NeelaHaritha

නීලහරිත

நீலாஹரித்த

The Climate Change Magazine of Sri Lanka

Vol. III December 2020

Climate Change Secretariat
Ministry of Environment

NeelaHaritha

නීලහරිත

நீலாஹரித்த

The Climate Change Magazine of Sri Lanka

Vol.III December 2020

Ministry of Environment

Climate Change Secretariat

NeelaHaritha Climate Change Magazine of Sri Lanka

Published by: Climate Change Secretariat, Ministry of Environment

First Published: 2020, December, Vol III

ISSN: 2536-8591

Contact Details: Climate Change Secretariat
Ministry of Environment
416/1 C, Robert Gunawardena Mawatha, Battaramulla, Sri Lanka

Printed by: NEO Graphics (Pvt) Ltd.
44, Udahamulla Station Road, Gangodawila, Nugegoda, Sri Lanka

Printing funded by: Climate Mitigation Action Support Project, Ministry of Environment

Editorial

Climate change is accepted as part of the equation in development planning all over the world, except for the minority climate skeptics who denies the anthropocentric reasons for the phenomena. However, in spite of these skeptic views, Sri Lanka has begun to move in the right path with the rest of the world in integrating climate change considerations into development planning based on strong policy, strategy and action plans relating to climate change in line with its global commitments. The Climate Change Secretariat (CCS) of the Ministry of Environment is spearheading the climate action in Sri Lanka.

Overtime, the CCS has facilitated required technical studies, to assess vulnerabilities of different sectors to climate change, technology needs assessment for addressing climate change in selected sectors, covering both mitigation and adaptation aspects. Nationally Determined Commitments, made under the Paris Agreement on Climate Change, are being reviewed and upgraded at present. Furthermore, a number of projects have been facilitated through international financing mechanisms such as Global Environment Facility (GEF), Green Climate Fund (GCF) and Adaptation Fund (AF) making use of the principles and provisions of the United Nations Framework Convention on Climate Change (UNFCCC) which the Government of Sri Lanka became a party in 1994. Despite the strong government commitment on addressing climate change in its development planning, there is lack of awareness on climate change at various levels of the society. Therefore, the main objective of the 'NeelaHaritha' Climate Change Magazine of Sri Lanka is to raise awareness and educate people in the country on climate change, its implications, what has been done and what needs to be done to face the climate change.

This is the third volume of the Magazine. In this volume, there are many areas covered including identification of vulnerability hot spots to water and agriculture; resilience and adaptation, impacts of extreme weather events and other climatic stimuli on major economic sectors, potential ecological consequences of predicted climate change on marine and coastal ecosystems, some solutions to reduce the impact of climate change using Indigenous Knowledge, low carbon technologies and energy management in climate change mitigation, etc. This is an interdisciplinary magazine essentially focusing on issues of climate change, and we look forward to further contribution of the articles and knowledge sharing by the researchers in the respective fields for its continued success.

Editorial Board

Contents

Vulnerable hot spots to water and agricultural risk in Sri Lanka

Upali A. Amarasinghe*, Giriraj Amarnath and Niranga Alahacoon

International Water Management Institute (IWMI), Colombo, Sri Lanka

u.amarasinghe@cgiar.org

- A large number of river basins in Sri Lanka are vulnerable to water and agricultural risks.
- Higher exposure and sensitivity, and lower adaptive capacity to risks lead to high vulnerability.
- High-resolution maps are useful for spatially targeting interventions to reduce vulnerability.

Introduction

The Nationally Determined Contributions (NDCs) addressing the challenges of climate change in Sri Lanka (CCS, 2016a) have four components: adaptation, mitigation, assessment of losses and damages, and means of implementation. For adaptation, the National Adaptation Plan (NAP) identified food security (agriculture, livestock, and fisheries) and water resources as key sectors requiring immediate attention. The other sectors of interest in the NAP are coastal and marine; health; human settlements and infrastructure; ecosystems and biodiversity; tourism and recreation; export agriculture; and industry, energy, and transportation (CCS, 2016b). However, knowledge and information gaps on climate and other exogenous risks are significant barriers to the implementation of adaptation plans.

The Government of Sri Lanka is investing heavily in enhancing the resilience of the water and agriculture sectors, which are critical for ensuring food and water security.

Since 2014, the World Bank has funded projects to the value of over USD 800 million. Some of these projects are the Climate Resilience Multi-Phase Programmatic approach (USD 317, 2019-2024), Climate Smart Irrigated Agriculture (CSIA) Project (USD 140 million, 2019-2024), Agriculture Sector Modernization Project (USD 169 million, 2016-2021), and the Climate Resilience Improvement Project (CRIP) (USD 110 million, 2014-2020, with additional financing of USD 82 million in 2016). In recent years, many other development agencies, such as the Asian Development Bank (ADB) and Japan

International Corporation Agency (JICA), are funding projects for agriculture to the value of hundreds of millions of dollars.

Climate-smart water and agricultural interventions are the focus of these large investments. However, the vulnerability maps available at the provincial or district level (Eriyagama *et al.*, 2010) are too coarse for prioritizing and spatially targeting interventions. Amarasinghe (2010) showed substantial water scarcities and productivity differences in river basins. Therefore, the vulnerable hot spots combining water insecurity and socioeconomic and environmental factors at the river basin level are useful for implementing sustainable CSIA interventions.

This paper presents vulnerability hot spots to water and agricultural risk in Sri Lanka at the river basin level

Key concepts of vulnerability

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as a function of exposure, sensitivity, and adaptive capacity to risks (IPCC, 2001). This paper uses 41 indicators to assess exposure, sensitivity, and adaptive capacity for identifying the vulnerable hot spots (Annex, Table A1).

Exposure

Thirteen of the 41 indicators assess exposure to risks. Water insecurity is a significant exposure risk. The extent of water scarcity (expressed as surface runoff per person), and water development and depletion are three exposure indicators assessing water security risks (Amarasinghe, 2010). The depletion indicators include the ratios of withdrawals and consumptive water use to the total surface runoff. The other exposure indicators include the spatial and seasonal variability of climate and runoff and the exposure to floods and droughts (Amarnath *et al.*, 2017). The latter is recurrent with monsoonal rainfall patterns. Climate change will likely increase the magnitude of exposure to risks.

Sensitivity

Fourteen of the 41 indicators assess sensitivity to risks. The vagaries in weather, potentially likely to increase with climate change, will mainly affect the agricultural communities, and production in rain-fed areas and small tank irrigation systems. This paper considers the minor irrigated and rain-fed paddy area and cropping intensity, along with socioeconomic conditions, as sensitivity indicators.

Adaptive capacity

Fourteen of the 41 indicators assess the adaptation capacity to risks. The level of education, poverty, and access to infrastructure (housing, roads, markets, electricity, and communication) are major indicators assessing the adaptive capacity of people and communities.

The indicators in the three groups have different scales and directions to risks. For example, lower water security indicates higher exposure, while areas exposed to smaller floods and droughts indicate lower exposure risks. Higher population density means, and a higher agriculturally dependent population means higher sensitivity. The higher level of education suggests higher adaptive capacity, while poverty shows lower adaptive capacity. To address the differences in scale and directions, we standardize the indicators (X_{ij}) to bring them to a common, increasing scale of risk (0-100).

The standardized indicator (Y_{ij}) is

$$Y_{ij} = \begin{cases} \dfrac{X_{ij} - X_{imin}}{X_{imax} - X_{imin}} \times 100 & \textit{when higher values show higher vulnerability} \\[2ex] \dfrac{X_{imax} - X_{ij}}{X_{imax} - X_{imin}} \times 100 & \textit{when lower values show higher vulnerability} \end{cases}$$

Where: X_{ij}, X_{iMin}, and X_{iMax} are the actual, minimum, and maximum values of the i^{th} indicator over different spatial units (j).

This study uses an arithmetic average to estimate composite indicators for different categories of vulnerability. The arithmetic average of the three composite indicators shows the overall susceptibility to risks. A unit has a higher vulnerability to risk if it has higher exposure, higher sensitivity, and lower adaptive capacity. There are five categories of vulnerability: very high (above one standard deviation [SD] from the average); high (between the average and one SD above the average); moderate (between the average and one SD below the average); low (between one and two SDs below the average); and very low (two SDs below average).

Data

The analysis requires estimates of indicators at the river basin level. However, only surface runoff data are available at the river basin level. All other data are available at administrative division (districts [25] or divisional secretariat [325]) level (Annex, Table A1). When data are available at the administrative divisional level, indicators at river basin level are obtained by apportioning the values of numerator and denominators according to the area of intersection of the river basins and administrative divisions. Estimates at the river basin level are derived from the equation below:

$$V_{ij}^{\text{Riverbasin}} = \sum_{k=1}^{K} \frac{A_{ijk}}{A_{ij}\text{Riverbasin}} V_{ij}$$

Vulnerable hot spots

Sri Lanka has 103 river basins. However, many of the coastal river basins are very small to obtain accurate estimates using the methodology used in the paper. Therefore, the analysis considers several small contiguous coastal river basins as a single river basin. The study, thus, examines 38 river basins, which include 20 large river basins, covering 68% of the total drainage area, including the Jaffna peninsula. Figure 1 shows the vulnerability of hotspots.

Group 1: *Very high vulnerability*: This group has 27 small river basins. These river basins drain to the sea from the northeastern side of the country, including Mannar, Kilinochchi, Vavuniya, and Jaffna districts. The River basins draining to the sea from Mullaitivu and Killinochchi districts have very high exposure and sensitivity to water risks, and low adaptive capacity. The Jaffna district has high exposure, very high sensitivity, and moderate adaptive capacity to risks.

Rainfall and runoff in these basins are seasonal and low and have relatively higher water withdrawals for agriculture. However, rain is the source of water for much of the agricultural production in this group. Moreover, most of the districts in this group were the center of internal arms conflicts in the last few decades. Therefore, not only do these areas require interventions that reduce their exposure and sensitivity, but also measures to increase their adaptive capacity.

Group 2: *High vulnerability*: This group has 49 river basins. Some are relatively large river basins such as Manik Ganga, Kumbukkan Oya, Gal Oya, Maduru Oya, Yan Oya, Ma Oya, Aruvi Aru (Malwathu oya) and Kala Oya. Most areas are in the dry and intermediate zones of the country, cutting across Monaragala, Ampara, Batticaloa, Trincomalee, Anuradhapura, Puttalam, and Kurunegala districts.

This group primarily consists of the agriculturally dependent population, and rely on a seasonal water supply with only a little rainfall between February and September. Agriculture in large areas depends on rainfall and minor irrigation tanks. Thus, they have very high exposure to water risks. With relatively low development in other economic sectors, these districts also have low- to very-low adaptive capacity. In fact, the Monaragala district has one of the highest poverty. Moreover, access to infrastructure is also relatively limited.

Group 3: *Moderate vulnerability*: This group has 23 river basins. Except for the Mahaweli River, many river basins in this group are primarily in the wet and intermediate zones of the country. The Mahaweli River cuts across all agroecological zones: wet, dry and intermediate zones, and has substantial variation in water availability and use. While upstream parts receive much of the rainfall and generate surface runoff, a large part of the irrigation water is used in the downstream areas of the basins in the intermediate or dry zones. Thus, some areas of large River basins, such as Mahaweli, may be facing water insecurity. The identification of such deviations requires further analysis at the sub-basin level. However, in general, most of the river basins in this group have moderate exposure, sensitivity, and adaptive capacity to risks.

Groups 4 and 5: *Little or no vulnerability*: The six river basins in this group have little or no vulnerability to risk, with a few exceptions. For example, a few coastal river basins in the southeastern part of the country have very high sensitivity, but have low exposure and high adaptive capacity to risk. Thus, their overall vulnerability is low.

The grouping shows that 79 small to moderately large river basins are high vulnerable hot spots. These river basins cut across 12 districts. They include all districts in the northern, eastern, and northwestern provinces, the Monaragala district in the Uva Province, Anuradhapura in the Northwestern Province, and Hambantota in the Southern Province. Low water availability, high climate variability, agriculture dependent on rainfall or small tanks, inadequate human development, and poor access to infrastructure contribute to the vulnerability in these districts.

However, the vulnerability maps still have the coarse spatial resolution to capture some extremely vulnerable local hot spots (Figure 2). It does not capture the areas often affected by floods in the Kelani, Kalu, and Nilwala river basins during the rainy season, and does not take into account the drinking water supply issues in the coastal areas during the dry season. Salinity ingress affects domestic water supplies in many coastal regions during the dry season. Moreover, some locations in moderately vulnerable river basins, such as Deduru Oya, have drinking water supply issues in the dry season. Further analysis at the sub-basin (watershed) or Grama Niladhari (GN) divisional level can determine the extremely vulnerable localized flood or drought hot spots. For example, droughts can affect some GN divisions even in river basins with low vulnerability (Figure 2). Access to clean drinking water supply in the dry season is a critical issue is these locations. High-resolution maps can provide detailed information for targeted policy and investment to address these specific vulnerability issues.

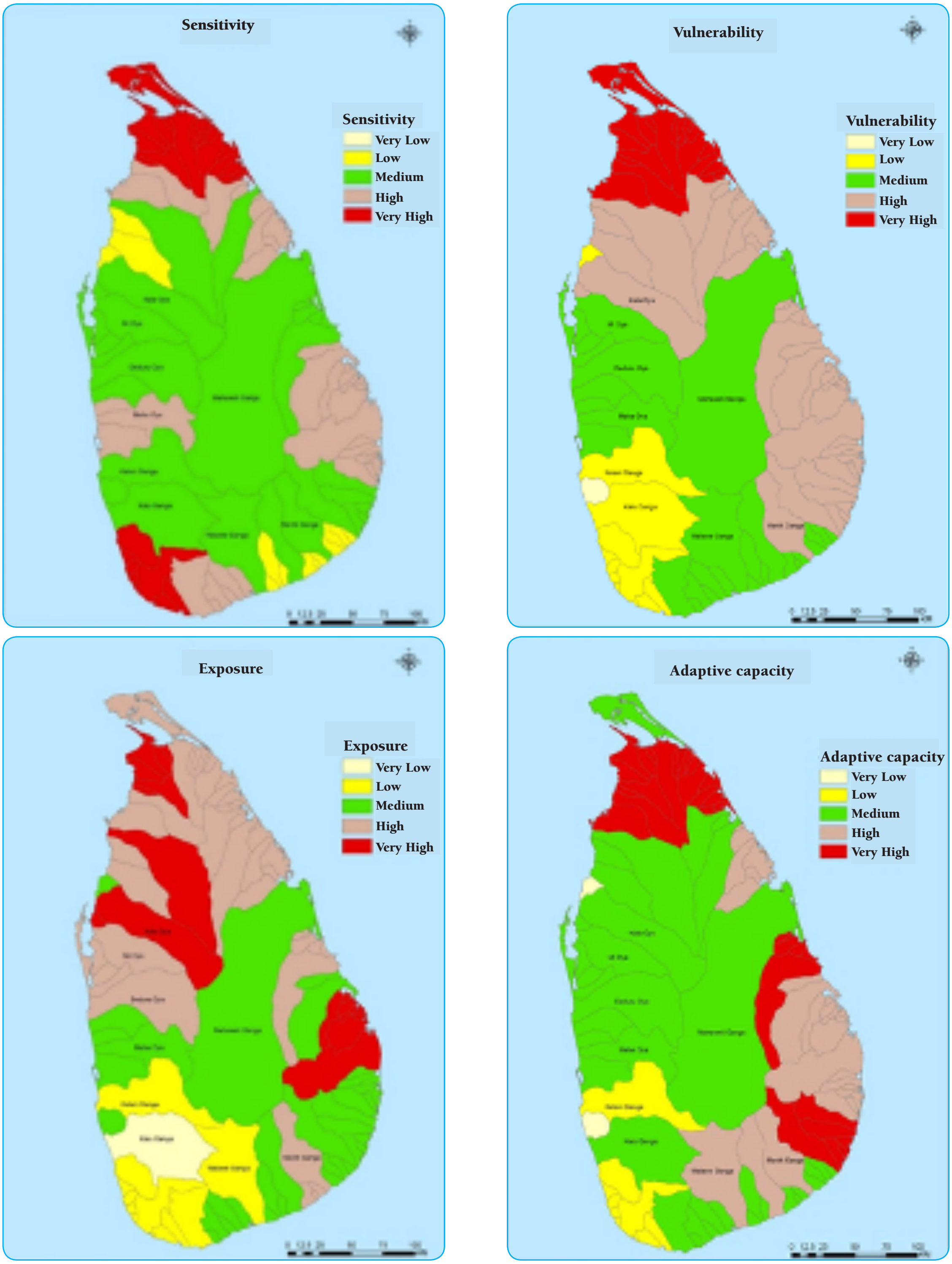


Figure 1. Exposure, sensitivity, adaptive capacity, and overall vulnerability of river basins to water and agricultural risks.

Source: Authors' estimation.

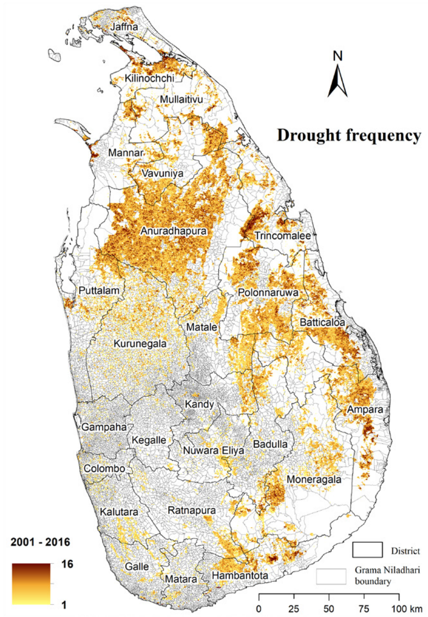


Figure 2. Frequency of droughts between 2001 and 2016.

Source: International Water Management Institute (IWMI)

Policy implications

The analysis in this paper shows that the hotspots require various investment, technical, and policy interventions for addressing vulnerability to water and agricultural risks. IWMI has conducted extensive discussions with farmers, policymakers, and development partners to identify various interventions to reduce water and agricultural risks (IWMI, 2017). These interventions, given below, range from national to local level interventions. The vulnerability hotspots however require a different bundle of interventions to enhance adaptive capacity and resilience.

Investments

- Develop open access, dynamic and interactive data, and information portal.
- Conduct a holistic tank and cascade/ reservoir development and rehabilitation.
- Improve on-farm soil health and water conservation and management practices.
- Improve rainfall (green) and irrigation (blue) water-use efficiency for productive purposes.
- Promote drought/flood-tolerant and short-duration crop varieties.
- Increase in water productivity.
- Develop infrastructure, including storage, roads, and regional makets.
- Assess and develop potential intraand inter-basin water transfers.

Technical interventions

- Develop reliable weather forecasting, monitoring, and early warning systems.
- Promote crop insurance.
- Develop a dedicated electronic media (TV/radio channel) for information dissemination.
- Pilot test climate-smart villages.

Policy interventions

- Reform farmers' organizations and water institutions.
- Maintain a consistent policy environment for modernization.

Further analysis of vulnerability hot spots for different sectors at a finer spatial resolution can provide information for selecting a bundle of spatially targeted climate-smart water and agriculture solutions. Such analyses are particularly important, given the increasing frequency of natural hazards and impacts. Moreover, this information better targets enormous investments made by the Government of Sri Lanka and international development agencies to address the challenges of climate change

References

Amarasinghe, U.A., (2010). Spatial variation of water supply and demand in Sri Lanka. In: Proceedings of the National Conference on Water, Food Security, and Climate Change in Sri Lanka, BMICH. Colombo, Sri Lanka, 9-11 June 2009, (eds.) Jinapala, K.; de Silva, S.; Aheeyar, M.M.M. Colombo, Sri Lanka: International Water Management Institute (IWMI). Pp. 19-33. Available at http://publications.iwmi.org/pdf/H042803.pdf (accessed on August 21, 2019).

Amarnath, G.; Alahacoon, N.; Smakhtin, V.; Aggarwal, P. (2017). Mapping multiple climate-related hazards in South Asia. Colombo, Sri Lanka: International Water Management Institute (IWMI). 41p. (IWMI Research Report 170). Available at http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub170/rr170.pdf (accessed on August 21, 2019).

CCS (Climate Change Secretariat), (2016a). Nationally Determined Contributions. Colombo, Sri Lanka: Climate Change Secretariat, Ministry of Mahaweli Development and Environment. Available at https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Sri%20Lanka%20First/NDCs%20of%20Sri%20Lanka.pdf (accessed on August 21, 2019).

CCS. (2016b). National Adaptation Plan for climate change impacts in Sri Lanka: 2016 to 2025. Colombo, Sri Lanka: Climate Change Secretariat, Ministry of Mahaweli Development and Environment. Available at https://www4.unfccc.int/sites/NAPC/Documents%20NAP/National%20Reports/National%20Adaptation%20Plan%20of%20Sri%20Lanka.pdf (accessed on August 21, 2019).

Eriyagama, N.; Smakhtin, V.; Chandrapala, L.; Fernando, K. (2010). Impacts of climate change on water resources and agriculture in Sri Lanka: A review and preliminary vulnerability mapping. Colombo, Sri Lanka: International Water Management Institute (IWMI). 51p. (IWMI Research Report 135). Available at http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB135/RR135.pdf (accessed on August 21, 2019).

IPCC (Intergovernmental Panel on Climate Change). (2001). Summary for policymakers. In: Climate change 2001: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, (eds.) McCarthy, J.; Canziani, O.; Leary, N.; Dokken, D.; White, K. Cambridge, UK: Cambridge University Press. Pp. 1-18. Available at https://www.ipcc.ch/site/assets/uploads/2018/03/wg2TARspm.pdf (accessed on August 21, 2019).

IWMI (International Water Management Institute). (2017). Assessment of risk in the agriculture and water sectors of Sri Lanka. Project report submitted to the World Bank.

Annex. Index for identifying the vulnerable hot spots.

Table A1. Indicators used for identifying vulnerability hot spots.

	Indicator (X_{ij})	Standardization(Y_{ij})	Mean[1]	Standard Deviation[1]	Remarks
	1. Exposure indicators				
i	Average annual runoff per person in 2015	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	67.4	26.9	Runoff estimates are available at river basin level
ii	75% dependable runoff per person in 2015	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	66.9	27.8	
iii	Withdrawals - % of average runoff	$(X_{ij}-X_{iMin})/(X_{iMax}-X_{iMin})$	25.7	24.0	Population estimates are available at divisional secretariat (DS) divisions
iv	Withdrawals - % of 75% dependable runoff	$(X_{ij}-X_{iMin})/(X_{iMax}-X_{iMin})$	22.4	22.8	
v	Consumption - % of 75% dependable runoff	$(X_{ij}-X_{iMin})/(X_{iMax}-X_{iMin})$	25.6	24.4	Water withdrawals and consumption data are available at the district level
vi	*Maha* season runoff - % of annual runoff	$(X_{ij}-X_{iMin})/(X_{iMax}-X_{iMin})$	53.4	33.3	
vii	*Maha* season rainfall - % of annual rainfall	$(X_{ij}-X_{iMin})/(X_{iMax}-X_{iMin})$	57.9	32.1	Rainfall estimates are available at district level
viii	Rainy days (>1 mm rain) in Maha season	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	46.0	21.4	
ix	Rainy days (>1 mm rain) in Yala season	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	71.8	27.2	Estimates of viii to xi are available at district level
x	Longest dry spell (<1 mm rainy days) in Maha season	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	40.7	21.2	Areas exposed to flood and drought are geographic information systems (GIS) estimates at DS/ river basin levels
xi	Longest dry spell (<1 mm rainy days) in Yala season	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	49.6	28.6	
xii	Flood-prone area - % of the total area	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	35.5	25.0	
xiii	Drought-prone area - % of total area	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	38.0	24.7	

Notes : Mean and Standard Deviation of river basins.

Indicator (X_{ij})		Standardization(Y_{ij})	Mean[1]	Standard Deviation[1]	Remarks
2. Sensitivity indicators					
i	Population density	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	8.8	16.8	Demographic estimates are available at GN/DS division levels from the Population census of 2011 Paddy area and cropping intensity estimates are available at the district level from the Department of Census and Statistics
ii	Household size	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	79.2	20.7	
iii	Rural population - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	49.9	20.4	
iv	Children (age <15 years) - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	42.2	29.6	
v	Old people (age >60 years) - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	47.0	20.3	
vi	Population with age <15 or >60 years - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	43.0	24.4	
vii	Widow/divorced - % of adult population	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	21.5	23.5	
viii	Migrants - % of the total population	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	23.3	29.7	
ix	Displaced/resettled - % of migrant population	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	36.0	24.3	
x	Employed population - % of the total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	65.8	24.3	
xi	Employed inagriculture - % of the employed population	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	29.8	29.7	
xii	Paddy area - % of total cultivated area	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	52.4	30.9	
xiii	Minor irrigated + rain-fed paddy area - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	59.3	27.3	
xiv	Cropping intensity	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	34.0	42.0	

Notes : Mean and Standard Deviation of river basins.

	Indicator (X_{ij})	Standardization(Y_{ij})	Mean$_1$	Standard Deviation[1]	Remarks
	3. Adaptive capacity indicators				
i	No schooling (< grade 5) population - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	44.3	25.3	Schooling data available at DS division level from the population census
ii	GCE (O/L) - College degree population - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	71.2	18.9	
iii	Poverty (headcount index) in 2015	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	38.6	26.2	Poverty data are available from household income and expenditure surveys at DS divisional level.
iv	Road density (class A&B roads)	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	75.0	22.4	
v	Road density (class C roads)	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	71.2	18.9	Road density is GIS estimates at DS divisional/river basin level
vi	Households with gas/ electricity for cooking - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	85.6	18.2	
vii	Households with lighting (gas/solar/electricity) - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	29.9	22.8	Access to infrastructure data are available from the population census
viii	Households with fixed-line communication - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	43.7	25.1	
ix	Households with mobile communication - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	55.0	23.3	
x	Households with safe sanitation - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	28.9	23.7	
xi	Households with safe water disposal - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	78.6	23.4	
xii	Households with zinc/ palmyra roof - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	23.9	23.2	
xiii	Households with mud walls - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	21.9	22.6	
xiv	Households with mud floors - % of total	$(X_{iMax}-X_{ij})/(X_{iMax}-X_{iMin})$	44.1	24.8	

Notes : Mean and Standard Deviation of river basins.

Adapting to climate change impacts through enhanced resilience in the Agriculture sector

Thilini de Alwis*, Frank Jayasinghe and R.A.Sunimal Chandrasiri.

Project on Addressing Climate Change Impacts on Marginalized Agricultural Communities Living in the Mahaweli River Basin of Sri Lanka

*thilini.dea@gmail.com

- The project on 'Addressing Climate Change Impacts on Marginalized Agricultural Communities Living in the Mahaweli River Basin of Sri Lanka' aims to improve resilient livelihoods and ensure food security of rural agriculture communities living in the upper and downstream of the Mahaweli river basin.

- These families depend on rainfall for their main livelihoods and due to climatic fluctuations, they experience flood conditions and prolonged droughts.

- The project has therefore strengthened their capacity to adapt to climate change, supported enhanced livelihoods and introduced various livelihood strategies to improve their resilience to absorb climate shocks.

Introduction

"Climate Change" is defined as a change of climate which is attributed directly or indirectly to human activity that alters the composition of global atmosphere and which is observed over a comparable time period (UNFCCC, 1992). This simply means that climate change causes changes in weather patterns and these adverse impacts result in storms, prolonged droughts, flash floods, rising sea levels, desertification, changing oceanic temperature and landslides *etc*.

Sri Lanka, owing to its geo-climatological position, is highly susceptible to such climatic fluctuations. The country's Second National Communication to the UNFCCC (2011) notes that "observable shifts in weather patterns, coupled with a continuous rise of ambient temperature across the country and increasing variability of rainfall, are projected to have large-scale effects on agricultural productivity, food and water security". In fact, nearly 25% of Sri Lanka's population who are employed in the agricultural sector (Department of Census and Statistics, 2018) are particularly vulnerable to the increasing food insecurity.

Sri Lanka has a rich history of irrigated agriculture where large reservoirs buffer the impact of rainfall variability. The Mahaweli Development Scheme is one of the largest irrigation schemes that support agricultural activities. However, large areas of the Mahaweli Basin remain untouched by the development benefits of the Development Scheme (Adaptation Fund, 2012). These are areas with rain-dependent small farms in remote villages, which are some of the poorest in the country without assured irrigation and exposed to natural hazards such as drought, floods and landslides. The International Water Management Institute conducted a study which attempts to identify the country's agricultural vulnerability hotspots through the development of a Vulnerability Index. "The maps indicate that typical farming districts such as Nuwara-Eliya, Ratnapura and Anuradhapura, Badulla, Matale and Polonnaruwa are more sensitive to climate change than the rest of the country due to existing soil erosion (up to 60 percent of the land area in Nuwara-Eliya district is affected) and their heavy reliance on primary agriculture" (Eriyagama *et. al.*, 2010).

1. Background to the Climate Change Adaptation Project

In the light of this context the project on 'Addressing Climate Change Impacts on Marginalized Agricultural Communities Living in the Mahaweli River Basin of Sri Lanka – Climate Change Adaptation Project (CCAP)' is implemented targeting vulnerable rain fed farming families living in upper and downstream of the Mahaweli irrigation system. The project is funded by the Adaptation Fund and is implemented by the World Food Programme (WFP). The total granted fund is USD 7.989 mn. The Project is executed by the Ministry of Mahaweli Development and Environment (MMDE) since 2014, and in 2017 the United Nations Development Programme (UNDP) joined the project as the second executing agency. The project is scheduled to end in February 2020. The Project targets rain-dependent farming families in two hazard-prone Divisional Secretariat Divisions (DSDs), being Medirigiriya and Lankapura in the Polonnaruwa District and Walapane in the Nuwara-Eliya District.

2. Project overview:

2.1 Overall Project Objective

The overall objective of this project is to build resilient community livelihoods and improve food security against climate change induced rainfall variability that leads to longer droughts and more intense rainfall. To directly address these climate-induced impacts, the project proposes to:

I. Develop household food security and build resilient livelihoods for rain-fed farming households

II. Build institutional capacity of village, local, regional administrative authorities to reduce risks associated with climate-induced rainfall variability

2.2 Targeted Beneficiaries

The beneficiaries for this project were selected through the minor Farmer Organizations (FO) registered under the Agrarian Services Centres, belonging to the Department of Agrarian Development (DAD) of the above DS divisions. The Project targets to reach a total of 183 farmer organizations and provides benefits for 14,039 beneficiaries' households in the project areas as elaborated in table1 below.

2.3 Implementation arrangements

The project implements its field activities through the intervention of government stakeholders with the coordination and supervision of Divisional Project Officers. Some of the main stakeholder organizations are the Divisional Secretariats, Department of Agrarian Development,Agriculture Department, Forest Department and Department of Animal Production and Health. These stakeholder

Table 1: The number of farmer organizations and beneficiary families covered by the project

District	DSD	Farmer Organisation	No. of beneficiary families
Pollonnaruwa	Medirigiriya	52	6898
	Lankapura	18	1696
Nuwara Eliya	Walapane	113	5445
		118	**14039**

organisations identify projects relating to climate change adaptation with the assistance of farmer organisations and forward the proposal to CCAP, with the consent of the Divisional Coordination Committee, to fulfil the funding requirements. The Project Management Unit reviews the proposal and, once it is approved, funds are disbursed directly to the stakeholder organisation to implement the project, after signing an agreement with them. The supervision and programme monitoring are carried out by CCAP officers with the collaboration of stakeholder organisations.

3. Project interventions and their implementation:

To achieve the overall objective, the project carries out various programmes to enhance the resilient livelihoods of the beneficiaries and introduces adaptive and alternative practices to mitigate climate impacts on households at the grass root level. In hand with these interventions, the project subsequently focused on strengthening the institutional capacity of service delivery entities and farmer organisations to increase their adaptability.

3.1 Home garden development

Beginning at the household level, the project focuses on developing diversified home garden- based Agro-Forestry systems to support household nutrition and to create additional incentives for farmer families. To promote this sub-programme, firstly seedlings such as African Mahogany (khaya), coconut, cashew and fruit plants were distributed to ensure resilient home garden diversity which is an indicator of the adaptive capacity of households to meet food, fodder, fuel and timber requirements. The project also introduced agro wells and rainwater harvesting tanks *etc*. to promote the efficient storage of water at household level during drought. Beneficiaries were also trained on organic home gardening to improve the marketability and productivity of home garden produce. Figure 1 demonstrates the number of home gardens developed with diverse interventions.

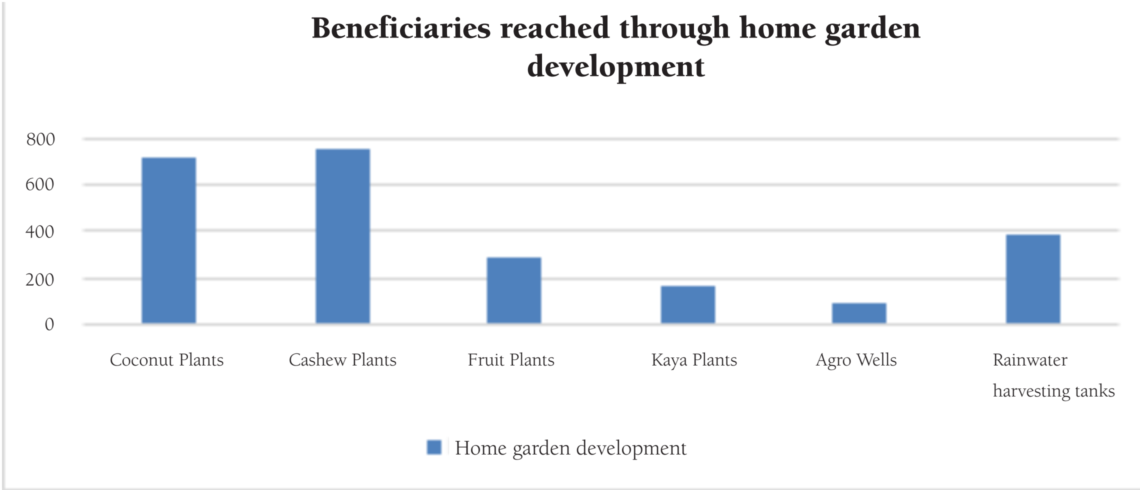


Figure 2: Number of beneficiaries introduced to home garden developments

3.2 Introduce drought tolerant crops and agronomic practices

Introducing drought tolerant crop varieties and agronomic practices is an important aspect to creating resilient livelihoods for farmers. Through this component, the project introduced farmers to cultivate drought tolerant crops which can survive with minimum soil moisture. The project also carried out soil and moisture conservation programmes such as establishing of contour drains, bunds, stone terraces, pitcher irrigation and micro irrigation systems.

A successful introduction through this project was cultivation in protected housing or polytunnels. The selected beneficiaries were provided with training and required materials to be able to begin cultivation under polytunnels. The advantage of cultivating in a polytunnel is the controlled climatic conditions, so that crops can be grown both during the drought and rainy seasons. This means that the polytunnel is used for cultivation throughout the year, thus increasing agricultural productivity by obtaining a premium price for products. The number of beneficiaries reached through this intervention is reported in table 2.

3.3 Improved post harvest technologies

While improving agriculture productivity, the project also promotes improved post-harvest technologies to protect the harvest from unpredictable rains, increase keeping quality and add value to the harvest to make it market ready so that farmers can generate a premium price for their produce. The Project provides required equipment and technology such as dehydrating machines, threshing machines and storage centers, ice cream and yoghurt processing machines and other processed food

Table 2: Progress of establishing micro irrigation systems and polytunnels

Activity	Walapane	Medirigiriya	Total
Micro irrigation systems	22	66	88
Polytunnel	55	-	55
Total	77	66	**143**

products to encourage this purpose. Figures 3 and 4 are examples of similar introductions.

3.4 Alternative income sources

Alternate livelihoods are important to enhance family income to supplement agricultural livelihood. During prolonged droughts, income that can be generated from farmlands is restricted. As a remedy to such situations, the project assists to create alternative income for farm families by introducing resilient off-farming income generation strategies such as animal husbandry, bee keeping, mushroom cultivation *etc*., as well as the produce from home gardens. The project assists in preparing these products for the market with food processing and packaging, as well as links the beneficiaries and their products to the local market chains. Figure 5 below maps out the project investment in introducing varied alternative sources of income. The Project also took a special interest in the women beneficiaries who are one of the most vulnerable groups affected by climate change. The project established community enterprises such as handicraft centres, handloom, textile, shoe manufacturing and garment factories, enabling the women to contribute to household income and ensuring a consistent income to households even in climate stress seasons.

Figure 3: Threshing machine (Walapane)

Figure 4: Cereal Processing Machine (Walapane)

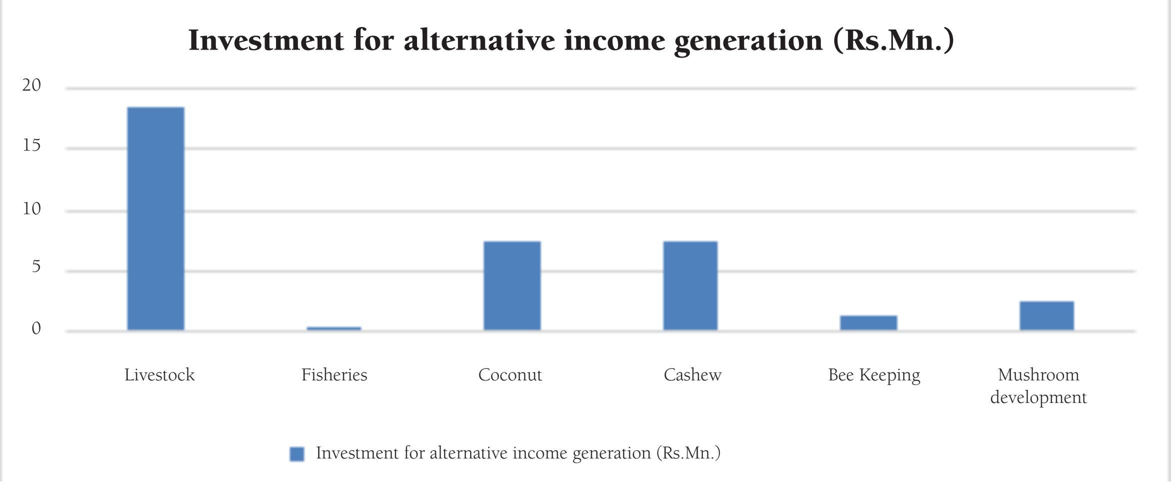


Figure 5: Project investment in introducing alternative income sources to beneficiaries

3.5 Development of Community assets

The development of community assets and livelihood resources such as minor tanks, irrigation canals and anicuts is a vital requirement for climate change affected communities since storage of available water is a major requirement to combat rainfall variability. Today, the small irrigation systems are plagued with a number of defects including abandonment, siltation, invasive species and disrepair of irrigation structures which leads to heavy water wastage. Therefore, building community assets leads to increased storage of rainwater, minimizes wastage of irrigation water and enables utilizing available water productively which in turn increases cropping intensity, during both seasons. As seen in figure 6, a number of minor village tanks in both DSDs required attention along with canals and anicuts.

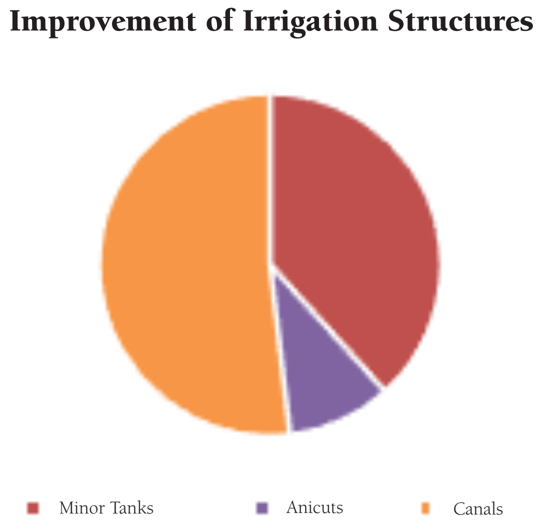


Figure 6: Number of irrigation facilities constructed and renovated by the project

3.6 Strengthening Farmer Organisations

When implementing adaptation strategies on ground level, the Farmer Organisations are the focal points as they are the key community based organizations in the village. Hence, the strengthening of farmer organizations with human capital, physical and financial capital is an important part of this programme to ensuring sustainability of climate adaptation process. Farmer Organizations receive awareness and training on climate risk identification and adaptation planning so that they are better equipped to face climate shocks. A total of 10,169 beneficiaries received training on adaptation strategies as indicated in table 3.

3.7 Capacity building for government officers

Climate change adaptation should be a sustainable process. It is still a novel experience for the village community and officials in service delivery organisations. Hence, the capacity building and mobilization of officers in the village, division and provincial level service delivery organisations are a paramount requirement of this programme in order to establish sustainable adaptive strategies among rain-fed farmers at village level and ensure the continuity of the resilient strategies to be introduced to the community.

Table 3: Details of capacity building programmes conducted

	Medirigiriya/ Lankapura Divisions	Walapane Divisions	Total
No. of training programmes	183	53	236
No. of Participants	7199	2970	10169
Cost (Rs. Mn.)	0.0428	0.81	0.8528

3.8 Catchment conservation

The watershed is an integral element that governs the climate condition of a particular zone. Management of the watershed enhances the climate change adaptation capacity and it ensures the safeguard of conditions necessary for agriculture such as soil and water which in turn would increase cropping intensity and extent cultivated. An Eco-restoration plan (Kattakaduwa) was developed focusing on 11 village tanks which are micro watersheds. It builds on a conservation system of planting trees along the tank bund between the tank and the cultivation areas. This ensures that the mineral salinity of the tank is absorbed by the growing trees so that the soil in the adjoining cultivation areas does not become saline over time which leads to cultivation lands to be abandoned due to the lack of productivity. These plans are implemented through the FOs cultivating around the relevant minor tanks, under the supervision of the Department of Agrarian Development. The FOs are solely responsible for the demarcation of Kattakaduwa area and maintenance of plants. Perennial plants and fruit plants were grown along the stream bunds, and also, the rural road networks were developed to ease the mobility within the catchment area. Soil and water conservation measures by adopting contour drains and bunds were also carried out. Table 4 demonstrates the scale of the catchment conservation programme.

3.9 Establishing early warning systems

As mentioned before, the visible climate change impact scenarios are droughts, flash floods and landslides in Sri Lanka. The identification of possible climate change impacts in advance leads to a minimization of loss and damage. Hence, the project has taken steps to establish climate early warning systems especially for landslides and floods with National Building Research Organization (NBRO). In total, 10 automated rain gauges and 20 manual rain gauges, 5 extension meters and moisture sensors have been installed in Walapane DSD and readings are being taken by National Building Research Organization to generate Early Warning (EW). Figures 7 and 8 show parts of the installed system. When rainfall exceeds 75mm, the NBRO office in Colombo is notified. Further, an alarm rings from the system ½ hour before a landslide occurs. Total investment for this initiative is 20 million rupees.

Table 4: Progress of activities for catchment conservation

Variety of trees	Number of trees planted	Investment (Rs. Mn.)
Mee	341	3.58
Kumbuk	341	
Karanda	341	
Khaya	161	1.54

4. Project results and outcomes:

4.1 Food security

As per the Baseline survey, the Food Consumption Score was 75.5% for Walapane DS and an average of 94.7% for Medirigiriya/Lankapura DS. A Household Dietary Diversity Score of 71.85 was recorded for Walapane DSD and 76.1% average for Medirigiriya/Lankapura DSD.

During the dry season, food availability is limited in markets. In response, the project has initiated several sub-projects to cultivate drought tolerant crop varieties and practices such as micro irrigation systems and establish agro wells in the targeted DSDs to cultivate both annual and perennial crops. Some of the annual drought tolerant crop varieties introduced is green grams, black grams, ground nuts, horse grams and soya beans, while the perennial drought tolerant crops are citrus, cashew, coconut, pomegranate and other fruit varieties. The project also introduced dehydrator machines and food preservation techniques via awareness programmes to improve post-harvest practices to reduce post-harvest losses and preserve excess production during off season.

To improve household nutrition levels, the project also took steps to stock fingerlings in village tanks. Through awareness programmes the community was taught the nutritional value of tank fish. 600 persons participated in the related awareness programmes. A total of 1.2 million fingerlings were released into 15 village tanks through this project.

4.2 Water access

Since these farming families live upstream of the major irrigation facilities, they are heavily dependent on the rain. According to the Baseline project reports (HARTI, 2017), the water supply systems in these areas are poor. The project rehabilitated minor tanks and canals which have had an impact on cropping intensity and

Figure 7: EW system being installed by NBRO

Figure 8: Automatic rain gauge installed in Walapane

Figure 9: Agrowell constructed through project funds installed in Medirgiriya

increased cultivation extent. Additionally, a majority of households in Medirigiriya and Lankapura (45%) obtained filtered water for cash for household purposes and travelled 0.5 – 1.5 km from their houses to purchase water. However, as places issuing filtered water are usually away from villages and due to the inability to afford filtered water most of the households use different types of wells. In Walapane, spring water was the most accessed source of water for all household purposes. 91% of households in Lankapura, 65% of households in Medirigiriya and 95% of households in Walapane had not practiced rainwater harvesting methods (HARTI, 2017). Only a total of 25 respondents in the baseline survey reported to use rainwater harvesting tanks due to lack of resources and awareness. Through this project therefore, a total of 330 rainwater harvesting tanks were distributed and 91 agro wells were constructed offering 421 families better access to water for cultivation and domestic purposes. Figure 9 is an example of the wells constructed through the project and as can be seen in figure 10 the rainwater harvesting tank is installed with collection pipes from the gutters of the house.

Figure 10: Rainwater harvesting *tank*

Figure 11: Cattle provided by the project

4.3 Alternative livelihoods

According to the Baseline surveys, loss of income from paddy due to floods in the last two years is averaged at 84,000 rupees in Medirigiriya and 103,000 rupees in Lankapura due to drought. Average loss of income due to floods in Walapane was 99,875 rupees. The targeted communities under these project interventions have been responding positively and reaping new benefits from improved livelihoods. About 350 women from the climate vulnerable families were selected to undergo a nationally recognized textile and apparel certificate training course conducted by the Sri Lanka Institute of Textile and Apparel (SLITA) of the Ministry of Industries and Commerce. Furthermore, a partnership was developed with National

Figure 12: Young poultry chicks provided by the project

Figure 13: Standard polytunnel built by the project

Enterprise Development Authority (NEDA) to develop four market driven, community managed and governed social enterprises, using aforementioned trained women. 200 women were selected from the villages and provided with training on handloom production with new designs with the Provincial Handloom and Textile Department of Central and North Central Provinces. This training is underway and 25% complete. NEDA will also provide the technical support for the development of the entrepreneur capacity of the women group to be market driven, self-managed social enterprise.

Income generating activities such as mushroom growing, bee keeping and floriculture were also encouraged under this project. Within this reporting year, crops such as Coconut and Cashew were introduced to households based on market demand for these produces and their resistance to floods and droughts, making these sustainable income generating strategies. Additionally, the animal husbandry programmes offered substantial income for 390 farmer families through dairy, goat and poultry farming, despite climate change effects on agriculture production. Figures 11 and 12 were taken during monitoring visits to beneficiairies in Medirigiriya whose livelihoods were enhanced through animal husbandry programmes. Under the polytunnel interventions, 55 farmers were given training in developing a cropping calendar to plan their cultivation. Under this programme, the farmer is able to grow produce even during the off season and obtain a premium price for his produce. They can also continue cultivation and receive continuous income throughout the year despite climatic fluctuations. Popular vegetables grown under these conditions are bell peppers, capsicums, tomatoes, lettuce, ice cabbage and strawberry *etc*. Figures 13 and 14 are the polytunnel and produce of a beneficiary in Walapane.

Figure 14: Mr. D.M. Ranbanda of Walapane with his crop of tomatoes

4.4 Increased cultivation extent

In the Medirigiriya and Lankapura DSDs, the farmers are struggling to overcome the dry weather conditions to earn a living and feed their families. As explained before, substantial intra-annual variations of rainfall severely constrain productive agriculture in Sri Lanka. Some quantity of irrigation is required to tide over water deficits in Maha season, while irrigation is a must for agriculture in Yala season. According to the project proposal, due to the lack of irrigation at the right time, in the right quantities, these farmers have low productivity and produce crops that do not have a high market value. During the Maha season, market prices fall and farmers earn barely enough to cover their cost of production. In order to build community resilience to climate variations therefore, the project rehabilitated 31 village tanks and 50 canals and anicuts which benefited 9415 families and reached 9294 acres of farm cultivation. Due to the successful rehabilitation of the tank, the farmers are now able to cultivate in both seasons. This increased harvest would result in higher disposal income for farm families making them more secure and resilient to climate change induced shocks. Figures 15 and 16 are examples of irrigation systems improved through the project.


Figure 15: Canal constructed by the project in Medirigiriya


Figure 16: Minor tank rehabilitated in Walapane

Conclusions and lessons learned

The project on "Addressing Climate Change Impacts on Marginalized Agricultural Communities Living in the Mahaweli River Basin of Sri Lanka" has enhanced the resilience in the agriculture community in these vulnerable DSDs by introducing several climate change adaptation strategies. The recommendations in the baseline studies for both DSDs highlight that the lack of labour in the agriculture sector is a growing concern for the country's economy. In order to attract the youth population into the sector, "agriculture should be a profitable business, and these project interventions have been introducing strategies to minimize the risk and uncertainty" (HARTI,2016). The project therefore, supported in improving the adaption and resilience in agriculture through rehabilitating irrigation systems, introducing new technology and equipment and providing efficient post-harvest technology. While doing so, the project simultaneously focused on improving resilience during climate stress periods by introducing alternative livelihoods. This ensures that the farming families have a continuous source of income throughout the year.

References

Adaptation Fund (2012) Sri Lanka: Addressing Climate Change Impacts on Marginalized Agricultural Communities Living in the Mahaweli River Basin of Sri Lanka (Fully developed project document) (WFP). Available at https://www.adaptation-fund.org/generic/proposal-for-sri-lanka/; accessed 17/05/2019.w

Department of Census and Statistics (2018) Quarterly Report of the Sri Lanka Labour Force Survey, Quarterly Report 2018 – Fourth Quarter. Available at http://www.statistics.gov.lk/samplesurvey/2018Q4report.pdf; accessed 08/05/2019.

Eriyagama, N., Smakhtin, V., Chandrapala, L., and Fernando, K. (2010) Impacts of climate change on water resources and agriculture in Sri Lanka: a review and preliminary vulnerability mapping. Colombo, Sri Lanka: International Water Management Institute. 51p. (IWMI Research Report 135). Available at http://www.iwmi.cgiar.org/publications/iwmi-research-reports/iwmi-research-report-135/; accessed 20/09/2019

Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI) (2016) The Baseline Survey Report of the Project on Addressing Climate Change Impacts on Marginalized Agricultural Communities Living in the Mahaweli River Basin: Medirigiriya Project Location.

Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI) (2016) The Baseline Survey Report of the Project on Addressing Climate Change Impacts on Marginalized Agricultural Communities Living in the Mahaweli River Basin: Walapane Project Location.

MoE (2011) Second National Communication on Climate Change submission to UNFCCC Secretariat. Ministry of Environment. Available at http://unfccc.int/resource/ccsites/zimbab/conven/text/art01.htm; accessed 22/05/2019

United Nations Framework Convention on Climate Change (1992) United Nations https://unfccc.int/resource/docs/convkp/conveng.pdf; accessed 22/05/2019

Spatial evaluation on the effects of extreme weather conditions on small holder tea cultivation in Galle

G.P.T.S. Hemakumara*, N. K. G. Harshani and Piyadasa Hewage

Department of Geography, University of Ruhuna

*shemakumara@hotmail.com

- Drastic changes in weather patterns have a great impact on agricultural activity and production
- Prolonged dry seasons followed by heavy rainfall have affected tea plantations adversely
- The impact of extreme weather conditions on the tea smallholdings in the Hawpe GN Division was observed
- The weather conditions have reduced the quality of tea in the South
- GIS information was used to map areas that were viable for tea plantation in the Hawpe area
- It is necessary to adopt new adaptation and mitigation methods in order to maintain high productivity of tea

Introduction

Changes in the regional climate are expected to include greater warming over land, with most warming at high northern latitudes, and least warming over the Southern Ocean and parts of the North Atlantic Ocean. Future changes in precipitation are expected to follow existing trends, with reduced precipitation over subtropical land areas, and increased precipitation at sub polar latitudes and some equatorial regions. Projections suggest a probable increase in the frequency and severity of some extreme weather events, such as heat waves.

About 18% of the daily precipitation extremes over land are attributable to the observed temperature increase since pre-industrial times, which in turn is primarily the result of human influence. For a 2° C increase in temperature, the fraction of precipitation extremes attributable to human influence rises by about 40%. Likewise, today about 75% of the daily temperature extremes over land are attributable to global warming. It is a rare and extreme event for which the greatest influence is anthropogenic, and that contribution increases nonlinearly with further warming.

There is evidence that some weather extremes have already shifted: cold nights have decreased globally, for example, while warm nights have increased (associated with heat waves). Droughts, intensity of storms, and heat waves have increased and will continue to do so. Most categories of extreme weather events, with the exception of cold waves, are predicted to continue increasing with global warming. In the business-as-usual (most pessimistic) IPCC projection scenario, the percentage of world land area that may experience extreme drought at any one time will increase from 1% today to 30% by 2100. Actual changes will depend on whether efforts to mitigate greenhouse gas emissions are successful and on the uncertainties involved in predicting Earth's behavior as a physical system. Although it may seem paradoxical, risk of extreme precipitation and flooding increases even as the risk of drought increases. Warmer air has greater water-holding capacity and so precipitation will occur in the form of more intense events with longer dry periods in between.

Lately, extreme weather has affected the agricultural sector in the world. Agriculture and other crop harvests have decreased due to changes in the rainfall pattern and temperature. Floods and droughts directly affect crops such as tea and paddy. Tea is the world's most popular beverage. Sri Lanka is a top tea exporting country, being the 4th largest tea exporter in the world.

