

Department of Zoology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*sathyaganegoda@yahoo.co.uk

Abstract

Formation of odorous and tasty compounds in drinking water, specially earthy and musty taste and odour (T and O) compounds have been a common and recurrent issue in drinking water sector. Although the health aspects of water are the primary focus, consumers generally judge the quality of water by its aesthetic value. T&O compound episodes are the cause for most consumer complaints and rejections related to portable water where flavour and smell of the water is the only measure of water quality for the end-user. Geosmin (trans-1, 10-dimethyl-trans-9-decalol) and 2-MIB (2-Methylisoborneol) are the responsible earthy and musty taints in drinking water. Hence, removing these two odorants from drinking water is a necessity for worldwide water authorities and consumers. Although there are several other methods available to remove T&O compounds in drinking water, with the inherent drawbacks and higher costs in all other methods, biodegradation has been proved to be a better approach to provide a sustainable solution. Therefore, the current study was designed to construct a modified sand filter entrapped with Geosmin and 2-MIB degrading bacteria in order to remove T&O from water. Gram positive aerobic B. subtilis was selected and entrapped into rice husk-based biochar in the biological layer of the sand filter where biological degradation occurred. Experimental results revealed that the modified biochar layer with aeration removed over 36% of Geosmin and over 50% of 2-MIB from water within 18 hours. In contrary the non-aerated experiment showed only 22% of removal of Geosmin and 25% of 2-MIB. Interestingly, although the non-aerated experimental setup showed complete removal of Geosmin within 48 hours, the aerated experiment showed a complete removal of Geosmin within 30 hours. Similarly, aerated setup removed 2-MIB in 30 hours while the non-aerated setup removed 2-MIB within 54 hours. Thus, the series of experiments clearly depicted that the modified biological layer with biochar and flow aerator significantly (p<0.01) increased the degradation rate and drastically reduced the time of incubation, making this solution more industrially feasible.

Keywords: Modified sand filter, Biodegradation, Geosmin, 2-methylisoborneol, Aeration
Development of Zeolite Based Repellent Formulations for the Sustained-Release of *Ruta graveolens* Essential Oil against *Sitophilus zeamais*

Perera W.*, Karunaratne S., Chinthaka M., Siriwardhene A.

*University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*wathsalaud@gmail.com*

Abstract

Essential oils (EOs) and their derivatives are considered to be greener alternative means for controlling many harmful insects, which have been used in stored-product insect pest control for centuries. However, application of EOs turns out to be limited, because of their rapid volatilisation associated with low stability. The present study was sought with the objective of developing aroma delivery formulations, for the slow release of *Ruta graveolens* EO, using biodegradable zeolite matrix as the release retardant of EO, to be applied as a repellent against *Sitophilus zeamais* for an extended period of time. The EO was isolated from the leaves of *R. graveolens* via hydrodistillation under laboratory conditions and incorporated into zeolite mineral matrix, at a weight ratio of 1:3, producing 300 mg of the powder formulation. The powder formulation was then evaluated for repellent potential against *S. zeamais* for an extended time period, characterised via analytical techniques of Scanning Electron Microscopy (SEM) and Thermogravimetric Analysis (TGA) and performed pre-compression assessments. For more convenient application purposes, a tablet was produced from the EO-zeolite powder blend by direct compression method, for which repellent and post-compression assessments were performed. Both powder and tablet aroma delivery systems of *R. graveolens* EO exhibited effective control on *S. zeamais* producing over 90% repellent activities for a prolonged time period of 90 days. Characterisation studies confirmed better incorporation of the EO to the parent zeolite matrix and high degrees of thermal stability of the formulation. Pre-compression assays elicited effective flow properties of the powder formulation to be compressed in the production of tablets and post-compression assays of resultant tablets depicted excellent handling properties for its commercial exploitation to be used in the integrated insect pest management programs.

**Keywords:** *Sitophilus zeamais, Ruta graveolens, Essential oil, Sustained-release formulations*
ISO 14000 Series of Standards, Emerging Needs and Expected Contribution from Stakeholders

Bandusoma L.H.D.*

Sri Lanka Accreditation Board for Conformity Assessment, Colombo 03, Sri Lanka
*lhdbandusoma@gmail.com

Abstract

Standardisation in the field of environmental management systems and tools in support of sustainable development are being carried out by the International Organisation for Standardisation (ISO) through its Technical Committee ISO/TC 207 and its various subcommittees. Standards developed by ISO/TC 207 are commonly named as ISO 14000 family. Up to now, 45 standards already developed on consensus and published as voluntary standards and 20 more are in the pipeline of standardisation. ISO 14000 family focuses on specific approaches such as audits, communications, labelling and life cycle analysis, as well as environmental challenges such as climate change. Organisations implement ISO 14000 family standards to demonstrate their environmental performance and commitment to manage environmental responsibilities in a systematic manner as it contributes to the environmental pillar of sustainability. In accomplishment of environmental objectives, support of conformity assessment services such as testing, inspection and certification available in the market is vital factor. Selection of suitable and credible conformity assessment services is burden to Environmentalist or anyone work for any organisation, enforcement and regulatory bodies and policy makers on environment in the country. Reliability and credibility of conformity assessment services and competency of bodies performing conformity assessments are ensured through accreditation process. A review of ISO 14000 family against the thematic areas of the symposium was conducted as primary data collection method under descriptive qualitative studies. The document review found that there are 32 standards related to Forest and Natural Resource Management, 14 standards related to Biodiversity and Ecological Health, 28 standards related to Climate Change and Disaster Management, 10 standards related to Sustainable Land Use and Urban Development, 14 standards related to Biomass and Sustainable Energy, 23 standards related to Waste Management and Pollution Control, 23 standards related to Wood Science, Wood and Non Wood Industry, 14 standards related to Environmental Economics in Resource Management, 14 standards related to Geology, Soil and Water Resource Management, 18 standards related to Environmental Engineering and Green Technology and 23 standards related to Corporate Responsibility and sustainable tourism. This article aims to provide an overview on ISO 14000 family standards in relation to thematic areas of the symposium and open up new window for environmental community to extend their research and development activities towards compliance & monitoring in accordance with international standards and revisit and amend existing environmental regulations, introduce new policies/regulations to facilitate emerging environmental needs and convert business processes to improve environmental performance.

Keywords: ISO 14000 Family, Monitoring and compliance, Conformity assessment accreditation regulations
Understanding the River Basin Classification of Sri Lanka

Katupotha J.1*, Gamge S.G.2

1University of Sri Jayewardenepura, Nugegoda, Sri Lanka
2Open University, Nawala, Sri Lanka
*katupotha@gmail.com

Abstract

The need has arisen to understand the rivers and river basins as a subject for achieving related policy making, development, conservation and management goals. The interpretation of the river basins concept was first attempted by Hunting Survey Corporation Limited, Toronto, Canada, and Surveyor-General of Ceylon (Sri Lanka) in 1962. Consequently, Arumugum in 1969 explained that the island could be divided into 103 components of natural river basins. Unfortunately, in the past six decades, misinterpretation of said river basins with rivers and misunderstanding of river drainage patterns have been identified many research articles and even in the Sri Lankan educational system. Most of the authors and scientists have misinterpreted the number of rivers in Sri Lanka as 103, and they flow radially from the Central Highlands to the sea. The present study is focused on providing clarifications of the river basin concept, rivers and understanding the drainage system of the island. Therefore, river basin maps and digital elevation models were developed to understand the river basins, river origin locations and flow patterns. These data coupled with previous field observations were then used to critically evaluate existing scientific literature. Accordingly, there are 29 rivers (15 perennial and 14 seasonal rivers) that flow directly to the sea. This could be further categorised as drowned river valley, bar-built perennials, bar-built seasonal, perennial delta estuaries, and seasonal delta estuaries. Considering the origin of these 29, only 8 rivers begin from the central highlands and its margins (over 1,200 m contour line), and most rivers/Oya emerge below the 1,200 m contour line. Another 64 rivers/Oya found out to be emptied into lagoons even though traditionally classified as flows directly to the sea. Mahsilawa, Katupila Ara, Pallakutti Ara and Rathmal Oya identified as rivers, but they connect to other rivers or salt marshes while, Bolgoda lake, Madu Ganga, Madampe lake, Telwatte Ganga, Rathgama lake and Koggola lake turned out to be back-barrier coastal lagoons mistakenly identified as rivers in the traditional classification. Also, all these originate from the coastal plain (below 100 m contour line). Hence, it is clear that there are some misreading of river basins and rivers in existing scientific studies. As this information is valuable in many ways to the country, misreading of these subject matters must be corrected immediately. Further studies on the river basins concept must be done analytically and the context of the Sri Lankan education system should be updated accordingly.

Keywords: River basins, Misunderstanding, Radial drainage, Central highland, Sri Lanka.
Determination of the Relationships between Consumption of Rice (*Oryza sativa*) With Heavy Metals and the CKDu Prevalence in Riddemalliyadda, Sri Lanka

Karunaratna I.H.1*, Liyanage J.A.1,2

1College of Chemical Sciences, Rajagiriya, Sri Lanka.
2Department of Chemistry, University of Kelaniya, Dalugama, Sri Lanka. *karunarathnaimasha4@gmail.com

Abstract

Chronic Kidney disease of unknown etiology (CKDu) is one of the major national health problems in Sri Lanka, and the dietary patterns of people can be considered as one of the causative factors for this kidney malfunctioning. Rice is the staple food in every metal among the CKDu patients, which gets supplied from their own paddy fields and nephrotoxic contaminants in the environments like toxic metals can be easily transported through rice. Therefore, the present study attempts to determine of the relationships between consumption of rice (*Oryza sativa*) with toxic metals and the CKDu prevalence in Riddemalliyadda-south, Badulla district, Sri Lanka. Triplicated ten rice grains samples (ground and powdered) were analysed by inductively coupled plasma mass spectroscopy (ICP-MS) for heavy metals such as lead, chromium, nickel, zinc, copper, iron and manganese followed by microwave digestion. The mean metal concentrations in (mg/kg) of rice grains were Pb;1.23±0.29, Cr;6.68±0.15, Ni;3.15±0.23, Zn;19.34±0.16, Cu;2.75±0.37, Fe;52.60±0.15, and Mn;7.77±0.27. Human health risk assessment via rice consumption was determined by calculating the estimated weekly intake (EWI) comparing with the Provisional Tolerable Weekly Intake (PTWI), which has been set by FAO/WHO. Calculated EWIs (mg/kg) for the concerned metals were 0.051(Pb), 0.28(Cr), 0.13(Ni), 0.81(Zn), 0.12(Cu), 2.19(Fe), and 0.32(Mn) respectively. EWIs for Pb, Cr, Zn, Fe, and Ni were exceeding the PTWI values and EWI for Cu complied with the PTWI levels. Hazard Quotient (HQ) is used to determine the non-carcinogenic effects of the consumption of rice. All the metals concerned in these samples HQ is less than one, therefore no significant risk of systematic toxicity. The total hazard index for rice consumption was 0.00387 with relative contribution of metals, Pb(41.97%), Cr(0.607%), Ni(21.478%), Zn(8.782%), Cu(9.375%), Fe(10.236%) and Mn(7.556%). According to the HQs, the analysed metals can be responsible for the concerned health risk in the order of Pb>Ni>Fe>Cu>Zn>Mn>Cr. Hence rice in the sampling area was more or less contaminated with heavy metals, long-term exposure to those metals can be cause for the kidney malfunctioning and the CKDu prevalence in Riddemaliyadda-south, Sri Lanka. Therefore, farmers are strictly advised to adhere to the rules imposed by the government and to follow health guidelines in cultivating their paddy fields.

Keywords: CKDu, *Oryza sativa*, EWI, Hazard Quotient, Long-term exposure.
Use of M-Sand for Manufacturing Concrete Paving Blocks for Sri Lankan Roads

Chathuranga R.A.I.¹, Udamulla K.M.L.A.²*

¹University of Wolverhampton, United Kingdom
²Department of Civil Engineering, Open University, Nawala, Sri Lanka
*lakshika0807@hotmail.com

Abstract

Sri Lanka is a developing nation undergoing many infrastructure development activities consuming more resources and civil engineering materials. River sand is one of the key raw materials that is used in civil engineering construction. Its scarcity compared to the rate of development has been a major issue in the construction industry. To overcome this issue and cater to the country’s demand, Manufactured sand (M-sand) has been identified as a cost-effective alternative to the river sand. This work investigates the possibility of using M-sand to manufacture concrete paving blocks. The paving blocks were cast in proportions of M-sand: natural sand in proportions of 100%:0, 75%:25%, 50%:50%, 25%:75% and 0%:100% for three series of Grade 15, Grade 25 and Grade 30 respectively. The mix proportions for Grade 15, 25 and 30 were 1:3:6, 1:1.5:3 and 1:1:2. The water-cement ratio of 0.5 was used for all three grades of concrete mixes. The compressive strength, unpolished slip resistance, and water absorption tests were carried out as prescribed in the Sri Lanka Standard 1425: part1:2011, the specification for concrete paving blocks: part 1-requirements. According to this specification the average compressive strength of class 1, 2, 3 and 4 denotes 50, 40, 30, 15 N/mm² respectively. In series 1 (Grade 15), all samples achieved the adequate compressive strength of the strength class 4. When considering series 2 (Grade 25) all samples achieved a satisfactory level of strength in class 3. When considering series 3 (Grade 30), M-sand: river sand 75%:25 and 25%:75 achieved the satisfactory compressive strength of strength class 2 and 1. The unpolished slip resistance values for all samples in the three series were greater than 55, thus complying with the standard. The water absorption of series 1 was around 6% as prescribed in the standards. However, the water absorption of series 2 and series 3 samples (except for the control sample-100% river sand) gave slightly higher values than the prescribed value. Results show that M-sand could be used as an alternative to natural sand in concrete paving blocks, thus safeguard the natural sand resources. The study will help to prevent river sand mining and related environmental hazards and develop a low-cost alternative method of paving block manufacturing.

