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NeelaHaritha

Climate Change Magazine of Sri Lanka

2023, Vol. IV

Climate Change Secretariat
Ministry of Environment

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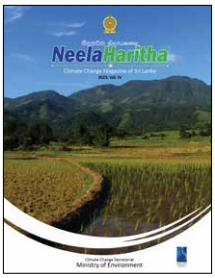

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Knuckles Conservation Forest © Indrika Pradeepa

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Editorial

Prof. W.L. Sumathipala
Chief Editor

Climate Change is Recognised by the Nobel Prize Committee

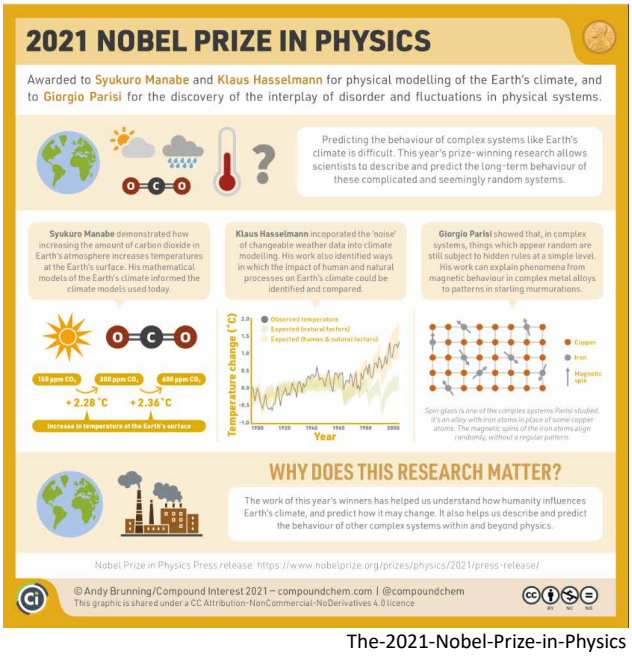
Introduction

The Nobel Prize in Physics in 2021 was awarded "*for the physical modelling of Earth's climate, quantifying variability and reliably predicting global warming"* and *"for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales*". Therefore, it is encouraging to note that climate change has been recognized and has been considered for the Nobel Prize.

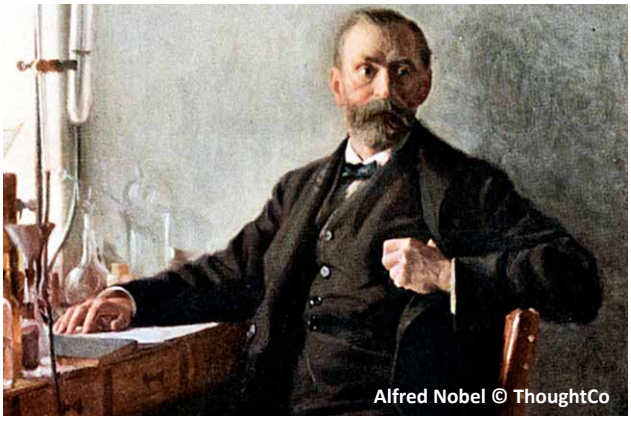
Climate change and the ozone layer depletion have become the most important environment subjects discussed at present among many other topics such as biodiversity, forestry etc. As these two are linked very closely they can be discussed as a single problem: climate change. Climate change influence is felt all over the world on living and non-living systems without any discrimination, and this problem is not limited to a particular country or a region; or developed or underdeveloped, rich or poor, continent or island. Since it is an atmospheric and global problem, the solution cannot be found by a single country. Therefore, the whole world has come together to find a reasonable, acceptable, manageable and affordable physical solution.

A treaty, specifically to tackle climate change named United Nations Framework Convention on Climate Change (UNFCCC) was agreed upon nearly 30 years ago in 1992. Discussions have taken place, practical solutions agreed upon and commitments made, but the results have not been satisfactory. Atmospheric greenhouse gases (GHGs) continue to rise and devastating weather related events such as forest fires, heavy rains, floods, landslides and prolonged droughts are taking place all over the world.

Amidst all these problems and even with the COVID 19 pandemic, the world leaders met at the Conference of Parties 27 (COP 27) in Sharm-El-Sheik in Egypt to discuss the way forward to a reasonable, agreeable and workable solution to tackle the problem. In the meantime, the Committee of the Nobel Prize has shown their concern about devastating and worsening climate change by awarding the 2021 Nobel Prize for Physics for work related to climate change.



The-2021-Nobel-Prize-in-Physics



Alfred Nobel © ThoughtCo

Brief History of the Nobel Prize

The Alfred Nobel Prize commenced in 1901 and was awarded to individuals for "contributions to our understanding of complex systems". The first Nobel prizes were awarded in Stockholm, Sweden, in the field of Physics, Chemistry, Medicine, Literature and Peace on the fifth death anniversary of Nobel as stipulated in his will. According to his last will, it is directed that the bulk of his wealth be placed in a fund and the interest be annually distributed in the form of prizes in the five fields stated above.

Noble Prizes Related to Climate Change

Even as far back as in 1995, the Nobel Prize for Chemistry was awarded to Paul J. Crutsen (Meteorology), Mario J. Molina (Earth atmosphere and Planetary Sciences) and F. Sherwood Rowland (Atmospheric chemistry) for their work on formation and decomposition of ozone (nobelprizes.org/prizes/chemistry/2007/summary/). Later, this discovery led to strong action on protecting the ozone layer and climate change mitigation. In 2007, the Nobel Prize was awarded to Intergovernmental Panel on Climate Change (IPCC) and US Vice President, Albert Arnold Gore (Jr) for their efforts to build up and disseminate greater knowledge about man-made climate change laying the foundation for measures that are needed to counteract such changes (nobelprizes.org/prizes/peace/2007/summary/). Further, in 2018, William Nordhaus received the Nobel Prize for Economics for integrating climate change into long-run macroeconomic analysis and growth models (nobelprizes.org/prizes/economic-sciences/2018/summary/).

It is noteworthy to highlight that the 2021 Nobel Prize for Physics has been awarded to three eminent scientists for their work on complex physical systems and the interplay of disorder and fluctuations of physical systems from atomic to global scale (nobelprizes.org/prizes/physics/2021/summary/). The field of Meteorology in Physics has been given prominence and it stresses the importance of the physical environment. Prof. Syukuro Manabe for his finding that carbon dioxide and water vapour leads to global warming and his lifelong work on modelling climate change; Prof. Klaus Hasselmann for his understanding that human activities made global warming and his work on climate change modelling and Prof. Giogio Parisi, a theoretical physicist for his work that helped to understand complex systems which have higher randomness and disorder (Eg. weather and climate phenomena) were awarded the prize. According to the committee on Physics, the committee has valued the work of these scientists for their independent studies showing that models could predict the complex nature of climate change. Their work broadens knowledge about the climate and it rests on a solid scientific foundation, based

A pyrocumulonimbus cloud – a thunderstorm cloud created by the intense heat from a massive wildfire © Kyle Brittain, The Weather Network

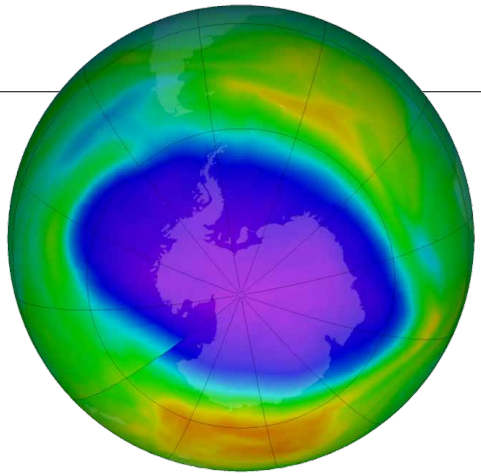
on rigorous analysis and observations. Their combined work recognizes the new methods for describing climate change and predicting long-term behavior.

From all the above facts, it is very clear that climate change is a subject that has to be taken very seriously and hopefully, the 2021 Nobel Prize for Physics, highlighting climate change will be an eye opener - especially to world leaders of industrialized and developed countries. Further studies on climate change, ozone layer depletion and the linkage between them will be very interesting and useful to save the planet earth for the survival of future generations.

Climate Change and Ozone Layer Depletion

These two global atmospheric problems are very closely interlinked and some of the links are discussed below.

- Primarily the earth atmosphere behaves according to the amount of energy it receives. Most of the energy is supplied by the Sun *via* radiation except for a small fraction that comes from the earth's interior as volcanic eruptions. The amount that is received at the earth surface is largely controlled by the ozone layer and decomposition of ozone at the upper atmosphere will let excessive amounts of radiation energy (high energy short wave Gamma rays, X-rays and UV rays) reach the earth surface and warm the earth atmosphere system resulting in global warming and climate change.
- If the ozone layer is destroyed the troposphere will rise up to 90km and clouds will develop to that level instead of 10km, producing an enormous amount of rainfall leading to disastrous floods and related problems.
- If the upper atmospheric ozone layer is destroyed, the harmful shortwave high energy radiation (UV rays) will reach the earth surface which will lead to the production of toxic ozone at the ground level which is a greenhouse gas leading to enhanced global warming and climate change.
- Additional energy received at the surface and warming the oceans will produce a high number of severe cyclones/ hurricanes.
- Hydroflourocarbons (HFCs) and Hydrochlorofluorocarbons (HCFCs) introduced by the Montreal Protocol as replacements to ozone depleting substances are powerful greenhouse gases that lead to global warming and climate change. However, the Montreal Protocol has taken steps to replace them with environment friendly substances.
- Warming activates the reaction that destroys ozone and more energy will reach the earth surface and further warming will take place. Therefore, there is a positive feedback process in a cyclic manner that increases warming and climate change.



Ozone depletion © NASA Ozone Watch

- Plant growth will be reduced due to high energy radiation reaching the troposphere. Due to this process, carbon dioxide sequestration will be reduced and global warming will be enhanced leading to a change of climate.
- Thin ozone layer will let UV radiation and UV-B penetrate much deeper in the oceans destroying phytoplankton which absorbs a large part of atmospheric carbon dioxide for the photosynthesis process and this in turn will lead to global warming and climate change.

Actions for a Better World

The United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol and Paris Agreement are struggling to fulfil agreed obligations for combatting climate change. On the other hand, the Montreal Protocol has fulfilled all its obligations and is considered the most successful environmental treaty. The Montreal Protocol accepted the linkage between climate change and ozone layer depletion and is taking steps to replace HFC which is not an ozone depleting substance but a powerful greenhouse gas, *via* the Kigali amendment to the protocol. Therefore, hopefully, combined efforts of both UNFCCC and the Montreal Protocol will achieve targets without further delay and save planet earth for the survival of future generations.

It will be worthwhile to highlight that the COP 27 and in future COPs the 2021 Nobel Prize for Physics and the work carried out on climate change, needs to be supported for work of this nature. The work of these three scientists on the understanding of complex physical systems and new methods for describing climate change and predicting their long-time behavior can be an example to the global leaders. Leaders need to understand the complex political and social behavior of the general public to predict and guide society to an environment and climate friendly and peaceful world for tomorrow.

Achieving Sri Lanka's NDCs:

Policy Recommendations for Effective Implementation

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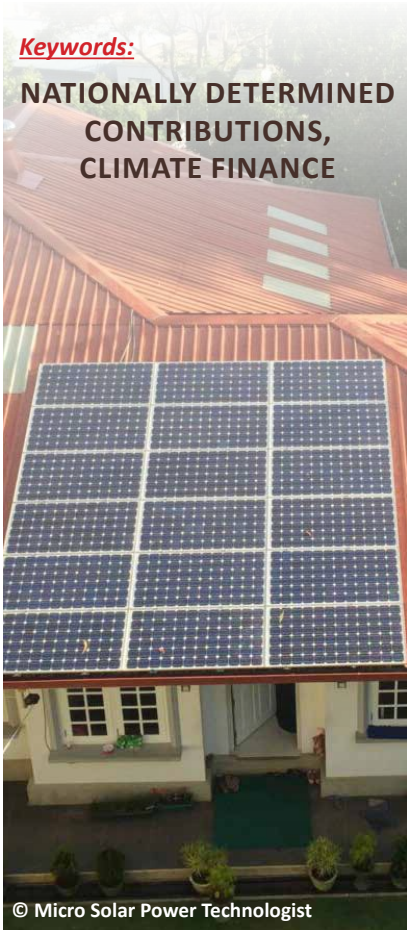
- **Sri Lanka's Nationally Determined Contributions (NDCs) to the Paris Agreement are ambitious in scope and timeline.**
- **A 'Whole-of- Government Approach" is required to achieve these targets which support cleaner, resilient development for the middle-income country while meeting climate change commitments as a responsible global citizen.**
- **This article spells out some necessary preconditions and policy prescriptions to achieve the NDCs.**

Keywords:
NATIONALLY DETERMINED CONTRIBUTIONS, CLIMATE FINANCE



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Introduction

Sri Lanka submitted its updated Nationally Determined Contributions to the Paris Agreement in 2021. The NDCs provided a bold platform on which the country could consolidate its low-emission development ambitions and showcase its development trajectory which favoured relatively cleaner, climate-friendly development in the past few decades, relative to regional comparators.

A recent study has upheld Sri Lanka as a rare example of a country that managed to progress to upper middle income with a low carbon footprint, when many comparable economies' progress to economic prosperity has been through an industrialized route with considerable impact on the environment and climate. Rooted in this 'sustainable' paradigm, Sri Lanka's economy is still low energy intensive, and its emissions remain under 1 ton CO_2 per capita.

However, the country's development pathway was heading towards a high consumption model. The transport sector especially is high GHG emitting with many people switching to private modes of transport (primarily motorcycles, three wheelers and small cars) to overcome the dearth of quality and punctual public transportation. Power generation was increasingly dependent on fossil fuels including coal and diesel. The government, in its policy directives and many public proclamations (including at the UN Climate Summit) over the last few years, has reiterated its commitment to low carbon development including sustainable transport, renewable energy, reduced nitrogen emissions and increased forest cover. The preamble to the NDCs clearly state the government's commitment to achieve carbon neutrality by 2050 by focusing on energy, transportation, agriculture and forestry.

To achieve the NDCs and the stated targets therein, however, several preconditions need to be met. These preconditions, explained below, will lay the groundwork for effective delivery of the sectoral implementation plans which breaks the different NDCs down to implementable actions with budgets and targets. These preconditions include policy coherence, institutional prioritization, planning frameworks, risk management and accessing additional financing for resilience building and emissions reduction.

NDC Implementation should have Required Legal Impetus

Currently, developing and implementing NDCs are solely reliant on priorities of sectoral agencies. However, given the global and national significance of NDC actions and their urgency, it is strongly recommended that the National Environmental Act (revision on-going) provides the necessary legal backbone for the implementation and monitoring of these commitments. Importantly, the revised National Environmental Policy (2022) and National Environmental Action Plan (2022) should also ensure that the Climate Change Policy of 2012 (revision ongoing) and the NDCs are cross referred to in their strategies.

The idea is not to have a number of overlapping policy commitments, but to have a coherent approach across environmental, sustainable development and climate change policies and strategies that supports and incentivizes NDC implementation. There may be other legal impediments to NDC implementation with sectoral policies and legal Acts focusing on productivity and efficiencies within the sector. Climate change should be mainstreamed in to NDC sectors at policy and programme level and the Ministry of Environment should be provided the necessary legal framework for this effort.

Facilitate Inter-ministerial Coordination for Effective Implementation of NDCs

NDC implementation requires strong coordination and cooperation across sectors. Even though the NDCs are presented sector-wise, many of the actions require close inter-ministerial, inter-sectoral, vertical (national to provincial) coherence. Actions relating to urban development, water management, vector control and industrial park management are some actions that require strong coordinated effort. A Climate Change Commission is recommended to ensure the NDCs are translated into on-the-ground investments and to monitor the long-term transformation/adaptation to climate change.

Institutionalize Climate Related Capacities in all Key National Agencies

Climate action needs to be backed with related institutional and professional capacities that create enabling conditions for NDC implementation. This includes specific technical capacities for vulnerability/risk assessment, monitoring and reporting mitigation benefits, data related to loss and damages, gender and social inclusion in NDCs and sector-specific climate modelling or downscaling of regional climate models.

Capacities related to climate change awareness,data and risk-incorporated planning of development initiatives need to be embedded within the key ministries and agencies responsible to deliver on the NDCs. However, beyond the sector agencies, climate change related data and planning capacities should be strengthened for Ministry of Finance, National Planning Department, Census and Statistics Department, Sustainable Development Council *etc*. A strong public sector can lead the way to providing guidance, direction, and incentives to steer the development landscape into the low carbon pathway envisaged by the government.

Situating NDCs within the National Sustainable Development Framework

Revisiting the NDCs provided an opportunity to align the climate actions with Sri Lanka's sustainable development ambitions as well. Sri Lanka's updated NDCs strongly resonate with the national development ambitions expressed in the government's vision. NDC implementation, therefore, need not compromise or counter-balance development objectives. For an example, actions relating to increased penetration of renewable energy and developing better disaster early warning systems are integral to achieving sustainable development, and will keep the country on the low-carbon pathway to upper-middle-income status. Sri Lanka has signed the global development agenda and adopted the Sustainable Development Goals. The draft National Strategy for Sustainable Development has prioritized NDC achievement and related investments. In finalizing and rolling out this strategic plan, it is important to ensure that NDC actions such as green industrial parks, waste-to-energy, climate smart agriculture, catchment conservation and green urban development etc.are given the required recognition in national, provincial and local level strategies and actions.

Integrate Climate Resilience (and where possible mitigation options) into Land Use Planning Processes and Tools

In 2019, the Government launched a climate -integrated National Physical Plan which was developed over three years and with wide ranging consultations across sectors. It is important that this plan is closely followed when developing and implementing NDC actions. While the plan is widely accepted by technocrats and experts, it does not have the necessary legal muscle or political backing to ensure its full implementation enforcement -even in the key sectors that require spatial planning guidance such as in forestry, agriculture, water, industry, coastal and urban development.

The issue of the non-adherence of development planning to the government's own National Physical Plan emerged in several sectoral consultations during the development of the NDCs. Further, the National Land Use Policy is being revised currently and a set of guidelines for participatory land use planning have been devised to inform

local level planners and administrators. The need to place NDC implementation in a climate resilient land use framework is essential in order to ensure that investments will be protected and pay off in the long-term.

Comprehensive Risk Management Framework

A Comprehensive Risk Management Framework should guide the planning and implementation of the NDC actions implemented nationally and locally by all relevant sectoral agencies. A Comprehensive Risk Management Framework, as recommended under the Loss and Damage sector, provides the basis to assess, manage and minimize the losses and damages from the entire spectrum of climate related extreme events, slow-onset disasters and natural processes attributed to climate change and anticipated future losses and damages. This will i). ensure that all NDC investments are risk sensitive and safeguarded from disaster risk, and ii). minimize possible L&D from the NDC actions.

Developing a Comprehensive Risk Management Framework can be led by the national planning, climate and disaster management sector agencies, to provide an overarching guide for all development investments, to ensure they are disaster and climate risk sensitive.

NDC Implementation must Consider Vulnerabilities and be Gender Responsive

While the country commits to a low carbon development and to the global goal of containing warming of the planet, Sri Lanka's NDCs predominantly support resilience buildings- due to the country's vulnerability to climate change. With its low industrialization and a majority of people dependent on agriculture and fisheries, Sri Lanka is both geographically and economically vulnerable to climate change impacts. The increase of extreme weather patterns, attributed to climate change, has placed the country successively among global hotspots for risk. There is a clear demographic and geographic distribution of risk and vulnerability within the country. This has been explored in greater detail in the Third National Communication to UNFCCC (2022) and other studies (updated sectoral vulnerability profiles supported by the Asian Development Bank, for example).

Gender issues cut across all mitigation and adaptation NDCs outlined under the different NDC sectors. NDC planning and implementation process is an opportunity to use the maximum potential of men and women through climate action, and to benefit from the knowledge and capabilities of men and women, to implement mitigation and adaptation measures. Planning and implementing the NDC actions in a gender responsive manner will lead to achieving the NDC targets and outcomes more effectively addressing the gender dimensions of mitigation and adaptation priorities.

Gender integration will also contribute to the national policy commitments on gender equality and women's empowerment and support the recommendation of the UNFCCC's Gender Action Plan, by gender mainstreaming in all climate change processes. The approach for gender responsive NDC planning and implementation is to conduct sector-wise gender analysis and to plan the NDC implementation plans informed by this analysis, so that the overall sector NDC plans incorporate gender aspects into NDC implementation plan of each sector.

Develop a Finance Roadmap and Activate a National Financing Framework for NDC Implementation

Sri Lanka's NDC's require substantial external financial assistance to support implementation. The high level costing exercise conducted for the NDCs demonstrated that around 80% of the mitigation actions and almost 95% of adaptation actions require external financing. The NDC financing requirements must be fully integrated to the country's development finance and external resources framework. Financing the NDC must be an integral part of the country's green and sustainable financing strategies such as the Central Bank's Sustainable Finance Roadmap. To support this effort, NDC sectors and related government agencies should introduce a regular budget line to track climate change expenditures against the 10-year NDC implementation and monitoring plans. Regular donor round tables should be conducted to present this framework, identify emerging financing needs and access new and innovative funding sources.

Develop Capacities to Engage and Negotiate Support through Formal UNFCCC Processes

Sri Lanka needs to develop the capacity to engage more proactively with the international conventions and convention mechanisms that deliver country support for implementation. This includes the ability to negotiate financing, technology transfer and capacity building support for loss and damage monitoring, downscaling global models and forecasts at sub-national level, MRV related tools and programmes.

The Paris Agreement facilitates technology transfer between developed and developing countries and puts onus on developed countries to share low carbon, climate smart solutions with countries such as Sri Lanka, which are still on an upward trajectory. Sri Lanka produced a Technology Needs Assessment for both mitigation and adaptation in 2014. However, updated and more specific technology needs should accompany the NDC implementation plans, paving the way for more effective support to realise the ambitious NDCs set forth in 2021.

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මූලපද:
අනුහුරුවීම, අවදානම, දේශගුණ විපර්යාස පිළිබඳ එක්සත් ජාතීන්ගේ රාමුගත සම්මුතිය

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- UNFCCC මගින් ගෙන ඇති එම පියවර ශ්‍රී ලංකාව වැනි සංවර්ධනය වෙමින් පවතින රාජ්‍යයන් දේශගුණ විපර්යාසවල අනිටු බලපෑම්වලට මුහුණ දීමට ඇති හැකියාව වැඩි කිරීම සඳහා ගනු ලබන ක්‍රියාමාර්ගවලදී මහගු පිටුවහලකි.

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හැඳින්වීම

සාමාන්‍ය උෂ්ණත්වය වෙනස්වීම්, සෘතුවල සාමාන්‍ය කාලපරාසය වෙනස්වීම, ආන්තික කාලගුණ තත්ත්ව සුලභ වීම, අයිස් කඳු දිය වීම වැනි විවිධ දේශගුණ විපර්යාසවල අතුරුඵල මේ වනවිටත් පෘථිවිය අත්විඳිමින් සිටී.

දේශගුණ විපර්යාස පිළිබඳ අන්තර් රාජ්‍ය මණ්ඩලය (IPCC) අර්ථදක්වා ඇති පරිදි, දේශගුණ විපර්යාස සඳහා අනුහුරුවීම යනු නිශ්චිත හෝ අපේක්ෂිත දේශගුණ විපර්යාස හෝ එහි බලපෑම්වලට අනුගතවීමේ ක්‍රියාවලියයි. අනුහුරුවීම මගින් දේශගුණ විපර්යාස නිසා පාරිසරික, සාමාජිය සහ ආර්ථික පද්ධතිවලට ඇති විය හැකි අවදානම අවම කිරීම බලාපොරොත්තු වේ. අනුහුරුවීමේ ප්‍රධාන කොටස් පහත ආකාරයට දැක්විය හැකිය.