According to the Central Bank reports, extreme weather has the effect of reducing Sri Lanka's tea production. Tea production declined marginally by 2 percent to 305 million kg in 2007. In 2009 tea production decreased by 9.1 percent to 290 million kg compared to 2008. The dry weather conditions experienced in all tea planting districts, especially in the first quarter of 2009, were largely responsible for the decline. Total tea production in 2011 dropped marginally by 0.8 per cent to 328.6 million kg compared to 2010. The decline in production was evident at all three elevations during the first two months when there was excessive rain, while the medium and high elevations were again affected in the third quarter, this time due to dry weather conditions. During the year, medium grown tea production had declined by 6.3 per cent to 52.6 million kg while the high grown production and low grown production grew only marginally; the high grown by 0.2 per cent to 79.3 million kg and the low grown by 0.3 per cent to 196.7 million kg, respectively. The smallholdings, bearing a cultivation extent of around 120,664 hectares of tea accounted for 69 per cent of the total tea production in 2011. In 2012, tea production declined marginally by 0.4 per cent to 326.3 million kg due to adverse weather conditions. Drought conditions that prevailed in all tea growing areas in the first half of the year in combination with the unusual cold weather conditions in the high growing areas towards the latter part of the year impacted tea production, which continued to decline in 2015 for the second consecutive year. Total tea production in 2015 declined by 2.7 per cent to 329 million kg from 338 million kg in 2014 due to supply side factors as well as in response to demand conditions. Tea production in 2016 witnessed a substantial decline due to both supply and demand factors. On the supply side, the prolonged drought in tea growing areas during early 2016, the changes in weather patterns with overcast conditions in mid-2016 and the severe drought condition experienced during the third quarter of 2016 had an adverse impact on the production of tea.

Literature Review

Extreme Weather in Sri Lanka

The annual rainfall for the year 2013 differed significantly from the average rainfall values over the previous 10 years. For example, Talawakelle, Kandy and Deniyaya areas received significantly higher annual rainfall (29%, 33% and 6% respectively), whereas in the Ratnapura and Galle areas rainfall had dropped by 4% and 9%

respectively (Abeysinghe, 2014). There is ample evidence to suggest that Sri Lanka's climate has changed noticeably. A series of annual mean temperature records from 1871 to 1990 show that a significant warming trend had occurred at most places in the country during the latter half of this period. The increase in temperature of Sri Lanka over the period from 1961 to 1990 averages 0.016° C per year. Sri Lanka's warming trend over the 100 years from 1896 to 1996 was 0.003° C per year. This warming trend can be observed throughout the country and could be due to the enhanced greenhouse effect and 'local heat island effect' caused by rapid urbanization and land use. No significant trend was noted in Sri Lanka's mean annual precipitation pattern during the last century although higher variability is evident (Karunaratne, 2015).

Being a small island in the Indian Ocean, the coastal regions of Sri Lanka are susceptible to changes in the sea level. The 2004 tsunami had indicated that the low-lying plains in the coastal zone will be vulnerable to any future rise in sea level. Important sectors of the economy such as tourism and fisheries could be affected due to the impact of sea level rise. A significant proportion of the population in the country is dependent on agriculture based livelihoods. Studies show that the food security of the nation can be adversely affected due to the impact of climate change (MMDE, 2015).

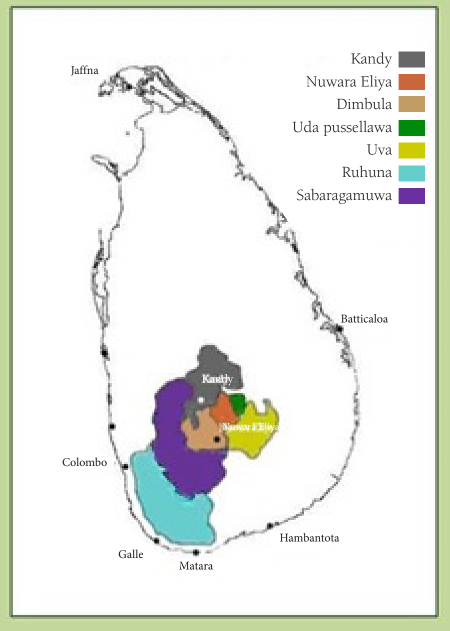
Extreme Weather and Tea Cultivation in Sri Lanka

Based on ecological parameters such as rainfall, soil type and topography, Sri Lanka is divided into three principal agro-climatic zones named as the wet zone, intermediate zone and dry zone (Panabokke, 1996). Sri Lanka is an island nation located at the Southern tip of the Indian peninsula, with an area of 65,610 sq. km. The country has a population of 20.5 million with a per capita GDP of US$ 4,102 (CBSL,2017). The majority of the population (70%) lives in rural areas where farming is widely practiced. Almost one-tenth of the population lives below the poverty line. The agricultural sector of Sri Lanka is dualistic in nature, comprising plantation and non-plantation agriculture. Plantation agriculture is export oriented and mainly involves the production of tea, rubber and coconut, while non-plantation agriculture is concerned with the production of staple food crops such as paddy, other cereals, pulses, yams, vegetables and fruits, mainly for domestic consumption. Spices are also an important agricultural product, consumed locally and exported.

Tea is grown as a rain fed plantation crop in Sri Lanka (Figure 1). Any changes in rainfall and temperature conditions directly affect tea production. The optimum temperature and rainfall for cultivation of tea are in the range of 18-22°C and 223-417 mm per month, respectively. Reduction of rainfall by 100 mm per month was found to lower the productivity by 30-80 kg of 'made' tea/ha/month (Wijeratne *et al.*, 2007). The decline in tea production due to the drought in 1992 was about 26% lower than in 1991 (Central Bank of Sri Lanka, 1992). Extreme events such as heavy rains can cause severe soil erosion, especially if the terrain of the tea plantation is sloping (Karunaratne, 2015). As a result of extreme weather conditions, tea smallholdings in the low country area were severely affected. The high temperature rise has caused much damage to the low country tea industry. Various afflictions of tea plants have also been aggravated by extreme weather conditions.

How to Use GIS to Evaluate Extreme Weather Affected Areas

The geographic information system (GIS) is a technological tool for easily comprehending geography and making intelligent decisions. GIS organizes geographic data in such a manner that a person reading a map can select the particular type of data relevant for a specific project or task. A thematic map has a table of contents that



From Sea Level		
High Grown Above	-	**4,000ft**
Nuwara Eliya	-	*Delicately Fragrant*
Uda pussellawa	-	*Exquisitely tangy*
Uva	-	*Exotically aromatic*
Dimbula	-	*Refreshingly mellow*
Medium Grown	-	**2,000 - 4,000ft**
Kandy	-	*Intensely Fullbodied*
Low Grown	-	**Below 2,00ft**
Sabaragamuwa	-	*Smooth & Fullbodied*
Ruhuna	-	*Distinctively Unique*

Figure 1: Agro-climatic tea growing regions of Sri Lanka,
(Source: Sri Lanka Tea Board, 2014)

allows the reader to add layers of information to a base map of real-world locations. GIS maps are interactive. On the computer screen, map users can glance a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map (Adiningsih, 2010).

A holistic approach is required to incorporate the regional scale analysis of relevant climate indices into the GIS map. In general, in climate or systems modeling, the value of geographic analysis and spatial visualization is well recognized as it enables users to improve on the interpretation of modeling outcomes across an area or region. This spatial analysis enhances the limited applicability of single site simulation. For these reasons, the use of geographic information system (GIS) software is widespread. However, use of such software is challenging and many potential users are not equipped to take full advantage of the comprehensive spatial and visualization analysis features provided. Such a GIS framework has the potential to provide an enhanced ability to assess the possible responses from a range of adaptation strategies to deal with climate change (Li Liu, de. *et al.*, 2011).

Problem Statement

Increase in the world's population has been accompanied by advances in agriculture, industry and transport, to meet the increasing needs of this larger population. This in turn has resulted in increasing greenhouse gas emission, which has now become a problem because it has led to extreme global weather conditions. At present, Sri Lanka has to face extreme weather conditions. Global climate change can cause weather changes in Sri Lanka by altering rainfall patterns, wind patterns, and indirectly, even soil stability. It so happens that when the weather changes drastically, it tends to affect the economy of Sri Lanka because the economy depends mainly on agriculture and export crops. Extreme weather is a problem because it results in reduction of income from agriculture and export crops.

The "tea crop" for example is highly sensitive to weather changes. Tea is an evergreen shrub, which if not trimmed can grow into a small tree. Imaduwa Divisional Secretariat is known as a tea growing area in Galle District in the low country wet zone. The reduction in tea leaf harvest has become a major issue and this has been caused by the increase in temperature and changes in the rainfall pattern. These changes also seem to affect the soil quality. Due to these problems the tea leaf production of smallholding tea estates has decreased and the quality of tea has also declined. Various problems have been caused by the weather changes in both large scale tea estates and small tea estates. Due to the mitigation and adaptation measures taken against these weather-related changes, it is now possible to produce high quality tea. The study intends to identify the tea growers in Hawpe Grama Niladhari Division area using GIS software to pinpoint all the issues related to extreme weather.

Research Problem

The main problem of this study is how to deal with extreme weather conditions affecting the smallholding tea estates in the Hawpe GN area and how they have adapted to meet the extreme weather conditions in order to mitigate these issues. Other problems are,

I. What is the distribution of temperature and rainfall in the area?

II. Where are the tea growing areas?

III. Which areas have extreme weather conditions?

IV. What are issues faced by tea owners as a consequence of extreme weather?

Research Objectives

The main objective of this study was to identify the effects of extreme weather conditions on tea cultivation. Accordingly, the following two sub-objectives were also considered in this study:

I. To identify the mitigation and adaptation measures adopted in the tea plantations to cope with extreme weather conditions.

II. To discover tea yield status in the study area using GIS.

Methodology

When conducting any detailed study, it is absolutely essential to have a clear methodology. The study method used for this research consists of three components, specifically data collection, data analysis and data presentation. Questionnaire survey is important and was used for collecting primary data. Sixty tea smallholders were selected from this area. Those selected as samples owned cultivated tea lands from 0.5 to 5 acres in extent. Land holders with less than 0.5 acres were not selected for this study. The five main themes of the questionnaire were as follows:

01. Family information

02. Information regarding economy

03. Climatic information

04. Adaptation method

05. Mitigation method

Identifying the effects of extreme weather on tea cultivation; Various methods were used to analyze the data. Both quantitative analysis and qualitative analysis were used in this study. Basic analysis was done using GIS software. The main purpose of this study was to determine the effects of extreme weather conditions on tea cultivation and for this purpose it was necessary to study the rainfall pattern and temperature changes first. The changes in temperature and rainfall did influence tea planting and variation in the soil quality too affected tea cultivation. The average temperature and rainfall values for the years from 2012 to 2017, and the changes in temperature and rainfall during the year 2017 also exerted influence on the tea yield. In this case, the effects of the extreme weather could be seen in two areas as physical effects and socioeconomic effects. The physical effects of extreme weather conditions could be identified as diseases and biological wastes from tea plants. The socioeconomic effects of extreme weather conditions could be measured by the drop in the yield of tea. This could be calculated by comparing the total tea yield of 60 tea growers when the weather is favorable and their total yield after experiencing extreme weather conditions. When the temperature and rainfall patterns are unfavorable there will be a reduction in the tea yield and tea quality to a certain extent.

By adopting the mitigation method and adaptation measures, the impact of extreme weather conditions on tea cultivation could be minimized. These adaptation and mitigation measures were tested at the Wilhena Tea Factory. Small-scale tea growers around this locality were able to observe the poor quality of their tea yield caused by the extreme weather conditions. It was also evident that the other reason for the unsatisfactory tea yield was the failure to follow prescribed procedures.

GIS analysis was performed based on the monthly tea yields of 60 selected tea growers using interviewed data which was collected in 2017. Tea lands were classified into 4 categories using GIS and according to annual tea yield. Based on the classification, suitable areas for tea cultivation could be identified. MS Excel was used for analyzing the quantitative data. Also, tables and charts were used for the analysis.

Analysis

Tea cultivation is done extensively in the village of Hawpe South in the Imaduwa Secretariat Division, and this was chosen as the study area. Large estates as well as small scale tea plantations can be seen here. Tea cultivation is carried out successfully in each of the tenant cultivations ranging from 0.5 to 5 acres. Therefore, for this survey, tea plantations from 0.5 to 5 acres were

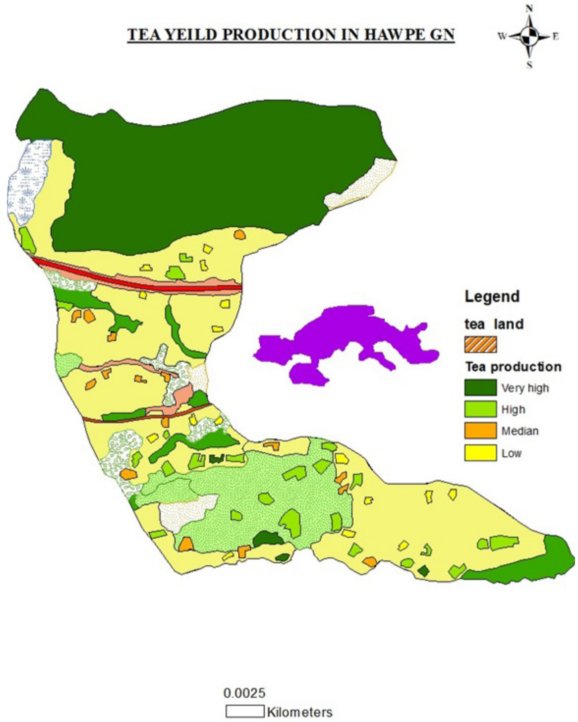


Figure 2; Identification of tea yield status in Study.

selected as the sample. The study notes that changes in the temperature and the rainfall pattern can also change the yield, the cost, *etc*. of the tea that is produced. Problems arising in the cultivation process can affect the tea yields, so the mitigation and adaptation procedures identified by tea growers are put into practice to minimize these issues.

GIS analysis was performed, based on the monthly tea yields of 60 selected tea growers' by conducting of interviews in 2017. Tea lands were classified into 4 categories using GIS and according to annual tea yield. Based on the classification, very high, high, moderate and low tea yield areas could be identified as in figure 2.

Physical Problems Caused by Extreme Weather

Changing rainfall pattern and temperature pattern can affect both the yield and quality of cultivated tea. Several types of physical problems

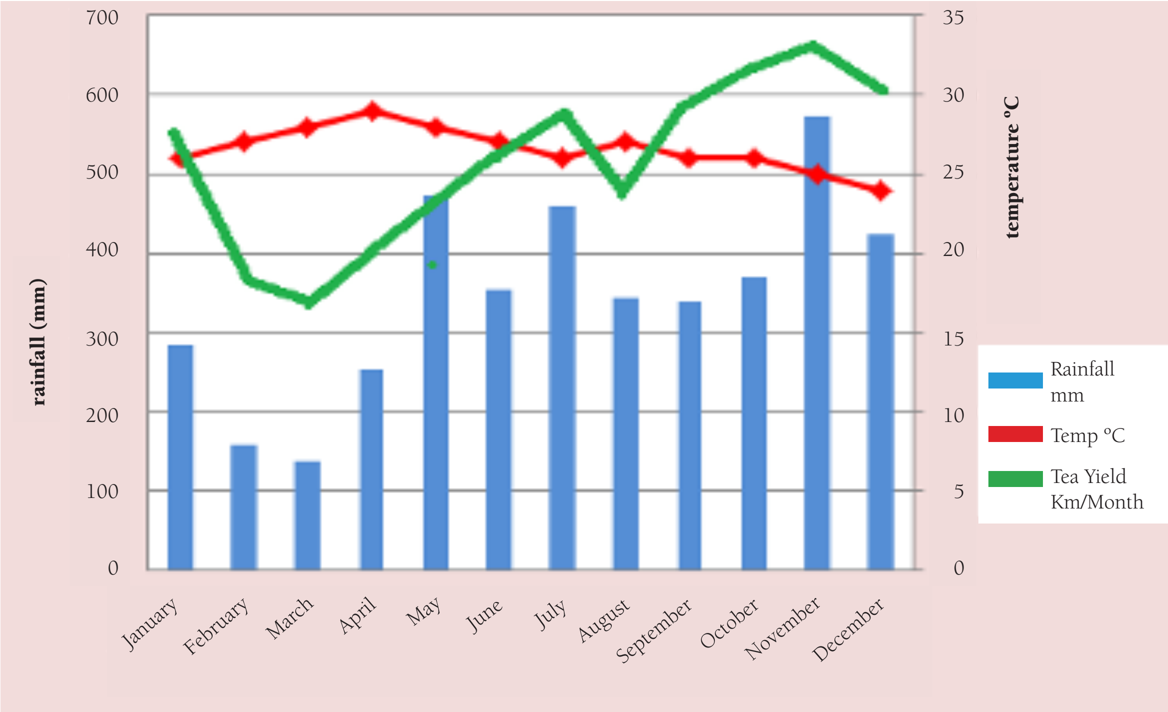


Figure 3: Rainfall, temperature and tea yield distribution of Study area in 2017
Source: Talawakelle Tea Estate PLC, Moragalla, Imaduwa and Field Observation

have occurred in this area due to extreme weather. Physical problems can be identified from the answers given in the questionnaire survey. Changes in temperature largely affect the new plantings. A considerable amount of upturned soil is exposed in a new tea plantation or on replanting. Therefore, excessive drying of the soil can occur due to extreme heat or during drought periods, and this can have a bad effect on the quantity and quality of the tea output. Tea Research Institute has clearly demonstrated that under these conditions the temperature of the tea leaves will increase by more than 5°C above what is deemed ideal. This can be very harmful to the tea tree, and the leaf will likely shrivel up. Gravelly soil may be affected if the ground heats up too much. The tea bush is usually in best shape when the weather is warm and wet. During prolonged dry and hot periods however, tea plants suffer heavy damage due to excessive drying of the soil and the increase in heat. In comparison with previous years, the temperature increased noticeably in 2016. Temperature rise directly affects the tea production. In this case, the amount of tea leaf that can be plucked is reduced. The quality of the tea is also low. Smallholders also face this problem. The temperature was high throughout 2016, and it was highest in April when it was nearly 30°C. It was also found that some tea fields in the study area have been abandoned after 2016. The average temperature in the study area in 2016 was 27.6°C in the shade, but the actual temperature of the exposed tea trees was higher by 5°C. That is, the temperature of the tea tree's foliage was about 32.6°C.

According to the chart in Figure 3, the month of November 2017 returned the highest harvest. According to the 2017 rainfall data, the highest rainfall was also recorded in November at 574mm with the temperature at around 25°C. This shows that the tea yield is high when the rainfall is high. This chart was prepared based on the harvest of 60 selected tea growers; it shows the rainfall data and the average yield of tea for each month for the year 2017.

According to this chart, the lowest yields were in February, March, April, May and August. When the relative temperature drops, the harvest is low and in the months with high rainfall the harvest is much higher. In 2017 the rainfall was high in May and November but there was a reduction in the total number of rainy days. There was a reduction in tea yield when there was a decrease in the number of rainy days.

Problems Encountered in Tea Cultivation due to Changes in Temperature and Rainfall

Changes in the rainfall and temperature have affected the tea yield. Ideal conditions are created for the spread of diseases by extreme weather. Increasing prevalence of biological diseases has the effect of reducing the tea yield and tea quality. The 60 tea growers surveyed in the study stated that there was a variety of diseases afflicting tea cultivation and that most of these were due to the extreme weather conditions. It was clear that this was a big problem for all tea growers in this area at present. The dying of tea bushes was a major problem and this was mainly as a result of high temperatures. As tea shrubs died, the tea lands would be diverted for cinnamon cultivation. The following series of pictures from figure 4 to 8 show the affected tea plants.

Tea Leaf Disease; Tea leaf disease often affects tea bushes and it is identified as a problem in this area. Prolonged high temperatures are bad for the tea leaf. Usually the tea leaf is green but rising temperature can turn the tea leaf yellow.

Diseases Caused by Pests; It has also been recognized that the tea-tree disease known as "blister blight" tends to spread very rapidly when there is a marked climate change. Additionally, the damage caused by termites to tea trees tends to increase at these times.

Figure 4: Dying tea bush
Source: Field observation, December 13.2017 (sample number 16)

Figure 5: Dying new tea plantbush
Source: Field observation, December 2017 (sample number 16)

Figure 6: Tea leaf disease
Source: Field observation, December 13, 2017 (sample number 19)

Figure 7: Termite damage
Source: Field observation, March 26, 2018 (sample number 01)

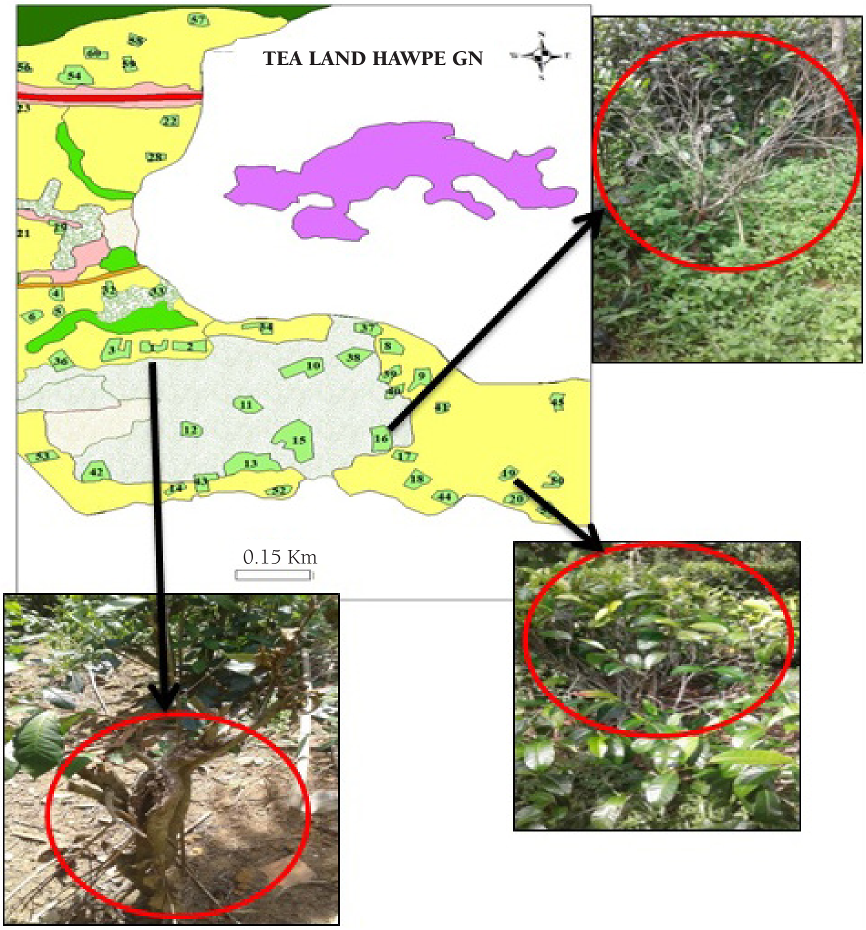


Figure 8: Effects of extreme weather on tea cultivation
Source: Field observation 2017, 2018

Conclusion

After mapping the region it was possible to select the most tea yields production areas using GIS. These areas were selected according to the harvests from tea cultivation. It was possible to clearly identify the southern part of the Hawpe Grama Niladhari division as producing higher tea yields. In the southern part of this area rubber cultivation and large-scale home gardens were rather widespread. Planting high trees in home gardens is also suitable for tea cultivation, because the tea shrub is a shade-loving plant. The following conclusions can be drawn from this study. Tea lands were being affected by weather conditions. The 60 selected tea growers who formed the sample of this study have also been affected by the rainfall and temperature weather conditions as shown in figure 3. Accordingly, the changing temperature really affected the tea plants, leading to a reduction in the quantity and quality of the tea leaf. Changes in the rainfall pattern also affected tea lands. It was observed that soil erosion has increased in this area.

With the rise of temperature beginning in 2016, many tea lands were abandoned the following year. Extreme weather mostly affected the smaller tea lands in the study area. The effect was most pronounced in the half (0.5) acre plots.

The abandoned tea cultivation lands were usually converted to grow other crops. Cinnamon cultivation was frequently carried out instead of tea cultivation on the lands as a result of increasing temperature. This is because when the available income from tea cultivation was reduced, the growers usually turned to other crops.

Total extent of tea cultivated land decreased due to various developments in the Hawpe Grama Niladhari Division. Many lands were expropriated due to the construction of an Expressway. At present, tea cultivation has also reduced due to several other construction activities. For example, people have now started building new homes on tea land.

Most of the tea land owners make poor use of the recommended clone. The use of a suitable tea variety for extreme weather conditions was also at a low level. The T2000 series 2025 type was most commonly used in the area. Few of them made use of the clones recommended for extreme weather. New varieties of tea with better weather resistance were not planted as often in smallholdings compared to the large tea estates.

References

Adiningsih, Erna Sri. (2010). The Applications of Satellite Remote Sensing on Climate Change and Food Security in Indonesia: Aerospace Analysis and Information Center.

Abeysinghe, S. B. (2014). Tea Research Institute of Sri Lanka. 228th Meeting of the Experiments and Extension Forum

Cavan, G., Butlin, T., Gill, S., Kingston, R., & Lindley, S. (2014). Web-GIS Tools for Climate Change Adaptation Planning in Cities. Handbool of Climate Change Adaptation. Springer Verlag, Berlin Heidelberg, Germany.

Central Bank of Sri Lanka (1992). Central Bank Annual Reports of Sri Lanka

Central Bank of Sri Lanka (2017). Central Bank Annual Reports of Sri Lanka

Elena. (March 18, 2018). Top 10 largest tea producing countries in the world: Trader magazine

Li Liu, D., Timbal, B., Mo, J., & Fairweather, H. (2011). A GIS-based climate change adaptation strategy tool. International Journal of Climate Change Strategies and Management.

Ministry of Mahaweli Development and Environment (2015), Sri Lanka National Adaptation Plan for Climate Change

Olufemi Adedeji, Okocha Reuben & Olufemi, Olatoye (2014). Global Climate Change: Journal of Geoscience and Environment Protection , 2 (02), 114.

Karunaratne, G., Nissanka, S., Punyawardena, B., & Gunawardena, A. (2015). Vulnerability of tea sector for climate change in the major tea growing regions in central hills of Sri Lanka. Journal of Environmental Professionals Sri Lanka, 4(1).

Panabokke, C. R. (1996). Soils and agro-ecological environments of Sri Lanka: NARESA.

Science Daily (2017). Extreme weather events linked to climate change impact on the jet stream. Pennsylvania State University

Wijeratne, M., Anandacoomaraswamy, A., Amarathunga, M., Ratnasiri, J., Basnayake, B., & Kalra, N. (2007). Assessment of impact of climate change on productivity of tea (*Camellia sinensis L.*) plantations in Sri Lanka. Journal of the National Science Foundation of Sri Lanka, 35(2).

Landslides: Linkages with climate change, land use practices and land cover changes

Thanura Madusanka[1]*, Nishan Sakalasooriya[2]

[1]Faculty of Graduate Studies, University of Kelaniya, Sri Lanka

[2]Department of Geography, University of Kelaniya, Sri Lanka

*ntmsilva123@gmail.com

- Landslides have become a crucial and calamitous disaster in the disaster profile of Sri Lanka.
- Heavy rainfall and inappropriate land use practices are considered as the two major physical and socio economic factors for triggering and occurrence of a landslide respectively.
- Additionally, the article explains this linkage with special concern to climate changes, land use practices and land cover changes by using contemporary studies

Introduction

Recently, global warming has become one of the most discussed topics all over the world. Among the impact of the climate change, hazards and disasters have become an ubiquitous situation (Banholzer *et al.*, 2013) for any geographic region and illustrating the worst painting of the catastrophic consequences of the extreme climatic changes on the natural and manmade environments.

In the local scenario, Sri Lanka is also challenged with dynamic rainfall and temperature changes (Silva, n.d.) When considering the variations of rainfall, contemporary studies revealed that Sri Lanka had depicted both increased and decreased rainfall patterns and seasonal rainfall patterns which had increased, especially in Southwest monsoon (SWM) and first and second inter monsoons (Karunathilaka *et al.*, 2017)

Disasters and hazards of Sri Lanka are recurring after weather incidents, and most of the hazards of Sri Lanka are water-borne due to either excessive rainfall (i.e. flood) or lack of wetness (i.e. drought). According to the Disaster Management Center, during 1974 – 2008, the pioneer disaster (considering the impact on people) was floods. Droughts and landslides also had some contribution and recent records show that the impact from landslides had also increased.

Land use and land cover (LULC) of Sri Lanka has considerable diversity in relation to the terrestrial size of the island. The changes of LULC are temporally as well as spatially due to both physical topographical physiognomies and anthropogenic activities. Elevation, landform, and slope are examples for physical characters whereas economic factors (i.e. price and demand) and social factors (i.e. poverty and labour availability) are the human factors for intervention of a particular LULC.

This short explanation focuses on climate changes, LULC changes and hazards to identify the linkages between these concepts in the present day environment concentrating on a case study of the highlands in Sri Lanka, and in this perspective has shown, the multiple impacts of climate change, which can be applicable to disaster management process as well.

Overview of biophysical and socio-economic background of Sri Lanka.

When looking at the topographical overview of Sri Lanka, there are three regions, namely coastal lowlands (CL - 30m -270m) uplands (UL - 270m-1060m) and highlands (HL-910m -2420m) (Gunatilake, 2016). Simultaneously, there are two major climatic regions based on the annual rainfall. And, the boundary of these regions are based on the annual rainfall level as isohyet 1905mm (Rathnaweera *et al*., 2012). The climatic year of Sri Lanka consists of four major seasons: First inter monsoon (FIM) season (March- April), South west monsoon season (SWM) – (May-September), Second inter monsoon season (SIM) (October – November) and North east monsoon season (NEM) (December – February). From the above seasons, usually the annual peak rainfall is denoted from SWM. The areas located in the central hill region have a peak rainfall, which is more than 3000mm (Climate of Sri Lanka, n.d.).

The economy of Sri Lanka represents three main sectors: Agriculture, Industry and Service. The major contributor to Gross Domestic Production (GDP) is the Service sector (57%) (Department of Census and Statistics, 2017), although the considerable amount of occupied headcount (27%) goes to the Agriculture sector (ibid) (Department of Census and Statistics, 2017). Sri Lankan agriculture sector mainly consists of Paddy agriculture, plantation agriculture (Tea, Rubber, and Coconut), vegetable and cash crops and minor export crops. These are spread in specified geographical regions of the island. Most of LULC changes happen in the agriculture environment and this study also focuses on agriculture base of LULCs.

Physical specialties and social behavior in the highlands

This explanation focuses on the UL and HL (hereafter ULHL) areas. The area has a unique complex of geomorphological characterishes such as plateaus, high plains, valleys, escarpments and slopes (Gunatilake, 2016). This complexity and difficult access had prevented human habitation during the times of ancient kings, and these lands were usually covered by natural vegetation. ULHL areas act as a platform to originate water springs, catchments and shade for first water drops of the river system of Sri Lanka.

After colonization, the area became a hotspot of plantation agriculture, and the most famous crop was Tea. The human habitation of ULHL areas spread paddy agriculture and mixed crops to these areas. The ancient agriculture system, the Kandian home gardens, had been conserving the fragility of this complex land. Nowadays, socio economic activities are increasing the population pressure of the area.

Causes of hazards and disasters in the highlands.

As mentioned above, the frequency of hazards and disasters have changed and their impacts are detrimental to the populace of the hill country. When we take the most common disasters in the wet zone, floods and landslides are caused by excessive rainfall in the hazard susceptible areas. The hazard incident becomes a disaster when considering the number of people affected and the damage caused.

The risk of flooding and landslides is already present in lowlands and highland sloped areas respectively.

Here the focus is on landslides of the highlands. It has become a prominent disaster after the heavy rainfall of wet zone and the occurrence of calamitous events in recent history. The major triggering factor for landslides is heavy rainfall (Polemio & Petrucci, 2000). Due to climate change the rainfall intensity would be increased (Rathnaweera *et al,* 2012) and it has a possible effect on landslide frequency (ibid). The relationship between landslides and rainfall intensity is strong (Ratnayake & Herath, 2005). The vulnerability to the hazard is increased due to population pressure, land use and economic issues. Increase of vulnerability causes the high probability of a disaster happening. Contemporary studies have identified several anthropocentric activities which are the root causes of disaster, and the LULC is one of the major causes including human induced effects of a disaster.

The authors have conducted a study on the anthropocentric influences of previous landslide occurred areas (Silva, T. M., & Sakalasooriya, N., 2018a) (Silva, T. M., & Sakalasooriya, N., 2018b) (Silva, T. M., & Sakalasooriya, N., 2018). It is understood that LULC changes have an impact on landslides.

Samasara mountain landslide – Siripuragama

This study is focused on the Aranayake, Siripuragama landslide that happened on 15th May, 2016 with the burial of 127 lives (Perera, *et al,* 2018) and properties. The landslide area is located in the Kegalle District of Sabaragamuwa province, Sri Lanka. The district is also one of the districts identified as prone to landslides (Bandara, 2013). The elevation varies from 50m to 1800m and covers all ULHL elevation breakdowns, which are mentioned above.

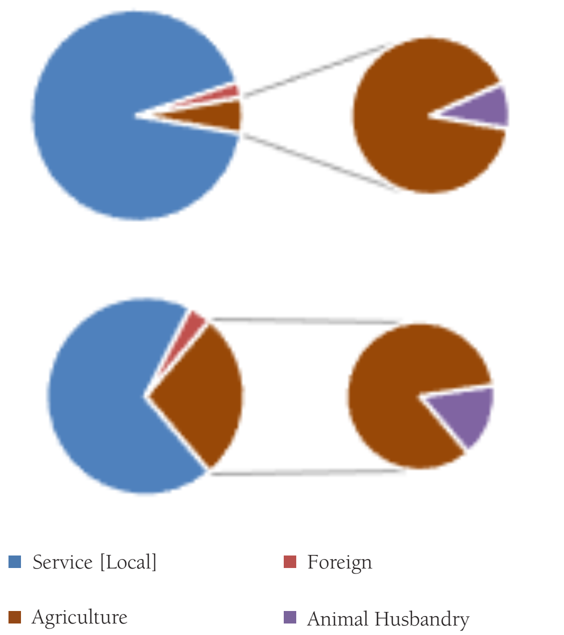


Figure 1 :Employment composition of Elangapitiya and Debathgama Pallebage (GNDS)
Source - Silva, T.M., & Sakalasooriya, N., 2018a

Samasara (or Ramasara) mountain and the landslide-prone area encompass a couple of Grama Niladhari Divisions (GNDs): Elangapitiya (EP) and Debathgama Pallebage (DP). Several houses were scattered in the mountainous area where the landslide occurred. This was a calamitous landslide in the history of landslides in Sri Lanka.

Livelihood status of the area

The explanation concentrates on socio economic activities of the selected area. In 2016, there were 1797 and 1504 people living in DP and EP respectively. According to the employment profile of the villagers, they were occupied in several types of employment. However, here it is categorized basically as land oriented and animal husbandry (Primary economic activities).

According to figure 01, agriculture and animal husbandry were prominent in both areas, but the majority goes to EP (Silva, T,M., & Sakalasooriya, N., 2018a). The field discussion with the villagers identified that most of the people had engaged in agriculture for the purpose of additional income, although they had another occupation. Here, the prominent agriculture activity is tea planting.

Land cover and Land use (LCLU) pattern of the area

Land cover is a physical view of a particular land due to either manmade or natural activities (Coffey, 2013). Land use consists of a series of land operations and anthropocentric involvement (Coffey, 2013). The study has been concerned about spatial and temporal changes of the land cover. The results regarding the temporal analysis show that there were significant land cover changes of the area within the past 60 years (Figure 2) (Silva, T.M., & Sakalasooriya, N., 2018a). Especially, the complexity of the land cover became increased. (Figure 2) Here, special concern was on three (3) characteristics in the spatial pattern of the land use: crop types, slope gradient and land processing.

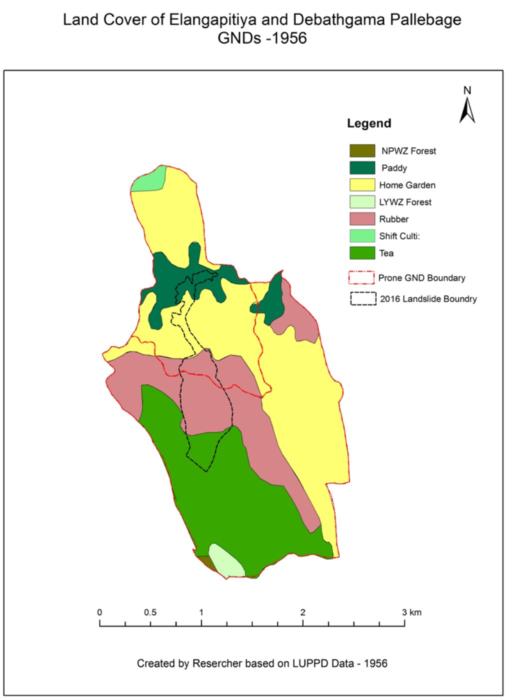
Concerning the crop type, Tea, Rubber and Home garden (HG) are dominant, and home gardens of the area consist of minor export crops such as pepper and cloves (Silva, T.M., & Sakalasooriya, N., 2018c) .The results due to complex LCLU changes are directed through elevation and slope gradient and land processing. Especially, the slope gradient of the area varies from 0% to more than 60% (ibid). According to the Land Use and Physically Planning Department (LUPPD), it should be natural vegetation on more than 60% gradient slopes. However, here it was identified that some manmade land cover (including Tea) were also available in the steep slopes, and two major manmade land cover (Tea and HG) have been quantified in. figure 03. The graph shows how temporal distribution of land cover existed on steep slopes (Silva, T.M., & Sakalasooriya, N., 2018b).

It is noted that there are issues about steep slope conservation due to high fluctuating manmade land cover on the steep slopes, which would have been covered by natural vegetation previously. Steep slopes are fragile and risky when their regular stability is disturbed. If an improper agriculture system or technological process is applied, that stability would be disturbed and the area would become risky. Less than 60% gradient slopes can be utilized for some agriculture activities, and areas with moderate slopes (17-60% slopes need proper conservation methods and more than 60% recommended forest and tree plants. (LUPPD, 2005) should be used with the application of relevant soil conservation methods. However, the field verification did not identify enough usage of proper land conservation methods. In this situation, slopes may become unstable with a risk of collapse.

Good condition of a land is an essential for proper agricultural practices. In general, the land processing is done to enhance the condition. However, sustainability of the land relies on the limitation of the land processes that should be applied. Land use analyses had found some extraordinary situations where the bed rock is exposed in the land (Figure 4). The field discussion identified this as a result of land over-processing.

The maps show the spatial and temporal expansion of the rock and it can be seen spreading through the steep slopes, with only a limited number of land conservation methods on the slope. In addition, the area is exposed to excessive land preparation, showing a very poor system of land management.

The landslide which occurred in 2016 has not been the only one, as there is also evidence from the history of paleo landslides (Perera, *et al*, 2018). Thus, we can say the area is physically prone to landslides.



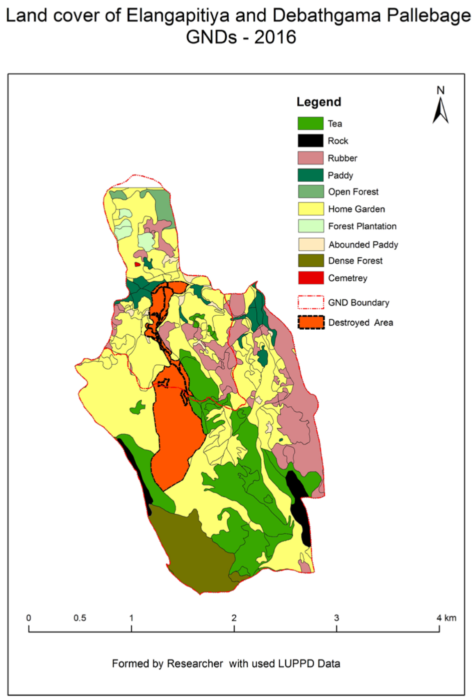


Figure 2 : Land cover of area in 1956 and 2016

Source - Silva, T.M., & Sakalasooriya, N., 2018a

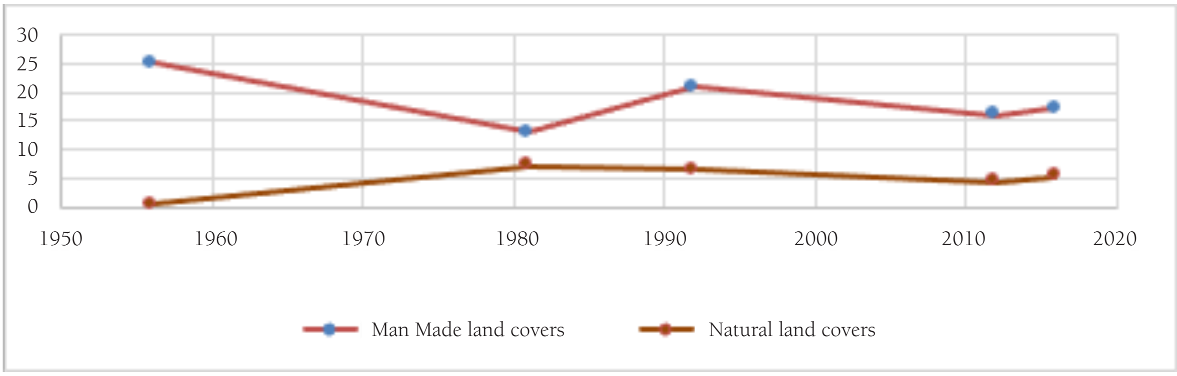


Figure 3 :Temporal extent changes of manmade land cover and natural land cover of steep slopes – (Hectare)

Source - Silva, T.M., & Sakalasooriya, N.,2018b

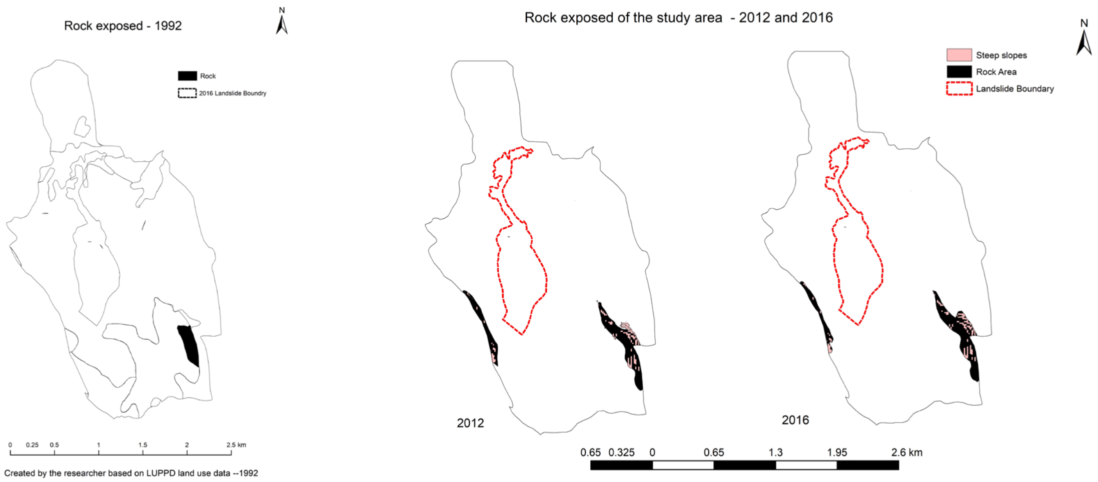


Figure 4 – Exposed Rock area (1992, 2012 and 2016)
Source - Silva, T.M., & Sakalasooriya, N.,2018c

Conclusion

Anthropocentric activities and mismanagement of land had made the area (hill country) prone to landslides under heavy rainfalls. Thus, the land stability had been minimized when facing extreme weather conditions. The case of Samasara mountain landslide shows that the landslide prone area has the danger of receiving excessive rainfall. It seems that the land use practices had united with the extreme climate changes to maximize the disaster. Therefore it is especially recommended to apply sustainable land use practices in this kind of fragile area ensuring the livelihood of the residents and the safety of property as climate changes are a continuous process and the application of sustainable practices would enhance resilience from the risk of disasters.

References

Bandara, R. M. S. (2013). Landslides in Sri Lanka. National Building Reserch Orgonisation, 1–45.

Banholzer, S.,James Kossin, and S. D. (2013). The Impact of Climate Change on Natural Disasters. In Reducing Disaster: Early Warning Systems for Climate Change (Vol. 9789401785, pp. v–viii). https://doi.org/10.1007/978-94-017-8598-3

Coffey, Ryan (2013) , The difference between "land use" and "land cover" , http://msue.anr.msu.edu/news/the_difference_between_land_use_and_land_cover

D. O. C. A. S.(2017). Economic Statistics of Sri Lanka 2017. Department of Census and Statistics.

Gunatilake, J. (2016). Geomorphology of the central hill country of Sri Lanka, (January 1995).

Karunathilaka, K. L. A. A., Dabare, H. K. V., & Nandalal, K. D. W. (2017). Changes in Rainfall in Sri Lanka during 1966 – 2015. Engineer: Journal of the Institution of Engineers, Sri Lanka, 50(2), 39. https://doi.org/10.4038/engineer.v50i2.7251

Land use Policy Planning Department (2005). Idam pariharana salasum margopadeshana sangrahaya (Land use planning guidelines) Colombo 05. Narahenpita.

Perera, E. N. C., Jayawardana, D. T., Jayasinghe, P., Bandara, R. M. S., & Alahakoon, N. (2018). Direct impacts of landslides on socio-economic systems: a case study from Aranayake, Sri Lanka. Geoenvironmental Disasters, 5(1). https://doi.org/10.1186/s40677-018-0104-6

Polemio, M., & Petrucci, O. (2000). Rainfall as a Landslide Triggering Factor : An Overview of Recent International Research. The 8th International Symposium on Landslides in Cardiff, UK, 3(June), 8 pages

Rathnaweera, T. D., Palihawadana, M. P., & Rangana, H. L. L. (2012). Effects of climate change on landslide frequencies in landslide prone districts in Sri Lanka ; Overview, 57–61.

Ratnayake, U., & Herath, S. (2005). Changing Rainfall and its Impact on Landslides in Sri Lanka, (March 2016). https://doi.org/10.1007/BF02973195

Silva, Ajith. (n.d.). Climate Change and Sri Lanka Location of Sri Lanka. https://unfccc.int/sites/default/files/nwp_integration_silva.pdf

Silva, T. M., & Sakalasooriya, N. (2018a). Changing Crop Pattern in Central Highlands of Sri Lanka ; Reasons and Consequences (A Case Study of Aranayaka Samasara Mountain area). In International Postgraduate Research Conference 2018– University of Kelaniya (p. 203). Faculty of Graduate Studies – University of Kelaniya.

Silva, T. M., & Sakalasooriya, N. (2018b). Impact of Land Cover Changes on Steep Slopes in Central Highlands for Accelerating the Landslides in Sri Lanka: An Experience from Aranayaka Landslide. ICSS 2018 Faculty of Social Sciences, (January).

Silva, T. M., & Sakalasooriya, N. (2018c). Land Cover Changes and Land Degrading of a Fragile Environment due to Disasters: Reasons and Consequences (Special reference to Samasara Mountain area of Aranayaka, Sri Lanka). International Journal of Science and Research (IJSR) Index Copernicus Value, Volume 7(Issue 9,September 2018), 1049–1057. https://doi.org/10.21275/ART20191195

Perception of people to Chronic Kidney Disease of unknown etiology (CKDu) as a societal hazard: A study in Padaviya Divisional Secretariat area in Anuradhapura District of Sri Lanka

L.M.A.P Gunawardhana
Department of Environmental Management, Rajarata University of Sri Lanka.
pradeeplmap85@gmail.com

- There is a spatial variation of the Chronic Kidney Disease of unknown etiology (CKDu) in Padaviya.
- Though there is no proven exact cause for CKDu, there are high-risk factors.
- Poor quality drinking water is the highest risk factor as perceived by people.
- Multi - disciplinary research is needed to mitigate the issues with CKDu.

Introduction

The health sector is a major area of focus in the National Adaptation Plan (NAP) to Climate Change. The adaptation plans could vary for different health issues. This paper assesses risk factors of the Chronic Kidney Disease of unknown etiology (CKDu), which is a major health hazard in the dry zone of Sri Lanka, where climate change could contribute to an increase in the risk.

Non-communicable diseases, which are rapidly increasing in both the developed and developing countries, contributed to about 58 million deaths which occurred in 2005. The Chronic Kidney Disease (CKD), which is one of the rapidly increasing non-communicable diseases, affects one in 10 adults or over 500 million people worldwide (Davids, 2014). The World Health Organization (WHO) has reported over 35 million CKD related deaths in 2005 (WHO, 2018). Within the Asian region, India, China, and Sri Lanka have high prevalence of CKD annually (Jayasinghe, 2011). Despite the increasing prevalence and fatalities, the exact causes of CKD remain unknown (International Society of Nephrology, 2017).

With huge expenses for treatment, the CKD is becoming a global public health problem. For example, over 30 million CKD patients in the USA, and over 37,000 in Japan report for kidney dialysis every year. The annual cost of dialysis and kidney transplantation alone range between US$35,000 and $100,000 per patient (International Society of Nephrology, 2017). The expenditure incurred for treatment of CKD is large due to late identification of the disease. Most CKD patients detect the disease when they require dialysis or kidney transplantation. Therefore, CKD is becoming a huge economic burden, especially for the low income countries (Davids, 2014).

The common risk factors for CKD are Diabetic Mellitus, Hypertension, Vascular diseases, Glomerular diseases, Tubulointerstitial diseases and Urinary tract obstruction (Gunatilake, *et al*., 2015; Mahon, 2006). All risk factors for CKD can be divided into three categories, as fixed, behavioral and biomedical. Fixed risk factors cannot be separated from birth such as family history and genetic, increasing age, previous kidney damage, low birth weight, and gender, *etc.* Behavioral factors are tobacco smoking, physical inactivity, and poor nutrition. Biomedical factors are diabetes, high blood pressure, cardiovascular disease, overweight and obesity (Jayasinghe, 2011). Most countries, including Sri Lanka, have formed their own institutions to address the CKD related issues.

In Sri Lanka, the first CKDu patient was reported in Padaviya area in the Anuradhapura district in the early 1990s. Most CKDu affected patients reported are in the North Central Province (NCP) of Sri Lanka, especially in the area of Dehiattakandiya, Girandurukotte, Kabithigollawa, Medawachchiya, Medirigiriya and Nikawewa (Gunatilake *et al*.,2015). After the first reporting of CKDu in the NCP, the disease was increasingly reported in other areas, especially in the dry zone of Sri Lanka. The NCP, the largest province of the country with 10,723 km ^{2} area or 16% of total land area, consists of two districts, Anuradhapura and Polonnaruwa. There are 29 Divisional Secretariat Divisions (DSD) in

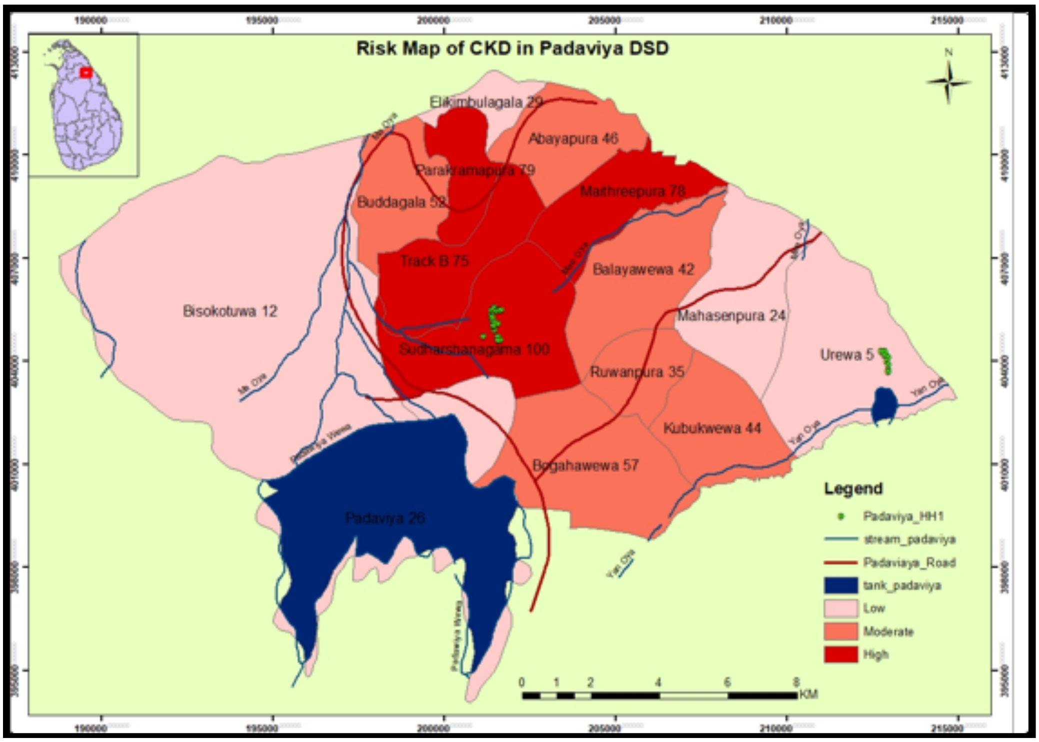


Figure 1: Risk map of CKD in Padaviya DS area
Source: Compiled by the researcher using IDW spatial analysis tool in GIS, 2019.

NCP i.e. 22 and 7 DSDs in Anuradhapura and Polonnaruwa districts respectively (Gunatilake *et al.*,2015). NCP had a population of 1,259,567 by 2011.

Objectives

The research in this paper has three objectives:

- Identify spatial distribution of CKDu and risk levels in Padaviya area in Sri Lanka,
- Analyze perception of the people in Padaviya area and by various scientists and institutions on the current risk factors, and
- Suggest potential solutions to mitigate the risk factors of CKDu in Padaviya having taken into consideration the perceptions of the CKDu victims of the area.

Methodology

The study used both primary and secondary data. Secondary data are from the DSD offices. Primary data are from a simple random sample of 57 households selected based on prevalence of CKDu from two Grama Niladari (GN) divisions, Sudharshanagama and Urewa in Padaviya DSD. Sudharshanagama is the GND with the highest CKDu prevalence, and Urewa has the lowest CKDu prevalence. Interviews of key persons provided the qualitative data. The analysis uses the mixed method and Geographic Information System (GIS).

Results and discussion

The analysis of spatial distribution of CKDu in Padaviya DSD area show clear difference between the GND divisions. Total of 704 CKDu patients

Table 01 : Total number of CKDu patients reported in Padaviya DSD by July 2018.

