NSF Research Summit 2016

"Empowered by Research & Innovation"

07th & 08th July 2016

BMICH, Colombo

Organized by

National Science Foundation
Ministry of Science, Technology & Research

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Minister's message

Hon. Susil Premajayantha (M.P.)

Minister of
Science, Technology & Research

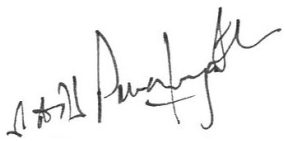
I am pleased as the Minister of Science, Technology and Research, to extend my warmest greetings to all those attending and contributing to the NSF Research Summit 2016. This gathering is an imperative forum for academia, industry and government to shape the future of Science and Technology in our nation.

The socio-economic development of any nation is being dictated by the innovations in Science and Technology. Innovation presupposes strong foundations of scientific research and its ultimate goal is the creation of value. The National Science Foundation is playing a major role to promote the use of Science, Technology and Research as an integral part of the effort to achieve the rapid economic growth, and improve quality of life. Its activities that involve scientists and technologists from different disciplines, sectors both from the government and private sector is praiseworthy. I take this opportunity to reiterate that our government supports and shares commitments to advancing Sri Lankan Science and Technology strategy to next level.

NSF Research Summit 2016 is a great opportunity to integrate different mindsets from different disciplines and sectors by creating the platform to deliberate on key areas that are vitally important to our country.

I am confident that these deliberators would provide the foundation for the imperative research and development programs for the country.

I extend my best wishes for an excellent and productive Research Summit.



Hon. Susil Premajayantha
Ministry of Science, Technology & Research
Stage I, Sethsiripaya
Battaramulla

05 July 2016

State Minister's message

Hon. Lakshman Senewiratne (M.P.)

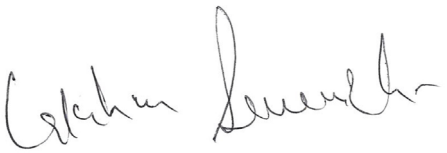
State Minister of
Science, Technology & Research

I am pleased to extend warm greetings to everyone participating in this NSF Research Summit 2016: Empowered by Research & Innovation. Innovation can play a critical role in addressing socio-economic objectives.

The Ministry of Science Technology and Research is very concerned with the innovative output of the Sri Lankan Scientists that will be reflected in the quality of their research, and most importantly, in their contribution to Socio-Economic development of the Nation. In this context, it is a pleasure to note that the NSF is taking steps to identify priority areas for funding that are likely to be beneficial to Sri Lanka and to promote research and development in such areas.

I hope that the NSF Research Summit 2016 will immensely help to exchange new and innovative ideas and provide opportunities for the academic research and industrial communities to venture into innovative programmes.

I congratulate the National Science Foundation for organizing this Research Summit and wish it all success.



Hon. Lakshman Senewiratne
Ministry of Science, Technology & Research
Stage I, Sethsiripaya
Battaramulla

05 July 2016

Chairperson's message

Prof. Sirimali Fernando
Chairperson

As the Chairperson of the National Science Foundation, I am privileged to send this message to the Proceedings of NSF Research Summit 2016: Empowered by Research & Innovation. The theme of the Research Summit portrays the goal of the summit which is to provide an open forum for researchers, policy makers, representatives from state and private sectors to present and share their knowledge and experiences in technological, research and commercialization spheres.

Through its vision and mission, the National Science Foundation prioritizes promoting Science, Technology and Innovation (STI) for socio-economic prosperity of the nation. Mandated by the Science and Technology Development Act, No 11 of 1994, of the Democratic Socialist Republic of Sri Lanka, the NSF is committed to strengthening scientific research potential in the country by funding STI activities through its numerous grant schemes.

To compliment this, the NSF Research Summit 2016 will open up a wider dialogue on the current status, latest scientific advancements and how STI could address issues and gaps in areas of Food & Agriculture, Energy & Environment and Health. The session on Industry Interaction will enable researchers and the private sector to discuss commercially viable new products and processes in these sectors. I am confident that these deliberations would direct our future research funding initiatives, for the next 3 years.

I thank and congratulate the Scientific Committee of the Research Summit 2016 and staff of NSF, especially, the Director General, Head and staff of the Research Division for their unstinted efforts and cooperation to make this event a success.

I wish NSF Research Summit 2016 all success.

Prof. Sirimali Fernando
National Science Foundation
Colombo 07

05 July 2016

Director General's message

Anusha Amarasinghe
Director General

I consider it a privilege and an honour to be able to send this message on this special occasion of the NSF, the Research Summit 2016: Empowered by Research and Innovation. The National Science Foundation, mandated to serve and strengthen the Science and Technology sector in Sri Lanka, performs its tasks in accordance with the functions set out in the Science and Technology Development Act No 11 of 1994. National Science Foundation being one of the responsible and leading institutions in the Science and Technology sector of the country, is committed to generate, disseminate and transfer of such knowledge and more importantly to ensure the effective utilization of such knowledge for the greater benefit of the people, as its prime objective. Focus on research, development and innovation is of vital importance to align and fulfill the expectations and gaps in the society in today's scenario.

It is with this backdrop, that the National Science Foundation organized the Research Summit – 2016 : Empowered by Research and Innovation, jointly with the Ministry of Science, Technology and Research, with the prime objective to draw up an agenda for research, innovation, and commercialization and to map out the future strategy of the National Science Foundation leading to socio-economic development of the country.

Research Summit 2016 provides a good opportunity and a national level platform to disseminate new knowledge based on latest research studies done in the country under three main vital and important themes; Food & Agriculture, Energy & Environment and Health, followed by an Industry Interaction session – *Harnessing Research and Development for socio-economic benefit : bridging the gaps of value chain*. Currently important national level issues such as climate change & natural disasters, solid waste management, diabetes, dengue and CKDu are also addressed under sub themes coming under above main themes. It is expected that this will ultimately facilitate the taking of research outputs beyond laboratory scale.

A large cross-section of participants including eminent scientists from universities, research institutes and the private sector, and future scientists such as undergraduate students and final year Advanced Level top performers are due to attend the summit.

It is always a challenge to organize a national level summit. Behind the successful organization of the Research Summit 2016, there is the Chairperson and the Board of Management of the National Science Foundation who always had the confidence in NSF staff taking up the drive towards the success of the organization and dedication, effort and timely deliverables of the Scientific

Committee of the NSF Research Summit, Panel Chairs and Members, Organizing Committee of the event and the NSF Staff. Ministry of Science, Technology and Research assisted NSF in many ways in ensuring timely organization of this Summit. I compliment all of you in meeting this vital emerging need of the country despite various challenges.

I am confident that this Summit will be a productive Forum to discuss and to share knowledge on a number of topics on which national emphasis in Research, Development and Innovation is needed in forthcoming years in order to achieve its objectives.

I wish the Research Summit 2016 a great success!

Anusha Amarasinghe
National Science Foundation
Colombo 07

05 July 2016

Keynote Address

Biotechnology- Societal Impact and Vision for Sri Lanka

Dr Sumedha Jayasena
Former Vice President, Translational Research, TransDerm Inc. Santa Cruz, California, USA

Biotechnology is not new. Humans have been using biotechnology since the turn of the human civilization. For example, Egyptians used yeast to make leavened bread and the Chinese perfected fermentation for brewing and cheese making. Those applications come under the classical biotechnology. Today, for most of us, biotechnology means the 'modern biotechnology', which was established after the discovery of restriction enzymes to cleave DNA at specific sequences followed by the invention of the recombinant DNA technology. The latter allowed swapping genes from one species to the other to generate transgenic animals and plants or genetically modified organisms (GMOs). At present, even without our knowledge, we are using products derived from biotechnology in day-to-day applications. This technology is revolutionizing many fields of science.

Applications of biotechnology in several areas, including agriculture, food, environment and healthcare have already impacted the society and will continue to do so. It has provided solutions to many man-made calamities such as oil spills, landmines, as well as to certain consequences of global warming. Bacteria that metabolize petroleum oil and detect TNT in landmines and zebra fish that change color in response to the presence of poly chlorinated biphenyls (PCBs) and dioxin in contaminated water have been introduced. In agriculture, major staple crops have been made insect resistant, eliminating the use of insecticides that are toxic to humans. Introduction of drought-resistant crops and those that can grow on alkaline soil have also been introduced, which will open up a previously unusable landmass for cultivation. The most significant impact of biotechnology has been and continues to be in medicine and healthcare. To treat human diseases, different therapeutic modalities, such as vaccines, monoclonal antibodies, small molecule inhibitors, molecules that inhibit the expression of disease-causing genes have been introduced. Emerging drugs based on such technologies are, in fact, curing human diseases, eliminating the cost of healthcare to manage patients. In the healthcare sector several game-changing technologies have already been introduced, including the sequencing of the human genome, genome editing and stem cell therapy. These technologies will change the way we practice medicine in the future.

Biotechnological advances also bring ethical, societal and environmental concerns as they cross already established and accepted boundaries in these areas. As a result, new policies must continue to evolve to prevent the abusive use of biotechnology applications.

In Sri Lanka, biotechnology research has already taken root in academia, government research institutes as well as in industry. A national policy for biotechnology has already been established. To enhance and accelerate research, applications and innovations in the biotechnology area, national commitment, harnessing human and natural resources in Sri Lanka should be paramount. Sri Lanka has unique natural resources to identify niches for developing products not only with intellectual property protection but also to carve out new markets.

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Food security – role of research and innovation

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According to the World Food Summit of 1996 food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. This in simple terms means the availability of food and one's access to it. Accessibility however, should not be confined to basic food needs for mere survival but must include a nutritionally adequate basket of food that is safe for consumption.

The absence of food (and nutrition) security is considered to be a problem of underdevelopment. It is complex and multi-dimensional and is not synonymous with food self-sufficiency. Many developed and developing countries are not fully self-sufficient in food but enjoy substantial food and nutrition security.

Economic advancement is a measure of 'development' of a country. Countries with a high per capita GDP tend to invest more in science and technology, and have a large critical mass of scientifically and technically qualified people to carry out research and development. This critical mass generally 'drives' the science and technology status of the country leading to innovation and wealth creation.

Availability of a food commodity in the domestic market depends to a large extent on the production of that commodity, with an adequate and well organized distribution system. Research plays a leading role in increasing productivity; for example introduction of novel agronomic practices, high yielding varieties that are insect and pest resistant or products having a longer shelf life. Although investment in research and development often leads to productivity gains, realization of benefits from investment in agriculture research often takes a long period of time.

According to Food and Agriculture Organization (FAO) estimates, about 32 % of all food produced globally is wasted, leading to many negative economic and environmental impacts and thereby compromising food security. At least 10 % of this global loss is due to diseases of crop plants that provide the bulk of food for human consumption, both in the field and post-harvest by pathogens such as viruses, bacteria, fungi and nematodes. One of the difficulties faced by plant pathologists is the reliable and rapid identification of the causal agent of a disease. Although methods are available for identification of pathogens current methods are complex, laborious and time consuming. Often they are costly and require expensive sample preparation and equipment.

As a result of innovation, new technologies have been developed that could facilitate early detection of pathogens that cause disease in food crops. Such technologies can be extended to detect toxins, chemical residues or adulterants in food at any stage of the production chain as well as to detect pathogens that cause food borne diseases, thus ensuring safety of the food we consume. These new and emerging technologies are rapid, inexpensive and simple and easy to use in the field.

Investment in research and innovation towards developing new technologies is essential in the light of the magnitude of the challenges for food security in the coming decades.

Research in energy and environment: vision based research and moving the nation

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When the Nobel Laureate Prof. Smalley (Rice University, USA) highlighted problems facing humanity for the next 30-50 years and tested his concept of identifying the most significant issues with the public, he identified that many described environment as a critical issue but no one placed energy as the most critical one. He argued and demonstrated that if the energy issue was resolved all the other problems facing humanity would become non-issues, and his argument was quite persuasive. He was seeking research on nanotechnology to address the 'energy problem' and subsequently all other problems. The aim of research as identified by him was to solve issue and ensure progress not only with current issues but with emerging issues in mind as well a concept that we should also be mindful of.

The Sri Lankan research ecosystem is neither broad nor dynamic; neither is it well populated. As multiple issues appear to stall the progress, one may identify the stagnant public sector investment which is well below the required levels as singularly responsible. National policies have been rarely influenced by domestic research and development and this is definitely a key issue to be addressed. How can one make indigenous research count? Why should policy makers reach out to the researcher in finding answers to their issues? There is work to be done by both parties and sooner the meeting of minds takes place the better it would be for the nation.

An analysis of research publications in energy and environment which COSTI commissioned, within the indexed journals indicate that although the quantity was not significant, quality is present when taking note of the field weighted citation index. While the research does indicate a decent impact positioning within the global publications, the impact locally needs to be addressed as per the earlier questions raised.

Sri Lankan energy research has concentrated on five categories such as general energy, energy engineering and power, fuel technology, nuclear energy and engineering, and renewable energy and sustainability. Field-weighted citation impact (FWCI) is an important parameter which indicates the volume and quality of research publications in a country. Sri Lanka's FWCI for energy is 1.74, which is above the global average.

There is a need for a more dynamic engagement throughout the whole process of research, publication and dissemination. Once connected then the monetized value of the research carried out will increase. With proven results on the ground, more investment to both public and private research funding can be realized. It is important that one argues for more results and impact based investment. The first step towards realizing this may lie with researchers and their own institutions.

The paradox of Sri Lanka's achievements and challenges in health development (Can Sri Lankans be healthy, wealthy and wise?)

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Sri Lanka had adopted some of the key principles of primary health care (PHC) almost four decades before Alma Ata and the results were quite dramatic in terms of the indicators in maternal and child health and in the control of communicable diseases in the past 5-6 decades. Life expectancy has increased and a Sri Lankan girl born today can aspire to an average of nearly 80 years of life. However, these gains in life expectancy have not been even and the male life expectancy has tended to lag behind and then stagnate since 1980s.

The significance of these achievements at our level of socio-economic development is noteworthy. Sri Lanka's health outcomes and indicators in relation to other countries provide evidence of the well functioning healthcare delivery system we had established in Sri Lanka.

However we now face newer challenges – mainly non communicable diseases (NCDs), newer and reemerging communicable diseases and intractable measles, mumps and rubella (MMR) and persistent malnutrition among them.

Sri Lanka, having transitioned from a low income country to a middle income country, is in an advanced stage of a demographic transition. The proportion of people 60 years and older is likely to more than double by 2040, to just above 24 %. In addition, an epidemiologic transition is shifting the disease pattern from maternal and child health and infectious diseases towards NCDs, which now account for nearly 80-90 % of the disease burden. Because NCDs are more common with aging, timely actions now could trigger many future benefits such as healthy aging, lower disability, and longer, more productive lives.

How can we best address them?

We need to adopt at least 4 key strategies - applying better what we now know, judiciously applying newer technologies and new knowledge, making preparations to enable early responses to emergencies and improving health financing and human resources management.

Sri Lanka holds the potential and the promise to continue to be a paradox for health development in South East Asia and outside and Sri Lankans can aspire to be healthy, wealthy and wise.

Synopses of Sub-themes

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The food situation in the last few years confirms that the country is food secure at the national level. As a whole, national level food availability has been on the rise due to increased domestic food production and importation of several commodities. The availability of adequate food at national level doesn't necessarily ensure food security at the household level. Hence, it is important to look at, whether the national food availability has sufficiently ensured access to food at the household level. The level of income and income distribution mainly determine the access to food at the household level. There is ample evidence that household food insecurity is a significant problem in the country. There are serious concerns with respect to household food security especially in terms of access to food and utilization.

Sri Lanka should focus on a combination of domestic food production, along with better market to farmers and introducing post harvest technologies etc. There will be systematic methodologies to predict what should be cultivated during a particular season to fetch a better income for farmers reducing huge harvest losses. Under the National Thematic Research Programme (NTRP) - Food Security programme of the National Science Foundation, such approach has been taken to address some of the issues and the success stories will be presented at the Research Summit. However further interventions are needed.

Key technologies needed to address priority issues in the area are; imposing climate smart agriculture practices; improvement of appropriate agro-technologies (e.g. nano-technology); plant breeding programmes for improved varieties; optimal use of lands which are under unfavourable stress conditions; popularization of use of alternative crops as substitutes for major food commodities; long term government policies and their efficient implementation mechanisms; promotion of extension programmes; development and improvement of postharvest handling systems, processing and storage methods at all levels.

Future food security projects should address the pressing needs of vulnerable small scale farmers, particularly women through innovations in crop and livestock production as well as preservation technologies to reduce postharvest losses using nanotechnology. Climate smart agriculture can be introduced to improve the carbon foot print as well as reduce methane emissions from farms.

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The objective of the present session is to develop a research and development program for cinnamon industry to gain the competitive advantage in cinnamon market by improving the production, processing and marketing aspects through networking and clustering of all stakeholders into an innovation system.

Currently Sri Lanka is the largest producer of Ceylon cinnamon accounting for 65 % to 70 % of the world product. Mexico and Latin American countries provide the world's largest marketplace for Ceylon cinnamon. The demand for Ceylon cinnamon in the world market including the EU and US markets are increasing due to its wider application in culinary, food and beverages, liquor, pharmaceutical applications, and perfumery industries. Technology incorporation is vital for the sector by mixing traditional with new knowledge to meet the market demand.

The key research areas needed to be addressed are; expansion of plantations to marginal lands, increasing the productivity of the plantations by introducing new varieties, and improving the agronomy to meet with the challenges of climate change. A complete revolution in the cinnamon peeling industry needs to be stimulated by introducing mechanization and new technologies. Clustering and branding of products, and education research for manpower development (training for the cinnamon peelers, planters, technologists, curricular development and commencing short and long term diploma and degree courses) are vital. Application research incorporating ICT, biotechnology to mix traditional with new knowledge, engage with research to promote new inventions in the fields of pharmaceutical and nutraceuticals, essential oil and aroma therapy sectors are promising research areas. Formation of cinnamon clusters, strengthening existing smallholder associations, value chain enhancement from farm to folk are emerging socio-economic research areas.

In the session; overview on avenues and challenges for product diversification, and new knowledge application for impact oriented research; research by the Department of Export Agriculture with special attention to patenting; industry collaboration and commercialization; new and traditional knowledge in cinnamon-based pharmaceuticals and neutraceuticals; mechanization and modernization of cinnamon peeling and essential oil industry to meet fair trade; challenges and way forward for economic transformation through private-public partnership building for research commercialization will be addressed.

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Sri Lanka has a strong tradition of quality research in the area of natural products. Considering the field from the point of view of utilization and commercialization, three major areas with potential for development can be recognized, namely: drug development, chemicals for use in agriculture and herbal products (phytopharmaceuticals, nutraceuticals, cosmetics). Although the presence of a high level of endemic plants and a wealth of traditional knowledge on the utilization of locally available plants create a favourable background for realizing this potential, there are several impediments that can be identified.

All three areas are affected by the lack of readily available advanced instrumentation for structure analysis and biological activity testing. Drug development is a long term and expensive enterprise and Sri Lanka does not have the human resources, infrastructure and the finances to be engaged in drug development on its own. Collaboration with foreign partners is essential and the legal and administrative framework for encouraging and facilitating collaboration needs to be set up by the relevant government agencies. The NSF could play a leading role in this effort.

The other two areas do not have the same difficulties as drug development and may be more likely to yield tangible results in the short term. The current emphasis by the government on reducing the usage of synthetic agricultural chemicals creates an opportunity to research and develop products based on traditional knowledge as well as on results of random screening. Similarly the ever increasing global enthusiasm for anything 'natural' presents an inviting opportunity for developing herbal products. No real innovation or sustainable progress will be possible without having competent personnel firmly grounded in basic sciences working in an enabling environment.

The NSF, by prioritizing research areas can facilitate development and help to create the required expertise and the knowledge base. However, it should be appreciated that establishing a product in the market requires many other inputs besides science, which are not within the purview of the NSF.

Prof. A R Ariyaratne
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Agriculture is a way of life and a complex process of producing food, feed, fibre and many other products to support activities by people. The practices which have been followed in this production system and the changes taking place at global level have resulted in a challenging environment for agriculture. The global climate change, exploitation of natural resources such as land and water, the ever increasing demand for food due to rising population, dependency on chemical based practices, and socio-economic changes have influenced the necessity to find ways for achieving sustainability of agriculture. Innovative approaches to the current practices and inputs for agriculture are needed not only to sustain it but also to meet the increasing demand for food. Improved technologies and innovations in agriculture are the key elements which will usher improved agricultural production systems to ensure a better future.

Development of sustainable and climate-resilient agriculture that is capable of meeting the dietary and income needs of the producers is the prime requirement in this sector. Insufficient livelihood development has resulted in the young generation moving away from agriculture. Hence, attracting youth into farming has become a key issue in the development of agriculture. Technologies have to be developed to meet the aspirations of the youth while considering the issues such as sustainability, food security and health.

Benefits such as food security and higher income can be drawn from the development of value chains that have gained importance and influence at national and international level. Research, development and innovations that are capable of increasing the productivity of agricultural and farming systems, and producing affordable, safe, healthy, nutritious and high quality food while assuring sustainable use of natural resources are needed. Technologies such as modified crops, precision agriculture, and advanced crop protection methodologies can be seen as promising answers to these challenges in agriculture.

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Energy has contributed for many achievements in economic development globally. However, extensive use of fossil fuels and their emissions have resulted in many challenging energy and environment issues. Accordingly, the concept of sustainable energy has evolved, and demands for improvements in energy efficiency (EE) and more usage of renewable energy (RE) sources, while ensuring universal access to modern energy dependent services. Sri Lanka has a less energy intensive economy; yet low EE is still apparent across all energy sectors. Although Sri Lanka has a variety of RE resources, which contribute to about 50 % of primary energy supply, there is much more potential for further developments. These challenges and opportunities demand for strategic implementation of research and development (R&D) in all sectors.

Energy supply sector requires efficient technologies in extraction, conversion, transmission, distribution and storage related to REs such as biomass (including waste), solar, wind, hydro, geothermal, ocean thermal and ocean wave. Less energy intensive economic development demands for the establishment of sustainable communities and smart cities for urban settlements, which rely on a sustainable and resilient energy system, built with an integrated approach for energy planning, smart supply technologies with inclusion of REs, energy storage, energy management systems, smart grids, green buildings and intelligent transport systems for sustainable mobility.

Deployment of REs essentially requires R&D interventions for establishment of effective tools/ technologies for mapping and characterization of REs, and the development of efficient conversion technologies with emphasis on local value addition/manufacture. Enhancement of grid-capacity for centralized/de-centralized RE integration through dynamic modelling, advanced forecasting and SCADA systems as well as development of smart energy storage systems become priorities. EE improvements could be realized through R&D in several areas such as sensor-based networks and grid management, smart energy storage, intelligent demand management, smart meters and machine to machine communications, smart appliances, processors and sensors, and intelligent waste management systems. In the transport sector, R&D interventions for the promotion of mass transport, electric mobility and charging infrastructure, non-motorized transport modes and transport demand management could contribute to sustainable energy targets.

Prof. W L Sumathipala
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Natural disasters associated with global warming induced climate change, are being experienced all over the world. As such climate change has become a major issue that has attracted the attention of world leaders. Many of these natural disasters can be considered as man-made by over exploitation of natural resources due to unplanned short-sighted economic development activities.

Some of the disasters that are mainly relevant to Sri Lanka and will create problems in time to come are, tropical storm associated heavy rainfall events, flooding, landslides, lightning, droughts, forest fires and vector borne diseases, sea-level rise, coastal erosion, salt water intrusion, spread of invasive species and biodiversity loss. In order to face the situation and find solutions, both in the short and long term, well planned and directed research needs to be carried out.

Most important will be to improve climate change predictive capabilities. Global models on climate change need to be studied and modified to give realistic predictions for Sri Lanka which is a small island in the large Indian Ocean. Modern equipment to observe and gather data will be needed to achieve a reliable and realistic forecast. With the experience of recent past it will be necessary to pay more attention on natural disasters such as flashfloods and landslides and prediction and warning systems have to be improved.

Climate change is due to increased emission of greenhouse gases (GHGs). As energy generation and transport sectors are responsible for such emissions, it will be a win-win situation for Sri Lanka to move towards renewable energy and environment friendly transportation. This will also contribute significantly toward sustainable economic development. It is necessary to ensure the availability of essential commodities such as food, water, shelter etc., under future climate change scenarios. Therefore in order for food security to be assured, research should be oriented towards producing crops with less water and saline conditions. Crops need to be developed or adopted to resist droughts, salinity as well as flooding conditions so that approved varieties can be used depending on the situation. High yield producing varieties with high tolerance rates will be useful. Innovative methods to manage watersheds for sustainable water supply will build resilience to climate change.

Oceans are the heat reservoirs that maintain and manipulate the weather and climate, specially for islands such as Sri Lanka. Ocean monitoring and use of data gathered will be of enormous use for climate change and sea level rise prediction.

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Climate change (CC) results in a range of serious consequences, with longer term impacts such as sea level rise and loss of biodiversity, and immediate obvious impacts such as intense rainfall and flooding. With an increased number of extreme weather events recorded recently in Sri Lanka, establishment of their link to CC has become a serious concern. However, CC and its impacts are scientific questions of great complexity, and simple answers are not to be expected. Sri Lanka has recognized the cross-cutting nature of the issue and the necessity of considering CC in the development-oriented decision-making process.

The government of Sri Lanka, being cognizant of the irreversible impacts of climate change on its development agenda, has launched several national initiatives to face the threat of climate change. The United Nations Framework Convention on Climate Change (UNFCCC) was ratified by Sri Lanka on 23rd November 1993 and entered into force on 21st March 1994. Sri Lanka was among the first 50 countries to have ratified the convention. This was followed by becoming a signatory to the Montreal Protocol (on substances that deplete the ozone layer) and the Kyoto Protocol, which commits countries i.e. mainly Annex I parties, to reduce their collective emissions of greenhouse gases (GHGs). Although Sri Lanka is a Non Annex I country with a per capita emission of GHGs as low as 0.6 ton of CO_2 equivalent per year, the objective of the government of Sri Lanka is to encourage and facilitate investments in climate-friendly development activities, while fulfilling the country obligations and contributing to the ultimate objective of the UNFCCC.