1. **දේශගුණික සහ දේශගුණික නොවන විචල්‍යයයන් නිරීක්ෂණය කිරීම.**
2. **දේශගුණ විපර්යාසවල බලපෑම් සහ අවදානම් සහිත බව තක්සේරු කිරීම.**
3. **අනුහුරුවීමේ සැලසුම්**
4. **අනුහුරුවීම සඳහා වූ ක්‍රියාකාරකම් ක්‍රියාත්මක කිරීම.**
5. **අනුහුරුවීමේ ක්‍රියාකාරකම් අධීක්ෂණය සහ ඇගයීම.**

ප්‍රජාවක, පළාතක, ප්‍රදේශයක හෝ රටක ස්වභාවය අනුව අනුහුරුවීම් විවිධ ස්වරූපයන් හා හැඩයන් ගනී. අනුහුරුවීම සඳහා 'එක හා සමාන විසඳුමක්' නොමැත. එනම්, ගංවතුර සඳහා බාධක ගොඩනැංවීම, සුළිකුණාටු සඳහා පූර්ව අනතුරු ඇඟවීමේ පද්ධති සැකසීම, නියඟයට ඔරොත්තු දෙන භෝගවලට මාරුවීම, සන්නිවේදන පද්ධති, ව්‍යාපාර සහ රජයේ ප්‍රතිපත්ති ප්‍රතිනිර්මාණය කිරීම වැනි විවිධ අවස්ථා සඳහා අනුරූපී විසඳුම යොදා ගත යුතුය. බොහෝ ජාතීන් සහ ප්‍රජාවන් දැනටමත් ඔරොත්තු දීමේ හැකියාව වැඩි සමාජයන් සහ ආර්ථිකයන් ගොඩනැංවීමට අවශ්‍ය පියවර ගනිමින් සිටියි.

අනුහුරුවීම යනු ජාතිකව, දේශීයව, කලාපීයව සහ ජාත්‍යන්තර වශයෙන් සියලු දෙනා මුහුණ දෙන ගෝලීය අභියෝගයක් බව දේශගුණ විපර්යාස පිළිබඳ එක්සත් ජාතීන්ගේ රාමුගත සම්මුතියේ සහ එහි පැරිස් ගිවිසුමේ පාර්ශ්ව විසින් පිළිගෙන ඇත. තවද, අනුහුරුවීමේ ක්‍රියාවලිය අනුගමනය කළ යුත්තේ එක් එක් රටට අනුකූල ලෙස, ස්ත්‍රී පුරුෂ සමාජභාවයට ප්‍රතිචාර දක්වමින්, පූර්ණ විනිවිදභාවයකින් යුත් ක්‍රමයක් අනුගමනය කරමින් මෙන්ම අවදානමට ලක්විය හැකි කණ්ඩායම්, ප්‍රජාවන් සහ පරිසර පද්ධති සැලකිල්ලට ගෙන, පවතින නවීනතම විද්‍යාව උපයෝගී කරගෙන සහ සුදුසු පරිදි සාම්ප්‍රදායක දැනුම, ආදිවාසීන්ගේ දැනුම හා ප්‍රාදේශීය දැනුම ද සැලකිල්ලට ගනිමින් බව පාර්ශ්වකරුවන් විසින් පිළිගෙන ඇත. ඒ අනුව, දේශගුණ විපර්යාස පිළිබඳ එක්සත් ජාතීන්ගේ රාමුගත සම්මුතිය මගින් අනුහුරුවීම වෙනුවෙන් වැදගත් පියවර රාශියක් ගෙන ඇත.

දේශගුණ විපර්යාස පිළිබඳ එක්සත් ජාතීන්ගේ රාමුගත සම්මුතිය විසින් අනුහුරුවීම වෙනුවෙන් ගෙන ඇති පියවර

1 ඌන සංවර්ධිත රටවල විද්වත් කණ්ඩායම (Least Developed Country Expert Group, LEG) පිහිටුවීම.

2001 වර්ෂයේ දී මරකේෂ් නගරයේ දී පැවැත්වූ UNFCCC පාර්ශ්වකරුවන්ගේ හත්වන සැසිවාරයේදී ඌන සංවර්ධිත රටවල විද්වත් කණ්ඩායම (Least Developed Country Expert Group- LEG) පිහිටුවන ලදි. මෙම කණ්ඩායම විසින් පාර්ශ්වකරුවන්ගේ සැසිවාරවල දී ඌන සංවර්ධිත රටවල් වෙනුවෙන් ජාතික අනුහුරුවීමේ ක්‍රියාකාරී වැඩසටහන් (National Adaptation Programmes of Actions- NAPAs), සහ ඌන සංවර්ධිත රටවල ක්‍රියාකාරී වැඩසටහන (LDC work programme) සඳහා තාක්ෂණික සහාය සහ උපදෙස් ලබාදෙන ලෙස ද, අනුහුරුවීමේ ජාතික සැලසුම (National Adaptation Plan- NAP) සඳහා තාක්ෂණික මගපෙන්වීම සහ සහාය ලබාදෙන ලෙස ද ඉල්ලා සිටින ලදී. මෙම විශේෂඥ කණ්ඩායම වාර්ෂිකව දෙවතාවක් හමුවන අතර, එහිදී ඌන සංවර්ධිත රටවල් සඳහා පුහුණු වැඩමුළු, මාර්ගෝපදේශ, මෙවලම්, තාක්ෂණික පත්‍රිකා, ප්‍රකාශන ආදි විවිධ ආකාරවලින් උපදෙස් ලබාදීම හා ජාතික අනුහුරුවීමේ ක්‍රියාකාරී වැඩසටහන (NAPA) සඳහා කෙටුම්පත් සමාලෝචනය කිරීම තුළින් හෝ ඒ සඳහා ඍජුවම උපදෙස් ලබා දීම තුළින් සහාය දක්වනු ලැබේ.

2 නයිරෝබි වැඩසටහන (Nairobi Work Programme- NWP) ස්ථාපිත කිරීම.

දේශගුණ විපර්යාසවල බලපෑම, අවදානම් සහිත බව සහ දේශගුණ විපර්යාස සඳහා අනුහුරුවීම සඳහා වූ නයිරෝබි වැඩසටහන 2006 වර්ෂයේ නයිරෝබි නගරයේ දී පැවැති UNFCCC පාර්ශ්වකරුවන්ගේ දොළොස්වන සැසිවාරයේදී ගනු ලැබූ තීරණ අංක 2/CP12 මගින් පිහිටුවන ලදි. අනුහුරුවීමට අදාළ ප්‍රතිපත්ති සහ ඒවා භාවිත වන ආකාරය පිළිබඳ තොරතුරු සහ දැනුම වර්ධනය කිරීම සහ ඒවා ව්‍යාප්ත කිරීම පහසු කිරීමත් උත්ප්‍රේරණය කිරීමත් සඳහා දේශගුණ විපර්යාස පිළිබඳ එක්සත් ජාතීන්ගේ රාමුගත සම්මුතිය යටතේ ඇති යාන්ත්‍රණයක් ලෙස මෙම වැඩසටහන ක්‍රියාත්මකවේ. මෙය ක්‍රියාත්මක කිරීම සම්බන්ධීකරණය කරනු ලබන්නේ විද්‍යා හා තාක්ෂණික උපදෙස් සඳහා වූ අනුබද්ධ ආයතනය (Subsidiary Body for Science and Technological Advice- SBSTA) මගිනි. එහි සභාපතිගේ මඟ පෙන්වීම යටතේ ලේකම් කාර්යාලයේ සහාය ඇතිව සහ අනෙකුත් පාර්ශ්වකරුවන්ගේ දායකත්වයෙන් සම්බන්ධීකරණය සිදු කරයි.

3 කැන්කුන් අනුහුරුවීමේ රාමුව (Cancun Adaptation Framework) යොදා ගැනීම.

2010 දී මෙක්සිකෝවේ කැන්කුන් නගරයේ දී පවත්වන ලද UNFCCC පාර්ශ්වකරුවන්ගේ දහසය වන සැසිවාරයේ දී කැන්කුන් ගිවිසුමෙහි කොටසක් ලෙස කැන්කුන් අනුහුරුවීමේ රාමුව අනුමත කරනු ලැබිය. මෙහිදී තහවුරු කරන ලද කැන්කුන් අනුහුරුවීමේ


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රාමුව, සම්මුතිය යටතේ ඇති දිගුකාලීන සහයෝගී කාර්යයන් සඳහා තත්කාර්ය ක්‍රියාකාරී කණ්ඩායම (Ad Hoc Working Group on Long-term Cooperative Action- AWG-LCA) වසර තුනක මුළුල්ලේ අනුහුරුවීම පිළිබඳ කළ සාකච්ඡාවේ ප්‍රතිඵලයකි.

මෙමගින් වැඩිදියුණු කරන ලද අනුහුරුවීමේ ක්‍රියාමාර්ග යොදාගනිමින් සංවර්ධනය වෙමින් පවතින රටවල හදිසි හා ක්ෂණික අවශ්‍යතා ඇතිවන අවස්ථාවල දී එහි අවදානම අවම කිරීමට සහ ඔරොත්තු දීමේ හැකියාව ගොඩනැගීමට උත්සාහ දරනු ලැබේ.

4 අනුහුරුවීමේ කමිටුව (Adaptation Committee- AC) ස්ථාපිත කිරීම.

කැන්කුන් අනුහුරුවීමේ රාමුවේ කොටසක් ලෙස පාර්ශ්වකරුවන් විසින් අනුහුරුවීමේ කමිටුව ස්ථාපිත කරනු ලැබුවේ දේශගුණ විපර්යාස පිළිබඳ රාමුගත සම්මුතිය යටතේ අනුහුරුවීම සම්බන්ධයෙන් වැඩි දියුණු කරන ලද ක්‍රියාමාර්ග ක්‍රියාත්මක කිරීම ප්‍රවර්ධනය කිරීම සඳහාය. පහත ක්‍රියාකාරකම් ඉන් කිහිපයකි,

- පාර්ශ්වකරුවන් හට තාක්ෂණික සහාය සහ මගපෙන්වීම ලබා දීම.
- අදාළ තොරතුරු, දැනුම, ලබාගත් අත්දැකීම් සහ නිවැරදි පුරුදු හුවමාරු කර ගැනීම.
- සහජීවනය ප්‍රවර්ධනය කිරීම සහ ජාතික, ප්‍රාදේශීය සහ ජාත්‍යන්තරව පවතින සංවිධාන, මධ්‍යස්ථාන සහ ජාල සමඟ සම්බන්ධතා ශක්තිමත් කිරීම.

මෙම අනුහුරුවීමේ කමිටුව සාමාජිකයින් 16 දෙනෙකු ගෙන් සමන්විත වේ. ඒ සඳහා, එක්සත් ජාතීන්ගේ කලාපීය කණ්ඩායම් පහේ (five UN regional groups) නියෝජිතයින් සහ සංවර්ධනය වෙමින් පවත්නා කුඩා දූපත් රාජ්‍යවල් (Small Island Developing States- SIDS), ඌන සංවර්ධිත රටවල් (Least Developed Countries-LDC), දේශගුණ විපර්යාස පිළිබඳ රාමුගත සම්මුතියේ I වන ඇමුණුමට අයත් රටවල් සහ I වන ඇමුණුමට අයත් නොවන රටවල් (Non-Annex I and Annex I Parties) ඇතුළත් වේ.

5 අනුහුරුවීමේ ජාතික සැලසුම් (National Adaptation Plans- NAPs) ක්‍රියාවලිය ස්ථාපිත කිරීම.

2010 වර්ෂයේ දී UNFCCC පාර්ශ්වකරුවන්ගේ 16 වන සැසිවාරයේ දී කැන්කුන් අනුහුරුවීමේ රාමුව යටතේ මෙම අනුහුරුවීමේ ජාතික සැලසුම් ක්‍රියාවලිය ස්ථාපිත කරන ලදි. එය මධ්‍යම සහ දිගුකාලීන අනුහුරු විය යුතු අවශ්‍යතා හඳුනාගැනීමේ මාධ්‍යයක් ලෙස ක්‍රියා කරන අතර, එම අවශ්‍යතා සම්පූර්ණ කිරීම සඳහා වැඩසටහන් සහ ක්‍රමවේද සකස් කිරීම හා ක්‍රියාත්මක කිරීම සඳහා වූ ජාතික සැලසුම් ක්‍රියාවලියක් සකස් කිරීමටත් ඒවා ක්‍රියාත්මක කිරීමටත් පාර්ශ්වකරුවන්ට හැකි වේ. එය රටකට විශේෂ වූ, ස්ත්‍රී පුරුෂභාවයට සංවේදී සහ පූර්ණ විනිවිදභාවයකින් යුත් ප්‍රවේශයක් අනුගමනය කරන අඛණ්ඩ සහ පුනරාවර්තන ක්‍රියාවලියකි.

6 අලාභ සහ හානි සඳහා වන වෝර්සෝ ජාත්‍යන්තර යාන්ත්‍රණය (Warsaw International Mechanism for Loss and Damage) ස්ථාපිත කිරීම.

කැන්කුන් අනුහුරුවීමේ රාමුවෙහි කොටසක් ලෙස 2010 වර්ෂයේ පැවැති UNFCCC පාර්ශ්වකරුවන්ගේ 16 වන සැසිවාරයේදී ආරම්භ කරන ලදි. දේශගුණ විපර්යාසවල අහිතකර බලපෑම්වලට විශේෂ අවදානමක් ඇති සංවර්ධනය වෙමින් පවතින රටවල්වලට දේශගුණ විපර්යාස නිසා ඇති වන අලාභ සහ හානි පිළිබඳ අවධානය යොමු කිරීමේ ප්‍රවේශයක් මේ අනුව සලකා බලනු ලැබේ. වසර දෙකක සාකච්ඡාවලින් අනතුරුව 2013 වර්ෂයේ දී පෝලන්තයේ වෝර්සෝ නගරයේ දී පැවැත්වූ UNFCCC පාර්ශ්වකරුවන්ගේ 19 වන සැසිවාරයේ දී අලාභ සහ හානි සඳහා වන වෝර්සෝ ජාත්‍යන්තර යාන්ත්‍රණය ස්ථාපිත කරන ලදි.

7 අනුහුරුවීම පිළිබඳ කාර්මික පරීක්ෂණ ක්‍රියාවලිය (Technical Examination Process on Adaptation) ස්ථාපිත කිරීම.

අනුහුරුවීම සඳහා වූ තාක්ෂණික පරීක්ෂණ ක්‍රියාවලිය (TEP-A), පාර්ශ්වකරුවන්ගේ 21 වන සැසිවාරයේ දී 2016-2020 කාල සීමාව සඳහා, පැරිස් ගිවිසුමෙහි ගත් තීරණවල අන්තර්ගත වූ 2020 ට පෙර වැඩිදියුණු කළ ක්‍රියාවල කොටසක් ලෙස ස්ථාපිත කරන ලදි. TEP-A හි අරමුණ වන්නේ, පහත දැක්වෙන කාර්යයන් හතර ඇතුළුව, අහිතකර බලපෑම්වලට ඔරොත්තු දීමේ හැකියාව වැඩි කිරීම, අවදානම් සහිත බව අවම කිරීම සහ අනුහුරුවීමේ ක්‍රියා පිළිබඳ අවබෝධය සහ ඒවා වැඩි වශයෙන් ක්‍රියාත්මක කිරීම සඳහා අවස්ථා හඳුනාගැනීමයි.

- යහ පිළිවෙත්, අත්දැකීම් සහ උගත් පාඩම් හුවමාරු කර ගැනීමට පහසුකම් සැලසීම.
- අනුහුරුවීමේදී සහයෝගී ක්‍රියාකාරකම් ප්‍රවර්ධනය කිරීම.
- ආර්ථික විවිධාංගීකරණය වැඩිදියුණු කළ හැකි සහ අවම කිරීමේ සම-ප්‍රතිලාභ ලැබිය හැකි ක්‍රියා ඇතුළත්ව, ක්‍රියාකාරකම් හඳුනා ගැනීම.
- නිශ්චිත ප්‍රතිපත්ති, භාවිතයන් සහ ක්‍රියා යන සන්දර්භය තුළ අනුහුරුවීම සඳහා සහාය වැඩිදියුණු කිරීමේ හා සබල පරිසරයක් ශක්තිමත් කිරීමේ අවස්ථා හඳුනා ගැනීම.

8 සංවර්ධනය වෙමින් පවතින රටවල් සඳහා අනුහුරුවීමට අවශ්‍ය සහාය ලබා දීම. (Adaptation Support for Developing countries)

8.1 මූල්‍යමය (Finance) සහාය

ඒවාට මුහුණ දීමේ හැකියාව බෙහෙවින් වෙනස් ය. එම නිසා දේශගුණ විපර්යාස පිළිබඳ චික්සත් ජාතීන්ගේ රාමුගත සම්මුතිය සහ කියෝතෝ සන්ධානය මඟින් අඩු ආදායම් සහිත හා අවදානමට ලක්විය හැකි පාර්ශ්වකරුවන්හට සංවර්ධිත පාර්ශ්වයන්ගෙන් මූල්‍යමය ආධාර ලබා ගැනීමට අපේක්ෂා කෙරේ. සම්මුතිය අනුව ක්‍රියා කිරීම සඳහා දේශගුණ විපර්යාස පිළිබඳ රාමුගත සම්මුතියෙහි II වන ඇමුණුමේ සඳහන් රටවල් විසින් සංවර්ධනය වෙමින් පවතින පාර්ශ්වයන් සඳහා මූල්‍ය සම්පත් සැපයිය යුතුය. මෙය පහසු කිරීම සඳහා සංවර්ධනය වෙමින් පවත්නා රටවලට අරමුදල් සැපයීම සඳහා මූල්‍ය යාන්ත්‍රණයක් සම්මුතිය මඟින් ස්ථාපිත කරන ලදි.

සම්මුතියේ 11 වන වගන්තියේ සඳහන් වන පරිදි, මූල්‍ය යාන්ත්‍රණයේ මෙහෙයුම් ක්‍රියාත්මක කිරීම දැනට පවත්නා ජාත්‍යන්තර ආයතන එකක් හෝ කිහිපයක් වෙත පැවරී ඇත. මූල්‍ය යාන්ත්‍රණයේ මෙහෙයුම් අර්ධ වශයෙන් ගෝලීය පරිසර පහසුකම (Global Environment Facility- GEF) වෙත පැවරී ඇති අතර, පාර්ශ්වකරුවන්ගේ දාහත් වන සැසිවාරයේ දී සම්මුතියේ මූල්‍ය යාන්ත්‍රණයේ මෙහෙයුම් ආයතනයක් ලෙස සම්මුතියේ 11 වන වගන්තියට අනුකූලව, හරිත දේශගුණ අරමුදල (Green Climate Fund-GCF) නම් කිරීමට තීරණය විය.

සංවර්ධනය වෙමින් පවතින රටවල්වලට ඔවුන්ගේ ක්‍රියාකාරකම් සඳහා අරමුදල් සැපයීම සඳහා මූල්‍ය යාන්ත්‍රණයක් අවශ්‍ය බව කියෝතෝ සන්ධානය විහි 11 වන වගන්තිය යටතේ පිළිගෙන ඇත. ගෝලීය පරිසර පහසුකමට (GEF) මඟ පෙන්වීමට අමතරව, පාර්ශ්වකරුවන් විසින් විශේෂ අරමුදල් හතරක් ස්ථාපිත කර ඇත. ගෝලීය පරිසර පහසුකම (Global Environment Facility-GEF) මඟින් කළමනාකරණය කරනු ලබන විශේෂ දේශගුණ විපර්යාස අරමුදල (Special Climate Change Fund-SCCF) සහ ඌන සංවර්ධිත රටවල අරමුදල (Least Developed Countries Fund-LDCF) ඉන් දෙකකි. එසේම, සම්මුතිය යටතේ පවත්නා හරිත දේශගුණ අරමුදල (Green Climate Fund -GCF) සහ කියෝතෝ සම්මුතිය යටතේ පවතින අනුහුරුවීමේ අරමුදල (Adaptation Fund) අනෙක් අරමුදල් වේ.

8.2 ධාරිතා සංවර්ධනය (Capacity building)

පැරිස් ගිවිසුමේ 11 වන වගන්තියේ සඳහන් වන්නේ පැරිස් ගිවිසුම ක්‍රියාත්මක කිරීම සඳහා සංවර්ධනය වෙමින් පවතින පාර්ශ්වකරුවන්ගේ ධාරිතාව ඉහළ නැංවීම සඳහා සියලු පාර්ශ්ව සහයෝගයෙන් කටයුතු කළ යුතු බව සහ සංවර්ධිත රටවල් විසින් සංවර්ධනය වෙමින් පවතින රටවල ධාරිතා වර්ධන කටයුතු සඳහා ලබාදෙන සහයෝගය වැඩි කළ යුතු බවයි.

8.3 තාක්ෂණයන් සංවර්ධනය හා හුවමාරු කිරීම (Development and transfer of technologies).

8.3.1 තාක්ෂණය සඳහා වූ විධායක කමිටුව. (Technology Executive Committee- TEC)

2010 වර්ෂයේ දී පිහිටුවන ලද තාක්ෂණය සඳහා වූ විධායක කමිටුව (TEC) තාක්ෂණ යාන්ත්‍රණයේ ප්‍රතිපත්ති අංශයයි. අඩු විමෝචන සහ දේශගුණ විපර්යාස සඳහා ඔරොත්තු දීමේ හැකියාව වැඩි තාක්ෂණයන් සංවර්ධනය හා ඒවා හුවමාරු කිරීම වේගවත් කළ හැකි ප්‍රතිපත්ති හඳුනාගැනීම කෙරෙහි එහි අවධානය යොමු වේ. සංවර්ධිත හා සංවර්ධනය වෙමින් පවතින රටවල් නියෝජනය කරන තාක්ෂණ විශේෂඥයින් 20 දෙනෙකුගෙන් මෙය සමන්විත ය. අවම වශයෙන් වර්ෂයකට දෙවරක්වත් හමුවන මේ කමිටුව, තාක්ෂණය හා සම්බන්ධ ප්‍රතිපත්තිමය ගැටලු විසඳීමට ගන්නා උත්සාහයට සහාය වීම සඳහා දේශගුණ විපර්යාස පිළිබඳ තාක්ෂණ සැසි පවත්වයි. සෑම වර්ෂයකම තාක්ෂණය සඳහා වූ විධායක කමිටුව එහි ක්‍රියාකාරිත්වය සහ ක්‍රියාකාරකම් පිළිබඳව පාර්ශ්වකරුවන්ගේ සැසිවාරයට වාර්තා කරයි. දේශගුණ විපර්යාස වැලැක්වීමට ගන්නා පියවර වේගවත් කිරීම සඳහා රටවල්වලට සහාය වීම, දේශගුණ විපර්යාස පිළිබඳ තාක්ෂණ ගැටලු විශ්ලේෂණය කිරීම සහ සමබර ප්‍රතිපත්ති නිර්දේශ සකස් කිරීම මෙමගින් සිදු කෙරේ.