Name of GN Division	No. of Family	No. of Persons	No of CKDu_patients
Bisokotuwa	389	1168	12
Padaviya	583	2169	26
Sudharshanagama	652	2583	100
B Yaya	663	1989	75
Buddangala	502	1431	52
Parakramapura	623	2298	79
Elikibulagala	520	2212	29
Maithreepura	461	1468	78
Abhayapura	526	1728	46
Kubhukwewa	442	1749	44
Urewa	63	172	5
Mahasenpura	426	1328	24
Ruwanpura	379	1407	35
Bogahawewa	675	2695	57
Balayawewa	321	1041	42
Total	**7225**	**25438**	**704**

Source: Divisional Secretariat office, Padaviya-2018.

were identified by July 2018 in Padaviya DSD area, which has 15 GN divisions. Further, Table 1 shows the number of CKDu patients reported by GND level up to July 2018.

Based on the prevalence of CKDu, GNDs have been divided into three groups as high, moderate and low-risks areas. Four GN i.e. Sudharshanagama, Track B, Parakramapura, and Maithreepura belong to high-risk area, six GN divisions belong to moderate- risk and five GN divisions belong to a low-risk area. Figure 1 above shows that the spatial distribution of risk level and the total CKDu patients reported in each GN divisions by 2018 in Padaviya. Table 2 below shows people's perception about the risk factors of CKDu in Padaviya area with and without CKDu patients.The various risk factors of CKDu reported in the literature, include lack of clean drinking water, agrochemicals, consumption of alcohol, change of traditional food pattern, use of aluminum utensils for cooking instead of clay utensils, snake bites, living in environment with high temperature, etc.These seven factors were analyzed separately to assess people's perception of risks. Among the sampled farmers, 98% believe that CKDu is caused due to lack of clean drinking water. People's perception is that the surface and underground water have been contaminated due to natural and human activities. The major source of drinking water supply in Padayvia GN is the well. Most of these wells may not be safe for drinking water because of their locations near agricultural fields and also due to poor construction. Hence, most of these wells are likely to be contaminated with agrochemical residues. Padaviya area has frequent droughts, and as a result, the water level of the wells goes down by more than 50 feet. During the drought period, quality and the quantity of drinking water supply is reduced rapidly in this area. Therefore, people in Padaviya area use drinking water after purifying the water using water filters with Reverse Osmosis (RO) technology as a solution. Purified water is costly, and people spend more than 2000 rupees per month for a family. High cost is a major constraint for access to clean/purified drinking water.

Within the sampled households, 79% of people believe that the use of the high amount of agrochemicals is a major cause of CKDu. More than 61% percent of people practice agriculture as their livelihood. As a result, most farmers have frequent exposure to agrochemicals due to the usage of unsafe methods.

Table 02: Perception of people about some risk factors for CKDu in Padaviya

Risk Factors	Household with patients			Household without patients			Total
	Agree	Disagree	Moderate	Agree	Disagree	Moderate	
Lack of clean drinking water	21	0	0	35	01	0	57
Excessive use of agrochemicals	15	02	04	30	03	03	57
High consumption of alcohol	05	14	02	11	16	09	57
Change of traditional food pattern	09	06	06	17	06	13	57
Use of aluminum utensils for cooking	06	09	06	13	04	19	57
Snake bite	07	12	02	03	23	10	57
Living environment with high temperature	05	10	06	08	18	10	57

Source: Field survey data conducted by the researcher in 2018

Another perceived risk factor for CKDu is the change in food consumption patterns. Within the sample, 45% believe that change of the traditional food pattern is a cause for CKDu. Although Padaviya is in a rural area, the food pattern has been changing as in the urban areas. According to the older population, some traditional healthy food such as Kurakkan, Manioc, Tamarind, certain kinds of leaves, *etc.* are not frequently used in the present day food consumption patterns.

Among the sampled households, 33% believe that the use of aluminum utensils for cooking, 28% believe alcohol use and 22% believe living environment with high temperature are major reasons. Another 17.5% think that snake bite is a cause for CKDu.

Survey shows that the people's perception of some risk factors is similar to those presented by various researchers, but the level of belief are different. The perception of the survey shows that lack of clean drinking water, agrochemicals, and food pattern change are the highest risk factors. However, CKDu can be identified as a social hazard, because within the 57 samples, 21 CKDu patients were found and most of them were in the last stage of the disease. The male population between 35 to 65 years old is most vulnerable to CKDu in Padaviya area. Their major livelihood is agriculture and they belong to the lower income category. A considerable number of new CKDu patients are reported annually. Survey results show that a CKDu patient spends 10,000 rupees per month on average for treatment, while the Government provides 5,000 rupees per month as subsidiary per person. Therefore, due to low income, more than 90% of CKDu patients request a grant of at least 10,000 rupees per month per patient from the government.

Conclusions

It is evident that CKDu is a major social hazard in Padaviya area. However, the reason for CKDu remains as an unknown etiology, although there are several high-risk factors. Therefore, while conducting research for identifying the exact cause for the disease, it is time to take action to avoid identified risk factors. For example, most researches as well as the people in the area, point out that the poor quality of the drinking water is the major reason for CKDu in Padaviya and other areas in the dry zone of Sri Lanka. Although the magnitude is unknown, the quality and quantity of groundwater available for drinking are likely to change with climate change. However, there is no proper program to provide clean drinking water for the people to mitigate the risks. The solution of purified water, using filters or purchase from traders, is costly. The high cost is a burden for the poor people living in this area. Hence, the Government should be directly involved in solving this issue.

Reduction of excessive use of agrochemicals and introduction of organic manure for agriculture could mitigate the risks. But, there are no promotional programs to increase organic fertilizer use to mitigate risks. Both structural and non-structural measures should be taken to mitigate this problem. Often, the responsible officials pay their attention only after the identification of CKDu patients. There is no program for early identification of patients through regular health check-ups at village level. It is essential to conduct awareness programs for early identification and monitoring of CKDu patients at village level. Awareness programs, especially in high risk areas of the CKDu, regarding the ways of reducing risk factors, such as avoiding alcohol, consuming more traditional food varieties *etc.*could also mitigate the risks. All parties i.e.people, responsible institutions and researchers in various fields should get together to find a sustainable solution for this problem.

References

Davids, M.R. (2014) "The global epidemic of chronic kidney disease." Chronic Kidney Disease 1-7 https://www.researchgate.net/publication/233795634.

Gunatilake, S.,Samaratunga,S.,Rubasinghe,R. (2015) "Chronic Kidney Disease (CKD)in Sri Lanka- Current Research Evidence Justification: A Review ." Sabaragamuwa University Journal 13-31.

International Society of Nephrology (2017) Global Kidney health 2017 and beyond : a roadmap for closing gaps in care, research, and policy . Canada : www.thelancet.com Published online April 20, 2017 http://dx.doi.org/10.1016/S0140-6736(17)30788-2.

Jayasinghe, Y.K.R.T. (2011) Chronic Kideny Disease : Risk Factor identification . Peradeniya 1-33: IWMI, Faculty of Agriculture,.

Mahon, A. (2006) Epidemiology and classification of Chronic Kideny Disease and Managment of Diabetic Nephropathy. Presidnet, Europian Dialysis and Transplant Nurses Association .

World Health Organization . (2018) World Health Statistics . Annual Report , Luxembourg: World Health Organiazation.

Enhancing the capacity of the road sector in Sri Lanka to withstand climate change risks

A.K.Jayatilake and U.M.Abeysinghe*
EML Consultants (Pvt) Ltd.
*udya.abeysinghe@gmail.com

- Natural hazards, including floods, extreme rainfall, minimum and maximum temperatures, consecutive dry days and droughts, earth slips and landslides, fog and smog expose road infrastructure and transport.
- Zonation of the country based on vulnerability to disasters helps road sustenance and transport.
- A road disaster risk index based on vulnerability can classify road sections and Divisional Secretariat areas to prioritize maintenance, and enhance resilience against disasters.

Importance of roads

Roads are vitally important for the connection of people, goods and services. Roads facilitate easier access to employment, social, health, educational, and many other services, and hence are essential for economic and social development and poverty reduction. Therefore, road infrastructure, such as bridges, culverts, road-side drainages, retaining walls, traffic light system, and control poles, is one of most important public assets. Road transportation has two sub-functions, namely, mobility and accessibility. In times of disasters, roads provide a vital link to emergency services, essential transport of personnel and goods, rescue and relief operations, as evacuation routes. They are critically important to mitigate secondary impacts of the disaster, like rescue missions, safety and aid supply for the impacted people. Therefore, the risk assessment of the road sector due to natural disasters is vital.

In Sri Lanka, the transportation sector is one of the major contributors of greenhouse gas. This includes not only road transportation but also railways, air and sea transportation. However, road transportation plays a dominant role in the arena. The road transport accounts for 93 percent of passenger travel and 98 percent of freight transport as stated by Kumarage, 2010. Therefore, improvement of road transportation is essential and critical for the continued development of the country.

Road sector of Sri Lanka

The road network in Sri Lanka, other than expressways, is broadly classified into national, provincial, and local roads, according to their functionality and management. While the national roads, classified as A and B class roads, are managed by the Central Government, through the Road Development Authority (RDA), the provincial roads, classified as C and D class roads, are managed by respective Provincial Councils (Table 1).

Currently, the RDA manages Expressways (169 km) and A and B roads (12,210 km) while the nine PRDAs have about 300,000km under them (Figure 1). All these roads are important for the operation and functioning of the day to day life and the overall economy of the country. They also act as the arteries that provide supply material and services to peripheral areas at all times since the railway has limited reach to rural locations.The jurisdiction of 12,340 km of roads is under the Road Development Authority. (Table 1). Within the road sector, buses dominate the passenger transport section (University of Moratuwa, 2011).

Table 1 : National Highway in Sri Lanka (Class "A", "B", & "E" Roads)

Road Class		**Road Length (km)**
Class "A" Roads		4,217.42 km
Class "AA" Roads		3,720.31 km
Class "AB" Roads		466.92 km
Class "AC" Roads		30.19 km
Class "B" Roads		7992.94 km
Total of "A" & "B" Class Roads in Sri Lanka		12,210.36 km
Class "E" Roads (Expressways)		169.13 km
Grand Total of National Highways in Sri Lanka ("A", "B' and "E" Class Roads)		12,379.49 km
Class "E" Roads (Expressways)		
Route Number	**Road Name**	**Road Length (km)**
E001	Southern Expressway	124.08
E002	Outer Circular Highway	19.245
E003	Colombo-Katunayake Expressway	25.80
Total of Expressways		169.13

Source: Road Development Authority of Sri Lanka

Road infrastructures are most essential as roads itself. Road infrastructure, which adds value to the functionality and safety of users, requires proper attention in construction and maintenance. Failures of road infrastructures and road signage create tremendous negative impacts on road functionalities especially during disaster situations. (Sri Lanka Floods and Landslides - Rapid PDNA Report, May 2017)

Current demand for Road transportation

As specified by Kumarage (2010) on Review of Sri Lanka Transport Sector, Sri Lanka incurs a huge economic loss of around Rs. 40 billion annually

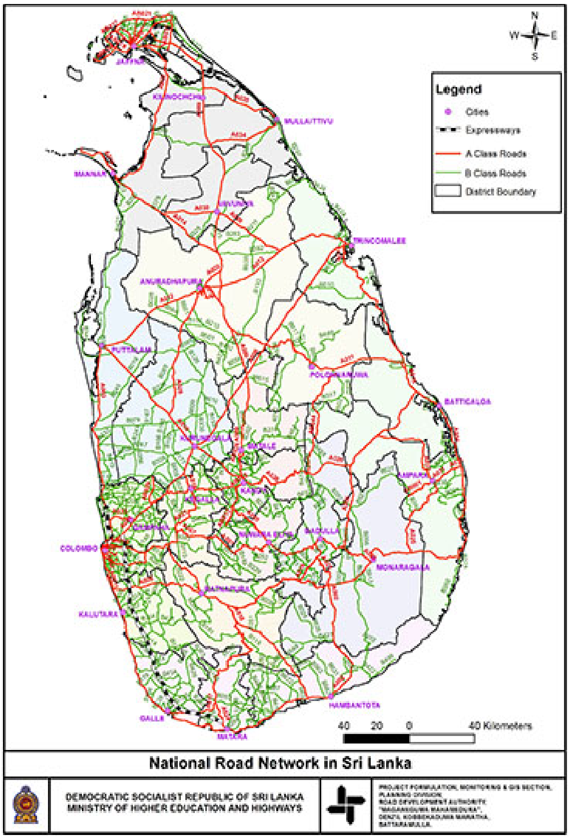


Figure 1: Road map of Sri Lanka
(Source: Road Development Authority of Sri Lanka)

due to road traffic congestion and air pollution with too many vehicles on a limited road network. "Unless the authorities take measures to modernize and improve public transport, the country cannot curb this massive, unproductive cost", noted a University of Moratuwa transport and logistics management expert. On average 250,000 vehicles, 15,000 buses, 10,000 trucks and 225,000 private vehicles enter the capital city of Colombo daily. Around 2.7 million vehicles use the road network daily in the country, although the number of vehicles registered was over 4.4 million vehicles.

Future road transportation demand

With the anticipated 6 to 8 percent growth in GDP, it is expected that the demand for passenger mobility will also increase at around 7 to 9 percent (Kumarage, 2012). Based on historical trends, the demand for passenger mobility is expected to double in 8 to 10 years. In addition to this, if the current rate of shift from public to private transport continues at 1-2%, this period will be reduced to 7 years. If public transport deteriorates further or if taxes on vehicles and fuel are reduced further, this could reduce a further 1-2%, then the time for doubling road space would reduce to 6 years. This demand will put enormous pressure on the transport infrastructure especially the road network, mainly in urban and suburban areas where the growth in economic activity will concentrate (Kumarage,2012)

Major natural disasters that impact on road sector of Sri Lanka

The floods, extreme rainfalls, higher day and night temperatures, consecutive dry days and droughts, earth slips and landslides, fogs and smog affect roads and infrastructure, and those in turn affect land transport operations as presented in Table 2. The disaster damages and losses varied geographically, depending on the degree of flooding, and the occurrence of landslides. The total assessed losses due to natural disasters to the transport sector alone is LKR 13,076.2 million in year 2017 (Sri Lanka Rapid Post Disaster Needs Assessment, 2017).

Table 2: Impacts of disasters on road transportation

Disaster situation	Impacts
Extreme rainfall events resulting unsafe driving conditions and floods and inundation of roads	• Low visibility, especially in the coastal and mountainous regions • Traffic hindrance and safety issues • Increase of seepage and infiltration pass • Increase of hydrodynamic pressure on roads • Decreased cohesion of soil compaction • Overtopping and wash away of roads surface and subsurface • Washed out sections of the roads and associated infrastructure
Excessive Seasonal and annual average rainfall resulting in inundation of roads and earth slips	• Impact on soil moisture levels, affecting the structural integrity of roads, bridges and tunnels • Difficulty to carry out repair works with asphalt laying and other maintenance work • Adverse impact of standing water on the road base structures • Risk of floods from runoff, landslides, slope failures and damage to roads if changes occur in the precipitation pattern • Damage to signals and other transport infrastructure
Higher maximum temperature (day time and night time temperatures) and higher number of consecutive hot days (heat waves)	• Concerns regarding pavement integrity, e.g. softening, traffic-related rutting, embrittlement (cracking), migration of liquid asphalt • Thermal expansion in bridge joints and paved surfaces • Impact on landscaping • Heat may break soil cohesion and increase dust volume which causes health and traffic accidents • Discomfort and health issues to passengers and pedestrians • Absorption of heat on road surface which may release or reflect them towards residential and occupied areas may increase the energy consumption
Drought (Consecutive dry days)	• Susceptibility to wildfires that threaten the transportation infrastructure • Damage to road signage's directly due to fire hazards • Increased dust making driving more exhaustive and difficult for pedestrians and residents along road sides • Consolidation of the substructure with (unequal) settlement as a consequence • More smog • Unavailability of water for compaction work • Drought decreases number of plants along roads and landscapes • In areas with high tendency to form dust, road construction and maintenance work will cause severe discomfort and health problems and may even delay the construction activities

Disaster situation	Impacts
Fogs (usually in mountain regions)	• Traffic hindrance and safety issues to drivers • May result in health problems to asthmatic patients
Smog (usually in dry lowland urban areas)	• Traffic can be disrupted but the worse conditions which have been reported in areas like New Delhi with huge pollution issues are not yet reported in Sri Lanka • May result in difficulty in driving in the night due to deflection of headlights • May result in health problems to asthmatic patients

Climate change projections and potential natural disaster risk in the future for Road Sector

Future projections for rainfall and temperature developed for the Climate Change Risk Assessment Project are used for discussion of disaster risks in the road sector of this paper. Representative Concentration Pathways (RCP) 8.5 is the business as usual scenario considered for the paper for year 2030. Climate change projections are derived from the climate models using information described in scenarios of greenhouse gas (GHG) and air pollutant emissions and land use patterns. The standard set of scenarios used in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5) is called Representative Concentration Pathways (RCP). The RCPs describe four different 21st century pathways of GHG emissions and atmospheric concentrations, air pollutant emissions and land use. The RCP 2.6 represents low emission scenario, RCP 4.5 and RCP 6 represent moderate emission scenario while RCP 8.5 represents high emission scenario.

This assessment particularly uses rainfall and temperature future scenarios downscaled by Department of Meteorology Sri Lanka (Figure 2 Average annual rainfall anomaly 2030).

As per the maps, anomaly of average annual rainfall, defined as sum of daily rainfall for a lengthy period of time (here it is 30 years anomaly which is the difference of the average annual rainfall between present-day and year 2030) is high in Wet zone of the country, particularly parts of Ratnapura, Colombo, Kalutara, Galle, Kegalle and Matara districts. With the heavy rainfall probability for floods, flash floods,

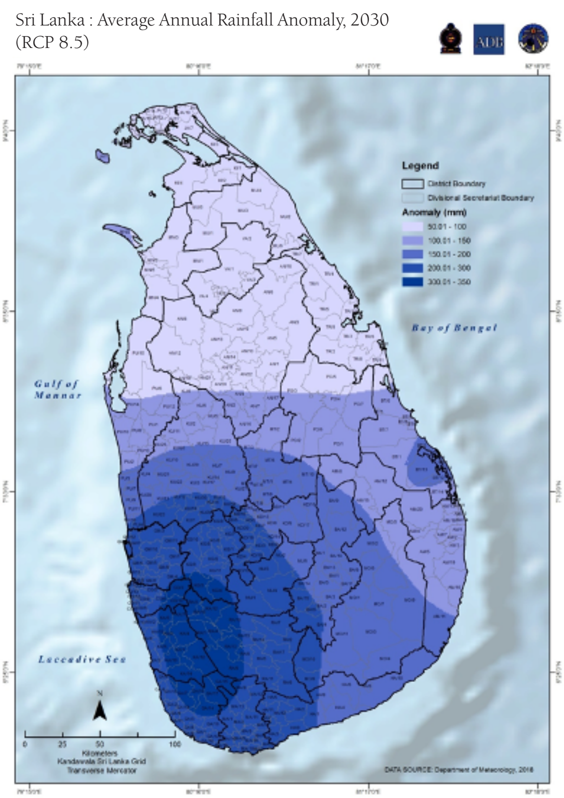


Figure 2: Average annual rainfall anomaly 2030
Source : Climate change Risk Assessment of Sri Lanka, 2018, ADB TA – 8572 – Un-published

Figure 3: Average annual maximum temperature anomalies for year 2030

Figure 4: Average annual minimum temperature anomalies for year 2030

Source : Climate change Risk Assessment of Sri Lanka, 2018, ADB TA – 8572 – Un-published

cutting failures and landslides are increased.

Below presented are the maximum and minimum temperature anomalies for year 2030.

As shown on the maps (Figure 3 and 4) of average annual temperature (average of the temperatures of a year) anomaly for maximum and minimum temperatures, the average annual maximum temperature anomaly for 2030, is low (0.81 - 0.9); in average annual minimum temperature anomaly is comparatively high (0.9-1.0) for entire country except for a small region in North West. However, positive anomalies of the temperature, consecutive dry days and number of drought events may increase in future.

Identification of disaster risk management options for road sector against future demand and climate projection in Sri Lanka

The strategy for recovery and to undo the effect of damages to the road sector is to restore accessibility, connectivity and mobility, as well as to improve upon previous conditions by repairing damages with preventive measures, so as to avoid similar damages in the future. (Sri Lanka floods and landslides RPDNA report,May 2017).

Considering the various disaster situations that may be experienced in the road development and management and maintenance, it is worth considering various options and strategies that could reduce the cost and increase the effectiveness of the disaster resilience of the road sector. In this regard, it may be worth introducing the following:

1. Zonation of the country considering different disaster types and their impacts on the road and their sustenance; such zonation will help the EIA (Environmental Impact Assessment) process as well as the road planners to choose areas that are least prone when exploring the options/alternatives available
2. Introduction of a road disaster risk level index based on the disaster vulnerability and resilience in each zone, so that the residents and the road users are aware of the level of risk posed under different disaster situations
3. Identify and classify the road sections and DSD areas that may have high vulnerability, if exposed, to be damaged so that the maintenance programs can focus and give priority to such areas/sections/points.

According to the annual average rainfall map of 2030, Wet Zone will get higher rainfall and therefore, flood risk will be increased. As shown in the map, Colombo, Kalutara, Ratnapura, Kegalle, Galle, Matara, Ratnapura, Nuwaraeliya, Kandy and Gampaha districts are highly vulnerable to the higher rainfalls and floods.

A road project can be categorized into three main phases, planning/design and construction and maintenance phase (Table 3,4 & 5).

Table 3: Disaster risk reduction measures for Floods and Heavy rains

Phase	Road structure/ Infrastructure	Flood plains (in urban and rural areas) Floods & heavy rainfall
Road Planning		• Introduce a classification index to identify the road sections that are susceptible/vulnerable to natural disasters to enhance public/user knowledge • Initiate a natural disaster-prone area mapping similar to landslide prone maps to identify those areas subject to common natural disasters. • Prepare road traces and alternate routes avoiding environmentally sensitive areas • Include climate and natural disaster risk assessments in the EIA process

Phase	Road structure/ Infrastructure	Flood plains (in urban and rural areas) Floods & heavy rainfall
Road design		• Avoid high flood risk areas • Consider the 100 year flood level and the rainfall intensity of the area • Raise the road level to avoid inundation • Pave road surfaces • Ponds (retention/ detention) areas to manage flow of water • Use groins and dams to control floods • Introduce flood control measures as part of the road designs • Preserve top soil in earth burrowing • Improve soakage damage potentials of surface and subsurface • Evaluate the land use activities in and around disaster prone areas to check on presence of triggering factors that should be addressed
	Drainage	• Improve cross drainage (culverts, bridges and spillways)
		• Ditches and drains • Permeable road • Install debris deflectors • Underdrain • Scour checks • Cut-off ditches • Gradients of the road surface
	Supporting road structures e.g. Embankments, causeways and other similar structures	• Avoid areas with high vulnerability to floods • Construct embankments in areas with potential floods • Assess and raise the embankments and other structures to meet potential high flood situations
	Road infrastructures and road signage	• Design and install warning road signs, visible clearly even in the flood situations.
	Traffic management	• Consider the traffic management under disaster situation in areas with potential for flood impacts rather than the normal vehicle flow • Consider construction of access roads to higher elevations for areas with flash flood threats

Phase	**Road structure/ Infrastructure**	**Flood plains (in urban and rural areas) Floods & heavy rainfall**
Maintenance phase		• Clear and clean culverts and drains • Ensure the safety of flood prevention structures that prevent flooding of the roads • Maintain road signage boards and update accordingly (for newly identified risk areas) • Introduce insurance schemes for critical structures that may get damaged due to floods • Research to be carried out on low cost technological interventions to prevent flood damages and to do quick repairs to flood damage roads

Table 4: Disaster risk reduction measures for Heat and Drought

Phase	**Road structure/ Infrastructure**	**Heat and drought**
Planning		• Plan to introduce tree cover to compensate for the loss due to road construction • Introduce facilities for rest areas for the travelers as part of the road plans to ensure that road users are not subject to fatigue and travel stress during long distance driving. • Include avenue tree planting and other tree cover to be part of the road design and construction both in urban and rural areas • Avoid those areas that are protected for watershed qualities and forest conservations • Carry out the disaster assessment as part of the EIA
Road design		• Introduce trees and other shelters as a part of road landscape to prevent high level of heat stress during hot days • Have sheltered pavements for pedestrians specially in the urban areas • Introduce skid resistant road surfaces and avoid sharp bends in the design
	Supporting road structures e,g. embankments, causeways and other similar structures	• Have preventive walls to cover the earth embankment and slopes with grass to avoid generation of dust during dry periods

Phase	Road structure/ Infrastructure	Heat and drought
	Road infrastructures and road signage	• Have clearly visible road signs and introduce new signs where the surface may get affected due to heat stress. • Provide watering points as part of road landscaping to reduce heat risks and to those pedestrians using the roads in urban areas
	Traffic management	• Avoid vehicle congestion in urban areas as stranded traffic add to emissions and particle concentration in air, causing health problems • When possible introduce uniflow traffic whenever other means of traffic management is unavailable
Maintenance phase		• Maintain road signage boards and update accordingly (for newly identified risk areas) • Use digital signage to make the visibility high • Introduce insurance schemes for costly structures • Research on the skid resistance surface laying which also withstand the heat stress related impacts
		• Provide resting areas and other facilities needed for long distance travelers along the roads to avoid fatigue that results under heat conditions • Plant new tree and shrubs varieties suitable for road sides that are resistant to strong wind damages

Table 5: Disaster risk reduction measures for Earth slips and Landslides

Phases	Road structure/ Infrastructure	Mountainous areas Earth slips & Landslides
Road planning and design		• Avoid high risk areas or consider possible disasters of the area during the design phase of the road • Incorporate soil erosion and earth slip prevention techniques for the road as well as surrounding areas • Introduce retention walls and groins to help stabilize cut slopes and banks • Conduct a complete hydrological evaluation of the proposed construction as part of the Environmental Assessment Impacts and make suitable recommendations to minimize potential damages to hydraulic dynamics. • Improve cross drainage (culverts, bridges and spillways) • Ditches and drains • Permeable roads • Install debris deflectors

Phases	**Road structure/ Infrastructure**	**Mountainous areas Earth slips & Landslides**
		• Underdrain • Scour checks • Cut-off ditches • Gradients of the road surface
	Supporting road structures e.g. Embankments, causeways and other similar structures	• Retaining walls for erosion prevention • Grass sodding Groins (stream or longitudinal erosion condition) • Avoid ponding of water in areas where the landslides can happen
	Road infrastructures and road signage	• Warn users with advance notice of possible earth slips and rock falls during heavy rains. • Consider restricting usage of these roads and provide alternatives during potential disasters
	Traffic management	• Introduce measures for the evacuation needs during potential landslides and traffic disruption. • Provide provisions for the movements of earth vehicles and emergency evacuation and relief operations in landslides prone areas
Maintenance phase		• Clear and clean culverts and drains • Inspect and repair of erosion protection and scour checks • Maintain road signage boards and update accordingly (for newly identified risk areas) • Introduce insurance schemes for repair of costly structures • Support research on designs for the prevention of earth slips • Identify the potential damages and areas that may be affected due to landslides and cut failures

As mentioned, fog and mist have not created major hazard conditions. Hence, it may be sufficient at present situation to give sufficient warning on such areas where the fog and mist are commonly encountered during certain times of the year. Also, educating the public through general awareness is useful on how to drive safely under fog affected conditions

References

Climate Change Risk Assessment of Sri Lanka, (2018), ADB TA – 8572 – Un-published

Kumarage A. S. (2010) Review of Sri Lanka Transport Sector

Kumarage A. S. (2012) Sri Lanka Transport Sector Policy Notes, World Bank Sri Lanka

Ministry of Disaster Management & Ministry of National Policy and Economic Affairs in collaboration with the United Nations, World Bank and European Union (2017) Sri Lanka Rapid Post Disaster Needs Assessment Floods and Landslides, Pp 119 -129.

http://www.dmc.gov.lk/index.php?lang=en (Accessed: 20th March 2019)

http://www.rda.gov.lk/source/rda_roads.htm (Accessed: 20th March 2019)

https://www.nbro.gov.lk/index.php?lang=en (Accessed: 5th April 2019)

දේශගුණ විපර්යාස හමුවේ අවධානමට ලක්වන මුහුදු තෘණ

සුසන්ත උඩගෙදර
තෙවන ජාතික සන්නිවේදන වාර්තාව සැකසීමේ ව්‍යාපෘතිය,
දේශගුණ විපර්යාස ලේකම් කාර්යාලය, පරිසර අමාත්‍යාංශය
susanthauoc@gmail.com

- මුහුදු තෘණ යනු ලවණ සහිත ජලයේ ජීවත් වීමට අනුවර්තනය වූ, සපුෂ්ප ශාක කාණ්ඩයට අයත්වන ශාක කොට්ඨාශයකි.
- මුහුදු තෘණ මගින් සිදු කරනු ලබන සේවා සහ කාර්යයන් නිසා මෙම පරිසර පද්ධතිය පාරිසරික සහ ආර්ථිකමය වටිනාකමකින් සමන්විත අද්විතීය පද්ධතියක් ලෙසද හඳුනාගෙන ඇති අතර, මෙනිසා තෙවන වැදගත්ම පරිසර පද්ධතිය ලෙසට පිළිගනු ලබයි.
- ආලෝකය, පෝෂ්‍ය පදාර්ථ, කාබන්ඩයොක්සයිඩ්, සුදුසු උපස්තර, ලවණ මට්ටම, උෂ්ණත්වය, pH අගයන් හා අනෙකුත් වැදගත් මූලිකාංග මුහුදු තෘණ ශාක වල පැවැත්ම සඳහා ප්‍රධාන වශයෙන් බලපානු ලබන අතර, එම මූලිකාංගයන්ගේ ප්‍රමාණයන් මුහුදු තෘණ විශේෂය අනුව වෙනස් වේ.
- ඔස්ට්‍රේලියානු පර්යේෂණ කණ්ඩායමක් මගින් දේශගුණ විපර්යාස පුරෝකථන වලට අනුව උෂ්ණත්වය ඉහළ යාම නිසා ඇතිවිය හැකි අවධානම ලෙස මුහුදු මට්ටම ඉහළ යාම, භෞතික හානි, ක්ෂණික ගංවතුර හා අනෙකුත් අනපේක්ෂිත හානීන් හේතුවෙන් මුහුදු තෘණ වලට වන බලපෑම වෙන වෙනම අධ්‍යයනය කොට ඇත.
- දේශගුණ විපර්යාස හේතුවෙන් මුහුදු තෘණ මහත් අවධානමකට ලක්වන පාරිසරික පද්ධතියක් බවට පුරෝකථනය ඇති අතරම තෘණ භූමි සංරක්ෂණය සඳහා විවිධ ක්‍රමෝපායන්ට එළඹීම තුලින් මෙම පරිසරයේ සුරක්ෂිතතාවය තහවුරු කළ හැකිවේ.

හැඳින්වීම

මුහුදු තෘණ යනු ලවණ සහිත ජලයේ ජීවත්වීමට අනුවර්තනය වූ, සපුෂ්ප ශාක කාණ්ඩයට අයත් පරිණාමයෙන් උසස් ශාක කොට්ඨාශයකි. මෙම තෘණ ශාක විශේෂ ගොඩබිම තුළ පවතින තෘණ විශේෂ වලට සමානතාවයක් දක්වන අතර, සාගර පරිසරය තුළ ජීවත් වන බැවින් "මුහුදු තෘණ" (sea grass) ලෙස හඳුන්වනු ලබයි. මෙකී තෘණ ශාක නොගැඹුරු සාගර හා කලපු පරිසරය තුළ හිරු එළිය ජලය තුළට විනිවිද යා හැකි මට්ටමට ව්‍යාප්ත වී ඇති අතර මීටර් 70 ක් පමණ ගැඹුරු සාගර ජලයේ දී පවා මෙම මුහුදු තෘණ වාර්තා වී ඇත (ජලයේ බොරහාවය අනුව - 'turbidity'). මුහුදු තෘණ ඒකබීජ පත්‍රී ශාක ගණයට ඇතුළත් වන අතර දැනට වසර මිලියන 70-100 අතර කාලයක් තුළ දී පරිණාමයට ලක් වූ විශේෂයකි.

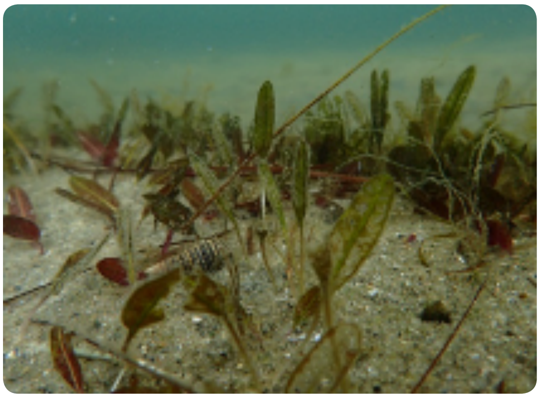
මෙම ශාක විශේෂයේ සාමාන්‍ය ව්‍යුහය සැලකීමේ දී එය, පත්‍ර, සමාන්තර දඬු, රෛසෝම සහ මුල් යනාදියෙන් සමන්විත වේ. මේවායේ සමහර විශේෂ වාතය මගින් ද තවත් සමහර විශේෂ ජලය මගින්ද

පරාගනය වේ. තවද, වර්ධක ප්‍රචාරණය මගින් ද මෙම තෘණ ශාකවල ව්‍යාප්තිය සිදුවේ.

මෙම පරිසර පද්ධතිය පාරිසරික විද්‍යාත්මක වශයෙන් වැදගත් කාර්යයන් රැසක් ඉටුකරනු ලබයි. උදාහරණ ලෙස ප්‍රාථමික නිෂ්පාදනය, අනෙකුත් ශාක සහ සතුන් සඳහා වාසස්ථාන සැපයීම, ශාක භක්ෂකයන්ට ආහාර සැපයීම, අවලම්භිත ද්‍රව්‍ය ස්ථායිකරණය කිරීම සහ පෝෂ්‍ය පදාර්ථ චක්‍රීයකරණය ආදිය සඳහන් කළ හැකිය. විද්‍යාඥයන්ගේ පර්යේෂණ වලට අනුව, නිවර්තන කලාපය තුල මුහුදු තෘණ පවතින ප්‍රදේශ වලින් 21 ගුණයක් පමණ වාසස්ථාන සඳහා උපස්ථර සපයයි. ලොව දැඩි ලෙස තර්ජනයට ලක් වු විශේෂයන් වන මුහුදු ඌරන් (Dugong) සහ කොළ කැස්බෑවන් (Green turtle) ලබාගන්නා ආහාර වලින් 90% ක් පමණම මුහුදු තෘණ භාවිතා කරනු ලබයි. මුහුදු තෘණ පරිසරයේ පවතින භෞතික, රසායන විද්‍යාත්මක මෙන්ම ජීවවිද්‍යාත්මක සාධක කෙරෙහි බලපෑමක් එල්ල කරන බැවින් මෙම පරිසර පද්ධතිය "පාරිසරික ඉංජිනේරුවන්" ලෙස හඳුනාගෙන ඇත. තවද, මෙම විශේෂවල ප්‍රාථමික නිෂ්පාදනය ගොඩබිම පවතින පරිසර පද්ධති වලට වඩා බෙහෙවින් වැඩි අගයක් ගනු ලබයි. ඇතැම් ස්ථාන වල පවතින විශේෂ වැඩිමනක් නයිට්‍රජන් අවශෝෂණය කොට නයිට්‍රජන් බහුල ස්ථාන ලෙස පවත්වාගෙන යමින් පවතී. මුහුදු තෘණ මගින් සිදු කරනු ලබන සේවා සහ කාර්යයන් නිසා මෙම පරිසර පද්ධතිය, පාරිසරික සහ ආර්ථිකමය වටිනාකමකින් සමන්විත අද්විතීය පරිසර පද්ධතියක් ලෙසද හඳුනාගෙන ඇත.

විද්‍යාත්මකව ගණනය කිරීමේදී මුහුදු තෘණ මගින් සිදුකරන කාර්යයන් පමණක් ඇගයීමකට ලක් කොට ඇති අතර, එහි වටිනාකම හෙක්ටයාර් එකකට ඩොලර් 34,000 පමණ වන බව මහාචාර්ය ෂෝර්ට් ඇතුළු පර්යේෂකයින් විසින් 2011 දී තහවුරු කොට ඇත. තවද, පර්යේෂකයන් විසින් තහවුරු කොට ඇති ආකාරයට මෙම විශේෂ හට නිවර්තන වැසි වනාන්තරවල කාබන් තිර කිරීමේ සීඝ්‍රතාවය ට වඩා 30 ගුණයකින් ඉහළ කාබන් තිර කිරීමේ හැකියාවක් ඇති බව හඳුනාගෙන ඇත. ලොව පවතින කාබන් සංචිතවල වැඩි දායකත්වයක් නිල් කාබන් (blue carbon) සංචිත මගින් සපයනු ලබන අතර මේ සඳහා මුහුදු තෘණ වැඩි දායකත්වයක් දක්වනු ලැබේ. එකී වැදගත්කම නිසා මුහුදු තෘණ පරිසර පද්ධතිය ලොව තුළ පවතින් **තෙවන** වැදගත්ම පරිසර පද්ධතිය (නිවර්තන කොරල් සහ නිවර්තන වැසි වනාන්තරයට පමණක් දෙවැනි වන) ලෙස පර්යේෂකයන් විසින් නම් කර ඇත.

ශ්‍රී ලංකාව අයත් වන්නේ ඉන්ඩෝ පැසිෆික් කලාපයට වන අතර, මේ වන විට ශ්‍රී ලංකාව තුල මුහුදු තෘණ විශේෂ 15 ක් පමණ වාර්තා වී ඇත. මෙහි ගණනයකළ ව්‍යාප්තිය හෙක්ටයාර් 23,819 පමණ වේ. ශ්‍රී ලංකාව තුල ව්‍යාප්තිය ගත්විට ප්‍රධාන ව කලපු සහ නොගැඹුරු මුහුද තුළ වේ. මුහුදු තෘණ බහුල ව ව්‍යාප්ත වී ඇති ප්‍රදේශ ලෙස පුත්තලම කලපුවේ සිට යාපනය අර්ධද්වීපය දක්වා කලාපය හඳුනාගෙන ඇත. ඉතා දුලබ විශේෂයක් වන මුහුදු ඌරන් (Dugong) මෙම ප්‍රදේශය තුළ වාර්තා වන අතර, එයට හේතුව මෙම විශේෂයට හිතකර මුහුදු තෘණ විශාල ප්‍රමාණයක් පැවතීම යි.



රූපය 1 : මඩකලපුවේ හමුවන *Halophila ovalis* මුහුදුතෘණ භූමියක්

නවතම දත්ත වලට අනුව ලොව මුහුදු තෘණ විශේෂ 72 ක් පමණ හඳුනාගෙන ඇති අතර, පාරිසරික ලක්ෂණ සලකා බැලීමේදී එය ප්‍රධාන ජීව ප්‍රදේශ (Bioregions) හයක ව්‍යාප්ත වී ඇති බවට හඳුනාගෙන ඇත.

මුහුදු තෘණ වල පැවැත්ම සඳහා බලපාන ප්‍රධාන සාධක

මුහුදු තෘණ ශාක වල පැවැත්ම සඳහා ප්‍රධාන වශයෙන් ආලෝකය, පෝෂ්‍ය පදාර්ථ, කාබන්ඩයොක්සයිඩ්, සුදුසු උපස්තර, ලවණ මට්ටම, උෂ්ණත්වය හා pH අගය යන වැදගත් මූලිකාංග හඳුනාගෙන ඇත. ඉහත සඳහන් කළ මූලිකාංගවල අවශ්‍යතා වල

ප්‍රමාණයන් මුහුදු තෘණ විශේෂය අනුව වෙනස් වන අතරම මෙම සාධක විශේෂ විවිධත්වය ඇති කිරීමට බලපානු ලබයි.

01. **ආලෝකය** ඃ ආලෝකය මුහුදු තෘණ ව්‍යාප්ත වන ගැඹුර තීරණය කරනු ලබන ප්‍රධාන සාධකයකි. එම නිසා සුදුසු ආලෝකයක් පවතින ස්ථාන වල මුහුදු තෘණ මඟින් වැඩි ප්‍රාථමික නිෂ්පාදනයක් සිදු කරනු ලබයි. පර්යේෂණ වලට අනුව ආලෝකය අවම ප්‍රදේශවල මුහුදු තෘණ විවිධාකාර හානිවීම් වලට ලක් වන බව තහවුරු වී ඇත. හැලොපිලා (*Halophila*) ගණයට අයත් විශේෂ ඉතා අවම ආලෝක තත්ත්ව සහ අධික අවලම්භිත පරිසරයේ ජීවත් වීමට අනුවර්තනය වී ඇත. නමුත්, මෙම ඝනයට අයත් විශේෂයන් දින 40ක් පමණ කාලයක් සෙවන සහිත පරිසරයක සිටියහොත් මිය යා හැකි අතර, පොසිඩෝනියා (*Posidonia*) ගණයට අයත් විශේෂයන්ට දින 140 කට අධික කාලයක් සෙවන පරිසරයේ ජීවත් විය හැක.

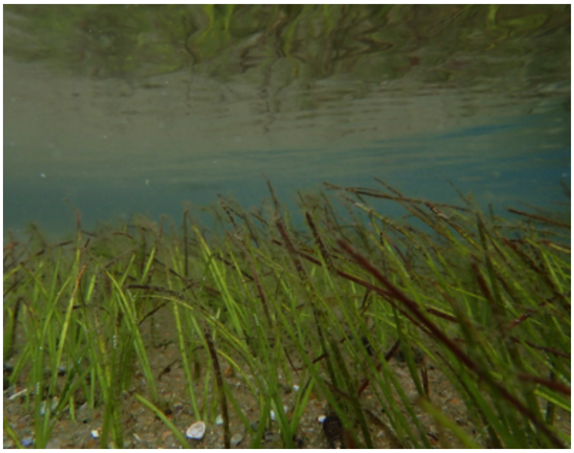
02. **පෝෂ්‍ය පදාර්ථ** ඃ පෝෂ්‍ය පදාර්ථ සමඟ මුහුදු තෘණවල නිෂ්පාදනය අනුලෝමව ක්‍රියාත්මක වේ. එම නිසා පෝෂ්‍ය පදාර්ථ වැඩි පරිසරයේ ඉහළ නිෂ්පාදනයක් වාර්තා වේ. නමුත් නිවර්තන කලාපය තුළ පෝෂ්‍ය පදර්ථ අධික ලෙස පැවතීම හා අධික අවලම්භිත පැවතීම හේතුවෙන් අහිතකර ඇල්ගී ව්‍යාප්ත වනු ලබන අතරම එමගින් ජලය තුලට ආලෝකය පරාවර්තනය විම වළක්වයි.

03. **භෞතික ලෙස සිදුවන හානීන්** ඃ මුහුදු තෘණ වල විශේෂ විවිධත්වය හා පැවැත්ම කෙරෙහි භෞතික තත්ත්ව බොහෝ සෙයින් බලපානු ලබයි. මුහුදු තෘණ ආහාරයට ගන්නා විශාල ශාක භක්ෂකයින් වන මුහුදු ඌරන්ගේ (*Dugong dugon*) අධික උලාකෑම නිසා, ගංවතුර සමඟ පැමිණෙන අධික අවලම්භිත ද්‍රව්‍ය සහ සුළිසුළං මඟින් ඇති වන හානි හේතුවෙන් මුහුදු තෘණ විශාල වශයෙන් හානියට ලක්වේ. මෙම විශේෂ, පාරිසරික තත්ත්ව වලට අනුගත වීමේ හැකියාවන්, විශේෂ විවිධත්වය හා විශේෂය අනුව වෙනස් වේ. භෞතික ක්‍රියාකාරකම් හේතුවෙන් ගල්පර ආශ්‍රිතව ඇති හැලොඩියුල් (*Halodule*) හා හැලොපිලා (*Halophila*) වල විශේෂයන් අධික හානියට පත්වේ. නමුත්, මෙම පරිසරයේ ඇති තැලසොඩෙන්ඩ්‍රෝන් (*Thalassondendron*) විශේෂයන්ගේ පවතින අධි ප්‍රතිජනන හැකියාව නිසා එම හානි වලට මුහුණ දීමේ හැකියාවක් මෙම විශේෂ සතුය.

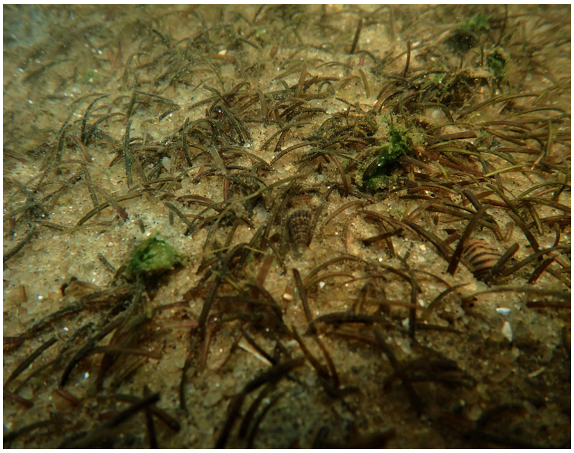
04. **ලවණතාවය, උෂ්ණත්වය, කාබන්ඩයොක්සයිඩ්, pH** ඃ මුහුදු තෘණ වලට හිතකර ලවණ මට්ටම 35 ppt වන අතර මෙම තෘණ විශේෂයන් 4-65 ppt පරාසය තුළ වාර්තා වී ඇත. මුහුදු තෘණ විශේෂ අතරින් හැලොපිලා ඔවාලිස් (*Halophila ovalis*) විවිධ ලවණ පරාසයන් තුළ ජීවත් වීමට අනුවර්ථනය වූ විශේෂයකි. උෂ්ණත්වය ශාක වල පැවැත්මට බලපාන ප්‍රධාන සාධකයකි. උෂ්ණත්වයේ වෙනස්වීම් හේතුවෙන් සාගර ජලයේ දියවන කාබන්ඩයොක්සයිඩ් ප්‍රමාණය වෙනස් වන නිසා pH අගය වෙනස් වීමකට භාජනය වේ. විශේෂ විවිධත්වය, කාබන්ඩයොක්සයිඩ් සහ pH අනුපාතයන්ගේ අවශ්‍ය ප්‍රමාණයන් විශේෂ අනුව වෙනස් වන අතරම එහි සංයුතිය දීර්ඝ කාලීන පැවැත්මට අත්‍යවශ්‍ය වේ. මීට අමතරව මුහුදු තෘණ විශේෂ වල මෙම සාධක බලපානු ලබන අතරම ඒවායේ වෙනස්කම් වර්ධන වේගයට සහ බාහිර තර්ජන වලට මුහුණ දීමේ හැකියාව සඳහා බලපායි.

දේශගුණ විපර්යාස හේතුවෙන් මුහුදු තෘණ වලට ඇතිවන අවධානම (Vulnerability)

ඔස්ට්‍රේලියාවේ මහා බාධක පරය ආශ්‍රිතව ඇති මුහුදු තෘණ, දේශගුණ විපර්යාස හේතුවෙන් ඇතිවන අවධානම පිළිබඳව පර්යේෂණයක් මහාචාර්ය මිචෙල් වේකොට් ඇතුළු විද්‍යාඥායන් පිරිසක් 2007 වසරේදී සිදුකොට ඇත (Waycott *et al.*,2007). මෙම පර්යේෂණ මඟින් දේශගුණ විපර්යාස හමුවේ මුහුදු තෘණ විශේෂ සහ වාසස්ථානවල ඇති දරා ගැනීමේ හැකියාව, දේශගුණ විපර්යාස වලට ප්‍රතිචාර දක්වන විශේෂයන්ගේ ව්‍යුහයේ සිදුවන වෙනස්කම් සහ ව්‍යාප්තියේ වෙනස්කම් අධ්‍යයනය කොට ඇත. දේශගුණ විපර්යාස පුරෝකථන වලට අනුව ඇතිවිය හැකි උෂ්ණත්ව වෙනස්කම් නිසා ඇතිවිය හැකි අවදානම් ලෙස මුහුදු මට්ටම ඉහළ යාම, භෞතික හානි, ක්ෂණික ගංවතුර හා අනෙකුත් අනපේක්ෂිත හානීන් හේතුවෙන් මුහුදු තෘණ වලට වන බලපෑම වෙන වෙනම අධ්‍යයනය කොට ඇත. මෙම ඇගයීම සඳහා දේශගුණ විපර්යාස පිළිබඳ අන්තර් රාජ්‍ය කමිටුවේ (Intergovernmental Panel



රූපය 2 ඃ මඩකලපුවේ *Halodule pinifolia* මුහුදු තෘණ භූමියක්



රූපය 3 ඃ ජාතිකව තර්ජනයට ලක්වූ *Halophila beccarii* වාලච්චේන කලපුවේ මුහුදු තෘණ භූමියක්

on Climate Change - IPCC) මඟින් නිකුත් කල හතරවන ඇගයීම් වාර්තාව (Assessment Report 4- AR4) තුල ඇතුලත් දේශගුණික විපර්යාස අවදානම් ඇගයීමේ ක්‍රමෝපායන් භාවිතා කොට ඇත. (Vulnerability Assessment Framework). මෙම පර්යේෂණයේ ප්‍රතිඵල සාරාංශයක් ලෙස පහත පරිදි ගෙනහැර දක්වා ඇත. තවද, ශ්‍රී ලංකාව දූපත් රාජ්‍යයක් මෙන්ම වෙන පරිසර අංග රාශියක් මෙම අධ්‍යයනය සිදුකල මහා බාධක පරය ආශ්‍රිතව ඇති පරිසරයට සමානකම් දක්වන නිසා මෙම අධ්‍යයනයේ ප්‍රතිඵල ශ්‍රී ලංකාව ආශ්‍රිතව පවතින මුහුදු තෘණ පද්ධතියට ඇති දේශගුණ විපර්යාසවල බලපෑම් වලට බොහෝ සෙයින් සමාන වේ.

දේශගුණ විපර්යාසයන් නිසා ඇති විය හැකි විචල්‍යන් වලට මුහුදු තෘණ ප්‍රතිචාර දක්වන ආකාරය.

01. සාගර මතුපිට සහ වායුගෝලයේ උණුසුම වෙනස්වීම

පර්යේෂණ දත්ත වලට අනුව මහා බාධක පරය ආශ්‍රිතව උෂ්ණත්වය පෙර අවුරුදු 250ට සාපේක්ෂව බොහෝ සෙයින් වෙනස් වී ඇත. දේශගුණ විපර්යාස පිළිබඳව ඇති පුරෝකථනයන්ට අනුව වර්ෂ 2100 වන විට උෂ්ණත්වය 1.2 ^{o}C සිට 4.1 ^{o}C මට්ටමකින් ඉහළ යා හැකි බව පුරෝකථනය කොට ගෙන ඇත. මේ හේතුවෙන් වෙරළ කලාපයේ (අන්තර් උදම් කලාපයේ) පවතින මුහුදු තෘණ අධික ලෙස අවදානමකට ලක්විය හැක. අන්තර් උදම් කලාපයේ සිදුවන බාදිය සංසිද්ධිය හේතුවෙන් වායුගෝලයට නිරාවරණය වන මුහුදු තෘණ භූමි වායුගෝලයේ අධි උණුසුම නිසා තර්ජනයට (පිලිස්සීමට) ලක්විය හැකි අතරම අවදානමේ ප්‍රමාණය මුහුදු තෘණ විශේෂය මත වෙනස් වේ. විද්‍යාගාර තුළදී ස්වාස්තික (*in-situ*) ආකාරයට අනුව සිදු කරනු ලැබූ පර්යේෂණයන්ට අනුව උෂ්ණත්ව වෙනස්කම් වලට අනුව මුහුදු තෘණ ප්‍රතිචාර දක්වන ආකාරය විශේෂ අනුව වෙනස් වේ.

අන්තර් උදම් කලාපය තුළ බාදිය සංසිද්දිය හේතුවෙන් වායුගෝලයට නිරාවරණය වන මුහුදු තෘණ වායුගෝලීය උණුසුම 5.0 ^{o}C කින් වැඩි වූ විට කෙටි කලක් තුළ විශාල ප්‍රමාණයක් විනාශයට ලක් වේ. තවද උණුසුම වැඩි වීම නිසා හානිකර ඇල්ගී ව්‍යාප්ත විය හැකි අතර එනිසා මුහුදු තෘණ හානියට ලක් වේ.

02. මුහුදු මට්ටම ඉහළ යාම හා වෙරළ කලාපය යට වීම

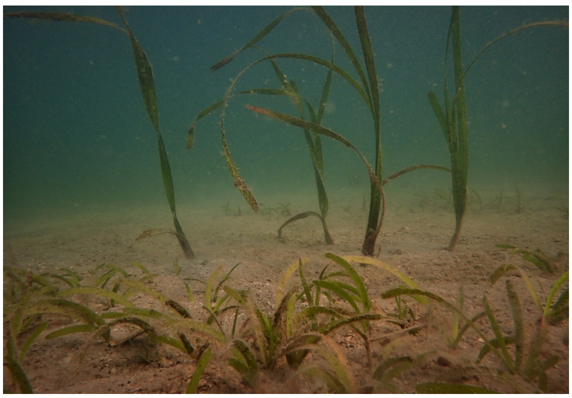
ඉහත සඳහන් කල පරිදි මුහුදු තෘණ ව්‍යාප්තිය ආලෝකය සමඟ ඍජු සහ සම්බන්ධතාවයක් පවත්වනු ලබයි. පර්යේෂණ දත්ත වලට අනුව වර්ෂ 2100 වන විට මුහුදු මට්ටම 10 cm සිට 90 cm දක්වා වැඩි වන බවට පුරෝකථනය කොට ඇත. මේ හේතුව නිසා පහත් බිම් ජලයෙන් යටවීම හේතුවෙන් එම භූමි හායනයවීම (පාංශු ඛාදනය හේතුවෙන්) සිදුවේ. එබැවින් මුහුදු තෘණවලට සුදුසු වාසස්ථාන අහිමි වේ. එමෙන්ම ආලෝකය සමඟ මෙම විශේෂ අභ්‍යන්තර සංචරණය (internal migration) වීමක් සිදුවේ. තවද, මෙලෙස පහත්බිම් යටවීමෙන් ඇතිවන භෞතික තත්වයන්ගේ වෙනස්වීම මුහුදු තෘණ විශේෂ වලට අහිතකර ලෙස බලපායි.