Keywords: Concrete paving blocks, M-sand, Compressive strength, Water absorption, Unpolished slip resistance
Analytical Hierarchy Process for Comparison of Organic and Chemical Farming of Tea Small Holdings in Baddegama, Galle

Jayasinghe D.1*, Wijesinghe M.1, Gunawardena U.A.D.P.2, Mohotti K.3, Thatsarani W.T.V.4

1University of Colombo, Colombo 03, Sri Lanka
2Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
3Tea Research Institute, Talawakalle, Sri Lanka
4University of Ruhuna, Matara, Sri Lanka
*jayasinghedinali@gmail.com

Abstract

Tea Small Holders in Baddegama, Galle typically use chemical fertilisers and pesticides for their tea cultivations. However, in recent years, there has been a gradual transition to organic and non-chemical practices, including a variety of soil conservation techniques such as stone hedges, live fences, lock and spill drains. Yet, no quantitative comparative studies have been carried out in Sri Lanka on these aspects for tea small holdings.

The present study broadly intends to compare costs and benefits related to four categories of tea small holdings which include: Organic plots with soil conservation (ORG+SC), Organic plots without soil conservation (ORG-SC), Chemical plots with soil conservation (CHE+SC) and Chemical plots without soil conservation (CHE-SC), selecting five plots per each category. Physical, chemical and biological parameters and economic parameters were used to estimate overall soil condition and quality in a given plot. The physical and chemical parameters included soil retention capacity and the nitrogen and carbon content. The diversity and abundance of soil organisms was selected as the biological parameter. The economic indicators were the income received from tea and other plants and the cost of production. The Analytic Hierarchical Process Method (AHP), a multi criteria analysis was adopted to select the best category that provide optimal benefits under small tea holding conditions.

The physicochemical parameters of soil retention and nitrogen and carbon content were more positive in the organic tea plots. The biological parameters such as earthworms, biological activity and arthropods in the soil were significantly higher in the organic plots. Benefit cost ratio of tea production for the small tea holders was higher in the organic plus soil conservation plots. AHP provided the ranking of the selected categories as ORG+SC, ORG-SC, CHE+SC and CHE-SC.

The study highlights the importance of understanding environment issues holistically. In order to understand the sustainability of a system both economic parameters and non-economic parameters have to be considered.

Key words: Analytic Hierarchy Method, Organic farming, Soil Conservation
Improving Organisational Sustainability Performance through Integrated Green Production Collaboration (GPC) and Environmental Management Actions (EMA) in Agro Based Manufacturing Sector in Anuradhapura District


Department of Environmental Management, Rajarata University, Mihintale, Sri Lanka
Department of Business Management, Rajarata University, Mihintale, Sri Lanka
Department of History, Rajarata University, Mihintale, Sri Lanka
*kaushimallawaarachchi555@gmail.com

Abstract

Green Production Collaboration is a key consideration in day-to-day business decisions. It is those formed by the people who living in employing the Eco-wisdom, knowledge and practices handed down and working system. The protection of eco management actions plays an important role in inducing technological change and facilitating sustainability growth. A number of researches have explored the benefits and the status of agro based manufacturing sector in Sri Lanka. However, research in Sri Lanka has little attention focused on external or institutional factors for sustainability with to greening process. This study aimed to fill this research gap by testing the relationship between Green Production Collaboration and Environmental Management actions and sustainability performance from a novel capabilities perspective. Therefore, this paper will look into the importance of greening for agro based firms and increasing sustainability performance. The objectives of this study are to exploring the global literature on impacts of going green production collaboration and environmental management actions on agro based manufacturing sector’s sustainability performance in Anuradhapura District, to identify the best various types of green production practices and environmental management actions and finally identified how impacts between green production collaboration and eco management actions on firm sustainability performance in Anuradhapura District. The authors proposed unique ideological and methodological framework for developed to realise the objectives. Therefore, it is necessary to integrate firm’s sustainability performance. The researchers offer key issues, challengers and needs of agro based firms in Anuradhapura District. The data is taken through survey. Researchers selected 100 manufacturing sector organisations in Anuradhapura district by using convenience sampling method. Based on the literature review, questionnaires and the interviews with the practitioners, a proposed set of ten critical success factors separately (five green collaboration factors and five environmental management actions) and three performance measures with triple bottom line was developed. Regression, correlation and descriptive analysis were used in the analysis of collected data. This study found that variables of green production collaborations and green management actions have a positive significant impacts and positive relationship on Organisational sustainability performance. This study will contribute to the all the society, decision makers and policy makers. The results also provide various implications for managers and present some suggestions for future researches.

Keywords: Anuradhapura district, Environmental management actions, Green production collaboration, Manufacturing sector organisations, Organisational sustainability performance
Factors Associated with the Technical Efficiency among Coconut Smallholders’: A Case Study in Kurunegala District of Sri Lanka

Nuwarapaksha T.D.¹, Liyanage, K.L.D.B.P.¹, Pushpakumara A.W.S.¹, Karunarathne K.H.M.I.¹, Dunsford L.B.², Gajanayake B.¹*

¹Department of Plantation Management, Wayamba University, Sri Lanka, Makandura, Sri Lanka.
²Civil Aviation Training Centre, Ratmalana, Sri Lanka.
*gajawyb@yahoo.com

Abstract

Coconut industry plays an important role in the economy of Sri Lanka and as a source of rural livelihood. More than 497,000 ha of land is under coconut cultivation which is dominated by the smallholders’ sector. Coconut smallholders’ contributes 75% of the area (371,220 ha) and contributes 60% to the national production. Currently, The coconut productivity (yield/ha) by smallholders’ shows a high variation, also the nut production depends heavily on environmental production conditions that are largely exogenously determined. In this study, the technical efficiency of coconut smallholders was estimated to identify the potential to increase the production without incurring additional cost for farm inputs. Study further investigated the factors associated with the technical inefficiency, productivity change and the technology gaps among smallholders. Data collection was done using a pretested questionnaire based survey covering 200 coconut smallholders’ in 15 Coconut Development Officers divisions in Kurunegala district. According to the stochastic frontier production function with Cobb-Douglas model employed, land extent (p=0.03), labour (p=0.09) and organic fertiliser cost (p=0.09) showed significant positive effects on coconut smallholders’ production efficiency. Cost of Dolomite (p=0.06) affected significantly and showed a negative effect to the production. The mean technical efficiency of the coconut smallholders’ was 73%. According to the inefficiency model, the inefficiency could be decreased significantly as a result of farming experience (p=0.05), livelihood (p=0.03) and participation in farmer training (p=0.08). However, technical efficiency decreased with the existence of higher education qualification to the smallholder (p=0.007). Coconut smallholders’ faced low productivity due to market constraints, lack of technology and government and non-government institutional related constraints. These findings are vital to formulate policies towards increasing productivity and technical efficiency among coconut smallholders’ in Kurunegala district of Sri Lanka.

Keywords: Coconut smallholders’, Resource use efficiency, Stochastic production frontier, Technical efficiency
Comparison of Conventional and Organic Modes of Low Country Tea Cultivation using Life Cycle Approach: A Study in Neluwa DS Division, Sri Lanka

Rodrigo H.C.I.1*, Gunawardena U.A.D.P.1, Abeygunawardena P.2

1Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
2Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka
*chamali.iroshani@gmail.com

Abstract

Tea industry is the fifth highest foreign exchange earner for the country. Despite such benefits, it generates significant environmental impacts along its entire life cycle. Environmental impacts of organic and chemically intensive tea cultivation practices of Sri Lanka has long been a controversial topic, hampered in part by lack of adequate evidence. The present study therefore aimed to quantify and compare the key environmental impacts along the life cycle of low country organic and conventional tea cultivation using Life Cycle Assessment framework.

The methodology involved four steps: goal and scope definition, life cycle inventory preparation, life cycle impact assessment and interpretation. Input-output data were gathered from small holder farmers in Neluwa DS division. Twenty one organic farmers and 15 non-organic farmers were selected. The functional unit was considered as 100 kg of fresh tea leaves. Six impact categories were considered, namely global warming, eutrophication, atmospheric acidification, human toxicity, terrestrial eco-toxicity and aquatic eco-toxicity. In order to determine the impact categories from the identified emissions, CML-IA baseline method in SimaPro 9.1 was used.

Significant differences were observed between organic and non-organic modes of cultivation under the selected six impact categories. Chemically intensive cultivations showed nearly five times higher global warming potential and eutrophication potential, nearly three times higher atmospheric acidification potential and over 330 times higher human toxicity potential compared to organic tea cultivations. It can be concluded that organic tea cultivation contributes to lower environment impacts than conventional tea cultivation methods. Greenhouse gas emissions from organic farming can further be reduced by nursery establishment and organic fertiliser production within close proximity to the tea cultivation. Implications for policy include the need to provide adequate incentives to encourage the practicing of organic tea farming in order to pave the way for a more sustainable industry.

Keywords: Life cycle analysis, Tea cultivation, Environmental impacts
Household Preferences and Willingness to Pay for Improved Solid Waste Management Services in Colombo 15, Sri Lanka

Addrell M.J.J.*, Gunawardena U.A.D.P.

Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Nupegoda, Sri Lanka
*vithy1996@gmail.com

Abstract

Inefficient collection and improper disposal of household solid waste is a common issue in urban areas of developing countries. A major part of the municipal waste management budget is allocated to the collection of the waste. In order to encourage sustainable solid waste management the quantity of the waste produced must be reduced. The main objective of the study is therefore to estimate the quantity current household generation, to analyse the composition and to understand waste separation and waste disposal practices of households in the study area.

Colombo 15 was selected as the study area. A face to face questionnaire survey was conducted from August to September in year 2020 among 100 households and the waste quantification measurements were recorded for a week. The waste was measured using a scale before it was collected by the municipality. The questionnaire intended to collect information on socioeconomic data, current waste collection practices, willingness to pay for better service and their attitudes.

Results indicate that average daily waste generation was 2.319 kg per household and 0.584 kg per capita. According to the data 84.3% of the waste generated is organic waste, 6.2% is polythene and plastic and 5.6% is paper and cardboard. Among the practices observed in the study area the separation was up to the satisfactory level. Even though waste collection is a free service people in the study area are paying on average LKR 29.22 per month and willingness to pay for an improved waste collection was estimated as LKR 41 per month per person. Data also shows that around 85% of the residents are willing to pay more than LKR 100 for a better collection service. The determinants of the willingness to pay were income, quantity of waste, respondent’s age and educational level.

Managing waste properly is essential for building sustainable and livable cities and it is important to design and implement efficient waste collection services taking into account household preferences.

Keywords: Household waste generation, Willingness to pay, Improved waste collection
Commuter Preferences and Willingness to Pay for Light Rail Transit System: A Study along the Proposed Green Line

Gunawardena U. A. D. P.*, Jayakody H., Samarasekara N.U.

1Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
2Western Region Light Rail Transit Project, Ministry of Urban Development and Housing, Sri Lanka
*prsanth@sjp.ac.lk

Abstract

Colombo city receives about 1.96 million daily passengers and large proportion of private vehicles. This has led to high road traffic congestion and declining peak hour traffic flow speed. The Light Rail Transit (LRT) system is proposed as a solution both to improve the public transportation and to ease the traffic issues in the urbanised core area of the Western Region of Sri Lanka. However, commuter preferences and aspirations towards such an LRT system remains unknown. The main objective of the study is therefore to investigate commuter preferences along the proposed Green Line which connects Kelaniya railway station and Moratuwa railway station with a length of 28.7 km and eighteen LRT stations. The study was based on primary data collected in 2019 using a pretested structured questionnaire. A total of 327 commuters were intercepted close to the proposed stations located between Moratuwa and Kirulapone. Data were collected on their socioeconomic characteristics and willingness to pay for the proposed LRT system. Results indicate that age of respondents range from 19-63 years with a mean of 37 years. Around 90% of the respondents have educational qualifications above ordinary level and 37% are graduates. More than 80% are employed and 59.63% are government employees. Public transport is popular among the respondents and 47.7% used buses. Majority had expressed concerns on the comfort issues of the public transport. Mean willingness to pay is LKR 79.18 and the participants who are using cars have the highest willingness to pay of LKR 155.33. Males are more willing pay compare to females and education contributes positively to the willingness to pay. Respondents who are working in private sector have higher willingness to pay compared to government employees. Private vehicle users have higher willingness to pay compared to users of public transport. Holding the other variables constant, willingness to pay will decrease with increase of travel distance. The results of the study will provide better guide to policy on desirability of the proposed project which could contribute to the economic and social development of the Western Region and improvement of urban environment.