Being a signatory to the Paris Agreement on Climate Change on 22nd April 2016 and the submission of Intended Nationally Determined Contributions (INDCs), are recent significant developments in Sri Lanka which facilitate the national and global effort to tackle dangerous climate change. Establishment of the Climate Change Secretariat (CCS) at the Ministry of Mahaweli Development and Environment (the National Designated Entity for UNFCCC); adoption of the National Climate Change Policy (NCCP – 2012); preparation of the National Climate Change Adaptation Strategy (2011-2016), Sri Lanka Disaster Management Act (No 13 of 2005); Sri Lanka Disaster Management Policy (2005), and Sri Lanka Comprehensive Disaster Management Programme (2014-2018), establishment of the Ministry of Disaster Management, Disaster Management Centre, and two National Experts Committees on Climate Change Adaptation and Mitigation; implementation of Nationally Appropriate Mitigation Action (NAMA) on energy generation and end use sectors and the National Program on 'Sri Lanka NEXT – Blue Green Era'; and finalization of the National Adaptation Plan (NAP) 2016-2025 are the major national initiatives taken by the government of Sri Lanka in this context.

Sri Lanka has also shown promise and strength to build up resilience with effective adaptive action, to minimize the adverse effects of the inevitable changes of the climate. Despite the magnitude of the efforts and initiatives taken by the government, demonstrating its commitment and obligations to the global context by ratification of conventions, a serious gap still exists especially in the implementation of policies and strategies. Creating awareness among the general public for constructive actions to address complex climate change issues is still far below the expected levels. Increasing speculations make the much-needed mainstreaming difficult to agree upon and implement and thus, further exacerbate climate risks.

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Abundance of safe water is a wealth of a nation. The United Nations directives declare that 'the human right to water entitles everyone without discrimination to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use.' Sri Lanka is not a water scarce nation! Presently 44 % of the population have access to piped water; 3 % have access to hand pump tube wells; 36 % have access to safe drinking water through protected dug wells, and 1 % of the population uses rainwater harvesting systems. The remaining 15 % of the population does not have access to safe water sources. An urgent need for a water management policy for Sri Lanka is emphasized. Majority of the water quality issues are dominant in the dry zone (which spans approximately two thirds of the total area of the country). Except in urban areas in the dry zone, the majority of the people (~85 %) use water at their own risk. Dry zone drinking water resources are characterized largely by contaminants received by lithogenic inputs. Information on agrochemicals in water is sporadic. The government of Sri Lanka is very cognizant of the water problem and targets to provide pipe-borne water to the entire nation by 2020. However, provision of good water supply and allied water related technologies under surveillance of the National Water Supply and Drainage Board is of utmost importance.

The technical session on water security is dedicated to identify pressing gaps in scientific knowledge, key technologies required, and innovative solutions to set up research priorities for the next decade for improved quality of life. Recommendations formulated during this session will be utilized by the NSF in deciding future research funding in the field of water security.

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Sri Lanka and many developing countries face epidemics of non-communicable diseases (NCDs), especially diabetes, hypertension and ischemic heart disease. Diabetes is especially important because it is estimated that more than 10 % of the adult population is affected by it, and its contribution to numerous other disorders such as chronic kidney disease, blindness, amputations of limbs and heart disease. There are no studies during the past decade which have comprehensively investigated the nation-wide prevalence of diabetes and related NCDs, its risk factors, complications and socio-economic burden. Though there is an obviously visible economic burden to the country, indigenous innovations and devices to help tackle the disease are few.

It is proposed that the country establishes a national level study to comprehensively investigate the prevalence of diabetes and associated NCDs, their risk factors and determinants, complications and socio-economic burden. This should be complemented with a facility survey and infrastructure to establish a subsequent cohort study. This will require the establishment of a national multidisciplinary research centre with collaborative links locally and internationally.

Key technologies should attempt to develop devices for screening, diagnosis, monitoring of progress and management. These would include non-invasive assay of serum glucose (e.g. using salivary levels), urinary strips to detect microalbuminuria, capillary blood strip-tests for HbA1c, early detection of foot disease, digital platforms and mobile-phone technology to assist in management, and mobile-phone based monitoring of blood glucose levels.

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Dengue fever (DF) continues to be of major concern in Sri Lanka. Although there is a significant decline in mortality, recurrent outbreaks throughout the country causing ill health, anxiety, loss of educational and productive activity and financial costs to individual families and the State contribute to continuing morbidity.

Intense monitoring with timely and proper fluid management has enabled the reduction of dengue associated mortality in Sri Lanka. However, it is difficult to monitor all patients with acute DF in resource-poor countries such as Sri Lanka, with hospitals facing heavy case loads during dengue outbreaks. The development of biomarkers, or devices which accurately predict severe dengue would enable close monitoring with early clinical response in patients at risk. For development of drugs to treat DF, it is crucial to understand the events that lead to vascular leak in dengue. Clinical trials are being conducted by Sri Lankan and foreign scientists to develop such drugs which either target the virus or the host.

Control of transmission by vector control remains the dominant means of control attempts, although relatively unsuccessful in Sri Lanka or elsewhere. *Aedes aegypti* and *A. albopictus*, the key mosquito vectors are day-biters, which breed in hard-to-eliminate collections of water. The rapid increase in cases following the recent rains emphasizes the difficulties of eliminating vector habitats. It is also possible that viraemia in asymptomatic and mildly symptomatic people allows rapid build up of a human reservoir pool for transmission, increasing the difficulties of control programmes.

Control of dengue in Sri Lanka needs to be multipronged and sustainable. Development of a device or a biomarker, which will identify patients who are likely to develop severe dengue, and determining the factors that lead to vascular leak and severe dengue are crucial for early detection of patients at risk of complicated dengue and for the development of drug(s) and vaccines for treatment and prevention of dengue. Island-wide surveillance of changes in dengue virus serotype and vector density as well as outbreak markers are essential to develop early warning systems which can elicit prompt public health responses. The development of more effective means of monitoring changes in vector densities, and effective and sustainable methods of vector control are also needed.

Scientists working in this field, by sharing their knowledge and their research findings will help towards moving this country to be dengue free in the foreseeable future.

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Chronic kidney disease of unknown origin (CKDu) is an illness recognized in Sri Lanka from the early 1990s. It is now seen in the Northwestern province, Northcentral province, some parts of Uva and Eastren provinces. It is seen in epidemic proportion and is of importance in view of its socio-economic implications to the poor farmers in these provinces.

Much scientific and clinical research in Sri Lanka from multiple sectors have thrown light on various aspects studied. The World Health Organization (WHO) and Ministry of Health (MoH) undertook a major study in 2005 for 04 years and the report was widely publicized and the Cabinet memorandum which followed led to several mitigational decisions. The National Science Foundation (NSF) co-funded this study.

However, no clear aetiology has been forthcoming and cadmium exposure has been highlighted as an important factor. Other scientists suggest arsenic, fertilizer, pesticide residues, glyphosate, hardness of water, fluoride in water etc. in different proportions and conditions. It is possible that different combinations of the suggested aetiological agents may be responsible in different districts. However, water appears to be a centrally important source closely related to the epidemic.

More recently, food as a source of likely contaminants is suggested needing further studies. Heat stress and dehydration is suggested in Mesoamerican areas.

The lack of a clear case definition and a national survey hinders long term strategies, comparative studies and cohort studies. This is considered a priority issue needing to be addressed without delay.

Another output of this session is to look for innovative solutions, eg. strip methods for point of care testing in epidemiologic studies and mobile dialysis options.

We hope to promote international and regional cooperation and research collaborations, and sharing of data between scientists.

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According to the Annual Health Bulletin 2013 of the Ministry of Health, the incidence of cancer is increasing. During the period 2009 to 2013, approximately 20,000 to 25,000 new patients with cancer sought treatment in government hospitals every year. In 2013, the most recent year for which complete data is available, cancer was the second leading cause of hospital deaths in Sri Lanka. The escalation of cost of treatment has resulted in upper limits being set on the value of treatment that patients can obtain free through the government health service. On certain occasions patients receive millions of rupees worth of free treatment just to gain an increased life expectancy of a few months. Therefore, the strain put on the national health budget by cancer and the suffering to the patients is enormous.

It is necessary therefore to identify and prevent cancer before it occurs. At molecular level, all cancers are genetic, and some are inherited. Therefore, it is necessary to identify biomarkers that would enable early detection and intervention to prevent cancer, or detect cancer at a very early stage and serve as diagnostic markers, prognostic markers, and targets for developing new drugs. To do such discovery research we have to establish a national bio-bank containing cancer tissue, blood, serum and other body fluids of patients with cancer together with properly collected clinical data. This could become a central resource administered by the NSF with proper guidelines. Once such a resource is established any researcher with an interest in access to samples to discover biomarkers can be given access, and subsequently funding to do the discovery that they propose. When discoveries are made, the NSF can patent the discovery, and commercialise it in collaboration with local pharmaceutical companies.

The huge financial strain put on the national budget for medicines imported from abroad makes it necessary for us to identify new anticancer compounds locally and use them in clinical care. To do so we can turn to the rich biodiversity of the country. To test the anticancer properties of such compounds we have to establish a standardized validated natural products panel for Sri Lanka and a cancer stem cell platform for validating anticancer properties of natural products. To do so the NSF can take the following approaches: firstly the NSF can set aside funding for the establishment of a standardized validated natural products panel for Sri Lanka; secondly the NSF can either set up a national high throughput screening facility or encourage various research groups to set up their own platforms. When such compounds are identified, the NSF can patent the discovery, and commercialise it in collaboration with local pharmaceutical companies. Taking such a compound to the market is a long process which only pharma companies can do because it involves – preclinical, phase I, phase II, and phase III trials as well as a long process of regulatory approvals.

Invited Presentations

Food & Agricuture

Agriculture mobile application for farmers

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Abstract

Timely and relevant agriculture information is essential for farmers to make effective decisions. Finding the right approach to provide this information to empower farmers is vital due to the high failure rate in current agricultural information systems. As most farmers now have mobile phones we developed a mobile based information system. We used participatory action research methodology to enable high farmer participation to ensure sustainability of the solution. Current version of the application based on the preliminary studies focused on the crop choosing stage, crop growing stage and crop prices and managing expenses of the farming life cycle. Currently, the system uses a database and a knowledge base to manage the information and there are over 100 crops and variety information that has been compiled for various vegetables. Farmers can also view their past farming activities during the process to make effective decisions.

Future research would link this application with some private sector companies in order to reach a wider farming community covering crops such as maize, gherkins and cinnamon. It would take some time to do the required analyses and identify the requirements before we can implement a suitable system with the companies own dash boards etc. As future work we are also looking at how to provide weather data, micro finance information etc., to the farmers.

The innovation provides the farmer with the opportunity to obtain information on crop management and necessary fertilizaer inputs and compute the required investment to grow a selected crop. It will have the potential for commercialization once we complete the project with the private sector. Over 30 farmers located in Dambulla and Polonnaruwa are currently using the system on a regular basis and they have found the information very useful to make their decisions.

Keywords: *Agriculture information systems, crop choosing stage, farming life cycle, mobile technology, ontology*

Development of web based crop forecasting system in Sri Lanka

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Abstract

Sri Lanka's quests for food security and global competitiveness requires reliable and timely crop forecasting system that can be used for monitoring, planning as well as strategic and tactical decision-making to ensure food security and marketing issues. This need is further exacerbated by the significant effects and impacts of changing climate which threatens agricultural production in our country. Our conventional method of data collection for progress monitoring and forecasting is through monthly progress review meetings and by reviewing the reports with aggregated data provided by relevant officers. In this system there are shortcomings such as delay and inability to find out the areas which should be focused since aggregate data are used.

The objective of this study carried out in collaboration with University of Colombo School of Computing (UCSC) under the thematic research program of National Science Foundation is to develop a web based system to provide timely and reliable information on crop yields, area planted and production, through the collection of agronomic and other farm information at farm level. This system involves three major components, namely: (1) collection of data on farm level crop information by means of an information networking system (2) crop yield/production forecasting (3) dissemination of information on extent of cultivation and production forecast. Information on cultivation of different crops by farmers will be fed to the system using the tablet by the Agriculture Research and Production Assistant (ARPA). This information will be updated twice a month. The system has the facility for storing data and generating analytical tables which contain useful information such as cultivated extent, expected production, marketable surplus, losses due to flood, drought and pest damage at Agrarian Service Centre, district and at national level for making decisions for ensuring food security, planning and monitoring. Further, all farmers would be registered with this system and this data base can be used to provide information to farmers and implement government programmes such as implementation of fertilizer subsidy scheme.

Keywords: *Changing climate, cultivated extent, droughts, expected production, marketable surplus*

Home garden: the practical solution for developing sustainable integrated food production systems to enhance household food and nutritional security

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Abstract

Family farming eventually has the potential to support sustainable food production at household level by providing nutritious and balanced food supplies. Home garden is the possible and viable way of crop and animal diversification at household level. It could provide food and nutrition and play a pivotal role in preserving the environment. Dependency on toxic agro chemicals could be totally eliminated by utilizing the biodynamic system that could exist in home gardens. The power of nature could be realized and restored inviting dynamic interaction of the biotic communities within the system of the home garden. Land with no crops could be transformed into a green environment with a variety of plants not only for beauty but also for supporting various nutritional supplements in the daily diet. Home garden could bring the natural green environment with the traditional varieties of plants. Diversifying the environment is possible under home gardening by selecting different plants comprising of leafy vegetables, vegetables, fruits, spices and condiments. Biotic communities, especially pollinators are attracted and protected due to the ready supply of pollen and nectar yielding flowering plants in addition to their charming outlook. Medicinal plants are essentially grown in home gardens to resist and repel the pests of crops while helping to enrich the soil fauna through mulching. The strata of plants grown in home gardens utilize the available resources with less care and organically fertilized. This ensures toxin free farming by recycling the wastes in situ while yielding healthy food with adequate nutritional supplement in the diet. Establishment of home gardens in every household needs to be encouraged through an effective implementation of programs. However, research should be focused on the ready availability of seeds of traditional crop varieties, seedlings and planting materials; recycling of organic wastes that generate within the household using eco-friendly methods like vermiculture and other possible use of effective microorganisms, availability of bio agents at the doorstep, utilization of underutilized plants, growing of medicinal plants, and the rearing of poultry and other animals with the help of suitable eco-friendly technologies. The research also aims to support and promote suitable home garden systems based on geographical areas and resources available.

Keywords: *Biodynamic, diversity, food and nutritional security, home garden, organic*

Application of novel techniques to minimize post harvest losses of five selected fruits and vegetables

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Abstract

Postharvest management determines food quality and safety, competitiveness in the market, and the profits earned by producers. In this connection, post harvest losses of five given crops namely capsicum, leeks, tomato, banana and mango were identified at farmer, wholesaler, retailer and customer levels. Thereafter prototype designs were developed and practised at the field level for the said commodities. To control evapotranspiration loss from leeks an edible grade coating was identified and applied on leeks. An encouraging result was found with regard to reducing post harvest losses. A consumer survey is being conducted to assess the consumer preferences on purchase of value added leeks (fan cuts in packets) from supermarkets. Polymer based corrugated air column sheets were developed to minimize handling and transport loss of leeks. Banana fingers were developed from raw ash plantain and seeni banana as a value added product to replace potato chips/ French fries. Also banana cookies, jam, cordial and fruit leather were developed as valued added products from over ripe embul banana. An effective method was developed to extend the green life of embul and seeni banana up to 9-14 days using an ethylene scrubber under modified atmospheric conditions.

Polymer based sheets will be assessed in the field to measure the post harvest loss compared to current packaging method for leeks. Interlocking packaging system has to be developed and assessed in the field for banana. Consumer preference survey will be continued and based on the results the feasibility of introducing fan cut leeks as a new product will be assessed.

Banana fingers can be commercialized to replace French fries in fast food industry. Cookies made from ripe banana can be commercialized as a health food targeting special segments in the market. Manufacturing polymer based corrugated air column sheets can be used to minimize bruise injuries during transportation of delicate fruit and vegetable producers. Therefore, future R & D efforts can be focused on these areas.

Keywords: *Banana, commercialization, leeks, post harvest loss, value added food products*

Overview of avenues and challenges for product diversification, and new knowledge application for impact oriented research

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Abstract

Cinnamon is indigenous to Sri Lanka which holds a virtual monopoly of cinnamon in the world, accounting for around 90 % of the global trade. In view of its aromatic properties and culinary values, cinnamon has gained wide acceptance in the food and beverage industries. It also possesses many other useful properties which have found application in a myriad of industries including pharmacological, neutraceutical, pesticide, perfumery, cosmetic, soap and liquor/liqueur production.

Though this crop has great industrial potential, performance of the cinnamon industry in Sri Lanka has not been commensurate with this potential. Low and stagnant bark yield (< 500 kg/ha/year), low volume of national production (about 15,000 - 16,000 kg/year), low peeling efficiency (2-3 kg of bark per peeler per day), dearth of competent peelers, high cost of production, poor compliance with food safety and phyto-sanitary standards, low value addition (about 10 %), inadequate R&D (0.11 % of GDP), inadequate overseas market promotion and lack of a conducive ecosystem for innovation have contributed to the above situation. Lack of adequate clinical trials to establish the claimed pharmacological and neutraceutical values of cinnamon deserves special mention.

In the global 'cinnamon trade', true cinnamon accounts for only about 15 %, while cassia produced mainly in China, Indonesia and Vietnam accounts for the rest in spite of the proven hepatotoxic properties of the latter. Because of the small production base of cinnamon in Sri Lanka, she cannot compete effectively in the lower end of the value chain of its bulk market. Therefore, Sri Lanka should be a niche player in the global market, which demands concerted research into current and emerging niche markets for cinnamon overseas.

Cinnamon has an export potential exceeding US$ one billion; yet its current export earnings hover around only US$ 100 million per annum. Development of novel and innovative products in line with the current and emerging niche markets and aggressive overseas market promotion supported by a coherent National Science, Technology and Innovation Policy, national export policy and national export strategy are of the utmost importance to realize the potential of the crop through increasing yield potential and national production, development of cost-effective and efficient peeling technologies, and improved compliance with the requisite food safety and phyto-sanitory standards.

Keywords: *Cinnamon, clinical trials, export strategy, market research, value addition*

Cinnamon research programmes of the department of export agriculture: scopes for the patenting, industry collaboration and commercialization

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Abstract

Cinnamon and Sri Lanka are synonymous in the world spice trade. True cinnamon (*Cinnamomum zeylanicum* Blume) has earned international reputation in view of superior quality and fragrance in comparison to cassia, the substitute for true cinnamon. At present, total area under cultivation of true cinnamon in Sri Lanka is about 32,555 ha, in 14 districts in the wet and intermediate agro ecological zones of the country. Cinnamon is the most important crop among the spice crops in Sri Lanka in respect to foreign exchange earnings, employment generation. Until today Sri Lanka maintains the reputation as world number one true cinnamon producer as well as exporter by claiming over 80 % of the global share. Genetic resources, soil conditions and climatic factors combined with the inherent technique of processing contribute to produce the superior quality of cinnamon to the world market. The art of cinnamon peeling which produces the typical cinnamon quill with Sri Lankan identity. Despite the long history and superior quality of Sri Lankan cinnamon, action taken to make the cinnamon industry in Sri Lanka a commercially competent venture is inadequate. Therefore, this paper describes how to commercialize cinnamon industry in Sri Lanka with the use of modern technical innovations, introduce different value addition techniques beyond the primary products and market promotion on cinnamon over the cassia in the world market.

National Cinnamon Research & Training Center (NCRTC) of the Department of Export Agriculture, has conducted research projects covering major areas of cinnamon crop improvement, fertilizer studies, post-harvest technology including processing and value addition with control of important pests and diseases during the last 30 years. Among the research findings, selection of two cinnamon varieties of Sri Gemunu and Sri Wijeya were identified first time in Sri Lanka. Introduction of cinnamon drink, freezing technique for cinnamon processing, control of rough bark disease and wood boring moth damage and seed storage method as well as vegetative propagation techniques are prominent research outputs. The NCRTC is also equipped with facilities to transfer technology to stake holders. Therefore, based on these research findings commercialization activities can be initiated under public-private collaboration.

Keywords: *Cinnamon quill, genetic resources, peeling, spices, true cinnamon*

Mechanization and modernization of the cinnamon peeling industry to meet quality demands and fair trade

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Abstract

Lack of proper mechanization, package to replace expensive labour for cinnamon quill processing is one of the hindering factors for its expansion in terms of quality and quantity of the market products. The program executed by the Department of Agricultural Engineering to develop such a package during last 20 years is discussed in the present paper.

In 1995, the Department patented a prototype machine, based on spring loaded mechanism (RUWEKA-CG) (Weerasinghe, Gunasena and Karunarathne, 1995) for cinnamon rubbing to increase the process efficiency by 59.7 %; the device was further improved with the addition of a poly cam mechanism (RUWEKA-PG) to facilitate the inserting process of the cinnamon sticks (patent A23N 7/10, 11/00B27J 3/00G05G17/00). In November 2005, a new industrial design for a cinnamon processing bench was registered. Currently a cinnamon quill making table and Katta peeling device are in the pipeline for patenting.

These technologies were slowly diffused to 'U 10' GTZ supported processing units, and Eastern Pharmaceutical company, in Kirinda. However, so far technology has not got the anticipated momentum to impact the change process.

In 2006, an industry collaboration project has been initiated with the Eastern Pharmaceutical company. A trained factory manager was appointed for process control along with field staff to collect and supply raw cinnamon sticks to the peeling centre at a rate of Rs.10.00- 15.00 per kg. Here a factory processing line was introduced and a trained labourer handled the entire machine rubbing process, along with 18 member female work force; It has been observed that average per person quill production rate was 3 kg/day. Analogical program was conducted in Rilhaena Estate, Rathnapura. Based on these studies future manpower need for mechanized cinnamon sector has been researched and results were documented in the Vocational Education Plan (2011).

The machinery and equipment developed so far for cinnamon processing needs to undergo further industrial testing and market research. At the moment machine production is undertaken by Dax Engineering company. Preliminary discussions have been initiated with the Hayley's technology arm for market expansion and research.

Keywords: *Cinnamon quill making table, katta peeling, polycam mechanism, prototype machine*

Modernization of cinnamon essential oil industry "technology and market needs"

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Abstract

Ceylon cinnamon (*C.zeylanicum*) bark and leaf oil are two major essential oils used as raw material in the global flavor and fragrance industry. Over 95 % of the world demand for true cinnamon oil is supplied by Sri Lanka. Largely oil production takes place in Sri Lanka using traditional water/ steam distillation units.

Modernization of these units is one of the critical issues which need immediate attention. Modernization need not be with sophisticated technologies eg. super critical fluid (SCF) or phytonic technology but rather to maintain high quality standards with steam distillation technology. The standardization of products and processors across cultures is increasingly becoming an important issue.

For better quality oil with mass scale production, equipment and infrastructure both need to be modernized with accredited norms of international standards eg. GMP, Fairtrade, ECO etc.

As a country supplying leaf oil and bark oil as a raw material for global flavor and fragrance industries, the establishment of production technologies of flavor and fragrances using our own oils in Sri Lanka needs to be explored This may not be possible with Sri Lankan essential oils alone but processing of derivatives, fractionated and isolated compounds of cinnamon and other oils and blending with appropriate aroma chemicals with the art of flavor and fragrance development should be a key directive which we have to adopt as a country.

Major perfumery and aroma industrial giants in the west are working in collaboration with other countries to establish processing facilities where best raw materials are available. It would be beneficial for Sri Lanka to also merge with International flavor and aroma companies as it may bring the advanced technology in to the country providing not only opportunity for production of better quality oils but also to fulfill the need of fragrances and flavors we import with heavy foreign exchange.

Keywords: *Cinnamon oil, derivatives, flavor, fragrances*

From laboratory to commercialization - how easy is it?

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Abstract

Pressures on research scientists to commercialize have increased over the past two decades since the formation of the World Trade Organization. Success in research is no longer measured in terms of quality or significance but on its potential for commercialization. A myth propagated by the West that all research should lead to commercialization is unfortunately believed by science administrators, politicians and sometimes even scientists themselves. Developing countries are encouraged to emulate the no longer relevant success stories of Korea and Taiwan. However, the fact is that even in the West, academic research has rarely provided returns sufficient to cover research expenditure.

In spite of all these negativities, there are occasions when a scientist makes a significant discovery with potential for commercialization. However, scientists in developing countries like Sri Lanka face many stumbling blocks when going through this process. Many do not realize that laboratory research successes have to go through a long process of development - optimizing yields, reducing number of steps, cutting energy costs, substituting with readily available cheap materials and identifying correct equipment for large scale production while ensuring that the process remains viable - involving engineering techniques before they can go into production. Furthermore, the scientist and engineer must provide technical support to the investor until the industry takes off. In countries like Sri Lanka without a commercialization culture, these are often difficult problems and so are the problems of intellectual rights protection, negotiations with banks and with potential investors and marketing of the products.

The best strategy to be taken by a scientist will vary depending on the level of innovation involved. Although it is often difficult to find local investors, they may be prepared to come in on low risk low capital projects where advances in technology are marginal and within their understanding. However, investors are often unwilling to get involved and scientists may be faced with having to start their own industry, often no easy task.

Where large investment is involved and foreign marketing a possibility, it may be necessary to look for investors from abroad. Here too the scientist may face difficulties in cross boundary negotiations, lack of trust, doubts regarding effectiveness of IPR protection, etc., which could lead to a disadvantageous agreement or none at all.

The presentation will look at the realistic strategies available to scientists from developing countries like Sri Lanka to commercialize their research results.

Keywords: *Innovation, investment, research commercialization, strategies*

Pheromone based, low cost trapping systems for the control of two devastating coconut pests in Sri Lanka

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Abstract

Rhynchophorus ferrugineus and *Oryctes rhinoceros,* commonly known as the red weevil and the black beetle respectively, are two devastating pests on young coconut and oil palms in Sri Lanka. Detection of these pests prior to causing heavy damage has been a major issue in the control of these pests.

Pheromones, the natural messenger chemicals of insects have successfully been used as bait to attract and trap insect pests in the world since the early 1960s. Consequently, the control of the red weevil and the black beetle by pheromone (4-methyl 5-nonanol and ethyl-4 methyloctanoate respectively) baited traps commenced since the mid 1990s. However, due to high costs of the pheromones, this practise was not viable in Sri Lanka at the time.