03. භෞතික හානි (කුණාටු සහ සුළි සුළං)

ඉදිරි වසර 100 ක කාලය තුල සුළි සුළං ඇතිවීමේ සීඝ්‍රතාවය (frequent) ඉතා ඉහළ අගයක් නොගන්නා බවට පුරෝකථනය කොට ඇත. නමුත්, කුණාටු සහ සුළි සුළං වල තිව්‍රතාවයේ (intensity) වෙනස්කම් නිරික්ෂණය කොට ඇත. මේ නිසා සාගර ජලය කැළඹිලි ස්වභාවයක් ඇතිවන අතර වායුගෝලයේ අඩුපීඩන කලාප නිර්මාණය වීම මඟින් තිව්‍ර වර්ෂා ඇතිවේ. තවද, කුණාටු සහ සුළි සුළං ඇතිවීමේ සීඝ්‍රතාවය සහ තීව්‍රතාවය එල්නිනෝ තත්වයක් සමඟ සහ සම්බන්ධ වී ක්‍රියාත්මක වන අතර ඒ හේතුවෙන් කුණාටු සහ සුළි සුළං ඇතිවීමට වැඩි ප්‍රමණතාවයක් දක්වයි. එබැවින්, මුහුදු තෘණ වලට සිදු වන භෞතික හානි අවම වන අතර, සාගරයේ රළ පහරේ වේගය වැඩි වීම නිසා ඇති අවලම්භිත ද්‍රව්‍ය වලින් මුහුදු තෘණ වලට බලපෑම් සිදු වේ. විශාල ශාක භක්ෂකයින් වන මුහුදු ඌරන් මෙකී තෘණ ආහාරයට ගැනීම හේතුවෙන් ඒවාට සිදු වන හානිය මාසයක් වැනි ඉතා කෙටි කාලයකින් ප්‍රතිස්ථාපනයට ලක්වේ.

04. තීව්‍ර වර්ෂාපතනය සහ ගංවතුර

දේශගුණ විපර්යාස පිළිබඳ පුරෝකථන වලට අනුව වර්ෂාපතන රටාවේ පැහැදිලි වෙනස්කම් නිරීක්ෂණය කල හැකිය. වර්ෂාපතන රටාවේ සහ අන්තර් මෝසම් රටාවේ වෙනස්කම් (internal variation) සිදුවන නිසා වර්ෂාව ලැබෙන කාලසීමාව සහ තීව්‍රතාවය වෙනස් වී ඇත. එහි ප්‍රතිඵලයක් ලෙස ඇතිවන ක්‍ෂණික ගංවතුර සමග විශාල අවලම්භිත සහ පෝෂ්‍ය පදාර්ථ විශාල ප්‍රමාණයක් කලපුවලට මෙන්ම සාගරයට මුදාහරිනු ලබයි. මේ නිසා ලවණ මට්ටමේ ක්ෂණික වෙනස්වීම් වලට භාජනය විය



රූපය 4 ඃ උතුරු මුහුදේ හමුවන *Enhalus acoroides* සහ *Cymodocea serrulata* වලින් සමන්විත මුහුදු තෘණ පද්ධතියක්

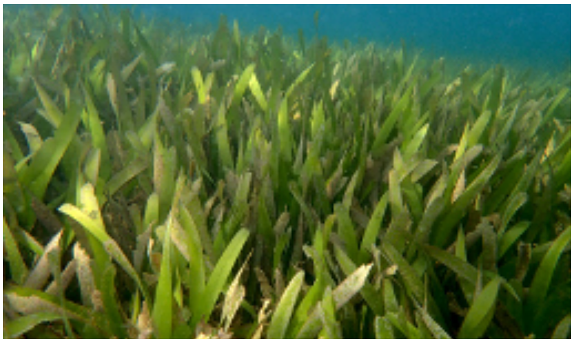
හැකි අතර ආලෝකය නොලැබීම හේතු කොටගෙන මුහුදු තෘණ හානියට ලක් වේ. තවද, මෙම ශාක අතර ගංවතුර සමඟ පැමිණෙන රොන්මඩ තැන්පත් වීම හේතුවෙන් ශාක කුණුවීමකට ලක්වන අතර පුෂ්ප හානියට පත් වේ. ගංගා වල මෝය කට ආශ්‍රිතව ඇති හැලොඩියුල් (*Halodule*), හැලොපිලා (*Halophila*) සහ සුස්ටෙරා (*Zostera*) ගණ වලට අයත් විශේෂ ගංවතුරට බොහෝ සෙයින් අනුවර්තනය වී ඇති නිසා මෙම විශේෂවලට ඇතිවන හානිය අල්ප වේ. තවද, ගංවතුර හේතුවෙන් අධික ජල කඳක් පැමිණීම හේතුවෙන් ශාක පටල වලට හානි වීමක් සිදුවේ. එමෙන්ම, ගංවතුර හේතුවෙන් මුහුදු තෘණ ශාක ප්‍රතිස්ථාපනයට සැලකිය යුතු කාලයක් ගතවන අතර අනාගතයේ දී ගංවතුර ඇති වන වාර ගණන වැඩි වුවහොත්, ප්‍රතිස්ථාපනය සඳහා ගත වන කාලය ද ඉහළ යාමක් සිදුවිය හැකිය.

05. ආලෝකය සහ පාරජම්බුල කිරණ

ආලෝකය සීමා වීමට ප්‍රධාන සාධක කිහිපයක් බලපානු ලබයි. ගංවතුර සමග පැමිණෙන අවලම්භිත සහ මේ සමඟ පැමිණෙන පෝෂ්‍ය පදාර්ථ හේතුවෙන් මුහුදු පතුල තුළට ආලෝකය විනිවිදයාමේ හැකියාව සීමා වේ. ඊට අමතරව දේශගුණ විද්‍යා පුරෝකථන වලට අනුව වැඩි සම්භාවිතාවයෙන් ඇතිවන පාරජම්බුල කිරණ නිසා බාදිය සංසිද්ධියේදී වාතයට නිරාවරණය වන අන්තර් උදම් කලාපයේ පවතින මුහුදු තෘණ ශාක වලට පත්‍ර පිලිස්සීමට ලක් වේ. හැලොඩියුල් (*Halodule*), හැලෝපිලා (*Halophila*) සහ සුස්ටෙරා (*Zostera*) ගණ වලට අයත් මුහුදු තෘණ විශේෂයන් ආලෝකය නොලැබීම හේතුවෙන් හානියට පත්වේ. නමුත්, තැලසියා (*Thalassia*) විශේෂයන් හට අඩු ආලෝක තත්ත්වයන් යටතේ විශාල දරාගැනිමේ හැකියාවක් පවති. එයට හේතුව එම විශේෂයෙහි ඇති ඉහළ කබොහයිඩේට් තැන්පතුවයි.

06. කාබන්ඩයොක්සයිඩ් මට්ටම සහ සාගර ආම්ලීකරණය

1950 වර්ෂයට සාපේක්ෂව 2019 වන විට වායුගෝලයේ කාබන්ඩයොක්සයිඩ් මට්ටම 300 ppm සිට 410 ppm දක්වා වැඩි වී ඇත. තවද පුරෝකථන වලට අනුව ඉදිරි අවුරුදු 100+ ක පමණ කාලය තුළ මෙම අගය දෙගුණයකින් පමණ ඉහළ යන බවට නිගමනය කොට ඇත. එම නිසා, සාගරයේ දිය වී ඇති කාබන්ඩයොක්සයිඩ් සාන්ද්‍රණය වෙනස් වීම හේතුවෙන් බයිකාබනේට් සාන්ද්‍රණය වෙනස් වීමකට



රූපය 5 ඃ වාකරේ නොගැඹුරු මුහුදේ ඇති *Cymodocea serrulata* මුහුදු තෘණ භූමියක්

භාජනය වේ. ඒ හේතුවෙන් ජලයේ pH අගය පහළ යාමකට ලක් විය හැකි වන අතර බොහෝ මුහුදු තෘණ ශාක සඳහා මෙම වෙනස් වීම හිතකර ලෙස බලපානු ලබයි. නමුත්, අධි සංවේදී විශේෂ වලට pH අගයේ සිදුවන කුඩා වෙනස්කමට පවා ප්‍රතිචාර දැක්විය හැකිය.

07. සාගර දියවැල් වල සංචරනයේ වෙනස් වීම

දේශගුණ විපර්යාස හේතුවෙන් සාගර දියවැල් වෙනස් වීමකට ලක්වන බව විද්‍යාත්මකව පුරෝකථනයකොට ඇත. එමගින් උණුසුම් දියවැල් ඇති වීමේ සීඝ්‍රතාවය වැඩි විය හැකි අතර, එය මුහුදු තෘණ විශේෂ වලට හානි ගෙන දේ. නමුත්, නිවැරදි ආකාරයට සාගර දියවැල් වල වෙනස් වීම මුහුදු තෘණ වලට බලපාන ආකාරය නිගමනය කිරීමට නොහැකි වී ඇත්තේ මේ පිළිබඳ සිදු කර ඇති පරීක්ෂණ වල සීමා සහිත භාවයයි.

නිගමනය

ගංගා, මෝය ආශ්‍රිතව පවතින සාගර තෘණ භූමි දේශගුණ විපර්යාස හේතුවෙන් විශාල අවධානමකට ලක්විය හැක. උෂ්ණත්වයේ වෙනස්වීම, වර්ෂාපතන රටාවේ සිදුවන වෙනස්කම්, වැනි හේතු නිසා මුහුදු තෘණ වැඩි ලෙස තර්ජනයට ලක්වේ. එබැවින්, මුහුදු තෘණ වල සෞඛ්‍ය සම්පන්න භාවයට හානි සිදු වන අතර මෙම වැදගත් පරිසර පද්ධතිය දේශගුණ විපර්යාස අවධානමට ලක් වීමෙන් සඳහටම තුරන් වී යා හැකිය.

නමුත්, දේශගුණ විපර්යාස හේතුවෙන් සිදුවන වෙනස්කම් මුහුදු තෘණ වලට බලපාන ආකාරය පිළිබඳ පර්යේෂණ තවමත් සීමා සහිත මට්ටමක පවතී. එමනිසා විශේෂ අනුව ප්‍රශස්ත උෂ්ණත්වය, ලවණ ප්‍රමාණය pH, අගය, දියවැල් වල ප්‍රවේගය, විෂ, අත්‍යවශ්‍ය පෝෂ්‍ය පදාර්ථ වැනි සාධක විචලනය වීම සැලකිල්ලට ගෙන දිගු කාලීන හෝ කෙටි කාලීන පර්යේෂණ සිදු කළ යුතුය. මෙයට සමගාමීව ජීව ස්කන්ධයේ වෙනස් වීම, පුෂ්ප ඇති වීම, බීජ ඇති වීම, බීජ ප්‍රරෝහනය, වර්ධන වේගය ඇතුළු පර්යේෂණ අනාගතයේදී සිදුකොට ඒ අනුකූලව කළමණාකරණය සහ සංරක්ෂණ ක්‍රමෝපායන් භාවිතා කිරීමෙන් දේශගුණ විපර්යාසවලට මුහුණ දිය හැකි මුහුදු තෘණ අනාගතයට ඉතිරි කර ගත හැකි වේ.

මිනිසා විසින් සිදුකරනු ලබන හානි වලට අමතරව දේශගුණ විපර්යාස නිසා සිදුවිය හැකි අයහපත් ප්‍රතිඵල හේතුවෙන් මෙම පරිසර පද්ධතියට ඇතිවිය හැකි හානි ඉතා තීව්‍ර වේ. එමනිසා සංරක්ෂණය සහ කළමණාකරණ ක්‍රමෝපායන් වලට එළඹීම සිදු කළ යුතුය. ශ්‍රී ලංකාව විසින් ඉදිරිපත් කර ඇති ජාතිකව නිර්ණය කල දායකත්වයන් (Nationally Determined Contributions) මගින් මුහුදු තෘණ සංරක්ෂණයේ වැදගත්කම හඳුනාගෙන ඇත. මේ සඳහා කෙටි කාලීන සහ දිගු කාලීන දත්ත මත පදනම් වු වැඩ පිළිවෙලක් සකසා ගත යුතු අමතරව විද්‍යාත්මක ක්‍රම හරහා පාරිසරික ප්‍රතිස්ථාපනය (restoration) ක්‍රියාත්මක කිරීම මගින් මුහුදු තෘණ වඳවීමේ තීව්‍රතාවය යම් මට්ටමකට අවම කර ගත හැක. තවද, මේ සඳහා නීතිමය රාමුව සවිමත් කිරීම, විශේෂයෙන් මුහුදු තෘණ භූමි පවතින ප්‍රදේශ සංරක්ෂිත ප්‍රදේශ ලෙස නම් කොට ඒවායේ මිනිස් ක්‍රියාකාරකම් අවම කරලීම මගින් ඉතා විශාල මුහුදු තෘණ භූමි සංරක්ෂණය සිදු කොට හැක. මෙකී ක්‍රියාකාරකම් (සංරක්ෂිත පිළිවෙත්) සඳහා එළඹීම තුලින් දේශගුණික විපර්යාස හමුවේ අවදානම අවම කළ හැක. අතිමහත් වැදගත්කම් රාශියකින් යුක්ත වන (ලොව තෙවන වැදගත්ම පරිසර පද්ධතිය) අනාගත පරපුරේ සුභසිද්ධිය උදෙසා රැකගැනීම අප නොපමාව සිදු කළ යුතු වගකීමකි.

ස්තූතිය : **Idea wild Equipment Grant**

ඡායාරූප ඃ සුසන්ත උඩගෙදර

භාවිතකළ මූලාශ්‍ර

ප්‍රධාන මූලාශ්‍රය

Waycott M; Collier C; McMahon K; Ralph P and (2007) Vulnerability of seagrasses in the Great Barrier Reef to climate change. In: J.E. Johnson and P.A. Marshall (eds) Climate Change and the Great Barrier Reef: A Vulnerability Assessment. 1st edition, Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Townsville, Australia, pp. 193–235.

අනෙකුත් මූලාශ්‍ර

Cullen-Unsworth, L.C; Nordlund, L.M; Paddock, J, Baker, D.S; McKenzie, L.J; Unsworth R.K.F. (2013) Seagrass meadows globally as a coupled social–ecological system: Implications for human wellbeing, Marine Pollution Bulletin.

Hemminga, MA; and Duarte, C.M. (2000) Seagrass Ecology. Cambridge University Press. New York.

Miththapala S. (2008) Seagrasses and Sand Dunes. Coastal Ecosystems Series (Vol 3) pp 1-36 + iii. Colombo, Sri Lanka: Ecosystems and Livelihoods Group Asia, IUCN.

Short, F.T; Polidoro, B; Livingstone, SR; Carpenter K.E; Bandeira, S; Bujang J.S; Calumpong, H.P; Carruthers T.J.B; Coles, R.G; Dennison, W.C; Erftemeijer, P.L.A; Fortes, M.D; Freeman, A.S; Jagtap, T.G; Kamal, A.H.M; Kendrick, G.A; Judson, Kenworthy W; La Nafie, Y.A; Nasution, I.M; Orth, R.J; Prathep, A; Sanciangco, J.C; Tussenbroek, B.V; Vergara, S.G; Waycott, M; Zieman, J.C; 2011. Extinction risk assessment of the world's seagrass species. Biological Conservation. 144, 1961–1971.

Udagedara, S; Fernando, D; Perera, N; Tanna, A; Bown R.(2017). A first record of *Halodule pinifolia* Miki den Hartog, and new locality of nationally endangered *Halophila beccarii* Asch, from the eastern coast of Sri Lanka, International Journal of Aquatic Biology, 5(5): 328-335

මුහුදු තෘණ, ඒවායේ ප්‍රයෝජන සහ සාංරක්ෂණ උපායන්, සොබා පරිසර ප්‍රකාශනය,
මහවැලි සාංවර්ධන සහ පරිසර අමාතයාංශය, 43 පළමු කලාපය XXVIII වෙළුම

The potential ecological consequences of predicted climate change on marine and coastal ecosystems in Sri Lanka.

Avishka Sendanayake
Janathakshan (Pvt) Ltd
avisedanayake@gmail.com

- Climate change is considered to be the most significant threat to humanity and the environment at present and for the foreseeable future.
- Island nations such as Sri Lanka are particularly vulnerable to climate change.
- Marine and coastal ecosystems provide an array of ecosystem services and this research looks at the potential ecological consequences posed on these ecosystems as a result of climate change.
- In addition, the importance of conservation is also highlighted in this article.

Introduction

Sri Lanka is an island in the Indian Ocean situated near the equator and it consists of a diverse variety of fauna and flora. Sri Lanka's biodiversity at present is facing the full force of predicted climate change. The current global increment in surface temperature is caused by the rapid increase of atmospheric carbon dioxide (CO_2) concentrations been emitted into the atmosphere, which can be initially attributed to the industrial revolution. If CO_2 concentrations exceed 500 CO_2 parts per million, the global average temperature will increase by 2°C from as latest as 2050 till 2100 (Guldberg, *et al.*, 2007). Understanding this prediction, it is difficult to ignore the reality of climate change impacts and the urgency required to tackle it before it has lasting affects on the natural system.

Habitat loss in addition to climate change is occurring on a global scale, resulting in a loss of species diversity. Tropical regions such as Sri Lanka (SL) are particularly under threat of losing more habitats if there is no legal action taken against deforestation and clearings. One of the main concerns in Sri Lanka is its vibrant coastal habitats which are most definitely being affected by climate change as a rise in sea level can inundate the ecosystems on the shorelines (Gates, 1993). The coast line of Sri Lanka is 1,585km and coral reefs cover an estimate of 2% of the coastline (Rajasuriya, *et al.*, 2002). Mangrove cover has a small percentage of 0.1 to 0.2 compared to the total land area of Sri Lanka (Karunatileka, 2003). Habitats along the coastal zones of the island are decreasing in size creating isolated fragments, these decreasing habitat spaces will constrict the options most species have in order to respond to changing climatic conditions (Shaw, *et al.*, 2010). This article will discuss the ecological consequences of predicted climate change in Sri Lanka in relation to coral reefs and mangroves.

Literature review

Coral reef ecosystems support a quarter of the fish species in the marine ecosystem (Parker, 2015). In Sri Lanka, there are known to be around 183 species of hard corals and these reefs provide habitats for 6 species of spiny lobsters and 5 species of sea turtles and dozens of ornamental fish species (Rajasuriya, *et al.*, 2002). The most concerning aspect of climate change is the warming of the earth's atmosphere, which has direct effects on the ocean and coastal species. For example, in 1998 an alarming quantity of coral reefs around the world, including the Indian Ocean faced mass coral bleaching events. Coral bleaching occurs when the coral is physically stressed causing the symbiotic algae that provides nutrition and colour to leave the coral, hence leaving it colourless or bleached (Reaser, *et al.*, 2000). However, this does not result in coral fatality but it does leave the corals vulnerable to destructive organisms or disasters. These events occurred as a result of the regionally specific El Nino and La Nina effects but certain researchers believe that it was also associated to global warming and rise in sea temperatures (Reaser, *et al.*, 2000). The recovery rate of the shallow (10 meters) coral reefs of Sri Lanka after the coral bleaching event was very poor and the increasing temperatures made it difficult for corals to re-establish as they are very sensitive to slight changes in sea temperature. If the coral reefs do not recover over time as a result of sea temperatures rising, most coral species will disappear and the reefs will break down as other predatory species such as sea urchins colonise. Loss of a reef would mean the loss of habitats for many fish species as a large number of them depend on reef structures for protection (Reaser, *et al.*, 2000).

Furthermore, another key issue is ocean acidification, which is a consequence of increased carbon dioxide emissions being absorbed into the sea, which inhibits the formation of calcium carbonate the substance responsible for coral skeleton growth (Guldberg, *et al.*, 2007). As coral reefs have a slow growth and can be sensitive to its surroundings if climate changes rapidly, the corals will not be able to respond to the new conditions in due time (Guldberg, *et al.*, 2007). If coral reef growth is inhibited through these processes mentioned above, all marine life depending on the reef for survival, food and protection will be driven towards extinction with the loss of a variety of different coral species in Sri Lanka.

Mangrove forests are another coastal habitat under threat in Sri Lanka, which can be categorised into two groups, known as true mangroves and associate mangroves. Both these groups of mangroves have more than 25 recorded species of flora and they are widely spread along the coasts of Sri Lanka (Karunathilake, 2003). Mangrove ecosystems in Sri Lanka also support a wide range of fauna; there are species that are confined to mangrove forests and others that can be found elsewhere. There is a variety of invertebrates that are confined to mangrove habitats such as gastropods and grapsid crabs and a few lobster species, refer to figure 01. There are around 150 species of fish but not all of them are specific to mangrove ecosystems. Around 100 species of resident and migratory bird species have been observed in mangroves forests of Sri Lanka as well as juvenile crocodiles and a few snake species (Karunathilake, 2003).

Further, climatic changes can have a challenging effect on the mangrove ecosystems as they generally occupy mid to high intertidal zones (Huxham, *et al.*, 2010). This means that mangrove forests in low tidal sites will be vulnerable to submersion as the sea level rises and the mangroves in high tidal zones will be threatened by the rising salinity of the sea water (Huxham, *et al.,* 2010). Mangroves therefore have a high likelihood of mortality if climate change continues to exacerbate. If mangrove ecosystems disappear, all the species depending on mangrove habitats will be driven towards extinction while populations of other species will potentially be under threat. It is important to state that the water purification function of mangroves protects coral reefs and therefore, if mangrove forests become limited, it would result in an increase in stress levels for coral growth (Barbier, *et al.*, 2011). Mangroves are also known to contribute to global carbon sequestration and if destroyed, would release large quantities of CO_2 into the atmosphere which will aid further global warming (Barbier, *et al.,* 2011).

Figure 01 - Grapsid crab species found in a mangrove forest in Sri Lanka by Avishka Sendanayake (2015).

Importance of conservation

In 2009, Mangroves for the Future (MFF) programme was initiated as the National Strategy and Action Plan for Sri Lanka. It was a partnership aimed at promoting investments towards the improvement of the coastal environment through conservation and sustainable development. Sri Lanka was selected as it suffered immensely from the 2004 tsunami, but mangrove ecosystems protected numerous parts of the island from being severely affected by the waves. MFF highlighted the importance of ecosystem services of coastal zones and ensured that by conserving the mangrove ecosystems, it would benefit coastal infrastructure development (SLNSAP, 2009). Sri Lanka was listed as the first nation set to conserve all of its mangrove forests in 2016 (Vyawahare, 2016). To educate the public and the new generation of Sri Lanka, the newly established Pambala Mangrove Conservation Forest and Museum provides information regarding mangrove flora and its associated fauna (Vyawahera, 2016). The Sri Lanka Mangrove Conservation Project was a five year project that costed $3.4million and it aims to protect the existing 8,815 hectares and restore 3,885 hectares of Sri Lanka's mangroves (Vyawahare, 2016). As of June 2019, this project has trained over 11,000 women and youth to conserve mangrove ecosystems and create livelihood opportunities (Seacology, 2020). Furthermore, micro-loans were received by 2,893 individuals for initiating or expanding sustainable businesses and achieving financial stability (UNCC, 2020). This type of conservation is essential for the survival of these ecosystems in regard to future predicted climate change impacts. For instance, if all the anthropogenic pressures are alleviated from the mangrove ecosystems, the possibility of mangroves to withstand global warming or changing salinity in sea water is inherently higher. The loss of mangroves currently is mainly due to deforestation for commercial purposes and climate change will be the secondary or future threat to mangrove ecosystems (Alongi, 2008).

Coral reefs are yet to be legally protected in Sri Lanka, there are efforts taken to minimise the threats to coral reefs to a certain extent through Marine Protected Areas (MPAs). The National Biodiversity Strategic Action Plan (NBSAP) was developed to address the need to protect our biodiversity, including coral reefs (NBSAP, 2016). Since this plan is from 2016 to 2022, there is time to improve protective measures for coral reefs. Furthermore, the fishing industry and other commercial marine life uses are very important to the economy of Sri Lanka, which means that loss of coral reefs would result in a decrease in fish populations. Therefore, increasing temperatures will have a negative effect on the economy which would force the government to take action to conserve the reefs on a national level. As stated by the National Oceanic and Atmospheric Administration (NOAA), 20 species of corals have been added to the endangered list as "threatened", with 15 species from the Indo-pacific region (Parker, 2015). Coral reefs play a significant part in carbon absorption within the sea and if lost could lead to further global warming.

Conclusion

In conclusion, Sri Lanka being a small island in the Indian Ocean is comprised of a diverse range of species especially within the coastal environment. It is evident from the literature available that the coral reefs and the mangroves worldwide are under threat from predicted climate change. However, there is a lack in literature available on climate change impacts specifically for the Sri Lankan coral reefs and mangroves. The information available from other regions can be used to predict or assume the effects that climate change would pose for Sri Lankan ecosystems. Both of the ecosystems discussed, are currently are under stress from anthropogenic activities but it can be predicted that an increase in the future carbon dioxide concentrations can have a damaging effect on the surviving corals and mangroves. These two ecosystems provide a wide range of benefits for other marine life and animals. Coral reefs provide numerous habitats for a variety of fish species and mangroves provide a unique environment for some gastropods and grapsid crabs. There are also resident and migratory birds that depend on species found in these two ecosystems as a food source. Therefore, it can be concluded that a loss of corals and mangroves in Sri Lanka can result in a large number of species being threatened by extinction due to habitat loss and availability of food as a consequence of climate change. If Sri Lanka effectively conserves coral reef and mangroves ecosystems there is a possibility for our coastal ecosystems to be more resilient to the anticipated climate change impacts. For Sri Lanka to protect the remaining coral reefs and mangrove ecosystems, comprehensive policies must be developed and implemented through relevant authorities, as these ecosystems are vital for the survival of local communities as well as marine and coastal biodiversity.

References

Alongi, D. M. (2008). Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. Estuarine, Coastal and Shelf Science , Vol. 76(1), 1-13.

Barbier, E. B. (2011). The value of estuarine and coastal ecosystem services. The Ecological Society of America , Vol. 81(2), 169-193.

Gates, D. M. (1993). Climate change and is biological consequences . Sunderland : Sinauer Associates, Inc.

Guldberg, H. O. (2007). Coral reefs under rapid climate change and ocean acidification. Science , Vol. 318(1737).

Huxham, M. K. (2010). Intra- and interspecific facilitation in mangroves may increase resilience to climate change threats. The Royal Society , Vol. 365(1549).

Karunathilake, K. (2003). Status of mangroves in Sri Lanka. Journal of Coastal Development , Vol. 7(1), 5-9.

NBSAP, (2016). National Biodiversity Strategic Action Plan 2016-2022. Retrieved: March, 10 2020. https://www.cbd.int/doc/world/lk/lk-nbsap-v2-en.pdf

Parker, L. (2015). As oceans heat up, a race to save world's coral reefs. Retrieved October 21, 2016, from National Geographic: http://news.nationalgeographic.com/news/2015/01/151015/coral-reef-death-climate-change-science-animals/

Perera, N. (2015). Coral reefs of Sri Lanka . Life Times Sri Lanka August 18.

Rajasuriya, A. Z. (2002). Status of coral reefs in South Asia: Bangladesh, India, Maldives, Sri Lanka. Research Gate .

Reaser, J. K. (2000). Coral Bleaching and Global Climate Change: Scientific Findings and Policy Recommendations. Conservation Biology , Vol. 14(5), 1500-1511.

Seacology (2019) Project Update Sri Lanka Mangrove Conservation Project. Retrieved March, 9, 2020, Seacology: https://www.seacology.org/project/sri-lanka-mangrove-conservation-project/.

Shaw, R. P. (2010). Climate change adaptation and disaster risk reduction: An asian perspective. Bingley: Emerald Group Publishing Limited.

SLNSAP, (2009). Mangroves for the Future, National Strategy and Action Plan. IUCN Sri Lanka Office. Colombo.

UNCC, (2020). Sri Lanka Mangrove Conservation Project | Sri Lanka. Retrieved: March, 9, 2020. United Nations Climate Change: https://unfccc.int/climate-action/momentum-for-change/planetary-health/sri-lanka-mangrove-conservation-project

Vyawahare, M. (2016). Sri Lanka set to become first nation to protect all mangroves. Retrieved October 22, 2016, from Mongabay: https://news.mongabay.com/2016/07/sri-lanka-set-to-become-first-nation-to-protect-all-its-mangroves/

காலநிலைமாற்றமும் அதற்கான சில பண்டையகாலத்து தீர்வுகளும்
(Some solutions to reduce the impact of climate change using Indigenous Knowledge)

S. Umasuthan
Central Environmental Authority
umasuthan.sm@gmail.com

- Climate change and its impacts in Sri Lanka.
- The use of Indigenous Knowledge to mitigate climate change impacts
- Traditional knowledge and examples of some activities which assist to reduce greenhouse gas emission into the environment.

“பூமி மனிதனுக்கு சொந்தமானதல்ல மனிதன் தான் பூமிக்கு சொந்தம்” என்று கூறப்படுவதுண்டு. ஆனால் மனித இனம் எல்லா காலகட்டத்திலுமே சொந்த நலனுக்காக பூமியை கட்டுப்பாட்டுக்குள் வைத்திருந்து அதன் இயற்கை வளங்களை சுரண்ட முயற்சி செய்துகொண்டிருக்கின்றது.

1750 ஆம் ஆண்டுகளில் உலகில் தொழில் புரட்சி தொடங்கிய காலத்திலிருந்து சுவட்டு எரிபொருட்களை மனிதன் அதிகமாக எரிப்பதன் மூலம் ஏற்படும் வாயுக்களால்தான் பருவநிலை மாற்றங்கள் ஏற்படுகின்றன என்று ஆராச்சிகள் கூறுகின்றன. இவற்றுடன் அபிவிருத்தியடைந்த நாடுகளின் பண்புகளான அதிகப்படியான தொழில்மயமாக்கல், காடழிப்பு, வணிகமயமான விவசாயம், மாறிவரும் உணவு முறைகள், அதிகமான வளங்களின் பயன்பாடு என்பனவும் முக்கியமான காரணிகளாகும்.

வாயு மண்டலத்தில் காபனீரொட்சைட் மற்றும் ஏனைய பச்சைவீட்டு வாயுக்கள் மேலெழுந்ததன் பிரதிபலனாக புவியின்மேல் வெப்பம் அதிகரிப்பதன் மூலம் காலநிலைமாற்றமடைவதால் ஏற்படும் பல்வேறுபட்ட தாக்கத்திற்கு முகங்கொடுக்க வேண்டியநிலை மனிதனுக்கு ஏற்பட்டுக்கொண்டுவருகின்றது. தீங்கு விளைவிக்கும் வாயுக்கள் மிக குறைந்த எண்ணிக்கையிலேயே வாயு மண்டலத்தில் இருப்பதோடு மனித நடவடிக்கைகளின் காரணமாக அது மிக விரைவாக அதிகரித்துக்கொண்டு வருகின்றது. இலங்கையிலிருந்து வாயு மண்டலத்திற்குச் சென்றடையும் பிரதான தீங்கு விளைவிக்கும் வாயுக்களில் காபன்டயொக்சைட்டு, மீதென், நயிட்றிஸ் ஒக்சைட், காபன்மொனொக்சைட், நைட்ரிஜன் ஒக்சைட் மற்றும் மீதென் அல்லாத ஆவியான சேதன திரவமும் அடங்கும்.

தீங்கு ஏற்படுத்தும் வாயுக்களை உற்பத்தி செய்யும் பிரதான முறைகளுக்குள் மின்சக்தியை உற்பத்தி செய்வதற்கான சுவட்டு எண்ணையின் எரிப்பு, கைத்தொழில் மயம் மற்றும் போக்குவரத்து முறைகள் பங்களிப்புச் செய்துள்ளது.

புவியில் ஏற்படும் காலநிலை மாற்றத்திற்காக எமது நாட்டின் பங்களிப்பு குறிப்பிடமுடியாத அளவிற்கு குறைவானாலும் தேசிய ரீதியாக பெரும்பாலான சுற்றாடல் தாக்கங்கள் நடைபெறலாம். காலநிலை மாற்றத்தினால் இலங்கைக்கு ஏற்படக்கூடிய

தாக்கங்களுக்கிடையில் கடல்மட்டம் உயருதல், குறைவான காலத்தினுள் கூடியளவான மழை வீழ்ச்சி, நீண்ட காலவரட்சி, சூழல் வெப்பநிலை அதிகரித்தல்போன்றன பிரதானமானவையாகும்.

இவற்றின் காரணமாக இலங்கையில் அமைந்துள்ள களப்பு, நதி, வாவிகளும், கண்டல்கள் சுற்றாடலும், வன கடற்கரை பிரதேசங்களும் காலநிலை மாற்றத்தால் அழிவிற்கும், சுற்றாடல் எழில் மாற்றத்திற்கும் உண்டாகின்றன. தற்பொழுது பிரதானமாக முருகைக்கற்பாறைகள் கூடிய அளவு வெப்பநிலையில் அழிவடைந்து வருவதோடு, கடல் நீரின் வெப்பநிலை மேலும் அதிகரித்து வருவதால் அவற்றின் மீள்உருவாக்கமும் குறைவடைந்து வருகின்றது. நீர்த்தாழை சுற்றாடல் தொகுதியும் கடல்மட்டம் உயர்வதால் தாக்கத்திற்கு உள்ளாவதோடு, அதனால் கடல் ஜீவிகளின் எண்ணிக்கையும் குறைகின்றது. அதற்கு மேலாக கடல் மட்டம் உயர்வதால் நதிகளினூடாக கடல் நீர் நாட்டிற்குள் அடித்துச் செல்லப்படுவதால ˙மண்ணின் உவர்ப்புத்தன்மை அதிகரிக்கின்றது.

குறுகிய காலத்திற்குள் கூடிய மழைவீழ்ச்சி ஏற்படுவதால் மலையகப்பிரதேசங்களில் மண்சரிவு ஏற்படுவதுவும், அதனூடாக பவ்வேறு அனர்த்தங்கள் ஏற்படுவதுவும், கடல்அரிப்பினால் மேட்டு நில அளவு குறைதலும் ஏற்படும்.

மேலும் காலநிலை மாற்றத்தால் விவசாயத்திற்கு அச்சுறுத்தல் ஏற்படுவதன் மூலமாக உணவு உற்பத்தி குறையும். அத்துடன் புவியின் வெப்பநிலை அதிகரிப்பதால் மக்களின் சுகாதார சம்பந்தமான அச்சுறுத்தல்கள் ஏற்பட ஏதுவாவதோடு பல்வேறு நோய்களின் பரம்பலும் ஏற்றாடுகின்றது. மேவதிகமாக இயற்கை அனர்த்தங்களான வெள்ளம், மண்சரிவு மற்றும் சூறாவளி போன்றவற்றாலும் உயிர்களுக்கும் சொத்துக்களுக்கும் சேதம் ஏற்படுகின்றது.

காலநிலை மாற்றத்திற்கு ஏதுவான காரணிகளை குறைப்பதற்கான, அவற்றால் ஏற்படும் பாதிப்புக்களை குறைப்பதற்கான மாற்று நடவடிக்கைகள் பல தற்காவத்தில் முன்மொழியப்பட்டாலும், பண்டைய காலத்தில் நடைமுறையிலிருந்த பல நடவடிக்கைகள் இலகுவானதாகவும் வினைத்திறனுள்ளவையாகவும் காணப்படுகின்றன.

வலுச்சக்தியை உற்பத்தி செய்யும்பொழுது தீங்கு ஏற்படுத்தும்வாயுக்கள் சுற்றாடலை சென்றடைவதற்காக இலங்கையில் பிரதானமாக பங்களிப்புச் செய்வது சுவட்டு எரிபொருளான பெற்றோலிய உற்பத்தியும் சம்பிரதாய பூர்வமான உயிரிய எரிபொருளுமேயாகும். எனினும் பண்டைய காலத்திலே அடிப்படை எரிசக்திப்பொருட்களாக விறகுகள், விவசாயக்கழிவுகள் மற்றும் சாணம் போன்றனவே அதிகமாகப்பயன்படுத்தப்பட்டன. இவற்றின் பயன்பாட்டின்போது குறைந்தளவான பச்சைசீட்டுவாயுக்களே சூழலுக்கு விடுவிக்கப்பட்டன. அத்துடன் விறகு எரிப்பு இலங்கையில் குறிப்பிடககூடிய வலுச்சக்தி பாவனையாக இருந்ததோடு அது காபன்டயொக்சைட்டை வெளியிடும்பொழுது பாரிய அளவில் பங்களிப்புச் செய்யாமைக்கு காரணமாவது, தாவரங்களை வளர்க்கும்பொழுது மீண்டும் காபன்டயொக்சைட் வாயுவை அவை உள்ளெடுப்பதாலேயே ஆகும்.

காபன்டயொக்சைட் வெளியேற்றும் பிரதான மார்க்கம் போக்குவரத்து துறையாதலால், அதற்கு பெற்றோல் மற்றும் டீசல் போன்ற எரிபொருட் தகனம் பங்களிப்புச்செய்கின்றது. இலங்கையில் போக்குவரத்தில் ஈடுபடுத்தப்பட்டுள்ள வாகனங்களில் எண்ணிக்கை வேகமாக அதிகரித்து வருவதே இதற்கு காரணமாகியுள்ளது. எனினும் பண்டைய காலத்திலே பொதுப்போக்குவரத்து முறையே அதிகளவில் பொதுமக்களால் பயன்படுத்தப்பட்டது. அத்துடன் மிதிவண்டிகளின் பாவனையும் அதிகமாகவே காணப்பட்டன. விசேட தேவைகளிற்கு மட்டுமே மோட்டார் வண்டிகளும், மோட்டார் கார்களும் பயன்படுத்தப்பட்டன. இதனால் தனி ஒரு மனிதனால் சூழலுக்கு வெளியேற்றப்படும் காபனின் அளவு மிகக் குறைவாகவே காணப்பட்டது.

நவீனயுகத்தில் குறைந்த காலத்தில் அதிக விளைச்சலை நோக்கியதாகவே விவசாயமுறைகள் காணப்படுகின்றன. எனினும் பண்டைய காலத்திலே விளைச்சலை விடவும் அப்பிரதேசத்திற்கு உகந்த பயிரினங்களே அதிகம் பயன்படுத்தப்பட்டன. இவற்றின் விளைச்சல் ஒப்பீட்டளவில் குறைவாகக்காணப்பட்டாலும் அவற்றின் வினைத்திறன் அதிகமாகவே காணப்பட்டது. அதாவது குறைந்தளவிலான நீர், பசளை என்பன இவற்றிற்கு போதுமானதாகக் காணப்பட்டதுடன் இவை காலநிலை மாற்றம், உவர்த்தன்மையான மண் என்பவற்றை தாங்கிக்கொள்ளக்கூடியனவாக இருந்தன.

தற்காலத்தில் குழாய்க்கிணறுகளே அதிகளவில் பயன்னடுத்தப்படுவதுடன் வலுகூடிய மோட்டர்களைப்பயன்படுத்தி நிலத்தடிநீரானது அதிகளவில் உறிஞ்சப்படுகின்றது. இவையும் நிலத்தடிநீர்மட்டம் குறைவடைதல், நீர் உவர்த்தன்மையாதல் என்பவற்றிற்கு முக்கிய காரணிகளாகும். எனினும் முற்காலத்திலே குளாய்க்கிணறுகளுக்குப்பதிலாக தோண்டப்பட்ட

கிணறுகளே அதிகம் பயன்னடுத்தப்பட்டன. அத்துடன் நீர்ப்பாசனத்திற்கும் மோட்டர்களுக்குப்பதிலாக கப்பிகளும், துலாக்களுமே அதிகளவில் பயன்படுத்தப்பட்டன. இவற்றினால் அதிகளவான நிலத்தடி நீர் உறிஞ்சுகை தடுக்கப்படுவதுடன், இதன்காரணமாக கடல்நீரின் (உவர் நீர்) உள்நோக்கிய வருகையும் தடுக்கப்படுகின்றது.

இவற்றைவிட திண்மக்கழிவுகள் தற்காலத்தில் ஒரு பெரும்பிரச்சனையாகக்காணப்படுகின்றது. குப்பை மேடுகளிலிருந்து சூழலுக்கு வெளியேற்றப்படும் மெதேன் போன்ற வாயுக்களின் அளவானது கால்நடைப்பண்ணைகளிலிருந்து வெளிவரும் வாயுக்களின் அளவைவிட மிகவும் அதிகமாகும். எனினும் முற்காலத்திலே வீட்டிலிருந்து சூழலுக்கு வெளியிடப்படும் கழிவுகளின் அளவு மிகவும் குறைவாகவே காணப்பட்டது. பொலித்தீன், பிளாஸ்ரிக்கின் பாவனை மிகக்குறைவாகவே இருந்தது. பாவனையிலிருந்த பொருட்களும் அதிகமுறை மீள்சுழற்சிக்குட்படுத்தப்பட்டன. அத்துடன் உணவுக்கழிவுகள், தாவரப்பகுதிகள் என்பன பெருமளவில் கூட்டுப்பசளை தயாரிப்பில் பயன்படுத்தப்பட்டன. இவை விவசாயநிலங்களுக்கும், வீட்டுத்தோட்டத்திற்கும் உரமாகப்பயன்படுத்தப்பட்டன. இவ் சேதனப்பசளைகள் மண்ணின் தன்மையை பேண உதவுவதுடன் மண்ணில் நீர் நிலைத்து நிற்கவும் உதவுகின்றன. அத்துடன் விவசாயத்தில் கூடிய சந்தர்ப்பங்களில் சேதனப்பசளைகளும், இயற்கைப்பீடைகொல்லிகளும் பயன்னடுத்தப்பட்டமையால் அவற்றால் ஏற்படுத்தப்படும் பக்கவிளைவுகளும் குறைவாகவே காணப்பட்டன.

நீர் முகாமைத்துவம் என்பது புராதன காலத்திலே மிகச்சிறப்பாகவே காணப்பட்டது. குளங்கள் சிறப்பாக பராமரிக்கப்பட்டன. இதன்காரணமாக மேலதிக மழைநீர் கடலைச்சென்றடைவது தடுக்கப்பட்டதுடன் வெள்ளப்பெருக்கு ஏற்படுவதும் பெருமளவில் தவிர்க்கப்பட்டது. இதனால் கோடை காலங்களில் நீருக்கான தட்டுப்பாடு குறைக்கப்பட்டதுடன் நிலத்தடி நீர் வளமும் உவர்த்தன்மையாகாது பாதுகாக்கப்பட்டது. அத்துடன் எளிமையாக வடிகட்டி, (துணி போன்றவற்றைப்பயன்படுத்தி) வீட்டுமட்டத்தில் பீலிகளைப்பயன்படுத்தியும் திறந்த வெளியிலும் மழைநீரானது சேமிக்கப்பட்டது. இதுபோன்ற நடவடிக்கைகளால் காலநிலை மாற்றத்தின் நீரின் மீதான பல எதிர்மறையான விளைவுகள் பெருமளவில் குறைக்கப்பட்டன.

இதுதவிர வீடுகள் அமைக்கப்படும் போது காலநிலை மாற்றத்தால் ஏற்படும் விளைவுகள் அதிகளவில் கருத்தில் கொள்ளப்பட்டே வீடுகள் அமைக்கப்பட்டன. அனேகமான வீடுகள் கிழக்கு நோக்கியே அமைக்கப்பட்டிருந்தன. இதனால் காலையில் வெப்பநிலை குறைந்த சூரிய ஒளி வீட்டினுள் சென்றாலும் மதிய நேரத்தில் நேரத்தில் வெப்பநிலை கூடிய கதிர்கள் உட்செல்வது தடுக்கப்பட்டது. அத்துடன் வெப்ப அரிதிற் கடத்திகளான சுண்ணாம்புக்கற்களும், மணற்கற்களும் வீடமைப்பின்போது பயன்னடுத்தப்பட்டன. இவை வீட்டினுள்ளே குளிர்ச்சியான வெப்பநிலையைப்பேண உதவின.

தொழில்நுட்ப வளர்ச்சியும் நகரமயமாக்கலும் நிறைந்த இக்காலப்பகுதியில் காலநிலைமாற்றத்திற்கெதிரான தீர்வாக பல விடையங்கள் முன்வைக்கப்பட்டாலும் தற்போதுள்ள தொழில்நுட்பம் மற்றும் நிதிக்கப்பாற்பட்ட தீர்வுகளே இன்னும் தேவைப்படுகின்றன. எனவே நம் முன்னோர்களுடைய நல்லெண்ணங்களையும், செயற்பாடுகளையும் பின்பற்றி புதிய உற்சாகத்தோடு நடைமுறைப்படுத்தவேண்டிய காலமிது.

References

Vinod Kumar (2014) Role of Indigenous Knowledge in Climate Change Adaptation Strategies: A Study with Special Reference to North- Western India. J Geogr Nat Disast 5: 131.

Nyong, A., Adesina , F. & Osman Elasha, B. (2007). The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. Mitig Adapt Strat Glob Change (2007) 12:787–797.

Theobald Frank Theodory (2016). Dealing with Change: Indigenous Knowledge and Adaptation to Climate Change in the Ngono River Basin, Tanzania.PhD Thesis.Faculty of Mathematics and Natural Sciences of the Rheinische Friedrich-Wilhelms-University of Bonn, xvi+225pp.

வீட்டு பராமரிப்புகளில் தூய காற்றும் ஆரோக்கிய வாழ்வும்
(Clean air in homes will ensure a healthy life)

Sivakumar Myilvaganam
Central Environment Authority
sivakumar@cea.lk

- Indoor air quality and its main sources and health impacts.
- The effects of several important ambient air pollutants such as smoke, radon. Formaldehyde, carbon dioxide, carbon monoxide, volatile organic compounds, molds and allergens, algae and asbestos fiber.
- Management of indoor air pollution including the best practice and the easiest method for managing indoor air quality.
- Several plant species has the ability to absorb air pollutants and such kind of plants can be placed inside homes or office premises to improve the quality of indoor air.

தீவிர அபிவிருத்தி நடவடிக்கைகளினால் உலகில் வளி மாசடைதல் தொடர்ந்து அதிகரித்துவரும் போக்காக அறிக்கையிடப்பட்டுள்ளதுடன் வளிமண்டலத்திற்கு விடப்படும் வெளிவிடுகைகளை கட்டுபடுத்துவது மக்களை உலகளாவிய ரீதியில் கண்திறக்கச் செய்துவருகின்றது. கடந்த தசாப்தங்களில் வளி மாசடைதலுக்கு எதிராக உலகளாவிய ரீதியில் செயற்பட பல நாடுகளும் சர்வதேச நிறுவனங்களும் தனிப்பட்ட முறையின் பல ஒப்பந்தங்களையும், உடன்படிக்கைகளையும், ஒழுங்குவிதிகளையும் உருவாக்க நடவடிக்கைகளை எடுத்துள்ளன.சுற்றுப்புற வளியின் தரம் என்பது அதன் முக்கியம் மற்றும் உள்ளார்ந்ததன்மையை கருத்திற்கொள்ளாது கைவிடப்பட்ட நிலைமையில் காணப்படுவதுடன் உலகளாவிய ரீதியில் வளித்தர முகாமைத்துவ வேலைத்திட்டத்தில் சுற்றுப்புற வளித்தர முகாமைத்துவம் ஒரு முக்கிய அம்சமாக கருதப்படுகின்றது. சமகால விஞ்ஞான அறிவு உணர்த்தியவாறு சுற்றுப்புற வளித்தரத்தை விட கெட்ட உட்புறக் காற்றின் உள்வாங்குகையினால் மக்கள் அதிகமாகப் பாதிக்கப்படுகின்றனர் அத்துடன் உலகளாவிய ரீதியில் நெருக்கடியான நகரக்குடியிருப்புகளில் இவ் நிலைமை விரும்பத்தகாத மட்டத்தில் காணப்படுகின்றது.

நவீன கட்டுமான கட்டிடக்கலை கட்டடங்களின் சக்தி வினைத்திறனையும் அதன் கூறுகளையும் உச்சப்படுத்துவதில் அதிக கவனம் செலுத்திவந்துள்ளதுடன் இது கட்டிடங்களுள் சுவாத்தியமான வெப்பநிலை மற்றும் ஈரப்பதனை அளிக்கும் சொகுசுத்தன்மையைய வழங்க காவலிடப்பட்ட கட்டிடங்களை வடிவமைப்பதில் கவனம் செலுத்தத் தவறவில்லை. இவ் முயற்சிகளினால் கட்டிடங்களினுள் புதிய காற்று உட்புகும் அளவும் கெட்ட காற்று வெளியில் செல்லும் அளவும் குறைந்து சுவாத்தியமான காற்றுச் சுற்றோட்டம் பாதிப்படைகின்றது.

பொதுவாக சுற்றுப்புறக் காற்றை விட உட்புறக் காற்றை நாம் கூடுதலாக சுவாசிப்பதால் மனிதவாழ்வின் தரத்தை அடைய உட்புறக் காற்று மாசைதலை ஒழிக்கும் வழிமுறைகளை உள்ளடக்கியதான உட்புற வளித்தரம் அதன் மாசடைதல் தன்மை மற்றும் கெட்ட உட்புற வளித்தரத்தினால் ஏற்படும் சுகாதாரப் பாதிப்புக்கள் விடயமான பூரண அறிவை நாம் கொண்டிருத்தல் அவசியம்.

உட்புற வளித்தரம் என்பது வீடுகள், கட்டிடங்கள் மற்றும் முறையற்ற விதமாக காற்றூட்டப்பட்ட பிரதேசங்கள் மற்றும் வீடுகளின் படுக்கையறை தொடக்கம் வாகன தரிப்பிடங்கள் வரை மற்றும் அலுவலங்களின் நியமிக்கப்பட்ட பிரதேசங்கள் தொடக்கம் வாகன தரிப்பிடங்கள் வரை சகல பகுதிகளுக்குள் காணப்படும் காற்றின் தரம் ஆகும். உட்புற வளி மாசடைதல் என்பது இரசாயன, பௌதீக மற்றும் உயிரியற் காரணங்களினால் வளி மாசாக்கிகள் உட்புறத்தில் சேர்வதனைக் குறிக்கும். உயிர் எரிபொருட்களின் தகனத்தின்போது விடப்படும் வெளிவிடுகைகள், புகைத்தலின்போது வெளிவிடப்படும் இரசாயனங்களும் புகைக்கரியும் மற்றும் சல்பர் டைஓட்சைட், கார்பன் மொனோஓட்சைட், போர்மல்டிஹைட்,ரேடன், சேதன ஆவிகள், பூஞ்சணம், பக்டீரியா மற்றும் அஸ்பெஸ்ரஸ் இழைகள் என்பன உட்புற வளி மாசடைதலைத் தோற்றுவிக்கும் இரசாயனங்கள் மற்றும் மாசாக்கிகள்என அடையாளப்படுத்தப்பட்டுள்ளது.

பெரும்பாலான உட்புறச் சுற்றாடலில் ஒன்றுக்கு மேற்பட்ட வளி மாசாக்கிகள் உள்ளதால் அந்த உட்புறச் சுற்றாடலில் உள்வாங்குகைக்கு ஏதேனும் ஆட்கள் உட்படும்போது அதுஅவர்களில் சுகாதாரப் பாதிப்புக்களை உருவாக்கும் மற்றும் சிலவேளைகளில் மாசாக்கிகளின் வகை மற்றும் செறிவு காரணமாக சிக்கலான சுகாதார நிலைமைகள் ஏற்படுவதற்கான சாத்தியங்கள் காணப்படுகின்றது.திருப்தியற்ற உட்புற வளித்தரத்தைக் கொண்ட வீடுகள் மற்றும் கட்டிடங்களில் வாழும் மக்களிடம் ஆட்களின் இனப்பெருக்கத்திறனை சிதைக்கும் "நோய்க் கட்டிட அறிகுறியினால்" மக்கள் அவதியுறுகின்றனர். உலக சுகாதார ஸ்தாபனத்தின் புள்ளிவிபரத்தின்படி உலகத்தில் தீங்கான உட்புற வளித்தரத்தின் காரணத்தினால் அண்ணளவாக 3.8 மில்லியன் மக்கள் சென்ற வருடத்துள் இறந்துள்ளதுடன் இதனால்இலங்கையில் சென்ற வருடத்துள் 4,300 இறப்புக்கள் பதிவாகியுள்ளது.

பல உட்புற வளி மாசாக்கிகளினால் ஏற்படும் முக்கிய தாக்கங்கள் மற்றும் பாதிப்புக்கள் பற்றி கீழே விபரிக்கப்பட்டுள்ளது.

1. புகை

உலக சுகாதார ஸ்தாபனத்தின் தரவுகளின்படி உலகில் 3 பில்லியன் மக்கள் அதாவது உலக சனத்தொகையின் அரைவாசியினர் சமைத்தலுக்கு மற்றும் வீடுகளை சூடேற்ற பிரதான உயிர்த்திணிவுகளான உமி, மரத்தூள் மற்றும் மரக்கரியை எரிபொருளாகப் பாவித்து தங்களது சாதாரணமான சமைத்தல் மற்றும் வீடுகளைச் சூடேற்றும் நடவடிக்கைகளை பூர்த்தி செய்கின்றனர். உலக அளவிலும் இலங்கையிலும் வினைத்திறனற்ற சாதாரண அடுப்புகள் உட்புற வளி மாசடைதலுக்கான ஒரு பிரதானமான மூலமாக காணப்படுகின்றது. நாடுகள் தோறும் 78% இற்கு மேற்பட்ட குடும்பங்கள் உயிர்த்திணிவான விறகைப் பாவித்து எரிப்பதுடன் இவற்றில் 84% ஆன குடும்பங்கள் கிராமப்புறமாகவும்34% ஆன குடும்பங்கள் நகரப்புறமாகவும் காணப்படுகின்றது.

அண்ணளவாக 65% ஆன சமையலடுப்புகள் வீட்டின் உட்புறத்தில் அமைக்கப்பட்டிருப்பதுடன் 9% ஆனவை சமையலுக்கு நியமிக்கப்பட்ட பிரதேசத்திலோ அல்லது கட்டிடத்திலோ அமைக்கப்படுள்ளதால் பரவலாக சமையலறையினுள் ஏற்படும் வளி மாசடைதலின் பாதிப்புகளுக்கு இல்லத்தரசிகள், சிறுவர்கள், முதியோர்கள் என்பனர் பலியாகின்றனர். உட்புற வளி மாசடைதலின் தீவிரத்தைக் குறைக்க பொதுவாக 72% ஆன சமையலடுப்புகள் புகைபோக்கியுடன் தொடுக்கப்பட்டுள்ளது.பல வீடுகளில் இல்லத்தரசிகள் இலகுவில் பற்றக்கூடிய மண்ணெண்ணெய், பொலித்தீன் மற்றும் பிளாஸ்டிக் பொருட்களை நெருப்பு பற்றவைக்க பயன்படுத்துவதால் உட்புற வளித்தரம் வெகுவாக கெடுகின்றது.இதன் புகையில் சிறிய நச்சுத் பதார்த்தங்களான கார்பன் மொனோஓட்சைட், நைதரசன் ஓட்சைட், சல்பர் டைஓட்சைட்,போர்மல்டிஹைட்,டையொக்சின் மற்றும் பியுரோன் போன்றவற்றின் உள்வாங்குகையினால் மனித சுகாதாரம் பாதிப்படையும்.பிந்திய ஆய்வறிக்கையின்படி ஒரு விறகு அடுப்பங்கரையிலிருந்து வெளிவிடப்படும் புகையின் தாக்கம் 75 தொடக்கம் 150 வரையிலான சிகரட்டுக்களின் தாக்கத்திற்குச் சமனாகும்.