8.3.2 තාක්ෂණ අවශ්‍යතා ඇගයීම (Technology Needs Assessment)

සංවර්ධනය වෙමින් පවතින රටවල දේශගුණ විපර්යාස පිළිබඳ තාක්ෂණ අවශ්‍යතා අවබෝධ කර ගැනීම දේශගුණ විපර්යාසවලට ඵලදායී පියවර ගැනීම සඳහා ආරම්භක ලක්ෂ්‍යය වේ. අවශ්‍යතා අවබෝධ කර ගැනීමෙන් හරිතාගාර වායු විමෝචන අඩු කර දේශගුණ විපර්යාසවල අහිතකර බලපෑම්වලට අනුහුරු විය හැක්කේ කෙසේද යන්න තීරණය කළ හැකිය. තම රටවල දේශගුණ විපර්යාස පිළිබඳ තාක්ෂණ ප්‍රමුඛතා තීරණය කිරීම සඳහා ඒ ඒ රටවල් තාක්ෂණික අවශ්‍යතා ඇගයීමක් (TNA) සිදු කරයි. මෙය ජාතික තිරසර සංවර්ධනයට සහාය වෙමින් ජාතික ධාරිතාවය ගොඩනංවන අතර, දේශගුණ විපර්යාස පිළිබඳ ප්‍රමුඛ තාක්ෂණ ක්‍රියාමාර්ග ක්‍රියාත්මක කිරීමට පහසුකම් සලසයි. 2001 සිට දේශගුණ විපර්යාස ආශ්‍රිත ගැටලු විසඳීම සඳහා සංවර්ධනය වෙමින් පවතින රටවල් 80 කට වැඩි ප්‍රමාණයක් තාක්ෂණ අවශ්‍යතා ඇගයීම සිදු කර ඇත.

8.3.3 දේශගුණ විපර්යාස පිළිබඳ තාක්ෂණ සංවර්ධනය හා හුවමාරුව (Climate Technology Center and Network- CTCN)

දේශගුණ විපර්යාස පිළිබඳ තාක්ෂණ සංවර්ධනය හා හුවමාරුව යනු එක්සත් ජාතීන්ගේ පරිසර වැඩසටහන (UN Environment Programme- UNEP) සහ එක්සත් ජාතීන්ගේ කාර්මික සංවර්ධන සංවිධානය (UN Industrial Development Organization- UNIDO) විසින් සත්කාරකත්වය දරන දේශගුණ විපර්යාස පිළිබඳ එක්සත් ජාතීන්ගේ රාමුගත සම්මුතියේ තාක්ෂණ යාන්ත්‍රණයේ මෙහෙයුම් අංශයයි. සංවර්ධනය වෙමින් පවතින රටවල සංවර්ධන ආකෘතිය කාබන් විමෝචනය අවම සහ දේශගුණ විපර්යාසවලට ඔරොත්තු දෙන සංවර්ධනයක් වෙත හා පරිසර හිතකාමී තාක්ෂණය වෙත මාරු කිරීම මෙම මධ්‍යස්ථානය මගින් ප්‍රවර්ධනය කරයි. මෙඅතුව එක් එක් රටවල අවශ්‍යතාවලට ගැලපෙන තාක්ෂණික විසඳුම්, ධාරිතා වර්ධනය සහ ප්‍රතිපත්ති, නෛතික හා නියාමන රාමු පිළිබඳ උපදෙස් සපයයි.

8.4 අනුහුරුවීම පිළිබඳ පර්යේෂණ හා ක්‍රමානුකූල නිරීක්ෂණය (Research and Systematic Observation on Adaptation)

8.4.1 පර්යේෂණ (Research)

තොරතුරු හුවමාරු කර ගැනීම හරහා පර්යේෂණ, ක්‍රමානුකූල නිරීක්ෂණ සහ දත්ත සමුදාය සංවර්ධනය වැනි කටයුතු ප්‍රවර්ධනය සඳහා සහයෝගීතාවයෙන් කටයුතු කරන ලෙස සම්මුතිය පාර්ශ්වවලින් ඉල්ලා සිටියි. පාර්ශ්වකරුවෝ ස්වකීය ජාතික හා ඒකාබද්ධ පර්යේෂණ ක්‍රියාකාරකම් සහ දේශගුණ විද්‍යාව සඳහා වන ඔවුන්ගේ දායකත්ව මෙන්ම නැගී එන පර්යේෂණ අවශ්‍යතා සහ ප්‍රමුඛතා පිළිබඳ ඔවුන්ගේ ජාතික සන්නිවේදනයේ දී වාර්තා කරති. දේශගුණ සම්මුතිය සහ පැරිස් ගිවිසුම යටතේ පර්යේෂණ ක්‍රියාත්මක කිරීමට සහාය දක්වන්නේ ලෝක දේශගුණ පර්යේෂණ වැඩසටහනෙහි (World Climate Research Programme- WCRP) සහයෝගිත්වය හරහාය. මෙය සම්බන්ධක ආදර්ශ අන්තර්-සැසඳීමේ ව්‍යාපෘතිය (Coupled Model Inter-comparison Project- CMIP), දේශගුණික විපර්යාස පිළිබඳ අන්තර් රාජ්‍ය මණ්ඩලය (Intergovernmental Panel on Climate Change- IPCC)) සහ අනෙකුත් වැඩසටහන්, ජාල සහ සංවිධාන සම්බන්ධීකරණය කරයි.

8.4.2 ක්‍රමානුකූල නිරීක්ෂණ (Systematic Observation)

දේශගුණ විපර්යාස පිළිබඳ විද්‍යාත්මක දැනුම වැඩිදියුණු කිරීම සහ දේශගුණ විපර්යාස අවම කිරීම හා අනුහුරුවීම පිළිබඳ තීරණ ගැනීම සඳහා දේශගුණික පද්ධතිය, එනම් වායුගෝලය, ගොඩබිම සහ සාගරය ක්‍රමානුකූලව නිරීක්ෂණය කිරීම ප්‍රධාන අවශ්‍යතාවයකි. තීරණවල දක්වා ඇති මාර්ගෝපදේශවලට අනුකූලව පාර්ශ්වයන් ජාතික සන්නිවේදනයන් හරහා සිය ජාතික ක්‍රමානුකූල නිරීක්ෂණයේ සවිස්තරාත්මක තාක්ෂණික වාර්තා ලෙස ලබා දේ. ගෝලීය දේශගුණ නිරීක්ෂණ පද්ධතිය (Global Climate Observing System- GCOS), පෘථිවි නිරීක්ෂණ චන්ද්‍රිකා පිළිබඳ කමිටුව (Committee on Earth Observation Satellites- CEOS), ලෝක කාලගුණ විද්‍යා සංගමය (World Meteorological Organization- WMO) සහ අනෙකුත් ආයතන හරහා ක්‍රමානුකූල නිරීක්ෂණය ක්‍රියාත්මක කිරීමට සහාය වේ.

නිගමනය

වර්තමාන ලෝකයේ නොවැලැක්විය හැකි අභියෝග යක් බවට පත්ව ඇති දේශගුණ විපර්යාසවල බලපෑම් සෑම මට්ටමකින්ම ක්‍රියාත්මක වීමේ අවශ්‍යතාව පෙන්නුම් කරයි. අනුහුරුවීම තුළින් මෙම බලපෑම් සමඟ කටයුතු කිරීම සඳහා පුද්ගලයින්, ප්‍රජාව සහ රාජ්‍යයන් හැඩගස්වනු ලැබේ. දූපත් රාජ්‍යයක් වන ශ්‍රී ලංකාව ද දේශගුණ විපර්යාසවල අහිතකර බලපෑම්වලට ලක්වීමේ ප්‍රවණතාවය ඉහළ වන අතර, මෙම තත්ත්වය යාමනය කර ගැනීම උදෙසා ජාතික වශයෙන් කටයුතු කිරීම මෙන්ම ජාත්‍යන්තර සහයෝගිතාව ලබාගැනීම ද එකසේ වැදගත් වේ. මෙහිදී ශ්‍රී ලංකාව ද දේශගුණ විපර්යාස පිළිබඳ එක්සත් ජාතීන්ගේ රාමුගත සම්මුතියේ පාර්ශ්වකරුවෙකු වශයෙන් ඉහත අනුහුරුවීම වෙනුවෙන් ගෙන ඇති වැදගත් පියවර අනුගමනය කර ඇති අතර, ඊට උදාහරණ කිහිපයක් ලෙස ජාතික අනුහුරුවීමේ ක්‍රමෝපාය අනුහුරුවීමේ ජාතික සැලසුම (National Adaptation Plan), තාක්ෂණ අවශ්‍යතා ඇගැයීම (Technology Needs Assessment) සහ අනුහුරුවීම සඳහා ජාතිකව නිර්ණය කළ දායකත්වයන් (NDCs on Adaptation) දැක්විය හැකිය. ඒ අනුව ගත් කළ UNFCCC මඟින් ගෙන ඇති ඉහත පියවර, දේශගුණ විපර්යාසවල අනිටු බලපෑම්වලට මුහුණ දීම සඳහා ශ්‍රී ලංකාව වැනි සංවර්ධනය වෙමින් පවතින රාජ්‍යවලට ඇති හැකියාව වැඩි කිරීම සඳහා මහගු පිටුවහලක් වී ඇත.

මූලාශ්‍ර

UN Climate Action
https://www.un.org/climatechange?gclid=Cj0KCQjwgO2XBhCaARIsANrW2X2BRODKf2DmUzfKorOjvAm_CRzgPMt2aa_LBJ-Fv-YnXgIdw-54A8MaAlA9EALw_wcB echange?gclid=Cj0KCQjwgO2XBhCaARIsANrW2X2BRODKf2DmUzfKorOjvAm_CRzgPMt2aa_LBJ-Fv-YnXgIdw-54A8MaAlA9EALw_wcB

Coastal Erosion at Iranawila © Eranga Jayawardena/AP Photo

Towards a Carbon Neutral Sri Lanka in 2050: Role of Forests

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Keywords:

NDC, FORESTRY, CARBON SEQUESTRATION, CARBON STORAGE, CARBON NEUTRAL

- **To achieve the carbon neutral status by 2050 it is required to reduce the emissions from other sectors (energy industry, transport, industry, household and commercial, waste, agriculture) and enhance the carbon sequestration capacity of the forests/trees.**

- **Forests significantly contribute towards achieving the target of reducing 14.5% of the GHG's by 2030. By increasing forests/ tree cover, achieving net zero status by 2050 is a possibility.**

- **It is a must to adhere to the targets of already prepared plans, programs and commitments such as Sri Lanka Sustainable Vision for 2030, Vistas for Prosperity and Splendor, Updated NDCs, Sustainable Agenda 2030, Forestry Master Plan (2021-2030) to achieve this task.**

- **According to the Updated NDCs for 2021-2030 of the forestry sector, Sri Lanka is to increase its forest cover up to 32% by 2030. This target is to be achieved by increasing the forest cover of natural forests, mangroves, plantation forests, rubber plantations and augmented by the Tress Outside Forests (TROFs).**

- **The carbon stocks lodged in Trees Outside Forests play an important role; home gardens, coconut and rubber plantations, shade trees in tea estates, urban forests and avenue trees provide a very important contribution. By encouraging planting of trees outside forests, the target of 32% of the country's land area under forests can be achieved.**

Introduction

Climate change due to global warming has been identified as one of the major threats to life on planet Earth. The emission of greenhouse gases (GHG) is the leading cause of global warming which severely impacts humans and all other life forms, as well as the environment and economy of a country. GHG emissions affect the whole world regardless of the country or the community which is responsible for emissions. A substantial reduction of GHG emissions - largely anthropogenic or man-made, is therefore critical to keep global warming at a manageable limit.

Thus, in accordance with the Paris Agreement, to which Sri Lanka is a Party to, global temperature rise must be kept well below 2°C relative to pre-industrial levels and efforts to limit the temperature increase to 1.5°C above pre-industrial level must be pursued. Through the Paris Agreement, Parties also agreed to a long-term goal for adaptation, to increase the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production. Additionally, they agreed to work towards making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development. Based on the Paris Agreement, countries who signed the UNFCCC, including Sri Lanka, submitted their first Nationally Determined Contributions (NDCs) in 2016 (MMD&E, 2016) and Sri Lanka submitted its Updated NDCs in 2021(MOE, 2021) which will be implemented during 2021-2030.

However, according to Emissions Gap Report 2021 (UNEP, 2021), climate pledges combined with other mitigation measures put the world on track for a global temperature rise of 2.7°C by the end of the century which is above the goals of the Paris climate agreement which intended to keep the global temperature rise well below2°C. Therefore,in order to address this alarming situation, many countries including Sri Lanka have taken steps to move forward to low carbon and sustainable development pathways. The term 'Low-carbon' does not necessarily imply that overall emissions in a country will decrease but implies that emissions will be kept below the business-as-usual scenario (BAU), to promote economic growth and sustainable development.

Lowland tropical and sub-montane forests
© Magical Isle Holidays (Pvt) Ltd

The Role of Forests in Climate Change Adaptation and Mitigation

Forests are a stabilizing force for the climate. They regulate ecosystems, protect biodiversity, play an integral part in the carbon cycle, support livelihoods and supply goods and services that can drive sustainable growth. Forests' role in climate change is two-fold. They act as both a cause and a solution for greenhouse gas emissions. Around 25% of global emissions come from the land sector, the second largest source of greenhouse gas emissions after the energy sector. About a half of these (5-10 $GtCO_{2e}$ annually) comes from deforestation and forest degradation (IUCN, 2021).

Forests are also one of the most important solutions to addressing the effects of climate change. Approximately, 2.6 billion tonnes of carbon dioxide, one-third of the CO_2 released from burning fossil fuels, is absorbed by forests every year. Estimates show that nearly two billion hectares of degraded land across the world -an area the size of South America - offer opportunities for restoration (IUCN, 2021).

Increasing and maintaining forests is therefore an essential solution to climate change. Halting the loss and degradation of forest ecosystems and promoting their restoration have the potential to contribute over one-third of the total climate change mitigation that scientists say is required by 2030 to meet the objectives of the Paris Agreement. Globally, 1.6 billion people (nearly 25% of the world's population) rely on forests for their livelihoods, many of whom are the world's poorest. Forests provide US$ 75-100 billion per year in goods and services such as clean water and healthy soils. Forests contain 80% of the world's terrestrial biodiversity (IUCN, 2021).

With regard to enhancing the climate risk management by forests, it is imperative to resort to combatting deforestation and forest degradation in areas of high biodiversity and cultural significance, such as primary forests and World Heritage sites. This helps conserve the benefits that people and societies obtain from forests, including forest carbon stocks and livelihoods.

Restoring forest landscapes helps enhance climate change mitigation and adaptation. There is a global effort to bring 350 million hectares of deforested

and degraded land under restoration by 2030. This could sequester up to 1.7 gigatonnes of carbon dioxide equivalent annually (Dhyani, S. *et al*., 2020). Enabling rights-based land use ensures community involvement in land-use outcomes. It is necessary to strengthen community control over forests, alleviate poverty, empower women and men, enhance biodiversity and sustainably manage forests.

Unlocking forest benefits is critical to a sustainable and equitable supply of forest goods and services. It is required to build capacity for implementing restoration, engaging the private sector and striving to make sure benefits, such as those from Reducing Emissions from Deforestation and Forest Degradation (REDD+), are equitably shared with local landowners and forest communities (GEF, 2021).

Status of Sri Lanka's Forest Cover

Despite Sri Lanka's relatively small land area, its high variations in rainfall, altitude, and soil characteristics create forests of high diversity, ranging from wet evergreen to montane forests and vast areas of dry monsoon forests with high species diversity and endemicity. 85% of the natural forest cover consist of dry-zone forests. Lowland rainforests and montane forests with higher biological diversity and higher levels of endemism are confined to small patches (Gunatilleke and Gunatilleke, 2005).

The total land areas of the country including internal water bodies amounts to 65,610km^2 and the latest forest cover estimates done in 2015 depict dense natural forest cover as 29.7% or 1.9 million ha (Forest Department, 2017) which includes forests, wildlife reserves and catchments. Forests play an important role in climate risk reduction including water regulation, land stabilization, reduction of heat, ensuring biodiversity and provision of habitats for fauna among many other benefits.

Natural forests in the country are not harvested for timber. The timber is supplied from forest plantations, home gardens and other non-forest tree resources. Forest plantations occupy 99,773 ha (1.52% of the land area of the country). Home gardens amounts to about 1,180,980 ha which is about 18% of the land area of the country as of 2020 (Ministry of Environment, 2021).

Table 1: Shows the forest cover by type.
Source: Forest Department (2015)

Forest Types	Extent_(ha)	%
Lowland Rain Forest	108,402.35	1.65
Dry Monsoon Forest	1,117,704.57	17.04
Moist Monsoon Forest	132,349.48	2.02
Sub Montane Forest	35,864.47	0.55
Montane Forest	40,475.50	0.62
Open Forest	394,110.68	6.01
Mangrove	19,756.79	0.30
Savannah	68,065.31	1.04
Total	**1,917,171.35**	**29.22**

Based on a global yardstick of concentrations of exceptional terrestrial biodiversity under threat, Sri Lanka and Western Ghats of south-western India have been grouped together as one of the 36 'Global Hotspots of Biodiversity', implying that biologically they are among the richest and at the same time the most endangered biogeographic regions on earth (Myers *et al*., 2000). Another indicator of threatened global biodiversity is the 'Global Ecoregion System' of the Worldwide Fund for Nature (WWF), in which 238 'Global 200'regions are considered biologically outstanding and prioritized for conservation action. Sri Lanka's lowland rain forests and montane rain forests have been recognized as one of their 142 priority terrestrial ecoregions, harboring exceptional levels of biodiversity, such as high species richness or endemism, or those with unusual ecological or evolutionary phenomena but at the same time having endangered conservation status.

The forest cover had shown a drastic decline from 1880s up to 1985 amounting to about 50,000 ha per year but since then the decline had been much reduced to about 7000 ha per year (Mattsson *et al.*, 2012). However, due to both natural and anthropogenic pressure forests are still facing a decline. Main four reasons for deforestation in Sri Lanka are encroachments due to agriculture, gem mining, human settlements, infrastructure development projects, commercial agriculture ventures and several localized drivers like cattle grazing, cardamom cultivation and forest fires. With the onset of the COVID 19 and the drastic decline of socio-economic status of the people, more emphasis had been placed on agriculture and thus the change of forest land use to non-forestry purposes has accelerated.


Gem mining © Alamy Stock Photo


Deforestation © Change.org

GHG Emissions and Sequestration by Forests

According to the UNREDD+ the emissions from the deforestation of 1 ha of forests per year is 150 tons (FAO, UNDP and UNEP, 2017). Accordingly, at the rate of deforestation of 7000 ha per year it is envisaged that 1,050,000 tons of CO_2 will be emitted to the atmosphere annually. However, the carbon sequestration capacity of the forests is phenomenal, and they are a unique ecosystem having the ability to capture the atmospheric carbon dioxide in their life activity of making their food (photosynthesis). The carbon sequestration/storage capacities of forests differ based on the type as shown below in Table 2.

Below

Table 2: Carbon sequestration /storage capacities of forests based on type

Forest Type	Carbon sequestration/storage	Source
Natural forests in the Knuckles Region	3.8 Tg	Pathinayake *et al* (2012)
Pine Plantations in the Knuckles Region	0.6 Tg	Pathinayake *et al* (2012)
Sinharaja Forest	1.624 Tg/146.4 mt/ha	Pathinayake *et al* (2012)
Lowland rainforests (Sinharaja and Kanneliya)	8.6 tons/ha/yr	Wahala, W.M.P.S.B., Ranasinghe, D.M.S.H.K. and Costa, J. (2013); Wahala, W.M.P.S.B. , PhD Thesis (2013)
Montane forests i.e.Horton Plains, Peak Wilderness	1.535 tons/ha/yr	Wahala, W.M.P.S.B., Ranasinghe, H and Costa, J (2013); Wahala, W.M.P.S.B. , Ranasinghe, D.M.S.H.K. and Amaraskera, H.S. (2013)
Soils in the Yagirala and Horton Plains Natural Forests	2.87 t C/ha/yr (Yagirala) 0.57 t C/ha/yr (Horton Plains)	Amarasekera L.A.M.C. and Ranasinghe D.M.S.H.K. (2006)
Home gardens in the Dry Zone (Moneragala)	56C/ha	Mattsson, E. Ostwala, M, Nissanka, S.P. and Pushpakumara, D.K.N.G. (2015)
Forest in Yagirala Forest Reserve – Wet Zone	51.3 t C/ha	Wahala, W.M.P.S.B., Ratnayake, R.M.D.D. and Ranasinghe, D.M.S.H.K. (2006)
Teak (50 years rotation)	133.66 t C/ha	Abayasiri S. and Ranasinghe, D.M.S.H.K. (2000)
Eucalyptus robusta and *E. grandis*	3.18 – 3.28 tC/ha/yr	Jayasinghe, G. & Ranasinghe, D.M.S.H.K. (2008)
Mahogany (12 yrs)	187.89 t C/ha	Perera, S. and Ranasinghe, D.M.S.H.K. (2013.)
Monoculture comprising of *Pinus caribaea* (44%), *Tectona grandis* (21%), *Eucalyptus grandis* (11%), *Eucalyptus camaldulensis* (7%) and *Swietenia macrophylla* (6%) in an area of 57618.8 ha in Sri Lanka	4.23 metric tons of C	de Costa, W.A.J.M. and Suranga, H.R. (2012)
Mangroves	323.57 -589.2 t C/ha	Gobishankar, S. and Ranasinghe, D.M.S.H.K. (2021)
Mangroves	387 t C/ha	Perera, K.A.R.S., de Silva, K.H.W.I. and Amarasinghe, M.D. 2017)
Kandyan Homegardens	103.9-381.2 t C/ha	Dissanayake, A. , Ranasinghe, D.M.S.H.K. and Wahala, S. (2009)
Homegardens in Low Country Wet zone Homegardens in Mid Country Wet Zone Homegardens in the Up Country Wet zone	74.82 t C/ha 91.79 t C/ha 24.68 t C/ha	Marambe, Y.H.B., Ranasinghe, D.M.S.H.K. and Wahala, W.M.P.S.B. (2019)
Homegardens in Nuwara Eliya District	711 million kg	Premakantha *et al.,* (2009)
Intermediate and low country home gardens	191.3- 345.9 t C/ha	Seneviratne, N.A.U.S., Ranasinghe, D.M.S.H.K. and Wahala, S. (2013)

Note: 1 Tg = 1,000,000 Mt;

However, despite all these pressures, as a signatory to the UNFCCC and Paris Agreement, the Government has expressed commitment to increase the forest cover up to 32% by 2030, although it is a herculean task. The Government has prepared its vision to adopt SDGs of the UN in its Vision document 'Sri Lanka's Sustainable Vision 2030', and also the manifesto of the former government, '*Vistas for Prosperity and Splendor*', in which an entire chapter had been dedicated to sustainable development,where forest resources development is integrated. In this context the following activities had been emphasized in the policy document: identification and reforestation of suitable lands, establishment of parks in urban and semi-urban areas, development of urban vegetation by establishing tree lines along express ways, implementation of tree planting programmes in industrial premises and restoration and rehabilitation of degraded ecosystems. The Nationally Determined Contributions (NDCs) submitted to the UNFCCC as a result of the Paris Agreement was revised to focus more on clarity of the combined contributions of individual mitigation targets. The period of implementation is 2021 to 2030 and a clear and concise implementation plan was prepared for each NDC.

It is expected that the implementation of updated NDCs of the forestry sector will result in the increase of carbon sequestration capacity by 7% against the BAU scenario (2% unconditionally and 5% conditionally) for the period 2021-2030 (Table 3). This is equivalent to an estimated additional sequestration of 705,000 MT unconditionally and 1,652,000 MT conditionally (total of 2,357,000 MT) of carbon dioxide equivalent during that period (2021-2030).