Key words: Light rail transit, Willingness to pay, Commuter preferences
A Study on the Compression Strength Performance of Finger Joints in Commonly Used Timber Species in Sri Lanka


1State timber Corporation, Battaramulla, Sri Lanka
2Department of Civil and Environmental Engineering, University of Ruhuna, Matara, Sri Lanka
3Department of Agriculture Engineering, University of Ruhuna, Matara, Sri Lanka
4Department of Crop Science, University of Ruhuna, Matara, Sri Lanka
*ck_muthumala@yahoo.com

Abstract

Finger joint technique is used to eliminate wood defects which weaken the strength of sawn wood plank. The variation of compression strength of seven wood species commonly used for manufacturing furniture in Sri Lanka was investigated to assess finger joint efficiencies of wood species. Stratified random sampling was applied to measure compression tests in un-jointed and finger-jointed samples. BS 373:1957 was used as the standard for test conducted with one Softwood species Pine (Pinus caribaea) and Hardwood species; Grandis (Eucalyptus grandis), Jack (Aartocarpus heterophyllus), Kumbuk (Terminelia arjuna), Big leaf Mahogany (Swietenia macrophylla), Satin (Chloroxylon swietenia) and Teak (Tectona grandis). Two finger lengths (13 mm and 19 mm) were used and tested by Universal Testing Machine, using polyvinyl acetate adhesive. Data were analysed by using ANOVA and Duncan's Multiple Range Test at 0.05 significant level. It was observed that the highest joint efficiency was recorded in 19 mm finger-jointed specimen of Grandis followed by 13 mm finger jointed Pine specimen for compression parallel to grain. The least joint efficiency was recorded in 13 mm finger jointed specimen of Kumbuk. Strength of compression perpendicular to grain of 19 mm finger-jointed specimens showed better performance than clear specimens, except Jack and Teak. Limited availability of historical data was a constraint during the study and Sri Lankan context, little effort has so far made on finger jointed manufacturing. The results will be utilised in the commercial application of finger joint manufacturing industry and useful to the traders and planners of the timber industry.

Keywords: Compression strength, Finger joint, Efficiencies, Timber
Investigating Hydroscopic Property of Historical Timber against Load Bearing: A Case Study on Ambalam(s) Sri Lanka

Mendis M.1*, Halwathura R.2, Amarasekera H.2, Jayasinghe R.2, Somadewa R.3

1University of Moratuwa, Katubadda, Sri Lanka
2University of Sri Jayewardenepura, Nugegoda, Sri Lanka
3University of Kelaniya, Dalugama, Sri Lanka
*malsharesearch@gmail.com

Abstract

Building material with a thousand-year history which is only being second for stone can be introduced as wood. Complexity of wood is found in the interrelationship between several cells at a much larger scale. Wood cell wall is made up of cellulose, hemicellulose and the hydroxyl groups on these chemicals make the cell wall hygroscopic. Lignin is the agent cementing cells together while rigidifying the cell wall. It creates a comparatively hydrophobic molecule. Moisture in wood has a resilient effect towards its properties, and wood-water relations greatly affects on the wood in application. The aim of the study is to investigate the impact of hydroscopic property of historical timber against load bearing in heritage structures in Sri Lanka. Ambalam(s); heritage structure, a way side resting place built under vernacular architecture was selected as the case study. Padivitiya Ambalama, Panavitiya Ambalama, Karagahagedra Ambalama, Giriwa Ambalama and Rukula Ambalama were selected as in prior to timber as the main constructive material. This paper reviews on wood-water interaction through mapping the grain orientation of exposed cross sections of the structural components. The capability of water to alter physical properties of wood are only deliberated in cases wherever there is an influence on state and in transition. Results depicted the historical structural components have overcome the impacts caused due to the hydroscopic property through proper grain oriented sectional applications. This had influenced the structure to rest stable against load bearing for years.

Keywords: Timber; Grain distribution; Hydroscopic property, Fibre saturation point
Utilisation of Wood Waste in Moratuwa Wood Working Industry

Himandi G.L.H.S.*, Amarasekara H.S., Perera P.K.P., Rupasinghe R.

Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*shashikahimandi@gmail.com

Abstract

Moratuwa is traditionally famous for the carpentry and furniture manufacturing. There are several types of wood working industries in the cluster. Among them carpentry shops, sawmills and integrated sawmills were identified as the wood waste generating industries. Main objective of the study is to identify the current wood waste utilisation patterns and optimising the wood waste flow. Questionnaire surveys were conducted and field measurements were taken to gather reliable data. Stratified sampling method was followed. The prominent species use in the wood working industry is Teak (38.7%) followed by species are Mahogany (28.8%) and Albizia (3.1%). Machinery usage varies among different industries. Integrated sawmilling industry has the highest diversity of the machinery usage. Circular saw (44.6%) is the most abundant type of machinery used by integrated sawmilling industry. In carpentry industry planer saw (41.0%) is the most frequently using mechanical tool. Sawmilling industry uses different types of saws but the prominent type of sawing equipment is the circular saw (73.0%). 6,489.879 MT of total wood waste is generated within a month by entire population of wood working industries in Moratuwa. Out of them, sawmills produce 4,279.750 MT/month of wood waste, 2,003,467 MT/month of waste by the integrated sawmills and carpentry shops produce 206,662 kg/month. Among the total wood waste generation saw dust contributes 76.5%, 16.5% of wanes and 6.9% of offcuts. It was found that 63.4% carpentry shops, 100.0% of sawmills and 91.0% of integrated saw mills already utilise their wood waste. Quantity of current overall wood waste utilisation within the area of 20 km radius is calculated as 2,903,625 kg/month which has a possible increment up to 4,198,319 kg only by improving the current wood waste transportation. Wood waste generation and utilisation flow diagram and shortest path among the utilisers and waste collection points were illustrated. By adopting this waste utilisation methods, several business opportunities can be created and waste can be utilised in environmental friendly manner.

Keywords: Sawdust, Wood waste, Utilisation
The Effect of Incising on Coal-Tar Creosote Treated Wooden Sleepers to Increase Retention

Amarasinghe W.V.T.D.*, Muthumala C.K.

Research, Development and Training Division, State Timber Corporation, Battaramulla, Sri Lanka
*rctharindu87@gmail.com

Abstract

Wooden sleepers have become the major source for railway ties in Sri Lanka over a century, which are produced by hardwood species, mainly from forest plantations. However, because of lack of appropriate wood sources, their material quality is declining over a decade, thus the criticism has also arisen against their durability. Moreover, concrete sleepers are becoming popular due to their higher durability and mass production quantity, which is a threat to the market of wooden sleepers. Nevertheless, concrete sleepers show comparatively higher negative environmental impact such as greater carbon emission in their life cycle. Thus, improvement of wooden sleepers is essential to regain their popularity for local utility in terms of durability and as a lesser carbon emitter. Sleepers of Eucalyptus grandis (Grandis) and Dipterocarpus zeylanicus (Hora) were tested; 35 incised and 35 un-incised sleepers from each species were used for the study. The moisture of the sleepers was reduced below 28% and incisions were applied parallel to grain (or length of the sleepers) by a locally developed incising machine. The depth and length of the incisions and distance between two parallel incision lines are 13 mm, 20 mm and 25 mm respectively. All sleepers of each species were treated by Coal-tar Creosote wood preservative in full cell process according to the BS 144:1997 Standard. Change of the weight of the sleepers was used to estimate the retention capacity of the preservative. The results show that the retention capacity of sleepers of E. grandis has increased significantly (p≤0.05) by 71% (23.5 kg m^-3) after incising process. The increment of retention capacity of sleepers of D. zeylanicus after incising is only 4%, which is not statistically significant. Moreover, un-incised sleepers of D. zeylanicus (121.82±35.21 kgm^-3) is significantly higher (p≤0.05) than un-incised sleepers of E. grandis (33.29±12.83 kgm^-3). The results concluded that the incising process can be used to increase the retention of E. grandis sleepers. However, incising on sleepers of D. zeylanicus is not effective. The retention capacity of sleepers of D. zeylanicus is higher than sleepers of E. grandis with or without incising.

Keywords: Incising, Sleepers, Creosote, Retention, Full cell process
Market Survey for Wooden Furniture Industry in Sri Lanka

Siriwardana V.R.A.*, Muthumala C.K.

Research Development and Training Division, State Timber Corporation, Battaramulla, Sri Lanka
*asvindya@gmail.com

Abstract

Subsurface investigation, instrumentation and monitoring are powerful tools in assessment and Sri Lankan wood based industry is performing as one of the important manufacturing sector with a wide range of products. Wooden furniture is a large sub sector of the wood industry in Sri Lanka. This includes furniture for household, garden and other forms include office furniture for commercial & institutional use. Private Sector ownership comprises about 95% of the industry with less government involvement. Market share for furniture of State Timber Corporation (STC) is approximately 1%. Although major portion of wood product manufacturing companies are small scale enterprises. This study is aimed to investigate the popular wooden furniture products, species, selling methods and other materials using for furniture in year 2018-2019 by studying 308 filled questionnaires by registered furniture shops in forest department. Marketing officers were conducted field survey in 15 selected furniture showrooms for each districts of Sri Lanka. According to the results of the field survey, household furniture is the main role of furniture industry of Sri Lanka. Among furniture items 43% belongs to bedroom furniture, tables and chairs have 27% of the furniture items and 15% belongs to living room furniture. Teak is the main timber species used for furniture manufacturing followed by Mahogany and Satin. More than 65% of furniture in showrooms was made by Teak 15% were made by Mahogany 11% were made by Satin and around 7.5% were made by other wood species. Additionally to 47% of wooden furniture some portions of furniture were found in showrooms made by other materials such as metal, plastic etc. Wooden and metal mix 11% and metal 13%. MDF and plywood 17% and 12% respectively. Selling methods of furniture were identified mainly in two categories. Most popular method is direct method (from manufacturer to customer) and 55% were used direct method. 42% of sellers were used indirect method. Most of the furniture sellers used to make customised designs for their production.

Keywords: Wooden furniture, Market survey, Sri Lanka, Selling method
Assessment of Technical and Financial Viability of Producing Biomass Pellets with the Use of Brewery Sludge and Saw Dust for Local Industrial Boilers

Lansakara A.*, Bandara R.

University of Kelaniya, Dalugama, Sri Lanka
*akila4529@gmail.com

Abstract

Energy has huge demand in the world present and future. The best way to meet the high demand increment in energy sector is through diversification. In this context, biomass appears as an attractive source for a number of environmental, economical, political and social considerations. There are several techniques exist in the world to obtain energy from biomass. Among these techniques, bio mass press pelleting is a newly discovered feasible and widely acceptable technique in many countries. In Sri Lankan context, Sustainable Energy Authority of Sri Lanka is focusing on replacing 85 MW of fossil fuel by renewable energies including biomass energy by 2037. At the same time, there is no proper economically viable solution for brewery sludge and saw dust management and these have become economical burden to the industries. This study was designed to make use of brewery sludge and saw dust by producing mechanically stable, financially feasible, energy rich and viable biomass pellets to use in biomass boilers in local industries. Brewery sludge and saw dust were pre-proceed by drying and grinding then used in different proportions (25:75-B1, 50:50-B2 and 75:25-B3) to produce pellets using a hydraulic type pellet press machine maintaining 65-70 MPa. Energy properties including moisture content, volatile matter content, ash content, fixed carbon and calorific value and mechanical properties including bulk density, compressed density, relaxed density, durability, water resistance capacity and water boiling time were measured and fuel wood value indices (FVI) of produced pellets were estimated using standard methods in 5 replicates from each type of pellets. All the parameters were subjected to one way ANOVA in MINITAB version 14 after following Anderson Darling Normality test. Tukey’s pair wise comparison was carried out to find out whether the values are significantly different. Cost Benefit Ratio, Internal Rate of Return and Net Present Value were calculated to find out the financial feasibility. The best type of pellet was selected and evaluated with the international standards and some cited findings. B3 pellets are the best mixing saw dust to brewery sludge in 50:50 to produce pellets are within the standards. According to the all analysis performed, the production of brewery sludge saw dust pellets are found financially and technically feasible. With the obtained results, it is recommended to start producing pellets as a commercial venture for biomass pelleting with use of brewery sludge and saw dust.