Research towards producing low cost baits commenced in 1996, in the Department of Chemistry, University of Kelaniya with funds from National Science Foundation (NSF) and other international sources. Local natural compounds (synergists) that could enhance the attraction of the pheromones were examined using lectroantennogram screening. This was followed by field assay with pheromone-synergist combinations and few local compounds that could effectively enhance the attraction of pheromones were recognised. Optimisation of those pheromone-synergist combinations led to two efficient attractant systems for the two pests that utilize lesser amounts of pheromones.

The above formulations were incorporated in a suitably designed trap and marketed in Sri Lanka by Semiochem Lanka Pvt Ltd in 2012. The trap catches of the red weevil and the black beetle were highly satisfactory using the above trapping system. By the year 2015, the pheromone-based trapping had become a major choice in the control of the red weevil and the black beetle in Sri Lanka. Compared to the international market prices, our baits cost only 88 % and 51 % for the red weevil and the black beetle respectively. This system has provided a satisfactory, eco friendly, cost effective alternative to protect coconut and palm oil estates in the country today.

Keywords: *Black beetle, pheromone, red weevil, trapping*

Agro-technological innovations for feeding the nation in future

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Abstract

The challenge we face today is to feed the nation with nutritious and healthy food, while conserving and managing the stability of the food production systems for the future. The world population is expected to increase from 7.4 billion as at present to 9.2 billion in 2050, which demands 70 % more food than what we consume today. This would have a huge impact on the external trade of basic foods in the world highlighting the need to be self-sufficient at least in the major staple and other essential food commodities. Sri Lanka achieved self-sufficiency in rice and some other food crops mainly due to commercialization of the innovations since independence. However, we still depend on importation of over 50 % of the need of other food and feed . With the increase in the per capita income to about 4000 US$ at present, the consumption patterns and food needs are already changing. The new food needs will have to be produced locally incurring a heavy burden on the already-depleted food production systems. Nevertheless, increasing productivity is the only option available, and is already a herculean task as the productive land area for crop husbandry is diminishing.

Enormous gains in productivity on many crops are often achieved with negative impacts on natural resource base, if soil health issues are not adequately addressed. Mining the soil without proper replenishment of required nutrients will have a serious impact on sustainability. Diminishing returns from depleted soils would add a further burden to the crop varieties, which are in the brink of the upper threshold level of the crop microclimate and are deteriorating rapidly with the climate change. With the changing climate, crop varieties are faced with ever-changing abiotic as well as biotic environments making farming a difficult enterprise. Managing biotic stresses with agro-chemicals and other means are often challenged. Therefore, the present pace of innovating new high yielding, biotic and abiotic stress-tolerant varieties and associated technologies for precision farming should be increased, while minimizing the damage to the environment and maintaining sustainability of the ecosystem.

With the increasing cost of production and scarcity of labour, mechanization and automation of farming land where possible, is very much in demand. Technology is needed to go beyond primary production. Value addition and strengthening the supply chain with market-oriented agriculture would not only increase profits but also attract youth to agriculture. Therefore, the ability to innovate, at an accelerated pace will be the most important determinant for the success in food and agriculture sector, which demands talented innovators. Further, creating and commercialization of these innovations at an accelerated pace to mitigate the already-lapsed time and to make agriculture as the 'new engine of growth' is of primary importance. Hence, an enabling environment guided with long term 'agriculture policy', backed by firm political commitments, is the need of the hour.

Keywords: *Commercialization, self sufficiency in food, value addition*

Needs for innovations: a vision for agriculture in 2050

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Abstract

At present, global population is around 7.0 billion and by the year 2030, it is expected to increase by another 2.0 billion to a total of 9.0 billion. It is the common understanding that the present technology and knowledge are not enough to produce adequate amount of food for 9.0 billion people. Hence scientists predict that this will require an increase of food by 60 %, energy by 50 % with 40 % more water for agricultural production. To acheive this, reduction of degradation of agricultural lands, introduction of crop varieties tolerant to many adverse conditions such as salinity, pests-diseases etc. are in the main agenda.

At present global agricultural production faces three major challenges; elevated carbon in the air, high air temperature, and climatic change.

Intensive agriculture with gene technology and greenhouse farming could be seen to provide high productivity. Application of satellite technology is becoming the norm and now developing more rapidly; specially in Japan and South Korea.

In future, solar energy will be the primary source of energy and will be available for free, and will be accessible at on farm level for agricultural production. Water for agriculture will be a negative issue and all surface water may not be freely available. Hence identification of underground water streams is needed.

Therefore, new mega research projects collaborating with international research have to be initiated. Scientists should design research on areas such as:

- Crop gene technology
- Space technology in agriculture
- New energy applications
- Food technology industries.

Keywords: *Agriculture, climate change, energy, food, water*

Biotechnology and its applications in developing Sri Lanka's agriculture

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Abstract

Biotechnology has been in existence in Sri Lanka for many decades. Public sector institutes have been in the forefront in doing research and using this technology. However, the question arises - have we used this technology to its maximum for development purposes?

Most of the research that is done in Sri Lanka needs to be continued to the field level, where finally the farmer needs to benefit. We need to get out of the stage of 'research stagnation'.

Annually many research papers are published on various biotechnology related fields.Researchers are encouraged to use public funds to support research that finally ends up in publishing a paper and presenting at a scientific forum.

We need to look at continuity of research for development purposes, which will encourage the donors to inject more funds into the system to develop the respective fields of biotechnology. We need to show tangible results.

Public-private-partnerships need to be encouraged and developed in Sri Lanka. This will entice the private sector too to be part of the development of science in Sri Lanka and will contribute immensely to the development of agriculture in Sri Lanka.

Keywords: *Agriculture, biotechnology, development, public-private-partnerships*

Energy & Environment

Sustainable production and consumption

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Abstract

The exponential growth of global population and increasing trends in consumption has generated a tremendous pressure on natural resources and ecosystems to such an extent that the sustainability of human society itself is threatened. A drastic shift from the present paradigm of economic development is needed to decouple economic growth from material consumption and environmental degradation. Sustainable consumption and production (SCP) is an approach which aims at minimizing the negative environmental impacts from consumption and production while promoting quality of life. The key principles of SCP include reducing material/energy intensity of economic activities and reducing wastes and emissions throughout the life cycle of product.

One of the main drivers of SCP is eco-innovation through which new products are innovated or existing ones are redesigned to reduce the lifecycle environmental burden. Increased consumer awareness has created a niche market for these greener products and there is a risk that those businesses that are not innovative would lose their market share to more innovative competitors. There is an urgent need to identify the interventions needed to embed innovation into Sri Lankan businesses so that they can survive the competition. Further, present day consumers demand declaration of environmental performance of products in a transparent manner through tools such as life cycle assessment and eco-labeling. These tools require accurate national inventory data related to power generation, transport, water purification and distribution and materials.

SCP for energy sector means generation, conversion and consumption of energy in such a manner that the life cycle environmental impact is reduced. In the generation side, the use of renewable energy sources through holistic impact assessment and improvement in conversion efficiencies are needed. Chemical looping combustion of renewable materials and supercritical water gasification are some of the approaches that focus on reducing the pressure on non-renewable fuels and environment. Innovating energy efficient consumer products and creating a conscious consumer through rating systems that not only consider the energy efficiency, but also the lifecycle environmental performance, can reduce the energy consumption. However, to achieve a radical improvement in energy and environmental performances, the innovation of a new low energy intensity production-consumption system is essential.

Keywords: *Eco-innovation, eco-labeling,lifecycle assessment, sustainable consumption and production*

Research needs in sustainable built environment

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Abstract

Energy use is undoubtedly the key factor in the economic development of modern society. The discovery of fossil fuels and the advent of the industrial revolution have entirely changed the supply and demand landscape of the global energy platform together with its interrelations to the terrestrial eco-system. This has forced the global community to work towards searching for meaningful solutions to address the underpinning issues on the global energy platform and its interrelations through a paradigm shift in hypotheses, policies, strategies, technologies, inventions and innovations and interventions developed and employed. Accordingly, all processes related to the said platform are seeing new dimensions and 'sustainability' takes the most important role. This role calls for new models in energy sources and supplies, in processes of their conversions into various forms and also in end-use strategies and applications. This translates into the strategic use of new and clean energy sources, of technologies and of end use with overall integrated approaches. In view of the paradigm shift that is taking place, the global energy platform has become very dynamic and evolves at a significant rate in terms of search for new sources, research and technological development, integrated approaches, modeling and optimization innovative business models, regulatory aspects etc. Each society, based on the competitive advantages, has the potential to be a party in this global platform. They need to very clearly and carefully identify the issues underlying and the challenges to face at their strength.

Conceptually, based on the current state of play in Sri Lanka with reference to technology development and manufacturing, the potential would be to strategically use intellectual capacity (mobilization of human capacity) to develop innovative solutions adopting already emerged products and technologies looking for suitable applications in the local context and for commercialization opportunities in the international market. Local applications will then develop the competencies needed in the human resource and employ backward integration supported by appropriate research and development. An innovation driven approach could be the priority at this stage.

Keywords: *Backward integration,clean energy, innovative solutions*

Research and development priorities in power sector

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Abstract

Ceylon Electricity Board, the major electric power utility in the island of Sri Lanka is now proximate to its treasured dream of 100 % electrification. Enrichment of life through power is our moto. Can 100 % electrification justify us for that moto? Power quality is the next concern of ours which will come to the number one priority in our list. Continuous addition of nonlinear loads to the grid has created unconventional set of issues which has become important topics of research.

Growth of power demand is an indication of growth of the economy. Catering to the increasing power demand and fulfilling the targeted grid share of renewable power sources is the national policy of Sri Lanka. The intermittent nature of renewable sources always challenges the utility to integrate them into the grid. It is research which can find the remedy to the issue. We want the grid to be green and reliable at minimum compromise.

Exceeding customer expectation is the end-of-the-day expectation of the utility. How are we to improve the quality of service to exceed the customer expectations? Research to improve the customer experience and adaptation of state of the art technologies like Smart Grids and Smart Metering systems are the areas we believe in.

Keywords: *Electrification, power demand, renewable power, smart grids and smart metering*

Improvements in climate prediction

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Climate prediction is a probabilistic forecast about the future climate conditions on time scales ranging from seasons to decades. It is based on conditions that are known at present and assumptions about the physical processes that will determine its future changes.

Numerical models representing physical processes in the atmosphere, ocean, cryosphere and land surface are the most advanced tools currently available for predicting global climate. While simpler models have also been used to provide globally-or regionally-averaged estimates of the climate, only GCMs, possibly in conjunction with nested regional models, have the potential to provide geographically and physically consistent estimates of regional climate.

Models depict the climate using a three dimensional grid over the globe, typically having a horizontal resolution of between 250 and 600 km, 10 to 20 vertical layers in the atmosphere and sometimes as many as 30 layers in the oceans. Their resolution is thus quite coarse and many physical processes that occur at much smaller scales such as those related to clouds cannot be properly modelled. Therefore, their known properties are averaged over the larger scale in a technique known as parameterization.

Extremely sophisticated models are presently used for climate prediction. These models summarize our understanding of the climate system and simulate, with as much reliability as currently feasible, the complex interactions between the atmosphere, ocean, land surface, snow and ice, the global ecosystem and a variety of chemical and biological processes. The complexity of climate models - the representation of physical processes like clouds, land surface interactions and the representation of the global carbon and sulphur cycles in many models - has increased substantially during the last two decades. More powerful supercomputers presently available have also contributed to model improvements allowing current models to resolve finer spatial detail. Today's models also reflect improved understanding of how climate processes work - understanding that has come from ongoing research and analysis, along with new and improved observations.

Keywords: *Climate prediction, models*

Remedial measures to overcome adverse effects of climate change

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Abstract

Climate change, the harsh reality of modern civilization possesses an immediate, growing and grave threat to Sri Lanka, cutting-across all sectors of its economy. Climate of the island has undergone a change to such an extent that correct amount of rainfall does not come at the correct time of the respective rainfall seasons. Variability of both Southwest and Northeast monsoon rains and rains of convectional origin (inter-monsoons) has increased significantly during recent decades. As a result, both extremes such as droughts and floods have become a recurrent problem across the entire island at different times of the year. It has been also evident that the occurrence of heavy rainfall events or in other words rainfall with high intensities are increasing, specially in the Central Highlands which may lead to accelerated land degradation and more landslides to occur in vulnerable areas. Down scaling of General Circulation Models (GCMs) has shown that the dry zone area of Sri Lanka will become more and drier, while the wet zone will become wetter at the turn of this century. Annual mean air temperature anomalies have shown significant increasing trends at a rate of 0.01 to 0.03 °C per year during the recent few decades in almost all regions of Sri Lanka. Very recent studies have also revealed that the occurrence of number of cold nights are decreasing significantly in most places of the country while there is a significant increase in the occurrence of number of warm nights.

While the academic world debates on the exact nature of impacts of climate change in Sri Lanka, it is evident and true that communities throughout the country are already experiencing some of the predicted impacts of climate change, specially in agriculture and water sectors which has become a real threat to national food security. Despite observing repeated number of climate related hazards during recent years, sometimes even in a quick succession, the issue has not been adequately addressed in agricultural development planning at any level, nationally or regionally. Thus, in line with the focus of the other developing nations of the world on the issue of climate change and food security, our agricultural development agenda should be tailored in such a way that appropriate adaptation strategies are in place. This may require technological advancement, revisiting traditional methodologies, strong commitment of both government and people and specially the changes in attitudes of scientists, law makers, policy makers and the community. This paper describes options available to minimize the adverse impacts of climate change on the agricultural sector in Sri Lanka.

Keywords: *Agriculture, climate change, adaptation measures*

Tackling problems on water sector including natural disasters due to climate change

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Abstract

Climate change is already beginning to impact our daily lives. Day and night temperatures are increasing, rain patterns are changing, seasons are shifting, and sea levels are rising. Consequently Sri Lanka is increasingly exposed to various water related disasters - 'hydro disasters'. Extreme meteorological and hydrological events transform water into the source of hydro disasters. Hydro disasters in the form of floods, droughts and landslides are the most common and most damaging natural disasters seen and felt around Sri Lanka. However, there are other climate change induced water related disasters, which are less discussed in the public domain such as forest fires, stronger wind and rain storms, rising sea levels, disappearing wetlands, loss of biodiversity and ecosystem services, increased human-wildlife conflicts, health risks, declining crop yields, hydro power and other economic losses. These will rapidly alter the land and water we all depend upon for survival, creating a very different world towards the end of this century.

The recent drought, flood and landslide events exposed, and are loud demonstrations of, our unpreparedness to meet such challenges.It is forecasted that Sri Lanka will face more severe and more frequent calamities in the future, along with the rest of the South Asian region.

Sri Lanka, being a small island nation, will find it challenging to cope with disasters unless it explores and adopts the best possible practices to safeguard communities and avoid economic burdens. This requires research to fill the gaps in all four steps of the disaster management cycle as well as overarching policy, strategy and institutional setups. More research and innovation is needed to take advantage of local conditions, build resilience, recognize useful indigenous knowledge and capacities and develop modern technologies. Up until now climate change matters have been left in the hands of a few government agencies. The need is to create a broader base, and to set-up mechanisms and procedures to harness and enhance capacities of the whole government, corporate sector and the civil society at all levels for disaster management. All society should be more innovative and contribute to turning this global threat into a development opportunity for all.

Keywords: *Climate change, hydro disasters, impacts, innovations, preparedness*

Recent research & development on landfill mining: Sri Lankan perspectives

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Abstract

Dumping of wastes has caused major environmental concerns. The tendency is to follow developed countries and construct sanitary landfills. It is an engineered landfilling method, requiring liner system, leachate collection and treatment, permanent closure after filling, lasting 30-50 years and installation of gas collection system and flaring or power generation. Diversion of wastes from landfills, applying 3R concept will reduce wastes ending up in landfills. A complimentary technology developed by the University of Peradeniya is landfill bioreactors that can be mined and reused over and over again, making them 'sustainable landfills'. It produces methane for power generation and can be a dual fuel in thermal plants. The residual derived fuel (RDF) processed from mining wastes, has low levels of fuel nitrogen, chlorine and sulphur, thus requiring less costs on maintenance of equipment and machinery, and flue gas cleaning.

In order to move from dumpsites to sustainable landfills, with integrated solid waste management, the dumpsites must be rehabilitated because of excessive emissions of leachate and air pollution. There are number of economic benefits in reclaiming dumpsites. However, leachate treatment and gas extractions are essential but costly components. Some examples of rehabilitation were Gohagoda at Kandy and Thirumpuaramthurai at Batticaloa dumpsites. The costs of Gohagoda rehabilitation and relocation of dumpsite tenants are estimated at Rs 280 million. Already direct costs were over Rs 100 million, apart from daily operational costs. The resource utility value is Rs 644 million, deducting all of the costs with revenues of Rs 1.89 billion derived from RDF sales. The economic value in saving environmental costs is much higher. Outcome of rehabilitating Thirumpuaramthurai dumpsite is good quality groundwater for the neighboring communities and safer environment.

An alternate or complimentary to RDF manufacture is forestry grade compost (FGC) for reforestation programs with nitrogen source farming, having two revenue generation schemes. It is feasible, since mining costs are known and technologies developed. Reforestation with 40 % of biodegradable and inert fraction of soil is not known and technologies to be developed. It is a commercially viable project that can generate profits of more than Rs 2 billion over 10 years.

Keywords: *Landfills, mining, landfill bioreactor, RDF, forestry grade compost (FGC)*

Water management and policy issues – identifying research gaps

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Abstract

Water Resource Management Policy (WRMP) aims to support human uses and protect the environment. There is an increasing attention on water policy issues due to rising water shortages, which can have economy-wide implications. WRMP addresses supply, use, disposal and sustainability decisions. As it is a political statement, water policies must often be negotiated among multiple stakeholders. Policies encourage and lead management processes, while best management practices and protocols are identified, evaluated, modified and disseminated by policy making bodies.

Despite the existence of several sub-sector policies guiding water services, Sri Lanka has no 'overarching publicly accepted' national water policy. Absence of a governing policy for this important resource is an obstacle for the advancement of water management.

Climate change has the potential to alter the existing water balance of the country and is expected to aggravate the existing spatial and temporal discrepancies of water availability. Water stress and scarcity in some areas will increase while other areas would experience floods and landslides.The development of numerous laws and institutions over 150 years is indicative of the growth in the demand for water and the diversity of its uses. This suggests a growing inter-sectoral competition for water. Water productivity in all use sectors appear to be very low. Research must be undertaken to identifying instruments that could promote water productivity improvements and conservation. At present, there is little concern for groundwater management. Competing demands for water between industrial and domestic, and irrigation and domestic use have already arisen. Water management is intended to be decentralized and participatory; however, there is no effort to coordinate the central and provincial agencies in regard to their water-related functions. There is a need to develop water shed management programs locally according to local conditions and priorities based on the spatial principle and the participatory principle. An ecosystem approach with heavy emphasis on cataloguing natural environmental features in every watershed and sub-watershed and developing technical guidelines for minimizing and mitigating the human impacts on them due to encroachment - be it urbanization, industry, power, or irrigation - requires new research.

Keywords: *Allocations, conflicts, development, policy, productivity*

Water quality issues- future research directions and priorities

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Abstract

In Sri Lanka, groundwater and surface water are the important sources of freshwater for drinking and irrigations purposes. However, the quality of water resources has highly deteriorated due to both natural and anthropogenic factors that adversely affect the potential uses. Aquifer lithology, weathering status of rocks, salt water intrusions and other characteristics of the flow path are the main natural factors that contribute to the geochemistry of groundwater. Industrial effluents, pollution occurring through domestic and agricultural activities are some of the anthropogenic factors that can change the chemical characteristics of surface water. In recent years, heavy application of agrochemicals for farming activities has posed greater threats to water resources. Consumption of contaminated water can adversely affect the health and well-being of humans. Hence, the quality of water resources is an important measure regardless of the modification having occurred through either natural or anthropogenic processes. On the other hand, most of the surface water resources in Sri Lanka are now excessively polluted. Since both surface and groundwater are currently utilized for drinking purposes, assuring the safety of such water is the primary objective of drinking water quality management and treatment to protect the health of the general public. Therefore more attention should be given to water quality related issues in order to protect the available water resources in the country. Some of the water quality related research areas that should be emphasized in the next decade are, (a) detailed hydrogeochemical mapping of water resources, (b) development of new techniques for measuring water flows and water quality, including applications of stable isotopes and *in situ* measurements, (c) investigating 'emerging contaminants', (d) setting suitable water quality standards for the country, (e) developing innovative techniques for preventing and reducing pollution, (f) understanding the impact of land use changes and best management practices on pollutant loading to waters, (g) controlling non point source pollutants, (h) understanding fate and transport of physical, chemical, and microbial contaminants, and (i) investigating the impact of global climatic change on water quality. The assessments of regional scale geochemical nature of water resources in the country are extremely important to prevent further water contamination and to develop water resources for the future demand. Geochemical mapping of water resources particularly groundwater should be given high priority as available maps are now almost 30 years old. Investigations on emerging contaminants in water resources in the country should be addressed urgently since such contaminants can cause adverse health impacts.

Keywords: *Contamination, geochemical mapping, ground water, surface water, water quality*

Innovative water treatment technology for Sri Lanka

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Even though, water is an essential element for the survival of mankind, 30 % of world's population has no proper access to drinking water. The pipe borne water supply coverage at the end of the year 2015 in Sri Lanka was 45.9 %. A considerable number of the population obtained their water from dug wells (36.4 %) and hand pump tube wells (3.2 %). However, the groundwater sources are being challenged for their safety because of the prevailing health issues such as CKDu, some cancers, flourosis and epidemics.

A detailed groundwater survey done in Sri Lanka has revealed that even though there is no heavy metal concentration exceeding World Health Organization (WHO) guidelines for drinking, challenges remain because of excessive presence of iron, manganese, fluoride and hardness. In addition, improper sewage management has caused bacteriological pollution in most of the groundwater sources. Even though, there is no detailed study done on the organic pollutants, it is obvious that agricultural and industrial pollution has made a significant impact. Accordingly, policy makers and utility providers in Sri Lanka find many challenges to ensure the access to safe drinking water due to various reasons such as insufficient capital cost, scattered population with relatively low densities particularly in the dry zone; lack of knowledge on operation and skilled and trained operators, etc. Accordingly, it is essential to find or adopt appropriate technologies for long term sustainability.

As there are no perennial surface water sources available throughout the dry zone other than man made tanks, the researchers shall look for innovative technologies on treatment, management and recovery. Domestic or community level water supply shall include novel technologies in bringing down levels of fluoride, hardness, iron, manganese and nitrate to the acceptable limits while removing organic and bacteriological pollutants. Use of conventional or advanced technologies such as nano technology in improving electro coagulation, oxidation, ion exchange, disinfection, membrane technology, reclamation, rainwater harvesting. Water reduction technologies shall be focused more to face existing challenges. Technologies on identifying best available sources from a rather complex hydrogeological system shall also be focused and simplified. Standardization of domestic treatment facilities for regional water quality is an immediate need until necessary technologies are made available. Also, improving user friendly testing methods especially for field testing and promoting use of bio indicators and markers would assist in bringing down the cost in identifying better sources. Application of efficient quality management tools for water treatment systems, such as water safety plans will ensure a holistic approach in ensuring water quality from catchment to consumer.

Health

Diabetes mellitus – research needs and opportunities

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Sri Lanka is facing a major public health challenge due to diabetes. The Sri Lanka diabetes and cardiovascular study (SLDCS) funded by the National Science Foundation in 2006 revealed that over 10 % of adults above 20 years had diabetes and another 11 % had pre-diabetes. According to the SLDCS the prevalence of diabetes in the Colombo district was 18 %. However, a recent study carried out in Colombo city has revealed a prevalence of over 25 % diabetes. The SLDCS showed that 36 % of patients with diabetes were undiagnosed.

The burden of diabetes for the society would be very disturbing due to its chronic complications. The SLDCS showed that 27 % of those with diabetes had retinopathy and 48 % had neuropathy. Since DR can cause blindness and neuropathy is the main risk factor for amputations these data are quite alarming on a public health perspective. The Sri Lanka young diabetes study (SLYDS) carried out during the same period in diabetes patients less than 45 years of age showed that 30 % adults had micro albumin urea and 20 % adults had erectile dysfunction indicating that it can cause significant morbidity among even younger people of working age.

To combat the diabetes epidemic and to minimise its effects on the population we need novel methods, which are cost effective, accurate and least invasive for early diagnosis of diabetes and its complications, disease control and monitoring. To achieve these objectives, more basic and applied research is needed. Scientists in the fields of health, biology, engineering and technology should get together and form multidisciplinary research collaborations to identify the needs and find out solutions. We need to focus on innovative methods of screening and diagnosis. For screening most people would prefer least invasive and hassle free methods (eg. non fasting tests).

New technology to identify diabetes foot disease and high risk feet at early stage would reduce amputations. Computer based technology for retinopathy screening would be another area that would need more research. IT based methods and platforms for patient management linking both patients and caregivers is another area in this era of fast growing mobile technology. Most patients now use smart mobile phones and new applications would help them better manage their disease.

To achieve the above objectives we need a national level program of research in diabetes and National Science Foundation would be the best organisation to initiate such a research program.

Keywords: *Amputations, chronic complications, neuropathy, prevalence, retinopathy*

Diabetic limb salvage

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Abstract

The increased risk of wounding coupled with poor healing and amputation that involves diabetic feet is well known. Every year, more than 1.3 million people with diabetes lose a leg as a consequence of their condition. This means that every 20 seconds a lower limb is lost to diabetes somewhere in the world. The majority of these amputations are preceded by a foot ulcer. The most important factors relating to the development of these ulcers are peripheral neuropathy, foot deformities, minor foot trauma, infection and peripheral arterial disease (PAD).

The spectrum of foot lesions varies from region to region due to differences in socio-economic conditions, standards of foot care, and quality of footwear. In developing countries, diabetes related foot problems are thought to be more common.

Based on recent epidemiologic surveys in Sri Lanka, we are dealing with approximately 1.5 to 2 million diabetics as of now. With an annual rate of 5 %, we are likely to be dealing with approximately 100,000 foot ulcers in diabetics every year. The resultant amputations, impairment of quality of life and cost must be enormous, although not quantified in Sri Lanka. The current focus on improving life expectancy alone is not sufficient. Quality of life issues must not be forgotten, and thus a strong commitment towards amputation prevention in Sri Lanka is required. Diabetes is the main cause for non-traumatic amputations and is also a contributor/ marker of premature death. Hence, there is an urgent need to focus on diabetic limb salvage in Sri Lanka.