Table 3: Forestry sector NDCs.
Source: Ministry of Environment, 2021

NDC#	NDC and Action	Timeline
NDC 1	**Increase forest cover* of Sri Lanka up to 32%** by 2030**	**2021-2030**
	1.1 Identify land for reforestation/forestation	2021-2022
	1.2 Develop forest management plans for natural forests to ensure sustainable management	2021-2025
	1.3 Implement forest restoration programme (18,000+ ha of non-forest lands will be reforested/afforested including mangroves)	2021-2030
NDC 2	**Improve the quality of growing stock of natural forests and plantations**	**2021-2030**
	2.1 Improve the quality of growing stock of degraded forests (200,000 ha)	2021-2030
	2.2 Improve the quality of forest plantations of 78,000 ha in state-owned lands	2021-2030
	2.3 Improve the quality of forest lands of "Regional Plantation Companies"	2021-2030
NDC 3	**Strengthen catchment protection of major rivers and cascade systems**	**2021-2030**
	3.1 Identify and prioritize multi-hazards of catchment/river basins	2021-2022
	3.2 Strengthen lower catchment protection of 10 major rivers through tree planting	2021-2030
	3.3 Strengthen upper catchment protection of water streams running through plantations through tree planting	2021-2030
	3.4 Strengthen catchment protection of cascade systems & isolated tanks through tree planting	2021-2030
	3.5 Continue the "Climate Resilience Multi-Phase Programmatic Approach" project in lower kelani river basin	2021-2025
NDC 4	**Improve and increase of Trees Outside Forests (TROF)**	**2021-2030**
	4.1 Adopt policy instruments and regulations supporting TROF (urban forestry, tree planting along roadside, religious premises, schools and other Government lands, home gardens)	2021-2023
	4.2 Establish an institutional setup and a mechanism to implement such programmes	2021-2024
	4.3 Conduct carbon stock evaluation for TROF	2021-2025
	4.4 Implement TROF programmes	2021-2030
NDC 5	**Generic enabling activities**	**2021-2025**
	5.1 Develop and implement a MRV system for forestry NDCs	2021-2025

*The forest cover was taken as the dense forest, open forest, mangroves and forest plantations and rubber plantations (as per the FAO definition of 'forests).

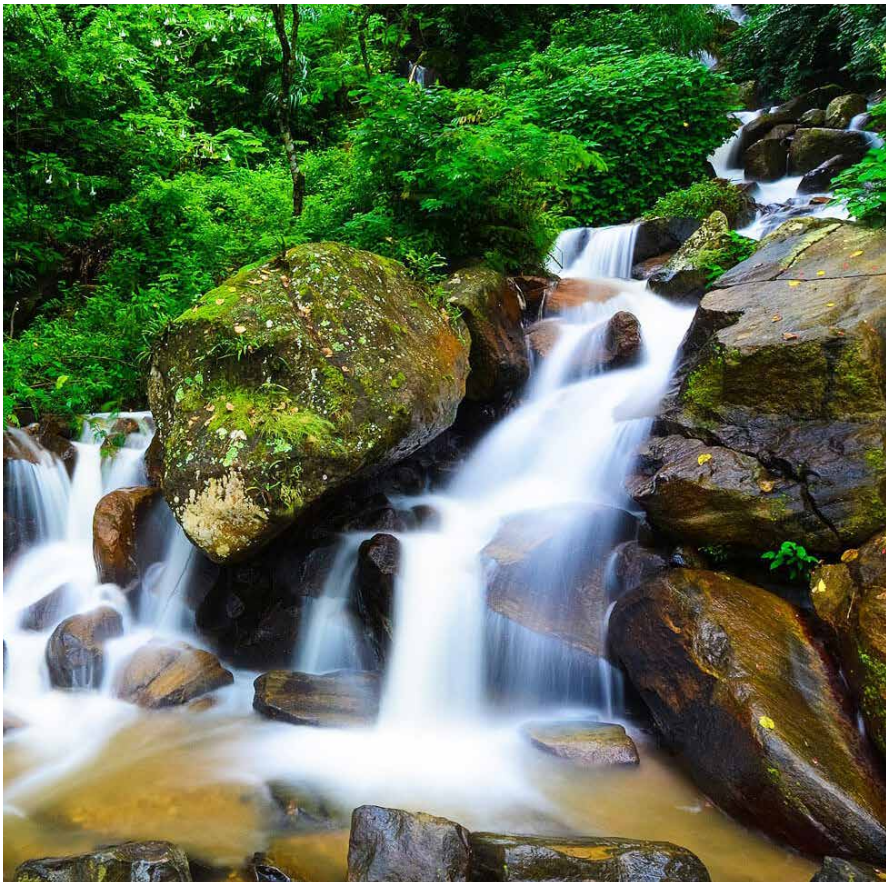
**30.8% to be achieved through forest plantations and natural forest and the rest to be achieved through TROF (Trees Outside Forests)

Situated in Moratuwa, a bustling city in Sri Lanka, the One Earth Urban Arboretum © Dilmah Conservation

According to the Third National Communication to the UNFCCC (MOE,2022), the GHG emissions from the significant sectors i.e., energy (electricity, transport, household, commercial and manufacturing industries), Industrial Processes and Product Use, Waste, Agriculture in the business-as-usual scenario will be 47,674 Gg CO_2eq in 2030, while forestry will reduce this amount to 44, 167 Gg CO_2 eq. In the mitigation scenario, including implementation of the NDCs, the total GHG emissions will be 33,780 Gg CO_2 eq and the forestry will reduce this to 29,907 Gg CO_2eq. The total reduction of the GHG emissions due to mitigations proposed in all the aforesaid sectors will be 30% while the contribution of the forestry sector to this will be 10%.

Forestry Master Plan which was in vogue from 1995 to 2020 is being replaced by a new plan which will be valid from 2021 to 2030. This is in the stage of preparation and will address issues such as climate change, sustainable forest management,

United Nations Sustainable Development Goals



Sinharaja Rain Forest © Thimira Samarakoon

restoration of forest landscapes, community forest management, valuation of ecosystem services, biodiversity enhancement, ecotourism and pandemic recovery among many other sectors which were already in the previous plan.

Links to the Sustainable Development Goals

The relevant SDG Goal for forestry sector is Goal 15 which is protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss.

Conclusion

After the review of the facts laid out in the preceding section, it is very clear that if the country needs to reach the goal of becoming a carbon neutral economy by 2050, it is vital to accrue the benefits from the wide range of forest ecosystems which are capable of providing a host of ecosystem services, including carbon sequestration/ absorption, thus reducing the GHG in the atmosphere and lowering the adverse impacts of climate change. Despite the temptation of succumbing to the short-term socio-economic upliftment, perhaps at the expense of finite forest cover, this can be overcome by planning the development carefully in considering the Sustainable Development Goals. The already prepared plans in this context, including implementation of the NDCs, Forestry Master Plan (being prepared for 2021-2030), Directions of the Vistas for Prosperity and Splendor and Sri Lanka Sustainable Vision 2030 need to be implemented with determination to reach our goals of being a carbon neutral country by 2050.

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Ella valley © Vyacheslav Argenberg

Sri Lanka's National Greenhouse Gas Inventory

Progress and Comparison of Methodological Approaches

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Keywords:

NATIONAL GREENHOUSE GAS INVENTORY, UNFCCC, NATIONAL COMMUNICATION

- **Sri Lanka, as a non-Annex 1 country, has prepared three national greenhouse gas inventories so far in line with the national greenhouse gas inventory submission requirements under the United Nations Framework Convention on Climate Change**
- **The composition of the inventory has improved from the first national communication to the third national communication, especially with the shift from 1996 IPCC revised guidelines to 2006 guidelines/ methodology**
- **So far, the most significant constraint leading to uncertainty in the emission estimates is the data gaps (i.e. unavailability, inconsistency in data from multiple sources, lack of consistent reporting even within a single source, etc.) in certain sectors and subsectors**
- **Enhancing the utilization of country-specific emission factors and further research targeting those are required for better accuracy in the emission estimates of future inventories**

Introduction

Under the United Nations Framework Convention on Climate Change (UNFCCC) of 1992, one of the key reports to be submitted by its member countries is the National Communication (NC), including a national greenhouse gas (GHG) inventory, which was started in 1994 for the developed (i.e. Annex 1) countries and in 1997 for the developing (non-Annex I) Parties (Dal Maso and Canu, 2019). In addition to the GHG inventory, an NC also includes measures for mitigating emissions and facilitating adaptation to climate change, and any other relevant information relevant to the achievement of the objective of the Convention. NCs are submitted every four years.

The national GHG inventory of a national communication provides a comprehensive report on sector (and subsector) wise GHG emissions within a country; a national GHG inventory report is a national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, developed using comparable methodologies agreed upon by the Conference of the Parties (UNFCCC; 2021; https://unfccc.int/national-reports-from-non-annex-i-parties.) National GHG inventories help countries in making policy decisions on potential mitigation action and setting targets for emission reductions.

Action to mitigate the increasing GHG emissions through international cooperation have accelerated since the beginning of the 1990s, with the adoption of the UNFCCC in 1992, Kyoto Protocol in 1997, and Paris Agreement in 2015. The UNFCCC entered into force in 1994 and so far over 190 countries have ratified it. The objective of the UNFCCC is to stabilize atmospheric GHG emissions at a level that would not further damage the climate system from human interference. Under the UNFCCC, member countries are expected to submit national GHG inventories in accordance with the adoption of Kyoto Protocol and the Paris Agreement. The ability to quantify emissions at national level is important. Parties to the UNFCCC are required to submit national GHG inventories, together with details on methods used in estimating their emissions.

Sri Lanka a Developing Country © Journeyz

Developed countries, which are listed in the Annex 1 of the UNFCCC (and referred to as 'Annex 1 countries') are expected to submit an annual National Inventory Report (NIR) containing detailed and complete information on their emissions for all years from a base year (which is 1990 for the majority of the countries) to the current year for the annual inventory submission (United Nations Framework Convention on Climate Change, 1999). Annex 1 countries have submitted national GHG inventories since 1994, and since 1996 they have made annual submissions.

The developing countries or non-Annex I parties to the UNFCCC (154 countries altogether; UNFCCC, 2022), do not have the same reporting requirements for an annual submission as Annex I parties do, but they also have submitted national GHG inventories as part of their national communications. Although nearly 100 non-Annex I parties have submitted two or more national GHG inventories along with their national communications to date, there has not been a definite time period in between their submissions. However, non-Annex I countries are required to submit national communications every four years and national GHG inventories every two years, starting from 2014 (UNFCCC, 2022).

Methodology Requirements

For transparency and comparability, the member countries of the UNFCCC are required to estimate the emissions under pre-defined sectors and sub sectors, following a common methodology (i.e. guidelines) developed by the Intergovernmental Panel on Climate Change (IPCC). The IPCC original guidelines (IPCC-GL) were revised in 1996 (IPCC 1997a, 1997b, 1997c) and 2006 (IPCC, 2006). In between the above revised guidelines, IPCC good practice guidance (GPG; IPCC, 2000; 2003) was developed with further guidance on default- and country specific methods and data (Lokupitiya and Paustian, 2006).

Currently, the Annex 1 countries are mostly using the 2006 IPCC-GL, in preparation of their GHG inventories. According to a decision taken at the 8th Conference of Parties of the UNFCCC (i.e. Decision 17/CP 8), non-Annex 1 countries are required to use Revised 1996 IPCC-GL. However, even certain non-Annex 1 countries have been using the improved methodology and emission factors (EFs) under the 2006 IPCC-GL. For Quality Assurance/Quality Control (QA/QC) of the GHG inventories such measures and Uncertainty related information have also been reported by the countries, for each inventory sector. Recalculations from the current inventory year backwards to cover the previous inventory year, using the methodological improvements in the latest inventory year have also been conducted.

Sector wise GHG Emissions to be Reported in the GHG Inventory

The main GHG emitted due to anthropogenic activities is carbon dioxide. In addition to that, several types of greenhouse gases are required to be estimated at national level, covering several key socioeconomic sectors and subsectors. According to Decision 17/CP8 (FCCC/CP/2002/7/Add.2), non-Annex 1 countries shall provide the estimates of anthropogenic emissions by sources and removals by sinks of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), in their national inventories; they are encouraged to provide information on the other less prevalent GHGs, which include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF6). In addition, they are encouraged to report carbon monoxide (CO), nitrogen oxides (NOx) and non-methane volatile organic compounds (NMVOCs), all of which are precursors of ozone, and sulphur oxides (SOx) as well.

Sri Lanka's Journey from the GHG Inventory in Initial National Communication to Third National Communication

Sri Lanka followed the Revised 1996 IPCC-GL as the basic methodology in the previous GHG inventories submitted by the country (i.e. Initial National Communication, (INC) Ministry of Forestry and Environment, 2000) and Second National Communication (SNC); Ministry of Environment, 2011), and 2006 IPCC-GL as the predominant methodology in its GHG inventory submitted with the Third National

Communication (TNC; Ministry of Environment, 2022). In moving from INC to TNC, the country has shown remarkable improvement in the inventory methodology used, utilization of the available country-specific data, and institutional framework.

Given the high uncertainty associated with the sector wise methodological changes from INC to TNC, only the energy sector emissions were compared, and there was a consistent increase in the overall energy-related emissions from 1994 (INC) to 2010 (TNC; Figure 1). The per capita emission of 1.0003 tonnes CO_2-eq (i.e. CO_2-equivalent units) for the year 2000 (SNC) and 1.09 tonnes CO_2-eq for the year 2010 (Table 1), indicating that Sri Lanka still has quite low per capita emissions, showing only a marginal increase during the decade of 2000 to 2010, as a non-Annex 1 country.

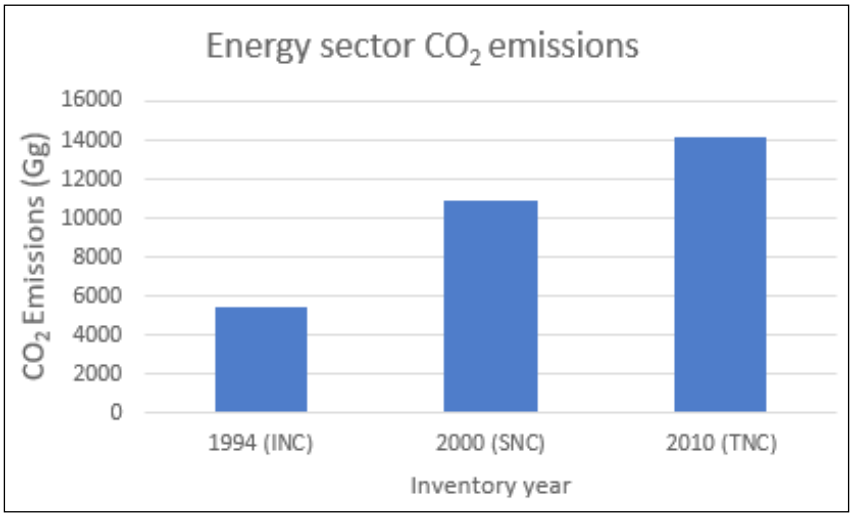

Figure 1: CO_2 Emissions from the Energy sector reported in the GHG inventories so far

Table 1: Comparison of the GHG inventories included in INC, SNC, and TNC

	INC	SNC	TNC
Base year	1994	2000	2010
Methodology	1996 IPCC-GL	1996 IPCC-GL and GPG (IPCC, 2000; 2003) with improved EFs from 2006 IPCC-GL	2006 IPCC-GL, GPG (IPCC, 2003 for certain EFs), and 1996 IPCC-GL (for HFC and precursor emissions)
Global Warming Potential (GWP)	None	GWPs based on IPCC Second Assessment Report (SAR; IPCC, 1996)	GWPs based on IPCC Second Assessment Report (SAR; IPCC, 1996)
Units	Gg (of individual gases); no CO_2 equivalent values given	Gg (individual gases) and final estimate in Gg CO_2- equivalent	Gg (individual gases) and final estimate in Gg CO_2- equivalent
Key sectors	5 (for both estimation and reporting- Energy, Industrial Processes, Agriculture, Land Use Change and Forestry (LUCF), Other Sources (Domestic and Industrial wastewater management))	5 (for both estimation and reporting- Energy, Industrial Processes, LUCF, Waste	4 for estimation Energy, Industrial Processes and Product use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU), and Waste and 5 for reporting (Energy, IPPU, Agriculture, Land Use, Land Use Change, and Forestry (LULUCF), Waste)
Per capita emission excluding LULUCF emissons	NE*	1.0003 tonnes CO_2-eq	1.09 tonnes CO_2-eq

(*- not estimated, due to certain high uncertainties observed)


Renewable resources
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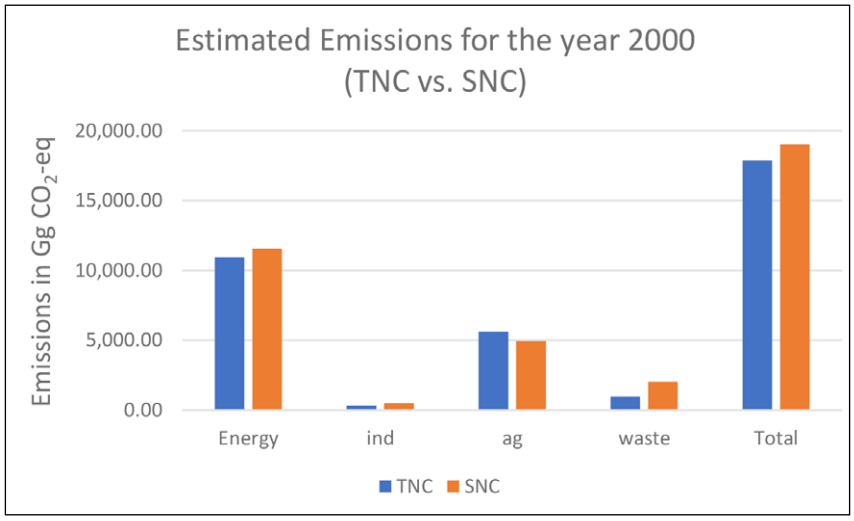
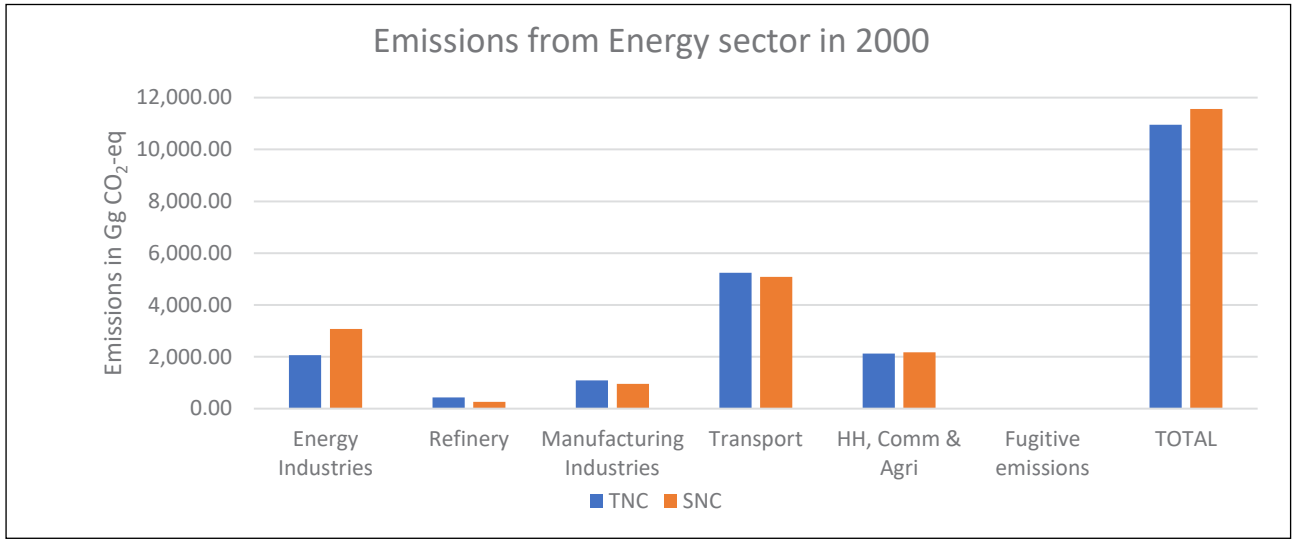
In the TNC, the time series calculations were carried out for the period 2000-2010, using consistent data sources and methodology described above. The recalculated estimates in the TNC for the total emissions excluding LULUCF sector for the year 2000 were only 05 percent lower in the TNC compared to the SNC (Figure 2); the largest variation was seen in the waste sector, which has been one of the sectors with the largest uncertainties due to data gaps. The recalculated emissions for the energy sector and its subsectors are shown in (Figure 3).



Left
Figure 2: Comparison of the sector wise emissions reported in SNC for year 2000 against the recalculated values for the same year in TNC

Below
Figure 3: Energy sector emissions for the year 2000 reported in the GHG inventories of the Third National Communication (TNC) and Second National Communication (SNC); [HH, Com & Agri- Household, Commercial and Agriculture]



Gaps and Improvements in the Inventory Preparation Process

There has been a significant change in the institutional arrangements from INC to TNC, in preparation of the national GHG inventory. The Ministry of Environment has consistently served as the National Focal Point, and a team of inventory specialists were involved in the preparation of each inventory. National communications are supported by Global Environmental Facility (GEF) funding. The INC was coordinated through a GEF-funded enabling activity project , while the SNC and TNC submissions were coordinated by the Climate Change Secretariat. From INC to TNC the number of experts involved in preparation of the GHG inventory was increased and the numbers of capacity building workshops, stakeholder consultations and meetings with external reviewers in the preparation of the inventory, were also increased. This enabled the consistent update of the inventory, especially the TNC, during its preparatory phase.

Overall, the methodological improvement by gradual transition from 1996 IPCC-GL to 2006 IPCC-GL and comprehensive and continuous consultative process, have led to a significant improvement and achievements in the overall inventory preparation process of Sri Lanka. So far, the most significant constraint leading to uncertainty in the emission estimates is the data gaps (i.e. unavailability, inconsistency in data from multiple sources, lack of consistent reporting even within a single source, etc.) in certain sectors and subsectors. A

proper mechanism of coordination and recording all the data by the respective stakeholders that warrants the Ministry of Environment to receive the required data in time, is essential for better quality and timely delivery of the future inventories. The stakeholders need to be communicated the required data and the utilizable format in which they should be recorded. Although certain country-specific EFs were used in the GHG inventory of the SNC, so far, the utilization of country-specific EFs has been minimal. Therefore, continued use of the available (and published in peer-reviewed journals) country-specific EFs, and further research targeting those, will increase the accuracy in GHG estimates with minimum uncertainty in the future inventories.

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Overview on Measurement, Reporting and Verification (MRV) Frameworks

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Keywords:

MRV, NATIONAL CLIMATE CHANGE DATA SHARING NETWORK, MITIGATION

- **MRV is a process/concept that potentially supports greater transparency in the climate change regime.**
- **Key elements of MRV include international, domestic MRVs and MRV of REDD+.**
- **National Communication, Biennial Update Report including the International Consultation and Analysis are key components of international MRVs while MRV of emissions, NAMA/mitigation action and support are included in domestic MRVs.**
- **MRV for REDD+ applies to parties seeking to obtain and receive payments for results-based actions**
- **National Climate Change Data Sharing Network (NCC DSN), which is a national level online platform, will support to gather data for international MRV covering all sectors in Sri Lanka**
- **The systematic institutional arrangement is a key to the sustainability of the MRV system.**
- **Ministry of Environment is the focal point to the UNFCCC from Sri Lanka. Thus far, the country has submitted three national communications.**

Norochcholai
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Introduction

The United Nations Framework Convention on Climate Change (hereinafter referred to as the Convention) provides the foundation for the intergovernmental response to climate change and its impacts on humanity and ecosystems. In order to collectively address climate change and achieve the objective of the Convention and the purpose and goals of the Paris Agreement, countries need to mobilize actions. Further, all the parties are obliged to communicate to the Conference of the Parties (COP) information on the actions they have taken or envisage they will take to implement the Convention. This is seen as a key implementation aspect of the Convention, as it allows Parties to inform one another of their national-level actions and serves as a basis for the COP to assess the implementation of the Convention by Parties.

The regular collection, analysis and use of reliable information on climate action and support to reduce GHG emissions and increase resilience, and data on GHG emission trends, both historical and projected, is essential for evidence-

based decision-making and information-sharing. This type of system creates reliability and builds trust and which in turn promotes stakeholder engagement. This data collection and reporting activity form a critical component of what is commonly known as 'MRV' under the Convention and has recently been encapsulated by the term ''transparency' under the Paris Agreement (UNFCCC, 2020). This article describes the existing MRV arrangements under the Convention.