Keywords: Pelleting, Saw dust, Brewery sludge, Biomass

Bhagya P.V.G.S.*, Premaratne W.A.P.J.

*Department of Chemistry, University of Kelaniya, Dalugama, Sri Lanka.
*sachinibhagya606@gmail.com

Abstract

Urea is highly water soluble, simple organic molecule which is widely used nitrogen fertiliser due to its high nitrogen content (46%) and comparatively low-cost production. But excessive leaching of urea can cause severe soil and water pollution that can lead to considerable resource and economic loss. In order to overcome the complications, slow release biomass fertilisers can be used. Using biomass fertilisers is the best method to avoid the shortcomings arising due to polymer based fertilisers such as their low degradability in the environment. Present study is focused to determine the nitrogen (N), phosphorous (P), potassium (K), ash and moisture contents in leaf, root, bark and stem of the *Wrightia zeylanica* (Wal-Idda) plant and to study the capability of using urea incorporated Wal-Idda wood chips (combination of stem and bark due to their capillary structures) as a slow releasing biomass nitrogen fertiliser. The new fertiliser system was prepared treating Wal-Idda wood chips (<5 mm) with saturated urea solution. Soil columns were prepared using soil matrix (200.0 g) and urea incorporated wood chips (10.0 g) to study the leaching of nitrogen in aqueous medium (pH 6.5). Nitrogen leaching was studied for 19 days. Each experiment and analysis were carried in triplicates. According to the experimental results the level of nitrogen in different parts of the wal-Idda plant varied from 6,230±400 mg kg⁻¹ to 18,620±300 mg kg⁻¹. It was found that phosphorous and potassium content in wal-Idda plant varied from 40±10 mg kg⁻¹ to 530±50 mg kg⁻¹ and from 1,700±60 mg kg⁻¹ to 13,600±800 mg kg⁻¹ respectively. According to the leaching experimental results 98% of nitrogen from the applied commercial fertiliser was leached during the studied period. When urea was directly applied to the soil 43% of nitrogen from applied amount was leached out and when urea was incorporated with wood chips, only 29% of nitrogen was leached out after 19 day. Therefore, the present investigation indicated that Wal-Idda wood chips has increased the retain ability of nitrogen fertiliser in the soil matrix by 14% with a slow release pattern. Experiment results has indicated that urea incorporated Wal-Idda woodchips have a potential to further develop as a urea incorporated slow release biomass fertiliser system.

**Keywords:** Biomass fertilisers, Wal-Idda, Slow-release pattern, Urea, Nitrogen
Process Optimisation for Efficient Production of Biodiesel from Microalgae (*Chlorella* sp.) Isolated from Sri Lankan Aquatic Habitats

Perera B.*, Ratnatilleke A.

1Department of Chemistry, University of Kelaniya, Dalugama, Sri Lanka
*binguntharushaperera@gmail.com

Abstract

Microalgae are a diverse group of aquatic organisms, which can capture excess CO$_2$ levels in the atmosphere and transform them into lipids, which can be applied in biofuel industry. The primary aim of this research work was to evaluate the potential of using microalgae, isolated from Sri Lankan aquatic habitats to produce biodiesel and to increase the production efficiency by developing well-optimised high yielding novel protocols using cheap raw materials. Different genera of microalgae were isolated and initially grown in BBM (Bold’s Basal Medium). Due to high cost of BBM, the medium was replaced with cheap and, nutrient compatible, commercially available Albert’s solution for mass production of microalgae. Apart from that, the novel media was used to demonstrate the growth rate of the microalgae. Biomass was harvested using ECF (Electrocoagulation and Flocculation) technique. Harvested microalgae were dewatered and dried. Newly developed sand crushing and heating methods were adopted to extract lipids from the harvested microalgae. Extracted lipids were trans-esterified by optimised stoppered bottle-mixing method. Produced fatty acid methyl esters (Biodiesel) were subjected to Gas Chromatography-Mass spectroscopy to analyse fatty acid profile. Variety of microalgae species isolated and morphologically characterised. *Chlorella* sp. was chosen for further studies among isolated microalgae species due to their abundance in aquatic habitats and ability to dominate in a medium. Cultivation of *Chlorella* sp. in Optimised novel medium (3.0 mL of standard Albert’s solution gave per liter of medium) recognised as a new high biomass-yielding (1.2659 g/L) medium for *Chlorella* sp. The cost reduction of the Albert’s optimised medium was 99% in comparison to BBM. 172 mg of lipids were extracted from 1.0 g of biomass with a lower amount of impurities. Fatty acid profile from transesterified lipids indicated that oleic acid (38.64%), linoleic acid (36.58%), palmitic acid (11.28%) and, stearic acid (5.53%) as major components in lipids present in *Chlorella* sp. Presence of high amount (75.22%) of C-18 fatty acids, further suggests that *Chlorella* sp. isolated from Sri Lankan aquatic habitats are promising candidate for quality biodiesel production. Hence, this study would be novel approach to economical biodiesel production in Sri Lanka in near future.

**Keywords:** Microalgae, Biofuel, Albert’s solution, Transesterification, Biomass
Determination of Potential Toxic Heavy Metals and Quality in Soil in a Chronic Kidney Disease of Unknown Etiology (CKDu) Hotspot, Sri Lanka

Sewwandi S.1*, Liyanage J.2

1College of Chemical Science, Rajagiriya, Sri Lanka
2Department of Chemistry, University of Kelaniya, Sri Lanka
*sakunthalasewwandi11@gmail.com

Abstract

CKDu (Chronic Kidney Disease of unknown etiology) concentrated mainly in North Central province in Sri Lanka and recently it appeared in Uva province as well. Soil can be taken as a main environmental source for occurrence of this kidney malfunctioning, as it is a material which is frequently used by the people in those areas and soil has a direct co-relation between food and water sources. Therefore, the present study attempts to investigate the potential toxic levels and the quality of soil in Rideemaliyadda South Grama Niladari Division (CKDu hotspot), Badulla district, Uva province, Sri Lanka. Triplicated 30 soil samples were collected according to random satisfied sampling including 13 home gardens, 9 cultivated areas, 5 forested areas and 3 tank sediment samples separately. The sample numbers from each stratum was estimated by ArcMap 10.2.2 software based on land use patterns. The soil samples were analysed for heavy metals using the Inductive Coupled Plasma- Mass Spectrometry (ICP-MS) followed by microwave digestion. The average concentration of selected heavy metals including Lead, Cadmium, Chromium, Zinc, Copper and Nickel in soil (in mg/kg) 8.850±3.870, 0.01±0.05, 43.62±33.88, 52.35±60.48, 15.74±9.66 and 12.96±7.02 respectively. The average Zn content in soil was exceeding the permissible levels given by WHO. The average pH of the soil samples were 6.798±0.840 which indicates a slightly acidic condition and it has not exceeding the permissible soil pH given by WHO. The average electrical conductivity of the soil samples were 145.30±282.80 µS cm⁻¹ which was lower than the permissible soil conductivity level. Hence, the soil in the sampling area was more or less contaminated with heavy metals, human long-term exposure to one or more of these metal toxicants is nearly unavoidable and they tend to be concentrated within human body under the dehydrated conditions. It may be one of the causative factors for the prevalence of CKDu in dry zone areas in Rideemaliyadda south GND.

Keywords: CKDu, Soil, Random satisfied sampling, Toxic heavy metals, Long-term exposure
Spatial Clustering of Dengue Fever Incidence and Its Association with Land Use and Land Cover: A study in Kolonnawa Divisional Secretariat, Sri Lanka

Perera T.1*, Jayawardana D.2

1University of Colombo, Sri Lanka
2University of Sri Jayewardenepura, Sri Lanka
*thisara@geo.cmb.ac.lk

Abstract

Land use and Land cover changes, a major constituent of global environmental change, potentially has significant consequences for human health in relation to mosquito-borne diseases. Especially, Land use change can influence mosquito habitat, and therefore the distribution and abundance of vectors, and land use mediates human–mosquito interactions, including biting rate. Land use such as Settlements, water bodies or certain construction works have been identified as likely risk factors for dengue because of the provision of suitable habitats for the vector. With more than 105,049 cases reported by the Epidemiology unit of Ministry of Health, the dengue outbreaks from 2011 to 2019 seriously impacted the outer region of Colombo, Sri Lanka. This study aims to assess the spatial autocorrelation of the dengue fever (DF) outbreak in Kolonnawa divisional secretariat from May to September in 2019, and to further understand the effects of Land use (such as Settlements, Water bodies, Construction sites and forest areas) allocation on DF. In this study, two different greenness indexes were used. The first green metric, the normalised difference vegetation index (NDVI), was provided by the long-term NASA MODIS satellite NDVI database, which quantifies and represents the overall vegetation greenness. The 2004 land use survey GIS database completed by the Survey department was obtained and updated to access another metric, land use in Kolonnawa. Spearman's rank correlation coefficient used to find out the relationship between DF and green space, and then four spatial autocorrelation methods, including Global Moran’s I, Nearest Neighborhood analysis, high/low clustering, and Hot Spot were employed to assess the spatial autocorrelation of DF outbreak. Results of spatial autocorrelation analysis showed a high aggregation of dengue epidemic in western parts of the Kolonnawa DS division, and the urban areas were the main hotspots. These hotspots were directly associated with Kolonnawa Canal, Construction sites and slums areas. Results of correlation analysis also showed a positive correlation between Water bodies and dengue fever. The forest areas and marsh lands metrics and other land cover types revealed a negative association with DF. The results indicate a high spatial variability suggesting that risk of exposure is spatially heterogeneous and varies according to land cover and land use. These findings may be an important asset for improving surveillance and control interventions of dengue in the region.

Keywords: Dengue, Land Use, NDVI, Autocorrelation
Stabilisation of Fine Grained Soil Using Fly Ash and Lime to Use as Embankment Material

Priyadarshani R.M.S.1, Udamulla K.M.L.A.2*

1Department of Civil Engineering, IESL College of Engineering, Colombo 07, Sri Lanka
2Department of Civil Engineering, Open University, Nawala, Sri Lanka
*lakshika0807@hotmail.com

Abstract

The objective of this study was to evaluate the effectiveness of self-cementing fly ashes with lime for stabilisation of soft fine-grained soils to assess whether the same could be used in construction of type I material of embankments. The material used for the top 500 mm of embankment shall conform to the requirements of type I material. Soil samples were collected from Kudaoya area in Monaragala District. The fly ash is from Lakvijaya Power Plant while lime was Quick lime (CaO). Index tests, modified proctor compaction tests and California Bearing Ratio (CBR) tests were conducted on mixtures prepared with soft fine-grained soils, fly ash and lime. The soils selected had a limited range of plasticity, with plasticity indices ranging between 27 and 29. All the samples were classified as high plastic clays (CH) according to the Unified soil classification system. Tests were conducted on soils and soil fly ash / lime mixtures prepared at 100% soil, 95%soil: 2.5% fly ash: 2.5% lime, 90% soil: 5% fly ash: 5% lime. Addition of fly ash and lime resulted in decrease in the dry density and an increase in the optimum moisture contents. Based on Institute of Construction Training and Development (ICTAD) specification, maximum dry density (MDD) should exceed 1.6 g/cm³ for type I material. All the mixtures were found to comply with the requirement for type I embankment material. Soaked CBR value of fly ash/lime mixture were found to increase with the increase in the fly ash lime content. Based on ICTAD RDA Specification 4 day soak CBR (at 95% compaction from modified MDD) value for type I material should exceed 7%. The CBR values of soil fly ash mixtures were 36% and 50% respectively while the virgin soil had 5% thus complying with the requirement. Liquid Limit (LL) and Plasticity Index (PI) values of fly ash lime mixture were found to increase with the increase in the fly ash lime content. Based on ICTAD RDA Specification LL and PI values for embankment I type soil should be less than 50% and 25% respectively. The LL values of virgin soil and soil fly ash mixtures were found to be 51.4%, 53.0%, 45.7% respectively. The PI values of virgin soil and soil/fly ash mixtures were found to be 29.27%, 28.09%, 12.96% respectively. Therefore the findings suggest the reuse of fly ash together with lime could be used to stabilise fine grained soils to achieve sustainable construction.

Keywords: Soil stabilisation, Fine grained soils, Embankment, Fly ash, Lime
Identifying Spatial Clusters of Vulnerability Levels to Floods: An Initiative to Improve Disaster Resilience

Mendis T.S.D.*, Sanjeewani R.M.S.S.