The primary challenge in diabetic limb salvage involves prevention of wounding in the first place and when that fails, healing without progressing to amputation; thereby preserving independent ambulation and quality of life.

Future research areas in diabetes can be categorized as for: prevention-risk assessment and stratification, education and early detection, footwear, wound assessment and dressings and prosthesis.

Innovations and potential for commercialization will also be discussed.

Keywords: *Amputation, diabetic, foot ulcers, limb salvage*

Pathogenesis with a view to treatment of dengue shock syndrome

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Abstract

Sri Lanka has been severely affected by regular epidemics of dengue for the past three decades. Although the case fatality rates have now almost dropped to 0.2 % due to tremendous effort taken by the clinicians and the Epidemiology Unit of Sri Lanka, dengue still causes a significant burden to resource poor countries such as Sri Lanka. Therefore, in order to reduce morbidity associated with dengue and to reduce the burden to the economies of developing countries, it is crucial to develop new therapeutic options for better management of dengue infections.

The three main groups of drugs that have been developed or undergone clinical trials are those that inhibit or reduce viral replication (antivirals), modulate the immune response (immunomodulators) and drugs that prevent the vascular leak. Among the main groups of antiviral drugs that have been developed and tested iminosugars, antiparasitic drugs and cholesterol reducing drugs are currently leading, with some undergoing phase 1 and phase II clinical trials. Some of the antivirals that were used for similar viruses such as dengue have been shown to have a low safety profile in dengue.

Among the immunomodulatory drugs steroids have been most extensively studied. A large double blind, randomised, placebo controlled trial using both high dose and low dose steroids showed that use of steroids had no effect on any of the clinical outcomes. Herbal treatments such as the use of *Carica papaya* for treatment of dengue have also been investigated. Although many small trials had been conducted earlier in many countries, recently two large multi-centre clinical trials were conducted in India. These two clinical trials showed that *Carica papaya* did increase the platelet counts in patients, although it had no effect on vascular leak or the overall disease outcome in acute dengue. However, all patients with very severe forms of dengue had been excluded from these trials.

We have mainly focused our research on finding drug targets which reduce or prevent vascular leak. As we found that platelet activating factor is an important cause of vascular leak, we are currently conducting a phase 2b, randomized, placebo controlled trial with a PAF.

Keywords: *Antivirals, dengue, immunomodulators, vascular leak*

Dengue vector control: present and future

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Abstract

Dengue is an important emerging and re-emerging infectious disease in Sri Lanka causing significant effect on livelihoods of people in endemic areas. In the absence of a vaccine, primordial prevention of dengue and its severe form remains dependent upon vector control measures.

Up to now different conventional vector control measures have been used but the expected reduction in dengue incidence has not been achieved. Novel vector control intervention can be integrated with the conventional control methods. Further, ecological, biological and social factors may have contributed to the development of increased dengue mosquito populations in different ecosystems.Therefore, more insights relevant to specific ecosystems, transmission dynamics and the possibility of intersectoral ecosystem management programmes for dengue vector control are also urgently needed. These insights will play a crucial function in defining locally relevant and appropriate interventions with the prospects for sustainable control of vector populations.

Development of novel products for control of dengue vector mosquitoes including biological (lavivorous fish, carnivorous copepods and *Wolbachia*) and chemical control agents (lethal ovitraps), new mechanical devices (insecticide impregnated bed nets, window curtains and net covers using nanotechnology) and modified dengue vector mosquitoes (transgenic *Aedes aegypti* with RNA interference-based resistance to dengue viruses, sterile male Aedesmosquitoes using ionizing radiations) can be performed. Exploring and combined analysis of the ecological, biological and social dimensions of dengue to define community-centered, intersectoral, participatory ecosystem management activities directed at reducing dengue vector larval habitats can also be performed.

Keywords: *Community engagement, dengue, novel vector control devices, vector control*

CKDu epidemiology: disease burden, case definition, national survey CKD + CKDu and other GIS, GPS

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Abstract

Chronic kidney disease of uncertain aetiology (CKDu) is an abnormality of kidney structure or function, with low estimated glomerular filtration rate (eGFR) (< 60 ml/min/1.76m2), protein urea [> 1+ on dipstick or ultra filtration rate (UFR) or urine protein to creatinine ratio (UPCR) > 0.2], microalbuminurea [urinary albumin to creatinine ratio (UACR) > 30] or other evidence of persistent kidney damage (urine sediment abnormalities, abnormalities due to tubular disorders) abnormalities detected on histology of which the aetiology cannot be attributed to known causes such as diabetes, hypertension etc.

The peculiar histology of interstitial inflammation with tibulitis, periglomerularfibrosis, perivascular fibrosis, focal interstitial hypocelleularfibrosis, tubular atrophy andglomerular sclerosis is suggestive of CKDu.

The cases were noted initially in 1990s and continue to report up-to-date.The special distribution is concentrated mainly to the North-central province and also encroached to the geographically adjacent areas. Over time, the case load increases with the widening of geographic boundaries.

The disease is more common among the farming community living in the dry zone and frequently seen above the age of 40 with a male preponderance, the male to female ratio being 2:1. The members of the same household are increasingly identified with the disease.

Enumerating the disease burden is a challenge since CKDu is a diagnosis of exclusion of known aetiologies and histology is not a conducive method of establishing the diagnosis due to many reasons. However, around 5000 to 6000 patients with CKD/CKDu are being registered every year at the renal clinics in the sentinel site hospitals.

The surveillance of CKD/CKDu was launched in November 2013 and it has been evolved to the National Renal Registry (NRR) which is a real-time web based system available on ckd.epid.gov.lk. The NRR serves as the national database on CKD/CKDu and has the facilities to provide an electronic bed-head ticket for all patients with any renal ailment.

The mapping of cases with global information system (GIS) technology was carried out up to the Grama Nilardhari Division level. The collected data are used for geospatial analysis to provide information for causality analysis, planning and execution of preventive measures.

A study on the 'state health sector expenditure on the management of patients with chronic kidney disease' is being conducted currently and the results will be available soon. Research aimed at establishing the causality would be of value since it can guide the development and adoption of preventive measures. Analysis of different treatment modalities would enrich the knowledge quantum for the benefit of the patients.

Role of water sources and heavy metals in the CKDu epidemic

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Abstract

The drinking of contaminated water, mostly from shallow wells, is one among numerous hypotheses on the cause of CKDu in Sri Lanka. It is widely accepted by the public as well as the authorities, although there is still no scientific proof of any sort. Meanwhile, some experts suspect heavy metals, in particular cadmium, while others blame agrochemicals, and one weedicide in particular, as the pollutant causing CKDu.

The provision of clean water has become a top order priority to tackle the disease.The government has rushed to establish reverse osmosis (RO) plants as a short-term solution and is seeking help for pipe-borne water supply systems as a long-term fix. The private sector has been accused of exploiting the situation by selling various filters and medicine. Now, after several years of supplying 'cleaned RO water', it is still not clear, whether drinking 'cleaned' water can 'prevent' or 'cure' CKDu. There are no current or planned studies to find out whether this contributes to disease mitigation or not. Moreover there are some indications that running water, be it surface or groundwater is safer to drink. Nevertheless, supply of potable water is a beneficial and socially justifiable 'no regret' measure.

Another early hypothesis for CKDu causation was the use of water with high fluoride levels in aluminum pots, but this did not get much traction.The most recent hypothesis is 'dehydration', yet there is no data to support this.

Attention is now being paid to the levels of fluoride and hardness of water in isolated wells in the affected areas. Although neither of these is a known causative for kidney damage, in combination they could dissolve or fortify proteins (the Hofmeister effect).

If the cause is the combined effect of fluoride and hardness, there are many simple methods to control this. If it is cadmium, then interventions will be difficult and expensive.Recent data shows little presence of heavy metals in drinking water. Whatever is identified as the ultimate cause, there is a need for improved regulatory measures and standards to be established, in order to safeguard those affected.

Keywords: *Cadmium, fluoride, hardness, water and food*

Rice varieties and fertilizer in relation to CKDu

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Abstract

Rice is the staple food crop of 21 million Sri Lankans whose per capita consumption has reached close to 104 kg/annum which is dependent on the paddy production in the country and the price of imported wheat flour. More than 30 % of the total labour force is directly or indirectly involved in the rice sector which is thus livelihood of more than 1.5 million farm families. Paddy occupies nearly 12 % of arable lands (820,000 ha) in Sri Lanka.

Reaching self-sufficiency in rice production in 2010 was a significant achievement in the quest for food security that had broader goal. It was documented that the rice farmers in Anuradhapura, Polonnaruwa and Badulla are affected largely with CKDu caused by multiple factors such as chronic exposure to kidney damaging pesticides, arsenic, lead and cadmium, poor diet and genetic susceptibility to kidney failure. Development of healthy-rice as a preventive measure against non-contagious diseases such as CKDu is feasible due to the vast diversity existing in our rice germplasm for various relevant characteristics including heavy metal absorption. Heavy metal absorption is closely related to the use of contaminated agro-chemicals such as fertilizer and other agro-chemicals for rice cultivation. Among fertilizers used for rice cultivation, triple super phosphate (TSP) contains high Cd percentage. Further, the Cd percentage varies with the manufacturer and the price of fertilizer. Research on developing rice cultivars that perform well without or with least amount of chemical inputs are continued by the rice scientists.

However, the government is taking a very high priority to promote organic fertilizers,to improve inorganic fertilizer use efficiency and to increase the quality of fertilizers that is imported to Sri Lanka. At present, the maximum allowable level of Cd content in TSP that is imported to the country is set to 3 ppm to maintain the higher standard of imported TSP. Research investigations to improve the fertilizer use efficiency has come up with several technologies such as leaf color charts, use of granular form of fertilizers, and alternative use of inorganic fertilizers. Soil analysis based fertilizer application and nanotechnology based fertilizer formulations could reduce the unnecessary adding of fertilizers to the rice.

Keywords: *CKDu, fertilizer, rice varieties*

Way forward in CKDu research

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Abstract

CKDu as a disease entity was first recognized in Sri Lanka in the early 1990s. CKDu research began from year 2000 onwards mainly with the aim of identifying causative factors for the disease. Despite many research efforts, there is no definite answer to its aetiology although available evidence has been subjected to review and debate among the scientific community. CKDu is a national priority, hence needs urgent interventions.

At this point in time, it is important to identify the major research questions and develop research strategies to find the answers as a way forward in CKDu research. It is also valuable to support the research community to develop Centres of Excellence and encourage the development of new innovations related to both research and clinical management of CKDu.

Main areas of research would be epidemiology, aetiological factors (cadmium, water hardness, fluoride in drinking water and other multiple factors), early detection, and natural history of the disease and treatment modalities.

In order to strengthen the accuracy of prevalence data and surveillance programmes, it is important to have a proper definition for CKDu to replace the current definition which makes a diagnosis by exclusion. A national team of experts should be appointed to work on this. Case control study comparing early CKDu (cases) with healthy controls along with environmental sampling of soil, water, vegetables and fish would enable us to study the effects of low dose exposure to cadmium. Fluoride alone or together with hard water is an aetiological factor that remains to be proven. Innovative laboratory studies should be planned to further examine this hypothesis.

An ecological study would be useful to examine the impact of multiple environmental factors in the causation of the disease, and will pave the way for a different approach to research related to CKDu with the unit of observation as the population or community. Disease rates and exposures can thus be measured and their relation to various exposures can be examined.

Development of point-of-care technology for early detection and new approaches to dialysis (mobile dialysis clinics, peritoneal dialysis fluid) will pave way for new technological innovations. Treatment protocols that would be effective in delaying the progression of the disease should be tested by controlled clinical trials.

In order to achieve above objectives, experts in different fields should work together under a national level steering committee and collaborations developed with both national and international centers of excellence for technology and expertise.

Keywords: *Chronic kidney disease, CKDu, aetiological factors, Sri Lanka*

Epidemiology of cancer in Sri Lanka: what are the common cancers?

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Abstract

The National Cancer Control Programme (NCCP) of the Ministry of Health is the national focal point for surveillance of cancers in Sri Lanka. Surveillance of cancers is evolving over the years from hospital based cancer frequency statistics to population based cancer incidence information. The instrument for disseminating cancer surveillance information is called the 'cancer incidence data-Sri Lanka', and eleven publications have been released covering cancer surveillance information from 1985 to 2009. The more recent publications are available online at www.nccp.health.gov.lk. The information available through the cancer surveillance system, hospital information system and information from Registrar General's Department were reviewed.

In the year 2015, the total number of newly detected cancer patients registered at all 09 government cancer treatment centres was 28474 (2008 -19,309; 2009 – 20,538; 2010 – 21,517; 2011 – 25,457; 2012 – 25,452; 2013 – 25,515; 2014 – 26,341). Since these figures include duplicate registrations, and as cancers not reported to cancer treatment centres are not considered, this is only a proxy figure to get some idea about the current situation in Sri Lanka. Cancer surveillance information gives more refined data since it is generated through an organized process of obtaining cancer incidence data from multiple sources including cancer treatment centre clinic data , histopathology, haematology and oral pathology laboratory data and oro maxillary facial unit data followed by the process of data verification including elimination of duplicates. A total of 16,888 cancers were identified in 2009 giving a crude incidence rate (CR) of 82.6 per 100,000 population (1985 – 5012, CR-31.6; 1990 – 6063, CR-35.7; 1995 – 7325, CR-40.4; 2000 – 10,925, CR – 56.4; 2005 -13,372, CR-67.9).

When cancer incidence data of 2005 -2009 is reviewed the highest incident male cancers were oral (2005 – 1249 CR-14.1 ; 2009 – 1773, CR-19.4), lung (2005 – 666 CR-7.7 ; 2009 – 875, CR-10.0), oesophagus (2005 – 498 CR-5.8 ; 2009 – 656, CR-7.3), colon (2005 – 388 CR-4.4 ; 2009 – 489, CR-5.8) and lymphoma (2005 – 360 CR-3.9 ; 2009 – 408, CR-4.3). The same for females were breast (2005 – 1859 CR-18.3 ; 2009 – 2293, CR-22.2), cervix (2005 – 881 CR-8.9 ; 2009 – 879, CR-8.7), thyroid (2005 – 592 CR-5.6 ; 2009 – 816, CR-7.4), ovary (2005 – 596 CR-5.9 ; 2009 – 698, CR-6.8) and oesophagus(2005 – 524 CR-5.5 ; 2009 – 608, CR-6.2). When age specific cancer incidence rates were reviewed, it was observed that peak incidence rates were observed among age groups of 65-69 and 70 -74.

Cancer mortality data is published by the Registrar General's Department. In year 2009, a total of 11,286 (in 2000 – 7842) cancer related deaths were reported in Sri Lanka giving a crude death rate of 55.2 (in 2000 - 41.1) and a proportionate mortality rate of 8.8 (2000 – 6.7). Since the cancer incidence information system and mortality information systems are not interlinked in Sri Lanka, it is not possible to generate cancer survival rates for Sri Lanka routinely.

Keywords: *Cancer, cancer surveillance*

Industry Interaction Session

Invited Presentations

Food & Agriculture

Innovation ecosystem of food and agriculture sector in Sri Lanka: current status, constraints and prospects

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Innovation in agriculture has taken place since time immemorial targeting novel and better ways of production and improving livelihood of people. Creative responses of scientists and practitioners in agriculture have continued to be important sources of improvement to agricultural productivity in many developing countries including Sri Lanka. For example, development of new improved varieties (NIVs) of rice with high yields, pest and disease resistance and climate resilience is one of the major achievements of Sri Lankan scientists - a significant contribution towards developing the food and agriculture sector and ensuring food security in Sri Lanka. The NIVs currently occupy more than 98 % of the rice cultivated extent in Sri Lanka.

Innovation emanates from multiple sources of research and is diffused through multiple extension processes.There is a growing realization in Sri Lanka that innovation is a prerequisite for maintaining competitiveness in global markets. Innovation is also critical for moving along with top-performing market economies. Moreover, the increasing rate of technological change has resulted in the emergence of platform technologies in Sri Lanka such as ICT, biotechnology and nanotechnology. However, Sri Lanka has yet to harness potential energy and existing talent pools to tackle problems that have continued to plague the food and agriculture sector over the years i.e.high cost of production and low profitability, lack of value addition in both domestic and export-oriented production, devolved agricultural extension system affecting technology transfer and capacity building, weak mechanisms to support commercialization of R&D outputs, poor intra- and inter-institutional coordination, weak national quality infrastructure and innovation ecosystems,and rapid changes in national level policies.

Carefully designed university-industry-government development partnerships (public–private partnerships) with win-win scenarios and strengthened entrepreneurial capacities will enable all parties in the food and agriculture sector to benefit and progress in terms of technological and economic development. Better coordination and new governance mechanisms to strengthen innovation ecosystems, increased private and public investments in R&D capabilities to enhance innovation potential and commercialization, and policies and agribusiness models that fit into the national development agenda and competitive markets at international levels are essentials to ensure that the food and agriculture sector in Sri Lanka will continue to grow in the foreseeable future.

Potential for commercialization of biological agent, *Cotesia plutellae* Kurdjumov. for Diamondback Moth, *Plutella xylostella L.* management in cabbage

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Diamondback moth (DBM), *Plutella xylostella L.* is a serious insect pest of cabbage, where farmers use insecticides indiscriminately for its management. In Sri Lanka, over use of pesticides has created a situation, where faunal diversity has been destroyed and resulted in detrimental effects to the environment and to the consumers. Biological control is a key element in the integrated pest management strategy, where parasitoids, predators and pathogens are used.

Commercialization of biological agents for insect pest control requires studies on mass production, rate and time of release, medium and long term storage and awareness creation among end-users. Research conducted at Plant Quarantine Unit, Gannoruwa with a National Science Foundation, technology grant to manage DBM by a locally available larval parasitoid, *C. plutellae* was found to be very effective. However, mass rearing of *C. plutellae* requires considerable space and manual labor; therefore infrastructure facilities need to be developed. However, available funds are inadequate for the purpose. An alternative for this problem is to rear the bio-agent with low cost artificial diets. In laboratory studies, out of 35 diets, one diet formulation was found to be comparable to cabbage leaves. However, though rearing in the laboratory is possible, mass rearing in cages sometimes caused fungal infections in diets.

Rate and time of release experiments were conducted in four seasons at Nuwara Eliya, Marassana and Thaluthu-oya in five locations. Each concluded that release rate of 1500 parasitoids/ha at two weeks after transplanting of cabbage was successful for DBM management. Savings in insect management using biological agents in this study was around Rs. 106,474.00/ha/crop.

Medium and long-term storage of biological agents is a key element in the cost-effective production and distribution of natural enemies. Further, adult biological agents reaching reproductive state quickly, predictably and synchronously, after storage are equally important. However, scope of our study did not include this aspect.

Unlike the conventional pest management, where instant results could be seen, with biological agents it is not quick enough to convince end-users. Therefore, technology transfer through awareness creation is really a problem in Sri Lanka. Moreover, the threats and counteractions by concerned parties could not be disregarded.

Standardized production of high quality natural enemies, which is crucial for commercialization purposes because of possible high variability of natural enemies produced under mass production programs. Moreover, in Sri Lanka there are no policy decisions taken to promote the use of biological agents yet. Funds for biological insect pest management needs to be enhanced by the government.

ITI experience on R&D commercialization: challenges and way forward

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Introduction: Science, technology and innovation are key drivers for knowledge based economic growth of a country where commercialization of R&D output, is an important input for economic growth. Technology and scientific knowledge generated within R&D institutions utilizing public funds need to support such growth. In Sri Lanka the Industrial Technology Institute (ITI - former CISIR) and private industries share a rich history of research collaboration and such collaborative partnerships should be strengthened in order to promote an innovative ecosystem within the country. Presently, 99 % of the agro-food research programmes conducted by ITI scientists are of an applied nature, targeting market ready solutions as the end product. ITI has promoted the commercialization of technology through consultation services and collaborative and contract research projects with industry partners. In addition, the commercialization of research through direct technology transfer has become more focused especially in the 'high-tech' innovations. This process takes place through technology license agreements which are signed between private sector companies and the institution on exclusive or non-exclusive basis with or without a royalty payment based on the Institute's intellectual property policy. Omega-3 enriched chicken eggs, Kothalahimbatu biscuit, Isotonic lime drink , bottled king coconut water and bottled fish products, 'kasper' technology to enhance '*kithul*' sap yield and 'basca' technology to control fruit fly are some of the recent agro-food research outcomes which are successfully commercialized by ITI. A series of technologies developed through local and international funding such as fish soup cube, glucose syrup, fruit vinegar, tomato puree, mayonnaise, probiotic beverages, bio wax to extend the shelf life of fruit etc., which has commercial potential are also in the pipeline for seeking suitable industry partners. While the expertise of the multidisciplinary scientific teams and the state-of-the-art facilities available at ITI can be leveraged to attract private industry for a wide range of partnerships and research collaborations, it is noted that only a small percentage of R&D outcomes of the institute has been commercialized so far.

Challenges: Some of the ITI inventions are based on the ideas generated by research teams. The outcome in this case is typically a 'technology push' rather than a 'market pull' scenario where the market searches for new inventions. Limited facilities available for pilot scale testing or prototype and scale-up level research and the lack of business incubation facilities within the institute hinder the successful commercialization of research outcomes. Insufficient funding opportunities for scaling up and commercialization process also affect the smooth functioning of this process. Lack of multidisciplinary R&D team work with commercialization expertise, absence of holistic consideration- especially technology marketing aspects- also causes failure in commercialization of research. Proper intellectual property protection when entering into co-research with the industry and clear protection of IP ownership rights also need to be strengthened. On the other hand most of the industrialists only look at short-term benefits and hesitate to pay for technology - a factor which may tarnish the level of innovativeness.

Way forward: Industry- ITI partnership needs to be based on trust, recognizing the value of the partnership, and on the ability to meet each other's needs. It is important to develop a shared

vision that clearly identifies the purpose and goals of the partnership and also to create a shared platform for the exchange of ideas and information through effective communication via frequent stakeholder meetings. The researchers should aim at developing market oriented research while the financial assistance criteria of government funding bodies should be based on the viability and the potential marketability of the research outcome. In case of new innovations the entrepreneur or the industrialist should be supported by the researcher to understand the innovation at the beginning and after the product is launched through marketing consultancy. For successful commercialization of R&D, ITI needs a technology transfer centre which is going to be established soon with the assistance of the Chinese government- 'the China-Sri Lanka, South Asia Technology Transfer Centre'. Availability of business incubation facilities, scaling up facilities and availability of finance for scaling up technology are equally important for successful commercialization process. Some of these activities are to be addressed with the relocation of ITI- R&D sections to the new R&D Complex, in Malabe. There should be an incentive system for scientists not only for publications via the peer review system, but also to recognize outstanding partnerships established with the industry collaborators. The technology licensing, royalty assessment should be done by considering the effort made by the inventor with the royalty payment being shared with the inventor in order to encourage more inventions. Another new and more effective way of commercialization of technology practiced in many countries is through the formation of joint ventures and creation of new businesses as spin-offs of public sector R&D institutions. Creating new inventions and R&D commercialization could be strengthened by introducing such systems to ITI like research institutions.

How aquaculture can contribute to food security in Sri Lanka

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Aquaculture, or the rearing of fish in captivity, is the world's fastest-growing protein-producing activity, with nearly 50 percent of all seafood being farmed rather than caught in wild fisheries. Sri Lanka has a high potential for developing aquaculture in both marine and freshwater, being an island country and having large and medium sized reservoirs with a cumulative extent of 130,000 ha and over 15,000 small reservoirs with a total extent of 39000 ha. Hence, introduction of culture based fisheries in reservoirs with good management practices could enhance the fish production, provide livelihoods, enhance incomes and strengthen the rural economy. However, innovative solutions through research are required for seed production, feed development, combating diseases and management of sustainable culture systems. Biotechnology can be applied to enhance reproduction and early development success in cultured organisms and expand periods of gamete and fry availability. Establishment of culture systems in reservoirs for rearing fry to fingerling is a necessity since facilities available in aquaculture institutes are not adequate. Transgenic technologies can be applied to enhance growth rates, feed conversion ratios, resistance to disease, sterility issues and tolerance to extreme environmental conditions. Research should also focus on production of all male offspring via YY males, production of specific pathogen free (SPF) or specific pathogen resistant (SPR) aquatic animals.

Diversification of culture species and culture systems is another area which can be used to enhance fish production and secure food for communities. Aquaculture also has high potential for development with the establishment of production systems for high value species such as crabs, sea cucumber, marine fin fish, and seaweeds. Selection of suitable sites, development of hatchery technology, fry rearing systems and grow-out systems for these high value animals is required to attract investors. Mariculture is another prospective aquaculture system that has not yet emerged in Sri Lanka due to the high costs involved. This kind of aquaculture could be initiated in collaboration with foreign investors.

Development of new products from cultured aquatic organisms and their by-products is another potential area for conducting innovative research. Production of leather, glue and gelatin from fish skins, chitosan from crustacean carapace, simulated caviar from egg mass of suitable fish, fish meal, development of various processing methods for fish and crustacean meat can be considered as research needs. Developing products from discarded parts of the aquatic animals may also reduce environment pollution which affects the health of the people.

However, any form of aquaculture introduced should recognize the importance of economic, social and environmental management as the three pillars of sustainability of the venture. Introduction of new technologies with these concepts in mind will ensure the food security in the country.

Food security through an innovative combination of social intervention, scientific research, renewable energy and application of smart technology

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Situation: With the world population expected to grow by over a billion to 8.5 Billion by 2030 and the effects of years of environmental destruction - supplying the world with potable water and safe food will be one of the major challenges of the coming years. Three of the ten most populace countries are part of our region and many are facing desertification of their arable land. This while being a threat to all of us could also be an opportunity for Sri Lanka if handled properly.

In Sri Lanka the population growth in the next decade and a half may not be as steep as the worlds. However, our challenge will be meeting the changing and expanding demand of our population, along with the requirement of around 5 million odd tourists who are expected to visit the country annually, while exporting agri-produce in return for badly needed foreign exchange. Uncontrollable issues such as erratic weather patterns will further negatively impact national food security. There are also a multitude of other issues that will impact food security for which we need to take correct action both decisively and in a timely manner. One of the most obvious of these being the migration of youth away from farming areas to urban centres looking for different types of jobs.

Being a water surplus compact agri-economy with a deep rooted association with water management and agriculture, the situation could be turned into opportunity with very positive economic outcomes making Sri Lanka a regional leader in modern agri-business and food production.