The arrangements for national reporting have evolved throughout the history of the Convention and its Kyoto Protocol into a more comprehensive measurement, reporting and verification framework. Figure 1 illustrates the evolution of MRV arrangement for developing country parties.

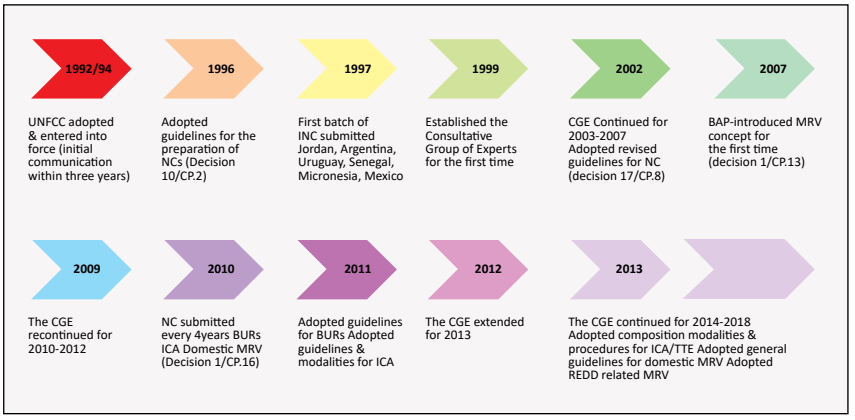


Figure 1: Evolution of MRV arrangement for developing country parties
Source: UNFCCC 2014, Handbook on Measurement, Reporting and Verification for developing country parties

Measurement, Reporting and Verification

Several elements were introduced to the MRV framework through a set of decisions taken by COP over the years. Some of these elements are implemented at the international level and others at the national level. Figure 2 illustrates the key elements of the MRV framework.

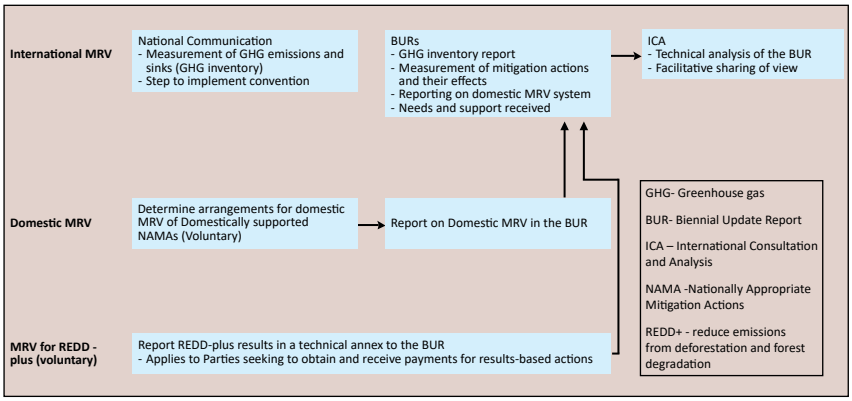


Figure 2: Key elements of MRV framework
Source: UNFCCC 2014, Handbook on Measurement, Reporting and Verification for developing country parties

International MRV

Measurement

Measurement for non-Annex I Parties applies both to efforts to address climate change and to the impacts of these efforts, including the level of GHG emissions by sources and removals by sinks, emission reductions and other co-benefits.

Reporting

Reporting for non-Annex I Parties is implemented through the National Communications (NCs) and Biennial Update Reports (BURs). Parties are required to report on their actions to address climate change in their national communications, which include information on the Greenhouse gas (GHG) inventories, adaptation, mitigation actions and their effects, constraints and gaps, support needed and received, and other information considered relevant to the achievement of the objective of the Convention. National Communications (NCs) are to be submitted every four years and prepared following the guidance contained in the revised guidelines for the preparation of NCs from non-Annex I Parties contained in the annexure to the decision. BURs are to be submitted every two years, providing an update of the information presented in national communications, in particular on national GHG inventories, mitigation actions, constraints and gaps, including support needed and received.

Verification

Verification is addressed at the international level through International Consultation and Analysis (ICA) of BURs, which is a process to increase the transparency of mitigation actions and their effects, and support needed and received.

National Communication (NC)

Each Party to the Convention prepares NC periodically, following the guidelines developed and adopted by COP. Non-Annex I Parties are required to submit their first NC within three

years of entering the Convention and every four years thereafter. National communication serves as a medium for the presentation of information in a consistent, transparent, comparable and flexible manner. As per Article 4, paragraph 1, of the Convention, the following information needs to be provided by Non -Annex I Parties in their NCs (UNFCCC, 2009).

(a) A national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, to the extent its capacities permit, using comparable methodologies to be promoted and agreed upon by the COP.

(b) A general description of steps taken or envisaged by the Party to implement the Convention.

(c) Any other information that the non-Annex I Party considers relevant to the achievement of the objectives of the Convention and suitable for inclusion in its communication, including, if feasible, material relevant for calculations of global emission trends.

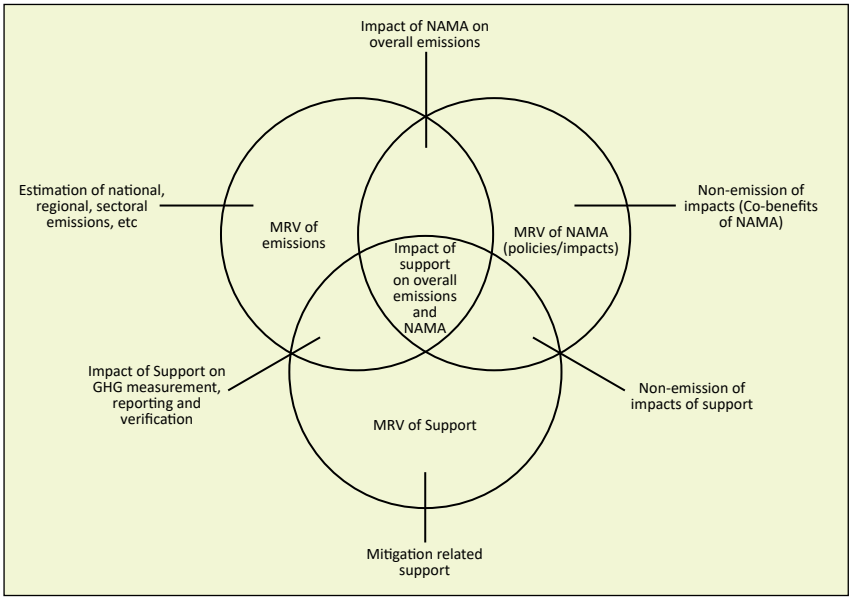
Biennial Update Report (BUR)

The scope of the BURs is to provide an update of the most recently submitted national communication and to provide additional information about mitigation actions taken or envisaged to undertake and their effects, as well as support needed and received. Non-Annex I Parties, consistent with their capabilities and the level of support provided for reporting, should submit their first BUR by December 2014 and every two years thereafter. The Least Developed Country Parties and Small Island Developing States may submit BURs at their own discretion. The BURs shall be prepared in accordance with the guidelines contained in decision 2/CP.17 (decision 2/CP17).

Domestic MRVs

At the national level, Parties are expected to implement the international guidelines for domestic MRV frameworks and to prepare and report information according to the guidance on reporting through national communications and BURs. As illustrated in Figure 3, the domestic/national MRV system includes three elements I) MRV of emissions, 2) MRV of NAMAs, 3) MRV of support.

Below
Figure 3: Elements of National MRV framework
Source: UNFCCC 2014, Handbook on Measurement, Reporting and Verification for developing country parties



MRV of Emissions

MRV of GHG emissions refers to estimating, reporting, and verifying actual emissions over a defined period of time. This type of MRV can be performed at the national level or by regional and sectoral levels.

MRV of Nationally Appropriate Mitigation Actions (NAMAs)

MRV of mitigation actions involves assessing (ex-ante or ex-post) GHG emissions reductions and/or sustainable development (non-GHG) effects of policies, projects, and actions, as well as monitoring their implementation progress. It also involves assessing progress toward mitigation goals.

MRV of Support

MRV of support focuses on monitoring the provision and receipt of financial flows, technical knowledge, and capacity building and evaluating the results and impact of support.

MRV for REDD+ Activities

Developing country Parties are encouraged to contribute to mitigation actions in the forestry sector by undertaking REDD+ activities
I) Reducing emissions from deforestation,
II) Reducing emissions from forest degradation,

III) Conservation of forest carbon stocks, IV) Sustainable management of forests, V) Enhancement of forest carbon stocks.These activities should be country-driven, correspond to national development priorities, circumstances and capabilities, and should respect sovereignty. Furthermore, they should be implemented in phases and evolve into results-based actions that should be fully measured, reported and verified.

Institutional Arrangements

The robust institutional arrangement is vital for the sustainability of a MRV system. The national institutional arrangements will facilitate individual Parties in ensuring that nationally appropriate procedures for collecting, processing, reporting and archiving required data and information are established and operational in a sustainable manner on a continuous basis (fig.4). These can facilitate effective coordination among all relevant stakeholders from the public and private sectors in meeting the reporting requirements under the Convention, as well as addressing the broader issue of climate change at the national level. In particular, institutional arrangements can assist Parties to:

- Meet reporting requirements under the Convention
- Build national capacities and ensure the sustainability of reporting processes
- Inform national and international policymakers at different levels
- Assist in institutionalizing activities relating to reporting on climate change.

However, there is no one-size-fits-all model for institutional arrangements. Systems should be designed and tailored such that they will be sustainable under the respective national circumstances.

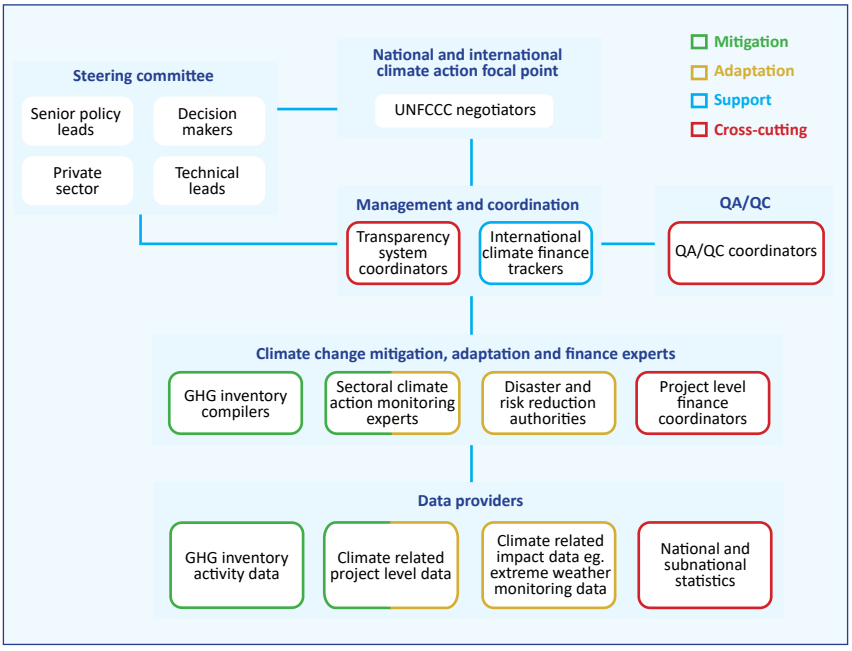


Figure 4: Model structure of the institutional arrangement
Source: UNFCCC 2013, Toolkit for non-Annex I Parties on establishing and maintaining institutional arrangements for preparing national communications and biennial update reports

MRV Systems in Sri Lanka

Sri Lanka ratified the Convention in 1993 and was among the first 50 countries to ratify it. Further, it has ratified the Kyoto Protocol and Paris Agreement in 2002 and 2016, respectively. Ministry of Environment, the national focal point to the UNFCCC, has established the Climate Change Secretariat under its purview to fulfil the country's commitment to the UNFCCC.

The country has submitted its First, Second and Third National Communications to the UNFCCC in 2000, 2012 and 2022 respectively. The country has established a National MRV system for the Transport Sector and is preparing an integrated MRV system at the national level. Further, it is also in the process of developing MRV for REDD+ activities as well. National Climate Change Data Sharing Network (NCCDSN), which is a national level online platform, will support to gather data for international MRV covering all sectors in Sri Lanka.

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Harnessing Climate Finance opportunities with Green Climate Fund

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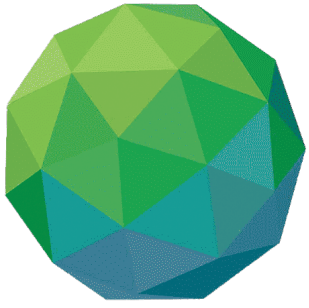


GREEN CLIMATE FUND

Keywords:

GREEN CLIMATE FUND, NATIONAL DESIGNATED AUTHORITY, ACCREDITED ENTITIES

- **The Green Climate Fund provides an opportunity for developing countries to reduce greenhouse gas emissions and increase climate resilience through funding for projects**
- **Investment areas and procedure to apply for funding and the programme activity cycle is explained in a simplified manner**

Introduction

The Green Climate Fund (GCF) was established in 2010 by the 194 country Parties to the United Nations Framework Convention on Climate Change (UNFCCC) as an operating entity of the Financial Mechanism of the UNFCCC under its Article 11. The Green Climate Fund (GCF) is the world's largest dedicated fund helping developing countries to reduce their greenhouse gas (GHG) emissions and enhance their ability to respond to climate change. The mandate of GCF is to promote a paradigm shift towards low-emission and climate-resilient development pathways by channeling Climate Finance (CF) to developing countries that have committed to climate action.

Role of National Designated Authority and Accredited Entities

GCF activities of each developing country are coordinated through a **National Designated Authority** (NDA)/Focal Point, nominated by the country itself, that serves as the interface between each country and the GCF. The NDA/focal point plays a key role throughout the project cycle in ensuring country ownership and a country-driven approach, which are core principles of the GCF business model. Ministry of Environment is the NDA for Sri Lanka.

GCF provides climate finance under several instruments including grants, concessional loans, guarantees, equities and results-based-payments. The debt-for-climate swap is the most recent instrument that the GCF is piloting. According to the business model of the GCF, it acts as a partnership organization. GCF does not directly provide finance to any country. The GCF provides finance through the "direct access" modality to help developing countries exercise ownership of funding and better integrate it with their national climate priorities . Funding of GCF is channeled through **Accredited Entities** (AEs).

Accreditation is a process by which entities are assessed and approved by the Board to access GCF funding. In this process of accreditation, how an entity can access GCF resources, maximum limits of GCF financial support for which the entity can apply in a single funding proposal, the financing modality, the financing instruments and the environmental and social risk levels are defined. AEs can be national, regional, or international institutions or organizations. Only AEs can submit a funding proposal to GCF with the endorsement of the respective NDA/s. AEs develop and submit funding proposals for appraisal and approval by GCF and oversee and monitor the management and implementation of projects and programmes approved and financed by GCF. There are two types of accreditation modalities: direct access and international access.

1. **Direct Access Entities -** The Direct Access Entities (DAEs) are sub-national, national, or regional organizations that need to be nominated by the NDA. DFCC Bank has been accredited as the first Direct Access Entity in Sri Lanka in July 2023. Four banks namely, NDB, Commercial Bank, HNB, and HDFC have already been nominated as the DAEs by the NDA and are in the process of accreditation.

2. **International Access Entities** - The International Access Entities (IAEs) include United Nations Agencies, multilateral development banks, international financial institutions, International Non-Governmental Organizations (INGOs), and regional institutions that are directly accepted by the GCF.

[1]https://www.greenclimate.fund/sites/default/files/document/gcf-brief-direct-access_0.pdf

Sustainable Finance © ESMA

During the accreditation process, an applicant entity's systems, policies and procedures, track record, and demonstrated capacity to undertake projects or programmes of different financing size categories, financing modalities, and environmental and social risk categories are assessed against the GCF standards. Each AE should have a set of fiduciary principles and standards that are equivalent to the GCF fiduciary principles and standards. The GCF accredits entities by specifying the types of projects and programmes of those AEs (DAE or IAE) that can be submitted for funding and implementation. Therefore, the AEs can only submit **Funding Proposals** (FPs) up to the size for which they have been accredited. The categories of the project sizes are as follows:

Micro: Up to USD 10 million

Small: Up to USD 50 million

Medium: Up to USD 250 million, and

Large: USD 250 million and above.

In implementing a project or programme, AE has to identify the executing entities related to the activities identified. **Executing Entity** (EE) is an entity which channels or uses GCF proceeds for a GCF-funded activity, and/or executes, carries out, or implements a GCF-funded activity or any part of it. An AE may also carry out the functions of an EE. The AEs must evaluate the capacity of the EE and engage the relevant EE based on its ability to channel or use GCF proceeds to implement the GCF-funded activity following GCF policies and requirements.

GCF is providing its finance under four mitigation and four adaptation investment areas mentioned in figure 1. GCF funds can be accessed through submitting project proposals under these investment areas. Project proposals should be in line with the GCF investment areas and should explain how the project activities can reduce emissions on GHGs or adapt to the adverse impact of climate change in the relevant area.

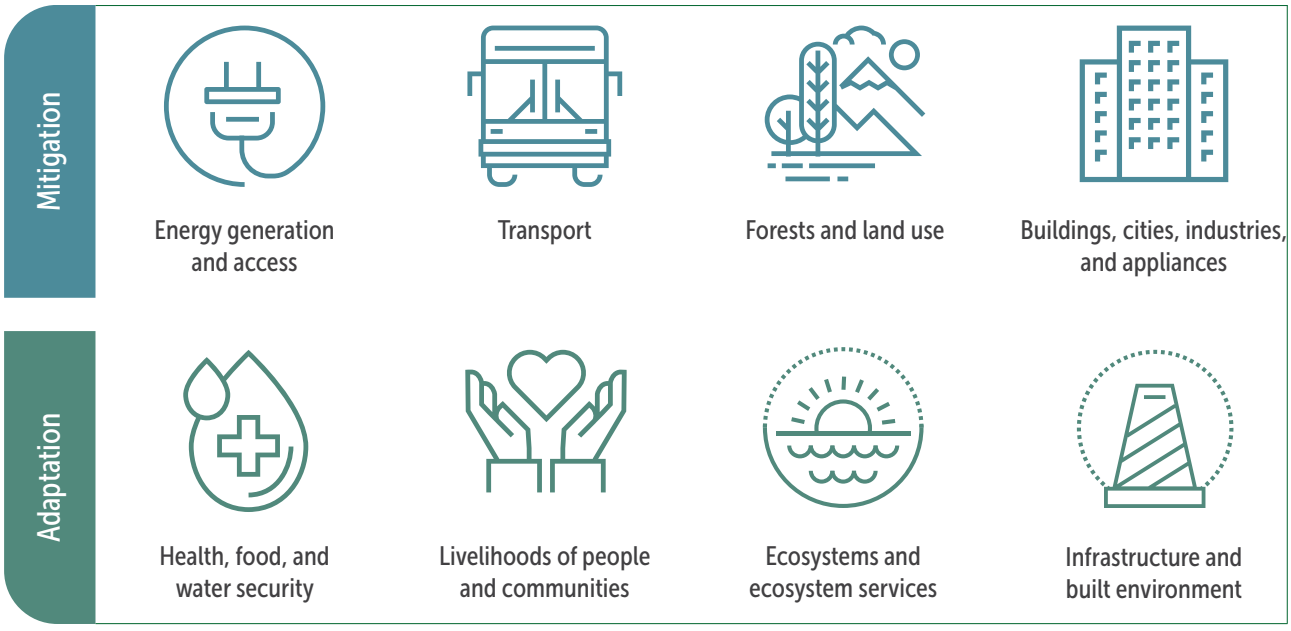
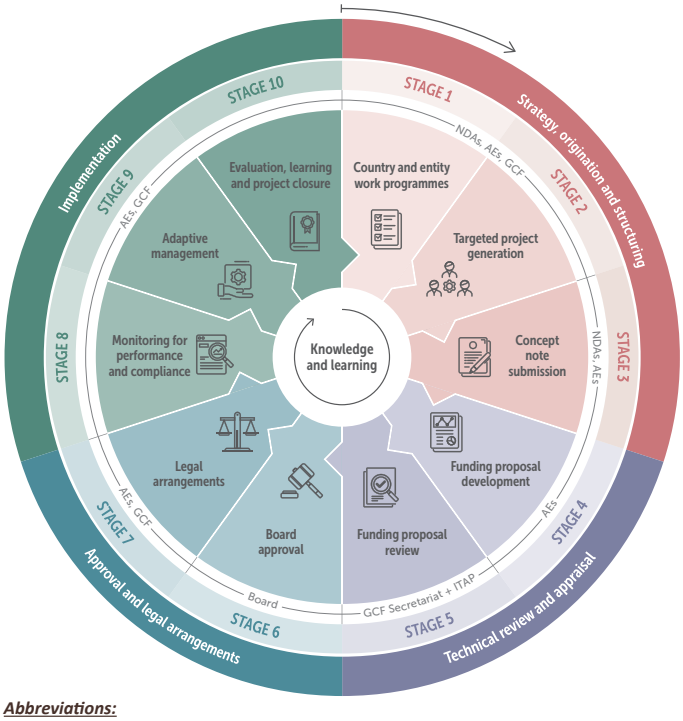


Figure 1: GCF Investment areas *Source:* GCF Programming Manual

Project Activity Cycle

The GCF involvement of a country in project approval is not clear and can be explained with the project activity cycle. The project activity cycle is comprised of 10 stages as demonstrated in figure 2. The cycle starts with the preparation of country programmes and entity work programmes for GCF.


GCF Community programme



Abbreviations:
AE= accredited entity,
NDA= national designatrd authority,
ITAP= independent technical advisory panel.

Figure 2: GCF project/ programme activity cycle *source:* GCF Programming Manual.

The **Country programme** is a document developed by the NDA/focal point that presents a country's climate change priorities to GCF. It includes a pipeline of projects that the country would like to develop with GCF for each replenishment period, an action plan for projects and programmes to be developed, the accredited or prospective entity with which to partner, and the readiness and project preparation support that requires funding from GCF.

The **Entity Work Programme** is a document developed by AEs that provides an overview of the envisaged partnership of the AE with GCF. This includes strategies and plans to address climate change, the comparative advantages, areas of work and priority sectors of the AE, alignment with Country Programmes as well as GCF sectoral guidance on the eight GCF result areas, and its experience in implementing projects and programmes across the eight GCF result areas. It also summarizes the indicative projects and programmes of the AE and outlines an action plan for engagement with GCF for each replenishment period.

With the identified priority areas from the country programme and entity work programmes, AEs, together with the NDA, should generate projects with the support of all relevant stakeholders.

Under the **Readiness support progremme**, GCF is supporting the developing countries to enhance the capacity of national institutions to engage efficiently with GCF. There are two types of readiness support given by GCF. They are NDA Readiness and National Adaptation Planning (NAP) Readiness. Based on the submission of high-quality proposals, the Readiness Programme may provide up to USD 1 million per country per year for NDA Readiness and up to USD 3 million per country as a one-time grant for a period of three years for formulation and implementation of national adaptation plans already present above and/or other adaptation planning processes.

Stage 1 identification of country programmes.

Stage 2 of the programme activity cycle is the generation of targeted projects or programme funding proposals. ideas for projects and programmes can originate from country programmes and **Entity Work Programmes** (EWPs). Additional funding proposals that meet the criteria of the GCF investment framework can be generated as issuance of targeted Requests For Proposal (RFPs) of GCF and also as bankable project ideas through dedicated platforms and innovative partnerships between the Secretariat and other non-accredited organizations. There are two ways to submit project proposals to the GCF:

(1) A project proponent develops a full FP with AE and submits it to the GCF with the consent of the NDA.

(2) A concept note is developed and submitted by the project proponent, with or without the AE, to the GCF and the funding proposal is developed after the concept note is approved.