மேலதிகமாக நுளம்புச்சுருளை பற்றவைத்தல் உட்புற வளிமாசடைதலில் பாரியளவு பங்களிப்பினை வழங்குகின்றது. மருத்துவ நிபுணர்களின் ஆய்வின்படி ஒரு நுளம்புச்சுருளை எரிப்பதால் ஏற்படும் வளி மாசாக்கல் 135 சிகரட்டுக்களைப் பற்றவைப்பதால் ஏற்படும் வளி மாசாக்கலுக்குச் சமனாகும்.அதேபோன்று ஊதுபத்தி, சாம்பிராணி என்பனவற்றை பற்றவைப்பதால் உட்புற வளி மாசடைதல் ஏற்படுகின்றது. பிந்திய புள்ளிவிபர அறிக்கையின்படி இலங்கையில் நுளம்புச்சுருளின் மாதாந்த விற்பனை 6 மில்லியன்

ரூபா மற்றும் ஊதுபத்திகளின் மாதாந்த விற்பனை 30 மில்லியன் ரூபா ஆகும்.

வீடுகளுக்குள்ளோ அல்லது அலுவலக வளவுகளிலோ முனைவற்ற புகைபிடித்தலினால் புகையை உள்வாங்குனர்கள் யாருமில்லாவிடினும் புகைத்தலினால் உட்புற வளி மாசடைதல் ஏற்படுகின்றது. ஆய்வாளரின் கருத்துப்படி சிகரட் புகையில் 39 வகையான மாசாக்கிகள் காணப்படுவதாகவும் இவை மனித சுகாதாரத்தைப் பாதிப்பதுடன் ஒரு சிகரட்டிலிருந்து 5 ட்ரில்லியன் (5×10^{12}) நுண்துணிக்கைகள் வெளிவிடப்படுவதுடன் இதில் 5μப அளவு பொலிசைக்கிளிக் அரோமற்றிக் ஐதரோகார்பன் உட்புற வளிக்கு விடப்படுகின்றது.இவ் நுண்துணிக்கைகள் 81% ஆன உயர்ந்த வீதத்தைக் கொண்டுள்ளது.செயலிலுள்ள புகைபிடித்தல் போன்றே முனைவற்ற புகை உள்வாங்குகையும் இதய மற்றும் சுவாசப்பைப் புற்று நோய்களுக்கு காரணமாகின்றது.

விறகடுப்பு மற்றும் சிகரட் என்பவற்றின் குடிமனை தகனச் செயன்முறையின் தகன வெப்பநிலை ஒப்பீட்டளவில் குறைவு ஆகையால் ஒப்பீட்டளவில் குறைந்த அளவுமேழுஉருவாக்கப்படுகின்றது.ஒப்பீட்டளவில் அதிகஅளவிலானபொலிசைக்கிளிக் அரோமற்றிக் ஐதரோகார்பன் புகையிலைப் புகை மற்றும் விறகடுப்பில் வெளிவிடப்படும் புகையின் திண்மப் பதார்த்தங்களில் காணப்படுவதுடன் இவற்றுள் நாப்தலீன், அந்ரசின், பெனந்திரின் என்பன புற்றுநோயயை உருவாவதைத் தூண்டுபவை ஆகும். புகை மூச்சுக்குழாய் எரிச்சல், வீக்கம் மற்றும் தொடுக்கப்பட்ட இழையங்கள் தடிப்பாதல், வடுவாகுதல் (Fibrosis) என்பவற்றை தோற்றுவிப்பதுடன் இது மூச்சுத்திணறல், அதிகரித்த ஆஸ்த்மா, கட்புரை, சுவாசத்தொற்று மற்றும் நாள்பட்ட நுரையீரல் அடைப்பு நோய் (COPD) என்பனவற்றிற்கு வழிவகுக்கும்.

2. ரேடன் வாயு (Rn)

ரேடன் (Rn, Z = 86) என்பது ரேடியம் (Ra, Z = 88) இன் சிதைவினால் உருவாகும் உன்னதமான நிறமற்ற வாயு ஆகும்.ரேடனில் இருபது வகையிலான சமதானிகள் காணப்படுவதுடன் இது கதிரியக்கத்தை ஏற்படுத்துபவை இவற்றின் α சிதைவினால் பொலொனியம் உருவாக்கப்பட்டு இறுதியில் ஈயமாக மாறும்.

ரேடன் தாக்கமடையாத மற்றும் முனைவற்ற வாயு ஆகையால் நாம் உள்ளிழுக்கும்போது நுரையீரலில் சிக்காது. ரேடன் மற்றும் இதன் மகள் உற்பத்திகள் இரண்டையும் உள்ளிழுக்கும்போது பிரிகையடைந்து α துகள்களை விடுவிப்பதுடன் நுரையீரலின் தண்டு உயிரணுக்களுடன் தொடர்புபட்டு புற்றுநோயைத் தோற்றுவிக்கும்.

ரேடனின் பிரதான மூலங்கள் வீடுகளிலுள்ள கனிமங்கள் மற்றும் கட்டுமானங்களுக்கு பயன்படுத்தப்படும் கனிம உற்பத்திகளான மண் மற்றும் கருங்கல் ஆகும். அனைத்து மண் மற்றும் கருங்கல்லில் கிள்ளுமளவு ரேடியம் காணப்படுவதுடன் இது சிதைந்து ரேடன் வளிமண்டலத்திற்கு வெளிவிடப்படுகின்றது.ரேடனின் அடுத்த பிரதான மூலம் நிலத்தடி நீர், இது சிறு அளவு யுரேனியம;(U, Z = 92), தோரியம்(Th, Z = 90), ரேடியம்(Ra, Z = 88) என்பனவற்றைக் கொண்ட நிலத்தடிப்பாறைகளின் சமநிலைப்படுத்தலினால் உருவானது. நிலத்தடிப்பாறைகளின் சமநிலைப்படுத்தலினால் நீருக்கு சிறு அளவு ரேடியம் சேர்கின்றது.

3. போர்மல்டிஹைட்

போர்மல்டிஹைட் ஐக் கொண்டிருக்கும் பிசின்கள் ஒட்டுப்பலகை, துகள்ப்பலகை மற்றும் கண்ணாடி இழை காவலித் தயாரிப்புகளில் அதிகம் பயன்படுத்தப்படுகின்றன.இதன் பாரம் குறைந்த தன்மையினால் இலவுகாகக் கையாளலாம் என்பதனால் இது வீட்டு மற்றும் அலுவலகக் கட்டுமானங்கள், காவலிப்படுத்தல் மற்றும் உட்புறச் சுற்றாடலில் பரவலாக பயன்படுத்தப்பட்டுவருகின்றது.பல்பகுதியம் நீரேற்றப்படும்போது சுயாதீனபோர்மல்டிஹைட் வெளிவிடப்படும் என்பதுடன் நீரேற்றும் செயன்முறையை அமிலத்தன்மை மற்றும் ஈரப்பதன் துரிதப்படுத்தும்.

போர்மல்டிஹைட்வாயு எரிச்சலூட்டும் மணத்தினை கொண்டிருப்பதுடன் போர்மல்டிஹைட்உள்வாங்குகையின் அறிகுறி குணாதிசியங்களாக அயர்வு, குமட்டல் மற்றும் தலையிடி, சுவாசக் குறைபாடு என்பவற்றைக் கொள்ளலாம்.இதன் செறிவையும் எதிர்மறைப் பாதிப்புக்களையும் குறைக்க சிறந்த செயன்முறைகளாக கருதப்படுவது அதிக காற்றோட்டமும் மற்றும் காற்றுச் சுழற்சியும் ஆகும்.

4. கார்பன் டைஓட்சைட்

கார்பன் டைஓட்சைட் என்பது வளி மாசாக்கியாக அல்லது தீங்கு விளைவிக்கும் வாயுவாக கருதப்படாவிடினும் இதன் அதிக செறிவு உள்வாங்குகை மூச்சுத்திணறலை ஏற்படுத்தும்.காற்றுப்புகாத கட்டிடங்களில் வேலை செய்யும் தொழிலாளர்கள் அடிக்கடி தங்களுக்கு சோர்வு மற்றும் கவனம் செலுத்த இயலாமை போன்ற அறிகுறிகள் ஏற்படுவதாக புகார் செய்கின்றனர் எனினும் காற்றோட்ட வீதத்தை அதிகரித்தல் மற்றும் புதிய காற்றை உளவாங்குவதால் இவ் அறிகுறி குறைவடையும்.

5. கார்பன் மொனோஒட்சைட்

கார்பன் மொனோஒட்சைட் என்பது குறைந்த செறிவில்தீங்கு விளைவிக்கும் வாயுஇதன்காரணம் இதுகுருதிச் செங்கல ஈமோகுளோபினுடன் மீளாத்தன்மையாக தாக்கம்புரிந்து கார்பொக்சிஈமோகுளோபினைத் தோற்றுவிப்பதால் செங்கல ஈமோகுளோபினை குறைவடையச் செய்கின்றது. ஓட்சிசனுக்கும்ஈமோகுளோபினுக்கும்இடையிலான பிணைப்பின் பலத்தைவிட இப் பிணைப்பு 200 ‘ 300 மடங்கு பலமானது.இது ஈமோகுளோபின்இ ஒட்சிசன் எடுத்துக்கொள்வதினை தடுக்கும்.ஆய்வாளர்களின் கண்டுபிடிப்புகளின்படி இவ் வாயுவின் 10 ppmv செறிவு சராசரி மனிதனின் ஈமோகுளோபினில் 2% ஐசெயலிழக்கச்செய்யும், இதன் 100 ppmv செறிவு 15% இனை செயலிழக்கச்செய்யும். இலேசான கார்பன் மொனோஒட்சைட்செறிவுநஞ்சூட்டலினால் ஏற்படும் அறிகுறிகள் தலைவலி, சோர்வு மற்றும் குறைந்த உசார்த்தன்மை ஆகும், அதிககார்பன் மொனோஒட்சைட்செறிவின் உள்வாங்குகையினால் ஆள் இறக்கலாம்.

வழக்கமான மாதிரியிலான மண்ணெண்ணெய் மற்றும் விறகடுப்புகள், நுளம்புச்சுருள்கள் மற்றும் ஊதுபத்திகளை பற்றவைத்தல் மற்றும் புகைபிடித்தல் என்பன கார்பன் மொனோஒட்சைட்டை பிறப்பிக்கும் உட்புற மூலங்களாகக் கருதப்படுவதுடன் வீடுகளுடன் இணைக்கப்பட்டுள்ள வாகனத் தரிப்பிடங்களில் நிறுத்தப்பட்ட இயந்திரங்களும் இவ் வாயுவை விடுவிக்கின்றது. உயர்ந்த தொடர் மாடிக்கட்டிடங்கள் மற்றும் அலுவலகத்தொகுதிகளின் அடித்தளத்தில் பாரிய வாகன தரிப்பிடங்கள் காணப்படுவதுடன் இவற்றில் காற்றோட்டம் நலிவடைந்துள்ளதுடன் காற்றுச் சுழச்சி அளவிடப்படுவதில்லை எனவே இவற்றினால் அருகாமையிலுள்ள பிரதேசத்தில் வாழும் மக்களுக்கும் அன்றாட அலுவல்களுக்கு வரும் மக்களுக்கும் அசௌகரியங்கள் ஏற்படுகின்றது. மேலும் அவசியம் ஏற்படும்போது மின்சாரத்தைப்பெற வீடுகளுக்குள்ளும் கட்டிடங்களுக்குள்ளும் மின் பிறப்பாக்கிகள் ஸ்தாபிக்கப்பட்டுள்ளதுடன் இவற்றின் புகையில் காணப்படும் கார்பன் மொனோஒட்சைட்டை சுவாசிப்பதால் மரணங்கள் சம்பவிக்கலாம்.

6. எளிதில் ஆவியாகக்கூடிய சேதனப் சேர்வைகள் (VOC)

எளிதில் ஆவியாகக்கூடிய சேதனப் சேர்வைகள் (VOC) என்பது திண்ம மற்றும் திரவ வடிவிலான வெளிவிடப்படும் தீழ்ப்புக்கள், இவை குறுகியகால மற்றும் நீண்டகால தீங்கான சுகாதாரப் பாதிப்புக்களை உருவாக்கும். VOC ஆனது தீந்தைகள் மற்றும் அரக்குகள் (lacquers), சுத்தம் செய்யும் பொருட்கள் (cleaning supplies), பூச்சிநாசினிகள், கட்டிடப்பொருட்கள் மற்றும் அலங்காரங்கள் மற்றும் அச்சு இயந்திரம்(printers), நகலி(copiers), அழிக்கும் திரவம்(correction fluids), துப்பரவு செய்யும் பொருட்கள்(detergents), வாசனையூட்டிகள்(நசகரஅந), பசைகள்(படரநள), பிசின்கள் (adhesives) போன்ற அலுவலக உபகரணங்கள் முதலிய பலதரப்பட்ட தயாரிப்புகளிலிருந்து வெளிவிடப்படுகின்றது.விசேடமாக புதிதாக கட்டப்பட்ட கட்டிடங்களில் கட்டிடப்பொருட்கள் இரசாயனரீதியில் சிதைவடைவதினால் அதிகளவு எளிதில் ஆவியாகக்கூடிய சேதனப் சேர்வைகள் (VOC) வெளிவிடப்படுவதாக அறிக்கையிடப்பட்டுள்ளது.

7. மோல்ட் மற்றும் ஒவ்வாமை அல்கா (Molds and Allergens Algae)

ஈரலிப்பான மேற்பரப்பு கொண்ட வளமான பகுதியில் மோல்ட் குழுமக்கூட்டம் விருத்தியாவதுடன் இது உயிர்-இரசாயன மற்றும் இயற்கைப் பதார்த்தங்களை தோற்றுவித்து வளிக்கு விடுவிக்கப்படுகின்றது. உகந்த ஈரலிப்பான நிலைமைகளின் கீழ் பூஞ்சணம் வளர்வதுடன் இது உட்புற வளி மாசடைதலை ஏற்படுத்துகின்றது. குளியலறை, நீர் வழங்கல் தொகுதியின் நீர்க்கசிவு இடங்கள் போன்ற நீர்பிடிப்பான இடங்கள் வீடுகள் மற்றும் கட்டிடங்களுக்குள் காணப்படுவதால் இது மோல்ட் மற்றும் அல்காக்கள் வளர உகந்த ஈரலிப்பு நிலைமைகளை வழங்குவதுடன் குறைந்த காற்றோட்டம் மற்றும் காற்றுச் சுழச்சி உள்ள நிலைமைகளில் இவற்றின் வளர்ச்சி அபரிமிதமானது. ஈரலிப்பான மேற்பரப்புகளில் பூஞ்சணம் வளர்வதுடன் இது ஒவ்வாமைத் துகள்களையும் வித்திகளையும் (உ+ம்: அஸ்பெர்ஜிலஸ்) பரப்பும். இயற்கையாக உட்புற வளியின் தரத்தை பாதிக்கும் விடயமாக செல்லப்பிராணிகளின் மயிரும் பூந்துணர்களில் மகரந்தங்களும் நுரையீரலுக்குள் உட்புகுந்து ஆஸ்த்மா மற்றும் ஒவ்வாமை போன்ற நோய்கள் ஏற்படுவதினைக் குறிப்பிடலாம்.

8. அஸ்பெஸ்ரஸ் இழை

அஸ்பெஸ்ரஸ் என்பது இயற்கையாகக் காணப்படும் கனிமம், எனினும் இது கூரைத் தகடுகள் உட்பட பலதரப்பட்ட உற்பத்திகளுக்கு மூலப்பொருளாக பயன்படுத்தப்படுகின்றது. அஸ்பெஸ்ரஸ் உற்பத்திகளை வெட்டும்போது, அரைக்கும்போது அல்லது துளையிடும்போது மற்றும் இவை பௌதீக மற்றும் இரசாயனத் தாக்கங்களினால் சிதைவடையும் போது மிக நுணுக்கமான அஸ்பெஸ்ரஸ் இழைகள் உட்புற வளிக்கு விடுவிக்கப்படுகின்றது. அஸ்பெஸ்ரஸ் இல் பல மாற்றுவகைகள் காணப்படுவதுடன் ”சேர்பென்ரைன்” என்பது பொதுவாகப் பயன்படுத்தப்படுகின்றது.

இது கற்றை வடிவத்தில் காணப்படுவதினால் நாம் உள்ளிழுக்க முன்னர் மேல் காற்றுப்பாதையில் இடைமறிக்கப்பட்டுவிடும். ”அம்பிபோல்” என்பது என்னொரு அஸ்பெஸ்ரஸ் வகை, இது மிகச்சிறியது ஆகையால் உள்ளிழுக்கும்போது நுரையீரலிற்குள் ஆழமாக ஊடுருவும், இதனால் அபாயகரமான சுகாதாரப் பாதிப்புக்கள் உருவாகும். அஸ்பெஸ்ரஸ் இன் சகல வகைகளும் புற்றுநோயினை உண்டுபண்ணும் என தற்போதைய நவீன விஞ்ஞானம் கூறுகின்றது, இதன்படி உள்ளிளுப்புகளிலிருந்து 20 தொடக்கம் 30 வரையிலான ஆண்டுகள் சென்றபின்னர்தான் புற்றுநோயுக்கான முதல் அறிகுறி தோன்றும்.

சுருக்கமாகக் கூறின் உட்புற வளி மாசடைதல் குறுகியகால நாட்பட்ட இதய நோய்களை தோற்றுவிப்பதுடன் சிலவேளைகளில் மரணங்களை விளைவிக்கும். உட்புற வளி மாசாக்கிகளின் உள்வாங்குகையினால் பொதுவாக நுறையீரற் புற்றுநோய், பக்கவாதம், கட்புரை, சலரோகம், நாட்பட்ட மற்றும் கடுமையான சுவாச நோய்கள் என்பன ஏற்படுகின்றது. பிந்திய ஆய்வறிக்கையின்படி கொலஸ்ட்ரால் இனால் ஏற்படும் நோய்த்தாக்கங்களை விட உட்புற வளி மாசடைதலினால் ஏற்படும் நோய்த்தாக்கங்கள் சிக்கலானது, தீவிரமானது. குறைநிறைப் பிறப்புக்கள், சிசு இறப்புக்கள், ஆஸ்த்மா மற்றும் வாய்ப் புற்றுநோய் என்பன உட்புற வளி மாசடைதலின் பொதுவான விளைவுகள் ஆகும்.

உட்புற வளி மாசடைதலை முகாமைத்துவப்படுத்தல்

தீங்கான வாகன வெளியேற்ற உமிழ்வுகள் மற்றும் புகைபோக்கிகளிலிருந்து வெளிவிடப்பட்டு வானத்தை முட்டும், இலகுவில் பார்க்கக்கூடிய உமிழ்வுகள் என்பன வளிமண்டல வளி மாசடைதலுக்கு பிரதான பங்காளிகள் ஆகவே உட்புற வளி மாசடைதலுடன் ஒப்பிட்டுப்பார்க்கப்படின் மாத்திரம் வளிமண்டல வளி மாசடைதலின் முக்கியம் இனங்காணப்படுவதுடன் இவற்றின் தீங்கான விளைவுகள் குறுகியகாலத்தினுள் அனுபவிக்கப்படும். எனினும் உட்புற வளி மாசடைதலினை இலகுவாக தீர்மானிக்க முடியாது அத்துடன் நீண்டகாலத்தின் பின்னர்தான் இதன் தீங்கான பாதிப்புக்கள் உருவாக ஆரம்பிக்கும். சொந்த வீடுகளில் நீங்கள் கூடிவாழும்போது உட்புற வளி மாசடைதல் என்பது ஒரு அமைதிக் கொலைகாரன் ஆக கருதப்படுகின்றது. அகவே உட்புற வளி மாசடைதலினை முகாமைத்துவம் செய்வது என்பது மிகவும் அவசியமான அவசரமான தேவையாக விளங்குகின்றது.

உட்புற வளியின் தரத்தை முகாமைத்துவம் செய்ய சிறந்த மற்றும் இலகுவான செயன்முறை கட்டிடங்களின் காற்றோட்டத்தையும், காற்றுச் சுழச்சியையும் மேம்படுத்தல் ஆகும், இதன் பயனுள்ள முடிவுகளை அடைய இவை கட்டிட வடிவமைத்தல் நிலையில் உள்வாங்கப்பட வேண்டும்.நன்றாக உள்ளக வளி சுற்றிச்செல்லும் போது புதிய வளியின் உட்புகுகையினால் வீடுகளுக்குள் காணப்படும் உட்புற மாசாக்கிகளின் செறிவு வெளியே அடித்துச்செல்லப்படும், இது சுகாதாரப் பாதிப்புக்களையும் சமூக சர்ச்சைகளை முகாமைப்படுத்த வழிவகுக்கும்.காற்றோட்டமுள்ள இடங்களில் போதுமான காற்றுச் சுழச்சியுடன் அடுப்புகளை ஸ்தாபிப்பதினாலும் வினைத்திறனற்ற சமையல் அடுப்புகளை வினைத்திறனாக மாற்றுவதினாலும் சமையலின்போது ஏற்படும் உட்புற வளித்தர பிரச்சனைகளை கட்டுப்படுத்தலாம். ஏதேனும் பட்சத்தில் சமையல் வீடுகளுக்குள் செய்ய வேண்டியிருப்பின் போதிய காற்றோட்டத்தைப் பேண சமையலறையில் போதிய யன்னல்கள் அல்லது திறந்த பகுதி காணப்படவேண்டும் அத்துடன் இவை சமையலின்போது திறந்திருத்தல் வேண்டும். சுற்றுப்புற வளி மாசாக்கலினை குறைக்கும் வண்ணம் உட்புற வளித்தரத்தை பராமரிக்க நவீன வீடுகளில் சமையலடுப்புகளிலிருந்து வெளிவிடப்படும் உமிழ்வுகளை சுத்திகரிக்க செயலூட்டப்பட்ட கார்பன் வடிகட்டிகள் பொருத்தப்படுதல் சிறந்தது.

அலுவலகக் கட்டிடங்கள் மற்றும் பொது இடங்களில் புகைபிடிப்பதினால் தீங்கான பாதிப்புக்கள் ஏற்படுவதினால் பல அபிவிருத்தியடைந்த நாடுகளில் இது தடைசெயயப்படுள்ளதுடன் மாசுக்கட்டுப்பாடு முறைமைகளை, புகைபிடித்தலுக்கு அனுமதிக்கப்பட்ட இடங்களில் ஸ்தாபித்து இவ்விடங்களில் புகைபிடித்தலுக்கு விலக்கு அளிக்கப்பட்டுள்ளது. புதிதாக நிர்மாணிக்கப்பட்ட கட்டிடங்கள் மற்றும் புதிய தளபாடங்கள், உபகரணங்களைக் கொண்ட கட்டிடங்களினுள் போர்மல்டிஹைட் என்ற யாவருக்கும் தெரிந்த உட்புற வளி மாசாக்கியின் செறிவு அதிகமாக காணப்படுவதினால் இவற்றைத் தடுக்க தரப்படுத்தப்பட்ட கட்டிடப்பொருட்கள் கட்டுமான வேலைகளுக்கு பயன்படுத்தப்படல் வேண்டும் அத்துடன் குடிபுக முன்னர் போதுமான காற்றோட்டம் வழங்கப்பட்டிருத்தல் வேண்டும்.

பல வகைப்பட்ட தாவர இனங்கள் வளி மாசக்கிகளை அகத்துறிஞ்சக் கூடியவை என்பதினை வலியுறுத்த ஆர்வமாயுள்ளேன், எனவே அவற்றை வீடுகளுக்குள்ளும் அல்லது அலுவலகக் கட்டிடங்களுள்ளும் வளர்ப்பதால் உட்புற வளியின் தரம் மேம்படும். பகற்பொழுதில் ஒளித்தொகுப்பின்போது கார்பன் டைஓட்சைட்டினை அகத்துறிஞ்சி ஓட்சிசனை உள்ளகச் சுற்றாடலுக்கு விடுகின்றது.ஆகவே ஏதேனும் தாவரங்கள் அவற்றின் உள்ளார்ந்ததன்மையால் உள்ளகச் சுற்றாடலின்

தரத்தை ஓரளவிற்கு உயர்த்த ஆற்றல் படைத்தவைஇ அத்துடன் இவை வீட்டுச் சுற்றாடலின் ஆன்மீக திருப்தியையும் இனிமையையும் பெருக்குகின்றது.

மன திருப்தியையும் வீட்டு அலங்காரத்தையும் வீட்டுச் சுற்றாடலின் இனிமையையும் பெருக்க வளர்க்க உகந்த பலவகையான தாவர இனங்களின் பொதுப்பெயர், விஞ்ஞானப்பெயர் மற்றும் வளி மாசாக்கிகளை அகத்துறிஞ்சும் தகைமைகள் கீழே காட்டப்பட்டுள்ளது.

மகாவலி அபிவிருத்தி மற்றும் சுற்றாடல் அமைச்சு மற்றும் மத்திய சுற்றாடல் அதிகாரசபை இலங்கையில் உட்புற வளித்தரத்தை முகாமைப்படுத்த வேண்டியதன் தேசிய முக்கியத்துவத்தையும் மற்றும் கால அவசியத்தையும் கருத்திற்கொண்டு கொள்கை மற்றும் வழிமுறைகளின் தொகுப்பை தயாரிக்க ஆரம்பித்துள்ளது.

இலங்கையில் வளித்தரத்தை முகாமைத்துவப்படுத்த மகாவலி அபிவிருத்தி மற்றும் சுற்றாடல் அமைச்சின் தலைமைத்துவத்தின் கீழ் ”தூய்மையான காற்று செயற்திட்டம்” என்ற தேசிய செயற்திட்டம் ஆரம்பிக்கப்பட்டுள்ளதுடன் இச் செயற்திட்டத்தின் முக்கிய கூறு உட்புற வளி மாசடைதலை முகாமைதத்துவம் செய்தல் ஆகும்.

Gerbera *(Gerbera Sp.)*
Trichloroethylene, Benzene

Peace Lily *(Spathiphyllum wallisii)*
Alcohol, Acetone, Trichloroethylene,Benzene, Formaldehyde

Aloe vera *(Aloe vera)*
Benzene, Formaldehyde

Bamboo Palm *(Chamaedorea seifrizii)*
Benzene, Formaldehyde, trichloroethylene, xylene, toluene

Spider plant *(Chlorophytum comosum)*
Carbon monoxide,Formaldehyde, Benzene

உசாத்துணை:

https://www.who.int

https://www.researchgate.net

The Open University of Sri Lanka (2011), Environmental Chemistry of the Atmosphere, 978 – 955 – 23 – 1344 - 8

A.I Mendis (2002), The Impact of Indoor Air Pollution on the Health of Women and Children in Low Income Groups in Sri Lanka, 955 – 9017 – 12 – 8

World Health Organization (2009), WHO Hand Book on Indoor Radon, 978 92 41 547673

Climate Change Policy Evaluation by the Use of Mitigation and Adaptation Indicators

M.T.O.V. Peiris

Department of Town & Country Planning, University of Moratuwa

vishtcp@gmail.com

- Sri Lanka has initiated mitigation and adaptation actions through sector based policy measures.
- This study compares the key climate driven performance indicators with historical data to evaluate climate change policy.
- Mitigation policies are evaluated by using GHG emission pathways under twelve (12) indicators and adaptation policies are measured under the national expenditure of key sectors of the economy under seven (07) indicators.

Introduction

Globally, people experience various extreme weather events such as droughts, heavy rainfall followed by floods and landslides, and earthquakes in different scales. This is influenced by man-made causes including economic growth backed industrial activities, changing consumption patterns, and land use changes and environmental degradation.

This study focuses on climate change policy analysis in terms of emission levels, and national expenditure factors of the country along with the scientific and economic indicators relating them into climate change policy implementation. The study is based on empirical data available for Sri Lanka from international sources such as World Development Indicators (WDI), International Energy Agency (IEA), and United Nations (UN). The study boundary under consideration is within the geographic area of the country, whereas country's impact on nearby regions or the external impacts (emission trading schemes and fuel use for international transportation) on country's climate change vulnerability has not been considered. In addition, selection of climate change indicators is based on the selected criterion related to the context of Sri Lanka.

Climate change mitigation and adaptation actions within the country form the basis for evaluation. National level performance indicators support the analysis while climate change actions are obtained for the period from 1990 to 2020. The policy performance is determined by the performance of prevailing climate change response targets with respect to the given period of time.

Indicators used to assess climate change policy

Indicators play a vital role in determining impacts of climate change and suitable indicators are necessary to manage policy implementation effectively (Cust, 2011). UNFCCC encouraged countries to report on CO_2 emissions as a key of data and information. It may be a comprehensive indicator system, but the most challenging task is to seek for availability of reliable and latest data for the evaluation. With reference to various criteria used by different experts in the field and spatial parameters suitable for the 'Sri Lankan context', themes identified in Table 1 are used as parameters for climate change policy evaluation.

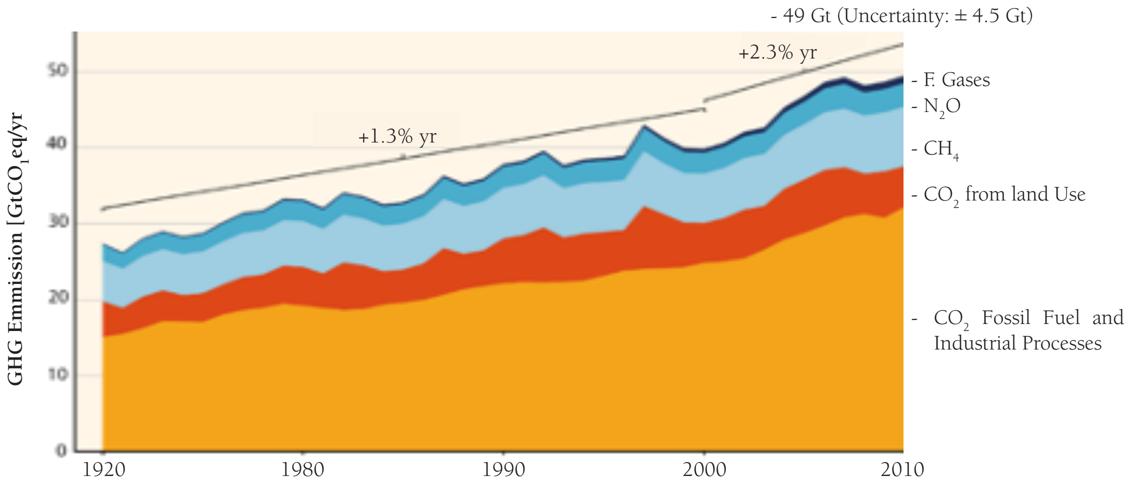


Figure 1: GHG emission growth rate from 1920 to 2010

Source: IPCC Fifth Assessment Report – Working Group III (2014)

indicator of climate change contribution. This has been universally recognized to view the threat of climate change for island nations like Sri Lanka. As an example, global Greenhouse gas (GHG) emissions caused by anthropogenic activities are shown in Figure 1 for the period from 1920 to 2010.

However, CO_2 emissions alone cannot provide the effects of economic policy decisions that reflect on climate change policy. IPCC uses scientific indicators (GHG Emission, Ocean and Surface Temperature Rise and etc.) for predicting vulnerability and magnitude of climate change impacts. The policy performance is determined by the performance of prevailing climate change response targets with respect to the given period of time. One key challenge for measuring climate change policy performance is the unavailability

However, there are additional socio-economic and political indicators required to measure the overall performance of policies and to guide decision makers on required amendments. As climate change policy cannot be measured through direct tangible terms, indicators are useful to measure the physical changes of the environment as well. Out of the assessed indicators, the critical indicators have been refined based on the following areas of concern:

- Relevance of indicator in terms of objectives of the study
- Possibility of obtaining common base for evaluation through data sources and country specific measures
- Ability of each indicator to provide guidance for policy decisions

Table 1: Data Sourcing of Evaluation Themes

Type of Theme	Source of Indicators
Adaptation	
1. Consumption Pattern and Food Security	WDI (World Bank), FAO, UNFCCC, UNEP, ISIC
2. Resource Management and Biodiversity Conservation	WDI (World Bank), IUCN, WWF, FAO
3. Human Settlement and Land Use Planning	UN-HABITAT, WDI (Work Bank), UNFCCC,ADB,APEC, ILC
4. Disaster Management	UN-HABITAT, WDI (World Bank), UNISDR, IMF, ADB
Mitigation	
5. Energy Consumption	IEA, WDI (World Bank), DCS (Sri Lanka), CEIC
6. Infrastructure Development and Transport Management	IEA, WDI (World Bank), CEIC, APEC
7. Industrial Development	IEA, WDI (World Bank), CEIC, UNIDO, WTO
8. Research and Development	WDI (World Bank), ADB
9. Institutional Set-up and Governance	CPIA (World Bank), APEC, ADB, WGI

Generally, fluctuations of GHG emission pathways help to measure climate change mitigation response of a country. By considering the GHG emission levels, energy supply, transportation, buildings, industry and waste management sectors are considered as key themes for mitigation analysis.

Socio-economic indicators generally express the pathway movement of an economy as a whole for climate resilient development. This involves direct political processes and public interests in general through top-down and/or bottom-up approach. Potential economic losses from anticipated scientific evidences are important facts for decision makers to create climate change adaptation and mitigation decisions. Adaptation measures can take different forms such as, vulnerability and risk assessment, anthropogenic causes of climate change, and elements at risk (McCarney, 2012). Therefore, this study has identified water, infrastructure and settlements, human health, urban transport, and energy as key adaptation themes of Sri Lanka which reflect the socio-economic responses for climate change adaptation actions.

Additional analysis used here is the GDP share of economic sectors as a proxy for adaptation. Data has been collected from 1990 to 2014 and the trend projected towards 2020. No weightage is assigned for adaptation and mitigation themes because both themes are considered equally important for the success of climate change policy implementation. The physical dimensions of indicators are as follows:

1. GHG emission pathways of different sectors (Mitigation of climate change impacts through GHG reduction).

2. GDP share of different segments of the economy (Adaptation to climate change impacts through reduction of expenditure on key segments of economy).

Based on the study objectives and availability of reliable data, key themes identified in table 1 have been derived to a measurable set of indicators as follows.

Table 2: Measurable indicators based on identified broad themes

Type of Theme	Relevant Indicators
1. Consumption Pattern and Food Security	The value of all goods and other market services received from the rest of the world. Includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production
2. Resource Management and Biodiversity Conservation	The sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents
3. Human Settlement and Land Use Planning	CO_2 emissions from other sectors, excluding residential buildings, and commercial and public services (kt)
4. Disaster Management	The sum of public and private health expenditure
5. Energy Consumption	CO_2 emissions from solid, liquid and gaseous fuel consumption, Other GHG Emissions (HFC, CH_4, NO_2, etc.),
6. Infrastructure Development and Transport Management	CO_2 emissions from transport sector, CO_2 emissions from electricity and heat production
7. Industrial Development	CO_2 emissions from manufacturing industries and construction, value added in mining, manufacturing, construction, electricity, water, and gas
8. Research and Development	Current and capital expenditures (both public and private) on basic research, applied research, and experimental development
9. Institutional Set-up and Governance	Domestic and foreign liabilities such as currency and money deposits, securities other than shares, and loans

Sources: WDI, MDG, IPCC Source/Sink Categories 1 A 4 and 1 A 5

Specific indicators are used to calculate the emissions and GDP share of the economy relevant to the study.

The composite graphs for mitigation and adaptation are illustrated separately. Since Climate Change Policy was implemented in 2012, it is highlighted in each graph. It is noted that data is analysed based on Business-As-Usual (BAU) scenario. BAU scenario involves the assessment based on historical data and patterns of change. Since Sri Lanka is an island nation with developing status, there are no mandatory pledges to reduce the emissions as opposed to developed nations. Therefore, BAU scenario would be the only scenario to assess the future emissions with the past trends. Also, this study objective is not to assess the emission reduction or any other set targets in global climate change agenda, but to evaluate the impact of existing policy dialogue in order to face climate change challenges.

Use of expenditure as GDP contribution has its own merits and demerits. It is difficult to compare indicators – as it is possible for mitigation analysis – because proxies hold different stands in the overall economy. There is no benchmarking for contribution to GDP as it can vary in short terms with government policy changes. Unlike the mitigation graph, the adaptation graph has to be used with individual sectors to review climate change policy. Nevertheless, sector based GDP contribution provides information on short-term strategies, which can be related to climate change policy, in order to achieve its success.

Based on the study objectives, mitigation responses are indicated by the GHG emissions and adaptation responses are indicated by the GDP shares of key vulnerable sectors in the economy. Accordingly, the time series analysis with area graphs are shown in Figure 2 and Figure 3 respectively.

Figure 2: Climate Change Mitigation Analysis (based on GHG emissions)

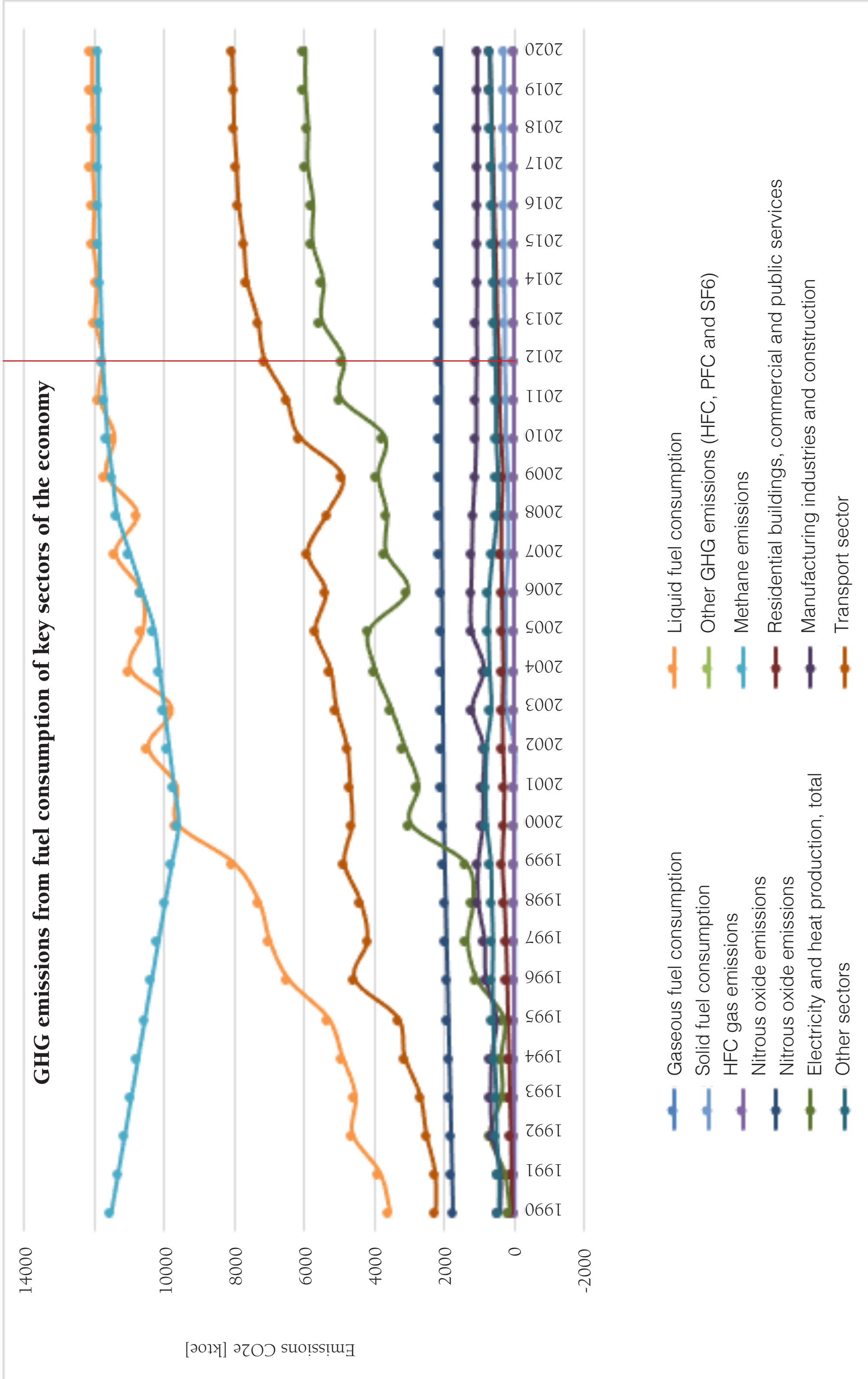
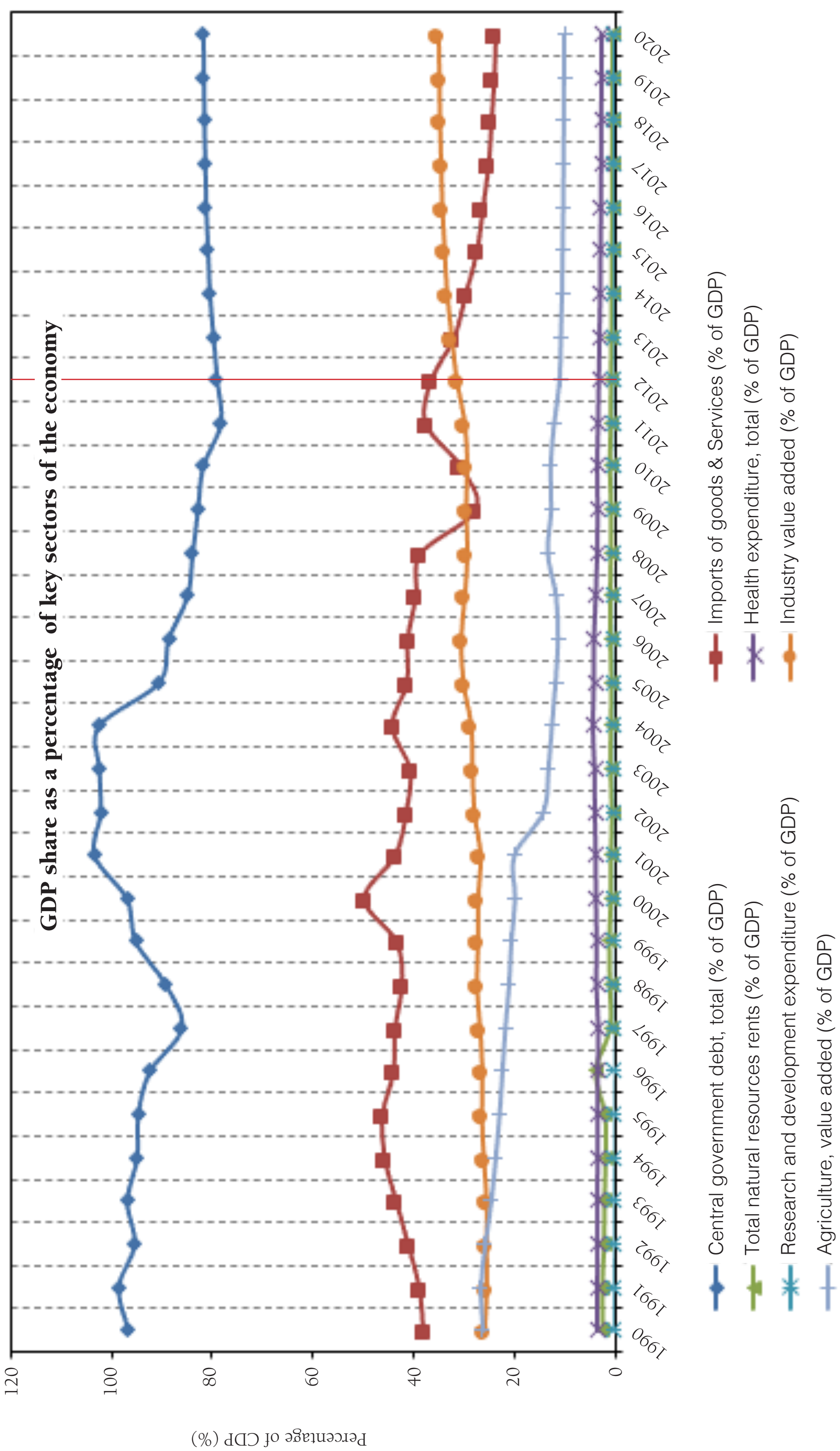


Figure 3: Climate Change Adaptation Analysis of Sri Lanka



According to Figure 2, steady fluctuations are evident throughout the mitigation timeline. However, when it is considered on the gradual increase per decade, total emissions has been increased by 52.8% during the period of 1990 to 2000 while it has increased by only 20.8% during the period of 2000 to 2010. In the same way it can be projected that the period from 2010 to 2020 will have only a 15% increase of total emissions. Therefore, the positive note is that it shows a decreasing rate of total emissions in the national context.

The thirty year terrorist conflict in the country has affected the economy at large, which can be a reason for the volatility of GHG emissions until 2009. With the post-war development in Sri Lanka, the government has initiated major infrastructure development projects including airports, harbours, coal power plants, and highways, which contribute to the steady increase of emissions. Emission pathway of Sri Lanka indicates that the highest GHG emissions is from fossil oil consumption and it reveals that Sri Lankan economy is heavily dependent on fossil fuel imports in energy and industrial sector. This reveals the need to integrate urban planning efforts not only in the infrastructure planning, but also in the energy and land use management sectors in Sri Lanka.

Furthermore, transport sector and electricity generation contributes highly to GHG emissions. The negative impacts of fossil fuel based power plants and subsidized fossil fuel based vehicle imports are evident in Figure 2. It is necessary for the government to prioritize mitigation actions of climate change towards key highlighted sectors of energy, industry, and transport sectors. Recent government efforts in introducing public transport modes could be a positive change for reducing private vehicle flow especially in the city limits. Also new introductions such as bus priority lanes, railway electrification and upgrade can also be positive changes to reduce the emissions in transport sector. At the same time, government could promote electric and hybrid vehicle market through tax concessions as a long term measure to reduce GHG emissions in the transportation sector. But it is not clear in the energy sector where dependency on fossil fuel is still the case for a developing country like Sri Lanka. The policy challenge is that the cost and technological barriers of alternative energy strategies such as natural gas and bio fuel hinder the promotion of comparatively clean sources for energy production. The emission graph clearly shows the policy challenges we face as a developing country and the need for mitigation actions to be in line with changing socio-economic strategies in Sri Lanka.

Adaptation trends are associated with expenditure on several impactful sectors of the economy. The simple assumption used here in the adaptation analysis is that if the economy is moving towards self-sustaining order (where country is less dependent on foreign goods and services), economy's resilience to climate change impacts increases. Thereby adaptive capacity is stronger than it is for an import oriented country. Thus, the analysis demonstrates adaptive capacity on the vulnerability to impacts. Figure 3 reveals that Sri Lanka has a positive movement where industrial value addition is increasing while dependency on imports is decreasing. Such positive changes occurred from 2012 onwards and central government debt is the only negative factor which is over 80% of GDP. Also the lower contribution of Research and Development (R&D) to the GDP is a clear negative sign for country's perception towards technological innovations to face climate change impacts. The policy level decisions must support further R&D in climate change adaptation and mitigation sectors to use the existing knowledge of professionals especially in the academia.

Upon implementation of climate change policy in 2012, Sri Lanka had a steady contribution to GDP in sectors such as industrial value addition (33% average), central government debts (81%

average), and agricultural value addition (11% average). Even though a number of other factors may have contributed towards the positive change, climate change policy has reflected the results of adaptation analysis. Qualitative analysis indicates that important changes are happening in agricultural and industrial value addition of Sri Lanka and food security through agricultural research and development which is addressed by climate change policy of Sri Lanka (Climate Change Secretariat, 2012). In addition, mainstreaming of climate change actions into local level planning is a positive move by Sri Lanka to improve adaptive capacity to climate change impacts (Mahanama *et al.*, 2014).

Based on the above analysis, sectors that need to be prioritized in climate change Policy of Sri Lanka can be listed as follows.

- Transport Policy reforms and Public Transport Strategies
- Urban Planning and Land Use Management for Development
- Institutional Set Up and Governance Mechanism for Climate Change Secretariat
- Research and Development on climate change Vulnerability and Mitigation Actions
- Environmental Policy and Protection Strategy of Natural Resources

Island nations are aware of possible impacts of climate change and the need for strong climate change policies and actions. The main problem with climate policy analysis is the difficulty in setting benchmarks to the expected goals and objectives of controlling emissions. Each country must use the best possible targets unless otherwise any global convention would not be successful in finding common consensus. Sri Lanka must use unique trade-off between development goals and climate change responsibility to reduce the emissions and thereby improve resilience to the climate change impacts. Based on the outcomes, factors that have significant impacts on climate change policy objectives are listed as follows:

- Lack of political will and socio economic dynamics
- Existing barriers for implementation as such the conflicting policies, non-compliance of technical knowledge among decision makers, and lack of long-term planning
- Natural setting of the country (geographic and climate related barriers)
- Non availability of appropriate tools to implement policy objectives
- Distorted timeline for action plans without considering the socio-political behavior of the economy

Conclusion

Traditional scientific indicators cannot necessarily measure climate change policy due to socio-economic and political decision making defining the climate change policy of island nations. Under such a situation, it is difficult to perceive an instant change in political and social perceptions towards climate change mitigation and adaptation. The public never accepts a change until credible information and reasons are provided for the change. Inherited uncertainty of climate change impacts causes complexity during conveying information to public. In such a situation, Sri Lanka has undertaken actions to face climate change impacts.

Most of the identified issues are due to the conflicts between economic strategies of the country with climate change action plan. As per the identified criterion for climate change policy analysis, recommended policy actions are listed in Table 3.

Table 3: Recommended Actions under Adaptation and Mitigation Criterion

Adaptation/ Mitigation Theme	Policy Recommendations for Sri Lanka
Consumption Pattern and Food Security	• Strong waste management strategy in line with climate change policy recommendations to avoid unnecessary emissions • Promote responsible consumption as a habit for people to be adaptive to climate change impacts
Resource Management and Biodiversity Conservation	• Improve linkage with international environmental protection agencies to conserve existing natural resources to protect the carbon sinks
Human Settlement and Land Use Planning	• Integrate the land use planning policy with population distribution strategy in line with climate change policy recommendations to avoid unnecessary emissions from land use
Disaster Management	• Land use policy amendment for disaster risk reduction for coastal vulnerable zone and fragile eco systems prone to climate change induced disasters • Long-term actions based on development plans to reduce disaster risks and thereby costs involved in
Energy Consumption	• Amendment of energy policy to reduce the fossil fuel sources and R&D in renewable energy sector • Implement energy efficiency regulations, building codes, and incentive system for energy savings in the industrial sector
Infrastructure Development and Transport Management	• Integrate the road development policy with transportation plan to improve public transportation efficiency • Encourage public transport actions and clean energy sources for vehicle standards
Industrial Development	• Improvement of industrial distribution strategy to minimize pollution and emissions both in the production and transportation sector (i.e. export processing zones near to the ports, bonded highways and bonded ware houses next to ports) • Target non-polluting industries which can utilize local resources
Research and Development (R&D)	• Integration of climate change policy with R&D institutions to identify mitigation options • Utilize local education system in to climate change based R&D
Institutional Set-up and Governance	• Reform institutional set up for climate change policy implementation as a collective form • Allow institutions to conduct independent research and decision making so as to guide climate change resilience as apex bodies

The priorities of governments are different in each sector of the economy and sector evaluation can use suitable weightage matrix (or similar interpretation) to highlight the comparative magnitude of impacts. Further, the method can apply into individual policy actions to recognize success or failure of individual sector based policies such as transportation policy, land use policy, or disaster management policy.

Adaptation and mitigation policies generally depend on the capacity of the country and political economic objectives for the future. In order to derive a sustainable global climate change policy, international climate change negotiations avoid free rider roles of developing countries in climate change policies, integrate economic impacts of climate change impacts, and bottom up approach in climate change action plans are vital. Consumerism and dependency on imports has created a blowhole in country specific climate change response as the carbon footprint is increasing. This study identified core sector based improvements for Sri Lanka, which then can relate in to island nations.

References

Climate Change Secretariat Sri Lanka. (2012, December). THE NATIONAL CLIMATE CHANGE POLICY OF SRI LANKA. Retrieved December 01, 2014, from Climate Change Secretariat of Sri Lanka: http://www.climatechange.lk/policy.html

Cust, J. (2011). Using intermediate indicators: lessons for climate policy. Climate Policy, 450-463.

IPCC. (2014). Climate Change 2014: Synthesis Report. Intergovernmental Panel for Climate Change, United Nations Environmental Programme.

Mahanama, P., Abeynayake, C., Jayasinghe, A., & Bandara, P. (2014). Climate Response of Local Authorities: A Case of Sri Lankan Coastal Urban Areas. International Journal of Research In Social Sciences, 59-66.

McCarney, P. L. (2012). City indicators on climate change: Implications for governance. Environment and Urbanization Asia, 3(1), 1-39.

OECD. (2009). Green Growth : Overcoming the Crisis & Beyond. Organisation for Economic Co-operation and Development.

UNHabitat. (2011). Climate resilient action plans for Coastal urban areas in Sri Lanka (CCSL). Colombo: United Nations Human Settlements Development Program.

UN-HABITAT. (2012). State of the World's Cities 2012/2013. New York: Routledge Press.

Greenhouse gas emissions associated with the teaching- learning process at higher education institutes

N.M.K.C. Premarathne
Department of Agricultural Systems
Faculty of Agriculture, Rajarata University of Sri Lanka
nmkapila@yahoo.com

- Higher Education is identified as a sector that emits Greenhouse gases (GHG).
- The efficiency of Teaching - Learning is affected by the thermal comfort.
- Low Energy consumption and Low GHG emissions in higher education institutions are required in order to reduce the negative impact of climate change.