Innovation in tandem with affective leadership at all levels will play a vital role in mitigating the impending disaster. The current mindset of pursuing large scale FDI'S and promoting off farm jobs as a quick fix will further escalate the country's dependency on food imports from a fiercely competitive global market which would in all likelihood be controlled by the rich and powerful nations of tomorrow. Sri Lanka, as a whole, will have to transform itself from its current slumber into a dynamic, innovative and pro-active nation while its leadership at all levels will have to come to terms with, and understand the simple realities of the need to feed the country's citizens, short term visitors and investors.

Social innovation & transformation: For many centuries a large majority of the Sri Lankan farming community has been poor. This continues to be so, forcing youth to migrate to greener pastures. The country will have to come up with innovative ways to keep youth on the farms and increase incomes while meeting their modern day aspirations. Current and future generations do not aspire to spend long hours under the hot sun, day in day out for meagre incomes.They aspire to be middle class citizens and look for appropriate technologies which will keep them informed of adoptive technologies which will modernize farming, offering them a better and easier life. Simple but innovative technologies such as mobile 'apps' disseminating information and data which will help make more informed investments would be an ideal start.

For a start, the question we should be asking ourselves is - after spending taxpayer money on free education and setting up hundreds of computer labs in schools around the country and proudly talking about our rapidly growing level of computer literacy - is a fertilizer subsidy the only way we can help and appease our farmers and help them meet their aspirations? Why are we fixated on decades old processors, inventing for the sake of scientific discovery and not utilising the benefits of modern technology? Why are we producing so many 'job seekers' and not more 'agri-prenuers'? Do we all have a role to play or is it the sole responsibility of State?

Investments in reducing farm costs with free and renewable energy and electrification of farm equipment and machinery in a country that has year round sunshine and ample space for setting up wind turbines is a possibility. The annual sum of Rs 50 billion spent on the fertilizer subsidy could be used as collateral to raise a fund which could meet the heavy initial capital investment which will ultimately rid the nation of this limiting burden.

Over use of chemical inputs is not only increasing costs but is also becoming a burden on the national health budget and acting as a prohibitive factor in growing exports. Simple cost effective but effective test kits which indicate the level of requirement of nutrients coupled with a mobile based 'app' which will instantly inform you of how much of what to apply could possibly reduce the use by large levels.The possibility of targeted delivery of just the required amount of inputs direct to the root activated from a distance using your mobile phone coupled with centralised digitised databases collecting information on purchases and application of inputs. Once again there is a need for initial capital outlay, however on the long run it will be more cost effective than the Sluggish juggernaut currently struggling to monitor and facilitate agriculture.

Application of higher than necessary or wrong pesticides is also one of the problems facing the country. Biodynamic and integrated pest management systems set up within farms together with cloud based data collection and connectivity could improve the situation on the long term. Farmers could send in a picture of insects and numbers to experts through mobile daily, collected from strategically placed 'insectocutors'. Such experts could analyse regional and farm data which could be used to activate effective and appropriate counteraction. Controlled dosage of insecticide could be released through low cost electronic mist blowers activated and controlled from a mobile devise.

Data from automated electronic moisture and temperature measurement systems together with weather data can be processed so as to instruct automated water distribution systems reducing labour utilisation and water waste and crop loss due to poor water management. Complicated calculations, data capturing and processing which would have been a lot of paperwork in the past can now be done by the phone in your pocket.

Simple scientific innovations coupled with innovative and appropriate technology could transform Sri Lanka into a comparative and competitive food producer. Coupled with innovative social engineering farming could be made to meet the aspirations of the youth who we need to stay on the land if food security is to be an reality for this country . Science and technology could be only be the magic we want it to be if the thought process is inclusive. If we could do this I truly believe Sri Lanka today has the human capital and the conducive environment to make the country food secure and a land like no other.

Research, innovation, commercialization and policy interventions to clear bottlenecks, constraints, impediments to growth and development of the food and agriculture sector

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Innovation is more likely to emerge in response to scarcity and socio-economic realities and opportunities. Though practitioners were responsible for most agri sector breakthroughs in the past, the role of research institutions in producing new innovations has drastically increased. However field experience is still key to inspire workable innovations. Research and Innovation should be prioritized based on their impact on socio-economics and must of necessity be based on market requirements.

Hence emphasis lies on agro-critical models such as those that increase yields and nutrition, reduce costs (labour/inputs), enhance quality, reduce risks and sustain the environment. In the current context key issues also involve improved post harvest technologies and improved shelf life of fresh agri produce to achieve a higher return on investment for farmers and all supply chain participants. Unfortunately, all these critical areas have lagged behind due to multiple factors.

New innovations currently in the agri business sector are mainly linked with discoveries in universities, the department of agriculture or labs of multinationals that have sustainable scale economies and conducive environments to endure and justify such investments. In the former instance respective governments facilitate these organisations with the necessary infrastructure, academic and institutional support, legal protection as well as regulatory approvals, subsidized finance, access to markets and other means of reinforcements to aid the innovation process. Unfortunately, the experience in Sri Lanka is that while some efforts have been successful, most fall far short of generating the required level of innovation success in the sector.

Likewise given the diverse but scale-limited bio resources of the country the agri sector must of necessity focus on high end value added markets and maximize produce through high-tech agronomy/agri processing, agri/food bio-technology and bio-refinery concepts to produce multiple premium outcomes with various application possibilities for different industries and market segments. This is of course with strong focus on the food and nutrition security aspects that the country needs at this point of time.

Further to the development process, commercialization of innovation in the agri - food sector requires upscaling and development, registration, marketing, and development of production capacity for such products. Patent protection is probably the most obvious incentive to innovation activities. An increase in public sector investment in applied and developmental research, innovation, together with development of internationally recognized intellectual property (IP) protection frameworks, would lead to higher patentable discoveries. Under these circumstances private companies may obtain the rights to such patents and pursue investment towards commercialization. Public-private partnerships are also areas of focus for commercialization of innovative outcomes.

Given the noteworthy contribution of agriculture to gross domestic production (GDP) a consistent percentage of GDP should be invested in research and development while facilitating a stable innovation environment.

Nevertheless political considerations are seen as a major influence in prioritizing public expenditure on developing new agricultural technologies. There also exists a significant interval between the time an innovation is developed and available in the market, and the time it is widely used by producers, hence impacting its revenue generating interval prior to being commoditized. Therefore, private sector companies should be oriented and recognize the unique capacity of universities to generate innovations. They need to support university research in exchange for access to the rights of these innovations. Government policies should also assist in accelerating commercialization via investments coupled with market stimulation policies. In parallel, given the substantial number of persons in the agriculture sector (28.5 % of the labour force),the agriculture education and training system as well as sustainable agriculture and agriculture extension system should be focus areas for immediate intervention. Similarly if research for example on development of seeds and planting material may not warrant investment due to scale economies, adopting and improving existing research on suitable varieties available globally or regionally should be encouraged and facilitated. Lastly the success record of research funding in the past 20-30 years may need to be reviewed and research work carried out by the Department of Agriculture, the agriculture faculties in the universities, other research institutes and the private sector etc, in similar areas of applied research be evaluated to learn from the impediments and challenges faced to improve the future success rate. Though the need for a facilitative policy is appreciated by all stakeholders, and is documented via the Ministry of Agriculture in consultation with the private sector and other key stakeholders, the challenge is clearly in a speedy and consistent implementation of the required policies.

Energy & Environment

Commercialization of renewable energy systems with emphasis on solar power

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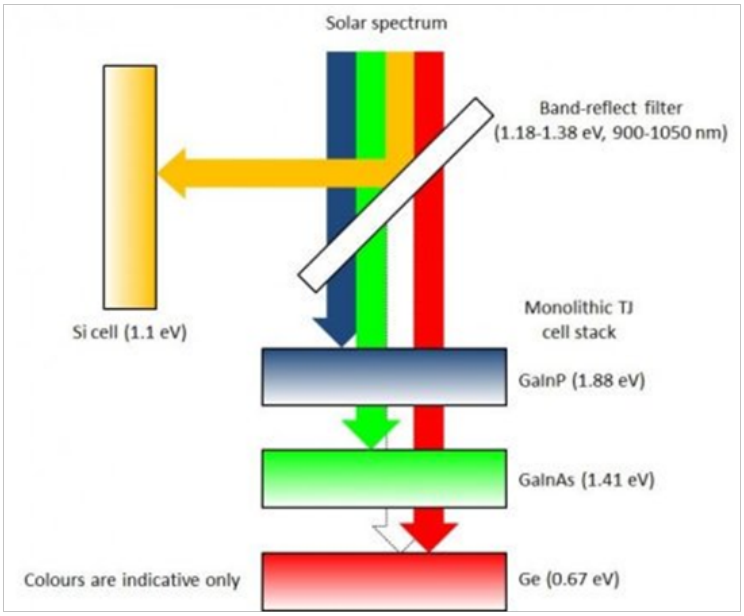
State of solar module manufacturing

Solar Energy has the highest conversion ratio to electricity of all forms of renewable energies including hydro, wind and biomass. The conversion ratio reached almost 20 % in mass production scale.



Credit: Rob Largent/UNSW

However, the world record of efficiency stands at 34.5 % at laboratory levels achieved at the University of New South Wales, Australia using multi–junction solar cells. Solar modules made of these cells will take much longer to come on to roof tops because it requires so much R&D effort to devise low cost mass scale manufacturing.

East Asia has emerged as a hub of solar module manufacturing with over 85 % being made in China, Korea and Taiwan which are considered as low cost manufacturing countries compared to Europe and USA. Some Japanese manufactures like Kyocera, Panasonic, Solar frontiers and Mitsubishi are still catering to high end local markets while REC Singapore and RECOM Malaysia are worth mentioning who hold considerably large manufacturing capacities outside China, Korea and Taiwan. The world has now accepted that solar module manufacturing has moved to East Asia, despite some manufacturers in Europe and USA who have incorporated some unique features. Ex: Solarworld (high quality) and First Solar (thin film). In 2015, world's solar module manufacturing capacity was 60 GWp and it is expected that this figure would reach 88 GWp this year. Solar module mass production outside East Asia is becoming nonfeasible, unless the manufacturer does not have a strong local market or some unique feature. Below are the strategies followed by some noteworthy module manufacturers.

Brand	Country of Manufacturing	Strategy
Trina	China	Low cost mass manufacturing, global supplier
JA Solar	China	Low cost mass manufacturing, global supplier
REC	Singapore	Unique quality, global supplier
Solarworld	Germany	Unique quality, global supplier, local market defended by anti-dumping duties for Chinese panels
Kyocera	Japan	Local Market
Solar Frontiers	Japan	CIGS Thinfilm; unique features & higher quality
Panasonic	Japan	Very high efficient solar modules , unique features
First Solar	USA	Thin film – unique product, low cost manufacturing
Sun Power	USA	Highest efficient solar modules, very unique and a global supplier.
Vicram Solar	India	Strong growth on local market

It is obvious that an investor requires a strong local growth in photo voltaic (PV) module market or some unique feature to have a sustainable solar module manufacturing business. However, some businesses run on a strong local market or anti dumping duties could collapse if the factors are removed. It is noteworthy to mention that even after very high capacity growth in the Indian market, they are yet to become a tier 1 solar PV module supplier globally.

Levelized Cost of Electricity (LCoE) : Solar 2016.

Energy Source	Cost / kWhr in Asia in 2015
Coal	USD 0.075
Wind	USD 0.082
Solar	USD 0.122

Source: Bloomburg- New Energy Finance

LCoE from solar power has already dropped considerably and to going down more rapidly than from any other Renewable Energy source. Some predict that this will reduce by 59 % down to 5 cents in the year 2025 (IRENA report). This is even lower than the present cost of Coal generated electricity and the savings could be used for integration of distributed battery systems that is required for stability.

Making renewable energy dispatchable

Although, LCoE of solar energy is claimed to have the steepest drop, this energy is not fully dispatchable. Hence, 'energy storage' is mandatory to make renewable energy fully dispatchable. Energy storage has been the 'code to break' for a very long time with concerns over higher levelized cost, charging and discharging losses, durability, speed of charge & discharge, energy density and safety. Presently, most of these are being addressed gradually and energy storage systems are just on the verge of commercialization. The critical concern is the cost which has come down with different technologies competing in the same void very aggressively.

Technology	Features	Cost /kWh
Pump Hydro	Proven technology & possibility of large capacity, efficiency 70-80 % Restricted by site location.	USD 350 to USD 800
Li-Ion Batteries	Steep drop in price, high efficiencies around 90 %, mass scale production already started.	USD 350 to 600
Flow Batteries	Easy scaling, virtually un-limited capacity, round trip efficiency - 70 %	USD 400 to 650

It is noteworthy that Li-Ion batteries have already stepped into mass scale production with several mega players like Tesla (USA), LGChem, Kokam, Samsung SDI (Korea) and Sony (Japan). Battery systems integration is one of the key areas that we can target to get a portion of the market that is presently dominated by Europe and Korean cells. We can give better lead-time for low cost systems either with our own battery management system or with the already popular brands with licensing or partnerships.

At the same time, we must focus on the opportunities in the service sector by providing renewable energy services locally and globally. Local developments in solar energy will give us plenty of opportunities to cater to the global requirement.

Energy efficiency

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Current status

The present economic development pathways across the globe have led to the much spoken about energy and environment crises at local and global levels. Extensive use of resources, including fossil fuels, for development activities have resulted in resource depletion in terms of both quantity and quality. In particular, the combustion of fossil fuels for energy generation has resulted in local environmental degradation and negative health effects as well as global climate change issues, challenging sustainability. As shown in Figure 1, there is a strong coupling of GDP growth with resource use, and today humans extract around 60 billion tonnes of resources each year, 50 % more

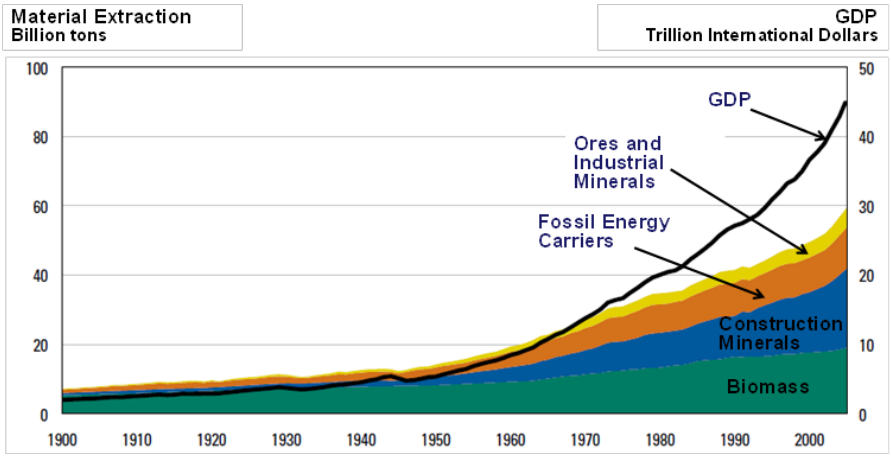

Figure 1: Economic growth and resource consumption

The ecological footprint at present shows that 1.5 Earths would be required to meet the demands humanity makes on nature each year, and the business-as-usual scenario demands for resources equivalent to those of three worlds by 2100. Carbon has been the dominant component of the ecological footprint, and it has been on an upward trend (from about 35% in 1960 to 55% today). The primary cause has been the burning of fossil fuels – coal, oil and natural gas, highlighting the significance of the energy sector on the global crises. Adding further complexity the global temperature rise would exceed the widely discussed goals of limiting global warming at 1.5 to 2^0C above the pre-industrial level.

Energy intensity in economy is also strongly linked to the industrial competitiveness of a country (see Figure 2). In fact, energy efficiency (EE) has become a core determinant of economic competitiveness and sustainable growth. Although Sri Lanka has a relatively less energy intensive economy, the low EEs are still apparent across all energy sectors, which pose challenges for the development of local industry and thus the economy of the country.

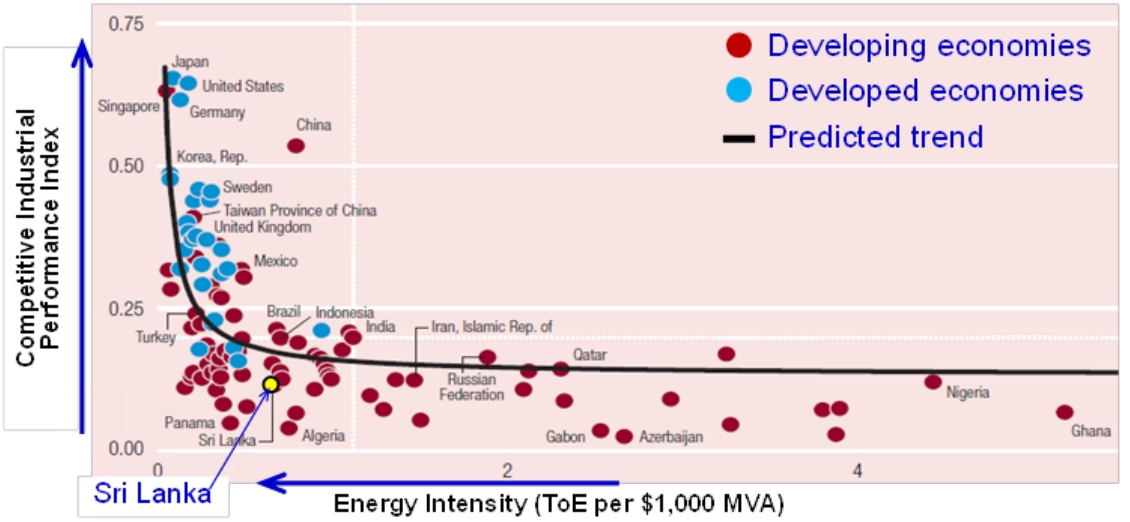

Figure 2: Industrial competitiveness and energy intensity

Increasing the EE (or decreasing energy intensity in economy) is therefore an integrated strategy to tackle economic, environmental and social issues at the same time and a requirement for a more sustainable path of economic growth.

Evolution of energy efficiency

Today, the world economy uses around 30 % less resources to produce one unit of world GDP than 30 years ago. Both technology improvements and system or structural changes across all energy sectors contribute to these improved performances. Figure 2 illustrates the evolution of EE in industrial sector, as depicted through energy intensity in terms of tonne of oil equivalent (ToE) per US$ 1,000 manufacturing value addition (MVA).

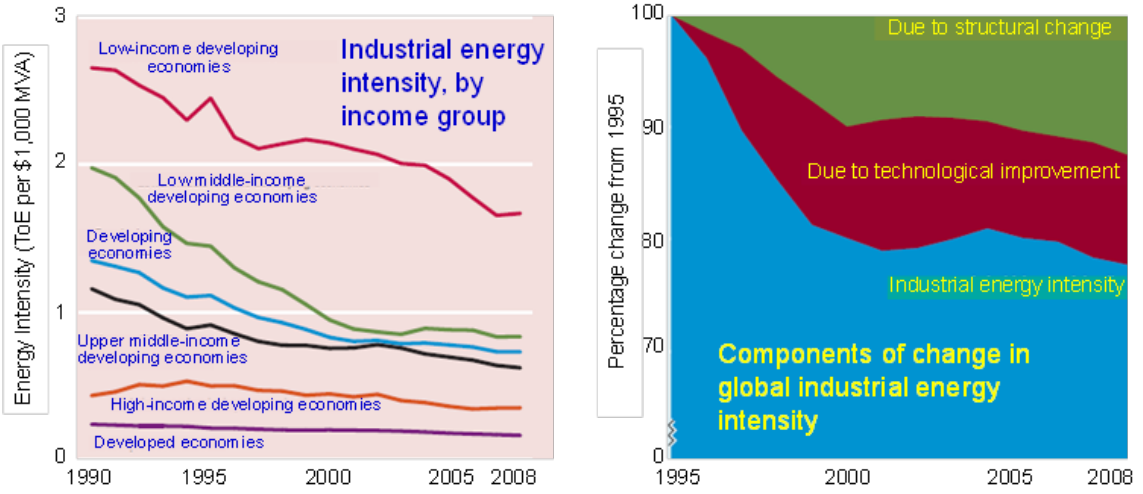

Figure 3: Evolution of energy intensity in industry

Globally, there has been a continuous decline in the primary energy intensity by approximately 1.5 % per annum since 1990, while the final energy intensity shows faster decrease of 1.9 % per annum that is attributed to greater end-use efficiency improvements. Since 1990, the global average efficiency of electricity production from all fossil fuels has increased by almost two percentage points to 36 %. However, the rate at which EE has improved since 1990 has been much slower than in the previous two decades. This rate will need to increase substantially in order to achieve a more secure and sustainable energy future.

The overall energy intensity of passenger transport has decreased by 5 % between 1990 and 2005. In the case of cars, improvements in the efficiency of engine technologies have been partially offset by the increased weight of cars and congestion-related effects. Present global average fuel economy of new cars is 7.1 litre/100 km, which is about 15 % improvement from 2005 value of 8.3 litre/100 km. The average fuel economy value of the new cars imported to Sri Lanka in 2014 is 6.5 litre/100 km without considering hybrid vehicles and 5.6 litre/100 km with hybrid vehicles. The fuel economy of transport is more meaningful when the passenger occupancy is also included in the estimates. In Sri Lanka, the average fuel economy values of passenger transport modes are estimated to be approximately 0.05, 0.03, 0.04, 0.02, 0.01 litre/passenger-km for cars, vans, motor-tricycles, motor-cycles and buses, respectively, indicating effectiveness of mass-transport mode over the others.

Despite the gains in EE, absolute de-coupling of energy use from economic growth is yet to be achieved. In fact, economic growth in developing countries, particularly in Asia, was much higher than growth in EE. Absolute levels of resource extraction and consumption are therefore still rising fast. There is still high potential to improve EE in developing countries, including Sri Lanka.

Role of R&D in achieving energy efficiency targets

Growing demand for energy – and the infrastructure needed to provide it – creates a unique opportunity for Sri Lanka to deliver greatest, fastest advances towards sustainable development goals (SDGs) by deploying energy efficient technologies and systems. For example, International Energy Agency (IEA) has recently proposed a bridging strategy that could deliver a peak in global energy-related emissions by 2020, which highlights a series of immediately practicable steps that can enhance energy sector action at no net economic cost. As illustrated in Figure 4, the largest contribution comes from increasing EE in industry, buildings and transport sectors, which is responsible for 65 % of the savings in 2020 and 50 % in 2030, relative to the intended nationally determined contribution (INDC) scenario.

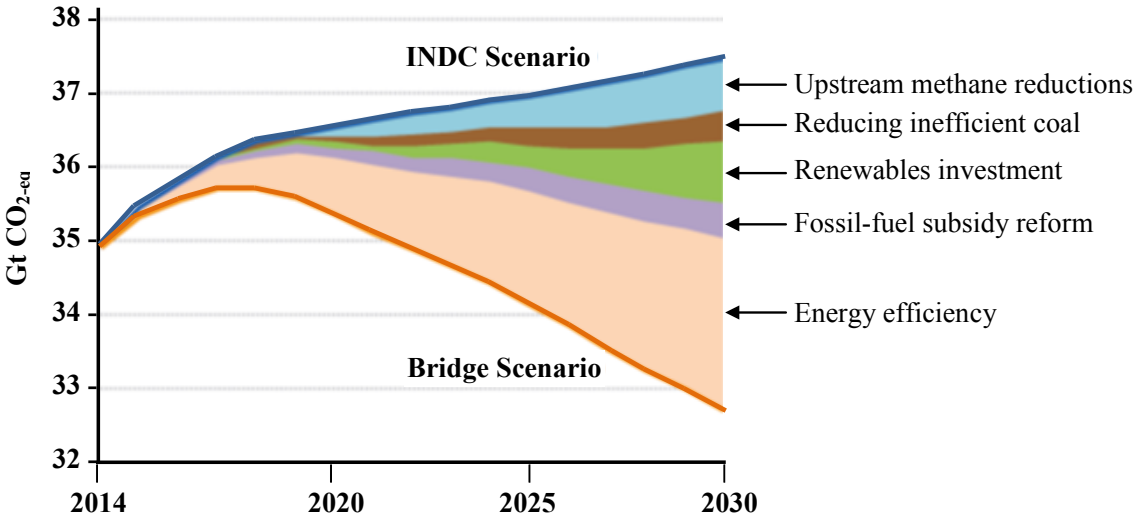

Figure 4: Global GHG emissions reduction by energy-related measures

It is emphasized that the proposed measures essentially require a further push on research, development and deployment (RD&D) for energy intensity reduction by improving technical efficiencies, production & resource efficiency improvements and structural & systems efficiency improvements across all the energy sectors (energy generation, distribution & storage, transport, buildings, industry, human settlements, etc.); particularly targeting the key technologies to be commercially available at the required scale by the early 2020s. Recent advancements in ICT could be utilized effectively meeting challenges for progress in the sector. RD&D interventions should also cover areas such as policies, regulations, standardizations, certifications, together with behavioural aspects of the community for influencing consumer choices towards sustainable life styles.

Waste to energy potential in Sri Lanka

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Waste to energy technologies have been in existence for a long time. However in Sri Lanka these technologies have not gained much prominence as a technology to solve our energy and environmental issues.

There are two main sources of waste that can be utilized in Sri Lanka to harness energy. They are,

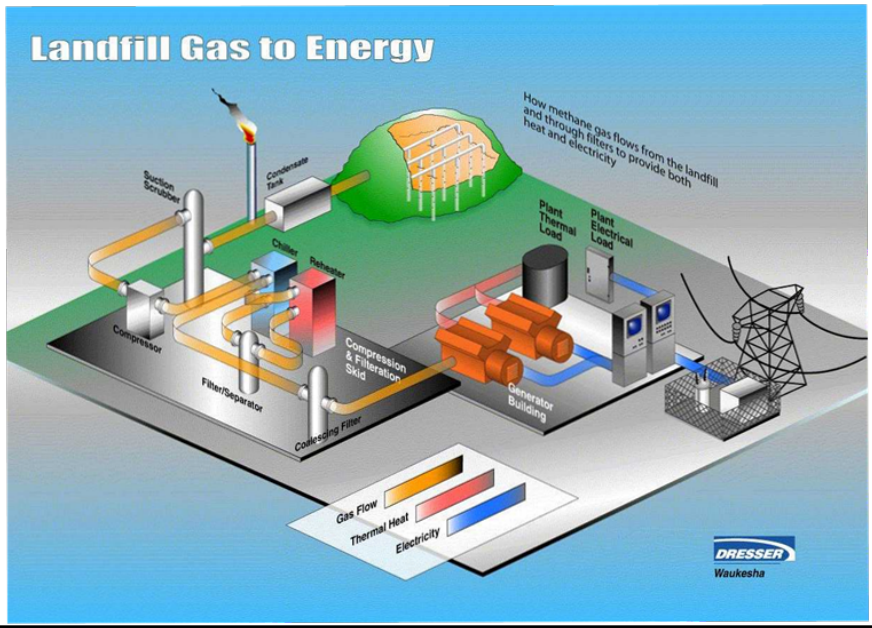
a) Solid waste
b) Agricultural waste such as rice husk.