Stage 3 of the GCF programme activity cycle is concept note submission. A concept note helps the prospective proponent to obtain confirmation from the GCF Secretariat whether the intended project is aligned with the funding criteria of GCF. The submission of a Concept Note (CN) is an optional step but is strongly encouraged, as concept notes can lead to higher 'quality at entry' of FPs, a reduced review time, and lower transaction costs for all stakeholders. However, the submission of a CN is mandatory if the Accredited entity wishes to get the funding under Project Preparatory Facility (PPF) for preparation of the funding proposal or the proposal is submitted under the Simplified Approval Process (SAP) which will be explained later in this article. Concept notes can be submitted either by the AE or the NDA.

Stage 4 of the GCF programme activity cycle is the development of a **funding proposal**. A funding proposal is the set of documents prepared by the AEs using GCF standard templates that are submitted to GCF to formally request funding for a project. Developing a funding proposal is a complex process to follow which includes many technical and financial details. To make the process less complicated for small projects with low environmental and social risks, the GCF has adopted a SAP. SAP is only applicable for projects which are ready for scaling-up, with low environmental and social risk (Category C) and a total budget of less than 25 million US$.

The GCF provides support for preparation for funding projects through the Project Preparation Facility (PPF). This PPF is especially targeted at DAEs, and for micro-to-small size category projects. The maximum PPF grant is 10% of the total funding requested or a maximum of 1.5 million USD whichever is lower in cost.

When developing a funding proposal, the AE is required to have a collaboration with the relevant country authorities. All funding proposals submitted to GCF must obtain a No Objection Letter (NOL) from the NDA/focal point. This letter implies that the government of the country has no objection to the funding proposal and it is in line with the national climate change priorities.

Stage 5 Once the project proposal is submitted to the GCF, it will be evaluated by the GCF secretariat and then by the Independent Technical Advisory Panel (ITAP). During the process, there can be several rounds of comments from the GCF side which AE needs to address.

Stage 6 After the review of the Secretariat, ITAP project proposal is submitted to the GCF Board for approval.

Stage 7 describes the legal arrangement after the funding proposal is approved. The AE will have to sign a Funding Activity Agreement with the GCF for each approved proposal.

Stage 8,9 and 10 of the Programme activity cycle describe the project implementation, monitoring, and management.

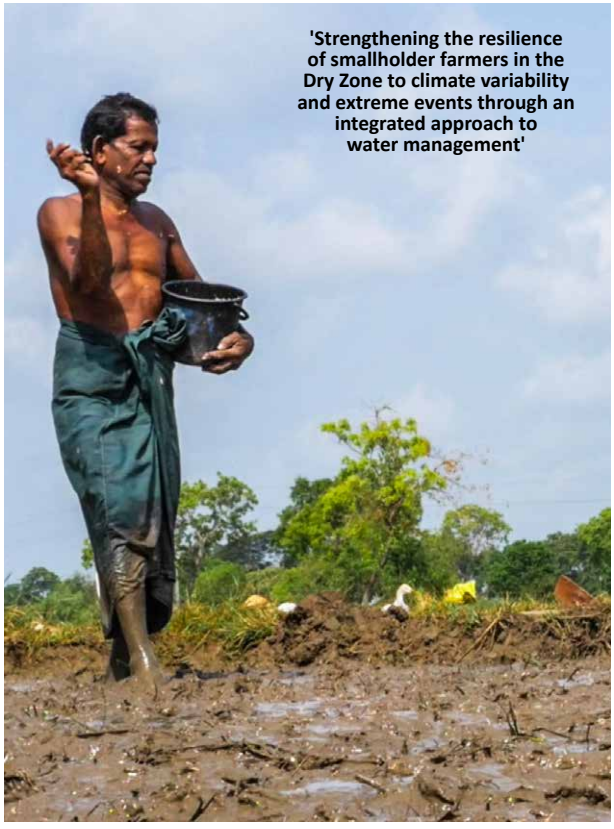
In the implementation of the project, AE is responsible for the overall management, implementation, and oversight of funded activities in line with GCF standards and legal agreements. AE should also ensure that their obligations under the legal agreements with GCF are passed on to the executing entities of the project when implementing GCF projects and programmes. AE should work closely with NDA in the implementation of the project. The NDA should ensure country ownership and stakeholder engagement throughout the project while supporting monitoring, evaluating, and learning by working with accredited entities to plan for evaluations/reviews and impact assessments. The NDA should participate in performance assessment reviews and evaluation workshops.

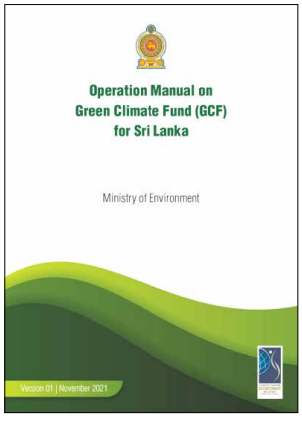
GCF provides all its templates and procedures on their website https://www.greenclimate.fund. It also contains information on the approved projects and stages they are implementing. Sri Lanka has prepared the Operation Manual and Stakeholder Engagement Strategy for the GCF-related activities in the country. Currently, the Climate Change Secretariat is in the process of preparing the Country Programme for Sri Lanka, reflecting the climate change priorities of the country.

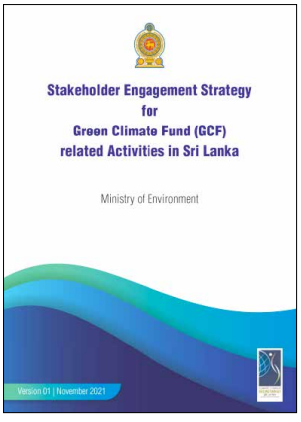
Recent GCF Projects

As of July 2023, Sri Lanka has received GCF funding support for two country-specific projects namely, “Strengthening the resilience of smallholder farmers in the Dry Zone to climate variability and extreme events through an integrated approach to water management and 'Strengthening Climate Resilience of Subsistence Farmers and Agricultural Plantation Communities residing in the vulnerable river basins, watershed areas and downstream of the Knuckles Mountain Range Catchment of Sri Lanka'. Sri Lanka is also participating in three recently approved multi-country projects namely, the 'Programme for Energy Efficiency in Buildings', 'Global Fund for Coral Reefs Investment Window' and 'Cooling Facility'. There are two readiness support initiatives funded by GCF for Sri Lanka. One is the general NDA Readiness Support and the other, the NAP Readiness Support. All the information on these projects and readiness actions can openly be accessed on the Sri Lanka Country Page of the GCF website.

The GCF is a very important part of the overall climate finance access plan of Sri Lanka and other developing countries. There are a number of unchartered waters for Sri Lanka within the GCF, including the private sector facility. Currently, the Climate Change Secretariat (CCS) is leading the way to capitalizing these potential through the GCF country programme and readiness actions.







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Adaptation planning and implementation – strengthening the processes and increasing the capacity to implement the National Adaptation Plan for Climate Change Impacts in Sri Lanka

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Keywords:

NATIONAL ADAPTATION PLAN, PROVINCIAL ADAPTATION PLANS, PROVINCIAL CLIMATE CELLS.

- **Build resilience of vulnerable sectors and communities in Sri Lanka to climate change impacts through vertical and horizontal integration of adaptation planning and implementation.**
- **Capacity building and strengthening relevant institutional mechanisms to support adaptation at the national and sub-national level and across vulnerable sectors.**
- **Comprehensive adaptation finance and resource mobilization approach adopted to enable scaling up of adaptation.**

Introduction

Sri Lanka is highly vulnerable to the adverse impacts of climate change (Climate Change Secretariat, 2016). The country is among the top 30 climate affected countries in the world (Global Climate Risk Index, 2021) and has been placed among the top 10 countries at risk of extreme weather events in 2016, 2017 and 2018. Occurrences of natural disasters due to extreme weather conditions such as prolonged droughts, flash floods and landslides deprive lives and livelihoods of people (Climate Change Secretariat, 2016) and inflict enormous costs on the government's budget (Fiertz *et al*., 2022; Climate Change Secretariat, 2022). There is evidence that points to Sri Lanka's dry zone getting drier and the wet zone wetter (Jayawardena *et al*., 2018 in Climate Change Secretariat, 2022), which has implications to all major economic sectors vulnerable to climate change, including for agriculture and export agriculture (Esham & Garforth, 2013).

To address climate change impacts and adapt to these impacts, Sri Lanka has already taken the first critical steps and has formulated important policies and strategies including the National Climate Change Adaptation Strategy (2011-2016) and the National Adaptation Plan (NAP) for Climate Change in Sri Lanka (2016 to 2025). Sri Lanka submitted its Updated Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) in July 2021.

The NAP process was officially established under the Cancun Adaptation Framework, in 2010, which was an outcome of the 16th Conference of the Parties to the UNFCCC. NAP is a key instrument to identify medium and long-term adaptation needs, and to develop and implement strategies and programs to address those needs (UNFCCC, 2010; Dazé *et al*., 2016). In 2015, at the 21st Conference of the Parties to the UNFCCC in Paris (the Paris Agreement), the importance of NAPs in the global effort to address climate change was recognized. Furthermore, at the same meeting, the Green Climate Fund (GCF) was requested by the COP to expedite support for the preparation of NAPs.

While Sri Lanka was one of the first countries to prepare its NAP in 2016, systematic implementation, reporting, and monitoring was delayed for various reasons, including due to the COVID 19 pandemic. Seeking GCF Readiness funding, Sri Lanka's National Designated Authority (NDA) to GCF, the Ministry of Environment, through the Climate Change Secretariat (CCS), together with the Global Green Growth Institute (GGGI), as the Delivery Partner, embarked on the implementation of the NAP Readiness Support Project in August 2021. GGGI has a Framework Agreement with GCF as a Readiness Delivery Partner.

Readiness for Supporting the Implementation of Sri Lanka's NAP

The NAP Readiness Support Project aims to build resilience of the most vulnerable sectors and communities in Sri Lanka to adverse effects of climate change by helping to bolster the adaptive capacity in these key sectors and in national and provincial level institutions. While providing support to further strengthen the National Adaptation Plan implementation process, the project facilitates technical and financial assistance to make these actions realistic at the ground. Recognising that climate change-related risks cannot be considered in isolation and that a multi-

sectoral approach needs to be taken, the project aims to seek integrated solutions and adaptation measures to address risks to key national development initiatives (GCF, 2020).

The target outcomes from this NAP readiness initiative include: (i) strengthened capacity in Sri Lanka to coordinate and guide the process of NAP implementation and revision; (ii) a competent national development planning system that seamlessly integrates climate change adaptation into polices, strategies and plans for vulnerable sectors and regions; (iii) capable national, sectoral and provincial stakeholders who are able to use the latest climate information and tools for adaptation planning; (iv) vulnerable communities and sectors empowered to respond to extreme events and disasters through exposure to adaptation research and knowledge sharing; (v) a comprehensive adaptation finance and resource mobilization approach adopted to enable scaling up of adaptation finance; and (vi) capacity created in Sri Lanka to monitor, report and evaluate results, as well as progress, and update the NAP; (vii) A Gender and Social Action Plan (GSAP) – to effectively mainstream gender and social inclusion across the NAP process.

In terms of implementation arrangements, as the delivery partner, GGGI has set up a team of local and international experts to carry out day-to-day execution of project activities, along with two partner organizations, the Sri Lanka Red Cross Society (SLRCS) and the International Water Management Institute (IWMI) who are responsible for the capacity building component and the climate information systems component of the project respectively. In addition to working in close collaboration with the CCS, a National Steering Committee has been appointed to play an oversight role, to monitor progress and provide recommendations and guidance. During the implementation process, the initiative engages with a diverse range of stakeholders, from government, private sector, civil society, development partners and academic institutions.

Key Project Interventions- Building Blocks for Accelerating Adaptation Action

While nine sectors have been identified as vulnerable to climate change in Sri Lanka, along with ten cross-cutting national adaptation needs in the NAP (2016-2025), an integrated approach is required to mainstream climate change adaptation into national planning in such a way that it contributes towards an inclusive and sustainable development agenda of the country. Both vertical and horizontal adaptation planning processes are crucial for this purpose and would underpin overall success during implementation.

Horizontal and Vertical Integration of Adaptation Planning and Implementation

Under the GCF readiness support project there is a focus on horizontal as well as vertical integration of adaptation planning. In regard to horizontal integration. The national level sector consultations for the nine vulnerable sectors identified under the NAP (2016-2025) with the objectives to review the implications of climate change to the sector, identify the current situation to address climate change adaptation (stock-taking) and the institutional set-up; develop recommendations to integrate adaptation interventions into national, sectoral policies and provincial development plans, revise the NAP sectoral adaptation plans (for the updating of the NAP), taking into consideration the updated adaptation NDCs, and the establishment of appropriate Sector Climate Cells (SCCs) for institutional coordination and ensuring that we build a cross-sectoral picture. Thus far, the project has completed eight of its nine sector consultations for (i) tourism & recreation, (ii) coastal & marine, (iii) health sector,

(iv) energy and transport (industry to be covered separately), (v) food security (agriculture, livestock, fisheries), (vi) water resources, (vii) human settlement and infrastructure and (viii) export agriculture. The other vulnerable sectors to be covered based on the NAP is (ix) ecosystems and biodiversity,

The primary focus on the GCF NAP readiness project to date has been on the vertical integration of the adaptation process, and the project has launched its activities at a sub-national level in terms of provincial adaptation planning, across the nine provinces in Sri Lanka and successfully concluded the first and second round of provincial workshops in all of the nine provinces. The project communicated to all nine provinces regarding the overall project objectives and interventions, receiving a nomination of a focal point for each province for the team to liaise with. A total of 518 participants attended the first round of workshops, of which 64% were male and 36% female, representing several stakeholder groups and sectors.

This initial round of workshops was important for the familiarization with the National Adaptation Plan (NAP) and to introduce the project and undertake

some awareness raising in terms of climate change and its implications, implementation of climate change adaptation and resilience building. In addition to an informative keynote address, an online app mentimeter was used to make the sessions participatory and interesting for the participants.

One of the key activities at the provincial level is the formulation of a Provincial Adaptation Plan (PAP) and a common outline for the PAP together with guidance for systematic data gathering was developed. Preparation of the PAP involves drawing on existing development plans and strategies from the province and also ensuring that the expert knowledge, information and experiences of the provincial stakeholders are taken on board. The workshops used participatory approaches to gather relevant preliminary data for the preparation of the PAP on the vulnerabilities of the province, previous and current adaptation interventions, and responsible agencies. The project team including the provincial adaptation planning consultants, played a facilitatory role, supporting the synthesis of the information, expert views and perceptions gathered from the local stakeholders.

Another important activity covered in the workshops was about setting up suitable institutional mechanisms at the provincial level for the implementation of the PAP and establishing the Provincial Climate Cell (PCC) as a decision-making body, and Provincial Climate Unit (PCU) as an operational unit, in each province for this purpose. Building on the earlier provincial consultations that had taken place on this topic under the Third National Communication in 2018 and 2019, the team used participatory mentimeter sessions to obtain the views and perspectives of the stakeholders on the composition, roles and responsibilities and terms of reference for these entities. The team received the fullest support of the Chief Secretaries, Deputy Secretaries, and other senior officers in the province in initiating this process, noting that each province may have its own unique needs. The participatory exercise helped the stakeholders recognize the importance of maintaining a relatively small membership for the PCC, comprising of 10 to 20 key decision makers to enable effective decision-making, whilst getting the technical support from a broader group of stakeholders/agencies upon request, as and when required. It was proposed that the Chief Secretary of the province should chair the PCC and convene the PCC quarterly to take decisions and review progress of climate actions related to the province.

In addition, data collection to assess the provincial level stakeholders' capacities needed for the successful implementation of the PAP was conducted at the workshop, by the SLRCS, using an individual questionnaire that was administered in a group setting. Data on technical and resource needs was collected covering six benchmarks; (i) climate information and risk assessment; (ii) policy, strategy, mandate, and standards; (iii) operational planning, resource mobilization and implementation; (iv) coordination and partnerships; (v) monitoring and evaluation; and (vi) information management. The information was collected through 69 questions of which 63 quantitative answers were gathered in rating scales, while 06 questions gathered qualitative data through open ended questions. A Likert scale is used for the quantitative questions, to measure the scale with six choices that range from "Don't know/not sure" to "Full Capacity". Analyses of results are underway provincial-wise and will be amalgamated in a final capacity needs assessment report, including recommendations under the six benchmarks.

When planning the provincial workshops, the team was reflective and used an adaptive, iterative approach, continuously fine-tuning the agenda and refining the sessions, taking on board the feedback and lessons learned from each of the workshops and applying it to the next one in the series. The team also noted, based on the feedback from the stakeholders that there was a need to foster cross-provincial interactions and integration in the consultation process, to make the outcome of the provincial adaptation more impactful and more sustainable in the long term and to ensure overall success. The project also linked up with other key adaptation initiatives operating under the purview of the Climate Change Secretariat at the provincial level, to ensure that the consultations were conducted in a coordinated manner.

Integrating Climate Information Systems into Adaptation Planning

To support medium and long-term adaptation planning, a critical component that is covered through the GCF NAP readiness project is the integrating of Climate Information Systems. The International Water Management Institute (IWMI) is responsible for this component, and climate modelling, and the development of climate scenarios and impact scenarios have commenced. Since the resolution of larger General Circulation Models are coarse, climate projections produced by them cannot be used directly in Sri Lanka. They need to be converted into a finer resolution. This project will do this using a method called "dynamic downscaling" which is considered more reliable for a small country like Sri Lanka. Through the project, a dynamic downscaling model is being developed by the Meteorological Department under guidance of IWMI, and the capacity will be retained within the Meteorological Department. The downscaled climate scenarios can be used to project impact scenarios for the nine vulnerable sectors under NAP. IWMI will also build on existing systems to design a multi-hazard information and dissemination platform, where early warnings to extreme climate events such as droughts, floods, and landslides etc., may be triggered based on identified thresholds of monitored indicators. The is expected to be interconnected and piloted in the Southern Province.

The Need for Enhanced Financing for Adaptation

To enable implementation and scaling up of adaptation interventions, a comprehensive adaptation finance and resource mobilization approach (that includes blended finance, international, domestic, private) is being developed through the GCF NAP readiness support project. The preparation of GCF project concept notes is a critical step in the comprehensive resource mobilization approach being taken to scale up adaptation interventions in Sri Lanka. During the sectoral consultations organised under the project, the stakeholders are provided with an overview of the methodology employed by GGGI in the preparation of GCF Project Concepts. The GCF has established sectoral project proposal development guidelines that align with the sectors covered by the NAP, and the GCF concept note template has been sensitized to the GCF NAP Readiness sector specialists. An iterative process will be used by the GCF NAP GGGI team and sector specialists to refine and ensure compliance with GCF guidelines before submitting the project concept notes to the NDA.

Moreover, the demand-driven and bottom-up approach emphasized in the methodology ensures that provinces are consulted before sectoral consultations are conducted, to ensure that the GCF Project Concepts align with the unique needs and context of each province. The Project's Provincial Consultants will also review the draft project concept notes, providing intelligence from a provincial perspective, which will further enhance the concepts and ensure that they are relevant and effective in addressing the climate change-related risks faced by vulnerable communities and sectors in Sri Lanka. Therefore, the process of preparing GCF project concept notes is comprehensive, participatory, and designed to ensure that the adaptation interventions are tailored to meet the needs of the local communities and sectors.

Conclusion

In conclusion, the Sri Lanka GCF NAP Readiness Support Project is a comprehensive and participatory initiative that seeks to build resilience in vulnerable sectors and communities to climate change-related risks. The project aims to facilitate technical and financial assistance to integrate climate change adaptation into national planning and policies, as well as provincial development plans. Through the development of Provincial Adaptation Plans and the establishment of Provincial Climate Cells, the project ensures that the adaptation interventions are tailored to meet the needs of local communities and sectors. The project also emphasizes the need for enhanced financing for adaptation, and the preparation of GCF project concept notes is a critical step in this comprehensive resource mobilization approach to scale up adaptation interventions in Sri Lanka. Overall, the project is making significant progress in strengthening Sri Lanka's capacity to coordinate and guide the process of NAP implementation and revision, as well as to empower vulnerable communities and sectors to respond to extreme events and disasters.

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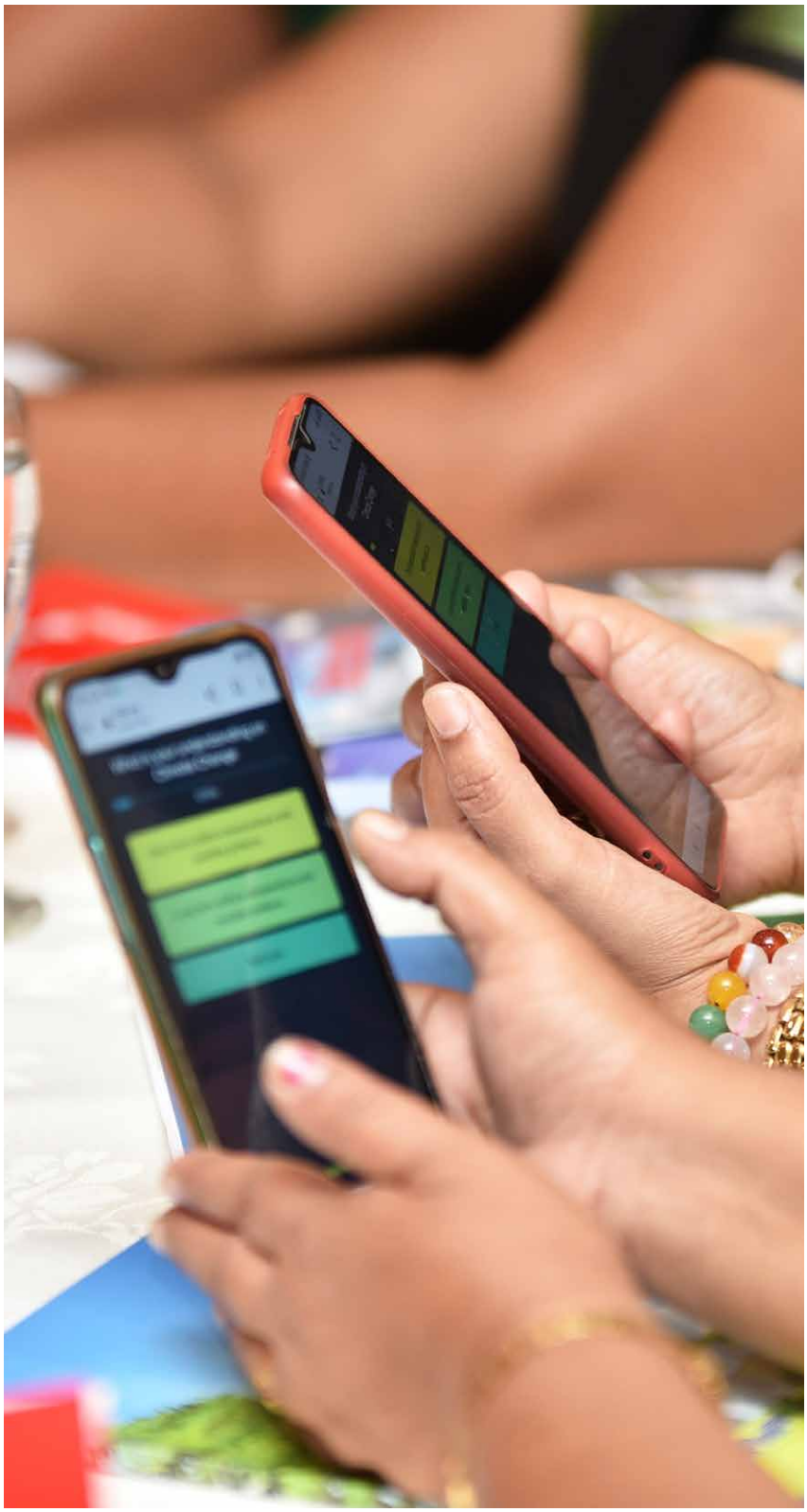

Green Growth Planning a need for the Central Highlands of Sri Lanka

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Keywords:

GREEN GROWTH PLANNING, CENTRAL HIGHLANDS, CLIMATE RESILIENCE

- **Green growth integrates economic performance with environmental performance**
- **Green growth recognizes environmental protection as a driver of global and national economic development.**
- **Green growth protects economies from negative impacts of climate change and facilitates transitions to more sustainable economies**
- **Green growth helps building climate resilience in vulnerable ecosystems such as the Central Highlands of Sri Lanka**
- **Green growth planning in the Central Highlands of Sri Lanka should strongly focus on expanding access to economic opportunities in an environmentally sustainable manner and to climate change risks**

Horton Plains National Park © Indrika Pradeepa

Introduction

The world has continued to face a twin challenge, namely, expanding economic opportunities for all in the context of a growing global population, and addressing environmental pressures that could undermine the ability to seize these opportunities. Green growth is where these two challenges meet, and is about exploiting the opportunities together.