University of Colombo, Colombo 3, Sri Lanka
*sehanidilhari@gmail.com

Abstract

Floods, the most frequent natural disaster in Sri Lanka, has become one of the significant barriers to the social and economic wellbeing of the country. Given that the frequency and intensity of the floods will be increased in the small island developing states in the tropical region as per the predictions of Intergovernmental Panel on climate change, it is timely essential to investigate how the vulnerability levels can be assessed as an initiative to strengthen the resilience of the communities. This study aims to identify spatial clusters of vulnerability levels of the flood-prone regions selecting Ihala Welgama Grama Niladhari division (GND) in Bulathsinha divisional secretariat division in Kalutara district as the case study. This study uses multi-dimensional aspects of vulnerability, including social, physical, economic, institutional and attitudinal aspects of vulnerability to deepen the understanding of the vulnerability levels and to identify spatial clusters. Accordingly, indices were developed based on selected variables related to each of the above aspects to derive the multi-dimensional vulnerability levels. A household questionnaire survey was developed to get the data required for calculating above indices, and this survey covered the entire population of the GND (100 households). Then, the indices were calculated for each household unit of the GND. Standardised values of each sub-index ranging from 0-1 were clustered using multivariate clustering of ArcGIS pro to identify spatial clusters. Three clusters (high, moderate and low vulnerable spatial clusters) were identified based on the optimised Pseudo F-Statistics. Highly vulnerable cluster accounted for 28% of the total households, and 51% of the households are moderately vulnerable to floods. Only 21% showed a low vulnerability. Majority of the households in the highly and moderately vulnerable clusters were located within the closer proximity to the river compared to the low vulnerable cluster. Mapping spatial clusters based on multiple dimensions of vulnerability is an effective way to identify clusters that need to prioritise in enhancing the resilience of households in flood-prone areas.

Keywords: Resilience, Vulnerability, Multivariate clustering, Spatial, Floods
Reconstruction of Quaternary Environmental Changes on Eastern Coast of Sri Lanka.

Wijewardhana T.D.U.\(^1\), Ratnayake A.S.\(^1\), Subasinghe H.C.S.\(^1\), Ratnayake N.P.\(^2\), Attanayake A.M.A.N.B.\(^1\), Haraguchi T.\(^3\), Goto K.\(^4\), Tetsuka H.\(^5\), Yokoyama Y.\(^6\), Miyairi Y.\(^6\)

\(^1\)Department of Applied Earth Sciences, Uva Wellassa University, Sri Lanka
\(^2\)Ocean University, Mattakkuliya, Sri Lanka
\(^3\)Graduate School of Sciences, Osaka City University, Osaka, Japan
\(^4\)Department of Earth and Planetary Science, University of Tokyo, Japan
\(^5\)Graduate school of Science, Tohoku University, Japan
\(^6\)Atmosphere and Ocean Research Institute, University of Tokyo, Japan

*dlmiwijewardhana94@gmail.com

Abstract

Coastal sedimentary archives are important to recognize the past dynamics of environmental changes and climate variability. The current study describes paleoenvironmental changes in the eastern coast of Sri Lanka. A core sample (length=10 m) was collected from a stagnant shallow water coastal body next to the Koddiyar Bay. The sampling site is not presently connected to the Indian Ocean through the Koddiyar Bay. Sediment samples were sliced into 5 cm intervals, and oven-dried at 60\(^\circ\)C for 48 hours before geochemical analyses. Weight percentages of Total carbon (TC), total nitrogen (TN) and total sulphur (TS) were measured using CHNS/O elementary analyser. Mineral phases of the sediments were determined using X-ray diffractometry (XRD). In the lower sedimentary succession, TC (range from 0.25% to 0.32%) and TS (range from 0 to 0.54%) are low from the depth of 460 cm to 205 cm. These values can suggest a low productive and oxic depositional environment. However, TC and TS values are slightly increased in the regions of 415 cm to 375 cm. This organic matter rich brackish chronozone can probably indicate short-lived environmental changes such as paleo tsunami or saltwater intrusion. In the upper sedimentary succession, TC (range from 0.25% to 0.32%) and TS (range from 0 to 0.54%) are low from the depth of 460 cm to 205 cm. These values can suggest a low productive and oxic depositional environment. However, TC and TS values are slightly increased in the regions of 415 cm to 375 cm. This organic matter rich brackish chronozone can probably indicate short-lived environmental changes such as paleo tsunami or saltwater intrusion. In the upper sedimentary succession, TC (range from 0.32% to 7.37%), TN (range from 0.1% to 0.37%), and TS (range from 0.54% to 3.19%) values are gradually increased in the depth from 210 cm to the Recent sediments. It can probably indicate anthropogenic activities in the watershed. In addition, this upper sedimentary succession is characterised by the deposition of organic matter rich sediment under the anoxic to oxygen-poor conditions. According to XRD results, clay minerals such as illite and smectite are abundant throughout the core. Pyrite can also be identified as an abundant mineral in upper sedimentary succession suggesting that bacterial sulphate reduction and formation of sedimentary pyrite. In conclusion, a clear unconformity can be identified for the major environmental change at 210 cm in depth may be due to land degradation in the region.

Keywords: Carbon burial, Sediments, Depositional environment, Paleo tsunami
Spatiotemporal Variability of Landslides as a Consequence of Land Cover Changes: A Case Study from Kegalle District

Perera C.1*, Gimhani K.1, Gunaratne C.2, Kuruppuarachchi P.3

1Department of Regional Science and Planning, Sanasa Campus, Hettimulla, Sri Lanka
2HEI SL Cell, Sanasa Campus, Hettimulla, Sri Lanka
3Faculty of Management and Finance, Sanasa campus, Hettimulla, Sri Lanka
*chinssu@gmail.com

Abstract

Landslides are the results of the complex spatial-temporal interaction of various landslide causative factors such as rainfall distribution, geology, hydrology, geomorphology, and land cover type. However, among the landslide causative factors, land cover change is a highly dynamic factor. According to National Building Research Organisation (NBRO) of Sri Lanka, 70% of the landslides in Sri Lanka are human-induced. Humans control most of the land cover changes from home gardens to large extent plantations especially in the Wet zone, Sri Lanka. Including, as many researches claim, the gradual increase in landslides in this region. Therefore, this study is focused to assess the spatiotemporal variability of landslides as a consequence of land cover changes as a case study from Kegalle District. In this study, land cover change was analysed by using multi-temporal satellite images for the year 1988, 1997 and 2017 obtained from Landsat 5, Landsat 8 respectively. Satellite images were classified into forest, croplands/irrigated, mosaic croplands/vegetation, and artificial areas to extract the conversion of thick vegetation to thin vegetation using supervised classification method. Statistical analysis of landslide frequency was combined with a Geographic Information System (GIS) to determine the relationship between, landslide frequency and land cover change. Results found that 1,242 km² of thick vegetation gradually decreased to 945 km² from 1988 to 2017 while showing upward trend in landslide frequency. Maximum changes occur in Aranayake (67%) and Ruwanwella (60%) from 1988 to 2017. Kappa statistics shown that, 83% of landslides occurred in areas subjected to convert thick vegetation to thin vegetation. According to Spearmen’s correlation coefficient, frequency of landslides and land cover change show strong positive correlations (r=0.7, P<0.05). It can be concluded that land cover change leads to an increase in landslide susceptibility. The results suggest that conscious land management system might contribute to reduction in landslide susceptibility within the area.

Keywords: Land covers change, Landslides, Satellite images
Modification of SM Soil Material Mixed with SC Soil material for Use of Dam Construction

Kithsiri D.M.P.*

Irrigation Department, Colombo 10, Sri Lanka
*prdpgunasekara@gmail.com

Abstract

Soil is a very important construction material in civil engineering. A suitable type of soil should be used for good quality constructions. The lack of suitable materials (soils) closer to work site is a common problem. In this research, Kuda Oya dam constructing under Uma Oya project and the worksite which is situated at Aluthwela village in Haldummulla divisional secretariat was selected. For dam construction, clayey sand (SC) type soil and high/linear plastic clayey soil are required. According to investigation reports, tank bed area contains so many soils but there are not required quantities of suitable SC type soil. The silty sand (SM) type soils are available in large quantities but SM is not a suitable soil for dam construction. The main objectives of this research are to check the ability of the use of SM type soil with mixing (manually) SC type soil and the study of variation of some physical properties of soil when mixing. The Maximum Dry Density (MDD), Optimum Moisture Content (OMC), Liquid Limit (LL), and Plastic Index (PI) are the properties that I considered in this study. The three numbers of different SM samples and a SC type sample collected from the relevant area. SC soil mixed with SM soil in different proportions and the mixed (modified) soils were tested for standard proctor compaction test and Atterberge limit test and results were analysed using Microsoft excel. The MDD of modified soils does not have a considerable difference. The MDD of all samples is in the range of SC type soil. The OMC is decreased when SM percentage is increased.

The relationship of OMC can be expressed as $OMC_m = (-0.048p) + 0.5(OMC_a + OMC_b) + 0.1LL_b$, where $OMC_a$-OMC of SC soil, $OMC_b$-OMC of SM soil, P-percentage of SM, m-modified soil. Liquid limit and Plastic index are the two important properties that change with the cohesion of soil. The LL of mixed soil linearly decreased than the LL value of SC. The relationship is $LL_m = (-0.113p) + LL_a$, (LLm-Liquid Limit of modified soil, p-mixed SM percentage, LLa-liquid limit of SC). The relationship regarding the plastic index of soil can be expressed as $PI_m = (-0.082p) + PI_a$, where $PI_m$-Plastic index of modified soil, p-percentage of SM, $PI_a$-plastic index of SC soil. The test results and analysis prove that the unsuitable soil can be used for the construction after mixing with suitable soil (SC). The percentage is varying with raw soil properties and it can be found using the above equations.

Keywords: Soil developing, Relationship of mixing soil, Soil for dams.

Hettiarachchige R.P.*, Jayawardana D.T.

Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*ruwihettiachchi6@gmail.com

Abstract

The presence of dyes in industrial effluents is a major cause of water pollution. Textile wastewaters generated from different stages of textile processing contains a huge amount of pollutants that are very harmful to the environment if released without proper treatment. However, the main challenge is to eliminate the color of wastewater, which is due to the remaining dyes. Textile industries are responsible for the discharge of large quantities of dyes into natural waterways due to inefficiencies in dyeing techniques. Though the industries use treatment techniques, dyes cannot be completely removed by means of conventional treatments. There are several studies carried to investigate the dye removal techniques using natural materials. Therefore in this study carbonate rocks are highly available in Sri Lanka has been selected as the filter material which having high adsorption capacity. The carbonate powder having agglomeration properties it needed to be treated with secondary material. The processing of carbonate is done by using Natural Red Earth which is available abundantly along the North-Western coastal belt of Sri Lanka. Carbonate samples were collected from the Naula area where containing pure white carbonate rock with less impurities. The Natural Red Earth samples were taken around the Aruwakkalu area. Then the both carbonate and natural red earth samples were ground into fine particles less than 50 µm size diameter and sieved using US standard sieve to get a sample with uniform size distribution. The main objectives of this research are to investigate surface properties and adsorption characteristics of natural carbonate powder prepared by Sri Lankan marble (dolomite) and to develop surface characteristics of carbonate powder under necessary amendments for the removal of industrial dyes from contaminated water. Characterisation of both materials was studied by using X-ray fluorescence, X-ray diffraction, Fourier Transfer Infra-Red spectrometer analysis and Elusion test methods. Batch adsorption experiments were carried out to study the effect of optimum condition of operational parameters such as pH, shaking time with adsorbent, the initial concentration of textile dye and dosage of the adsorbent on the dye removal efficiency by the soil mixture. The adsorption rate data were analysed using the intra-particle diffusion model, pseudo first order and the pseudo second order kinetic models to determine adsorption rate constants. The isotherms of adsorption data were analysed by various adsorption isotherm models such as Langmuir, Freundlich and Temkin. The results obtained from X-ray fluorescence analysis confirmed that there is no detection of heavy metals and Fourier Transfer Infra-Red spectrometer analysis suggested that the change in functional groups may have caused the adsorption of dye molecules. According to the results highest adsorption capacity observed for dye solutions when the contact time was 120 minutes, at pH 12 with 10 g of soil mixture, of 1 ppm dye solution. Under optimum conditions removal efficiency of the soil mixture was 96.67%. Kinetic data suggests the Pseudo first order kinetic model fit best for Red dye and it confirmed that a physisorption occurs at the rate determining step. The pseudo second order model for Dye mixture shows chemisorption at the rate determining step of the reaction between the dye mixtures and adsorbent. The adsorption data for both Red dye and Dye mixture fitted well with the Langmuir isotherm at pH 12 with correlation coefficients greater than 0.9, suggesting mono-layer coverage of dye.