Energy from solid waste

In the Western Province of Sri Lanka 3500 metric tons of solid waste is produced and of this only about 20 % is recycled or turned in to compost. The balance is disposed in unsanitary landfills creating many environmental and health issues to society. The recent floods in Sri Lanka and the flooding of many garbage dumping sites in the outskirts of Colombo highlighted the immediate perils and escalated the wider issues that Sri Lanka faces coping with disposal of solid waste.

The toxic gasses mainly methane produced by such landfills is 20 times more potent as a greenhouse gas (GHG) by weight than carbon dioxide. In many other countries methane generated is used as a fuel to generate electricity and/or heat energy thus reducing the harmful effects of methane as a GHG. The leakage of harmful substances from unsanitary landfills can enter the water table and contaminate the fragile water resources. Therefore a long term solution to this issue must be found.

Schematic of a typical sanitary landfill with electrical energy generation is illustrated below.



Sanitary landfills can solve not only the soil and water contamination issue but also produce electrical and heat energy by using methane to run LFG generators and also produce heat for other uses as shown in the above illustration.

What needs to be done,

a) Develop a policy and regularity framework for public, government and private enterprise to work together in finding a solution to the garbage issue facing Sri Lanka by way of a policy framework.
b) Establish private public partnership to find 'home grown' technologies that can produce energy from solid waste including the following.
    a. Waste collection and sorting techniques
    b. Designs and construction techniques for sanitary landfills
    c. Efficient LFG generating technologies
    d. Effective gas scrubbing technology
    e. Improved technologies to convert gas to electricity (e.g. co-generation)

c) Partnerships with foreign technology providers to share existing technologies.
d) Small scale pilot projects with private/public partnerships to test such technologies.

Energy from agricultural waste

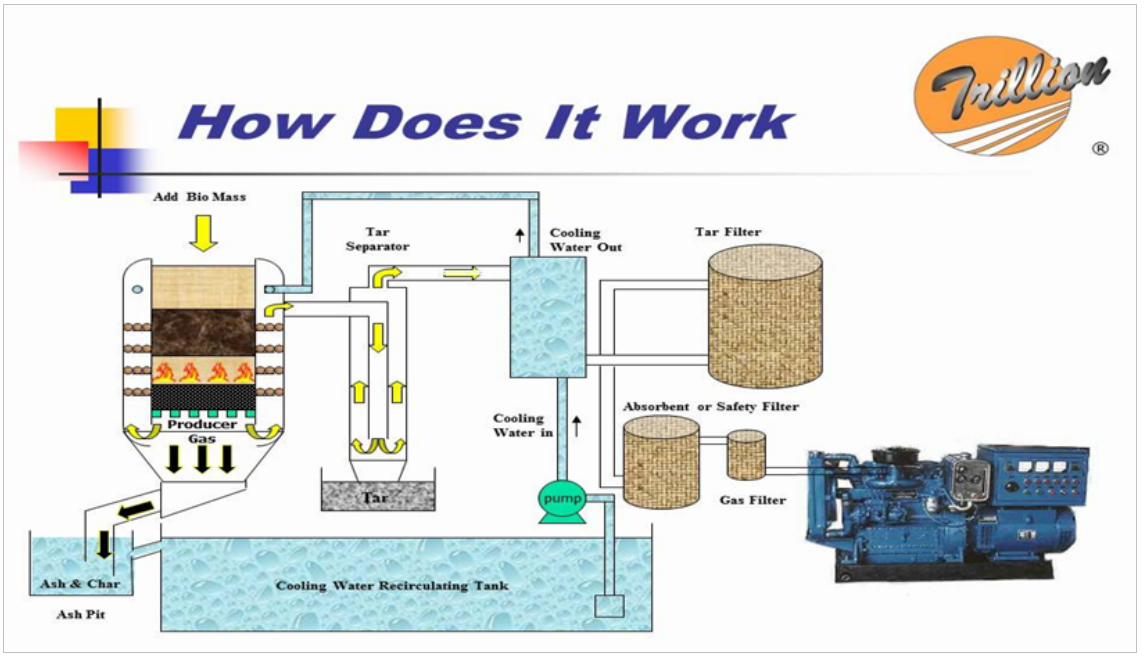
Sri Lanka's primary agricultural output is paddy. The paddy husk and straw produced as bi-products have the potential to be fuels for producing electrical or heat energy. Though research in this area has been done extensively in Sri Lanka (mainly gasification and direct firing technologies), it has not been commercially adopted extensively and therefore not reached its commercial potential.

Paddy husk contains 3000 kcal/kg of energy and one tonne can produce 410-570 kWh of electricity. Paddy straw contains 2400 kcal/kg of energy and one tonne can produce 300-400 kWh of electricity.

The benefits of using rice husk and straw technologies are numerous. Primarily, it provides electricity and serves as a way to dispose of agricultural waste. In addition, heat, a bi-product of power generation, can be used for paddy drying applications, thereby increasing local incomes and reducing the need to import fossil fuels. Paddy husk ash, the byproduct of rice husk power plants, can be used in the cement and steel industries. As per studies, Sri Lanka has the potential to produce 180 GWh of electricity per annum using paddy husk by using gasification or direct firing technologies.

Based on the location of farming communities small scale off-grid power plants (0.5-1 MW) power plants utilizing this technology can be set-up. For example with assistance from the government farming communities in rice producing areas (eastern and north-central provinces) of Sri Lanka can get together and develop a community based power plant to produce low cost electricity for their homes and mills. Also hybrid solutions can be adopted whereby solar energy is incorporated to produce electricity during daytime and the rice husk power plant can produce electricity during nighttime. This practice is currently being adopted in many Indian village communities whereby off-grid electrical generation projects are initiated saving the government expenditure on transmission and subsidy costs.

Schematic of a typical power plant using rice husk is illustrated below.



Way Forward?

1. Develop private public co-operation in R&D for energy efficient small scale low cost power plants using paddy waste.
2. Joint scientific corporation with Indian scientific institutions doing extensive research in this area.
3. Study already established technology and establish pilot projects incorporating new technologies to extensively test efficiency to select best technology.
4. Fund rural paddy farming communities to set up community electrification projects.
5. Study the possibility of net-metering solutions for large scale rice mills.

The grid of the future: Opportunities for research and innovation

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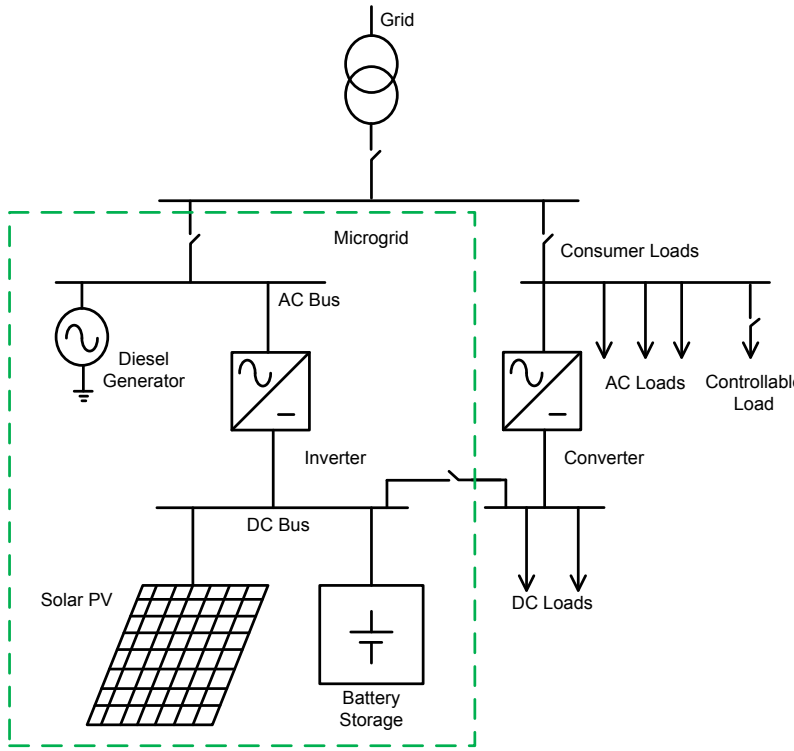
The power grid of the 20th century is undergoing a transformation, moving into the 21st century. Electricity like many other commodities, can now be either purchased and used by the customer, or produced by the customer and used, or have the option of both. In the late 1990s, governments introduced regulations to enable customers to choose their supplier, reducing the role of the traditional transmission and distribution utilities to that of a service provider, to convey electricity from producer to customer. Meanwhile technology and markets have moved on, with the concept of mini-grids and micro-grids.

The determinant of this transformation, is the declining cost of producing electricity from renewable energy sources. Although feasible, producing electricity at micro-scale using fossil fuels, is a demanding task which involves equipment operating at high temperatures and pressures, which needs specialised knowledge and regular attention. With renewable energy it is different.

A modern mini-grid serves a community, using a mix of renewable sources, storage devices, and a back-up generator. The main grid, if available in the vicinity, could serve as a further back-up. A modern micro-grid would be a smaller version of the mini-grid, typically serving one customer's premises.

So what is needed to be studied, and researched is what is unique in Sri Lanka, that stands-out in the international effort to develop a participatory grid ?



Research and Development

Load control: A mini-grid or a micro-grid should have controllable customer loads, for it to be efficient in managing the resources. What are the controllable loads in a household, a commercial customer premises, and in a manufacturing industry? What are the most suitable control strategies, to optimise costs and energy yield? What specific issues on Sri Lankan practices and loads, should be dealt with? What new storage devices and systems can be built?

Resource Intermittency: Solar and wind resources are intermittent. What are the specific features of various zones of Sri Lanka that require attention, in future widespread mini or micro grids?

Cost optimisation: Electric utilities will provide the back-up services and a price for any energy drawn, based on the time of use. How can a customer optimise the benefits of his micro grid investment?

Direct current grid: Electrical equipment use direct current, whereas the grid supply is alternating current. Renewable energy-based generation (solar) is direct current. Is there a case for each household and commercial premise to have a dc grid?

Health

A biotech manufacturing initiative in Sri Lanka: the CeyGen biotech experience

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High tech based biotechnology is one of the frontier technologies in the 21st century. The key market segments of this technology are the recombinant pharmaceuticals, regenerative medicine, diagnostics; industrial enzymes, bio-fuels, transgenic animal, plants and crops productions, marine industry and synthetic biology. The global biotechnology market has been estimated to reach US$ 414.5 billion by 2017 with a steady growth of CAGR 11.6 % from 2012-2017. Many developed nations have used the translational nature of Biotechnology to achieve sustainable economic development. Sri Lanka perhaps is one of the few countries which has not availed itself of this opportunity, otherwise would have saved foreign exchange and secured employment opportunities for the highly-skilled work force and eventually generated foreign exchange through exports.

Molecular diagnostics is one of the fastest growing market segments of biotechnology and will supersede convention diagnostics in the very near future. This is due to the ability of these tests to detect infections, genetic and heamatological disorders etc., and cancer at an early stage, and to personalize medicine with high precision and short turnaround time. The costs involved in in-ward patient care and other investigations will also be reduced. However, the major drawback for clinicians and patients to reap the benefits of these tests in Sri Lanka are the high costs of molecular tests as due to high costs incurred in importing these reagents. Therefore, the only way to reduce the cost and make it affordable to patient and, government and private health care sector is to produce these reagents in Sri Lanka.

In this backdrop, to make a significant difference in the molecular diagnostic facility in the health sector, enabling the local service providers to successfully conduct molecular diagnostics and related research activities using our own reagents at an affordable price, CeyGen Biotech (Pvt) Ltd was established in 2009 with a mission to reduce the cost of reagents used in molecular diagnostics and other molecular related research. Since then, the **CeyGen Biotech (Pvt) Ltd** has developed a series of testing platforms based on nucleic acid detection, approved by the Cosmetics Drugs and Devices Authority (CDDA, Ministry of Health) to be used in molecular diagnostic testing. The production line consisted of nucleic acid extraction kits, recombinant protein and enzymes, DNA markers etc., with many more developments to take place in the future.

The reagents produced by CeyGen Biotech have shown comparable sensitivity and performance when compared to the molecular reagents commercially available in the market. A variety of governmental service providing organizations including the Medical Research Institute, Blood Bank, and other university based service organizations could be benefited by these products, so cost of their assays/ research work could be reduced. This would benefit patients in this country requiring these tests for their health issues. Further, these products can also be used in the fields; agriculture, environmental and veterinary science. Supported by a NSF Technology grant, CeyGen Biotech has been able to reach several milestones such as the establishment of high tech recombinant protein expression and purification system, process for quality certification of biotech

product for the first time in Sri Lanka, commercialization of Sri Lankan made biotech products in the local market - thereby making available economical molecular reagents for advanced molecular diagnostics, local research and training in Biotechnology and most importantly saving foreign revenue, which has resulted in a significant reduction in the millions of dollars spent on importations of these reagents into Sri Lanka. Further, the technologies currently in hand can be used to produce industrial enzymes, recombinant therapeutics, vaccines, hormones, growth factors, monoclonal antibodies and diagnostic kits. However, for future developments, specialized infrastructure and equipment for scaling up, tax concessions for importation of raw materials and a buy back policy etc., would be required.

Medical device manufacturing industry in Sri Lanka

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Contribution from high-tech product manufacturing industry to the national economy of Sri Lanka is not significant. There are many challenges for a new industry to get established, especially with competitive pricing of globally reputed manufacturers. Professional medical device manufacturing industry is not mainly driven by the cost, but subject to other factors such as quality, reliability, and safety. The medical devices industry has been identified as one of the fastest growing industries in the world in the next couple of decades. Sri Lanka has a huge potential to succeed in this industry and for the industry to contribute to national economic growth.

Strengths – Experts in the specialized areas of biomedical/ mechanical/ electronics/ communication engineering essential for medical product development are currently available in the country. There are many examples of successful development of prototype medical products within the universities. Sri Lanka is blessed with a large number of medical specialists with unparalleled experience in their respective fields, who have numerous new ideas for medical products but lack a way of realizing them. If these ideas can be turned into medical products, it would not be that difficult for Sri Lanka to become a leading country in medical product development.

Weaknesses – Risk averse nature of the local private sector is a major weakness as there is a visible reluctance to fund commercialization of products developed in Universities. To minimize the risk, there is a possibility of first strengthening the base by developing existing and high turn-over products at the beginning and then moving into the novel products.

Opportunities – Sri Lanka imports almost all medical devices required for both public and private healthcare sectors. There is a willingness of many local medical specialists and the government to accept high quality locally developed and manufactured products. One of the biggest advantages of local medical product development is the possibility of providing a faster and reliable maintenance service which can extend the life of a product. This will avoid the accumulation of defective equipment lying idle in hospitals due to non-availability of maintenance services. Various government funding agencies have shown interest in funding these projects for building up the capacity for local product development and manufacturing. There is also the possibility of exporting these products initially to regional markets outside the country before targeting wider global markets.

Threats – There is a possibility of cheap but a comparable foreign made products being introduced to the local market. However, unlike other product segments, medical devices are subjected to stringent quality control. As a result, the possibility of inferior quality products being accepted for use in local hospitals is quite low. Possible patent claims for some of the products can be a major risk when exporting locally developed medical devices and should be addressed with care during the product development process.

What we have done: The University of Moratuwa partnered with Premium International Pvt. Ltd. primarily to target professional medical product development and manufacturing in Sri Lanka. The final, market ready prototype of the first product, the Pulse Oximeter is now completed. The NSF supported this project by funding for equipment needed for safety analysis and quality assurance. We had to face several hurdles along the way due to the lack of an eco-system for this kind of a project. There were many delays in procurement process. However, we have learned from this experience for future products. Our next step is to get this product into the local hospitals before going out for limited exports. We have developed the product to comply with highest international standards and exceeded the performance of reputed brands. We will soon find out if the country is ready to accept a high quality local product. We urgently need a strong government policy that allows cost and quality based competition between local and global products.

The government can promote local medical device manufacturing industry through funding, tax relief and buy back guaranties during the initial stages. When the initial barriers are broken by a few brave investors, there will be many more local and foreign investors entering the industry. There is huge potential for Sri Lanka to succeed in medical device development and manufacturing.

Issues, challenges in the innovation ecosystem for promoting R & D entrepreneurs

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University

- Aligning research in universities (undergraduate and postgraduate) to the commercial needs of the public and private sector of Sri Lanka. Currently, a lot of the research is only for publication purpose with no commercial exploitation. Can propose solutions to make this alignment.
- No commercialization arm for university research. Some universities are in the process of creating this, and the government needs to support it.
- Reaching out to the private sector to solve problems. Universities should think of themselves as R&D consultants and offer their services to industry. That way the collaboration will happen faster.
- No guidance to students and staff at the university for the commercialization of research and framework to do so. This can be a part of the curriculum.
- No incentive for the lecturers to commercialize research fundings or reaching out to the private sector. This collaboration should be encouraged.
- Continuity of research projects from one batch to another. This would be a role of the supervisor.

Entrepreneurs

- Entrepreneurs are struggling to find the funding required to commercialize their ideas, prototypes. Early stage healthcare startups rely on private sector funding to take products to market. Government should support these funding requirements or match funding provided by private sector.

- Intellectual property (IP) protection advice and costs. Advise on taking inventions global. IP landscaping support. Entrepreneurs have little knowledge about how to protect their ideas locally and globally. They cannot afford the costs of protecting it regionally or globally.

- Difficulty in PPP. Bureaucratic processes impeding private sector working with government institutes. This can be for joint grants, funding opportunities brought forward by private sector, connecting grantees with the private sector. For example, match the funding of the private sector.

- Regulatory approval delays for local medical devices. Should be encouraged by streamlining the process. National Medicines Regulatory Authority (NMRA) should facilitate a special contact person to fast track these opportunities. Encourage government buyback.

Private sector

- Openness of private sector for open-innovation. Currently very few companies are open to work with external research institutes. The trust needs to be established.
- PPP incentives need to be more transparent and clearly communicated to business leaders and R&D leaders.

Poster Presentations

Food & Agricuture

Antioxidants rich whole grain cereals in Sri Lanka: potential functional substitute to wheat in food industry

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Abstract

Background: Whole grain cereals are rich sources of naturally occurring antioxidants. The typical Sri Lankan diet comprises of variety of cereals. However, limited information is available on anti-oxidant properties (AP) of such cereals in the country as compared with other cereals worldwide. Therefore, present study evaluated AP of a range of whole grain cereals.

Methodology: Methanolic extracts of whole grains of red (BW 361) and white (Bg 359) rice (popular new improved rice varieties), finger millet (Oshada, popular and widely cultivating variety), corn, barley, wheat and oat were evaluated for total polyphenolic content (TPC), ferric reducing antioxidant power (FRAP), oxygen radical absorbance capacity (ORAC), 2-azino-bis (3-ethylbenzothiazoline-6-sulfonic) acid (ABTS) and 1,1-diphenyl-2-picryl-hydrazyl (DPPH) AP (n = 3 each sample, complete randomized design).

Results: Significant differences were observed among cereals for the investigated AP. Finger millet exhibited the significantly highest activities for all AP studied. Red rice variety, BW 361 had the second highest TPC, FRAP and ABTS while for ORAC and DPPH it was barley. In contrast, oat had the lowest TPC, ABTS and ORAC. This was 41, 14, 24 times lower respectively compared to finger millet. Further, both oat and Bg 359 had the lowest FRAP while for DPPH it was Bg 359. The observed lowest FRAP and DPPH activities were nearly 23 and 11 times lower respectively compared to finger millet.

Conclusion: Finger millet possesses highest AP of all the anti-oxidant roperties studied. The second highest AP were observed for red rice (TPC, FRAP and ABTS) and barley (ORAC and DPPH).

Potential for Commercialization: The present study indicates the possibility of development of value added health foods from whole grains, especially finger millet and red rice to meet the current demand of health conscious consumers.

Keywords: *Antioxidants, cereals, finger millet, functional foods, red rice and barley*

Effect of soil application of potassium and silicon on pre and post harvest qualities of tomato (*Lycopersicon esculentum L.*), capsicum (*Capsicum annuum L.*) and leeks (*Allium porrum L.*)

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Abstract

Background: Tomato, capsicum and leeks are widely grown commercial vegetables in Sri Lanka. Anthracnose is one of the major diseases in tomato and capsicum causing significant reduction of marketable yield. Leeks is highly susceptible to mechanical injuries resulting in reduced shelf life, even when stored under refrigerated conditions.This study was conducted for improving post harvest quality of tomato, capsicum and leeks by pre-harvest application of higher doses of potassium(K) or application of partially burnt rice hull (PBRH) as a source of silicon (Si).

Methodology: Three potassium treatments i.e. recommended dosage of Department of Agriculture (DOA) (K1), double the recommendation (K2) and triple the recommendation (K3), were used in each trial and treatments were arranged in a randomized complete block design with three replicates. Silicon, as a form of PBRH was applied into soil at three different levels (0 kg/ $1m^2$; control, 2 kg/ $1m^2$ bed or 4 kg/ $1m^2$ bed). Plant growth parameters (no of leaves, branches, plant height etc.) and postharvest quality parameters (physical and physico chemical parameters, yield, % weight loss, shelf life etc.) were evaluated. For both trials, disease resistance of tomato and capsicum was evaluated by challenged inoculation of *Colletotrichum sp*.

Results: Significant reductions (71 % and 75 %) of anthracnose disease were observed in tomato and capsicum treated K3 compared to K2 followed by control. In addition, fruit firmness and cell wall and fruit exocarp cell thickness of K3 treated fruits increased significantly. However, there was no significant change in pre or post harvest parameters observed in K treated leeks as compared with the control. The leeks grown in field incorporated with PBRH at 2 kg/m^2 bed, resulted in significant improvement of the post harvest quality parameters: % weight loss, rate of leaf yellowing and higher levels of chlorophyll retention. Silicon depositions (phytoliths) and thicker cuticle were also observed in leeks treated with PBRH. Silicon treated tomato (20 g/kg of soil) exhibited a significant reduction (80 %) of anthracnose disease, increased fruit firmness and cuticle and exocarp thickness.

Conclusion: Silicon as a form of PBRH or higher level of K (triple the dosage of potassium) could be used to reduce the incidence of anthracnose disease in tomato and capsicum and improve some postharvest qualities of leeks, which in turn reduces postharvest losses.

Potential for Commercialization: These pre harvest technologies; in combination with DOA recommended fertilizer levels or else, as a commercial products of PBRH and higher doses of K may be commercialized after confirming the above field trials recommendations with DOA Sri Lanka.

Key words: *Capsicum, leeks, potassium, silicon, tomato*

Effect of silicon on postharvest quality of hydroponically grown chillie pepper (*Capsicum annuum L.*)

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Abstract

Background: This study was conducted to investigate effect of silicon on pre and post harvest quality traits of capsicum grown in different hydroponics systems (liquid culture or simplified hydroponics system). Potassium silicate and rice hull were tested as possible silicon (Si) sources and two nutrient solutions. New formula with Si for growing stage (NFSB) of the crop and new formula with Si for blooming stage (NFSB) of the crop were prepared using potassium silicate.

Methodology: Five separate experiments were conducted in a completely randamized design (CRD) with three replicates for each treatment, to investigate; (i) the optimum concentration of Si treatment during different growth stages (growth or bloom), (ii) effect of root or foliar applications of potassium silicate, (iii) the effect of rice hull leachate, (iv) the effect of simplified hydroponics system (sand: rice hull) in the media as a Si source. The disease resistance was assessed by challenged inoculation of harvested fruits with *Colletotrichum spp.*

Results: Anthracnose disease was significantly reduced (75 %) by application of either 75 mg/l or 100 mg/l of Si with delayed initiation of disease. The disease agent *Colletotrichum gloeosporioides* was reduced by 71 % by treatment of Si during only blooming stage. The disease reduction against *C. gloeosporioides* given by root application of Si was significantly greater (67 %) than that of foliar application (39 %). Supplement of rice hull leachate enhanced shoot length (>12 %), number of leaves (>16 %) and leaf area (>31 %), fruit fresh weight (>29 %) and fruit length (>10 %) with significant reduction of the disease against *C. gloeosporioides* (by >34 %). The simplified hydroponic system reduced the disease by more than 83 % and enhanced root length (>77 %), fruit fresh weight (>22 %), fruit length (>11 %), fruit firmness (>16 %) and fruit cuticle thickness (>79 %). Cell wall bound phenol levels (CBP) was increased (about 30 %) in fruits from Si treated plants compared to that of Si free plants while total soluble phenols (TSP) was not affected significantly.

Conclusion: Root application of 75 mg/l of Si during only blooming stage would be optimum and economical against the anthracnose disease of capsicum grown in liquid hydroponics system. The simplified hydroponics system would give beneficial effects of Si leached by rice hull against anthracnose disease and enhanced fruit quality parameters.

Potential for Commercialization: The formulations with Si (NF) have been patented and the pilot project with the simplified hydroponics system has been successful thus leading to commercialization in small scale for home gardening.

Keywords: *Capsicum, hydroponics system, silicon, simplified hydroponics system*

Rhizobial inoculants for low cost environmentally benign food production

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Abstract

Background: Field testing with soybean demonstrated that coir dust based rhizobial inoculants could completely replace urea application without yield reductions. This study presents results of field testing such inoculants with mung bean (*Vigna radiata*), vegetable beans (*Phaseolus vulgaris*) and the pasture legume white clover (*Trifolium repens*).

Methodology: Trials with vegetable beans conducted in farmers' fields in three locations had as treatments: (i) control without any additions, (ii) fertilizer application without inoculation and (iii) inoculation without fertilizer.

Mung bean trials conducted in farmer's fields included treatments with (i) urea at recommended levels, (ii) urea at recommended levels & inoculation with two strains of rhizobia (iii) inoculation with two strains of rhizobia and (iv) control: without inoculation and urea additions.