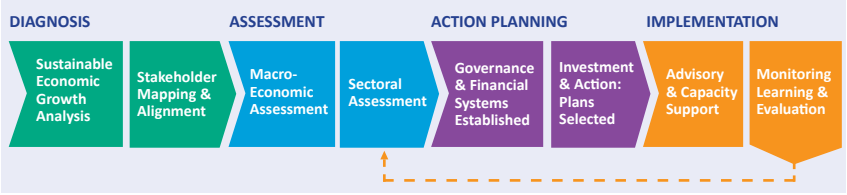
Green growth fosters economic growth and development while ensuring that the natural ecosystems continue to provide the resources and environmental services. This activity will no doubt improve the well-being of people, underpin sustained growth and give rise to new economic opportunities. Green growth is not a replacement for sustainable development, however, it provides a practical and flexible approach for achieving concrete, measurable progress across the economic and environmental pillars, in this case, the Central Highlands of Sri Lanka. It takes into full account the social consequences of greening the growth dynamic of economies.

Green Growth Planning (GGP) is an integral part of the structural reforms needed to foster strong, more sustainable and inclusive growth. They can unlock new growth engines by enhancing productivity, boosting investor confidence, opening up new markets, contributing to fiscal consolidation and reducing risks of negative shocks to growth. The GGP is the process of (1) envisioning and attending to possible climate scenarios and other foreseen developmental challenges, (2) identifying a collectively desirable pathway, and (3) building consensus around choices that would put a country on that path. It involves allocating resources to green sectors, and, in some cases, reallocating resources away from traditional sectors, which may require some initial investment but pays for itself in the long term.

The basic steps of GGP includes (a) Diagnosis - a national or regional (within country) analysis, (b) Assessment – the identification of interventions, (after careful consideration of positive and negative aspects) and (c) Action planning - project, policy and institutional planning, followed by the implementation of the plan (Figure 1). Strategies for Green Growth need to be tailored to fit specific country circumstances. Those strategies will need to carefully consider how to manage any potential trade-offs and how to best exploit the synergies between Green Growth, poverty reduction and environmental health. Given the centrality of natural assets in low-income countries, Green Growth policies can reduce vulnerability to environmental risks and increase the livelihood security of the poor.

Below

Figure 1: Green Growth Planning process (Source: https://www.greengrowthknowledge.org/sites/default/files/learning-resources/action/Green%20Growth%20Planning%20Guidelines.pdf)



Knuckles Conservation Forest
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The Central Highlands of Sri Lanka

The Central Highlands of Sri Lanka is uniquely characterized by Peak Wilderness Protected Area, Horton Plains National Park and Knuckles Conservation Forest, and was inscribed on to the World Heritage List in 2010 in recognition of the sites' values within one of the world's richest concentrations of biodiversity. The Central Highlands (Figure 2) include the largest and least disturbed remaining areas of the sub-montane and montane rain forests of Sri Lanka. The highlands are a global conservation priority on many accounts and considered as a super-hotspot within the Western Ghats and Sri Lanka biodiversity hotspot.

More than half of Sri Lanka's endemic vertebrates, half of the country's endemic flowering plants and more than 34% of its endemic trees, shrubs, and herbs are found in these diverse montane rain forests and adjoining grassland areas. Furthermore, the Central Highlands of Sri Lanka consist of two distinct aquifers supporting domestic use and agriculture while the radial network of country's rivers begins in the central highlands, with 103 distinct river basins that cover 90% of the island (de Silva 2014). Hence, conservation and management of the biodiversity and water resources in Central Highlands would have a major contribution to the overall sustainable development of Sri Lanka.

Climate and climate change in Central Highlands

The tropical climate in Sri Lanka is represented with a mean annual air temperature ranging from a low of 15°C in high altitudes to a high of 28°C in low altitudes. The diurnal variation of temperature is high in mountainous regions (Central Highlands of the country) in comparison to the coastal regions. The mean monthly temperature changes by ±3°C in high altitudes and by ±1°C in low altitudes. The rainfall pattern of the island is essentially governed by the southwest monsoon from May to September and northeast monsoon from December to February. The transition period between the two monsoons is defined by the first inter-monsoon from March to April and the second inter-monsoon from October to November. The country is divided according to the temporal and spatial variation of rainfall into wet, dry, and intermediate zones (Marambe *et al*. 2015).


Central Highlands © Slycan Trust

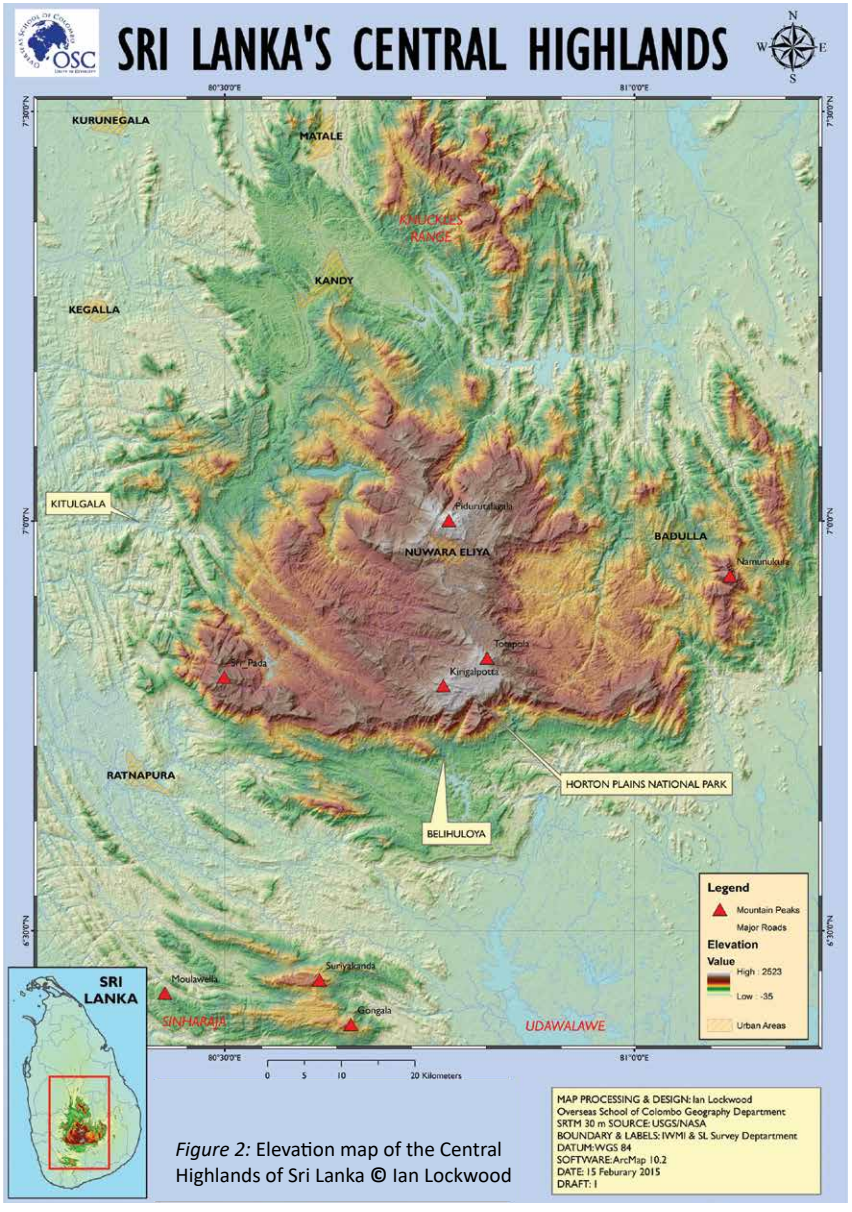


Figure 2: Elevation map of the Central Highlands of Sri Lanka © Ian Lockwood

Adams Peak (Sri Pada) © Sri Lanka Spirit

The Central Highlands is located in the wet zone of the country, and is situated in an area receiving more than 2,500mm of annual rainfall. The elevation of the highlands ranges from about 300 to 2,524m, with Pidurutalagala being the highest peak. The Central Highlands receive as much as 3,000-4,000mm of annual rainfall during south-west monsoon period (PWRI, 2007). Past studies (De Silva & Sonnadara, 2016) indicated that the annual rainfall is showing decreasing trends while the annual mean temperature is showing an increasing trend, and that heavy rainfall events have become more frequent in Central Highlands during the 21st century (Punyawardena *et al*., 2013). Further, a 17% reduction of rainfall in the upper Mahaweli watershed in the Central Highlands is predicted by 2025 (Shantha & Jayasundara, 2005).

Several studies have estimated the impact of climate change on central highlands. Extreme climate events, especially heavy rainfall during south-west monsoon, have been reported to increase runoff in the Central highlands (De Silva *et al*., 2007). The predicted increase in runoff in Kandy/Katugastota area in the Central Highlands of Sri Lanka has been estimated as 66.4% in 2030, 83% in 2040 and 100% in 2050 compared to the period 1961-1990 (De Silva, 2014). Furthermore, a clear relationship has been reported between erosion in upstream catchments owing to heavy rainfall and poor soil conservation measures, and irrigation supply to downstream agriculture through sedimentation that is reducing reservoir capacity. Rantembe reservoir in the central hills has lost about 47% of its original capacity during the period 1990 to 2015, while the Polgolla reservoir has lost 45% of its capacity between 1971 and 2000 (GCF, 2020). Higher environmental temperatures at Rahangala (20.3°C) has resulted in potato crop completing its life cycle a month earlier by fulfilling the thermal time requirement, compared to that of Seetha Eliya having lower average temperature (15.1 °C) (Abhayapala *et al*., 2014).

The Need for Green Growth Planning in Central Highlands

The Central Highlands host important development projects of the country, including the Mahaweli Development Project. The Development Projects carried out over the years, intensive agricultural activities, including mono cropping with inadequate attention on soil conservation, have resulted in severe land degradation in the most parts of the Highlands. Climatic changes and the destruction of natural assets have further exacerbated the negative

impact on the Central Highlands. A development and a growth strategy with a plan for sustainable utilization of resources together with the preservation of natural assets, and their effective implementation are, hence, urgent needs to secure the value of this unique tropical highland both in terms of conservation and sustainable utilization of biodiversity and water resources.

The Central Highlands of Sri Lanka fall within three out of nine provinces of the country, namely, Sabaragamuwa, Uva, and Central provinces. The Integrated Provincial Development Plans for the period of five years (2019-2023) have been developed highlighting the commitment to sustainable environmental management (Figure 3).

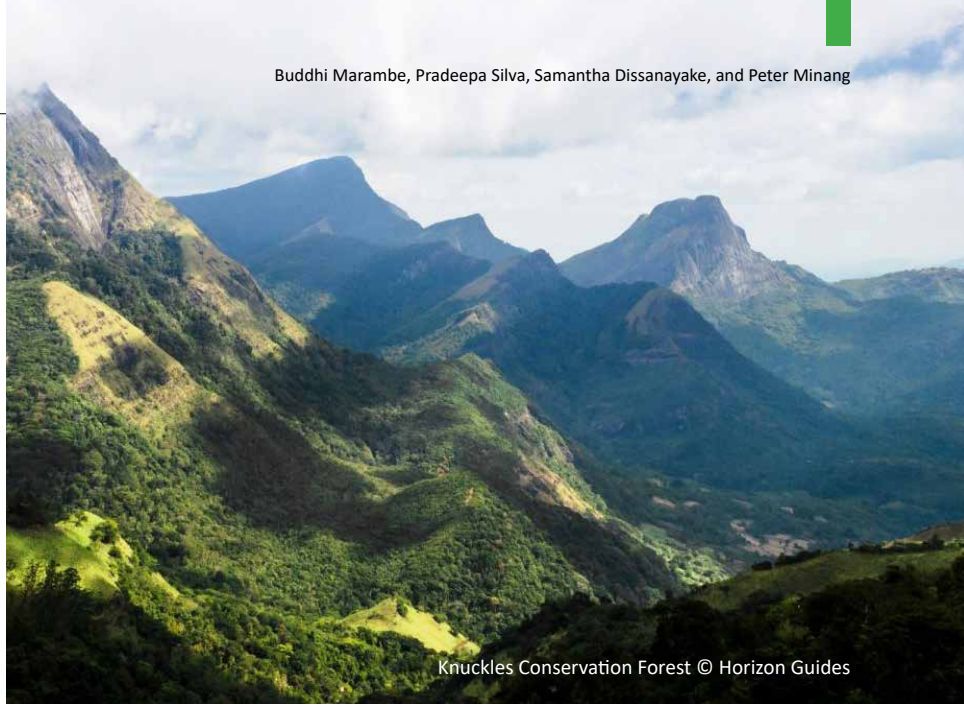


Figure 3: Cover pages of the integrated 5-year Development Plans of Sabaragamuwa, Central and Uva Provinces occupying the Central Highlands of Sri Lanka.

These vision-based development plans identifying projects that have been developed through stakeholder consultation, along with budgetary allocations and monitoring and evaluation plans, include activities strongly linked to green growth. These actions, thus, can be upgraded with a more refined approach with the involvement of the planning divisions of the respective provinces.

Green Growth Planning has historically been connected to macroeconomic planning, especially to modernize existing industries, create new industries, retrain workers, foster investment and research and development (R&D) and develop stable markets (Nielsen, 1984). Both developed and developing countries have used macroeconomic policy tools such as public financing and lending, reduction of or exemption from taxes and fees, R&D funding, public procurement and preferred purchase system (L&C) to achieve growth (GGGI, 2020).

Green growth integrates key aspects of economic performance, such as poverty reduction, job creation and social inclusion, with those of environmental performance, such as mitigation of climate change and biodiversity loss and security of access to clean water and energy. Green growth has progressively emerged on the agenda of governments in developing Asia (Howes & Wyrwoll, 2012). The limits of the climate system prohibit countries with different economic strengths from following the same development path. Hence, sector-based Green Growth Planning should be carried out while aligning the development needs with required actions to avoid irreversible impacts of climate change.

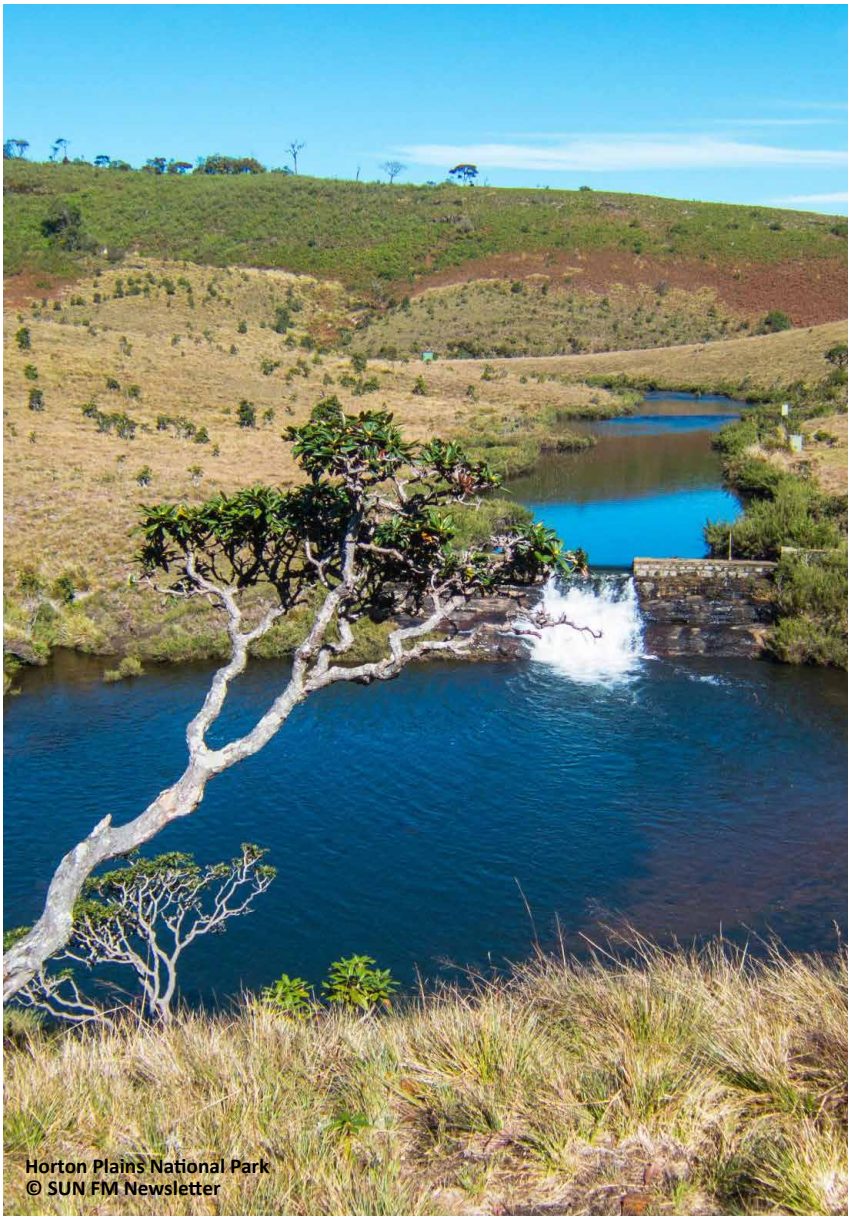
Green growth will protect economies from the negative impacts of climate change and facilitating transitions to more sustainable economies. A careful Green Growth Planning process will allow even the lesser developed and hydrocarbon-based economies to identify the paths, programs and policies that may be most relevant to their national contexts to achieve macroeconomic goals. Furthermore, many measures have been proposed at global level to monitor how countries perform in achieving a more inclusive and environmentally sustainable pattern of growth, especially focusing on the development objectives. In this regard, the Asian Development Bank (ADB) has proposed the 'Inclusive Green Growth Index' (IGGI), which is designed to help guide policymakers to make informed decisions on prioritizing infrastructure investments and financial allocations to deliver a better quality of growth (ADB, 2018).

The National Designated Authority (NDA) Readiness and Support Proposal approved for Sri Lanka by the Green Climate Fund (GCF) has identified the development of a climate-smart/green growth strategy for the Central Highlands of Sri Lanka (GCF, 2019). This process will draw from the provincial development plans that exist in Sri Lanka to derive a set of feasible and context relevant climate smart options that will form the basis for GCF concept notes to be developed. Through this program, the First Analysis Towards the Development of Green Growth Plans for Three Sri Lankan Provinces (Sabaragamuwa, Uva & Central Province) has been prepared (unpublished) through stakeholder engagement process.

Conclusion

Green Growth is an emerging concept that recognizes environmental protection as a driver of global and national economic development. Such efforts will focus on qualitative growth of the society rather than simply increasing the gross domestic product (GDP). Green Growth planning is a process of mainstreaming climate resilience and low carbon development into key sectors of the economy.

Green growth strategies would help build climate resilience in Central Highlands of Sri Lanka. Such efforts will help to achieve energy security by supporting the development of green Industry and services, sustainable land use and water resource management that result in food security, conservation of biodiversity and ecosystem services, and social protection with improved health and disaster risk reduction, thus reducing the overall vulnerability of the Central Highlands to climate change. In Green Growth Planning for Central Highlands, Sri Lanka should also focus strongly on effective access to economic opportunities for all segments of society in an environmentally sustainable manner and attuned to climate change risks.



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Engaging the private sector in climate change adaptation in Sri Lanka, importance, opportunities *and* challenges

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- **Engaging the private sector in climate change risk reduction, and adaptation needs to be a priority in developing countries.**
- **The Private sector has an important engagement in climate change adaptation with opportunities in different perspectives.**
- **Several challenges exist for the private sector in Sri Lanka to contribute to climate adaptation responses.**
- **Overcoming challenges include promoting investments in climate change adaptation.**
- **Robust involvement of the private sector in managing climate risks will bring resilience to vulnerability as well as systematic long-term sustainability to private investments.**

Key words:
PRIVATE SECTOR, CLIMATE ADAPTATION, FINANCE

Introduction

Climate change is one of the greatest challenges faced by humans in the 21st century. It is real and the world is already experiencing its adverse impacts. Projections from the Intergovernmental Panel on Climate Change (IPCC) suggest that those impacts will become even more intense in the future with further increase in warming, rising sea levels, intensifying the water cycle with variable rainfall and associated floods and droughts etc., (AR6, 2021).

Garment workers manufacturing items for British retailer Marks and Spencers at a factory in Seeduwa © Ishara S Kodikara


Man working in a farm irrigated by sprinklers in Jaffna © Hamish John Apple by IWMI

Addressing climate change challenges to overcome such impacts is a multifaceted challenge. Although the public sector has taken major actions in both climate change mitigation and adaptation, the private sector has taken less contribution for climate change adaptation. However, the businesses need to be very concerned about climate change, because it can reverse the economic success achieved to date. The private sector is the driving force in modern market economies, and the impact of climate change has a severe impact on their economic activities. Therefore, the private sector has an important role to play in adaptation responses to climate change.

Engaging the business community in climate change risk reduction and adaptation needs to be a much higher priority in developing countries. Private sector companies should integrate adaptation into their strategies and investments for several reasons. Firstly, the economic interest; many of their investments in development sectors are at risk; therefore, integrating adaptation planning and measures will make their investments and returns less risky with sustainable profits. Secondly, the clients' interest; without adaptation measures, most development investments in vulnerable countries are not sustainable. Thirdly, to support the climate change interests of their countries of operation. The private sector must become an active partner in adaptation efforts in developing countries as they can strengthen governments, help define and complement effective public adaptation measures and build national and international support through their influence. Although there is an emerging business voice, it needs to be more vocal and effective (CAN, 2013).

Need of Engagement of the Private Sector in the Climate Process in Sri Lanka

Sri Lanka has been identified as a highly vulnerable country to the adverse impacts of climate change. The impacts of climate change are already being felt with the increase of frequency and intensity of rainfall and drought events. These extreme events may put lives, livelihoods, and infrastructure at risk through riverine flooding, flash floods and landslides (ADB, 2020). About 74 percent of disasters took place between 1990 - 2018 due to adverse impact of climate change, such as floods (58%), landslides (5%), storms (7%), and drought (4%) (CRED, 2019). Damage due to flooding between 1990 - 2018 was estimated over USD 2 billion, half of which occurred in 2016. The damages occurred in many sectors, namely, human settlements, health and nutrition, education, food security (agriculture, livestock and fisheries), industry and commerce, irrigation, water and sanitation, transport, power supply, employment and livelihood, and environment. Climate change considerably impacted on the local economy and the International Finance Corporation (IFC) stated "Without significant investment in climate resilience, the country could lose about 1.2% of the annual GDP growth by 2050 due to climate change (IFC, 2019). As the contribution of the public sector alone is not sufficient to address this in the future, the involvement of the private sector is also required.Therefore, private sector investments are needed to address climate change impacts, promote adaptation measures to the impacts that are already occurring, and build resilience.