Introduction

Global warming is defined as an increase in combined surface air and sea surface temperatures averaged over the globe over a 30-year period. Unless specified, warming is expressed relative to the period 1850–1900. In this regard, human-induced warming has reached approximately 1°C (likely between 0.8°C and 1.2°C) above pre-industrial levels in 2017, and it is increasing at 0.2°C (likely between 0.1°C and 0.3°C) per decade (IPCC,2018). The reason behind this human induced warming is anthropogenic greenhouse gas emissions. The anthropogenic greenhouse gas emission has started with the economic development and population growth from the pre-industrial era. Finally, it is higher than ever at present (IPCC, 2014). As a result, precautionary methods are needed to be taken to avoid it reaching 1.5°C and irreversible losses that would take place at 2°C or above (IPCC, 2018).

There are many processes of greenhouse gas (GHG) emissions with major contributions from certain sectors. For instance, transportation has contributed 29% of the total GHG emissions in the United States in 2017 (EPA, 2017). The other industries or service providers also have a certain level of GHG emissions. But, their contribution is not discussed within the big picture comparatively to the major culprits. However, exploring the potential for changes in product service systems to address climate change and other global environmental issues have been considered in some studies (e.g. Roy *et al.*, 2001). Among them, education sector also has been identified as such a service provider.

This emphasises the necessity for reducing the GHG emissions within the educational service provider institutions.

Nevertheless, it has been identified that the global warming has certain impacts on the teaching - learning environment as well. For instance, studies have revealed that temperatures above what is neutral for heat balance should be avoided in tropical school classrooms due to their negative effects on the performance of schoolwork (Porras Salazar *et al.,* 2018).

On this back drop, it is important to identify some mechanisms to reduce GHG emissions within the education at institutes. Such an initiation would contribute to reduce global warming in one hand and on the oher hand to minimize the expected negative impacts of global warming on the teaching – learning process.

Climate change and classroom teaching - learning performance

Thermal conditions inside the buildings are varied with both time and space. However, it is expected to have high temperatures in the future due to climate change impacts. (Holmes and Hacker, 2007). At present, the effects of temperature on comfort have been recognized. However, the effects on productivity have received less attention. Hence, evidence has shown that indoor thermal conditions influence the productivity of the general tasks like writing, typing, and communication etc. For instance, performance decreased by 2% per 1°C increase of the temperature in the range of 25-32 °C (Seppanen *et al.,* 2006).

Further, the empirical evidences have shown that the students generally preferred "cooler-than-neutral' temperatures where the temperature is 2–3°C below the neutrality level, which is predicted for adults under the same thermal environmental conditions (Kim and Dear, 2018). In this regard, the indoor operative temperature of about 22.5°C has been found as the students' neutral and preferred temperature in Australia. This is generally cooler than the expected temperature for adults under the same thermal environmental condition (de Dear et al., 2015). However, the optimal thermal conditions for students in tropical regions have been a few degrees higher than the temperate regions (Montazami *et al.*, 2017; Trebilcock *et al.*, 2017). As an example, 26.8 °C has been found as optimal in a study conducted in Hawaii (Kwok *et al.,* 1998). For the tropics generally, neutral temperature was estimated to be about 27°C (Kwok *et al.,* 1998; Porras Salazar et al., 2018).

When we consider the impacts of temperature on the learning- teaching process, it has been identified that both long term and short term consequences for the learning process which can affect both school work and the working life (Porras Salazar *et al.,* 2018). For instance, Danish pupils who were exposed to increasing temperatures had shown a reduction in grammatical reasoning and the performance of multiplication when classroom temperature increased from 23 to 28°C. Moreover, the performance of a memory task reached a maximum at 26°C and decreased at higher temperatures (Wargocki. and Wyon., 2007). Similarly, a study in the USA has found that the average score in mathematics improved by 0.5% for each reduction in classroom temperature by 1°C in the range of temperatures between 25°C and 20°C (Haverinen and Shaughnessy, 2015).

Even though, at present, mostly the adults undertake higher education, these temperature requirements are worthwhile to consider for them as well due to the increasing temperature. Moreover, a comfortable learning-teaching environment is needed for better performances in higher education, especially if it is planned to provide early entry to higher education institutes for young groups under the future higher education policies.

How higher education sector contributes to GHG emissions

Similar to any other sector, the higher education (HE) sector uses different resources and energy. Therefore, GHG emission is an obvious fact. In this regard, environmental programmes aimed at the HE sector focus on two main areas. Those are reducing energy consumption and waste generation within the higher education institutes (Delakowitz and Hoffmann, 2000; Altan, 2000). In this regard, efforts have been made on greening the curriculum by reducing paper work, e-learning and distance learning modules *etc.* (Department for Education and Skills, 2003;Roy *et al.,* 2008). Similarly, some studies have been conducted to measure the CO_2 emissions from greening the curriculum versus the conventional modes of teaching. For instance, the four main types of learning systems in the UK (i.e. full-time campus, part-time campus, part-time print-based distance and part-time online courses) have been compared to 100 hours of total study (10 CAT points - Under the UK Credit Accumulation and Transfer system, 1 CAT point = 10 hours of total study) and it has been revealed that compared to full-time campus, students undertaking part-time studies have reduced energy use and CO_2 emissions by 65 percent even considering the computer works and printing.

However, the GHG emissions have not been much considered over the social value of education (Roy *et al.*, 2008). For Instance, even though the CO_2 emission due to the travelling of staff and students was similar to the total emissions from its building stock of the University of Bradford, it has been neglected by considering the value of education (Hopkinson and James, 2005). Similarly, the emissions due to air travel of international students to and from UK universities have been estimated at around 652,000 tonnes Carbon in 2003/2004 (Roy *et al.,* 2008). However, this was not considered in recruitments of international students regarding the social value of education (Fawcett,2005). However, this emphasizes the importance of reduction of energy use and emissions. Nevertheless, GHG production ultimately contributes to global warming and would impact on teaching-learning environment itself as mentioned above. Thus, reduction of the GHG emissions within the HE sector needs to be started.

The global warming and temperature projections in South Asia.

The past and present climate trends and ¬variability in South Asia can be characterized by increasing air temperatures. Further, the rate of warming in South Asia is projected to be significantly faster than that in the 20th century, and more rapid than the global mean rate of warming (Sivakumar and Stefanski, 2010). Similarly, high temperatures are expected for Sri Lanka in the future (Esham and Garforth,2013). For instance, Sri Lanka has experienced 0.016°C increase per year between 1961 to 1990, all over the island and 2°C increase per year in central highlands (Cruz *et al.,* 2007). However, the temperature projections depend on the GHG emission levels in the region as well as the future global levels. This emphasises the importance of ambient classroom temperatures with thermal comfort for a better teaching-learning process. However, the energy utilization should be minimized for the thermal regulations to avoid the contribution to global warming itself, which is the major culprit of increasing temperature at present (Holmes and Hacker, 2007). Therefore, it needs to reduce GHG emissions from all the possible emission paths.

The importance of accounting net carbon flux to "Green" the higher education institutes.

The United Nations Framework Convention on Climate Change (UNFCCC) highlighted the importance of accounting for net carbon(C) flux with special reference to emissions by sources and removals by sinks. (UNFCCC,2011). Moreover, The Kyoto Protocol (1997) has pointed out that CO_2 emissions from fossil-fuel use and from other sources can be balanced by removal of CO_2 from the atmosphere via a net increase in the carbon stocks of the biosphere (West and Marland, 2002). This emphasizes the importance of accounting GHG emissions within the sites. Therefore, the net carbon flux can be calculated using standard protocols and measures within higher educational institutions. For that, identification of CO_2 sources and sinks within the institutions is important. (i.e. CO_2 emissions due to human respiration, wastage disposal, energy use, absorptions of biosphere). After all, the low energy using sustainable educational buildings (Zeiler and Boxem, 2013; Hutton,2011) and CO_2 sinks (i.e. Tree Planting, grass covers) are needed to be designed according to the carbon flux.

Actions to increase the thermal comfort for conducive teaching – learning environment and to reduce the GHG emissions.

The concept of green schools or greener higher education (i.e. less paper work, e- classes, web based teaching, distance learning modules) can be adopted in the educational institution policy. That will reduce the CO_2 emissions in printing, residencies and travel during the service production. However, a certain motivation is required to adopt these systems and awareness creation on the importance of greening curriculums among the students to implement these changes along with reducing the self-limiting motives (i.e. Recycling, reducing printing) (Roy *et al.,* 2008). Activities such as tree planting will ensure the thermal comfort while ensuring a comfortable learning-teaching environment (i.e. the shade reduces heating due to solar radiation). Nevertheless, a 25-ft tall tree can reduce annual heating and cooling costs of a typical residence by 8 to 12 percent (McPherson and Rowntree, 1993). The trees use heat to evaporate water from the leaves before it heats the air. Thus, it keeps away the air conditioners. For instance; if the tree canopy evaporates 100 gallons of water per day, it would be approximately similar to cooling provided by five air conditioners running for 20 hours. As another measure, lightening the color of the building and pavement surfaces have a significant potential to reduce energy use for cooling (Akbari, 2009).

Conclusions

The green approaches in higher education are important to reduce GHG emissions. The greener concepts in education can be used to plan the courses, mode of delivery and providing teaching aids. Nevertheless, sustainable educational buildings can be used to provide the thermal comfort which is essential to enhance the teaching - learning process. The future buildings in higher educational institutes should be designed to use renewable energy sources and minimum energy uses. An account of the net carbon flux can be used to design the low energy demand or low GHG emissions. Further, tree planting is a viable option to both GHG emissions and heat which could be used to balance the net carbon flux. Furthermore, the practices of open-learning systems and e-learning will also contribute to the reduction of GHG emissions. Therefore, the green approaches in higher education will impact on the on-site CO_2 emissions and thermal comfort, as well as the overall CO_2 emission reductions.

References

Akbari, H., (2009) Cooling our communities. A guidebook on tree planting and light-colored surfacing.

Altan, H., (2010) Energy efficiency interventions in UK higher education institutions. Energy Policy, 38(12), pp.7722-7731.

Cruz, R.V., Harasawa, H., Lal, M., Wu, S., Anokhin, Y., Punsalmaa, B., Honda, Y., Jafari, M., Li, C. and Ninh, N.H., (2007) Asia. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

de Dear, R., Kim, J., Candido, C. and Deuble, M., (2015) Adaptive thermal comfort in Australian school classrooms. Building Research & Information, 43(3), pp.383-398.

Delakowitz, B. and Hoffmann, A., (2000) The Hochschule Zittau/Görlitz: Germany's first registered environmental management (EMAS) at an institution of higher education. International Journal of Sustainability in Higher Education, 1(1), pp.35-47.

Esham, M. and Garforth, C., (2013) Climate change and agricultural adaptation in Sri Lanka: a review. Climate and Development, 5(1), pp.66-76.

Fawcett, T., (2005) UKERC Working Paper: Energy use and carbon emissions from the higher education sector, Environmental Change Institute, University of Oxford.

Haverinen-Shaughnessy, U. and Shaughnessy, R.J., (2015) Effects of classroom ventilation rate and temperature on students' test scores. PloS one, 10(8), p.e0136165.

Holmes, M.J. and Hacker, J.N., (2007) Climate change, thermal comfort and energy: Meeting the design challenges of the 21st century. Energy and Buildings, 39(7), pp.802-814.

Hopkinson, P. and James, P., (2006) How Yorkshire and Humberside higher education can help to minimise the region's carbon dioxide emissions, HEEPI Project, University of Bradford, Bradford, UK, May.

Hutton, P.C., (2011) Zero Energy Schools–Beyond Platinum. Educational Facility Planner, 45(3), pp.43-46

IPCC Fifth Assessment Report, (2014)

IPCC (2018). Global Warming of 1.5 ºC —. [online] Ipcc.ch. Available at: https://www.ipcc.ch/sr15/.

Kim, J. and de Dear, R., (2018) Thermal comfort expectations and adaptive behavioural characteristics of primary and secondary school students. Building and Environment, 127, pp.13-22

Kwok, A.G., Reardon, J. and Brown, K., 1998. Thermal comfort in tropical classrooms/Discussion. ASHRAE Transactions, 104, p.1031

McPherson, E.G. and Rowntree, R.A., 1993. Energy conservation potential of urban tree planting. Journal of Arboriculture, 19, pp.321-321.

Montazami, A., Gaterell, M., Nicol, F., Lumley, M. and Thoua, C., 2017. Developing an algorithm to illustrate the likelihood of the dissatisfaction rate with relation to the indoor temperature in naturally ventilated classrooms. Building and Environment, 111, pp.61-71

Porras Salazar, J.A., Wyon, D.P., Piderit Moreno, B., Contreras Espinoza, S. and Wargocki, P., 2018. Reducing classroom temperature in a tropical climate improved the thermal comfort and the performance of elementary school pupils. Indoor air, 28(6), pp.892-904.

Roy, R., Potter, S. and Smith, M.T., 2001, January. Exploring ways to reach sustainability in transport, housing and higher education. In Proceedings Greening of Industry Network Ninth International Conference,'Sustainability at the Millennium: Globalisation, Competitiveness and the Public Trust.

Roy, R., Potter, S. and Yarrow, K., 2008. Designing low carbon higher education systems: Environmental impacts of campus and distance learning systems. International journal of sustainability in higher education, 9(2), pp.116-130.

Seppanen, O., Fisk, W.J. and Lei, Q.H., 2006. Room temperature and productivity in office work.

Sivakumar, M.V. and Stefanski, R., 2010. Climate change in South Asia. In Climate change and food security in South Asia (pp. 13-30). Springer, Dordrecht.

Trebilcock, M., Soto-Munoz, J., Yanez, M. and Figueroa-San Martin, R., 2017. The right to comfort: A field study on adaptive thermal comfort in free-running primary schools in Chile. Building and Environment, 114, pp.455-469.

UNFCCC (2011). Decision 2/CMP.7 of the Conference of the Parties serving as the Meeting of the Parties to the Kyoto Protocol, Adopted by the 17th Conference of the Parties of the UNFCCC meeting in Durban in December 2011. UNFCCC

US EPA, O. (2017). GHGRP 2017: Reported Data. [online] US EPA. Available at: https://www.epa.gov/ghgreporting/ghgrp-2017-reported-data

Wargocki, P. and Wyon, D.P., 2007. The effects of outdoor air supply rate and supply air filter condition in classrooms on the performance of schoolwork by children (RP-1257). Hvac&R Research, 13(2), pp.165-191.

West, T.O. and Marland, G., 2002. A synthesis of carbon sequestration, carbon emissions, and net carbon flux in agriculture: comparing tillage practices in the United States. Agriculture, Ecosystems & Environment, 91(1-3), pp.217-232.

Zeiler, W. and Boxem, G., 2013. Net-zero energy building schools. Renewable energy, 49, pp.282-286.

Partnership for Market Readiness (PMR) and Preparation for Future Carbon Market in Sri Lanka

Methmali Rajaguru
Climate Change Secretariat, Ministry of Environment
methmali@yahoo.com

- Introducing the carbon market to the world through the Kyoto protocol
- Preparation of PMR countries for the new carbon market.
- Preparation of Sri Lanka for the future carbon market through the implementation of PMR project.

Global Approach

People living all over the world are expecting a greener and more sustainable Earth. In order to do so, a greater value must be given to the environment. Therefore, over the last decade, several initiatives by international organizations have caused industries to adopt global sustainable operations. The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992 and its major aim was to limit greenhouse gas (GHG) levels to a point that it would not interfere with the world climate. Later, in 1997, the Kyoto Protocol was adopted under the UNFCCC to strengthen international response to climate change.

The Kyoto Protocol is an international agreement that called for industrialized nations to reduce their greenhouse gas emissions significantly. The main objective of this was to address the issues of climate change by introducing a proper market mechanism. It has been noted in the past that the global carbon market is growing rapidly and is well diversified across various forms of markets, such as the Clean Development Mechanism (CDM), Voluntary Emission Reduction (VER) and emission allowance trading. Global carbon market is an important instrument for international climate change mitigation (Batagoda, 2008). It is a cost-effective way to reduce greenhouse gas emissions and in channeling mitigation finance to developing countries.

There are two ways to motivate firms to cut their GHG emissions: carbon pricing instruments, which provide a direct incentive to reduce emission, and carbon markets, which help to reduce the cost of meeting emission reduction targets, and thereby provide an indirect incentive to meet the targets. For carbon markets to play their role as a tool for climate mitigation, there needs to be a predictable demand for low cost carbon credits. When there is no demand for carbon credits, there will be no market for generating and supplying these credits.

Therefore, based on the Kyoto experience, the Paris Agreement established a market-based mechanism under Article 6 to support countries achieve their targets at low cost and help raise their ambition. The Paris Agreement provides for a robust and ambitious basis for the use of international markets and reinforces international targets, transparency and the accountability of Parties. Although the new "rules, modalities and procedures" for implementing the new market mechanism are still being negotiated, the opportunities for rebuilding the global carbon markets as an additional tool for low-cost climate mitigation are significant.

At the same time, several countries are considering the possibility of establishing domestic market mechanisms to limit the growth of their GHG emissions in a cost-effective manner. To advance these proposals and to introduce the design process for these new mechanisms, opportunities need to be created. The World Bank launched the Partnership for Market Readiness (PMR) in December 2010 considering the above facts.

Partnership for Market Readiness (PMR)

The major objective of the PMR programe is to mitigate the adverse effects of climate change by reducing GHG emissions by the identification and implementation of Carbon Pricing Instruments. It promotes the development of market-based instruments in developing countries and also helps to reach the mitigation targets of the National Determined Contributions (NDCs), to which all countries agreed after the ratification of the Paris Agreement. In order to achieve these objectives, the PMR world programme supports in the following manner:

- Providing grants for countries to build market readiness components.
- Piloting, testing, and sequencing new concepts for market instruments.
- Creating a platform for sharing experiences and information about market readiness.
- Creating and disseminating a body of knowledge on market instruments that could be tapped for country-specific applications.
- Sharing lessons learnt, including with the UNFCCC.

The PMR is a trust fund and it is administrated by the World Bank. The PMR provides financial and technical supports and it acts as a dialogue forum for the exchange of experiences between countries that already have market-based instruments and countries that are currently introducing them (MRP, 2017).

The PMR is country-led and builds on countries' own mitigation priorities and considerations of market mechanisms. PMR countries are at different stages of development of market readiness. As such, they approach the use of market mechanisms at different paces and in different ways. Some focus on building new systems for monitoring, reporting and verification and data collection and establishing regulatory institutions and others go further towards implementation of an appropriate domestic or international market-based scheme. Regardless of a country's choice, such capacity building and piloting can have cross-cutting benefits relevant to implementing non-market-based mitigation actions, designing low emission development strategies and identifying areas of low-cost mitigation potential (World Bank, 2018).

The work performed by the PMR is based on a two-tier process. In the first phase, the participating countries prepare Market Readiness Proposals (MRPs) in which they list specific deficits of and measures for targeted development and implementation of Carbon Pricing Instruments (CPIs). The MRPs are presented and approved at a preliminary meeting of the PMR. In the second phase, the countries receive technical and financial support to enable them to develop and implement the planned instruments (World Bank, 2016). The vast majority of countries involved are now at the implementation phase. In addition to these concrete support measures, the PMR also promotes the transfer of knowledge between participating countries by offering workshops, training seminars and regular meetings at which participants can exchange knowledge and experiences.

In the world there are 19 Implementing Country Participants, 13 Contributing Participants, and 10 Technical Partners for this PMR program. The Government of Sri Lanka has been an Implementing Country Partner of PMR since April 2016.

Partnership for Market Readiness Program in Sri Lanka:

At the request of the Government of Sri Lanka to the World Bank, the Climate Mitigation Action Support Project is being implemented to support Sri Lanka in identifying, developing and implementing PMR activities. After successful submission of the Market Readiness Proposal (MRP) by the Ministry of Environment, the PMR endorsed a grant to Sri Lanka for the implementation of the proposed activities as laid out in the MRP (MRP, 2017).

Other than the above major objective of the PMR program in world, there are some specific objectives of the Sri Lanka PMR program.

Specific Objectives and the tasks of the Project

- Identify the current status, achievements and challenges of existing Carbon Pricing Instruments (CPIs) in Sri Lanka.
- Evaluate the effectiveness of existing mitigation policies, identify the need for new policy instruments, and understand the potential interaction between new and existing policies and initiating the development of an optimal policy package.
- Develop a national MRV system, National climate change data sharing network and a Sri Lanka carbon registry system which require an analysis of NDC targets.
- Develop a roadmap to explore the potential Carbon Pricing Instruments (CPIs) which can be implemented in the future where required to ensure that the economic development in the country is in a low carbon development pathway.
- Enhance Sri Lanka Carbon Crediting Scheme (SLCCS) to support CDM developers in the country.

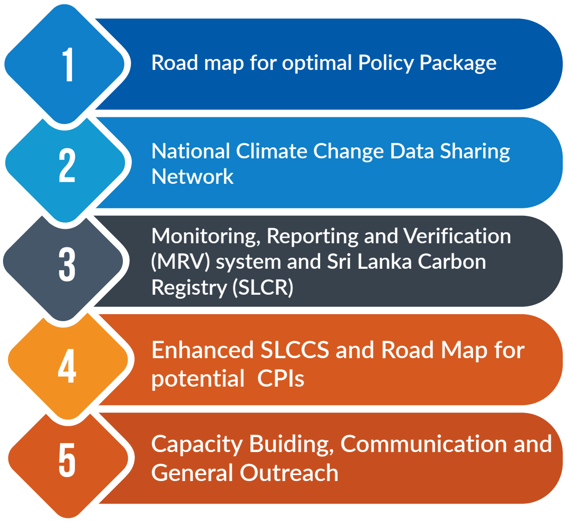


Figure 1 : Major Achievements of the Project

Sri Lanka explores new mechanisms and policy instruments to achieve the country's NDC goals. Carbon Pricing Instruments are identified as possible mechanisms to complement and enhance the role of Sri Lanka Carbon Crediting Scheme (SLCCS) in supporting the NDC implementation. Ministry of Environment aims to evaluate whether new CPIs would help Sri Lanka in effectively achieving its NDC goals while also shifting the economy towards a low carbon pathway. In the longer term, the country intends to scale up its mitigation activities by eventually participating in international trading of emission reductions, which could potentially include linking with CPIs in other countries/ regions.

Sri Lanka Carbon Registry aims to design a national registry system for recording project or mitigation action details, registration and approval, reporting of monitoring data, and the transactional features of carbon units. The registry is an essential tool through which the success of the mechanism will be measured and improved. It will be used for all reporting, collecting, and checking purposes, storing compliance data and identifying any cases of enforcement. It will also track the emissions and trading activity for registered users over the lifetime of a particular scheme.

Another important aspect of developing the MRV and data management system is that Sri Lanka can use the systemized data for NDC reporting, to measure and report on impact of climate action and thus help mobilize finance. The MRV system can be used to translate overall NDC targets to sector sub-targets, while providing a framework and data for reporting on those targets, making NDCs more realistic and transparent.

The objective of the climate change data sharing network is to establish a comprehensive data sharing system in Sri Lanka to fulfill various types of data needs in relation to climate change. The network will gather and share data and information which will be useful for a wide range of stakeholders such as policy makers, actuarial analysts, government agencies, private sector, international donors, researchers, *etc.*, and link to the already existing climate change related databases.

Sri Lanka Carbon Crediting Scheme (SLCCS) is a voluntary program which supports greenhouse gas emission reduction and enables companies to earn Sri Lanka Certified Emission Reduction Units (SCERs) for their efforts to reduce emissions. These units can either be used to offset emissions or be traded among fellow companies. Firms in other countries already trade carbon credits they generate internationally, whereas Sri Lanka is yet to reach that level. There is a lack of demand for carbon credits generated in Sri Lanka in international markets as credibility has yet to be built up. Therefore, the SLCCS program itself needs to be further strengthened and recognized as a credible scheme in the global carbon market. For this purpose, the framework for monitoring, reporting, and verification, and registry needs to be strengthened and made internationally compatible.

References

Batagoda, B.M.S, (2008). Carbon Trading : A New International Business opportunity in Sri Lanka. Economic Review June/July, PP 41 -46

MRP, (2017) Market Readiness proposal to the Partnership for Market Readiness, Sri Lanka.

World Bank, (2016); carbon pricing watch.

World Bank, (2018); Carbon Market for Green house Gas Emission Redaction in Worming world, An Evaluation of the world Bank Groups Supports to Carbon Finance.

Key Outputs, Major Achievements and Challenges in preparation of Third National Communication on Climate Change in Sri Lanka

T.M.A.G.Tennakoon

Climate Change Secretariat, Ministry of Environment

ambikagtennakoon@yahoo.com

1.0 Introduction:

All the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are required to report periodically on information on climate change and their activities in relation to the achievement of the objectives of the UNFCCC. The preparation of these periodic reports, known as National Communications are submitted by Parties to the UNFCCC Secretariat.

Presently, Climate Change Secretariat (CCS) of the Ministry of Environment (MoE), as the national focal point to the UNFCCC, is finalizing the Third National Communication (TNC) Report on Climate Change. The main objective of the TNC Report was to prepare a comprehensive report on climate change information on how Sri Lanka is implementing the Convention and further for highlighting the issues, gaps and constraints faced by the country on implementing climate actions. The data and information of the Second National Communication (SNC) which was submitted to the UNFCCC Secretariat in 2012 were updated and upgraded in the TNC Report.

The TNC Report comprises of mainly five thematic areas which include current national circumstances on climate change, national inventory of anthropogenic greenhouse gas (GHG) emissions and removals (carbon sequestration) for the base year 2010, climate change vulnerability and adaptation measures to provide adequate resilience to climate change adverse impacts, potential mitigation options for reducing GHG emissions and increasing removals and other relevant information such as the need of capacity building, education and public awareness, technology transfer, financial and technical assistance.

2.0 The means and ways of preparing the TNC

The means and ways used for the preparation of the TNC Report have been a multi-phased process in conducting literature surveys, reviewing information in the SNC Report, expert judgments, independent reviews, peer reviews, sectoral and national level stakeholder consultations for data collection and validation of the findings of each section such as GHG emissions and removals, mitigation assessments and essential information related to vulnerability and adaptation measures.

The data and information provided by the stakeholders and data collected by the sector experts have been evaluated by using selected formulae and approaches of Inter - Governmental

Panel on Climate Change (IPCC) and followed UNFCCC Guidelines for the preparation of the TNC Report.

Accordingly, the 2006 Revised Guidelines of the IPCC were used to calculate emissions from Energy, Industrial Processes & Product Use (IPPU), Agriculture, Forestry and Other Land Uses (AFOLU) and Waste for the GHG Inventory. Revised 1996 Guidelines of IPCC were used for the calculation of emissions of precursors, CO, NO^x and NMVOC in the energy and estimation of HFC emissions in IPPU sectors. Emissions were calculated in unit of mass and in CO_2 equivalents using the Global Warming Potential (GWP)[1]. Emissions and carbon sequestration in the GHG Inventory were estimated using the Tier I Method (applying default emission factors developed by the IPCC) for the time period of 2000-2010.

Potential Mitigation Options that could be implemented in nationally appropriate manner in Sri Lanka were identified based on the GHG Inventory prepared for the TNC Report on the above sectors. Further, potential Mitigation Options were identified for the respective sector for the period of 2010-2030 using the GHG Inventory prepared for the TNC Report. The baseline scenario and the mitigation scenarios were developed to identify potential GHG emission reductions for the above period.

Vulnerability to the adverse effects of climate change has been assessed with the degree of climate change risks in the future for floods, droughts, landslides and sea level rise affecting agriculture, livestock, fisheries, irrigation, water resources, health, biodiversity and ecosystems, human settlements and tourism sectors, in line with Nationally Determined Contributions (NDCs)[2] and National Adaptation Plan (NAP)[3], in keeping for different geographical areas such as districts and divisional secretariats.

Past and future climate analysis were conducted using data of 19 surface weather stations maintained by the Department of Meteorology of Sri Lanka from 1980 to 2015. Future climate predictions have been projected using short, medium and long term time horizons; using downscaled (25km grid resolution) Representative Concentration Pathway (RCP)[4] 4.5 and 8.5 as per the Fifth Assessment Report (AR5)[5] of the IPCC) (IPCC, 2014)

Socio economic analysis was principally conducted based on secondary information and data using expert judgment. The analysis focused on socio economic impacts due to climate

1 GWP is a quantified measure of how much of heat a greenhouse gas taps in the atmosphere up to a specific time period, relative to carbon dioxide. GWP weighted emission are measured in units of CO_2 equivalent.

2 NDCs are the national commitments under the Paris Agreement communicated by the parties to the UNFCCC to achieve the long term global goal of the Paris Agreement.

3 The NAP process was established under the Cancun Adaptation Framework (CAF). It enables Parties to formulate and implement national adaptation plans (NAPs) as a means of identifying medium and long term adaptation needs and developing and implementing strategies and programmes to address those needs. It is a continuous, progressive and iterative process which follows a country-driven, gender-sensitive, participatory and fully transparent approach.

4 RCP is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC. Four pathways were used for climate modeling and research for the IPCC fifth Assessment Report (AR5) in 2014. The pathways describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases (GHGs) emitted in the years to come.

5 AR5 is the latest in a series of reports published by the IPCC assessing scientific, technical, and socio-economic information regarding climate change impacts. It was released in three installments over the course of 2013 and 2014 and an additional synthesis report was published in November 2014.

change as well as impacts due to implemented adaptation measures. PESTLE (Political, Social, Technology, Leal and Environment) methodology was used to the assessment. AR5 climate risk framework has been applied for this assessment and Deutsche Gesellscharft for Internationale Zusammenarbeit (GIZ)[6] Risk Formula was used for risk calculations (GIZ, 2017).

Preparation of the TNC Report is a multifaceted approach in consultation with different sector experts.The diagram in Figure 1 shows the preparatory arrangement of the TNC Report.

The TNC Project Executive Board was established under the Chairmanship of the Secretary, MoE comprised of members representing the Department of External Resources, Department of National Planning, CCS and UNDP Sri Lanka for overall supervision and advising on the activities identified in the TNC Report.

A Project Management Unit (PMU) was established in the CCS of the MoE in order to internalize the TNC activities. The PMU worked closely with the experts, UNDP Sri Lanka and the other stakeholder organizations in data collection, selection of methodologies, determining the guidelines for the assessment, validation of clear pathways for the preparation of TNC Report.

Consultancy services have been obtained for the preparation of TNC Report from the sector experts of GHG Inventory, Mitigation Options, Vulnerability & Adaptation and other information related to national circumstance, socio economic assessment, climate education, technology transfer and gaps & constraints.

An Independent Review Panel was formed to guide the process of preparation of the TNC Report and provide inputs for any adjustments, amendments and further analysis required to ensure the accuracy and the quality of the TNC Report. Bi weekly meetings with sector experts and monthly progress review meetings with Independent Review Panel were conducted to overcome the obstacles for effective climate change communication through the TNC Report. The inputs and comments given by the members of Independent Review Panel were incorporated into the reports produced by the experts. Further, Independent Review Panel meetings were organized for mutual understanding between the consultants and PMU to ensure quality outputs.

Furthermore, Technical Evaluation Committees scrutinized all the technical reports including data capturing, selecting of default emission factors, IPCC guidelines, calculations, vulnerability assessments and other related issues of the sectoral reports submitted by the consultants.

3.0 Key Outputs of the TNC Report

3.1 National Greenhouse Gas Inventory

National Greenhouse Gas Inventory of the TNC Report provides the estimates of anthropogenic emissions and removals by sources in Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O). The TNC Report also provides information on gaseous emissions such as Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF_6) and information on emissions of precursor Carbon monoxide (CO), Nitrogen Oxides (NO_x), Non-Methane Volatile Organic Compounds (NMVOCs) and Sulphur Oxides (So_x) for the reported period of 2000 - 2010.

Relevant Ministries and Departments were involved in the GHG Inventory preparation process, including but not limited to MoE,

6 GIZ standers for German Corporation for International Cooperation. GIZ has involved in the various environment and climate change related activities in adaptation and mitigation. GIZ has developed a Climate Risk Formula to assess the vulnerability to adverse effects of climate change.

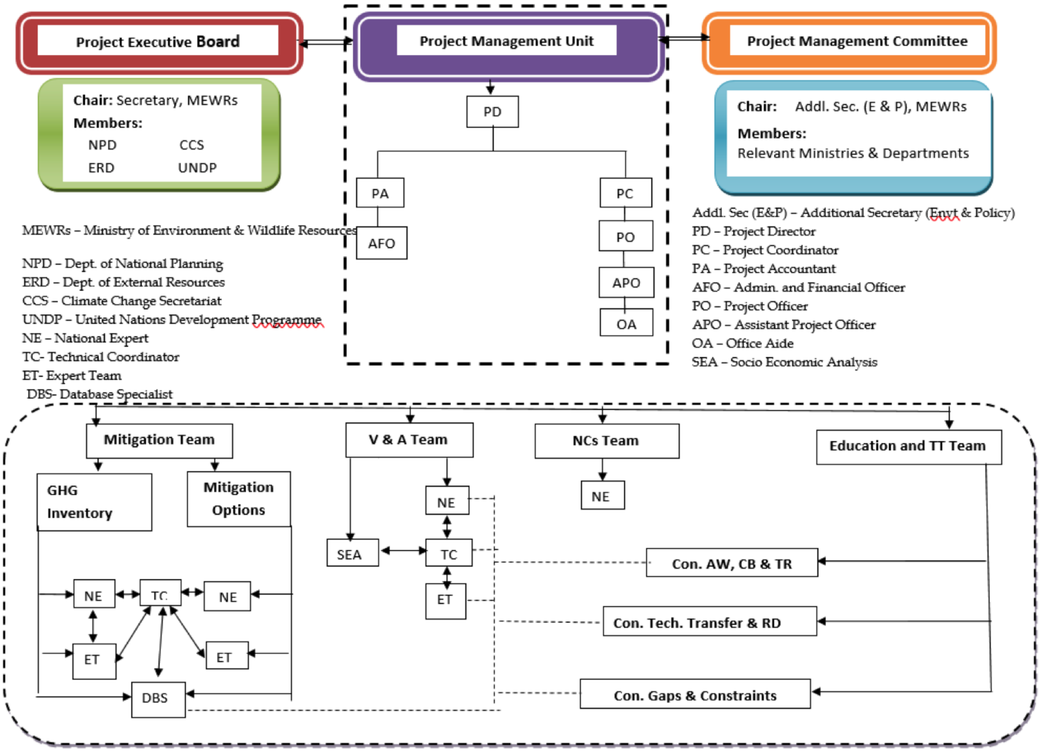


Fig. 1: *Preparatory arrangement of TNC*
Source: *Writer developed for the 1st Project Executive Board*

Ministries of Agriculture, Energy, Industry, Livestock, Water, Finance, Planning *etc.* to provide necessary information and policy guidance for including GHG Inventory recommendations in sectoral plans and national strategies.

3.2 Vulnerability and Adaptation Measures (VAMs)

The Department of Meteorology of Sri Lanka using the emission scenarios developed by the IPCC that was RCP 4.5 (moderate emission) and RCP 8.5 (high emission) have identified the variations of temperature and rainfall during the four seasons namely; First Inter Monsoon (FIM), South West Monsoon (SWM), Second Inter Monsoon (SIM) and North East Monsoon (NEM) for three horizons, stipulated as short term (2020-2040), medium term (2040-2060) and long term (2070-2090).

These projections have identified negative rainfall anomalies in the dry zone leading to prolong droughts and positive rainfall anomalies with more intensive and frequent rainfalls in the wet zone, leading to flash floods in the low lands and landslides in the up country. These projections have spatial differences in four monsoon periods.

Focusing on the risks of the climate change vulnerability, required changes in laws and regulations, institutional set up and their coordination structure have been identified for combating vulnerabilities and addressing them with requisite adaptation measures.

The findings of sectoral reports can be used as mean to identify the most vulnerable sectors, areas and activities of national priorities in terms of adapting to climate risks and mitigating climate change. Results of VAMs provide Sri Lanka with a basis on which to plan adaptation measures more strategically and to raise awareness and strengthen capacities related to climate change resilience building.

3.3 Mitigation Options

The assessment of mitigation options aims to identify the actions already taken and potential mitigation measures that can be implemented to reduce anthropogenic emission of greenhouse gases in different sectors at national level in Sri Lanka with the aim of supporting the global effort of limiting the human-induced global warming.

The baseline scenario reflects a future in which there will be no addition all policies or programmes designed to require actions that need to reduce GHG emissions or enhance carbon sinks. A baseline scenario is considered a critical element in the abatement assessment since the benefits and incremental cost of mitigation options are directly linked to the sound definition of the baseline scenario (UNFCCC Resources Guide, 2009).

In this scenario, the most recent and current emission levels were projected to future emission levels envisaged for each type of activity up to 2030. The projections were made based on assumptions of population growth, GDP and other macro-economic variables obtained from official sources.

The mitigation scenario was structured in accordance with a set of criteria reflecting country specific conditions such as potential for large impacts of GHG reduction, economic impacts, consistency with national development goals, potential effectiveness of implementation policies, sustainability of an option, data availability for evaluation and other sector specific criteria.

Potential mitigation options can be used to investigate how to promote national climate change actions and mobilize financial resources based on the long term outcome of mitigation options.

The findings of mitigation options of the TNC Report provide relevant information and valuable insights for the policy makers. It also helps to identify what further work is needed in order to determine emission reduction targets of NDCs under the Paris Agreement.

4.0 Major Achievements

4.1 Development of Sri Lanka Climate Change Knowledge Repository

Sri Lanka Climate Change Knowledge Repository (SLCCKR) was digitally developed, as a one-stop repository of climate change related information in Sri Lanka.This repository can be utilized to disseminate the knowledge and share the research outputs on climate change among academia, policy makers, private sector, civil society and the general public across the country (http:// www.cckr.climatechange.lk).

4.2 Development of Climate Change Database for Future Reporting

TNC database included all the data sets used for GHG Inventory preparation, vulnerability assessment and formula used for TNC Report to identify the amalgamated impacts/risks of climate change in different sectors and the actual vulnerability at the Divisional Secretariat Division (DSD) level. This database developed following the IPCC and UNFCCC guidelines, will help to minimize the data gaps for various actors in the climate change fields. The CCS invited respective institutions and the experts to share the relevant data and information on climate change in Sri Lanka through this database.

4.3 Communication and Research Strategy on Climate Change

The Climate Change Communication and Research Strategy (2019-2030) was developed to address communication and awareness gaps in Sri Lanka for efficient, effective and result oriented climate change communication. This strategy is also aimed at addressing the existing research gaps and future needs and constraints in communication through establishing a sustainable mechanism to connect with different stakeholders that contribute for reducing vulnerabilities to adverse effects of climate change and mitigate greenhouse gas emissions in the future.

Under this Project, CCS called proposals for research grants in 2018. This is the first step towards creating a national strategy and action plan for climate research. The proposed research has addressed one of the areas on climate change adaptation/loss and damage, vulnerability to climate change, climate change mitigation/ GHG emission reduction and/or integrated cross cutting fields which is related to climate change.

4.4 Development and Validation of Country Specific Emission Factors

The CCS has identified the need for establishing a transparent and coherent mechanism to develop country specific emission factors under 08 thematic areas[7] to use in assessing the GHG emissions in the country. In the TNC Report preparation process, default emission factors were used. Using default emission factors for calculating GHG emission in the country does not reflect the real/accurate values. Therefore, many experts' forums recommended to develop or establish country specific emission factors. The CCS invited the researchers in the country to contribute their research findings on country specific emission factors for validating them for using to assess anthropogenic GHG emission in Sri Lanka for future reporting.

4.5 Awareness Creation and Capacity Building on Climate Change

As it was expected to incorporate provincial data and information into the TNC Report on climate change, stakeholder consultation workshops were conducted for the nine Provincial Councils to make them aware of on-going climate change programmes and activities for obtaining their inputs and increase their capacities for addressing climate change issues in the respective Province with the intension of establishing a Provincial Climate Data Portal for future communication purposes.

Awareness and capacity building programmes were conducted for selected officials of all the Provinces to establish provincial climate institutional set - ups for the preparation of Provincial Adaptation Plan (PAP) for each Province focusing on the essential elements and resilience building opportunities and climate data collection mechanism. Establishment of a Climate Cell under the purview of the Chief Secretary would enable the Government of Sri Lanka to accurately and timely contribute their situations in the National Communications reporting.

The capacity building programmes were successfully conducted to enhance the capacities of the stakeholders who were involved in the TNC preparation process to effectively contribute for climate change reporting. Further, the awareness materials; 10 story boards, 10 video clips, 02 documentary films and newspaper articles on climate change were produced to make all aware of the impacts of climate change. A television programme was organized to make the general public aware of prevailing climatic conditions in Sri Lanka and how to build resilience to meet the adverse effects of climate change.

5.0 Constraints and Challenges

5.1 Data and Information Gathering

The issues related to inadequate data availability, unavailability of required data in required format/reporting template, reliability issue

7 Thematic areas for developing country specific emission factors such as energy industry, transport, manufacturing/ construction, commercial and household, agriculture, Industrial Process and Products Use, land use, land use change and forestry and waste.

in data sources, lack of frequency of data collection, availability of fragmented data, lack of information and researches on climate change, lack of coordination among the line Ministries and their relevant agencies, unavailability of data sharing mechanism among the state organizations are some of the constraints faced, during the operationalization of the Project.

Delays in submission of reports by the consultants/ experts due to lack of data, prolonged debates among the national experts and stakeholders on selecting formulas to be used for GHG Inventory preparation, lack of expertise for vulnerability assessment of different sectors and controversial debates pertaining on selection of methodologies were some of challenges among the many.

5.2 Insufficient Research Findings on Climate Change

There was a challenge that the consultants faced on delivering their specific reports on time due to unavailability of required data and information mentioned in their Terms of References.

Further, there is still a lot of obstacles in the process, as the required information is lacking for effective decision making and related action. One of the main reasons was insufficient research conducted on the climate change scenario building.

6.0 Recommendations

The TNC Report preparation process identified several areas which need urgent attention, that include the assessment of vulnerability of the different sectors on climate change adverse impacts particularly vulnerability due to sea level rise, drought, floods, landslides, increase of temperature, development and introduction of adaptation measures and actions for reducing GHG emissions in the industrial, transport and agricultural sectors, need of regularly update the GHG emission inventory *etc*..

Information of TNC Report preparatory works ensured that climate change issues were not isolated and considered the national and local set up as well as national development priorities. Environmental concerns were integrated into national and provincial strategic planning processes to mitigate climate change issues. This national communication was also an important strategic tool to help Sri Lanka to align her interests and priorities. As such, TNC Report continues to serve as an educational tool and an information source to other multilateral and bilateral processes under the UNFCCC.

Further, national communications are highlighted the need for the strong cooperation and collaboration among the various stakeholders in the country. The information and data gathered in the GHG Inventory and vulnerability & adaptation studies are beneficial for developing adaption projects and adaptation related policy directives.

Furthermore, the critical issues should be addressed during the project development phase focusing on the existing government policies, regulations, institutional set up and information sharing system in the country. Mitigation assessment, as a part of the national communication, should focus for identification and screening of mitigation options, not only in terms of GHG reduction potentials but also regarding the opportunities for local environmental and economic benefits.

The TNC Report preparation process, in a nutshell, provided enormous benefits for the country in terms of raising awareness on climate change related issues among all the strata of the society, built the capacities of many stakeholders who are responsible for addressing climate change related issues in the country, established a solid network among the relevant stakeholders, identified the gaps, constraints and national needs to address the climate change issues in the country efficiently and effectively.

References:

IPCC (2006), IPCC Guidelines for National Communications prepared by Intergovernmental Panel on Climate Change.

IPCC (2006), IPCC Guidelines for National Greenhouse Gas Inventories, prepared by the National Greenhouse Gas Inventories Programmes.

UNFCCC Resource Guide for preparing National Communications. http//: unfccc/intel. resource/ docs/publications.

UNFCCC Guidelines (2010) for National Communications. unfccc/Intel/national_ reports/non annex 1 countries.

Website unfccc.intel.com for National Adaptation Process.

Website unfccc.intel.com. for Nationally Determined Contributions.

Wikipedia (2020), Global Warming Potential available at: http://en.wikipedia.org.

Wikipedia (2020), Representative Concentration Pathway available at: http://en.wikipedia.org.

Estimation of carbon retention potential in timber logs of State Timber Corporation, Sri Lanka

Nimal Ruwanpathirana*, W.V.T.D. Amarasinghe, C.I.M. Arachchi
State Timber Corporation, Battaramulla, Sri Lanka
nimalruwan@gmail.com

- This study was conducted to estimate carbon retention potentials in harvested timber logs from state-owned Teak, Eucalyptus and Pinus Plantations.
- Carbon retention potential of logs was estimated based on collected field data and compared with carbon gained by stand trees, which was determined by yield tables.
- According to the study, the average carbon retention of all three species is 157.18 tonnes per hectare and the average amount of sequestrated atmospheric CO_2 is 576.86 tonnes per hectare. This study emphasizes that Pinus logs have retained the highest carbon amount (81.68 tonnes per hectare) while Teak reported the lowest (14.34 tonnes per hectare).
- According to the results, Eucalyptus shows the highest annual carbon retention per tree (12 kg tree^{-1}year^{-1}) while Teak shows the least 1.52 kg tree^{-1}year^{-1}.
- Therefore, Eucalyptus contributes to sequester the highest amount of CO_2 (44.04 kg tree^{-1}year^{-1}) over the other two species.

Introduction

Carbon dioxide (CO_2) is the most effective gas among greenhouse gases (GHGs) which provoke the greenhouse effect, global warming and propel to cause several other climate effects. Climate change occurring throughout the globe is a serious issue that affects both biotic and abiotic systems of the earth. Three most powerful greenhouse gases in the atmosphere are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

Carbon (C) is one of the most abundant elements on earth and it is a naturally occurring component of the earth's atmospheric gases such as carbon dioxide (CO_2) and methane (CH_4). Due to industrialization and human interference carbon emission in the atmosphere has increased tremendously. Some of the emerging threats to the environment include increasing greenhouse gases and damage to the ozone layer. Heat-trapping of CO_2 leads to the greenhouse effect which results in global warming. Therefore, various measures are required for long-term carbon retention to reduce the atmospheric CO_2 level.

CO_2 is naturally captured from the atmosphere by trees for long-term storage in their lifetime through the process of photosynthesis. Forests absorb CO_2 from the atmosphere and store in the biomass of trees. Forests are a very effective sink of carbon, which captures a substantial amount of carbon dioxide and converts into fruitful bio-products like timber, food, fibre and fruits for human consumption.

Capturing carbon (C) from atmospheric CO_2 and converting the inorganic carbon to organic compounds are involved in the process of carbon sequestration. According to the Inter-Governmental Panel on Climate Change (IPCC), there are five carbon pools of a terrestrial ecosystem involving biomass: above-ground biomass, below-ground biomass, the dead mass of litter, woody debris and soil organic matter.

The aboveground biomass of a tree constitutes the major portion of the carbon pool. It is the most important and visible carbon pool of the terrestrial forest ecosystem. The below-ground biomass, which constitutes all the live roots, also plays an important role in the carbon cycle by transferring and storing carbon in the soil (Abeysekara *et al.* 2018).

The 7th conference of parties (CoP 7) of United Nations Framework Convention on Climate Change (UNFCCC) that met in Bonn (Germany) in July 2001 decided to include Afforestation and Reforestation (A/R) as an effective way to reduce atmospheric carbon by building up terrestrial carbon stocks and to produce Certified Emission Reductions (CERs). It has been suggested that improved land management could result in sequestration of a substantial amount of soil carbon and could be an option to reduce atmospheric CO_2 concentration (Paustian *et al.*2000; Post *et al.* 1990; Yadev *et al.* 2012). Forest management such as rotation length is seen as an activity that countries may apply under the Kyoto Protocol to help them meet the commitments for the reduction of greenhouse gas emissions (Watson *et al.* 2000). Individual trees sequester carbon within their main stem wood, bark, branches, foliage and roots. Carbon sequestered by the main stem wood results in longer sequestration while other components sequester and release carbon at shorter intervals due to natural pruning and decomposition. Carbon sequestration potential of trees varies with species, climate, soil and management.

Globally, the importance of plantation forestry is increasing due to the depletion pressure on natural forests and the difficulties in accessing increasingly remote areas of natural forests available for wood supply (FAO 2001a). In addition to their industrial timber products, the importance of forest plantations has increased substantially during the last two decades, because of the increased awareness on global climate change and the role of forests in regulating the global carbon cycle (Dixon *et al.*1994; Clark *et al.* 2003; Clark 2004a; Houghton 2005). Thus, carbon stock is essential for the sustainable forest management (SFM); it is also important in assessing the contribution for the carbon sink potential amounts of the logs of the forest plantations.

In Sri Lanka, forest plantations have been established by the Forest Department since the 1880s to meet the increasing demand for timber and fuel wood (Pushparajah 1987; Sahajananthan 1987). State Timber Corporation (STC) is the prioritized leader which provides the timber requirement of Sri Lanka. Timber is the basic requirement in household and industrial basis and needed locally for building constructions, manufacturing furniture, producing railway sleepers, electrical transmission poles and elephant poles *etc.* Almost all the existing forest plantations of Sri Lanka consist of fast-growing exotic trees such as species of *Eucalyptus sp.*, *Pinus sp*., and *Tectona grandis* (Vivekanandan 1987).In Sri Lanka, a majority (33%) of the plantations consists of Teak, the second-largest percentage (28%) consists of Eucalyptus and the other plantations consist mainly of Pinus (12%) (FAO, 2009). In higher elevations (1200 m and above) *Pinus* spp. and *Eucalyptus spp* such as *Eucalyptus grandis*, *Eucalyptus microcorys* are the more successful plantations (Sivananthawerl and Mitlöhner, 2011).

The carbon sequestration potential of a forest is determined by its biomass production. Increasing forest biomass per year indicates the potential of absorbing atmospheric CO_2 and decrement of atmospheric temperature within a given period. Many methods have been developed to estimate biomass in forests and other vegetation types. These methods differ in procedure, complexity and time required depending on the specific aim of the estimation (Gunawardena, 2014). The most common approach to estimate the aboveground biomass is to estimate the biomass with tree variables such as Diameter at Breast Height (DBH) or and tree height (stem volume) and the wood density at the oven-dry stage of the log.

The objective of the study

The purpose of this study is to estimate the carbon retention capacity of felled timber logs in comparison to the carbon retention capacity of tree stands in order to surmise which sequesters more carbon during the lifetime.

Methodology

Usually, some percentage of carbon is emitted during the process of harvesting, nevertheless, log form can be considered as the form that stores carbon for a long period. The data of the Management Information System (MIS) of STC were used for this study.

The data was collected from clear-felled plantations throughout the country by STC in 2017 and 2018. The total felled extent was 1,779.80 hectares which, having 422,665 trees, produced a log volume of 167, 077.51 m^3 (Table 1). According to the data, the average age of selected Teak plantations was 46 years while the Pinus plantations were an average age of 43 years and the Eucalyptus plantations were an average age of 30 years. Selected Teak plantations were distributed among the districts of Ampara, Anuradhapura, Jaffna, Kandy, Kurunegala, Monaragala, Polonnaruwa while the *Pinus spp.* were distributed among Bandarawela, Matara, Nuwara Eliya, Rathnapura, Kandy districts and the *Eucalyptus grandis* and *Eucalyptus microcorys* were distributed in Bandarawela and Nuwara Eliya districts.

Sequestered carbon amount was calculated through the harvested log volumes of the clear-felled plantations. Wood volume was calculated through the mid girth and the length of the log of felled trees according to the STC volume table. Amount of carbon stock of logs was determined based on IPCC (2006) guidelines. Species-specific wood density at 0% moisture level and the log volumes were used to calculate the biomass. Total carbon of logs was calculated by IPCC default carbon fraction (0.47) and the amount of trapped CO_2 in logs was estimated by converting carbon to CO_2 by using the multiplication factor of 3.67. All calculations were done separately for the selected species: Teak, Pinus and Eucalyptus. Appendix 1 contains the equations used for this study. Appendix 2 contains the yield table data for the three species.

Results and Discussion

Table 1 shows the results of the estimate of carbon and volume calculations based on data in 2017 and 2018 of selected plantation species. Out of these three species, teak was found in the majority i.e 1406.20 ha of forest plantations released by the Forest Department for clear felling. Although Teak possesses the highest percentage of hectares i.e. 79.01% among the plantations of Teak, Pinus and Eucalyptus, carbon sequestration from Teak is less than that from Pinus (Table 1). Among the analyzed three species, Pinus sequestered the highest percentage of carbon from the total sequestered amount representing 48.24% (284.50 ha). In harvested logs of those three species 47,783.94 tonnes of carbon was retained in harvested logs for both 2017 and 2018, which sequestered 175,367.05 tonnes of atmospheric carbon during those two years.

Table 1: Estimations of carbon retention amounts through calculating volumes based on the density values and other data collected in the year of 2017 and 2018 relevant to the selected three species

Logs – Species	Year	Hectare (Ha)	Enumerated Trees(Nos)	Produced Total Log Volume (m^3)	Log zVolume (m^3 ha^{-1})	Estimated Carbon in Logs (tonnes)	CO_2 (tonnes)
Teak *Tectona grandis* Avg age - 46 yr Wood Density (0% MC) – 643 Kgm^{3}-	2018	836.40	155,072	35,954.20	42.99	10,865.72	39,877.19
	2017	569.80	121,352	29,562.00	51.88	8,933.93	32,787.53
Total Teak		**1,406.20**	**276,424**	**65,516.20**		**19,799.65**	**72,664.72**
Pinus *Pinus sp.* Avg age - 43 yr Wood Density (0% MC) – 571 Kgm^{3-}	2018	124.30	56,230	40,177.50	323.23	10,782.44	39,571.54
	2017	160.20	76,402	45,732.00	285.47	12,273.10	45,042.27
Total Pinus		**284.50**	**132,632**	**85,909.50**		**23,055.53**	**84,613.80**
Eucalyptus *E. grandis* *E. microcorys* Avg age 30 yr Wood WoodDensity (0% MC) – 670 Kgm^{3-}	2018	26.60	2,518	6,393.81	240.37	2,013.41	7,389.22
	2017	62.50	11,091	9,258.00	148.13	2,915.34	10,699.31
Total Eucalyptus		**89.10**	**13,609**	**15,651.81**		**4,928.75**	**18,088.53**
Total of all the species	2018	987.30	213,820	82,525.51	606.59	23,661.57	86,837.94
	2017	792.50	208,845	84,552.00	485.48	24,122.37	88,529.11
Total of both years		**1,779.80**	**422,665**	**167,077.51**		**47,783.94**	**175,357.05**

Table 2 shows the comparison among the selected species on the differences between the average timber stocks and carbon stocks. According to the estimated average values of 14.34 tonnes ha^{-1}, 81.68 tonnes ha^{-1} and 61.17 tonnes ha^{-1} of average carbon amounts are deposited in logs of Teak, Pinus and Eucalyptus respectively. The average felled Teak plantation extent was 703.10 hectares annually which consisted of 138,212 average numbers of trees and produced 32,758.10 m^3 average log volume. As it consisted of 199 average Teak trees per hectare, it was able to produce 47.43m^3 average log volume per hectare. This volume retained an average of 9,899.83 tonnes of carbon. This number represents 41.43% of the total carbon production of all three species. Thus, the amount of average carbon retention per Teak tree is 0.07 tonnes.