Trials with white clover conducted at the Ambewela livestock farm had treatments to compare the basal dressings of either coir dust based inoculants, liquid inoculants or urea followed by the addition of either urea or liquid inoculants as top dressings after taking crop cuts. Root nodulation and plant growth were estimated on 3 plants per plot uprooted prior to the 1st crop cut. Crop cuts were obtained from three randomly selected ½ m^2 quadrats per plot to record biomass production as dry weights. Top dressings of urea or inoculants were applied 5 days after each crop cut.

All treatments had 3 replicates arranged on a randomized complete block design.

Results: Growth and nodulation of vegetable bean and mung bean were higher under inoculation than with urea application.

Results from vegetable beans ranged from equal yields (Doragala), 6 % (Rikillagaskade) to 9 % (Hanguranketha) increases due to inoculation over fertilizer additions.

An 8 % and a 6.8 % increase of seed yield over N-fertilizer treatment were recorded in mung bean with strains I & II respectively.

Highest mean biomass of clover (a 21% increase over the control) was obtained with basal solid inoculants followed by top dressing of liquid inoculants, while urea additions gave only a 16 % increase.

Conclusion: In all experiments rhizobial inoculants produced equal or better effects than urea applications.

Potential for Commercialization: Successful inoculants from this study will be commercialized minimizing cost of production and environmental pollution.

Bark of Ceylon cinnamon (*Cinnamomum zeylanicum* Blume): a potential natural product for novel hypolipidemic functional foods and nutraceuticals

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Abstract

Background: Ceylon cinnamon (*Cinnamomum zeylanicum Blume*) known as 'true cinnamon' has been used as a spice in many countries including Sri Lanka for centuries. Bark of CC is reported to possesses diverse pharmacological activities. However, to date it's antilipidemic activities (ALAs) are poorly investigated worldwide. The present study therefore investigated the antilipidemic activities (mediated via impairment of lipid synthesis, digestion and absorption) of bark of CC via range of antilipidemic assays.

Methodology: Ethanol (95 %) and dichloromethane:methanol (1:1) bark extracts (BEs) of authenticated CC were used in this study. As ALA HMG-CoA reductase (HR), lipase, cholesterol esterase (CE), cholesterol micellization (CM) inhibitory activities and bile acids binding (BAB) were studied *in vitro*. Ten individual compounds in BEs were also evaluated.

Results: BEs showed ALA in all the assays studied. The IC50 (µg/ml) values ranged from 153 ± 8 – 277 ± 32, 297 ± 11 – 301 ± 4, 30.62 ± 1.67-34.39 ± 0.91 and 230 ± 20 - 480 ± 20 respectively for HR, lipase, CE and CM inhibitory activities. The BAB (3mg/ml) for taurocholate, glycodeoxycholate and chenodeoxycholate ranged from 19.74 ± 0.31 - 20.22 ± 0.31, 21.97 ± 2.21 - 26.97 ± 1.61 and 16.11 ± 1.42 - 19.11 ± 1.52 % respectively. The observed ALAs were moderate compared to the reference drugs studied. Individual compounds in BEs ranged from 2.14 ± 0.28 - 101.91 ± 3.61 and 0.42 ± 0.03 - 49.12 ± 1.89 mg/g of extract. Cinnamaldehyde and gallic acid were the highest and the lowest among tested. The ethanol extract had significantly ($p < 0.05$) high quantities of individual compounds (except euginol) and ALA sinvestigated.

Conclusion: It is concluded that bark of CC possesses marked antilipidemic activities mediated via multiple mechanisms.

Potential for Commercialization: Bark of Ceylon cinnamon (CC) possesses range of anti-lipidemic activities which indicates its potential in the functional foods and neutraceuticals industries for the development of plant based natural foods

Keywords: *Ceylon cinnamon, true cinnamon, Cinnamomum zeylanicum, bark extracts, antilipidemic activities, phenolic profiles*

Hybridization among selected true cinnamon (*Cinnamomum zeylanicum* Blume) accessions for varietal improvement

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Abstract

Background: Cinnamon is mainly propagated by seeds. As its floral behavior shows protogynousdichogamy (two types of floral cycles, A and B) in nature cross pollination occurs predominantly and almost all the plants are heterogeneous. Type A plants first female opening is in the morning and the second or male opening is in the afternoon of the following day and type B plants first opening is in the afternoon and second opening is in the morning of the following day. Thus, artificial cross pollination between accessions is challenging.

Therefore, the study was initiated to determine the possibility of producing elite varieties with superior quality characteristics, through hybridization among selected cinnamon accessions.

Methodology: Artificial cross pollination was done initially among four elite accessions out of ten elite lines selected earlier from the germplasm collection at NCR & TC. Crosses were made considering the active period of male and female stages of Type A (variety Sri Gamunu, CRS 201) and Type B plants (variety Sri Wijaya, CRS 351). Each cross was made for 250 flowers.

Results: Successful seeds from the crosses were collected at the maturity and 46 crossbreed plants were established at NCR&TC and screening and evaluation for elite characteristics are ongoing.

Conclusions: Controlled pollination among cinnamon accessions for hybridization and varietal improvement in future crop improvement programs is potentially achievable.

Potential for commercialization: Lack of high yielding elite varieties has become one major issue which can be overcome by varietal improvement through hybridization programme.

Keywords: *Cinnamon, cross pollination, hybridization, Lauraceae, protogynousdichogamy*

A study of the antioxidant potential of the bran of red and white rice varieties from Sri Lanka

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Abstract

Background: Rice bran, one of the most abundant by products produced in the rice milling industry is well known for its naturally occurring antioxidants. Although rice is the dietary staple in Sri Lanka, there have been limited research attempts on antioxidant potential (AP) of Sri Lankan rice varieties.

Methodology: Freeze-dried ethanolic extracts of brans of 9 red and 20 white rice varieties were evaluated for total polyphenolic content (TPC), ferric reducing antioxidant power (FRAP), 2-azino-bis (3-ethylbenzothiazoline-6-sulfonic) acid (ABTS), 1,1-diphenyl-2-picryl-hydrazyl (DPPH) and oxygen radical absorbance capacity (ORAC) *in vitro* antioxidant assays. Gallic was used as the standard antioxidant in TPC assay, while trolox was used in rest of the antioxidant assays. Korean black rice variety was also studied for comparison.

***Results*:** Anti-oxidant potential (AP) of bran of red rice is significantly high ($P<0.05$) compared to bran of white rice. The means TPC, FRAP, ORAC and DPPH and ABTS (% inhibition) AP of red rice varied from 840 ± 32, 2808 ± 26 mg gallic acid equivalents (GAE)/100g bran, 25.70 ± 0.79 - 58.01 ± 0.64 mg trolox equivalents (TE)/g bran, 15.41 ± 0.28 - 26.63 ± 0.23 mg TE/g bran, 33 ± 1.02 - 68.58 ± 3 % and 50.72 ± 1.97 - 98.28 ± 0.40 % respectively. Where as those of white rice was in the range of 21.91 ± 2.68 - 328.83 ± 4.77 mg GAE/100g bran, 1.71 ± 1.37 - 11.07 ± 0.18 mg TE/g bran, 3.81 ± 0.09 - 13.64 ± 0.77 mg TE/g bran, 5.02 ± 0.55 - 21.84 ± 2.18 % and 15.01 ± 1.70 - 36.63 ± 1.64 % respectively. The observed AP of bran of red rice is moderate compared to the standard antioxidants used. Further, among red rice, the varieties which had the highest AP showed significantly high ($P<0.05$) or comparable antioxidant activity in comparison to black rice variety studied.

Conclusion: It is concluded that bran of red rice had significantly high anti-oxidant potential compared to bran of white rice

P***otential for Commercialization:*** Findings show that utilization of bran of red rice may contribute more antioxidant when developing value added health foods.

Keywords: *Antioxidants, functional foods and nutraceuticals, red rice bran, Sri Lankan rice, red and white rice.*

Evaluating the tyrosinase, elastase, hyaluronidase inhibitory and antioxidant properties of the ethanol extract of *Camellia sinensisas* refuse tea, a potential cosmetic ingredient

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Abstract

Background: *Camellia sinensis* leaves and leaf buds are processed to produce the popular beverage tea. During the black tea production process, considerable amount of refuse tea is leftover as a waste material. The objective of this study is to evaluate tyrosinase, elastase and hyaluronidase inhibitory activities and anti-oxidant activity of extracts of refused *C. sinensis* leaves to identify its potential as anti-aging, whitening and moisturizing ingredient in cosmetic formulations.

Methodology: Air-dried and powdered leaves were extracted with ethanol following a cold extraction protocol. Ethanol extract was evaluated *in vitro* for tyrosinase and elastase, hyaluronidase inhibitory activities, DPPH (1, 1-diphenyl-2-picrylhydrazyl) free radical scavenging, ferric ion antioxidant potential (FRAP) activity, oxygen radical absorbance capacity (ORAC) and for total phenolic content (TPC) following standard protocols. Kojic acid, quecertin, tannic acid and trolox were used as positive controls for tyrosinase, elastase, hyaluronidase and DPPH assays respectively.

Results: Ethanol extract of *C. sinensis* refuse tea exhibited marked hyalurondase inhibitory (74.9 %), moderate elastase (26.8 %) and tyrosinase (11.2 %) inhibitory activities at 500 µg/mL with compared to those of black tea brew (33.6 %, 500 µg/mL and 11.0 %, 40.7 %, 400 µg/mL respectively). Kojic acid, quecertin and tannic acid showed 100 %, 100 % and 95 % tyrosinase, elastase and hyaluronidase inhibition at 500 µg/mL respectively. Ethanol extract of refused tea showed a high DPPH free radical scavenging activity having IC50 value of 9.96 ± 0.05 µg/mL comparable to those of Sri Lankan black tea (IC50 9.70 ± 0.13 µg/mL) and green tea (IC50 6.71 ± 0.12 µg/mL) ethanol extracts and trolox (IC50 5.29 ± 0.09 µg/mL). Ethanol extract of *C. sinensis* refuse tea showed a ORAC value of 1676.218 ± 38.99 mg TE/g of extract with compared to those of black tea brew (1128 mg TE/g of extract). The ethanol extract of *C. sinensis* refuse tea showed a good FRAP value which was 2161.0 ± 25.66 mg TE/g. In this study the ethanol extract of *C. sinensis* refuse tea showed a TPC value of 93.4 mg GAE/g of extract with compared to black tea brew (124.0 mg GAE/g). To our knowledge this is the first report of tyrosinase, elastase, hyaluronidase inhibitory and DPPH, ORAC, FRAP activities of refused tea even though same activities are reported for black tea except for FRAP.

Conclusion: It is evident that the ethanol extract of *C. sinensis* refuse tea showed inhibitory effects on tyrosinase activity, elastase and hyaluronidase activity *in vitro*.

Potential for Commercialization: *Camellia sinensis* refuse tea extract has good hyaluronidase inhibitory and antioxidant activities and moderate tyrosinase and elastase inhibitory activities. Therefore the extract can be considered as an ingredient for the functional cosmetic products industry.

Keywords: *Antioxidant, Camellia sinensis, elastase, hyalurodidase, tyrosinase*

Design and development of power weeder for lowland paddy fields

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Abstract

Background: Use of man power for the weeding of paddy fields is uneconomical due to high labour wages and use of chemicals is not environment friendly due to harmfulness of the chemical components of herbicides. As a solution, an user friendly power weeder was designed, fabricated and developed to remove weeds in paddy fields.

Methodology: The main components of the designed power weeder are the hub with weeding arms, a vertical shaft engine, an adjustable floater and mud guards. Design criteria were developed to gain trafficability and weeding action as a hybrid action of traction wheels, buffalo footing action and ancient plough action.

Results: The developed power weeder can control weeds in the field within 8 inch gaps between rice rows (belts). The results revealed that the weeding efficiency of the power weeder was more than 80 %, with field capacity of 0.25 Ac/h. The fuel consumption of the machine was 4 l/Ac. Engine capacity was 1.25 kW, two stroke petrol engine. The machine is portable and easy to handle due to the light weight of the power weeder. Weeding components of the machine and the labourer who operates the machine are well protected by mud guards.

Conclusion: The machine is a solution for weeding problem in Sri Lankan paddy fields. It saves time and money in addition to solving the problem of labor scarcity. Moreover, the power weeder a user and environment friendly equipment without any health, soil and chemical hazardous.

Potential for Commercialization: Machine can be fabricated at any workshop with available materials in Sri Lanka. However the power source, vertical shaft engine has to be bought to fit in with the specifications.

Keywords: *Paddy field, power weeder, weeding*

Remote sensing based approach for identification of degrade prone lands in Kandy district

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Abstract

Background: The steep slopes, high intensity rainfall and inappropriate land uses have led to high rates of soil erosion, land-slides and the degradation of lands. Land degradation can be investigated through remotely sensed techniques as a cost and time effective method which can be monitor a large extent of land using satellite imageries.

Methodology: This study focused on identifying degrade prone areas of Kandy district using remote sensing, derived with soil erosion factors, surface runoff (with annual average rainfall), vegetation cover developed from Landsat 8 OLI satellite image (2015) while incorporating socio economic factors which influence land degradation. Accordingly, the spatial distribution map of physically degraded lands in Kandy district under different severity levels has been developed.

Results: Accordingly, 33.92 ha of highly degraded lands, 72.34 ha of moderately degraded land and 85.84 ha of low potential degraded lands were identified from the district. Positive correlation is observed among the spatial data of past 10 years landslide incidents with derived land degradation areas.

Conclusion: The accuracy assessment was done by conducting 169 GPS based field observation points with 63 % overall observations and 0.41 Kappa accuracy. The outputs of this study can be used as a tool for future land suitability analysis, planning and management in Kandy district.

Potential for Commercialization: Development of a methodology for identification of degraded land areas is a vital requirement for future land use planning, management and conservation.

Keywords: *Land degradation, remote sensing, soil erosion, vegetation cover*

Potential entomopathogenic fungus for shot-hole borer (*Xyleborus fornicatus*) control in tea cultivation

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Abstract

Background: Entomopathogenic fungi (EPF) are potential biocontrol agents for integrated pest management programs (IPM). Focus on the commercialized products of EPF is currently increased since it is an environmental friendly technique in pest control.

Methodology: A local strain of EPF was isolated from a diseased and dead beetle *(Epilachna sp.)* found in a home garden in Welimada. Dead beetle was inoculated in Molisch's agar after surface sterilization using 5 % NaOCl and incubated at 25°C. Pure isolate was obtained after single spore culturing and was identified as *Beauvaria bassiana* using characteristics of mycelia, sporulating structures and spores. Laboratory efficacy of the fungus against shot-hole borer beetle (*Xyleborus fornicatus*) was evaluated using the spore concentration $2.2x10^6$ spores/mL. Pencil thickness stems exactly 9 cm length dipped in the spore solution were kept in the 5 petridishes as 5 replications. Adult beetles (10) were introduced to each petridishes and mortality was obtained at 3 days intervals up to 10 days. Corrected mortality was obtained using Abbott's formula. Highest mortality (100 %) was observed after 9 days.

Results: The local isolate was mass cultured successfully in red raw rice with vegetable oil. Field efficacy of the isolate was evaluated against shot-hole borer in Attampitiya Tea Estate. The spore solution with the concentration of $2.5x\ 10^7$ spore/ mL was sprayed during the period of colonization. Mortality (20-30 %) of the beetle was observed in fungus treated plots against untreated plots showing potential to use as a control strategy in IPM of shot-hole borer. Further, field efficacy is being evaluated with two applications within the colonization period of beetle to improve the efficacy.

Potential for Commercialization: The local isolate *B. bassiana* has a high potential for incorporation in IPM of shot-hole borer.

Keywords: *Beauvaria bassiana, biocontrol, entomopathogenic fungus, shot-hole borer, xyleborus fornicatus*

Sri Lankan *Bacillus thuringiensis* isolates with insecticidal and chitinase activity

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Abstract

Background: *Bacillus thuringiensis* (Bt) is a naturally occurring soil born microorganisms. Insecticidal *Bt* strains are used worldwide as a microbial biopesticide. *Bt* produces insecticidal crystal proteins that are toxic to different insect orders, especially to lepidoptera, coleoptera and diptera. The objective of the present study was to isolate and identify insecticidal and chitinase producing *Bt* isolates from Sri Lankan soil.

Methodology: *Bt* was isolated from soil samples. Sodium acetate / heat treatment method was performed to isolate spore forming *Bacilli*. Isolated *Bacilli* were grown on chromogenic *Bacillus* agar to differentiate *Bt* like colonies. Phenotypic characterization was carried out to confirm the isolates as *Bt*. Gyrase B gene of *Bt* was sequenced to identify the subspecies of the strains. PCR was carried out to detect the insecticidal Cry genes. Leaf dip bioassay was performed to evaluate the insecticidal activity against diamond back moth (DBM) larvae. *Bt* isolates were screened for chitinase activity following disk dipping method.

Results: All *Bt* isolates gave positive results for gram staining and visualized as blue/green colonies on *Bacillus* agar. Crystals were visualized in dark blue colour when stained with Coomassie blue. Gyrase B gene sequencing revealed *Bt* isolates as *Bt kurstaki (Btk*; 3 isolates), *Bt graciosensis* (*Btg; 8 isolates)*, *Bt poloniensis* (*Btp; 1 isolates*), *Bt canadensis (Btc; 1 isolates)*, *Bt konkukian* (*Btkn; 2 isolates*) and *Bt israelensis* (*Bti; 2 isolates*). PCR analysis revealed the presence of Lepidopteran toxic *Cry1, Cry2* genes in *Btk, Btg, Btp; Cry9* gene in *Btg, Btp, Btc, Btkn*. Coleopteran toxic *Cry8* gene in *Btk, Btg.* Dipteran toxic *Cry10* gene in *Btk, Btg, Btp, Btk*n. One of *Btk* isolate showed 100 % mortality (3.84×10^{15} spores/mL) and a LC50 value of 3.87×10^{6} spores/mL against DBM larvae. Remaining isolates showed 20-35 % mortality at the tested concentrations, ranging from 10^{7}-10^{8} spore/mL. One of Btk isolate showed the highest chitinase activity having a chitinolytic index of 1.55 while other Bt isolates showed moderate chitinase activity. All tested Bt strains showed chitinase activity (chitinolytic index ranging from 1.10 to 1.55) except one of Btkn isolate.

Conclusion: One of the *Btk* isolates showed potential insecticidal activity against DBM larvae at laboratory level and chitinase activity. Hence it can be used as biological controlling agent against DBM as an alternative for synthetic pesticides.

Potential for Commercialization: *Bacillus thuringiensis (Bt)* microbial pesticides have potential for commercialization as biopesticides.

Keywords: *Bacillus thuringiensis, bio controlling agent, chitinase, cry genes, Gyrase B*

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In vitro antimicrobial activity of *Pediococcus pentoceus* isolated from rice variety, Madathawalu

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Abstract

Background: *Pediococcus pentoceus* was isolated in our laboratory from rice var. *madathawalu*, identified phenotypically, biochemically and genotypically. Using a Wistar rat model, acute and chronic toxicity of the isolate was investigated and was no toxicity observed. Therefore suitable to use as a starter in food materials.

Methodology: Antimicrobial activity of *P. pentoceus* was evaluated against fourteen human food borne pathogens including Multi Drug Resistant organisms namely *E.coli* ATCC 2592, *E.coli* ATCC 35218, *S. aureus* ATCC 6571, *S. aureus* EMRSA 17 COCR, *S.aureus* EMRSA 16 NCTC 13143, *E. faecalis* ATCC 49532, *E. faecalis* ATCC 700802, *S. mutans* ATCC 25175, *S. pyogenes* ATCC 700294, *S.sanguinis* ATCC 10556, *S. salvarius* ATCC 13419, *S.enterica* ATCC 700408, *A.baumannii* ATCC 17978, *S. flexenari* ATCC 12022 using agar well diffusion technique. Imipenem was used as a control. The diameter of inhibition zones were measured and statistically analyzed.

Results: Out of the 14 pathogens, *S.salvarius* ATCC 13419, *E.coli* ATCC 2592, *E.coli* ATCC 35218, *A.baumani* ATCC 17978, *S.aureus* 16 EMRSA NCTC 13143 and *S.enterica* ATCC 700408 were significantly inhibited by *P.pentoceus*, whereas, *S. aureus* ATCC 6571 and *S.aureus* 17 EMRSA COCR illustrated a moderate activity. *P.pentoceus* could not inhibit *E.faecilis*, ATCC 700802, *S.sanguinis* ATCC 10556, *E.faecilis* ATCC 49532 and *S.mutans* ATCC 25175.

Conclusion: The *in vitro* antimicrobial activity demonstrated by *P.pentoceus* shows its potentiality for use in food formulations.

Potential for Commercialization: Indigenous rice based fermented food with starter *Pediococcus pentoceus*, can be developed as an alternative for treatment of human food borne pathogens.

Keywords: *Antimicrobial activity, Madathawalu rice, Pediococcus pentoceus*

Acknowledgement: *Financial assistance from NSF Grant RG/2011/AG/07 is gratefully acknowledged.*

Relation of persistence and degree of water repellency to the saturated hydraulic conductivity of organic manure amended soils

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Abstract

Background: Saturated hydraulic conductivity (K_{SAT}) between 1–15 cm/h is required for agriculture. High K_{SAT} in farmlands increases the losses of soil nutrients by leaching. Water repellency (WR) is caused by organic matter present in soils and expected to affect soil hydrological processes. Addition of organic manure in farmlands may induce WR and affect processes such as K_{SAT}. The purpose of this study was to examine the relation of WR caused by organic manure on K_{SAT} of an Ultisol under laboratory conditions.

Methodology: Ultisol samples were amended with 5 % *Gliricidia* spp. (GL), *Casuarina* spp. (CE), cattle-manure (CM), and goat-manure (GM) and tested for a continuous period of 30 days. WR was measured using sessile drop contact angle method (SDM) and the water drop penetration time (WDPT) test. K_{SAT} was determined with the falling head method.

Results: Addition of organic manure, except highly hydrophilic GL, induced slight WR in soil. K_{SAT} decreased with increasing WR as measured by contact angle and WDPT showing strong negative power correlation. K_{SAT} of control was between 18–50 cm/h. GL and GM caused only very slight decrease in K_{SAT}. CE and CM caused decrease in K_{SAT} to be between 2–18 cm/h.

Conclusion: WR caused by manure additions decrease K_{SAT}. However the levels were acceptable for agriculture. It would keep leaching levels low, and allow filtering of pollutants.

Potential for Commercialization: Introduction of water repellent materials into composting so that the leaching from farmlands can be minimized.

Keywords: *Contact angle, organic manure, saturated hydraulic conductivity, water repellency*

Colour enhancement and the growth performance of Buenos Aires Tetra fed on diet containing natural plant pigment sources

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Abstract

Background: Commercial Colour enhanced feeds are comparatively expensive and is an essential component of ornamental fish industry. Feed cost represented 40-50 % of total production costs of aquaculture operation and there is a continuing effort to reduce feed cost. In this context, use of low cost natural pigment sources in fish feeds will help to reduce the feed cost and therefore to enhance the economical benefits by reducing a major cost in culture operations.

Methodology: Two natural ingredients ie:marigold petal meal (*Tagetes erecta*) (in MD diet) and pumpkin meal (*Cucurbita* sp.) (in PD diet) were used as cheaper pigmenting sources in order to enhance the colouration of the Buenos Aires tetra (*Hemmigrammus caudovittatus*) under the aquarium culture conditions. Control diet (CD) with no pigment source and the commercial feed (SR) were used as comparisons. Each treatment had three replicates and Randomized block ANOVA was carried out to test the effects of the diets containing natural pigment sources on the growth performance of fish. One way ANOVA was carried out to test the differences in % specific growth rate (SGR), feed conversion ratio (FCR) and total carotenoid content in different treatments.

Results: Food consumption, final body weight, length, SGR, FCR of fish did not show any significant difference among treatments. The total carotenoid content of the B A tetra are 2.04 mg/g, 6.15 mg/g, 6.36 mg/g and 4.86 mg/g respectively for the CD, MD, PD and SR feeds.

Conclusion: The addition of dietary carotenoids from marigold petal meal and pumpkin meal had no adverse effect on the growth rate, food conversion and the survival of fish though it significantly enhanced the colouration of the fish.

Potential for Commercialization: Low cost marigold petal meal and pumpkin meal have high potential to be used as commercial feeds to enhance the colouration of the Buenos Aires Tetra fish.

Keywords: *Colouration, low cost feed, pigments*

Preliminary investigation: antibiotic resistance of carp in ponds

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Abstract

Background: Several types of antibiotics are used in aquaculture industry which encourages the development of drug resistant bacteria. Therefore the aims of the present study were to 1) isolate and identify the bacteria inhabiting three carp ponds in Sri Lanka 2) study the antibiotic susceptibility of bacteria isolated from the above mentioned carp ponds for some selected antibiotics 3) investigate the difference in antibiotic resistance among bacteria isolated.

Methodology: Eighteen water samples were collected aseptically from three carp ponds (A=6, B=6, and C=6) in Muruthawela fish farm and were cultured on nutrient, MacConkey agars and nutrient broth. The colonial morphology of isolates was studied & further identification was done using *Hi25TM Enterobacteriaceae Identification* Kit. Kirby-Bauer technique was performed for each bacterial isolate, using amoxicillin, chloramphenicol and oxytetracycline disks (30 µg/disk, Himedia, India) on Mueller-Hinton agar. The plates were incubated overnight at 37^0C and the diameters of zones of inhibition (ZI) were measured.

Results: *Pseudomonas aeruginosa, Serratia sp, Klebsiella Pneumoniae* and *Bacillus subtilis* were isolated. Zones of inhibition demonstrated by amoxicillin, oxytetracycline and chloramphenicol for ponds A,B and C were recorded as (13.30 ± 0.99 mm, 20.02 ± 1.49 and 24.43 ± 1.82 mm) (10.99 ± 0.80 mm, 20.33 ± 1.49 mm and 25.59 ± 1.88) and (12.88 ± 1.10 mm, 19.09 ±1.63 mm and 25.83 ± 2.22 mm).

Conclusion: Highest susceptibility was shown by chloramphenicol (25.29 ± 1.18mm) followed by oxytetracycline (19.79 ± 0.92 mm). Highest incidence of resistance was evident against Amoxicillin (12.39 ± 0.58 mm).