Keywords: Limestone, Natural red earth, Industrial dye, Adsorption, Kinetics
Characterisation of Kaoline Rich Laterite Soil for the Development of Soil Based Cosmetic Products


Department of Forestry and Environment Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*sandalidissanayake89@gmail.com

Abstract

The present study aims to characterise the properties of the raw and thermally activated laterite soil to be used in the development of cosmetic products. Collected soil samples were air-dried for 48 hours to remove the extra moisture content. Air-dried soil was crushed to prepare 500 µm powdered materials. Thermally activated soil samples were prepared by heating the laterite soil at 100° C, 200° C, 300° C and 400° C for 3 hours in a muffle furnace. The Cell Forming Unit (CFU) was counted in raw soil sample and thermally activated soil samples at the beginning. An uncountable amount of microorganisms per gram was observed in the raw soil sample and fewer microorganisms were counted in 100° C and 200° C samples. The CFU was zero microorganisms per gram for the 300° C and 400° C samples. Anti Microbial Assay was tested with Candida albicans, Pseudomonas aeruginosa, Staphylococcus aureus microorganisms in raw and thermally activated laterite soil. The optical density of the culture is measured to estimate the growth of the microbial cells. The soil showed good antibacterial activity against all the three microbial species. Oil absorption, sweat absorption and swelling capacity were used to characterise the samples with 300° C and 400° C thermally activated soil. The characterisation results indicate that chosen soil samples have good oil and sweat absorption, good swelling capacity and microbiological safety, making them suitable for cosmetic applications.

Keywords: Cosmetics, Cell forming unit, Laterite soil, Anti Microbial assay
Performance of Thermally Activated Laterite Soil as Adsorbent for the Removal of Phosphate and Fluoride

Dissanayake N.U.S.*, Pupulewatte P.G.H., Jayawardana D.T.

Department of Forestry and Environment Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*sandalidissanayake89@gmail.com

Abstract

The present study aims to examine the efficiency of two different laterite grain sizes and thermal activated laterite soil as an adsorbent for removal phosphate and fluoride ions from synthetic wastewater under laboratory conditions. The soil was collected from the Western province of Sri Lanka by auger drilling method. Collected soil samples were air-dried for 48 hours to remove the excess moisture content. Air-dried soil was crushed to prepare powdered material (2 mm and 500 µm). Thermally activated soil samples were prepared by heating the laterite at 100° C, 200° C, 300° C and 400° C for 3 hours in a muffle furnace. Adsorption conditions of phosphate and fluoride ions for the soil samples were determined by batch experiments conducted under room temperature and natural pH. Based on the results of studies, 300° C and 400° C (2 mm and 500 µm) thermal activated laterite soil proved to be an effective adsorbent and had higher removal capacities than other soil samples. 20 mins for 2 mm grain size and 10 mins for 500 µm were the optimal contact times for maximum removal of phosphate and fluoride ions. 0.75 g of laterite soil was identified as the optimum soil dosage. The results concluded that, the percentage of removal rises with the increase in temperature. In contrast, results revealed that, thermal activated laterite soil has a strong ability to remove the phosphate and fluoride from water.

Keywords: Adsorption, Activated Laterite, Phosphate, Fluoride, Optimum time
Spatial Distribution of Water Quality Parameters in Malala Lagoon of Bundala National Park, Sri Lanka

Madushani K.P.K.1*, Amarasinghe M.D.1, Ratnayake R.M.C.S.1, Dahanayaka D.D.G.L.2

1University of Kelaniya, Dalugama, Sri Lanka
2Open University, Nawala, Sri Lanka
*madushani_2017@kln.ac.lk

Abstract
Malala Lagoon of Bundala national park is one of the major wetland ecosystems on the southern coast that supports migratory and residential avifauna. However, the physicochemical characteristics of this lagoon have largely been influenced recently due to upstream irrigation works, especially, Lunugamvehera irrigation scheme, the drainage water of which is partly released into. The presence of invasive plants in these wetlands/lagoons is commonly attributed to the ecological changes that possibly have resulted from altered water salinity caused by increased freshwater input into these wetlands. This study was conducted to investigate the current status and spatial variation of water quality in the Malala lagoon. Water samples were randomly collected from fifteen locations from three strata, i.e. Malala North (MN), Middle (MM), and South (MS). Water samples collected for 2 years, representing wet and dry seasons were analysed for nitrate-nitrogen (NO\textsubscript{3}-N), ammonium nitrogen (NH\textsubscript{4}-N), total nitrogen (TN), orthophosphate (PO\textsubscript{4}-P) total phosphate (TP), pH, salinity and electrical conductivity (EC). These parameters were interpolated using ArcMap 10.2.2 software to determine the spatial distribution patterns. Results revealed that concentrations of NO\textsubscript{3}-N, NH\textsubscript{4}-N, TN, PO\textsubscript{4}-P, TP forms, and EC, pH, the water level of the entire lagoon were ranged as 303.0-510.8 µg L\textsuperscript{-1}, 202.7-452.8 µg L\textsuperscript{-1}, 500.1-2200.1 µg L\textsuperscript{-1}, 4.1-27.4 µg L\textsuperscript{-1}, 11.1-52.3 µg L\textsuperscript{-1}, 598.0-1973.0 µS cm\textsuperscript{-1}, 7.05-8.14 and 63.0-217.0 m respectively. The highest concentration of all species of nitrogen and phosphorous were observed from the northern part of Malala lagoon (MN), this is the area that receives the drained irrigation water or agricultural runoff. These higher concentrations gradually decrease towards the southern part of the lagoon which is closer to the outlet. Lower EC and salinity in the Northern section of the lagoon is also due to the dilution with the excessive freshwater that enters the lagoon. The present study provides an insight into the spatial variation of the quality of water that manifests the anthropogenic impact on lagoon ecology.

Keywords: Wetland ecology, Water quality, Malala Lagoon, Impact of agricultural drainage
Assessing and Mapping the Shoreline Change in Pottuvil Region, Sri Lanka from 1987 to 2018: using GIS and Remote Sensing Technique

Perera K.M.S.¹*, Bandaranayaka G.M.², Kumara B.A.S.C.²

¹Coast Conservation and Coastal Resource Management Department, Colombo 10, Sri Lanka
²University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*maheshasameera@yahoo.com

Abstract

Coastal changes defined by the accumulation or loss of lands in the near shore area by wave actions. These changes often result from social and natural factors such as human activities, sea-level changes, and Strom surge and hurricane occurrences. Coastal erosion is one of the serious problems in the coastal zone of Sri Lanka. The existing information reveals that more than one third of Sri Lanka's coastline is subject to coastal erosion. The causes and the intensity of the erosion vary from place to place. At present, some changes of the shoreline have occurred in the Pottuvil region in Ampara District, Sri Lanka. The Pottuvil coastal zone is about 28 km long and important for different aspects. Lagoons, mangroves, dunes, beaches, beach associated scrublands, rock outcrops, and marshlands are the major natural terrestrial habitats in the area and recently impacted by shoreline changes. Significant coastal erosion has been reported in 2015 and again repeated in 2017 in the Pottuvil area. This paper assessing and mapping the shoreline changes from 1987 to 2018 using Geographic Information System and Remote Sensing, Arc GIS extension of the Digital Shoreline Analysis System (DSAS). In this context, used available Aerial photographs (1987), Quick Bird Image (2005), Worldview (2014), Worldview (2017) and Google Image (2009) over 1987-2018 for tracking the shoreline change and estimating its change rate. The study region divided into seven shoreline segments based on morphological characters of the coastal zone and DSAS generates 284 transects at a spacing of 100 m from Crocodile rock to Sangamankanda point to calculate the statistical parameters of the Net Shoreline Movement (NSM) and End Point Rate (EPR). The result reveals that the End Point Rate record at the rate of -0.49 m Y⁻¹ from 1987 to 2005 and -0.76 m Y⁻¹ from 2005 to 2018. The cumulative rate recorded as -0.51 m Y⁻¹. The study identified that in two epochs considered, there were general erosion trend in the shoreline changes and clear indication of the rate of erosion is increased during past fourteen years (most recent years). Analysis result indicated that erosion and accretion occurred due to coastal processes of currents and sediment transport. Further, this study emphasises the importance of the use of GIS and Remote Sensing, Digital Shoreline Analysis System (DSAS) techniques for the detection of shoreline changes in the coastal zone.

Keywords: Coastal changes, Sea-level changes, GIS and Remote sensing, DSAS, End point rat
Quantification of Stem Flow in Seven Tree Species in an Urban Environment of Sri Lanka

Balasuriya V.G., Chandrathilake G.G.T.*

Department of Forestry & Environmental Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*thilakawansha@sjp.ac.lk

Abstract

Stemflow (SF) is a small fraction of precipitation which contacts with the canopy and reaches to the ground by flowing along the stem of the tree. The SF generation of urban environment in single rain events are less frequently reported than in forested ecosystem. Therefore, SF was studied for 20 rain events starting from dry canopy condition for 7 selected tree species with 3 replicates in University of Sri Jayewardenapura with reference to tree morphological characteristics. Stemflow collars were fixed at diameter at breast height (DBH) and connected to storage tanks. Tree height, DBH, canopy height, canopy volume, canopy diameter to height ratio, bark thickness, furrow depth and number of furrows per DBH were considered as tree morphological characteristics. Tree architectural models were determined for studied species by leaf shape, leaves arrangement and canopy shape. Gross precipitation was recorded using an automated weather station located in an open area in the study site. According to the results DBH, canopy volume and bark thickness have a negative relationship with SF. Pterocarpus marsupium Roxburgh and Felicia decipiens have resulted the highest and the lowest DBH, bark thickness and canopy volume respectively since, the highest and the lowest SF were generated by F. decipiens and P. marsupium Roxburgh respectively. However, there were no significant relationships between SF and other listed morphological characteristics as well as with the tree architectural models. The results suggest a significant variation in SF by species and study trees can be arranged as F. decipiens > Mesua ferrea L. > Dipterocarpus zelandicus Thwaites > Delonix regia (Boj. ex Hook.) Raf. > Azadirachta indica > Casuarina equisetifolia L. > P. marsupium Roxburgh in species specific SF. Thus, the results of the study will be useful for climate sensitive selection and siting of urban trees towards integrated rainwater management.

Keywords: Stemflow, Strom water management, Tree architecture, Tree morphology, Urban forestry
Paired Watershed Delineation and an Analysis to Identify Its Morphological Features in Yagirala Forest Reserve

Kodithuwakkul L.1*, Chandrathilake G.G.T.2

1Faculty of Graduates Studies, University of Colombo, Colombo 03, Sri Lanka
2Department of Forestry & Environmental Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka

*lakshidi30@gmail.com

Abstract

Watersheds are the basic hydrological unit for water resource management. Watershed morphological characteristics like shape, watersheds area, perimeter, axial length, form factor, compactness factor, circulatory ratio, elongation ratio, basin slope channel length, stream frequency, drainage density, stream texture and overland flow are important in understanding the hydrology of the watershed. Thus, computation of watershed morphological characteristics is a prerequisite for detailed hydrological studies. Therefore, this study focused delineation of paired watershed and identification of their morphological features in Yagirala Forest Reserve (YFR) (6°21′ to 6°26′ N and 80°06′ to 80°11′ E) a secondary lowland rainforest in southern Sri Lanka. Manual and automated approach based on Triangulated Irregular Network (TIN), Digital Elevation Model (DEM) was made for the delineation of paired watersheds. Two watersheds; Watershed one (WS1) located in forest enriched with Pinus caribaea and the second was in natural forest (WS2). Morphological characteristics were examined using ArcGIS and mathematical formulas. Morphometric analysis showed that the watersheds areas were 0.91 km² of WS1 and 1.60 km² of WS2 which both are smaller in size with elongated and oval in shape respectively. According to the results perimeter was 5.14 km, axial length 1.46 km and channel length 1.29 km of the delineated watershed in WS1 whereas perimeter was 5.16 km, axial length 1.62 km and channel length 3.34 km of the WS2. The present study computed that Form factor was 0.43, Compactness factor 1.50, Circulatory ratio 0.43, Elongation ratio 0.6 and Basin slope 2.70% in WS1 whereas with values 0.61, 1.14, 0.75, 0.8 and 5.46% for the same parameters respectively in WS2. The stream frequency was 1.09 (No of streams per km²), Drainage density 1.41 (km per km²), Stream texture 1.53 km and Overland flow 0.35 km of WS1 whereas they were 1.25 (No of streams per km²), 2.08 (km per km²), 2.60 km and 0.20 km of the WS2. In conclusion, delineation of paired watershed and estimation of its morphological analysis in YFR provides a prerequisite for advanced forest hydrological studies in tropical lowland rain forest.