Table 2: Comparison of all the average amounts of timber stocks & average amounts of retained carbon amount in selected three species within both 2017 & 2018 years

Species	Percentage of the extent to total%	Hectares	Trees ha^{-1}	Volume (m^3 tree^{-1})	Carbon (tonnes)	Carbon (tonnes ha^{-1})	Carbon (tonnes tree^{-1})	Carbon (tonnes year^{-1})	Volume (m^3 ha^{-1})	Expected Volume (m^3 ha^{-1})	Expected carbon (tonnes ha^{-1})	Difference between expected and actual (%)
Teak	79	703.1	199	0.24	9899.83	14.34	0.07	215.21	47.43	113	34.1	-57.9
Pinus	16	142.3	465	0.66	11527.77	81.68	0.17	268.09	304.35	296	80.0	2.0
Eucalyptus	5	44.5	136	1.69	2464.38	61.17	0.36	82.15	194.25	320	100.77	-38.7
Totak		**889.9**			**23891.97**							

Expected volume is referred from provincial yield table. The expected yield of the volume per hectare can differ with the age, log dimensions and the site classes. However, 46-year-old Teak plantation should produce 112.8 m^3 log volume per hectares at clear-felling stage according to the yield table data (Appendix 2). Even though 47.43 m^3 of timber volume were gained from Teak per hectare, it has shown a 57.9% of timber volume reduction than expected. This has affected to decrease the sequestered carbon amount per hectare. However, these plantations have the potential to sequester 19.76 tonnes more per hectare of carbon if there are no administrative and management issues. The reason for this reduction might be poor forest management practices with other adhering facts, such as inadequate financial allocations, illegal felling *etc.*

Estimated timber and carbon stocks differ in the other two species. The total extent of Pinus released from the Forest Department to State Timber Corporation is 142.3 hectares per year. This extent contains an average number of 66,170 trees, which produced an average 42,954.75 m^3 of log volume. This amount is very high in comparison with Eucalyptus plantations. The reason might be the higher amount of stocking (465 trees ha^{-1}), that produces 301.97 m^3 average log volumes per hectare.

According to the calculations, Pinus plantations have fixed 11, 527.77 tonnes of carbon annually in logs (81.68 tonnes per hectare). The mean carbon storage in a stand is is 0.17 tonnes tree^{-1}. Moreover, Pinus plantations produce 2% more than the expected timber production. Therefore, it can be reasoned that with released plantations that a majority of felled plantations might be categorized under a better site class.

The extent of felled Eucalyptus species (*Eucalyptus grandis* and *Eucalyptus microcorys*) is only 5% of the total released extent due to the temporally logging ban in higher elevations of the country. The average stocking of Eucalyptus was 136 trees ha^{-1} in felled plantations and the average amount of retained carbon is 2,464.38 tonnes. This amount represents approximately only 10% of the total carbon retention of all three species. According to the estimations, the retained average carbon amounts of Eucalyptus sp. were calculated by considering both hectares and enumerated trees. Accordingly, the estimated values for the average retained carbon amounts gained for Eucalyptus are 61.17 tonnes ha^{-1} and 0.36 tonnes $tree^{-1}$.

According to the provincial yield table (Appendix 2), Eucalyptus species can produce a 260 m^3 $ha^{-1}$of timber volume at the age of 25 years with 13.8 m^3 mean annual increment. Consequently, a 30-year-old plantation would have the ability to produce approximately 320 m^3 ha^{-1}. However, it shows a 38.7% of decrement of carbon retained amount than expected, as Eucalyptus plantations retained 61.17 tonnes than the expected 100.77 tonnes of carbon per hectare. Additionally, Amarasinghe *et al.* (2018) reported that a 30-year-old *Eucalyptus grandis* and *Eucalyptus microcorys* can produce 182.15 tonnes ha^{-1} and 202.91 tonnes ha^{-1} above ground carbon (AGC) respectively. When this is converted, AGC to carbon in logs is 109.07 tonnes $ha^{-1}$and 121.50 tonnes ha^{-1} in *Eucalyptus grandis* and *Eucalyptus microcorys* respectively. Thus, Eucalyptus plantations of Sri Lanka have more potential to sequestrate carbon than the other two species. Less sequestration might be due to low stocking and the other susceptible factors such as improper forest management due to lack of funding and the stocking decreasing up to 136 trees ha^{-1} than the optimum value (200-250 trees ha^{-1}). Proper management of forest plantations is the key to obtain maximum yield and for effective sequestration of atmospheric CO_2.

This study confirmed that carbon fixation varies vastly among species due to differences of growth, wood densities and the stocking. The results of this study show Eucalyptus as the best CO_2 sequestration species among the three species due to the highest mean annual carbon retention value per tree and also per hectare. All three species studied retain 23,892 tonnes of average carbon amounts in logs which are equal to 87,683.5 tonnes of average sequestered CO_2. Average carbon retention per tree varies with the selected species as 70 kg $tree^{-1}$, (Teak) 170 kg $tree^{-1}$ (Pinus) and 360 kg $tree^{-1}$ (Eucalyptus). Therefore, mean annual carbon retention per hectare of Teak, Pinus and Eucalyptus are 0.30 tonnes ha^{-1} $year^{-1}$, 1.90 tonnes $ha^{-1}year^{-1}$, 2.06 tonnes ha^{-1} $year^{-1}$ respectively and the mean annual carbon retention per tree is 1.52 kg $tree^{-1}$ $year^{1}$, 3.95 kg $tree^{-1}$ $year^{1}$, 12 kg $tree^{-1}$ $year^{1}$ for Teak, Pinus and Eucalyptus respectively. Through the reduction of CO_2 through proper forest management, wood products will be an added advantage for increasing terrestrial carbon stock while enhancing carbon sequestration and contributing to climate change mitigation. Accordingly, the above-selected species contributes to reducing CO_2 from atmosphere by 5.57 kg $tree^{-1}$ $year^{1}$, 14.49 kg $tree^{-1}$ $year^{-1}$, and 44.02 kg $tree^{-1}$ $year^{1}$ consequently from Teak, Pinus and Eucalyptus respectively.

Both Teak and Eucalyptus have reported less timber volume than the expected amount in provincial yield tables, resulting in less carbon retention, and the reason might be the poor growth performances and poor silvicultural management. By comparing the results with provincial yield tables, the deficiency of carbon retention amounts or the CO_2 sequestered amount in logs from one-hectare plantations of Teak and Eucalyptus is 57.9% and 38.7% respectively.

However, it clearly emphasizes that maintaining proper forest plantations consisting of high stocks in high dense wood species such as Eucalyptus will contribute to sequester atmospheric carbon in high amounts. According to the age of the plantations, younger plantations sequestrate more carbon than the older plantations (Zhou *et al*. 2017). Therefore, managing younger plantations and establishing new plantations after harvesting matured (old) plantations assist to sequestrate the maximum amount of CO_2. Reduction of CO_2 by proper forest management and wood products will be an advantage for increasing terrestrial carbon stock while enhancing carbon sequestration. Through this, it will contribute as a mitigation strategy for climate change impacts. Compared to the global scale, carbon stock in the wood of forest plantations of Sri Lanka may be very little even though it is very important at local scale emission reduction. UN-REDD (2017) reported Sri Lanka's forest reference level and reported that the total emission from deforestation is estimated to be 4529 ('000 tons of CO_2 equivalent) whereas total removals from forest gain are 70("000 tons of CO_2 equivalent). Thus, long-term carbon stocking of wood from forest plantations may have a significant impact to increase forest gain.

Finally, by increasing the biomass of the trees, proper production of wood and establishing high stock plantations after felling old plantations will benefit to capture more CO_2 from the atmosphere and to sequester the maximum level of carbon that will lead to higher carbon deposition in logs. Stored CO_2 from the atmosphere as a carbon component in timber can be preserved by practicing correct timber conservation and preservation methods, the right use of timber species and application of \ preservatives and seasoning standards. Further, the correct use and maintenance of end wood products will result in increasing the lifetime of wood products. The Institutes in Sri Lanka such as STC which directly engage with proper forest management and proper preservation of wood products will be added advantage for increasing terrestrial carbon stock and saving carbon for long-term as converted wood products. The reduction of CO_2 through proper forest management and storage in wood products will give an added advantage for increasing terrestrial carbon stock while contributing towards climate change mitigation

Conclusions

- Carbon fixation varies vastly among species due to differences of growth, wood properties and the stockings
- According to the results of this study, Eucalyptus can be identified as the best species for CO_2 sequestration due to gaining the highest mean annual carbon retention amount in logs
- All three species studied retain 23,892 tonnes of carbon amount in logs within selected years which is equal to 86,683.5 tonnes of sequestered CO_2
- Carbon retention per hectare varies with the species as 14.34 tonnes ha^{-1}, 81.68 tonnes $ha^{-1}$and 61.77 tonnes $ha^{-1}$of Teak, Pinus and Eucalyptus respectively
- Carbon retention per tree varies with the species as 70 kg $tree^{-1}$, 170 kg $tree^{-1}$ and 360 kg $tree^{-1}$ of Teak, Pinus and Eucalyptus respectively
- Mean annual carbon retention per hectare of Teak, Pinus and Eucalyptus are 0.30 tonnes ha^{-1} $year^{1}$, 1.90 tonnes $ha^{-1}year^{1}$, 2.06 tonnes ha^{-1} $year^{1}$ respectively.
- Mean annual carbon retention per tree varies as 1.52 kg $tree^{-1}$ $year^{1}$, 3.95 kg $tree^{-1}$ $year^{1}$, 12 kg $tree^{-1}$ $year^{1}$ for Teak, Pinus and Eucalyptus respectively.
- Accordingly, Teak, Pinus, Eucalyptus sequestrate about 5.57 kg $tree^{-1}year^{1}$, 14.49 kg $tree^{-1}year^{1}$, and 43.2 kg $tree^{-1}year^{1}$ of atmospheric CO_2 subsequently.

- Teak and Eucalyptus produce less timber volume than the expected yield in the provincial yield tables, the reason might be the poor growth performances due to site characteristics and poor silvicultural practices.
- Thus, teak and eucalyptus species have sequestered less atmospheric CO_2 than the expected potential, which is only 57.9% and 38.7% of the expected amount for Teak and Eucalyptus respectively.
- Proper management of forest plantations to maintain apposite stocking of fast growth and high carbon accumulating species such as Eucalyptus is one of the key facts for higher carbon gain and also higher CO_2 reduction amounts.

References

Abeysekara, A.M.S.K., Yatigammana, S.K., Premakantha K.T., Biomass and Carbon Stock Estimation of Udawattakele Forest Reserve in Kandy District of Sri Lanka. (year) Journal of Tropical Forestry and Environment Vol. 8, No. 02: 13-2.

Amarasinghe, W.V.T.D, Terada, T. and Yamamoto, H. (2018).Forest management options to increase carbon sequestration in Eucalyptus plantations of Sri Lanka.Proceedings of the symposiums of the Sustainable Forest Ecosystem Management and the IUFRO 4.02.02, Sun Moon Lake, Nantou, Taiwan, 28 – 31August 2018.113-118.

Clark, D.A. (2004). Sources or sinks? The responses of tropical forests to current and future climate and atmospheric composition. Philosophical Transactions of the Royal Society of London, Series B 359 (1443): 477-491.

Clark, D.A., Piper, S.C., Keeling, C.D. & Clark, D.B. (2003).Tropical rain forest tree growth and atmospheric carbon dynamics linked to inter annual temperature variations during 1984-2000. Proceedings of the National Academy of Sciences, USA 100 (10): 5852–5857.

Dixon, R.K., Brown, S., Houghton, R.A., Solomon, A.M., Trexler, M.C. & Wisniewski, J. (1994).Carbon pools and flux of global forest ecosystems. Science 263 (5144):185–190.

FAO (2001a).World View of Plantation Grown Wood.Food and Agriculture Organization of United Nations, Rome.

FAO (2009). Sri Lanka Forestry Outlook Study. Food and Agriculture Organization of United Nations, Rome.

Gunawardena, A.R. (2014). Land use, land cover types in Sri Lanka using remote sensing as non-destructive sampling technique. PhD thesis, Post graduate institute of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.

Houghton, R.A. (2005). Above-ground forest biomass and the global carbon balance. Global Change Biology 11 (6): 945–958.

Intergovernmental Panel on Climate Change. (2006). IPCC Guidelines for National Greenhouse Gas Inventories: Kanagawa, Japan.

Paustian, K., Six, J., Elliott, E.T., and Hunt, H.W., (2000). Management options for reducing CO_2 emissions from agriculture soils, Biogeochem., 48: 147-163.

Post, W.M., Peng, T.H., Emanuel, W.R., King, A.W., Dale, V.H. and De Angels, D.L., (1990).The global carbon cycle, Am. Sci., 78: 310-326.

Pushparajah, M. (1987).Forestry as an asset in the national development. Sri Lanka Forester 18 (1 & 2): 31–34.

Ruwanpathirana, N.D. (2016). Sri Lankan Timber trees; Properties and uses (Timber manual): pp. 366,370,372.

Ruwanpathirana, N.D. (2016). Sustainable Forest Management: pp. 211-212.

Sahajananthan, S. (1987). Forest management in Sri Lanka: A glimpse at the past and present. Sri Lanka Forester 18 (1 & 2): 45–51.

Sivananthawerl, T. and Mitlöhner, R. (2011). Eucalyptus grandis and Other Important Eucalyptus Species: A Case Study from Sri Lanka. In: Günter S., Weber M., Stimm B., Mosandl R. (eds) Silviculture in the Tropics. Tropical Forestry, vol 8: Springer, Berlin, Heidelberg.

UN-REDD (2017). Sri Lanka's Forest Reference Level submission to the UNFCCC, REDD in Sri Lanka.

https://redd.unfccc.int/files/sl_frl_modified_submission_november_2017.pdf (Accessed 04/06/2019).

Vivekanandan, K. (1987). Fifty years of forestry research. Sri Lanka Forester 18 (1 & 2): 35–39.

Watson, R.T., Noble, I.R., Bolin, B., Ravindranath, N.H., Verardo, D.J., Dokken, D.J. (2000).Land use, land use change and forestry - A special report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, IPCC, Additional human-induced activities, Article 3.4: 189-217.

Yadav, R. (2012). Soil organic carbon and soil microbial biomass as affected by restoration measures after 26 years of restoration in mined areas of Doon, Valley, Int. J. Env. Sci. 2(3):1380-1385.

Zhou X.,Yuanguang, W., Uromi, M.G., Hua, Z., Hongguang, Z., Xiaoqiong, L., Yeming, Y., Li, Y. (2017). Optimal rotation length for carbon sequestration in Eucalyptus plantations in subtropical China: International Journal on the Biology, Biotechnology, and Management of Afforestation and Reforestation. Vol.48, Issue 5, pp. 609-627, September, 2017 :1573-5095 (Online)

Appendix 1

Equations used for the analysis

Carbon estimation

IPCC (2006) guideline was used for the carbon calculations.

Equation 1 was used for carbon estimation per log:

$$C_{log} = (V_{log} x\ D)\ x\ CF \qquad (1)$$

Where C_{log} is the carbon per log, kg; V_{log} is the timber volume, m^3; CF is the carbon fraction of dry matter, $t(\text{tons d.m.})^{-1}$, (default = 0.47)

Equation 2 converts Wood density at 12% moisture content to 0 % moisture content

$$Y = \frac{\text{Wood density (12\% MC) x 100}}{112} \qquad (2)$$

Y = Wood density at 0% moisture content, kgm^3

MC = Moisture content

Density values - Ruwanpathirana, N.D. (2016). Timber manual: pp. 366,370,372. Carbon dioxide estimation

Carbon dioxide estimation

Equation 3 converts the amount of log carbon to atmospheric CO_2.

$$At_{CO2} = C_{Log} x\ Eqr \qquad (3)$$

Where C_{log} is the carbon per log, kg; Eqr is the CO_2 equivalent ratio: 3.67

Appendix 2

Yield Tables for Teak, Pinus & Eucalyptus

EXTRACTED INFORMATION FROM THE YIELD TABLE FOR PINUS, TEAK & EUCALYPTUS					
Species	Age Years	No. of Trees/ha	Removals Vol / ha m^3s.ob	M.A.I m^2s.ob	Cutting Type
TEAK	50	220	128	3.8	Clear Felling
PINUS	30	380	206	9.1	Clear Felling
EUCALYPTUS	25	200	260	13.8	Clear Felling

Ruwanpathirana, N.D. (2016). Sustainable Forest Management: pp. 211-212.

By using above values from the yield table, the expected volumes for a hectare were calculated for all species.

Finger-joint technique to mitigate climate change

C.K. Muthumala[1]*, Sudhira De Silva[2], K.K.I.U. Arunakumara[3] and P.L.A.G. Alwis[4]

[1]Research, Development and Training Division, State Timber Corporation, Sri Lanka
[2]Department of Civil and Environmental Engineering, Faculty of Engineering, University of Ruhuna, Sri Lanka
[3]Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Sri Lanka
[4]Department of Agric. Engineering, Faculty of Agriculture, University of Ruhuna, Sri Lanka
*ck_muthumala@yahoo.com

- Finger joint is a recognized technique connecting two small pieces of timber together
- This technique is used in Sri Lanka for non-structural purposes such as making timber boards and furniture
- Issues related with the strength of the joints are still not fully investigated under Sri Lankan conditions
- With higher tensile strength, finger -joint technique can be used to manufacture furniture and minimize the use of small sawn timber planks in boilers
- This technique will enhance the mitigation of greenhouse gases and assist in carbon sequestration

Introduction

Human induced climate change is one of the most pressing and complex issues facing society in the 21st century. Increased use of forests and wood products, does make an important contribution towards tackling the problem of climate change although it does not necessarily reduce greenhouse gas emissions at source (Hannah *et al*, 2004). Trees sequester carbon during their lifetime, absorbing carbon dioxide (CO_2) from the atmosphere and storing it in their mass. For every kilogram of wood grown, 1.5 kg of CO_2 is removed from the atmosphere (ASCE, 2010). Storing CO_2 in wood could therefore be considered as an effective means of mitigating climate change, though wood also releases CO_2 when it is used as fuel (Philippe, 2013).

When comparing the various heat sources: wood, coal, fuel oil, gas or electricity, in respect to climatic impacts, the pertinent characteristic is the emission factor, which is the amount of carbon (or carbon dioxide) emitted per unit to released energy. Substitution of wood for fossil fuels does not reduce emissions of carbon dioxide because the emission factor of wood shows a higher value than that of other fuels in common use. Thus, giving the primacy to carbon sequestration is vital to increase the carbon stock in forests, wood products or in some kind of long-term wood storage, (Philippe, 2013).

While using timber in construction and furniture manufacturing industry, waste timber materials and short-length sections of timbers which are dumped by sawmills is considered to be a matter of concern. However, some of this discarded timber planks are already being used to fuel kiln dried boilers. Finger joint is a sustainable, eco-friendly and economically valuable concept in furniture industry (Sandika *et al.*, 2017). Finger joint is a recognized technique connecting two small pieces of waste timber together to ensure sustainable utilization. Currently, the technique is used in Sri Lanka for non-structural purposes such as making timber boards and furniture. However, issues related with the strength of the joints are still not fully investigated under Sri Lankan conditions. Consumers are paying their attention to the strength of finger joint productions. This study was undertaken to determine the tensile strength performance of both un-jointed (clear) and finger-jointed four species of timber with 13 mm finger lengths and 4 mm finger pitch.

Materials and methods

Un-jointed and jointed finger joint samples were cut from seasoned defect-free sawn wood timber to calculate tensile strength properties. Finger joint specimens were made at finger joint factory of the State Timber Corporation (STC) at Boossa using 13 mm finger joint length cutters, and an assembling pressure of 6 Nmm-^{2} was used in this study. Clear timber specimens taken as control specimens and finger jointed timber specimens with same dimensions were made with constant finger geometry such as 13 mm Finger Length, 1 mm Tip width and 4 mm finger pitch. A recent research reported that no significant difference in the tensile strength of finger-jointed lumber was found between horizontal and vertical finger formation (Min-Chyuan *et al.* 2011). Finger joint geometry is shown in figure 1. Polyvinyl acetate (PVA) SWR adhesive was used as bonding agent (Glue type) for finger jointed wood (Muthumala, 2018).

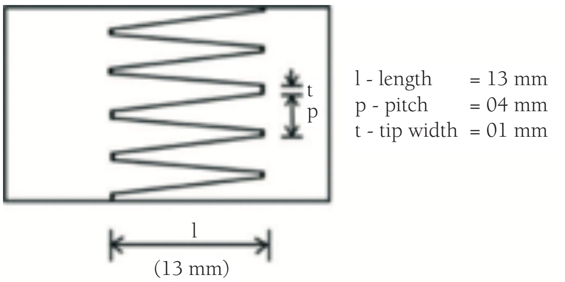


Figure 1: Finger joint geometry

Table 1 shows the timber species mainly used in furniture industries in Sri Lanka. In this study these timber species were used to calculate tensile strength properties.

The specimens were prepared from defect-free sawn woods, and dimensions of the sample prepared for above test are shown in figure 2.

Table 1: Four timber species mainly used for furniture manufacturing industries in Sri Lanka.

Timber Species	Botanical Name	Timber Class (STC)
Grandis	*Eucalyptus grandis*	Class –II
Mahogany	*Swietenia macrophylla*	Luxury
Pine	*Pinus caribaea*	Class-III
Teak	*Tectona grandis*	Supper Luxury

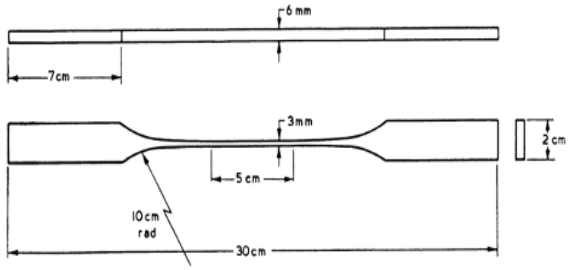


Figure 2: The dimensions of the samples prepared for tension test.

The density values were calculated for seven timber species using the following equation (Eq 01). Dry weight of the timber samples was taken by placing in the electric oven at 105°C for a period of 48 hours (BS EN 373:1957).

$$\text{Density} = \frac{\text{Weight of oven dried wood (kg)}}{\text{Volume of wood (m}^3\text{)}} \quad (\text{Eq} - 01)$$

Determination of basic density was done based on the green volume and oven-dry weight using a water displacement method. Moisture contents were measured using a moisture meter.

Ten replicates were made for each timber species. Samples which were placed in normal room temperature conditions showed good structural performance compared to hot and wet conditions (Vievek *et al*,2016).

BS 373: 1957 and BS EN 15497:2014 were used as standards for tests. The test for tensile strength was performed by Universal Testing Machine (UTM 100 PC).

Determination of the Tensile strength

Maximum load act in timber section was taken into calculation. Equation 2 was used to calculate the Tensile strength (BSI, 1957).

$$\text{Tensile strength of timber} = \frac{\text{(Maximum Load)}}{\text{(Average cross section area of specimen)}} \ \text{N/mm}^2 \quad (\text{Eq-02})$$

Results and discussion

Dry density values and moisture content of the timber species are shown in table 2. Dry Density values varied between 460 (kg/m^3) to 720 (kg/m^3) in 12 % moisture content.

Table 2: Dry density values and moisture content of timber species

Timber species	Density (kg/m3)	Moisture content %
Grandis	570 ± 5	11 ± 2
Mahogany	570 ± 3	12 ± 1
Pine	460 ± 2	12 ± 2
Teak	720 ± 5	12 ± 2

Table 3: Finger joint efficiencies of four timber species

Timber species	Mean tensile strength of clear specimens(N/mm^2)	Mean tensile strength of finger- joint specimens (N/mm^2)	Strength Difference (Clear - joint) (N/mm^2)	Joint efficiency %
Grandis	103.16	50.24	52.92	48.70
Mahogany	47.64	35.77	11.87	75.08
Pine	83.23	17.04	66.19	20.47
Teak	124.25	36.47	87.78	29.35

Table 4: Mean C stock (t ha^{-1})

Timber species	Mean Carbon stock (t ha^{-1}) of monoculture forest plantations of Sri Lanka in 2008 (De Costa & Suranga, 2012)
Grandis	132.72
Mahogany	97.57
Pine	130.19
Teak	42.70

According to Table 03, the highest mean finger-joint efficiency percentage (75.08%) was obtained from Mahogany timber species and the second highest mean finger-joint efficiency percentage (48.70%) was recorded in Grandis timber species. The least mean finger- joint efficiency percentage (20.47%) was recorded in Pine timber species. Mean finger- joint efficiency percentage varied as:Mahogany>Grandis>Teak >Pine.

Table 4 shows the mean Carbon stock (t ha^{-1}) of commonly used timber species of monoculture forest plantations of Sri Lanka in 2008 (De Costa & Suranga, 2012). The lowest amount of mean C stock was showed in the timber species of Teak (42.7t ha-1) and the highest amount of mean Carbon stock was showin the timber forest species of Grandis (132.72t ha^{-1}). However, fast grown species generally consume higher amount of resources, which are more sensitive to resource availability (Amarasinghe, 2018). Pine is a fast-growing species, which shows the second highest Carbon stock (130.19t ha^{-1}). Therefore, use of short- length sawn timber pieces for finger- jointed furniture production could contribute to carbon storage.

Conclusion

The following conclusions can be drawn from this study:

The highest tensile strength was recorded in Teak clear specimens and the lowest was recorded from finger- jointed Pine timber specimens.The highest mean finger- joint efficiency percentage (75.08%) was obtained from Mahogany timber species and the lowest (20.47%) was recorded in Pine timber species.

This study illustrates the joint efficiency of finger- jointed four timber species. The present findings could be effectively used in finger- joint manufacture.

Furniture is the portable equipment used in various human activities such as seating, working and relaxing. This end can be considered as a form of decorative art. Finger- joint techniques can be used to manufacture furniture and minimize the use of small sawn timber planks in boilers through which sequestration of the carbon stock in wood products could be enhanced.Hence, investigating the tensile strength of finger jointed products is important.

References

Amarasinghe, W.V.T.D., Terada, T and Yamamoto, H. (2018). ''Forest management options to increase carbon sequestration in Eucalyptus plantations of Sri Lanka," Sustainable Forest Ecosystem Management, IUFRO, Taiwan.Pp 113- 118 https://www.researchgate.net/.../330214337(Accessed: 6June 2019).

ASCE.(2010). Sustainability Guidelines for the Structural Engineer. D. Kestner, P.E.; J. Goupil, P.E.; and Emily Lorenz, P.E. https://materialspalette.org/wood/ (Accessed: 30 ,May 2019).

British Standards Institution.(1957). BS 373: 1957, Methods of testing small clear specimens of timber.British Standards Institution. London.

British Standards Institution. (2014). BS EN 15497:2014, Structural finger jointed solid timber Performance requirements and minimum production requirements, European Committee for Standardization. B 1000 Brussels.

De Costa, W.A.J.M and Suranga H.R.(2012). Estimation of carbon stock in the forest plantations of Sri lanka, J.Natn.Sci. Foundation Sri Lanka, 40(1) 9-41

Min-ChyuanY,Yu-Li,L and Yung-Chin H.(2011). Evaluation of the Tensile Strength of structural Finger-Jointed Lumber, Taiwan J forSci 26(1): 59-70 www.airtilibrary.com(Accessed: 3 August 2018).

Muthumala C.K., De Siva S, Alwis PLAG and Arunakumara K.K.I.U.(2018a). Factors affecting the glue strength of finger-joints in commonly used timber species in Sri Lanka. International symposium on Agriculture and Environment.Faculty of Agriculture. University of Ruhuna, Sri Lanka. Pp. 126-128.

Muthumala C.K., De Siva S, Alwis PLAG and Arunakumara K.K.I.U.(2018b). Investigate the most suitable glue type for finger-joints production in Sri Lanka, Research journal of Agriculture and Forestry Sciences, ISCA, India, Vol. 6(11), 6-9, November, Pp. 6-9

Philippe L.(2013). Wood preservation (carbon sequestration) or wood burning (fossil-fuel substitution), which is better for mitigating climate change? , Annals of Forest Science (2014) 71:117–124, https://hal.archives-ouvertes.fr/hal-01098394/document (Accessed: 30May 2019).

Sandika, A.L., Pathirana G.D.P.S. and Muthumala C.K. (2017). Finger joint timber products for effective utilization of natural resources: An analysis of physical properties, Economic factors and Consumers' perception, International Symposium on Agriculture and Environment, University of Ruhuna, Sri Lanka. Pp. 109-111.

Vievek, S., De Silva S., De Silva, S and Muthumala, C.K. (2016).Finger joint and their structural performance in different exposure conditions, 7thInternational Conference on Sustainable Build Environment, Kandy, Sri Lanka.Pp. 207-210

Building 'Climate Smart Cities'

Hasula Wickremasinghe[1]* and Sujith Rathnayake[1]
Climate Change Secretariat, Ministry of Environment
*hasulaw@yahoo.com

- Cities are more vulnerable to climate change with sprawling population and unplanned development
- Cities generate more greenhouse gas contributing to global warming.
- Both mitigation and adaptation measures are required to enhance the resilience of cities.
- Urban planning should focus on features of climate smart cities to ensure sustainable life styles

Background

Cities are magnets for employment, businesses, and education opportunities in many countries. However, cities consume 78% of the world's energy and contribute to 60% of global greenhouse gas emission (UN Habitat, 2019), a major cause for climate change. City ecosystems are increasingly vulnerable with increasing population, often fueled by rural-urban migration in the face of adverse climatic conditions and loss of rural livelihoods. Rising sea-level and increasing frequency and intensity of storms, cyclones, drought, floods, landslides, and heat and cold waves expose a large population and infrastructure of cities.

Densely populated cities face the brunt of the damages of climate induced disasters. Displaced population, loss of lives and livelihoods, and damages to property and infrastructure contribute to large economic losses. According to the International Disaster Database (2018), climate related and geo-physical disasters resulted in 10,733 deaths, and over 60 million people affected all over the world (CRED/IRSS/UCLouvain (Review 2018). In 2018, natural disasters cost the world $225 billion. In the Asia Pacific region alone, extreme weather-related disasters caused 89% of the economic losses (downtoearth.org). One of the most disastrous events of 2019 was typhoon Hagibis, which flooded 25,000 ha in Honshu, Japan. The typhoon claimed 79 lives, left more than a dozen people missing and 2400 homes damaged or destroyed (Tokyo, CNN).

Although the cities are the engine of economic growth in many countries, they also give rise to formidable socio-economic and environmental challenges. At the forefront are social inequities, management of water, land, and waste; inadequate or inappropriate development of infrastructure for transport, energy, and buildings; governance; and environmental degradation and increasing ecological footprint. Increasing frequency and magnitudes of natural hazards exacerbate many of these challenges.

When cities expand amidst unplanned, inadequate, and poorly managed service systems, they lead to unsustainable production and consumption patterns and as a consequence pollution and environmental degradation. How should our cities look like in the future?

William Eisenstein (2001) highlighted in "Ecological Design, Urban Places, and the Culture of Sustainability" that the world faces a future characterized by expanding metropolitan regions and ecological crisis. According to Eisenstein, the 21st century will be the first in the history in which a majority of humanity lives in cities. And if the present trend continues, it may also be the one in which those urban populations inflict irreversible damages on the earth's living system. It is imperative that we re-think the relationship of urban dwellers to the natural environment.

The 20th century models of urbanization didn't include full consideration of future outcomes and path dependencies. The use of the private mode of transport and urban sprawl became dominant trends. However, in the 21st century, planning and management of global urbanization expect the cities to fully achieve their potential to increase prosperity and social cohesion and bring about improved standards of environmental efficiency, citizen health, and well-being and strengthen international relations (foresight.futureofcities@bis.gsi.gov.uk).

In recent years, many urbanization concepts emerged, especially to address the challenges of population growth, water scarcity, Urban Heat Island, energy demand and health. Popularly known as, Sustainable Cities, Ecocities, Green Cities, Water Cities, SMART Cities, and Climate Smart Cities, all hope to achieve;

a) Resource augmentation
b) Material and energy intensity management
c) Smart and intelligent systems
d) Pollution and waste prevention
e) Pollution and waste management
f) Land use planning for urban ecosystems
g) Mobility management
h) Socioeconomic equity

Defining 'Climate Smart Cities'

There are many definitions for climate smart cities, converging from those that focus exclusively on the infrastructure to those that focus more on enabling citizens and communities to act smarter. While no one definition suits all cities, a definition which suit most concepts is:

"A **smart city** is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, the efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations concerning economic, social and environmental impacts. (Moir *et al.*, 2014)

With the growing concern for global warming and the urge to keep the temperature below 2°C, the United Nations Framework Convention on Climate Change (UNFCCC) has introduced the program on Climate Smart Cities (www.climatesmartcities.org). The UNFCCC framework highlights energy efficient technologies and climate resilience.

Therefore, **Climate Smart City** is a city with built infrastructure with resilience to adverse impacts of climate change, and low carbon technologies to reduce greenhouse gas emissions, ensuring healthy and comfortable living for the urban population (MMDE, 2019).

India's Climate SMART Cities

India is one of the top 10 emitters of greenhouse gases accounting for 6.5% of global GHG emissions (WRI,2017). The Government of India declared its intension of reducing the emission intensity by 33-35% by 2030. Nearly 44% of India's rapidly growing carbon emissions have urban origins, deriving from transport, industry, buildings, and waste.

The Ministry of Housing and Urban Affairs (India) initiated the "Climate SMART Cities Assessment Framework for the 100 smart cities envisaged to provide solutions to address water stress, heat island effect, increased frequency and severity of extreme weather events such as urban floods/ droughts and air quality. This program has identified 30 indicators across five sectors, namely, energy and green buildings, urban planning; biodiversity and green cover, mobility and air, water resource, and waste management. This assessment framework aims to be SMART (Specific, Measurable, Actionable, Relevant and Time-bound). (GoI, 2019).

Planning Climate Smart Cities

Risks from natural hazards vary with locations of cities in mountainous, plateau, or coastal regions and those adjacent to major rivers. Governance is a major issue in enhancing resilience, but participatory management of local governments and the communities is a key feature of Climate Smart Cities. Local governments need to establish a baseline of potential hazards and vulnerabilities and prepare a GHG inventory for mitigation measures. India identified 31 indicators of the five sectors to assess requirements and monitor the effectiveness of Climate Smart Cities (GOI 2019). While local governments and communities are better informed and empowered to confront the potential impacts of climate change, it is equally important to promote policies, technologies, and citizen's participation to manage Climate Smart Cities.

Implementation of 'no-regret' policies and measures in the five sectors is a better option regardless of the consequences of climate change. A well planned Climate Smart City has adequate capacity to face natural disasters with climate resilient adaptation and mitigation strategies and hazard-specific awareness and capacity building of the population (Paterson, 2009). Furthermore, Climate Smart Cities should have various policies and management instruments such as regulations and standards, taxes and charges, tradable permits, financial incentives, voluntary agreements, information instruments, and research and development, after consideration of the national circumstances and sectorial context (Paterson, 2009).

Mitigation and adaptation actions to natural disasters in Climate Smart Cities should be implemented simultaneously. They complement each other and needs streamlining to address climate change impacts and together address part of the risks of Climate change. Reducing the GHGs by changes in lifestyle, behavioral patterns, and management practices can make significant contributions in improvements to the regional environment and could contribute to better health and well-being and economic efficiencies in households and businesses. The application of low carbon development technologies such as renewable energy, smart traffic systems, etc., and circular economy concepts for waste management will enhance the establishment of Climate Smart Cities (Moir *et al.*, 2014)

Cities in Sri Lanka

According to the last population census in 2011, Sri Lanka has 20.359 million people, of which 3.704 million (or 18.2% of the population) are urban residents living in 64 municipal areas in nine Provincial capitals (Table 1). According to this definition of urban residents, Sri Lanka ranked 11th lowest urbanized country in the World in 2018 (UNDESA, 2018). However, the official definition of urban population data does not show the true extent of urbanization. According to the Agglomeration Index (Uchida and Nelson, 2008), an alternative measure of urbanization using multiple indicators, shows between 35 and 45% of the total population is urban, while the recent government of Sri Lanka (GoSL) policy documents estimate 50% urban population.

Urban expansion has occurred outside the municipal boundaries creating low density urban sprawls. This 'hidden' urban fringe shows the need for revisiting the definition of urban areas and a revision of municipality boundaries. Further, there is an unequal distribution of resources and services across cities. A greater range of urban services and access to resources are available in cities in the Western province, especially those connected to the capital Colombo, while access to resources in cities in the north, east, and more remote central areas are limited (GoSL,2018).

Table1: Sri Lanka's urban areas as per 2012 census (Source: GoSL,2018)

Province	No. of Municipalities	Urban Population	Provincial Capital	Population of Capital
Western	21	2,272,194	Colombo	561,314
Eastern	8	389,687	Trincomalee*	48,351
Central	10	270,971	Kandy	98,828
Southern	7	261,677	Galle	86,333
Northern	6	176,808	Jaffna	80,829
Sabaragamuwa	4	115,444	Ratnapura	47,105
North Western	4	97,294	Kurunegala**	24,833
Uva	3	69,800	Badulla	42,237
North Central	1	50,595	Anuradhapura	50,595
Sri Lanka (entire)	**64**	**3,704,470**		

Notes: In the following cases, the Provincial Capital is not the largest in its Province.
**The largest town in the Eastern Province in Kalmunai (population 99,893) followed by Batticoloa (population 80,227)*
***The largest town in the North Western Province is Puttalam (population 45,511).*

Climate risks in Sri Lanka's cities

The main climate risks for cities in Sri Lanka are floods, landslides, droughts, sea level rise, and heat waves. Issues associated with these risks are public health, access to safe water and sanitation, unsafe infrastructure, and unreliable energy supply. With an average annual affected people of about 900,000 (approximately 4.1% of the population), the long-term financial losses are estimated to be about Rs.50 billion annually (GoSL,2018). The increasing frequency and severity of climate risks and associated losses and damages have contributed to Sri Lanka's ranking of the 2nd highest climate risk country in an analysis conducted by Germanwatch using climate risk data from 1998-2017 (Ekstein *et al.*,2019)

Exposure to risk is closely related to the distribution of rainfall across Sri Lanka. The average annual rainfall is above 5000 mm in the central hills of the Southwestern region and below 1000 mm in the semi-arid region of the northwest. Sri Lanka receives rainfall in four distinct seasons; the southwest monsoon with rainfall exceeding 3000 mm from May to September; a relatively dry inter-monsoon period from October to November; Northeast monsoon contributing to 200 to 1200 mm from December to February and another relatively dry inter-monsoonal period from March to April. The El Nino and La Nina conditions and the Inter-Tropical Convergence Zone also influence precipitation patterns (USAID, 2018). With changes in climate and unplanned development, cities are facing significant water shortages, floods and landslides (Table 2). The Western province, with many large cities, had 95% and 74% of the flood and drought exposed population. respectively Droughts mostly affect the drinking water supply.

Table 2: Climatic zone and risk exposure in nine Provincial Capitals (1974-2017). Source: GoSl,2018-(modified)

City	Climatic zone	Exposure	Flood		Landslides		Drought	
			Affected	Deaths	Affected	Deaths	Affected	Deaths
Jaffna	Dry	Drought, flood, cyclone	40,268	0	0	0	2150	0
Anuradhapura	Dry	Drought	4030	0	0	0	19,645	0
Trincomalee	Dry	Drought	33,535	0	0	0	18,187	0
Kurunegala	Intermediate	Drought	2774	2	0	0	141,074	0
Badulla	Intermediate	Flood, landslides	2251	0	6424	41	0	0
Kandy	Wet	Landslides	505	0	2615	7	0	0
Ratnapura	Wet	Flood, landslides, drought	113,260	9	6969	47	4313	0
Galle	Wet	Flood, landslides	27,206	0	23	4	0	0
Colombo/ WRM*	Wet	Flood	3,807,394	223	2084	36	530,763	0
			4,031,223	**234**	**18,115**	**135**	**716,132**	**0**

*WRM=Western Region Megapolis

Note: water shortages, especially of potable water, are experienced in Badulla, Kandy, and Galle, are not mentioned in the category of exposure.

Key features for Climate Smart City Designs in Sri Lanka

Considering Sri Lanka's climate, the average ambient temperature has increased during the last 25 years. The highest annual average temperature was in 2016, where the average ambient temperature was 0.005°C to 0.856°C higher than the previous years. Rainfall patterns have been erratic and despite the overall decrease in the overall precipitation, the trend of maximum one-day and five day precipitation and total precipitation on extreme rainfall events showed an increasing trend.

Therefore, changing climatic trends should factor in planning expansion and urban development.

Water scarcities, flooding, and urban heat island (UHI) effect are three prominent risks that cities encounter with natural disasters. UHI effect occurs with increasing paved surfaces, concrete buildings, and power consumption. High energy use and insufficient transport infrastructure, housing, waste disposal, and recreational space are impacts due to urban expansion, which contribute to climate change and environmental degradation. These categories of causes and effects of climate risks need consideration in Climate Smart Action Planning. A typical plan for Climate Smart Cities is depicted in figure 1.

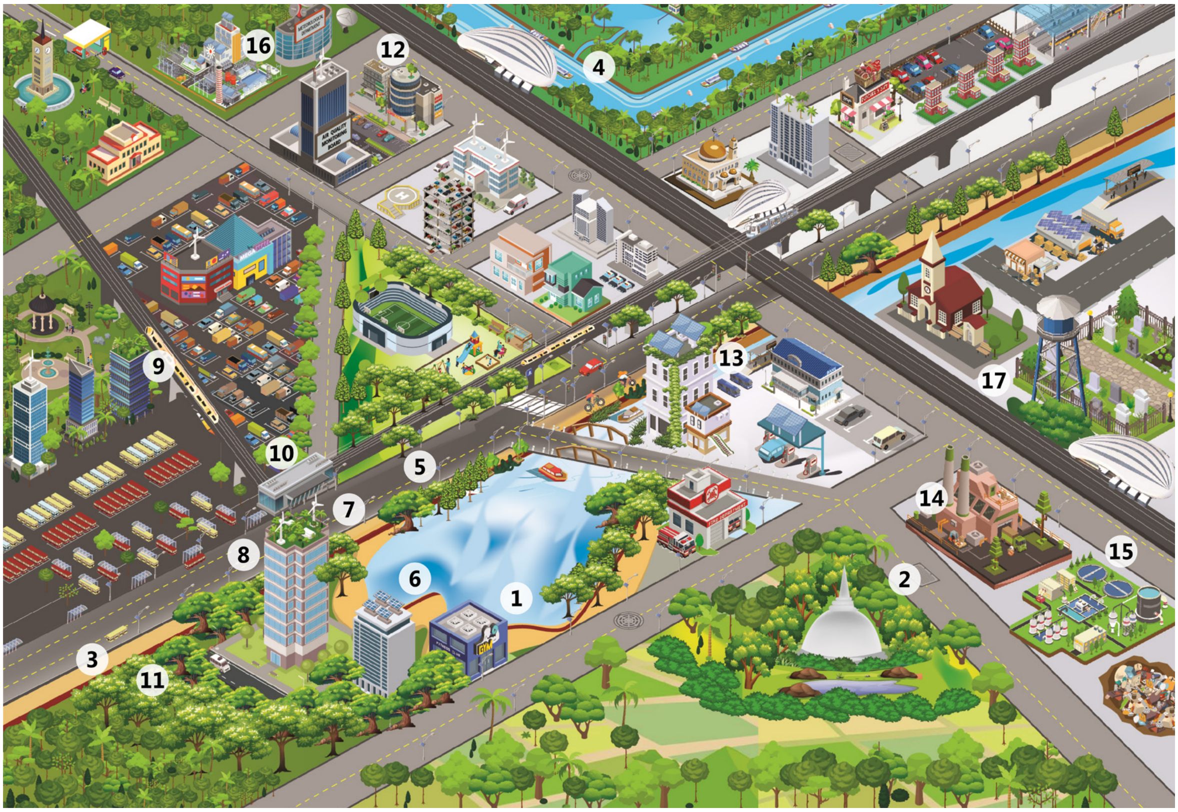


Figure 1. Main features of a Climate Smart City. Source: MMDE, 2019

Key features

1. Rain water harvesting
2. Rain water garden
3. Permeable brick pavement
4 Storm water drainage and recycling system
5 Street solar lighting
6 Roof top solar
7 Wind power
8 Green buildings
9 Energy Efficient Buildings
10 Multi modal transport hub
11 Urban Parks
12 Water recycling
13 Vertical gardens
14 Incinerator
15 Waste water treatment plant
16 Water treatment plant
17 Infiltration trench

Table 3 shows potential sub features within those 17 categories to incorporate in to city development, and their benefits of ensuring economic growth, healthy lifestyles, and environmental conservation.

Table 3: Key Features of a Climate Smart City and its benefits

Key Features of a Climate Smart City		Benefits
Energy	a) Expansion of renewable energy generation and use of solar (net metering in buildings), wind and waste, etc. b) Energy efficient air conditioning systems (with EE star rated ACs) c) Efficient ceiling fans to replace conventional ceiling fans d) Replacement of streetlights with Solar powered lamps e) Replace Incandescent Lamps with LED f) Frequent energy audits, carbon footprint assessments	a) Energy saving b) Reduction of greenhouse gas emissions c) Economic benefits
Sustainable transport	a) Promoting public transport systems and traffic management mechanisms b) Electrification of mass transport (bus/train) c) “hop on hop off’ electric transport means for short distances d) Solar charging stations e) Areas set aside for parking f) Car pooling	a) Less traffic congestion b) Saving of time in commuting c) Energy saving d) Reduction of greenhouse gas emissions e) Reducing air pollution f) Increasing connectivity
	g) Traffic management h) Synchronized traffic lights i) Introducing LED traffic signals j) Promoting walking, cycling k) Integration of safe network for pedestrians and cycling paths within and between developments	
Water Management	a) Rain water harvesting systems b) Water efficient plumbing c) Treatment and reuse of waste water d) Preventing siltation of water bodies e) Enabling ground water recharge f) Encouraging horizontal water filtration Building infrastructure in a way that leaves soil /grass areas for water percolation. g) Frequent water audits	a) Availability of potable water b) Water conservation c) Groundwater recharge d) Reduced water pollution e) Reduce water scarcity during dry periods

Key Features of a Climate Smart City		**Benefits**
Green Buildings	a) Follow green building guidelines (as appropriate) b) Use of energy efficient systems for constructions c) Using green designs d) Use green roofs e) Central AC systems / solar cooling systems f) Cross ventilation g) Natural lighting h) Soil bricks i) Solar lighting j) Infiltration trenches/ basins for storm water drainage k) Permeable car parks	a) Cooler buildings b) Environment friendly and healthy work spaces c) Energy saving d) Reducing greenhouse gas emissions e) Economic saving
Urban Ecosystems	a) Greening the cities by growing trees on either side of the streets (should leave space for pavement rain water to filter to underground horizontally) b) Pavements lined with either cement blocks containing space for the grass or permeable blocks for horizontal filtering of rain water c) Green areas set aside for leisure d) Revitalize urban wetlands e) Urban forest parks f) Green round a-bouts g) Use of native plants h) Green belts ,Tree belts i) Vertical gardens. (in urban areas that have no spce to plant trees, vines could be grown as greenery) j) Green fencing, Live fences k) Rain gardens (in minimum space to build a rock and foliage garden where the ground is sloped to collect rainwater) l) Tree box filters for streets (Space left around tree roots without concrete, sloped towards the trunk to collect and filter storm water) m) Wetlands linked with canals creating blue belts	a) Increases evapotranspiration b) Water conservation c) Prevention of soil and water pollution d) Soil conservation e) Conservation of ecosystems and biodiversity f) Reducing the effects of drought g) Reducing the Urban Heat Island effect

Key Features of a Climate Smart City		**Benefits**
Waste Management	a) Waste segregation at source b) Creating awareness to separate waste c) Collection points for recyclable wastes as well as recycling d) Production of biogas, compost e) Introducing Integrated waste management systems	a) Reducing soil and water pollution b) Reducing health risks c) Reducing plastic pollution d) Providing economic co-benefits through sewerage residue compost e) Reducing water contamination by pathogenic bacteria
	f) Waste to energy systems g) Establish hazardous waste disposing mechanisms h) Solutions for non-degradable waste like ceramics i) Managed landfills, incineration, etc. j) Adoption of 'no plastic' zones k) Discouraging 'single-use' plastics within city limits l) Constructed wetlands as sewerage filtering systems m) Linking residential and commercial sewerage into a common sewerage treatment plant	
Drainage systems	a) Flood control systems b) Storm water drainage systems (these could contain soak ways at regular intervals where the porosity of the ground permits aquifer recharge). c) Waste water transfer through canals to on-site treatment plants (and use treated water for irrigation of common areas) d) Drainage of roads using infiltration trenches, tree boxes and rainwater garden concepts for round-a-bouts	a) Reducing urban flooding b) Increasing the availability of ground water c) Reducing water contamination

State of Climate Smart Cities development in Sri Lanka

Commencing with making cities Sustainable and Climate Smart, Sustainable Development Goal number 11 highlights 'Sustainable Cities and Communities' as a range of concerns including the livability of a city and its resilience to climate change. The Kigali Cooling Efficiency Programme too addresses the need to utilize gases that do not contribute to global warming when using air conditioning and refrigeration to cool the heated up cities.

Sri Lanka's Nationally Determined Contributions (MMDE 2016a) include 'Urban City planning Human Settlements' as an important sector of climate adaptation. The National Adaptation Plan (MMDE ,2016b) has outlined actions for implementation for enhancing climate resilience.

As a step towards establishing Climate Smart Cities, Sri Lanka has embarked on various programs.

1. Enhancing urban resilience to climate change, the Kurunegala Municipal Council, together with the Climate Change Secretariat of the Ministry of Environment, has commenced designing a "Climate Smart City" for Kurunegala focusing on measures to reduce heat stress and water scarcity. and mitigation options for energy, transport and waste.

2. The Strategic Cities Development Project (SCDP) of the former Ministry of Megapolis and Western Development, together with the Urban Development Authority, has embarked on strategic investments such as integrated urban services improvement and public urban space enhancement to enhance the functional aspects as well as the attractiveness and livability of the cities. This program presently focuses on cities outside of Colombo with funding from donor agencies such as the World Bank, French Development Agency and Asian Development Bank.

3. The interventions are underway in Kandy, Galle, and Jaffna cities as well as proposed infrastructure and institutional strengthening of Trincomalee, Dambulla, Kurunegala, and Ratnapura, and Anuradhapura as an important historic city. These programs target the development of cities outside Colombo with potential for growth, as priority economic corridors and important nodes across the country.

4. The SCDP has obtained grant finances through the "Cities Development Initiative for Asia" for the feasibility study of Matara Integrated Urban Development Project and Sustainable Urban Mobility Planning Study of Kurunegala through "Mobilize Your City Programme."

Conclusions

Various programs, such as the above, are being designed to improve mobility, air quality, reduce heat stress and water scarcity, energy efficiency, etc. in Sri Lanka. However, these programs require the incorporation of information technology, policy, and regulations so that the implementation will contribute towards achieving climate resilience and reduction of greenhouse gas emissions of the City. Therefore, some features in table 3 can be incorporated into city design by urban planners in order to make the cities 'climate smart'.

Reference

Eisenstein, W. (2001). Ecological design, urban places, and the culture of sustainability. San Francisco planning and urban Research Association Report 399. http://www.spur.org/documents/ecodesign.pdf

Ekstein, D., Hutfils, M-L, and Winges, M. Global Climate Risk Index 2019: Who suffers most from extreme weather events? Weather-related loss events in 2017 and 1998 to 2017. Germanwatch

GoI, (2015) Smart City: Mission Statement and Guidelines, Ministry of Urban Development, Government of India. smartcities.gov.in/upload/uploadfiles/files/SmartCityGuidelines(1).pdf

GoI (2019) Climate SMART Cities; Assessment Framework

GoSL (2018) The State of Sri Lankan Cities, 2018. Colombo: UN-Habitat

MMDE (2016a) Nationally Determined Contributions, Sri Lanka, climate change Secretariat, Ministry of Mahaweli Development & Environment.

MMDE (2016b) National Adaptation Plan (2016-2025) Sri Lanka, climate change Secretariat, Ministry of Mahaweli Development & Environment.

MMDE, 2019.Climate Smart Cities.Brochure.

Moir E, Moonen,T and Clark,G (2014) What are future cities? Origins, Meanings and Uses.Compiled by The Business of Cities for the Foresight. Future of Cities Project and the Future Cities Catapult

Paterson, David (2009) Climate Smart Communities: A guide for local officials; State of New York

USAID, 2018. Climate Risk Profile, Sri Lanka: Fact Sheet

UNHabitat (2019) Climate Action Summit.https://www.un.org/en/climatechange/cities-pollution.shtmlUchida H and Nelson A (2008) Agglomeration Index: Towards a new measure of urban concentration. http://siteresources.worldbank.org/INTWDR2009/Resources/4231006-1204741572978/Hiro1.pdf

UNDESA (2018) 2018 Revision of World Urbanization Prospects. un.org/en/desa/2018 - revision - world - urbanizahan - prospects (Accessed : June 2019)

World Resources Index, 2017.https://www.wri.org/blog/2017/04/interactive-chart-explains-worlds-top-10-emitters-and-how-theyve-changed. Accessed June 2019

Win-win situation for the National Economy and the Utility : Rooftop Solar PV Systems with Battery Storage

Gayan Subasinghe
UNDP- NAMA Project
gayan.subasinghe@undp.org

- Benefits and drawbacks of roof-top solar Photovoltaic (PV) systems
- What could be done differently to enhance roof-top solar Photovoltaic (PV) systems capacity additions
- Way forward for behind-the-meter battery energy storages

Introduction

Solar Photovoltaic (PV) has become popular among all consumer groups including domestic customers. This technology application has some significant advantages as well as there are some concerns from the national and utility's perspective. Application of battery energy storages with domestic solar PV installations were piloted under the Appropriate Mitigation Actions in the Energy Generation and End-user Project and this article discusses how the application of battery energy storages can address some of these concerns and indicate future directions of the application.