Potential for Commercialization: This warrants further investigations in other carp ponds for confirmation of antibiotic resistance and thus may help in developing controlling actions of antibiotic use in carp ponds.

K***eywords:*** *Bacteria, antibiotics, carp ponds, Sri Lanka*

Energy & Environment

An investigation of optimum growth conditions for electro-deposition of CdS and CdTe semiconductor materials used in fabrication of solar cells

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Abstract

Background: As the supply of fossil fuels is physically limited and serious pollutions result from fossil fuels, solar energy is now regarded as one solution to the global energy crisis.In this regard solar cells play a vital role in converting solar energy to electricity and at present thin film CdS/ CdTe solar cell has evolved as one type among the few with high efficiencies. Despite the availability of wide variety of techniques, the cost of fabrication of CdS/CdTe solar cell is still relatively high. Owing to its simplicity, low-cost, scalability and manufacturability the electro deposition (ED) technique was investigated to identify the optimum growth conditions for fabrication of CdS and CdTe semiconductors.

Methodology: In this study CdS and CdTe semiconductor materials were grown using the technique of electrodeposition. For electrodeposition of CdS semiconductor, $CdCl_2$ and $Na_2S_2O_3$ salts were used as Cd and S precursors respectively and ED-growth parameters namely;pH of the solution, deposition temperature, cathodic deposition voltage and time were optimized in order to grow CdS layers with high photovoltaic activities. For CdTe material, $CdSO_4$ and TeO_2 were utilized as the precursors for Cd and Te respectivelyand thedeposition parameters were optimized following a procedure similar to that used for CdS. In the process of optimization of growth conditions for both CdS and CdTe materials, their electrical, optical, structural and morphological properties were assessed using current-voltage measurements of photo-electrochemical cells, optical absorption spectroscopy, x-ray diffraction and scanning electron microscopy respectively.

Results: For CdS, the optimum valuesof growth parameters; pH, deposition temperature,cathodic deposition voltage and time were identified to be in the ranges of 1.6-1.8, 55-65 °C, 650-680 mV and 20-40 min. respectively. For CdTe, the optimum values of pH and cathodic deposition voltage were identified to be in the ranges of 2.1-2.3 and 620-660 mV respectively.

Conclusion: A set of optimum growth conditions for electrodeposition of CdS and CdTe semiconductor materials with significant photovoltaic activities were identified.

Potential for Commercialization: Thin film CdS/ CdTe solar cell has long been regarded as one promising choice for development of cost-effective and reliable solar cells and at present it has stepped up towards commercialization.

Keywords: *Cadmium sulfide thin films, cadmium telluride thin films, electrodeposition, semiconductors,solar energy materials*

Experimental study on the effect of forced draft intensity on combustion efficiency of intermittently-fed biomass boilers

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Abstract

Background: Intermittently-fed biomass combustion is commonly found in small to medium scale industrial boilers in Sri Lanka, such as ones used in the tea industry. Mainly due to cost concerns, most of such boilers use primitive on-off control techniques where, batches having similar firewood mass are manually fed intermittently to the combustion chamber by an operator. The combustion is controlled by on-off switching of the forced-draft fan based on process parameters such as the steam pressure or the hot gas temperature. This conventional control approach can often result in lower overall energy efficiency, higher operating costs and adverse emissions which can potentially be rectified using appropriate automatic control technologies. In this background, this research aims to develop a control system to improve combustion efficiency of intermittently-fed biomass combustors by understanding the dynamics of biomass combustion as a function of the intensity of the air supply.

Methodology: A lab-scale biomass combustor was developed and was attached to a single-pass water-tube heat exchanger to study the time variation of the gross heat output under different fan speeds. Water flow through the heat exchanger was maintained constant at 4 l/min while the fan speed was varied from 500 rpm to 2800 rpm. The heat output was measured using the heat gained by the water flow.

Results: Results implied that the overall rate of heat energy produced depends on the fan speed, with an optimal fan speed yielding the maximum gross rate of heat-output for a given batch of biomass. The maximum heat absorption by water occurred at between 500 rpm and 1000rpm. At 2800 rpm the total heat absorption by water is approximately half of maximum recorded heat absorption. In the experiment, higher fan speeds tend to produce heating effect quicker, but heat output dies quicker.

Conclusion: The combustion performance of the batch-fed biomass boilers depends on the force draft fan speed. Therefore the overall system efficiency can be maximised by proper fan speed control. The stack losses contribute to significant energy losses if higher fan speeds are used. Varying fan speeds at different stages of intermittently-fed biomass combustors may lead to more uniform heat output from the system.

Potential for Commercialization: These findings can be used to develop a cost-effective automatic combustion controller particularly applicable for small and medium scale boilers used in local industries such as the ones used in tea factories.

Keywords: *Batch feeding of biomass, biomass boiler, biomass combustion, boiler controller, combustion efficiency*

Shoreline erosion of Sri Lanka
Case study: Coastline along the Southern province

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Abstract

Background: Coastal erosion is an important contemporary problem and crucial to countries with low lying coastal areas. It is a silent disaster and it takes a considerable time to understand the pattern and magnitude. It has been a severe problem over the years especially in the south, west and north-western coast of Sri Lanka. It is a collaborative impact of rise in sea level, global warming, human interference and present extreme climate change scenarios. It is important to identify the individual impacts of these several factors, (eg. distinguishing inundation from erosion).

Methodology: The impact of erosion was differentiated from the inundation of sea level rise by using the Inter governmental Panel for Climate Change (IPCC) predictions of the Indian Ocean from year 2006 to 2015. Vegetation line was used as the coastal line. The Coastlines for last 10 years were extracted using different dated satellite images, maps and aerial photographs. Further they were verified through discussions with 100 persons from coastal areas through a semi structured questionnaire and this information was used to evaluate erosion rates.

Results: The study reveals that the net erosion has been recorded up to 1.7 m per year. On the other hand, the accretion rate has not exceeded 0.1m per year. The average net mean rate of erosion for the entire study area varies from 0.2 to 0.5 m per year. Further, the study predicted future coastlines using DSAS tool in GIS environment.

Conclusion: It is recommended that policy makers take immediate action over this, since Southern coastline has a major impact on tourism and thus economic development.

Recommendations for Policy Formulation: The data can be used to take preventive measure to reduce shore line erosion of the Southern province.

Keywords: *Coast, erosion, GIS*

Transport induced volatile organic compound concentration in the city of Colombo

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Abstract

Background: Volatile organic compounds (VOCs) constitute an important fraction of air pollution contributing to variety of health and environmental impacts directly as well as indirectly through generation of secondary air pollutants. However, there is lack of information and knowledge on the subject locally. In general, international research studies have found that exposures to typical mixtures of VOCs in the range of 1 to 10 ppm or above results serious health effects.

Methodology: In order to fill this gap, field measurements of total VOC (TVOC) were conducted at seven locations in Colombo. Hourly spot measurements were conducted beside the road during 10.00 am to 11.00 am at these sites using MiniRAE Lite TVOC monitor during weekdays of month of May 2014. Monitor was fixed at 150cm above the ground (approximate breathing zone of an adult with average height) and 1m away from the side of the road. Further TVOC levels were measured on road by fixing TVOC monitor inside a moving vehicle keeping air flow tube outside the vehicle window to understand concentration variations away from the junctions between the sites.

Results: Weekly average TVOC hourly median concentrations beside the roads in ppb were 226.5, 194.5, 190.0, 99.0, 91.5, 72.5 and 56.0 at the sites Grandpass, Maradana, Borella, Dehiwala, Narahenpita, Kollupitiya, and Fort, respectively. The corresponding TVOC concentrations in ppb on the road were 536.0, 321.5, 216.0, 195.0, 189.0 and 183.0 between Narahenpita to Grandpass, Maradana to Borella, Borella to Narahenpita, Fort to Maradana, Kollupitiya to Fort and Dehiwala to Kollupitiya, respectively.

Based on the results TVOC levels in Colombo were categorized and presented with a colour index as; above 200 ppb for very high TVOC level (Red), 200 ppb-150 ppm for high TVOC level (Orange), 150 ppb to 100 ppb for medium TVOC level (Yellow), and below 75 ppb as low TVOC level (Green) as the transport induced outdoor TVOC levels in Colombo. High median TVOC concentrations at Grandpass, Maradana and Borella could be attributed from high vehicular traffic congestion during monitoring periods. Low TVOC concentration was observed at Kollupitiya, most likely due to comparatively high sea breeze that leads to high pollutant dispersion and dilution. The lowest TVOC concentration at Fort indicate that VOC are emitted mainly from gasoline-fueled vehicles rather than diesel fueled vehicles. It was clearly shown that TVOC levels were high on the road (273.4 ppb) than beside the road (132.8 ppb), probably due to immediate tail-pipe emissions from ongoing vehicles.

Conclusion: There is a considerable TVOC concentration in the urban environment of Sri Lanka, which is dependent on vehicle density on road with level of traffic congestions, and metrological parameters such as sea breeze.

Environmental impact: Research findings highlight the urgent need for appropriate urban air quality management policies and strategies in Sri Lanka.

Keywords: *Urban air quality, vehicular pollution, volatile organic compounds*

Mid–Late holocene sea level changes in the Indian Ocean around Sri Lanka

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Background: Understanding the variability of the natural sea level is a fundamental requirement to predict the future variability. Lack of the long-term sea level record for the central Indian Ocean and discrepancies in existing Holocene records prompted the carrying out this research to understand the Holocene sea level changes in the Indian Ocean around Sri Lanka.

Methodology: Raised and buried inland reefs, which are reliable sea level indicators, at Delft Island situated in the north and Madiha, Akurala in Southern province were studied. Eight coral samples were extracted by hand drilling and were radio carbon dated. Elevation to the sampling locations were obtained by levelling to the mean sea level.

Results: Radiocarbon dating yielded 6360 ± 160, 6280 ± 160, 6194 ± 28, 6058 ± 32, 6170 ± 160, 3853 ± 32, 5050 ± 30, 5573 ± 27 calyears BP ages for corals situated 0.21 m, 0.68 m, 1.58 m, 1.16 m ,1.137 m, -0.06 m, -1.42 m, and +1.34 m above msl respectively.

Conclusion: Coral results provide strong evidence for submergence of north, south and southwestern Sri Lanka by a minimum +1.5 m sea level highstand around 5500 – 6300 calyears BP. Results also suggests that coastal lowlands in Akurala and Madiha areas were converted to paleo-bays during this Holocene high stand.

Recommendations: Results of this study would be useful to predict future sea level variability. Coastal zone management, planning development activities and preparations for the impacts of sea level changes on navigation and defence activities will directly rely on such future predictions.

Keywords: *Coral, delft, holocene, Indian Ocean, sea level*

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Modeling of post-consumer plastic flow in municipal solid waste stream: a case study from Kandy municipal council in Sri Lanka

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Abstract

Background: Recycling is the most appropriate resource recovery solution to minimize plastic waste problem in Sri Lanka. This study used the materials flow analysis (MFA) principles to quantify the post-consumer plastic (PCP) generation, discharge, collection, processing and disposal in and around Kandy Municipality during the years 2014 - 2015. The comprehensive outcome was to derive quantitative estimates on processes and flows of plastics within the system and to assist decision making process of plastic waste management.

Methodology: The quantities of PCP in municipal solid waste (MSW) stream of Kandy municipal council (KMC) were numerically analyzed by software STAN® as a network of flows, stocks and processes. The inventory data required for the MFA were extracted from secondary sources. Verification and data validation were done through scheduled interviews and field observations.

Results: The average daily PCP generation in KMC for year 2014 -15 was 12.0 tonnes, in which 87 % was soft-film plastic and 13 % solid plastics. Recyclers in Kandy recover 30 % of PCP in which 17 % is processed to crushed pieces, 15 % is processed to manufacture goods, 67.5 % transport to Colombo and rest returns to dumpsite as manufacturing waste.

Conclusion: The analysis showed that 30 % PCP is recovered in KMC areas, yet there is an opportunity for increasing the recycling rate. It was also found that MFA with STAN® is an appropriate technique for decision making in recycling system planning and operation.

Potential for Commercialization: Material flow analysis (MFA) tool can be applied to the plastic recycling industry.

Keywords: *Material flow analysis, post-consumer plastic, plastic recycling*

Designing of a novel nanofiltration system for wastewater treatment

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Abstract

Background: Wastewater management will become an enormous problem as urban populations are projected to double in 40 years. Silver nanoparticles (AgNPs) are a very promising approach to treat wastewater due to its antimicrobial activity. Previous works had tested antibacterial effect of AgNPs coated polyurethane (PU) foam in wastewater, but no designed polyurethane filter or the minimum amount of AgNPs and time period required for the filtration has been tested.

Methodology: Initially, effectiveness of modified AgNPs was tested directly by treating of wastewater at different time periods with different AgNPs concentrations; 5 mg/L and 10 mg/L, and the nanofilter system was designed thereafter. Three filtration systems were set up using designed filters coated with crude AgNPs, modified AgNPs and charcoal separately to determine the antibacterial effect of each filter and filtered with wastewater. The modified AgNPs filtration system was tested with 20 mg and 10 mg of modified AgNPs separately to determine the minimum amount needed for nanofilter. The treated samples were collected at different time periods and plated on nutrient agar plates.

Results: Colony reduction of 80 % and 50 % was obtained for 5 mg/L of wastewater treatment system for 1 h and 3 h respectively while 95 % and 45 % colony reduction was obtained for 10 mg/L of wastewater treatment system for 1 and 3 h respectively. The filter made with 20 mg of modified AgNPs gave the maximum reduction of 100 % colony reduction. Further minimum time needed for maximum colony reduction was found to be 8 h.

Conclusion: Nanofilter made with 20 mg of modified AgNPs and filtered for 8 h was recommended as the best filter set up to remove the bacterial contaminants from wastewater. However, further experiments are needed to test the other quality parameters to recommend the nanofilter for the industry.

Potential for Commercialization: Potential development of a novel low-cost, environmentally benign and eco-friendly filter for the removal of bacterial contaminants from wastewater.

Keywords: *Bacterial contaminants, nanofilter, silver nanoparticles, wastewater*

Health

Inhibitory potential against alpha amylase and alpha glucosidase activity of selected plant extracts from underutilized fruits

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Abstract

Background: Diabetes is a multifactorial disease affecting millions of individuals worldwide. The present study evaluated the inhibitory potential against alpha amylase and alpha glucosidase of four selected underutilized fruits; *Elaeocarpus serratus (veralu), Cynometra cauliflora (Nam nam), Flacourtia inermis (Lovi-lovi) and Phyllanthus acidus (Rata nelli/ Goose berry)*.

Methodology: The ethanol (75 %) extract of selected fruits were fractionated between ethyl acetate (EA) and aqueous medium. Each portion was tested for phenolic content andinhibitory potential against alpha amylase and alpha glucosidase. Total phenolic content was determined using the Folin-Ciocalteu reagent assay.

Results: Ethanol extract of *E. serratus* (44.94 ± 1.96 mg GAE/g) had the highest content of phenolics while EA fraction of *P. acidus* (0.80 ± 0.23 mg GAE/g) had the least. The highest inhibitory potential against α-amylase (lowest IC50) was in *F. inermis* (aqueous fraction, 196.0 ng/g) while the highest inhibitory potential against α-glucosidase was in *E. serratus* (EA fraction, 204.0 ng/g).

Conclusion: These results suggested that selected underutilized fruits have a good in vitro inhibitory potential against α-amylase and α-glucosidase.

Potential for Commercialization: Alpha amylase and alpha glucosidase inhibitors are capable of reducing the post prandial blood sugar elevation in diabetic patients. Therapeutic diets which contain these active ingredients is therefore an option for treatment

Keywords: *α-amylase, α-glucosidase, diabetes, inhibition, underutilized fruits*

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Design and development of a customized foot plantar pressure and temperature measurement system for diabetic patients

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Abstract

Background: The majority of diabetic foot complications leading to amputations begin with a formation of an ulcer at the foot plantar. Early detection and appropriate treatment of these ulcers can prevent up to 85 % of such amputations. The main focus of this work was to identify the pressure distribution and temperature variations of a foot plantar.

Methodology: To complete these objectives, two systems were designed and developed to measure foot plantar pressure and temperature. Pressure was measured using a textile based sensor which did not alter the pressure distribution. The temperature was measured using IR sensors which have a high response time compared to contact temperature sensors.

Results: Skin temperature distribution and pressure map of the foot plantar of both feet were recorded and analyzed. Several data sets were collected from volunteering non-diabetic controls and diabetic patients who had foot ulcers.

Conclusion: Ulcerations were observed in the foot plantar which had a greater local temperature of 20 ^{0}C compared to the same location of the other foot plantar of the same subject. Pressure distribution of the foot plantar can be clearly observed using the textile based sensor.

Potential for Commercialization: As an integrated device with foot plantar pressure and temperature does not exist in the world market the results can be utilized to develop such a device locally.

Keywords: *Diabetes, ulcer, foot plantar, temperature,pressure*

Protein carbonyl as a biomarker of oxidative stress for differentiating critical phase dengue infections from severe leptospirosis

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Abstract

Background: Both dengue and leptospirosis are endemic in Sri Lanka. During dengue epidemics, severe leptospirosis cases are often misdiagnosed as dengue which leads to inappropriate patient treatment/ management. We have identified serum protein carbonyl (PC) as a biomarker for severe leptospirosis. The aim here was to assess the potential of serum PC in differentiating critical phase dengue infections from severe leptospirosis.

Methodology: Clinically diagnosed leptospirosis patients were recruited from two hospitals in Colombo District, confirmed by microscopic agglutination test using paired serum samples and clinically categorized to define severe leptopspirosis (SL) based on WHO criteria. Patients with dengue were recruited during the critical phase of illness (DC), based on WHO guidelines. Age-gender matched healthy individuals were recruited as controls (HC). Serum PC and lipid hydroperoxide (LP) were measured in SL (n = 60 each) and DC (n = 30) patents and in HC (n = 30).

Results: Serum PC and LP levels were significantly higher in leptospirosis patients compared to DC patients ($p < 0.005$). High serum PC levels appear to differentiate SL from DC [area under curve (AUC) = 0.96; $p < 0.001$].

Conclusion: Use of serum PC as a biomarker in differentiating severe leptospirosis from dengue would provide the opportunity to save lives via prompt patient management.

Potential for Commercialization: Availability of specific laboratory diagnosis of dengue and leptospirosis will aid in prompt appropriate patient management.

Keywords: *Biomarker, dengue, Leptospirosis, oxidative stress, protein carbonyl*

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Potential non-structural protein1 (NS1) epitopes as diagnostic markers for type detection of dengue

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Abstract

Background: We screened the natural antibody responses of two bioinformatically predicted epitopes from the non-structural protein 1 (NS1) of dengue virus, to investigate their potential use to develop as a dengue type detection markers. The two epitopes EP1, and EP2 correspond to 72 - 86 and 102-112 amino acids of NS1 protein, respectively.

Methodology: Peptides that best represent the two epitope sequences from each DNEV serotype were subjected to enzyme linked immune sorbent assays (ELISAs) using sera obtained from dengue sero positive healthy volunteers from Sri Lanka (DENV1 n=13: DENV2 n=12: DENV3 n=10 and DENV4 n=12). The cut-off value for ELISA assays was set by taking the mean response of sera from 15 sero-negative healthy volunteers, plus three standard deviations.

Results: For both epitopes, the responses to the peptide sequence of a given serotype was highly positive only to the sera from the same serotype, indicating serotype specific antibody responses demonstrated by those epitopes. The calculated sensitivities and specificities of EP1 were 69 % and 91 % (for DENV1), 42 % and 94 % (for DENV2), 60 % and 97 % (for DENV3), and 58 % and 100 % (for DENV4), respectively. The sensitivities and specificities of EP2 were 69 % and 97 % (for DENV1), 58 % and 91 % (for DENV2), 70 % and 100 % (for DENV3), and 75 % and 94 % (for DENV4) respectively.

Conclusion: If the sensitivities of these two epitopes of NS1 with some serotypes could be improved, they appear promising in developing as type detection diagnostic markers for dengue viral infections.

Potential for Commercialization: B-cell epitopes of dengue virus proteins are good candidates as type detection dengue diagnostic markers.

Keywords: *Dengue NS1 protein, epitopes, serotypic diagnostic markers, ELISA*

Natural antibodies targeting the linear B-cell epitopes of dengue envelope protein

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Abstract

Background: The natural immune response against conserved linear B-cell epitopes of envelope (E) protein of dengue virus (DENV) was investigated for their potential use as a broadly active vaccine candidate. The study epitopes (twelve) were predicted by 3in-silico tools (BepiPred, Ellipro and SVMTriP), in a previous study from our group.

Methodology: Fifteen peptides (P1-P15) that best represent the selected epitopes (> 50% pan-serotype conservancy) were screened using the antibody responses in sera samples obtained from dengue sero-positive healthy volunteers from Sri Lanka (DENV1: n=12, DENV2: n=12, DENV3: n=12 and DENV4: n=12)by enzyme linked immune sorbent assay (ELISA). P1-P15 corresponds to 7-23, 30-46, 60-76, 72-88, 89-104, 110-126, 238-254, 279-295, 308-324, 370-386, 376-392, 393-409, 417-433, 423-439 and 458-474 aa respectively of DENV1 E protein. The cut-off value for ELISA= mean OD value of sera from 12 sero-negativesamples +3 standard deviations.

Results: Peptides, P4 (EP3/E), P5 (EP3/E), P12 (EP19/E), P13 (EP20/E) and P15 (EP23/E) showed high positive responses to sera obtained from all four serotypes. P4 includes the bc loop (73-79 aa) and P5 includes the fusion loop (89-104 aa), of Domain (D) II, important in viral fusion. P12 (EP19/E) is located on DIII and stem regions. Remaining two epitopes P13 and P15 are located on the C-terminus. The peptides P2, P3, P11 and P14 showed positive responses only with sera of three DENV serotypes. Two peptides, P9 and P10 were positive with DENV1 and 3 sera but negative with DENV2 and 4 sera. The antibody responses against the remaining four peptides P1, P6, P7 and P8, were negative for sera from all the four serotypes. The peptides P1 and P8 are located in DI and other two peptides, P6 and P7 are located in the DII.

Conclusion: The study shows five E protein epitopes (P4, P5, P12, P13 and P15) which have broad antibody responses against all the four dengue serotypes, indicating their potential use as a candidate for future vaccination strategies, upon verification of their neutralization potential.

Potential for Commercialization: Conserved linear B-cell epitopes with viral neutralization potential could be suitable candidates for broadly active vaccine development.

Keywords: *Bioinformatics, dengue, E protein, natural infections*

Microarray analysis in chronic kidney disease of unknown aetiology (CKDu) patients: personalizing diagnosis and treatment

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Abstract

Background: CKDu has a significant socioeconomic impact to Sri Lanka. However, current diagnosis and treatment is not specific to the disease. The purpose of this study was to analyze blood transcriptome patterns of CKDu patients in comparison to healthy individuals, and to identify significantly differentially expressed genes (DEGs) in relation to biological processes which will provide better understanding of the disease, earlier diagnosis and personalized treatment protocols.

Methodology: Total RNA was isolated from whole blood of CKDu patients at stages 1,2,3,4 and 5 from Girandurukotte, a CKDu endemic region and healthy individuals from Kandy, a CKDu non-endemic region. The pooled RNA (stage-wise) were amplified, reverse transcribed and hybridized to Illumina HumanHT-12 v4 Expression BeadChip arrays. Resulting gene expressions were compared to that of healthy individuals using *iPathwayGuide* analysis software (Advaita).

Results: A progressive change in biological processes was observed from Stage 2 to Stage 5 CKDu, with differential expression of primarily cellular metabolic processes in Stage 2 and Stage 3 CKDu, to primarily immune system responses in Stage 4 and Stage 5 CKDu. Of particular interest was biological processes related to current hypotheses of CKDu, with 142 DEGs in response to oxidative stress and 19 DEGs in response to cadmium ion in Stage 2 CKDu.

Conclusion: Analyzing whole transcriptome of CKDu patients provides detailed insight into biological processes involved, which could in turn lead to a more personalized approach to diagnosis and treatment of CKDu.

Potential for Commercialization: Personalized diagnosis and treatment potential for chronic kidney disease of unknown aetiology (CKDu).

Keywords: *DEGs, immune response, microarray, oxidativestress, RNA*

Isolation and characterization of novel anti-cancer compounds against human ovarian carcinoma from the medicinal herb *Flueggea leucopyrus* wild

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Background: *Fluggea leucopyrus* Wild. known as '*katupila*' in Sinhala, is a medicinal herb belonging to the family Euphorbiacea. It has been used in aryuvedic drug regimes to treat different diseases. Although anti-cancer effects of *F. leucopyrus* on different human cancers have been previously reported, no investigation has been done on human ovarian carcinoma. Therefore, the objective of this work was to investigate cytotoxicity of different extracts of *F. leucopyrus* and isolated compounds on human ovarian carcinoma.

Methodology: Aqueous and ethyl acetate extracts of the leaves were prepared using soxhlet extraction method and maceration followed by solvent-solvent partition method respectively. The cytotoxicity of the crude extracts and the isolated compounds from the ethyl acetate crude through column chromatography were tested for cytotoxicity by subjecting to the MTS cell proliferation assay and HTERT assay on human ovarian carcinoma.

Results: Concentration dependent inhibition of human ovarian cancer cell proliferation was observed for ethyl acetate crude and for two isolated compounds, the IC50 values were 36.35, 12.36 (compound-1), 48.53 µg/mL(compound-2) respectively in MTS assay. HTERT assay for ethyl acetate crude and isolated compounds indicated a depletion of HTERT content at all the concentrations of compound-2. Rapid depletion of HTERT content in human ovarian cancer cells was observed at 50-200 µg/mLof the compound-2. Two active compounds (compound-1 and 2) were characterized as Bergenin (known anti-oxidant) and its isomer at C-9 and C-14 respectively, using NMR and mass spectroscopic analysis.

Conclusion: This study showed that *F. leucopyrus* possesses high anti-cancer effects against human ovarian carcinoma and potent anti-cancer compounds present in the leaves are Bergenin and its diastereoisomer, a new anti-cancer compound identified in this study.

Potential for Commercialization: There is a potential for commercialization of *F. leucopyrus* as a crude drug for cancer after conducting necessary clinical trials.

Key words: *Anti-cancer compounds, Flueggea leucopyrus, HTERT activity, human ovarian carcinoma, MTS assay*

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