Keywords: Paired watersheds, Watershed morphology, Watershed delineation, Yagirala Forest Reserve, GIS, DEM
Synthesis of a Bifunctional Chitosan Derivative and Its Applications in Removal of Metal Ions in Aqueous Solutions


Department of Chemistry, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*dhananjani97@gmail.com

Abstract

Chitosan has proved to be versatile for so many environmental applications as it possesses major functional groups including -OH and -NH₂. As a natural polymer ligand, chitosan shows good metal binding properties towards various metal ions. However, the efficiency of chitosan is limited at some instances due to several reasons such as acid instability, lower selectivity towards metal ions etc. These constraints can be overcome by modifying chitosan structure to produce various derivatives with the introduction of different functional groups. This study was mainly based on two such derivatives namely Carboxymethyl Chitosan (CMC) and Ethylenediaminetetraacetic acid Chitosan (EDTA-CS) which are already reported in literature as excellent adsorbents for various metal removal purposes. As a further development in this direction, the main objective of this research study was to synthesise a new bifunctional chitosan derivative namely Ethylene-diaminetetra-acetic acid Carboxymethyl Chitosan (EDTA-CMC) by attaching both Carboxymethyl and EDTA functional groups on to the polymer backbone and thereby enhancing the metal binding properties furthermore. Combined synthetic procedures of CMC and EDTA-CS given in literature were used in the synthesis of bifunctional derivative. Synthesised EDTA-CMC was characterised qualitatively by FT-IR Spectroscopy and TGA. According to TGA, thermal stability of derivatives were in the order of EDTA-CMC>EDTA-CS>CMC. In adsorption experiments, different colors were observed for different metal ions indicating the metal adsorption behavior. Metal uptake by EDTA-CMC was almost 100% in 100 ppm, 200 ppm and 300 ppm Cu²⁺ solutions with an adsorbent dose of 5 mg and for a contact time of 4 hours. Therefore EDTA-CMC appeared to be efficient as a polymer ligand in binding Cu²⁺ compared to other two derivatives; CMC and EDTA-CS. However, such successful results were not obtained for Co²⁺ and Mg²⁺.

Keywords: Polymer ligand, Chitosan derivatives, Metal adsorption
Adaptation and Optimisation of Cloud Point Extraction Procedure to Determine Aluminium Content in Aqueous Solutions

Amarasena D.W.P.U.*, Cooray A.T.

Department of Chemistry, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*prasadiniamarasena@gmail.com

Abstract

Due to the adverse effects (high risk of Alzheimer’s disease, encephalopathy/dialysis dementia, Parkinson’s disease, and osteomalacia) of Aluminium on all living beings, monitoring the concentration of Aluminium in water is very important to ensure water quality. A pre-concentration step is required, because of the complexity of matrices and low concentration of trace metal, before doing the instrumental detection. Cloud point extraction (CPE) has been used for the pre-concentration step for the determination of Aluminium in aqueous solutions prior to its detection from Atomic Absorption Spectrometry and UV Visible Spectrometry. In this method, Eriochrome Cyanine-R (ECR) and non-ionic surfactant Polyethylene glycol tert-octylphenyl ether (Triton X-114) used as the complexing agent and surfactant respectively. The main objectives of this study are to develop a cloud point extraction method for the pre-concentration of trace Aluminium prior to its determination, Optimisation of the developed method by changing variables. Mainly two CPE methods were developed. The developed methods are based on the complexation of Aluminium ions with ECR and then entrapped in Triton X-114 at a higher temperature (70°C) and room temperature. As Method 1; general CPE procedure was followed according to literature. Since the expected recovery percentage was not obtained, as Method 2, the general cloud point extraction procedure which used previously was carried out with minor changes. The minor changes are omitted heating step, increased concentration of Triton X-114, and except 0.2 M sodium sulfate other solutions were added in a different order. In Method 1 at 70°C, the recovery percentage was in the range of 7.5%-31.0%, but in method 2 at room temperature, the recovery percentage was in the range of 12.0%-58.0%. Since method 2 obtained the maximum recovery percentage values, chemical variables affecting the method 2 cloud point extraction procedure optimised in order to find the optimum operating conditions. Optimum conditions were pH=6.5, Triton X-114 volume=10 mL, and Triton X-114 concentration=0.25% (v/v). In these methods, the Aluminium ion concentration was investigated in the range of 4-15 ppm. Under the optimisation of ECR concentration maximum recovery percentage was obtained, when a neutral metal-ligand complex is formed in the medium which is Al (ECR) 3. In order to form that complex, excess ECR concentration is needed in the medium. The obtained method needs to be further improved by optimising factors such as salt concentration, centrifugation rate, and diluting agent.

Keywords: Cloud point extraction, Aluminium, ECR, Recovery percentage
Modeling the Water Quality of Attanagalu Oya

Perera B.B.R.¹, Bandara N.J.G.J.²*, Ransinghe R.P.K.C.M.¹, Pathirana C.D.K.²

¹Department of Mathematics, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
²Department of Forestry and Environmental Science, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
*binurip95@gmail.com

Abstract

Attanagalu Oya is an economically important river in Sri Lanka which is a major source of supplying potable water, water for industries, irrigational activities and for the maintenance of aquatic ecosystems. Rapid urbanisation and anthropogenic activities in the catchment area increase the level of pollution of the river basin and it is one of the river basins that is constantly affected by floods. The current study focused on the statistical analysis of data that had been acquired through assessment of the water quality of Attanagalu Oya and the impact of rainfall on the river basin using 16 water quality parameters collected from 10 water quality monitoring stations and 5 rainfall gauging stations. The trends in rainfall in the river basin and water level were investigated using Mann-Kendall’s test and Sen’s slope estimator test. The results of trend analysis of rainfall showed a negative trend in January and a positive trend in June for the Katunayake rain gauge station. The results of monthly trend analysis for the water level confirmed the potential for flood occurrence in May. Generalised linear and ARIMA models were developed to predict daily precipitation and water level of the river basin and flood alerts in Attanagalu Oya were forecasted with sufficient lead time. Multivariate analysis revealed that cluster analysis is an efficient technique to identify homogeneous clusters among sampling sites and water quality parameters. Moreover, the principal component analysis and factor analysis determined the major sources of pollutants contributing towards water pollution in each identified homogeneous cluster. The ordinal logistic model fitted predicts the flood alerts with an accuracy of 93.7%. Therefore, the results and techniques used for this study could be applied in further research work to explore the pollution extent of the river. Thus, this model can be used by the respective authorities for decision making purposes in effective water quality management.

Keywords: Attanagalu oya, Water quality, Multivariate analysis, Trend analysis
Observation of Behavior of Elephants (*Elephas maximus*) with Special Emphasis on Stereotypic Behavior under Different Management Practices in Captivity

Senaratna D.\(^1\), Paranahewa S.\(^1\), Samarakone T.S.\(^2\)

\(^1\)University of Ruhuna, Matara, Sri Lanka
\(^2\)University of Peradeniya, Peradeniya, Sri Lanka
*dulcy@ansci.ruh.ac.lk*

Abstract

Human-elephant conflict has been raised due to the habitat destruction of elephants. Therefore, elephant orphanages are essentially required to safeguard the elephants. However, under captive environments, elephants pose stress related behaviors mainly stereotypic behavior (SB) which leads energy loss. Objective of the study was to estimate behavior of elephants at different age groups under different management practices (MPs) with special emphasis on SB. Treatments were; four MPs (feeding, bathing, tie-up and roaming [Control]) and four age categories; juvenile, adults, sub-adults (SA) and prime adults (PA) arranged in 4×4 factorial experimental design. Behaviors of elephants were taken continuously for 2 hrs. for each MP (in total 8 hrs/day within 4 days a week for four months). Undisturbed continuous data were recorded by direct focal observations following an ethogram focusing on eighteen behavioral traits (feeding, waving, pacing, head bobbing, resting, standing, dust bathing, defecation, suckling, digging, contacting, chasing, mounting, urination, walking, drinking, object playing and other. Data were analysed using generalised linear model of SAS. Effects of age, MPs and age×MPs interactions were tested. Significant main effects and interactions were compared using DMRT. Behaviors showed significant \((p<0.05)\) difference with either MPs or age. Highest frequency of SB was observed with tie-up over other MPs. Elephants showed lowest feeding behavior at bathing. Highest social behaviors were performed during bathing and at roaming. Similarly, walking was highest at bathing and roaming. Defecation and urination were not showed any remarkable results either with MPs or with age. Drinking was highest at bathing over other MPs. Dust bathing and digging only showed at feeding and roaming. It is concluded that most of the elephant behaviors were significantly affected by the MPs more than the age of the elephants. Under captivity, highest SB was shown with tie up management practice.

Keywords: Age, Captivity, Elephants, Management practices, Stereotypic behavior
Modeling the Spatial Pattern of Carbon Stocks in Uva Province of Sri Lanka Using InVEST Tool


1Faculty of Graduate Studies, Sabaragamuwa University, Belihuloya, Sri Lanka
2Department of Natural Resources, Sabaragamuwa University, Belihuloya, Sri Lanka
*iduhasantha@gmail.com

Abstract

Natural forests have the ability to sequester carbon in their biomass and reduce the rate of increase of atmospheric carbon dioxide. Therefore, forested areas form an important option for mitigating global warming and consequent climate change. Although the Uva province in Sri Lanka consists of ~50% of such forests and scrublands, the spatial distribution of carbon storage is rarely studied. Thus the objective of the present study was to model the spatial pattern of carbon stocks of the Uva Province in Sri Lanka using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Carbon Storage and Sequestration model and ArcGIS 10.4 software. The input variables of the model were land use/land cover (LULC) raster and the carbon stored in each LULC type. Twenty-four (24) LULC types were delineated in the study area. The four carbon pools viz. aboveground biomass, belowground biomass, soil, and dead organic matter of each LULC type were determined using relevant secondary information generated from both local and international research. The model outputs are maps of carbon storage densities of LULC raster and the model summarises results into raster output of the spatial distribution of total carbon storage. Results have shown that with a land area of 850,000 hectares the Uva province currently stores 9,663.52 million tons of carbon whereas carbon storage varies within different LULC types. The LULC type with rich vegetation had a higher amount of carbon stored on a per hectare basis. Natural forest obtained the largest carbon stored with 6,863.69 million tons which comprise ~71% of the total carbon stock in the area. However, this study highlights the importance of natural forests for carbon sequestration and storage and the results of this study would help in formulating forest conservation planning in the Uva province.

Keywords: Carbon storage, GIS, InVEST, Sri Lanka, Uva province
Performance of Recycled Cement Aggregates as Alternatives to Construction Materials

Dissanayaka D.*, Christopher P., Ratnayake A.

Uva Wellassa University, Badulla, Sri Lanka
*deepani.thilinid@gmail.com

Abstract

Demolition of buildings generates sand and other construction aggregates bonded in cement matrix. This study was focused on recycling demolished cement and sand based aggregate material and assessing its performance to be used as an alternative for river sand. These materials are generally disposed to the environment as waste. The cement-based aggregate waste was processed from simple crushing and sieving methods which generated two types of end products, a waste aggregate (<2 mm) and a powder product (<125 μm). The feasibility of replacing river sand with the generated sand aggregate and the percentage of cement that could be saved by utilising the powder product in low strength cement works was tested and studied. The sample cubes were made to 50x50x50 mm dimensions for the strength measurement tests. X-ray diffraction and Fourier transform infra-red spectroscopy tests were carried out to study the hydration of cement phase and to enhance the mineralogical understanding of the products. The acquired 28th day strength is 44.08 MPa for the 90% replacement of sand with the recycled aggregates. Replacement of cement with 30% of powder product acquired 52.25 MPa at 28th day strength, where the pilot test acquired 60.12 MPa at 28th day strength. Up to 90% of river sand used in construction works was found to be replaceable by the sand aggregate material generated by recycling cement-based demolition waste. The powder product (<125 μm) could be used as a strength enhancer alternative. Both products could be used in low strength demanding construction work.

Keywords: Aggregates, Cement, Recycling
Novel Biomass Fertiliser System Using Urea Incorporated Chinese Croton Plant Bark Particles: Development and Characterisation

Maduwanthi K.W.C.C.*, Premaratne W.A.P.J.

Department of Chemistry, University of Kelaniya, Sri Lanka.
*kwccm.me@gmail.com

Abstract

Conventional commercial fertilisers often cause environmental pollution and resource waste, because of the instant dissolution rate of those fertilisers. Therefore, use of slow-release fertilisers is a type of fertilisation optimisation that has become increasingly valuable in recent years. Slow-release fertilisers are used to reduce the overall amount of plant nutrients introduced into the environment and to reduce the energy consumption for fertilisers. The main objective of this study was to develop and evaluate new slow-release biomass fertiliser system using the *Excoecaria cochinchinensis* ‘Variegated’ (Chinese Croton) plant bark. The fertiliser system was developed from Chinese Croton bark particles (<5 mm) after treating with saturated urea solution. The release patterns of nitrogen from urea incorporated bark particles (10 g) in a soil matrix (200 g) were studied using columns with deionised water (pH 6.5). Parallel studies were carried out to evaluate the leaching patterns of a commercially available nitrogen fertiliser sold in Sri Lanka in the soil matrix using the columns. Control experiments for the soil leaching patterns were carried out with urea in a soil matrix and soil matrix alone instead of using fertiliser. Each experiment and analysis was carried in triplicate. Experimental results showed that the level of nitrogen content in different parts of the plant varied from 3,990 mg kg\(^{-1}\) to 8,250 mg kg\(^{-1}\). It was found that phosphorous content in the plant varied from 64 mg kg\(^{-1}\) to 531 mg kg\(^{-1}\). Potassium in different parts of the plant varied from 1,830 mg kg\(^{-1}\) to 7,290 mg kg\(^{-1}\). Nitrogen content of the plant bark particles was increased by 307% after treating with saturated urea. According to the experimental results, within 5 days more than 40% of nitrogen from urea and more than 50% of nitrogen from the commercial fertiliser were eluted in the soil matrix given. However, even after 15 days that eluted nitrogen amount was recorded as only 30% from that urea incorporated Chinese Croton bark particles. Therefore, Chinese Croton bark particles can be considered as a potential nitrogen fertiliser carrier for the development of a new slow-release fertiliser system.