Pros & Cons of Rooftop Solar PV Systems

On-site power generation also known as distributed generation has become competitive in the global context on economic and financial terms due to various reasons including conducive regulatory and policy environments, technological innovations, reduced capital costs and maintenance requirements, almost free operational cost, relatively easy access to inexpensive technologies, and other benefits.

The above is true for Sri Lanka too where Solar Photovoltaic (PV) is becoming increasingly popular among domestic, commercial and industry consumers. More than 217MWp Solar PV rooftop installations have been connected to the grid since the net-metering scheme was introduced in early 2010s where the consumers could self-generate power from renewable sources including solar PV and credit excess production back to the utility (CEB 2020) Subsequently net-accounting and net-Plus schemes were introduced.

The accelerated deployment of distributed solar PV through net-metering has also offered several benefits to consumers as follows;

- Net-metering scheme is attractive to middle and high-end electricity consumers paying exorbitant tariffs for the last few blocks of electricity units they consume. Although the upfront investment is quite significant to own a solar PV system, the payback period is relatively short for high-end electricity consumers.

- Solar PV generation need not necessarily match on-site consumption. Higher capacities of Solar PV systems are possible through the export of excess generation to the utility. Higher capacity means a lower per kWp investment and greater financial return.
- Customers having net-metering or net-accounting facility can use the grid to buy electricity when their own systems are not producing enough energy to meet their needs. The grid acts as a bank of energy for these consumers eliminating the need for expensive battery storage systems. Especially in solar PV they need to use grid energy during the night anyway.
- Owning and investing in solar PV systems, commercial and industrial consumers have the advantage to use these as green investments and as strategies they follow to reduce their carbon footprint. Some of these consumers use these in their marketing strategies to get competitive advantage at national and international level.

Apart from above individual benefits, there exists several economic, environmental and social benefits to the country as well as to the utility which can be detailed as follows;

- Net-metering schemes (including net-accounting and net-plus) promotes the use of clean energy eliminating the need for the construction and operation of expensive and polluting conventional fossil fuel based thermal power plants. This encourages consumers to play an active role in clean energy production.
- Electricity generation at the point of consumption similar to distributed solar PV generations reduces thestrain on distribution systems and prevents energy losses in long distance transmission and distribution. This makes the grid more efficient and reduces the cost of grid maintenance.
- Solar PV net-metering schemes has provided substantial economic benefits in terms of job creation, income and investment. There are more than 250 plus solar PV service provider companies in the country and direct employment of over 7,000 plus in this industry.
- This scheme has attracted individual and private sector distributed investments of more than 25b LKR towards the power and energy sector which would otherwise have to come from the utility or the government.
- It is estimated that the schemes can generate approximately 260 GWh/year solar PV electrical energy, off-setting similar amount of fossil fuel based electricity. A significant foreign exchange out-flow (through purchase of fossil fuel) has been prevented as a result of solar PV electricity generation.

Despite the fact that the programme has many benefits, there are also several drawbacks as well.

- With the introduction of net-metering schemes, it has been the medium and high-end consumers whose tariff is above the utility's cost (around Rs 19/kWh in 2018) who have gone for solar PV installations, and by entering into net-metering (or net-accounting) scheme they can reduce their high electricity bills by offsetting the electricity that they would have otherwise purchased at a higher price. (Out of around 5.5 million domestic consumers, high-end consumers are less than 2% but they contribute to a significant share of the utility's revenue)

NET METERING

This scheme which exists at present, allows any electricity consumer to install a renewable energy based electricity generating facility and connect it to the utility's electricity network. This connection will be metered by an export/import energy meter which records the export and import of the customer separately. At the end of each billing period, the utility will read the consumer's export energy meter reading and the import meter reading. The electricity bill will be prepared for the difference between the import and the export records. If the export is more than the import in any billing period, the consumer will receive an export credit, and will be brought forward to consumer's subsequent months.

NET ACCOUNTING

This Scheme has introduced an additional element to net metering scheme where export energy in any excess will be paid at an export tariff. As per the existing tariff , the customer will be paid Rs 22.00 per exported unit during the first 07 yrs and from the 08th year to 20th year he will be paid Rs 15.50 per export unit. If the consumption is greater than the energy generated from the solar panels, the consumer will be issued a bill using the existing electricity tariff for the import.

NET PLUS

Total generation of electricity from the solar PV power installation will be metered through a dedicated export energy meter for which the customer will be paid. The energy import will be measured through a separate import energy meter.

Source: LECO,2020

- This reduces the revenue earned by the utility. Though individuals are benefited by net-metering, it would be a revenue loss to the utility.
- Another alarming trend of such users is that due to the reduced electricity bills, they tend to add more and more electricity consuming devices to their systems (rebound effect).
- Although solar energy produced at daytime can be re-distributed among other day time users and helps to reduce the system demand during daytime, many net-metering consumers are evening peak time consumers and hence a burden to the utility where peak demand management has been a challenge.
- Net energy consumption of a net-metering customer is zero or negative and the consumer has to pay only the fixed charge which is as low as Rs.30. These consumers avoid paying for all the other fixed costs of utility for keeping the electricity grid viable and capacity charges. This is an unsustainable financial model for the utility and the government, and these costs will have to be charged from the customers without net-metering systems.
- Significant share of solar PV investments is toward the purchasing of solar PV panels, inverters and related accessories which are almost all imported from foreign countries leading to excessive outflow of foreign exchange.

Need of the Hour

In this background, solar PV Net-metering and net-accounting schemes need to be looked at from two important but contrasting perspectives; what are the national benefits in terms of increasing the renewable energy content of the national energy mix so that energy dependency could be reduced, while reducing the drain of foreign exchange for fossil fuel. Meantime, the short-term negative consequences of the utility such as loss of revenue, system balancing and other technological issues, etc. need to be managed in order to reap the long-term benefits of either delayed or avoided investment on fossil fuel based thermal power generation to meet the increasing demand.

Supplying of night peak in Sri Lankan grid is very challenging due to the operation of high cost power plants to cater the night peak demand. In order to relieve the utility's biggest burden of curtailing the evening peak demand, solar PV systems can be supplemented with a battery storage system. Domestic Solar PV net-metering system with battery storage has also been identified as one of the key initiatives in Demand Side Management (DSM) practices.

Nationally Appropriate Mitigation Actions (NAMA) Project Intervention

In this context, through UNDP /GEF funded NAMA project, Sri Lanka Sustainable Energy Authority in association with Ceylon Electricity Board, conducted a pilot programme to supplement 14 domestic rooftop solar PV systems with battery storage in the "Green Zones" of CEB and LECO in Kurunegala and Kotte areas respectively. Solar panel capacities were selected from 500 W to 3 kW and battery capacities were selected from 2.4 kWh to 9.6 kWh depending on the customer's energy usage. Both Li-Ion and Pb-Acid maintenance free deep cycle batteries were installed under this pilot programme.

During the daytime, domestic solar PV system converts solar energy to electricity and caters for domestic load requirement and any excess energy is stored in the battery bank. If more excess energy is available, this energy is exported to the national grid. Stored energy is used during the evening peak hours (6.30 PM - 10.30 PM) and if the domestic demand is higher than the system capacity or the battery has insufficient energy to cater for domestic load, the system draws electricity from the national grid. If there is a power failure or load shedding in national grid, the system caters for the domestic load requirement with islanding operation (battery stored energy is provided to the household load after household load is disconnected frame the grid). Battery storage is not allowed to be charged from the grid or feed the grid at any time of operation.

Research and Development Branch of CEB carried out a study on the above installed solar battery hybrid systems to analyze the technical performance of each system, to check the grid dependability (daily dependability and night peak dependability) and the effect of the total system (when considering all 14 installations as one system) on the utility grid.

Results of the Pilot Programme and Conclusion

Results of the pilot programme indicate that the rooftop solar PV systems with battery storage are technically capable of meeting the consumer demand during the national peak period provided that the battery storages are correctly sized and hybrid inverters are properly configured; (1) to deliver the maximum power of the battery storage during the national peak time (2) to stop battery charging using the imported grid energy and (3) to prevent system voltages rise. It was observed that up to 70% of peak demand management and energy independencies were achieved for consumers of this pilot study.

Apart from above key takeaways from this programme, few more benefits of battery energy storage application with solar PV consumers have been identified from the utility's point of view as follows;

- Distribution loss reduction;
- Investment differing for voltage correction (Remote Locations);
- Increasing feeder hosting capacity for more rooftop solar PV installation capacity;
- Potential solution for overvoltage and reverse power at selected points;
- Potential to support emerging concepts such as virtual power plants.

However, the consumers will only benefit by using battery or any other energy storage, if this concept has to be supplemented with policy and regulatory measures such as a favorable tariff arrangement to encourage the use of energy storage and own consumption during the national peak time. Further, it is essential that the energy storage users are allowed to use stored energy during power failures and load shedding with necessary protection requirements.

This overall concept is a win-win situation in terms of national benefits of increasing the renewable energy content of the national energy mix to meet the increasing demand without having to depend only on fossil fuel-based power generation while reducing the burden of utility to cater to the national night peak demand with expensive oil-based power generation.

With the night peak being slowly shifted to daytime with the development now taking place in the country, solar PV systems would be more beneficial as its daytime generation could supplement the daytime national peak demand. However, the peak shift from night to day may not happen in the foreseeable future.

As the technical feasibility is now established, it is expected that many high-end domestic consumers and even some industrial and commercial establishments will embrace this technology (solar PV systems with battery storage) once it is found to be financially viable with the reduced battery cost.

It is expected that the cost of batteries will come down considerably in the near future as many worldwide manufactures are engaged in R&D to make their products cost effective to be able to patronize hosts of emerging new applications such as battery storage in hybrid and electric vehicles, solar PVs, etc.

However, low end domestic consumers will never be able to afford the investment or to expect a reasonable return on their investment (even if they can afford the investment) with the prevailing highly subsidized tariff system even with reduced battery prices.

In addition to the establishment of the technical feasibility, this pilot programme is useful for SLSEA and the utility to understand the consuming patterns and related behavioral aspects of different user groups to formulate strategies for up scaling this effort to the national level. Futher, Sri Lanka has taken steps to approve hybrid inverters integration with the Sri Lanka Standards Institution (SLSI 1680 Standard) In 2020, and some of the learning has supported to fast-track this standard.

Way Forward

The formulators of the present electricity tariff structure have fixed a lower price for low-end consumers. This segment is heavily cross-subsidized with the surplus revenue earned from the high-end consumers. Under the prevailing socio-political situation of the country, authorities may not be able to do away with this subsidy and hence it would be an eternal subsidy with negative economic consequences.

As said before, this segment of consumers will never be able to afford a net-metering system at the prevailing market rates despite zero rated import duties for renewable energy generating technologies and equipment including solar PVs and grid-tie inverters.

Low-end domestic consumers' average tariff is well below the actual CEB generation and distribution cost. More than 70% domestic consumers which is around 3.9 million pay only less than Rs. 10 per unit whereas the actual cost of electricity generation and distribution was Rs. 19.12 per unit in 2018, and the associated subsidy can be estimated as Rs 30 billion per year.

Therefore, by taking the national benefits into consideration, it is advisable for the government to device a scheme with this technically proven Solar PV system with battery storage to do away with the eternal subsidy burden.

Reference

Lanka electricity company Pvt Ltd . (2020). Net Meter Connection. [Online]. [29 January 2020]. Available from:http://www.leco.lk/services/net-meter

Ceylon Electricity Board. (2018). Statistical Digest 2018. [Online]. [29 January 2020]. Available from: https://www.ceb.lk/front_img/img_reports/1567487133Statistical_Digest_2018.pdf

Ceylon Electricity Board. (2020). Statistical Digest 2019. [Online]. [30 November 2020]. https://www.ceb.lk/front_img/img_reports/1601877736Statistical_Digest_2019_Web_Version.pdf

Sri Lanka Sustainable Energy Authority. 2020. Conversation with Gayan Subasinghe. 30 January 2020

Variable Frequency Drives Application in the Tea Sector as an Appropriate Mitigation Action

Chamila Delpitiya
UNDP-NAMA Project
del.chamila@gmail.com

- Withering process consumes a high percentage of energy in manufacture of tea
- Variable Frequency Drives (VFDs) were introduced to achieve energy saving and reduce GHG emissions
- Energy NAMA project assisted to install 590 VFDs in 70 tea factories
- 20-30% energy savings of the baseline energy consumption was observed

Tea production is one of the main sources of foreign income for Sri Lanka. Ceylon Tea industry has secured its place among the top tea exporters in the world. This vital industry supports over 1 million dependents, whereas the annual tea export accounts for nearly 14% of export earnings (Sri Lanka Export Development Board web site: http://www.srilankabusiness.com/tea/tea-export-growth.html).

Withering is the most important step in black tea manufacturing process. According to different energy audits, withering consumes 35% - 50% of the total electrical energy required in tea manufacturing. During withering, the moisture content in the leaf is reduced by blowing ambient air through fresh tea leaves spread on a flatbed, making the leaf flaccid and pliable and preparing the leaf for further processing.Axial flow fans driven by electrical motors provide air for withering, and the flow variations are done by restricting the air inlet by means of mechanical methods, such as louvers. Usually, the airflow needs to be reduced at later stages of the withering process.

Though Variable Frequency Drives (VFDs) were introduced to the Sri Lankan Tea Industry in the 1990s it was not a popular energy saving option in the sector. The project identified the following major reasons for the unpopularity of the technology.

- Unawareness of the energy savings achieved
- Frequent failures due to lightning and harsh operating conditions
- Poor aftersales services by suppliers

A programme was launched under Nationally Appropriate Mitigation Actions (NAMA) : Energy generation & end - use sectors project addressing the above issues, and to make the application of VFDs popular amongst the tea industry, whilst achieving energy saving and corresponding to GHG emission reductions. The main initiatives undertaken by the Project were creating industry awareness through practical demonstrations and success stories, assisting tea plantations and producing companies with the selection of ideal VFD products to match operating conditions and external conditions, and maintaining a group of reliable technology suppliers for the programme. The programme assisted over 70 tea factories with a part-financing subsidy to install 590 VFDs under a strict quality control and assurance process. Further, comprehensive training was provided to the factory on operations of VFDs and the energy savings were systematically accounted through the web-based energy management portal developed by the project. Interface of the web portal is shown in figure 1. The project has successfully implemented an online monitoring application in two tea factories. Status of each VFD can be remotely monitored, and it has the capacity to store operations information which is accessible through any type of mobile device or computer. Figure 2 depicts the dashboard of the VFD online monitoring application. Figure 3 depicts a graphical representation and energy savings recorded.

> "Appropriate Mitigation Actions in the Energy Generation and End-Use Sectors in Sri Lanka" (Energy NAMA) is a project supported by the United Nations Development Programme (UNDP) and Global Environment Facility (GEF) with the objective of supporting appropriate climate change mitigation actions in the energy generation and end-use sectors as part of the initiatives to achieve the voluntary GHG mitigation targets of Sri Lanka. The Project is being implemented by the Sri Lanka Sustainable Energy Authority and Climate Change Secretariat of the Ministry of Environment

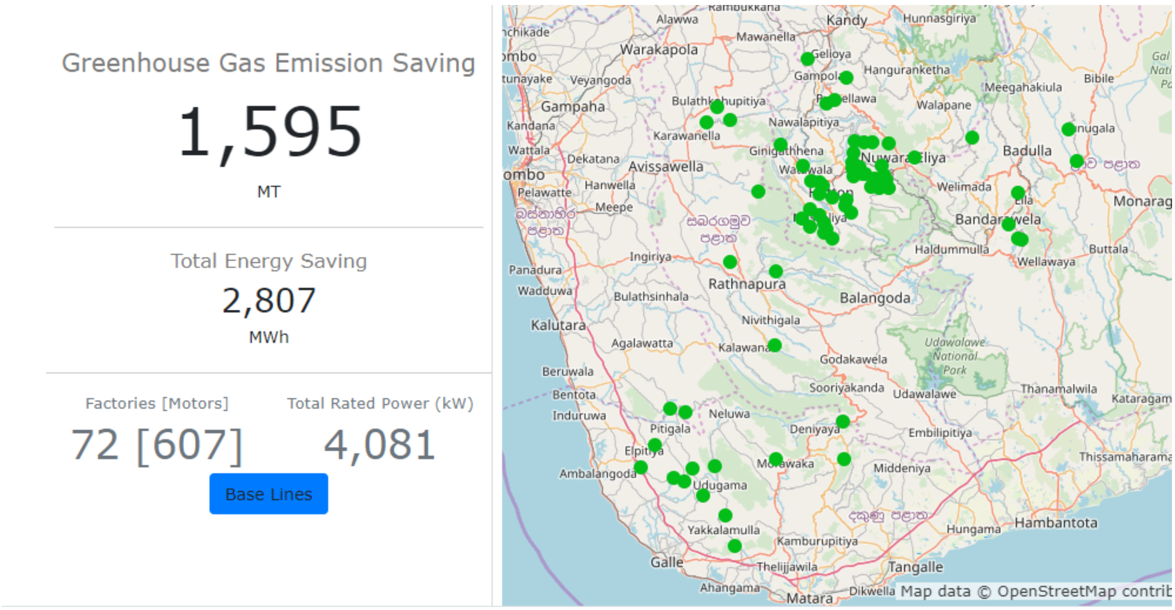


Figure 1: Online MRV portal (https://clean.energy.gov.lk/hem_vfd.php)

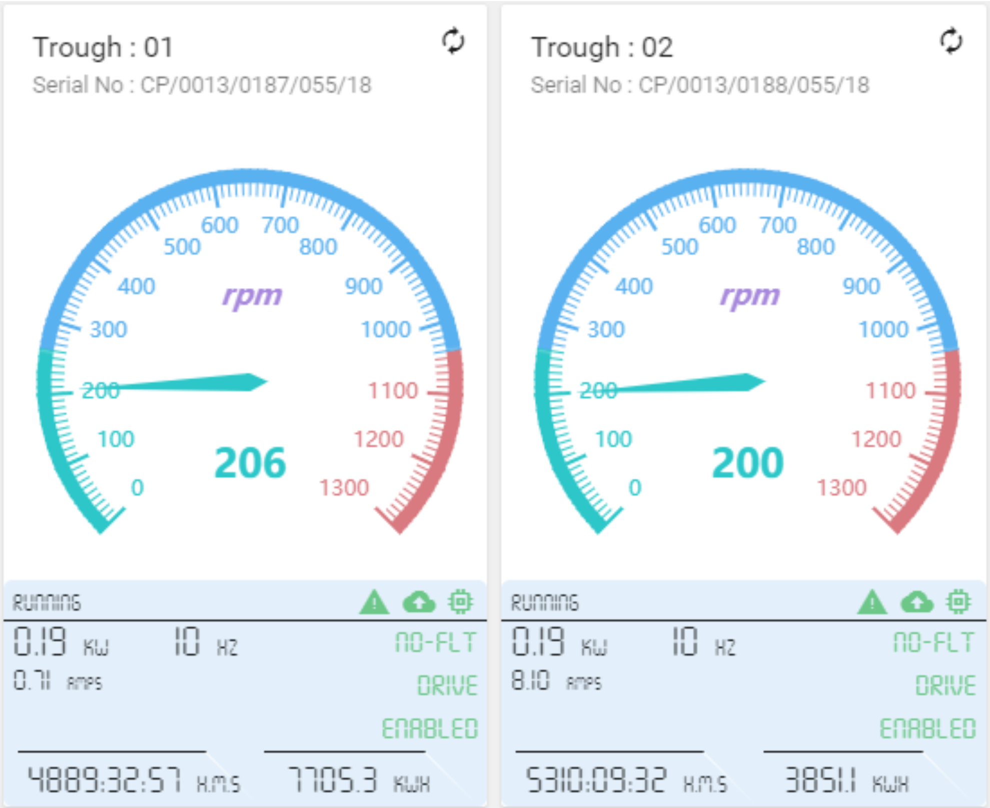


Figure 2:Screenshot of the VFD Online Monitoring Application Dashboard

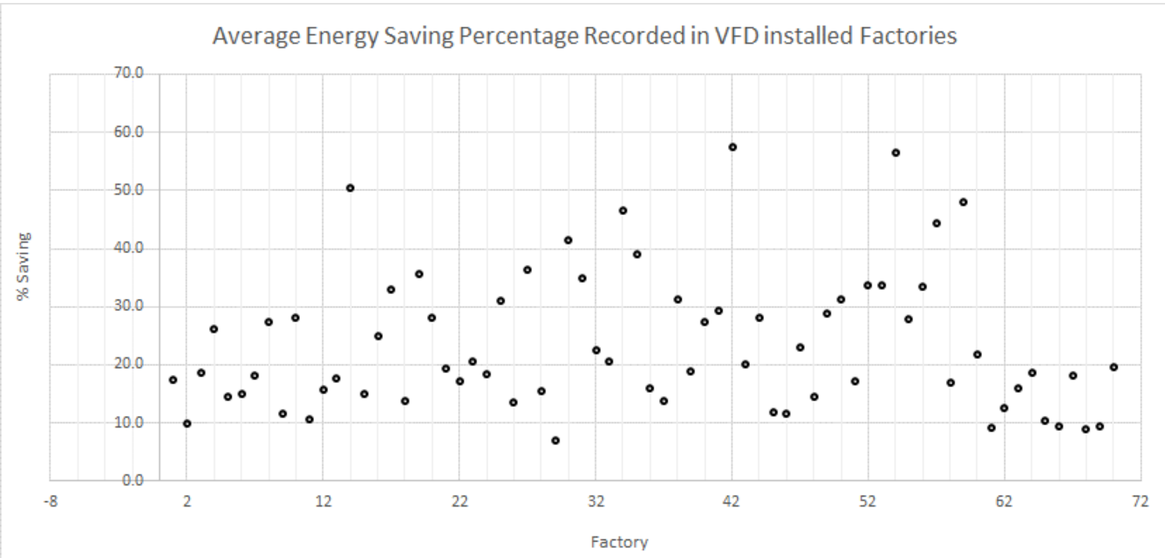


Figure 3: Graphical Representation of Energy Savings Recorded

Typically observed energy savings are in the range of 20 - 30% of the baseline energy consumptions. In addition to the energy savings and emission reductions, beneficiaries claimed that they are now able to control the tea withering process properly, resulting in higher product quality and reduction in waste/refuse tea quantity.

A more significant outcome of the Programme was the leverage in private sector financing for energy saving activities with GHG emission reductions, gaining more than USD 500,000 investment into the Programme, which can be considered as a significant achievement.

The project has covered approximately 10% of the total number of tea factories operating in the country, and with the results of these it is expected to increase the number to approximately 7000 VFDs in the industry.

Further, the project has initiated introducing the same technology intervention to other industries as well as other suitable applications in tea factories.

No of Factories Supported	70
VFDs Installed	590
Total Capacities	4,032.5 kW
Expected Energy Saving	3.387 GWh/annum
Emission Reduction	2,438 tCO_2/annum
Programme Support	USD 159,000
Co-investments by the Factories	USD 511,000

Fig: 4 VFD instruments

Fig: 5: Withering trough

Below, are remedial actions to overcome issues faced by users of VFD technology

Identified Issue	**Remedial Action to overcome the issue**
Frequent failure due to lightning	Mandatory to have a class II surge protection Device
Frequent Failure due to harsh environment (dust)	Should be of high ingress protection rating IP54 or above
Unawareness/Doubt about savings	Energy savings monitoring portal introduced online monitoring application development
Poor aftersales services by VDF suppliers	Selected and pre-registered qualified and reliable organizations

Climate Change and Energy Management: Low Carbon Energy Technologies and Strategies

Namiz Musafer
Sri Lanka Energy Managers Association
namizm@gmail.com

- The energy use in buildings worldwide accounts for over 40% of primary energy use and release of 24% of GHGs.
- Adopting energy management practices and more use of renewable energy sources help us reduce GHG emissions.
- Good behavioural practices by the occupants and visitors of the buildings, and implementing sound energy management systems are some approaches to mitigate climate change.
- The low carbon energy technologies and strategies make great strides to ensure sustainable development ensuring future generations meeting their needs

Introduction

The International Energy Agency (IEA) claims that energy production and use is the largest source of global greenhouse gas (GHG) emissions. Global energy-related CO_2 emissions have recorded a historic high of 33.1 Gt of CO_2. Power sector has accounted for nearly two-thirds of GHG emissions growth in 2018. The coal-fired power plants have been the single largest contributor to the growth in GHG emissions observed during this period.

'Energy' is simply defined as 'the ability to work', and is used by people at homes, institutions, commercial establishments, industries, farms, in transportation, and by many other sectors for different applications. Accordingly, many appliances, equipment, machinery, and vehicles *etc.* used by people, demand energy. With the increasing population, and improved affordability and quality of life, the demand for energy grows exponentially.

When it comes to buildings, the energy use in them worldwide accounts for over 40% of primary energy use. They amount to 24% of GHGs. As more and more energy is demanded, more energy has to be produced. Since most of the energy is produced by burning fossil fuels (coal and other petroleum products), this results in more environmental concerns and emission of greenhouse gases (GHGs), which lead to global warming and climate change. Therefore, to curtail emission of GHGs, no or less fossils should be used for energy generation and the proportion of renewable energy has to be increased. Another key alternative at our disposal is to improve energy management and energy efficiency, so that for the same or more amount of activity, less amount of energy is used, ensuring much more comfort and cost effectiveness, saving money while reducing pollution.

Some of the energy management measures practiced demonstrate that, in addition to curtailing the energy costs, sustainability and environmental concerns also have given a boost to improving their energy performance. Further, the investments made on energy efficiency improvements give good returns on investments made. How the institutions reduce their energy costs, and thereby contribute to climate change mitigation by reducing their GHG emissions, is attributable to some of the best energy management practices they adopt.

The best practices in energy management by the institutions can be visualized and analysed from the following key categories.

- Behavioural Practices
    - Employees
    - Guests and Visitors
- Management Systems
- Technology

The best practices by the employees can be improved by good awareness and training provided to them, sound internal communication systems and employee participation, deploying specialized staff, and implementing the preventive maintenance schedules. The behavioural aspects, such as a person leaving the premises last switching off the electrical devices and appliances (such as air conditioners, fans, bulbs) and reducing the number of times a cold room freezer doors and their curtains are opened and reducing the duration of them being kept opened, are some of the examples.

The users of buildings (the occupants, guests and visitors) too can help the institutions to bring down their energy consumption. A common practice adopted is to make polite requests through visible notices to seek their cooperation for energy conservation. For example, near an elevator lift, there may be a notice displayed requesting to take the steps to climb a few floors instead of taking the elevator for that purpose or to use a fan instead of an air conditioner.

More progressive institutions take some strategic and firm steps to reduce their energy consumptions. To name a few: adopting a sustainability policy or an energy policy, making green procurements giving emphasis to lifecycle costs and benefits rather than to mere purchase prices, setting and monitoring energy performance targets, having energy budgets in addition to having financial budgets, and having energy performance measurements etc.

When it comes to technology, the best would be to look for possibilities to avoid using any energy consuming devices. For instance, the buildings can be designed for maximum use of natural ventilation and lighting. Using energy efficient devices would be a key option, while every effort has to be made to reduce the duration of use and correct sizing of the devices for the intended purposes. Low Carbon Energy Technologies and Technical solutions, such as power factor corrections, could be done, especially if there are larger inductive loads. Some simple options such as card key systems and automatic room light controllers also help in the reduction of energy consumption.

Some prominent and visible measure adopted not only at institutions, but at homes, are replacement of incandescent bulbs with Light Emitting Diodes (LED) or Compact Fluorescent Lamp (CFL) bulbs. In places where electric motors and pumps are used with considerable changes in loads, variable speed drives could reduce the energy consumed. Institutions which produce significant amount of organic waste can adopt biogas technology where biogas can replace use of other energy sources such as Liquefied Petroleum Gas (LPG), natural gas, biomass, or electricity. Using other renewable sources, such as solar Photovoltaic (PV) for power generation and solar water heaters, too can boost energy saving.

Institutions can begin their energy conservation efforts from the no cost or low cost energy saving measures. There is proven evidence that such measures have an impact in reducing energy demand or making improvements in energy performance in buildings. For example, the low cost options can lead to significant energy savings by making some adjustments to equipment scheduling or set-points. These type of measures are not only conveniently implemented, but also can produce cost saving results immediately. While the human behaviour can make some contributions to reduce energy use, whether by the occupants, employees, visitors, and guests *etc*., sound management systems and appropriate technologies can make big tides, although they demand investments. Coupled with knowledge and skills, good awareness and motivation, the behaviours and practices of people could be changed for better energy performance, which ultimately leaves a sustainable world for the future generation, beginning with and sustaining a good attitude and energy consciousness.

Case Study

This is a story in brief of a star hotel having over 150 guest rooms and over 400 personnel working. This hotel has fully integrated the concept of sustainability into its business operations emphasizing on the business proposition of making economic profits, while protecting the environment and promoting sustainable development to achieve a win-win situation.

As an initial step in improving energy management, the hotel replaced most of its tungsten bulbs with Compact Fluorescent Lights (CFL) or Light Emitting Diode (LED) bulbs. This made an annual saving of over 100,000 electrical units (kWhs).

Air conditioners make a bigger portion of total energy costs. Therefore, the functioning of the chillers are closely monitored and regulated. For instance, during lower room occupancies, some chillers are switched off and air handling units and fan coil units of some air conditioners are switched off in unoccupied spaces of the hotel. The temperature of the water leaving the chiller is adjusted depending on the ambient temperature. Further, the components of the air conditioning system, such as fan coil units, air handling units, and condensers are cleaned periodically to ensure higher efficiency of the overall system. This has led to an annual saving of nearly 150,000 units of electricity.

The hotel has introduced sub-metering to continuously monitor electricity and water consumption to help in the better controlling of them. The measured records of consumption are then analysed to observe the trends and changes to take remedial actions. Further, related benchmarks are set to compare the energy performance.

The hotel has adopted the ISO 50001 Energy Management System. A team headed by an Energy Manager is given the overall responsibility to look into energy aspects, with representatives from all major departments being part of the team. However, Energy Management is not considered as just one person's responsibility, but a responsibility of all the staff from the General Manager to the staff members at the bottom of the pyramid. The cooperation from the guests is considered significant too. The energy policy statement, with guidance at the top,helps in setting related targets and objectives for implementation with an action plan, assigning accountability, and allocation of resources, which are again reviewed regularly. In the meantime, many energy related training is provided to the energy team members, and energy awareness is provided to the other staff while encouraging their suggestions and feedbacks to improve energy performance of the hotel. During monthly meetings of the management, the absolute energy costs and their share from total overhead costs are considered. The notices displayed in rooms encourage the long-stay guests to re-use their towels and other linen so that the consumption of energy and water is decreased.

The hotel has introduced capacitor banks to reduce its maximum electricity demand. For the major pumping systems, Variable Frequency Drives (VFD) have been installed. There are many energy conservation measures taken at the laundry. They include avoiding operation of the laundry during peak hours, reducing idling operating time, doing some improvements to the drain valve of the washing machines, and conducting annual steam trap tests. As for cool rooms, their doors are kept closed to the maximum possible duration to reduce cool loss. The hotel also maintains the boiler and gasifier properly while attending to preventive maintenance as per schedule. Special efforts are also are taken to preserve water.

The efforts of the hotel have resulted in a sharp drop of per room annual energy consumption from nearly 283 kWh_{eq} (1,020 MJ) to 228 kWh_{eq} (820 MJ) within a year (20% reduction) while the revenue has increased by nearly 12.5% during the same period. They have restricted their annual GHG emissions to nearly 3,000 tCO_{2eq}, which contribute to mitigate climate change and global warming.

References:

i. ASEAN Centre for Energy, Best Practices in Energy Efficiency and Conservation – ASEAN Energy Awards (2017). (Year of publication not available)

ii. Asia-Pacific Economic Cooperation Secretariat (2017), APEC 100 Best Practice Analysisof Nearly/Net Zero Energy Building

iii. https://www.iea.org/geco/emissions/

Notices that encourage the public to conserve energy

Vertical expansion of human settlements for sustainable cascade ecosystems in the dry zone and the mountain regions of Sri Lanka

C.P. Gunasena
Project Assistant (UNIDO), Environmental Pollution Control and Chemical Management Division, Ministry of Environment
cpg810@gmail.com

- Horizontal expansion of human settlements degrade ecosystems services and increase vulnerability to climate change.
- Vertical expansion of human settlements with appropriate policy can facilitate sustainable management of land, water, and other biotic and abiotic natural resources.
- Address the conservation and protection of environment and services around vertical habitats as a community responsibility

Introduction

The planet has unique terrain features comprised of highlands, lowlands, and water ways in between. Forest cover in the highlands reduce soil erosion and facilitates infiltration. During the rainy periods, a part of the surface runoff recharges groundwater aquifers and stores in water bodies such as tanks and reservoirs, and the rest flows in rivers and streams. Infiltrated water in underground aquifers maintains flows in streams and rivers during the dry periods. These terrain features and the hydrological processes support and provide habitats for all living beings.

Human lineage originated about 2.5 million years ago in dense forests in east Africa (Charles, 2011). Subsequently, people migrated from forests and settled down in savannas. With this radical change, food consumption patterns have changed, and selective mono cropping commenced. Gradually, the land use pattern was changed due to the expansion of mono cropped fields and horizontal expansion of human settlements.

Diversity of flora and fauna reduced drastically in the encroached lands, which contributed to creating adverse impacts on the climate, globally as well as locally (Gunasena, 2018).

Humans have passed several development phases. The Stone Age, Bronze Age, and Iron Age (Essential humanities, 2013), were followed by the green revolution and industrial revolution. It is now heading for the fourth industrial revolution with increasing needs for growing population (Klaus, 2016). Historically, the livelihood requirements were achieved by expanding settlements horizontally, while compromising ecosystem services and resilience and exaggerating the vulnerabilities to climate change.

Mahendra and Seto (2019) showed the irreversible land development that affected the consumption patterns of resources such as land, energy and water. Some of the issues illustrated by Mahendra and Sato are associated with the expansion of urban areas. These include increase in per capita cost to provide public services, social costs associated with congestion, pollution, and the inefficiencies associated with increase in volume and height of buildings constructed as human settlements. Detail factors highlighted by Mahendra and Seto (2019) justify the vertical expansion or upward growth of human settlement in cities. Even though sky scrapers provide housing for growing population, the horizontal expansion of sky scrapers everywhere will not provide sustainable solution for the fragmentation of lands and its impacts over ecosystems.

Gunasena (2018) identified that the human settlements in Sri Lanka are expanding horizontally across all ecosystems from the ancient time, and likely to continue in the future too. Fragmentation of land was the major feature in catering to the increasing individual and public needs. Vitharana (2005) highlighted that the land fragmentation in Sri Lanka was one of the major environmental threats, initially aggravated with the commercial plantations during the colonial period. These threats could be identified as major causes for climate variability in Sri Lanka.

According to the Climate Risk Index published in 2019 by German Watch (Eckstein *et.al.*, 2018), Sri Lanka was ranked as the 4th highest climate risk of 182 countries in 2016, and was ranked 2nd in 2019 according to 2017 data. The ranking was based on vulnerabilities to natural hazards and weather related loss events. In Sri Lanka, with the steady increase of population many natural ecosystems are being destroyed with the need for housing. Settlement expansion results in creating vulnerability to climate change impacts.This paper highlights the land fragmentation and its impacts in Sri Lanka using two case studies, namely the Rajarata "Ellangava" ecosystem and wet zone downstream ecosystems with small mountain peaks. It proposes vertical expansion of human habitats for highlands and lowlands as a measure of mitigating impacts of climate change.

Expanding human settlements across "Ellangava" ecosystems in Rajarata

The water and land ecosystems in the "Rajarata" area in the ancient periods were managed by tank cascade systems, or generally called "Ellangava" systems. Ecosystem and the associated livelihoods in Ellangava collapsed and hydraulic civilization was abandoned in 12th century, due to foreign invasions (Dharmasena, 2010). According to Panabokke *et.al.*, 2002, the small tank systems have been in existence since the medieval period and removing of "Rajakariya" management system during the colonial period was identified as one of the major reasons for the abandonment of land resources in "Ellangava" ecosystem. The constructing of large agricultural wells to use groundwater resources happened due to the degradation of Ellangava ecosystems and abandonment of land resources.

Furthermore, the multipurpose irrigation projects catering to increasing human settlements were the causes for further reduction of the density of small tanks and feeder channels, leading to abandonment of land resources in the "Ellangava" ecosystem. Presently, amidst the increasing impacts of climate change (Senaratne *et.al.,* in 2009), Sri Lanka is struggling to find new lands for settlement schemes and agricultural and industrial purposes. This also resulted in clearing of natural forest cover even in the catchment areas of "Ellanga"cascade ecosystems.

Figure 1 shows that human settlements around Nuwara Wewa expanded horizontally over the catchment areas of "Ellangava" or cascade ecosystems.

Figure 1 (a) Densely populated areas in the western side of the Nuwara Wewa near "Kada Panaha" wewa in Anuradhapura (b) Closer view of land fragmentation near "Kada Panaha" wewa
Source: Google Map

Lowland areas are also encroached for agricultural purposes. Horizontal expansion of human settlements created bare and highly impervious lands while lowering the infiltration capacity and increasing the surface runoff during the rainy season. These degraded ecosystems have low suitability for human settlement.

Makarieva and Gorshkov's (2007) found that atmospheric low-pressure areas are created above forest cover in any land area due to higher evaporations than that from the sea surface. The low pressure systems trigger flows of moisture laden wind towards the land and generate inland precipitation. Reduction of forest cover decreases the moisturized wind flows towards the land and consequently reduces the inland precipitation. This concept clearly shows the relationship between the forest cover and the precipitation. Therefore, the deforestation that took place for human settlements and agricultural purposes may have increased the drought and flood vulnerabilities in the Rajarata area.

According to the World Bank estimates, average annual expenditure for natural disasters in Sri Lanka is around 68 billion rupees (GFDRR, 2019). Hence, new settlement schemes using vertical space rather than horizontal spread in village system will reduce the damages of disasters and safeguard the ecosystems for future generations.

Proposed vertical settlement scheme for "Ellangava" ecosystem

To address the issues raised by Mahendra and Seto (2019) and the land fragmentation taking place in Rajarata area, it is proposed to expand human settlements vertically along the interface where highland meets the lowland areas. Selecting the interface could be identified as the unique feature of the present paper compared to the global approach discussed by Mahendra and Seto, which does not provide criteria to identify specific land parcels to minimize the impact over ecosystem services and resilience. This Interface was selected to free the upper catchment areas for planned agriculture and afforestation. It is also expected to minimize impacts over natural drainage patterns heading towards tanks in cascades. Better management practices are proposed to improve the groundwater recharging along drainage lines towards tanks in cascades. Hence, the ecosystem services and resilience will have significant improvement against devastating climate change impacts.

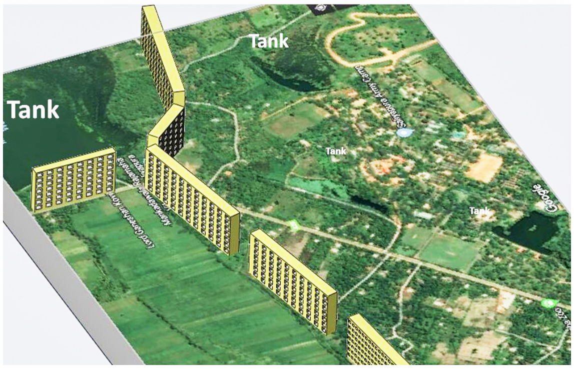


Figure 2: Proposed vertically expanded human settlements, industrial zones commercial zones and other utility facilities in "Rajarata" area
Source: Personal

All residential schemes, industrial zones, commercial areas, including schools, hospitals and other public services must be established in these proposed settlement schemes (Figure 2). Housing schemes will be constructed to have privacy with more space. Community centers will be provided to develop the social and ethnical harmony.

Policy initiatives for land and other natural resource management

New land policy initiatives must be formulated to manage the existing individual land ownership, while allowing to have common environmentally friendly cultivation programs for the entire cascade system. Such policies can optimize the production per unit land area while maintaining the ecosystem services and the resilience of those "Ellanga" ecosystems. Nearly 25 percent of the total land area of Sri Lanka belongs to the wet zone of the country and the rest belong to the intermediate and dry zones. Most of the fertile soils could be found in intermediate zone and dry zone areas. The 103 river basins flow radially from the central hills via the three agro-climatic zones, and end up in the sea through river deltas. Most downstream areas of these rivers comprise of mountains of elevations around 200 meters. The Nilwala river downstream is a case study for illustration.

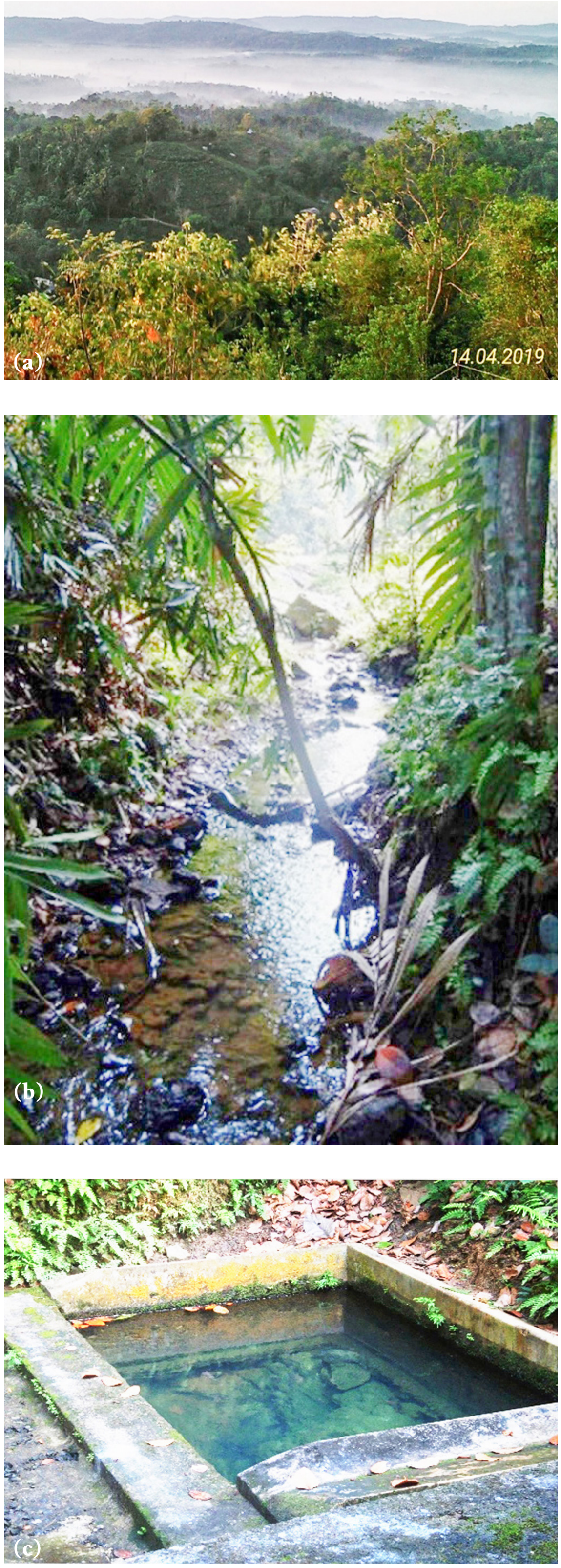


Figure 3: (a) Hilly areas of the Nilwala downstream and (b) small tributaries, (c) water springs and (d) anicut systems
Source: Personal

Figure 3, shows the mountain areas, small streams, water springs and anicut systems belonging to the downstream of the Nilwala river. Due to population increase, many of these areas are now being cleared for livelihood improvements. Similar changes in landscape exist in most river basins in Sri Lanka.

The mountain regions with elevations around 200 meters are common in the downstream of the Nilwala river basin (Figure 4a). These small hill tops were cleared mainly for human settlements (Figure 4b) altering hydrological processes that are needed for healthy ecosystems and better quality surface and ground water resources. The surface and groundwater reserves in these small hills will determine the future livability of the Nilwala downstream.

The Nilwala River is the source of drinking water supply for the entire Matara district (Piyadasa and Navaratne, 2008). The first water pumping station was established 8 km away from the river delta. Later, it was shifted 19 km further away from the delta up to Balakawa due to the salinity intrusion. Salinity intrusion takes place during the dry season where river water level goes below mean sea level due to lack of enough groundwater flux from upper reaches.

The land exploitation in the upper reaches increases the imperviousness of soil, drastically lowering the infiltration capacity and increasingthe surface runoff. This could happen in downstream of all other river basins in Sri Lanka. If appropriate land policy initiatives (Gunasena, 2019) are not in place to increase the groundwater recharging in upper reaches where land slide threats are minimum, severe ecological disasters could be expected due to changing ecosystem services and resilience.

Figure 4: Hilly areas of the Nilwala downstream (a) Fragmentation of hilly areas near Kadawedduwa town (b) Closer view of one mountain
Source: Personal

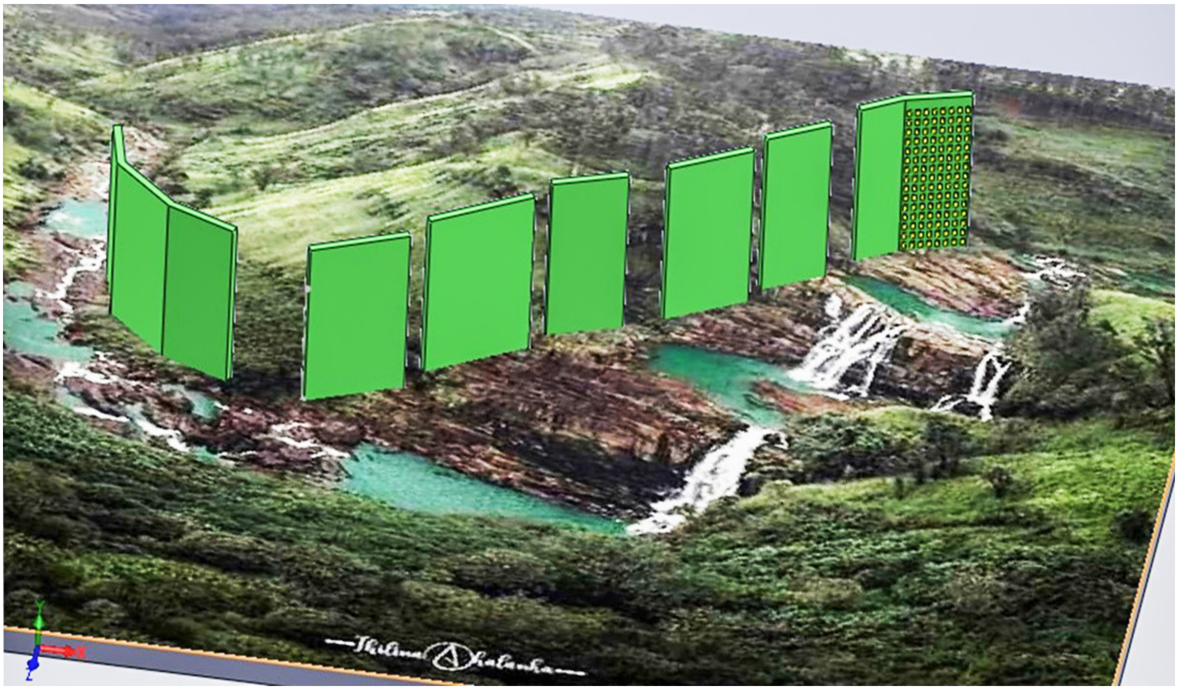


Figure 6: Proposed settlement scheme for hilly areas Source: Personal

Vertical habitat for hilly areas as a climate change mitigatory measure

As shown in Figure 6, vertical habitats must be established along the foot of mountain areas. This will release the mountain land parcels to be kept as natural forest covers or to be cultivated with soil conservation measures, minimizing impervious areas. Accordingly, natural infiltration process and groundwater recharging process will be improved. Soil masses in these hill tops will hold enough water as soil moisture to be released to nearby streams, water springs and reservoirs during dry spells. Therefore, these vertical habitats will act as a climate change mitigatory measure, allowing to manage ecosystem services and resilience efficiently than horizontally expanding human settlements over the mountain tops. Furthermore, vertical habitats will minimize fragmentation of natural ecosystems in hilly areas and improve the livelihoods of humans living around the mountains environmentally as well as aesthetically.

The vertical expansion of human habitats will act as a strong climate change mitigatory measure. Vertical expansion compared to horizontal expansion will safeguard ecosystem services and resilience in cascades or the "Ellangawa" systems. Further, these habitats will provide an opportunity to maintain the sustainability of "Ellangava" ecosystems in Rajarata and sensitive water sources in upper catchment areas for the future generations. Vertically expanding human habitats can reduce the degradation of fertile lands in the Rajarata ellanga systems and the drying up of the Central hills due to clearing evergreen natural forest cover for settlements and for unplanned agriculture.

Furthermore, managing power and telecommunication, water supply, sewerage and drainage services, and establishing solid wastes recycling projects could be much easier. Cost effectiveness of these services will be much higher than in traditional horizontal spreading settlement schemes. Proposed vertically expanding human habitats will provide opportunities to build up human livelihoods as a community, not only accepting the cultural and ethnical diversity but also baring the responsibility of sustainability of ecosystems as a community responsibility. Everybody can have an apartment according to income level, while enjoying the aesthetically pleasing environment collectively.

Conclusion

The limited land resources in Sri Lanka have to be well managed when developing future human settlements.The paper proposed vertical expansion of human settlements. Most issues arising with horizontal expansion of settlement could be minimized with the vertically expanding human habitats. It facilitates management of the ecosystem and services as a community responsibility. Establishment of commercial and industrial production units, mobilizing financial, natural and human capital efficiently with a better transportation system, efficient power and telecommunication system, and effective solid waste, sewerage and drainage management systems can improve the livelihoods of people. Policy initiatives are essential to develop a code of ethics for utilizing natural resources such as, land, water and other biotic and abiotic resourcesas a community responsibility.

Note:

Figure 2 is drawn only to elaborate the possibility of using land parcel where upland meets the low land area specially in "Rajarata" to construct vertical human habitats. Drawing does not illustrate the actual design parameters to be considered prior to the project formulation. Similarly, Figure 6, only represents the possibility of constructing vertical human habitats in a very sensitive ecosystem near a foot of a hill and near to a water fall. Drawing does not represent actual design parameters which must be considered during the project designing phase. Those drawings are only representing the possibility of safeguarding sensitive ecosystems and their services, while utilizing those spaces to cater to the increasing population density. It is the responsibility of present generation to utilize those sensitive ecosystems and their services to improve their livelihoods while maintaining the ecosystem resilience with good management practices for future generations.

Reference:

Charles Q. Choi, (2011), Savanna, Not Forest, Was Human Ancestors' Proving Ground, Live science, https://www.livescience.com/15377-savannas-human-ancestors-evolution.htmlDated May 10, 2019

Eckstein, D,Hutfils, M..L, Winges, M (2018), GLOBAL CLIMATE RISK INDEX 2019, Germanwatch e.V. Office Bonn https://germanwatch.org/en/16046Dated September 17, 2019

Global Facility for Disaster Reduction and Recovery, (2019), Sri Lankahttps://www.gfdrr.org/en/sri-lanka

Gunasena, C. (2018). Innovative approach for developing human settlements, commercial and industrial zones to maintain the sustainability of "Rajarara" ecosystems for future generations in Sri Lankahttps://www.researchgate.net/publication/327283314_Innovative_approach_for_developing_human_settlements_commercial_and_industrial_zones_to_maintain_the_sustainability_of_Rajarara_ecosystems_for_future_generations_in_Sri_Lanka Dated May 10, 2019

Anjali Mahendra and Karen C. Seto, (2019), Upward and Outward Growth:Managing Urban Expansion for More Equitable Cities in the Global South, WORLD RESOURCES REPORT | Towards a More Equal City. https://files.wri.org/s3fs-public/upward-outward-growth_2.pdf Dated September 18, 2019.

Essential humanities, (2013). an introductory guide to history and art history, http://www.essential-humanities.net/history-overview/stone-bronze-iron-ages/Dated May 10, 2019.

Klaus Schwab. (2016). The Fourth Industrial Revolution: what it means, how to respond, https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/ Dated May 10, 2019.

Somaratne K.C. (2019). Our vulnerability to climate risk: Second only to Puerto Rico, http://www.ft.lk/columns/Our-vulnerability-to-climate--risk--Second-only-to-Puerto-Rico/4-669975 Dated May 11, 2019.

Vitharana, L.D.S. (2005). Land fragmentation in rural Sri Lanka: A Sociological analysis of a Southern Sri Lankan Village, In: Proceedings of the 10th International Conference on Sri Lanka Studies, University of Kelaniya, pp 08http://repository.kln.ac.lk/handle/123456789/5770?show=full Dated May 11, 2019.

Wikipedia, (2018), Rajarata, https://en.wikipedia.org/wiki/Rajarata Dated May 11, 2019

Dharmasena P.B,(2010). Indigenous water resources management in Sri Lanka, https://www.academia.edu/15386298/INDIGENOUS_WATER_RESOURCES_MANAGEMENT_IN_SRI_LANKA, Dated May 11, 2019.

Athula Senaratne, Nethmini Perera, Kanchana Wickramasinghe, (2009). Mainstreaming Climate Change for Sustainable Development in Sri Lanka: Towards A National Agenda for Action, Institute of Policy Studies of Sri LankaVersion: Series No.14, https://www.researchgate.net/publication/316685762_Mainstreaming_Climate_Change_for_Sustainable_Development_in_Sri_Lanka_Towards_A_National_Agenda_for_ActionDated May 11, 2019

Piyadasa, R.U.K. and Navaratne , C.M. (2008) River Sand Mining in Southern Sri Lanka and its Effect onEnvironment, http://archive.riversymposium.com/index.php?element=PIYADASADated May 11, 2019

Gunasena, C. (2019) Need of a new land policy directives to manage land resources in Sri Lankahttps://www.academia.edu/38593767/Title_Need_of_a_new_land_policy_directives_to_manage_land_resources_in_Sri_Lanka Dated May 11, 2019.

Panabokke, C. R., Sakthivadivel, R. & Weerasinghe, A. D., 2002. Evolution, present status and issues concerning small tank systems in Sri Lanka, Colombo: International Water Management Institute.

https://core.ac.uk/download/pdf/6843891.pdf

Makarieva and Gorshkov's , 2007, How Forests Attract Rain: An Examination of a New Hypothesis,

https://www.researchgate.net/publication/232695799_How_Forests_Attract_Rain_An_Examination_of_a_New_Hypothesis

Climate Change Secretariat
Ministry of Environment
416/C/1, Robert Gunawardena Mawatha,
Battaramulla, Sri Lanka