Keywords: Biomass fertiliser, Chinese croton, Slow-release, Urea, Nitrogen
(90)

Birds as a Potential Resource in Sustainable Tourism at a Leading Tourist Resort in Sri Lanka

Karunananda H.T.A.R.¹*, Fernando T.S.P.², Gunawardena M.P.³

¹Biodiversity Educational Research Initiative, Kirulapona, Sri Lanka
²Department of Zoology, Faculty of Natural Sciences, Open University, Nawala, Sri Lanka
³Faculty of Science, Horizon Campus, Malabe, Sri Lanka
*htarkarunananda@gmail.com

Abstract

Tourism is one of the fastest growing industries in the world and creates many job opportunities in different sectors. Tourism industry in Sri Lanka is the third biggest foreign exchange earner and the total foreign exchange earned by Tourism sector in 2018 was 4.4 billion US dollars. Globally, with the increase in climate change and threats to the biodiversity, sustainable tourism has become popular. These concepts enable to make a positive impact on the environment, society as well as the economy. Sri Lanka being a biodiversity hotspot is an ideal location to promote such concepts. A research was conducted to determine the potential of promoting sustainable tourism at Aliya Resort and Spa, Sigiriya using birds as an indicator species. The Resort is located in land space of over 23 acres which includes various habitats: Forest Patch, Waterbody, paddy field and a farmland which provide feeding, breeding and residing habitat for avifauna. Data was collected using the Line Transect method (800 m Transect, species between 50 m either side of the transect were recorded) for a period of 9 months from July 2019 to March 2020. Sampling was carried out during the mornings (6.30 a.m.-7.15 a.m.). Opportunistic observations were taken when a bird was encountered in the field other than the time interval. According to the results a total of 953 individuals belonging to 75 species were recorded. The most anundant bird species that were recorded were Spotted Dove (Spilopilia chinensis), Cattle Egret (Bubulcus ibis) and House Crow (Corvus splendens) with relative abundances of 11%, 10.8% and 7.8% respectively. More importantly, 5 endemic species were recorded: Sri Lankan Jungle Fowl (Gallus lafayetti), Sri Lanka Swallow (Cecropis hyperythra), Sri Lanka Gray Hornbill (Ocyceros gingalensis), Black-capped Bulbul (Rubigula melanicterus) and Sri Lanka Green Pigeon (Treron pompadora) representing 15% of the endemic species found in Sri Lanka. The value of the Simpson’s index was calculated, which was 0.95. The results indicate a high diversity of avifauna. In conclusion, there is a high diversity of birds at Aliya Resort and Spa hence, awareness programs and training must be conducted to the local communities within the region which will enable them to earn an income by conducting nature trails and nature based activities.

Keywords: Avifauna, Diversity, Shannon Weiner index, Simpson’s index
Avian Species Composition during Anthropause in Royal Botanic Gardens, Peradeniya

Galappaththi H.G.S.S.*

College of Forestry, Guangxi University, Daxuedonglu 100, Nanning 530004, China
*supun.galappaththi@outlook.com

Abstract

“Anthropause” or the global slowdown of human activities, upon covid 19 pandemic, has caught the attention of scientists worldwide. Restricted human activities due to less mobility have reduced anthropogenic disturbances on wildlife globally; hence it is assumed that wildlife is less affected during this “anthropause”, by human activities. Sri Lanka being a tourist destination underwent drastic changes in tourist visitations due to travel restrictions. Therefore, the objective of this study is to assess the bird community during anthropause in Royal Botanic Gardens, Peradeniya, which is a popular tourist destination, located in Kandy; the capital of the Central province of Sri Lanka. This botanic garden spans over an area of 59.5 ha margined by Mahaweli River and Kandy-Colombo main road. The landscape is rich in diversity of flora and offers a range of habitat types, which support a large variety of birds. The present study was conducted in June-July 2020, during partial lockdown in Sri Lanka, when the study site had limited human activities. Data were collected using point count technique, covering the total area, under four landscape categories, i.e., “riverine habitats”, “arboretum”, “human-disturbed habitats”, and “other landscapes”. Data analysis was conducted using “Vegan” package in R. The survey recorded 54 bird species of 29 families, of which five species are endemic, and total species richness is comprised of 29.5% of uncommon breeding residents. Riverine habitats accounted for 35.3% of total abundance, while arboretum, human-disturbed habitats, and other habitats accounted for 22%, 23%, and 20% respectively. However according to Nonmetric Multidimensional Scaling (NMDS) based on species composition, arboretum showed a dissimilar species composition to all other landscape types, while other landscape types showed similar species composition with each other. Shannon-Wiener diversity index ($H'$) of 3.13 was recorded for the study site indicating fairly high diversity. Yellow-billed Babbler ($Turdoides affinis$), Common Myna ($Acridotheres tristis$), and Large-billed Crow ($Corvus macrorhynchos$) were recorded as the three most abundant species with relative abundance values of 14.5%, 14.1%, and 12.3% respectively. The common urbanophilic species, House Crow ($Corvus splendens$), recorded a low relative abundance value of 1.0%. This could be due to less availability of food sources with the absence of tourists. The study suggests occurrence of similar species composition in all landscape patterns, except arboretum where canopy cover is higher. However, further studies are required to make robust comparisons on species composition of the particular community, before, during, and after the pandemic induced anthropause.

Keywords: Pandemic, Covid 19, Anthropause, Anthropogenic disturbances, Species diversity
Advanced Level Students’ Knowledge on Climate Change: A Case Study in Dehiowita Educational Zone of Kegalle District


Department of Plantation Management, Wayamba University, Makandura, Sri Lanka
*gajawyb@yahoo.com

Abstract

Climate change is a global phenomenon of unbalancing the weather of earth, which adversely affects the sustainability of the planet’s ecosystem, the future of humankind, and the global economy mainly due to improper anthropogenic activities. Climate change is resulted by global warming due to human emissions of greenhouse gases and the resulting large-scale, long-term shifts in weather patterns, which is one of the most serious global environmental problems in the 21st century. As the main source of knowledge, education plays a significant role in human behavior. Mainly primary and secondary education decides what the future will be. Therefore empower the young students with knowledge, skills and attitudes regarding, global warming, climate change and adaptation, and mitigation is essential to deal with this global challenge confidently. It will change the human influence and action on climate change. This study was conducted with the aim of identifying the levels and types of knowledge of Advance Level (A/L) students on climate change in the Dehiowita educational zone in Kegalle district as a case study. Stratified random sampling was employed to collect the data from 100 students in five streams, vis. Agriculture, Biology, Physics, Commerce, and Arts, through a pretested semi-structured questionnaire-based survey. The questionnaire contained 35 statements under specific knowledge categories of physical, casual, effect, and action related. Response to the given questionnaire was converted into a score. The sample contains 55% male respondents and 45% female respondents. All the respondents showed an average score of 57% for the questionnaire, which interprets that the study group has a piece of adequate knowledge on climate change. Agriculture students have recorded the highest score of 69.7%, while biology, mathematics, commerce, and art students have 67.9%, 59.8%, 47.4%, and 46.6%, respectively. Students have good physical knowledge and satisfactory level of casual knowledge while having an adequate level of effective knowledge and action related knowledge. Effect knowledge has recorded the highest average value (61.9%) among specific knowledge categories. Effect knowledge was measured based on the expected consequences of climate change. Sri Lanka as an island already experiencing negative consequences of climate change such as frequent extreme weather conditions. The study will assist the development of more effective strategies for knowledge mobilisation to improve the awareness of climate change among the A/L students.

Keywords: Adaptation, Awareness, Climate change, Effect knowledge, Mitigation
Adoption of Sustainable Agricultural Practices by Sugarcane Farmers: A Case Study in Sewanagala Area


*Department of Plantation Management, Wayamba University, Makandura, Sri Lanka
*gajawyb@yahoo.com

Abstract

Sugar is considered as one of the main food items consumed in Sri Lanka and during the past two decades, more than 85% of the country’s annual sugar requirement was fulfilled through imports, costing billions of country’s income. Previous years, sugar sub-sector was given less concern by the authorities resulting unsustainable cultivation with low productivity. Sewanagala is one of the main sugarcane cultivating areas in Monaragala District of Sri Lanka. A significant variation of crop productivity among sugarcane farmers of this area were observed causing negative impacts on land productivity, sustainability of cultivation and their income. Therefore, this study was conducted to identify important agronomic practices for sustainable sugarcane cultivation; to develop a farmer level index (for sustainable agricultural practices-SAPs) and to evaluate the degree of sustainable cultivation practices and to quantify the level of adoption of SAPs of sugarcane farmers in Sewanagala area. A survey using a pretested questionnaire was used to collect data from simple random sampling technique and selected 60 farmers, who cultivate sugarcane under mahaweli authority, representing six divisional areas of Sewanagala area. Adoption Index was developed to quantify the level of adoption of sustainable agricultural practices among the study group. Results revealed that the age range of the most of farmers (51.6%) was between 30-50 years and 80% of the study populations were male. Sugarcane farmers in division 2 (Samanalagama) exhibited the highest SAP adoption whereas the division 1 (Katupila) exhibited the lowest SAP adoption. Increased percentage of SAP adoption suggests a good impact on average yield, indicating 157.2t in division 2 (Samanalagama) which was the highest among six study areas. Among 12 selected sustainable agricultural practices used for this study, the highest percentages of adoptability were shown by the rate of harvesting on time, the rate of gap filling on time and machine usage to land preparation, indicating 93.7%, 89.3% and 87.7% respectively. The lowest percentages of adoptability were shown by application organic manure, application of inorganic manure and usage of correct land preparation methods. The major barriers to sugarcane small holders recognised from the study were namely lack of capital, lack of technical knowledge and lack of skilled labor. Study concludes that there was a significant variation in SAP adoption among small sugarcane holders in Sewanagala area. The level of SAP adoption among sugarcane small holders can be uplifted by improving the technical knowledge and skills, providing accurate updated information and providing financial assistance by the relevant authorities.

Keywords: Adoption, Sugarcane, Sustainable agriculture, Technology


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<td>Yakandawala K.</td>
<td>13,31</td>
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<td>Yapa P.I.</td>
<td>11</td>
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<td>Yokoyama Y.</td>
<td>81</td>
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<td>Zabith S.H.M.</td>
<td>44</td>
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</table>
The Mangrove Nursery within our factory premises hosts 10,000 saplings belonging to 7 native species.

Since inception, we have planted over 65,000 mangrove trees around the Trincomalee bay, together with Sri Lanka Navy.

We follow the natural composition of mangrove habitat in Cod Bay to replant.

17,000 saplings planted along the coast around our factory is now a flourishing mangrove habitat.

Our biomass energy programme currently has a total capacity of 24MW/h.

We have planted over 6 million Gliricidia trees as fuel for our power plants in Trincomalee and Mahiyangana.

We are 100% energy independent & our entire local production process is based on Renewable Biomass Energy.

This has helped us reduce our carbon footprint to 100,000MT CO² per year.

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**Reef Ball Deployment**

Reef balls deployed as at mid-2020
- Jaffna - 56
- Seenigama - 46
- Galle - 34
- Passikudah - 400
- Trincomalee - 85
- Kalpitiya - 60
- Rumassala - 10

**Research & Education**

Established a long-term coral reef monitoring program.

Capacity building by providing research training to university students and volunteers.

Community education and collaborative cleanups.

Support extended to conduct a study on breeding grounds of Eels and Eels, in and around the seas of Jaffna Peninsula.

**Conservation**

Facilitate the declaration of the Kayankerni Marine Sanctuary as the 27th Marine Protected Area in Sri Lanka.

Mapped the Kayankerni reef system, which became one of 7 sites globally to be included in the Global Coral Atlas (a global initiative to map and monitor coral reefs).
Control Union is a specialist in certifications, commodity inspections, quantity and quality control and risk management with a global presence. We have in-depth knowledge and experience of all aspects in the logistics chain in many commodities, including biofuels and biomass. Our international network of offices, laboratories and accredited agents enable us to offer a full range of services worldwide.

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CONTACT US
Control Union Inspections (Pvt) Ltd.
No. 100/8, 3rd Floor, FPA Building, Nawala Road, Narahenpita, Sri Lanka
T: +94112678607
E: cusrlanka@controlunion.com

Environmental Science, University of Sri Jayewardenepura, Sri Lanka

www.pETERSONCONTROLUNION.com