Opportunities for the Private Sector:

Private sector engagement in climate change adaptation is essential as they can contribute in various perspectives.

- The private sector can play a critical role in mobilizing private sources of financing to address climate adaptation opportunities in priority economic sectors.

- Private sector corporations also can develop and deliver many adaptation services such as insurance, development and implementation of improved data bases and information systems, weather observation technology and early warning systems

- The private sector has particular competencies which can make a unique contribution to adaptation through innovative adaptation technology and design of resilient infrastructure such as in agriculture. Investment may be needed for developing irrigation equipment and technologies, drought-resistant seeds and other agricultural products, along with water management infrastructure and technologies. Having

climate-resilient infrastructure is crucial for safeguarding economic development in the face of a changing and more variable climate.

● Private sector can also contribute to the research projects, capacity building and increase awareness among employees and business partners about climate change mitigation and adaptation.

Potential Challenges:

There is a need for the private sector to be more engaged in identifying climate change risks, response measures, and adaptation in Sri Lanka. However, it is a big challenge for the private sector in Sri Lanka, like most of the developing countries to contribute to climate adaptation responses, due to the following;

▲ **Lack of knowledge, capacity and awareness**: There are knowledge, capacity and awareness gaps on climate risk among the private sector entities. Although the private sector is aware of the climate hazards on their operations, their understanding of climate risk and vulnerability is limited, which discourages investment decisions in climate adaptation.

▲ **Limited data and information**: Country-level climate risk and vulnerability data and information services are limited, which can be used for decision making and to guide investment. Therefore, limited information on climate risk makes it difficult to develop a monitory value for climate vulnerability in order to consider investments.

▲ **Gaps on required capital investment**: Limited clarity on the government's capital investment gaps to achieve adaptation goals and/or on where private investment is needed.

▲ **Business type and business models**: Many private sector businesses of Sri Lanka are micro, small, and medium enterprises (MSMEs). Their business models are designed to gain a quick return for the investment, and climate adaption, which has no immediate result, may not be a priority for them.

▲ **Lack of proper institutional arrangement**: There is no proper institutional setup for the engagement of the private sector for climate change adaptation activities with the government agencies. Further, the lack of specific guidelines on private sector engagement in climate adaption is a barrier to private sector investment. Therefore, there is an inability of the private investor to benefit from the actual returns on its investment and capture the full environmental and social benefits generated by adaptation investments

▲ **Absence of effective financial incentives mechanism**: Absence of effective financial incentive mechanisms and low-cost financing instruments for adaption such as soft loans, a mix of loans and grants, and lack of an investment option or investment opportunity portal for climate adaption investments for the private sector

Overcoming Challenges:

Several ways can be proposed to overcome the challenges and promote the engagement of the private sector for climate investments in climate change adaptation:

▲ **Training and awareness raising for private organizations and communities**: Raising awareness and spreading knowledge on effects of climate change and building resilience across private sector organizations and communities to sensitize them towards climate actions.

▲ **Development of localized climate risk and vulnerability data system**: Having an accurate database makes it easier to make investment decisions.

▲ **Setting up effective institutional arrangements for multi-sector adaptation planning**: Better articulation of adaptation and resilience goals at the national level, establishing the policies/ regulations/standards, and articulating clear plans.

Uplifting the lives of the Mihintale Farming Community © Cargills (Ceylon) PLC.

Economic transformation pathways
© Chamindu Perera

- **Promote incentives mechanisms**: Strengthening financial incentives (or reducing risks/costs) for private participation through low-cost finance instruments such as loans with low interest rates, concessional loans, credit enhancement, and other targeted risk reduction or revenue-boosting measures.

- Consider rapid scaling of adaptation interventions for Green Awarding program which is already being implemented in Sri Lanka.

Several key private sector players can be identified to promote investments for climate adaptation. The Chamber of Commerce can mobilize/organize the private sector players who belong to the Chamber of Commerce. Financial Institutions (Banking and Non-Banking and Microfinance) can provide the support for low cost investments and easy access to financial tools. The business analyst groups can identify the vulnerabilities in an easily understood way to the business community or private sector. The insurance sector can attract the business community for risk finance. The accredited entities can prepare project proposals to obtain international climate finance.

Conclusion

A robust involvement of the private sector in managing climate risks in developing countries, including Sri Lanka, will reduce vulnerability, as well as provide a systematic long-term sustainability to private investments. A stronger public-private partnership will also be important to enhance climate resilience and at the same time create business opportunities.

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Extended Producer Responsibility (EPR) to ensure sustainable management of Plastic Waste

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- **Plastic pollution is a key environmental hazard in the marine environment**
- **Producers need to take up responsibility for their products while consumers should take responsibility for methodical disposal of waste**
- **Extended Producer Responsibility (EPR) is a policy mechanism through which producers are given the responsibility (either financial and/or physical) for the treatment or disposal of post-consumer products**
- **Sri Lanka is currently preparing a Roadmap for EPR to ensure sustainable management of plastic waste**
- **This article highlights the importance and need for EPR in Sri Lanka**

Recycling giant
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Keywords:

EXTENDED PRODUCER RESPONSIBILITY, PLASTIC WASTE, RECYCLING, WASTE MANAGEMENT

Each year, over 640,000 metric tonnes of plastic leak into the Indian Ocean from Sri Lanka (Clean Cities, Blue Ocean, June 2020). The Western Province alone generates around 7500 metric tons of solid waste every day, out of which only 3500 metric tons are collected (Central Environmental Authority, 2018). Of this, close to 15% becomes compost, 10% is recycled and 75% is disposed of into open dumps. While plastics have made essential products more accessible, the impact on the environment needs to be addressed.

As consumerism evolves, the earth continues to suffer. For over half a century, consumers have been placed at the forefront to bear the brunt of the burden they have placed on the Earth. But, are only consumers to be blamed? Consumers are a key stakeholder in the waste management process but they share this responsibility alongside legislators, civil society, importers of

plastic and producers who use plastic in their manufacturing and packaging processes.

Today's consumers are even more aware of what they consume and hold these products, services and brands to renewed standards of transparency and accountability. Due to this, the conversation on sustainability among brands has shifted from a mere marketing gimmick to a legitimate requirement that is demanded by the next generation of consumers the world over.

The 3Rs of responsible waste management - Reduce, Reuse, Recycle - will remain the holy mantra across the spectrum of sustainability. However, as producers take up accountability, important questions need to be raised. Are organizations able to switch to alternatives to plastic? and meet their current demands? How will this affect the product design and its safety for consumption? Elimination and reduction will only take away from the end consumers the ease of access to the product. The end consumers in this case, are civil society.

In a socio-economic study conducted by the Ceylon Chamber of Commerce, challenges such as the contamination of recyclables due to unseparated plastic waste rendering the cleaning process expensive to recyclers, lack of information on plastic volumes due to unregistered plastic producers, lack of communication between government regulators and industry and shortage of funding and weak implementation due to lack of penalties for non- compliance were revealed (USAID,2021).

Ocean Pollution
© Pacific Whale Foundation

How do we Address the Issue of Plastic Waste?

This is where Extended Producer Responsibility (EPR) comes into play. According to the Organization for Economic Co-operation and Development, Extended Producer Responsibility is a policy mechanism through which producers are given the responsibility (either financial and/or physical) for the treatment or disposal of post-consumer products. EPR is a critical tool in driving linear economies into a circular economy, as they supplement an extended product cycle even after the product's initial use. Assigning such responsibility could, in principle, provide incentives to prevent waste at the source, promote environmentally friendly product design and support the achievement of the national recycling goals.

EPR is a systematic approach to ensuring commitment to the waste hierarchy of the 3Rs by facilitating producers to remain responsible in the treatment and disposal of post-consumer products. This, at present, is a more sustainable tool over bans as most products are created for utility and cannot be removed from the market overnight. For recyclable items such as Polyethylene Terephthalate (PET) and High Impact Polystyrene (HIPS) plastic, better alternatives need to be sought which encourage recovery and recyclability.

Specific Strategies Highlighted in the Proposed EPR Roadmap

- Mandatory national packaging, recycling and recovery targets to be set for all industrial and commercial producers of consumer packaging waste
- Post-consumer packaging waste to be collected, sorted and recycled according to established national targets
- Companies must publish their annual production of plastic and how much was recovered for recycling purposes using the reporting formats mandated
- Companies must finance the infrastructure necessary to collect back the equivalent of the packaging they placed in the market within an agreed time period and must support consumer education campaigns on the prevention of littering or on the proper sorting of discarded packaging
- Data deficiency on plastic use by industries is evident in the country and it is recommended that the GoSL impose mandatory reporting regulations alongside a monitoring and tracking system
- Each household shall use four bins or separation units for organic, paper, plastic and glass and metal or a minimum of two bins for recyclable and non-recyclable waste
- Each local government body must be made accountable for efficient Solid Waste Management by setting targets for plastic waste collection and must establish systems to impose penalties for not meeting targets and incentives for good performance
- Fines and penalties will be put in place. Penalties would be placed on producers if they do not meet their agreed annual recycling target, households if they do not segregate their waste and the public for littering, open dumping or open burning

(USAID, 2021)

The Way Forward

The Ceylon Chamber of Commerce together with the support of USAID and the endorsement of the Ministry of Environment and involvement of Central Environmental Authority and other key government agencies has been working together with key stakeholders from public sector participants to recyclers and collectors, manufacturers, brand owners, importers and environmental lobbyists to address the issue of post-consumer plastic recycling. In the Chamber's work towards developing feasible solutions for sustainable plastic waste management, an EPR roadmap has been formulated with the collective input and partnership of all key stakeholders.

Further to the above strategies, the Chamber, with the financial assistance of USAID's Clean Cities, Blue Ocean (CCBO) Program and collaboration of the Ministry of Environment, Central Environmental Authority and other relevant Government Agencies, has also initiated a pilot project to implement EPR system for PET and HIPS through a Private-Public-Partnership (PPP) approach. Plastic packaging manufacturers, producers and brand owners have pledged their commitment to collect-back a substantial percentage of plastic packaging released into the environment. The voluntary EPR model which will soon be implemented in Sri Lanka, will be the first of its kind. With the 'Mandatory Reporting and Collect-Back System', brand owners, importers and manufacturers will have to report their annual sales volume of primary packaging used. Each brand owner/ producer will be assigned collect-back targets based on annual usage of plastic packaging in accordance with the country's set target for collection, and this will progressively increase over the years. The Chamber has reiterated the need for incentives and reward mechanisms set in place to further reinforce and encourage organizations committed to sustainable management of plastic waste. The Chamber will also ensure that brand owners maintain transparent records of their collection and recycling data.

The Initial EPR system will be rolled out for recyclable materials like PET and HIPS, which are materials used in the packaging of commonly found food like beverage and yoghurt products. Both products are recyclable. Primary packaging such as PET that exists in the market already, is a safer alternative to single use plastics. While PET is a part of the larger plastic family, it is recyclable and can be recycled many times over before it is no longer suitable for consumption. The product does not contain high density polythene (HDPE) and is bisphenol-A (BPA) free and has made significant improvements over the past 30 years, as producers are now using a lighter version of the product than they did three decades ago.

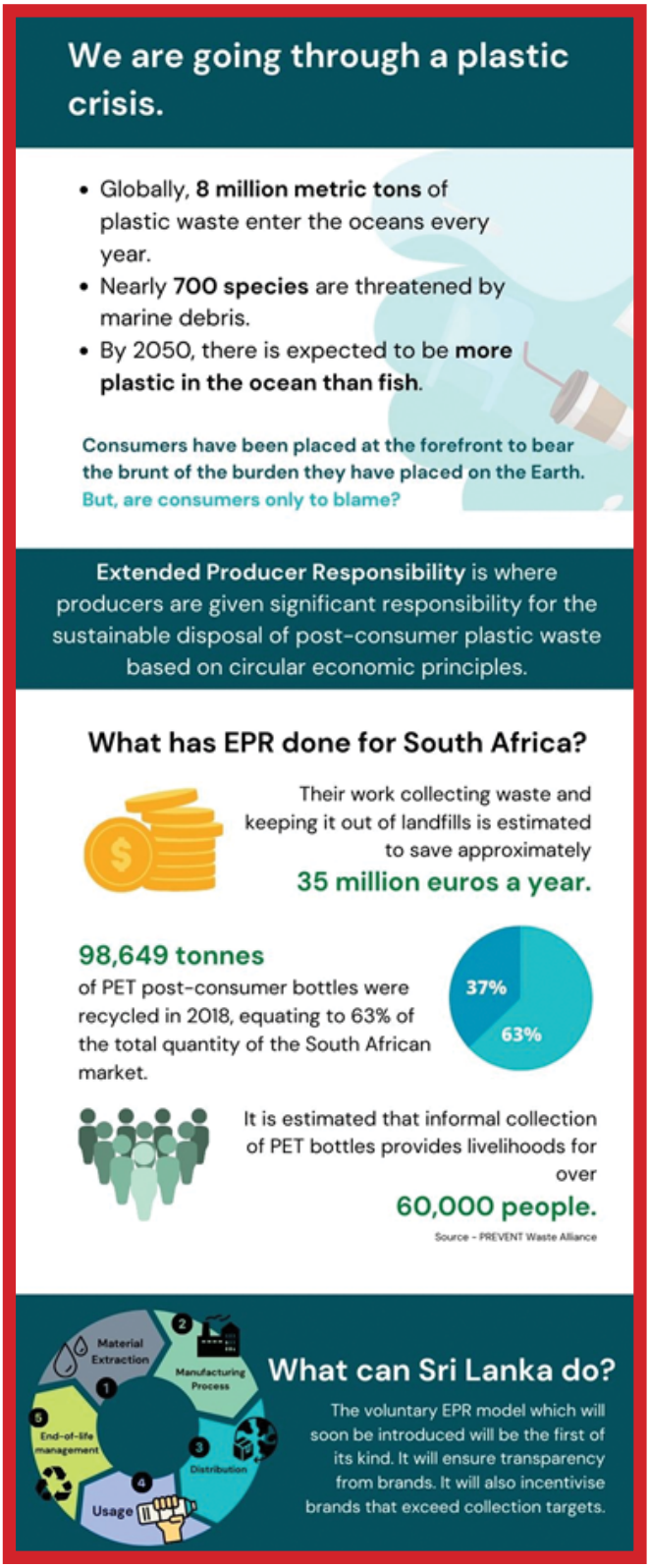
Conclusion

Everyone stands to benefit from collectively playing a collaborative role in managing our waste problem. EPR is only a single, but an extremely crucial, extension of a larger solution that holds the ecosystem of stakeholders accountable from the time the product is designed to the time the consumer disposes of it, and until it reaches back to the recycling and production process.

In Sri Lanka, we are fortunate to have a large number of plastic waste collectors ranging from informal to institutional collectors working across the island, providing material to recyclers. More often than not, these recyclers run under capacity. A steady provision of the required feedstock will enable them to function at full capacity, and empower them to further enhance their contribution to the national economy. Therefore, it is imperative to consider what more could be done with the existing products in the market. To this end, EPR will play a role in ensuring better waste management at large, while subsequently minimizing the ecological footprint created if producers had to switch to an alternate single use material.

Under the EPR, the Mandatory Reporting and Collect Back (MRCB) model was launched in June 2022. This model requires plastic users to declare their annual usage and collect back an agreed percentage. It is at first to be implemented for PET and HIPS packaging on a voluntary basis.

The new bans on the plastic packaging and waste generation may come as a rude awakening, as these bans will only take away quality of life from the end consumer. Enforcing an industry level EPR program will be a more rational alternative to banning the use of the recyclable plastic material altogether. That is why all stakeholders should remain accountable and responsible reaffirming the role that we play as individual consumers, manufacturers, collectors, recyclers and policy makers in this larger waste management issue. After all, the circle will never truly be complete until all of us are bound together to do our part.



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Recognizing Climate Change-induced Disaster Risks *in* Small & Medium Enterprises Development

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* **Disaster impacts on business infrastructure as well as on market chains are significantly increasing. Sri Lanka is highly vulnerable to climate change, hence climate change-induced disasters are becoming more frequent. Lapses in preparedness have made businesses, especially small and medium enterprises (SMEs), incapable to bounce back following disasters.**

* **Sri Lanka's small and medium enterprises have chronic problems with legal and financing matters. Hence, when they face natural disasters the business recovery after facing repercussions of disaster becomes extremely difficult.**

* **With less capital and technology, the small businesses are least able to adapt to climate change-induced disasters, hence their business continuity is threatened with the least resilience.**

* **This article explores the impacts of climate change-induced disasters on small and medium enterprises and proposes engagement strategies through reviewing the literature on disaster impact on SMEs, risk avoidance, and business continuity.**

* **The findings reveal that a majority of SMEs are unprepared for disaster risks.**

Keywords:

CLIMATE-INDUCED DISASTER RISKS, SMALL AND MEDIUM ENTERPRISES, RISK INFORMATION, RISK TRANSFER AND BUSINESS CONTINUITY

Introduction

Sri Lanka's economic drive is dominated by Small and Medium Enterprises (SMEs). As per their labour and business turnover, the majority of small enterprises can be further categorized as micro-enterprises. In fact, 92% of Sri Lanka's business establishments are micro-enterprises (De Silva, 2020). Hence, the SME sector's resilience to climate change-induced disasters is directly proportional to the local economic development. The escalation of natural calamities induced by climate change has caused serious setbacks on local businesses and market chains as local businesses were considerably damaged due to disasters consecutively during the past years (UNDP, 2017; UNDP, 2016).

This article reviews the adaptation options available for SMEs in Sri Lanka to enhance resilience against climate change. The research methodology was a field survey conducted in Badulla, Monaragala, Matale, and Nuwara Eliya Districts involving 84 SMEs including 77 industries and 7 services (Janathakshan, 2020).

The SMEs (including the micro-enterprises) is a vehicle to achieve sustainable, equitable, and inclusive growth, triggering income distribution at the lower percentiles of the economy with a variety of businesses (Wijesundara, 1996). The SME sector acts as a breeding ground for entrepreneurs to strive towards becoming large corporates. SMEs are generally labor-intensive and thus, can move ahead with relatively less capital. However, many factors, barriers, and constraints influence the performance of SMEs and their development (Asian Development Bank, 2018). In Sri Lanka, the SMEs contribute for 75% of the total number of

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Shop with candlelight
© Inclusive Urban Infrastructure

enterprises, provide 45% of the employment (with nearly 2.3 million employed), mainly in the service sector. SMEs contribute to 52% of the Gross Domestic Production (GDP) (Ministry of Industry, 2015). SMEs' contribution of GDP in Sri Lanka is one of the highest among Asian Countries, surpassing India, Malaysia, and Singapore (Daily FT, 2018). The country has more than 750,000 SMEs, each employing 3 to 5 persons on average. An estimated 52 % of GDP comes from registered as well as unregistered enterprises in this sector (Department of Census and Statistics, 2015). Hence, undoubtedly there are a large number of persons and families engaged with Micro, Small and Medium Enterprises (MSMEs).

Meanwhile, Sri Lanka's SME sector has some chronic problems. When it comes to doing business, starting the business, getting a location, access to finances, doing day-to-day operations and securing business environments are some of the problems. Sri Lanka, with the world rank 100 for business easiness, has been overtaken by some fast-developing Asian economies such as Nepal, India and Indonesia (World Bank, 2019). Therefore, disaster risks, especially when escalated with the influence of climate change, add another burden to the SME sector which is already suffering from the above issues. Among the 9 prioritized sectors in the National Adaptation Plan for Climate Change 2016-2025 (NAP), 6 sectors dominate and is directly linked with SMEs (Ministry of Environment, 2015).

Entrepreneurship and climate change

The greater frequency and intensity of extreme weather and chronic climate impacts impose real costs on small businesses. Extreme weather causes asset damage, upsets business operations and disrupts market chains (Federal Reserve Bank of San Francisco, 2018). Business sectors more closely tied to natural resources, such as agriculture or tourism, are particularly vulnerable to climate change repercussions, especially when they are inadequate with financial or preparedness plans to recover (Green Journal, 2020). Data from global statistics show that climate-related disasters are accelerating across the world (WMO, 2021). Applying appropriate changes according to the business environment is a part of business strategizing.

Unlike large businesses, many small businesses are less capable of adapting to examine the climate risks they face and increasingly experience difficulties (Deloitte, 2021). With the majority of Sri Lanka's SMEs being micro-businesses that have an annual turnover of less than 5 million, it is unlikely that SME's have investments for risk reduction. SMEs may not have plans in place to respond and recover from weather events, which makes them particularly vulnerable. A study on business insurance (Janathakshan, 2020) revealed that despite the majority of SMEs having faced natural disaster impacts especially those climate-induced disasters like floods,

droughts, and strong winds, the number of SMEs with risk coping plans was negligible. Their post-disaster business recovery methods were pawning assets, borrowing funds from individuals, sometimes borrowing from informal money lenders at high interest rates, or restarting from zero. Such hindrances have caused personal mishaps as well as local economic development setbacks.

The SMEs related to agriculture, animal husbandry, and food and beverages were the most impacted by natural disasters. Among non-agricultural SMEs, it was found that drought-led power cuts were hampering the cold productions (such as yogurt and jelly), and unpredicted dry winds were destroying flower nurseries. The SME Policy framework (Ministry of Industry, 2015) is advocating the nurturing of green growth while focusing on comprehensive interventions such as enabling environments, technological support, and providing access to finance. However, as per the NAP, such SME policy aims would be significantly affected by the adverse conditions of climate change.

Climate Risk Information for SMEs

The availability of appropriate information is the key to business resilience against all types of hazards. A study conducted in the Central and Uva Provinces in Sri Lanka (Crysalis, 2020) identified that most of the SMEs were sensitive to 'some' climate changes within their communities, based on their subjective experience. However, the responders have least access to scientific or official information disseminated from technical agencies like the Disaster Management Center (DMC), except for the information given out by public media.

There are several climate and disaster risk information management agencies in Sri Lanka, based on the specific hazard type (DMC, 2019). The DMC is the state organization to coordinate and share all such information from agencies like the Meteorological Department, the National Building Research Organization and the Department of Irrigation. Moreover, it was identified that the SMEs would like to have risk information beyond emergency-related hazard early warning (e.g., quick evacuations to save lives), so that the business community, especially the SMEs, have adequate time to prepare themselves (e.g., make arrangements for an impending drought), which was missing. Moreover, the study identified a need for a mechanism that could provide information about a long-term disaster such as diminishing rainfall or changes in the rainy seasons. It was then identified that such information can be produced from different technical agencies like the Department of Agriculture, the Agrarian Development, the Hector Kobbekaduwa Agrarian Research and Training Institute, and the Meteorological Department.

It was found that the agricultural sector SMEs, mainly the small-scale farmer producers, preferred to have weather predictions about three months from the cropping seasons so that they could choose an appropriate cropping variety. Some of the information is being shared by the Department of Agriculture, but further accuracy and technical information are expected. However, with everchanging global warming-influenced weather systems, more advanced technologies would be needed to have such long-term, but far more accurate, predictions (Ghoniem, 2011). It was identified that, for non-agricultural businesses, early warning two weeks in advance would be helpful to make arrangements such as storage and supplies, and to adjust production chains. Another common interest identified from both agricultural and non-agricultural sectors was to receive weather information in understandable 'language'. For instance, a "wind speed of 50 km/hour" may not be sensible to the common public. Again, "a rainfall of 100 mm in a location" would be useless information unless the public is aware of whether the access roads are going to be flooded or not. Then the study found that, disaster risk information would be far useful if it is categorized according to the types of business and the types of hazards specifically affecting those businesses. For example, in vegetable cultivation, both producers and collectors should receive specific information related to heavy rains, drought, strong winds, etc., and the increase in ambient temperatures would be related to some industries. The study identified that 52% of businesses were affected to some degree by disasters during the past 5 years and the small scale food industry was affected the most.

Market in Ella © Picfair

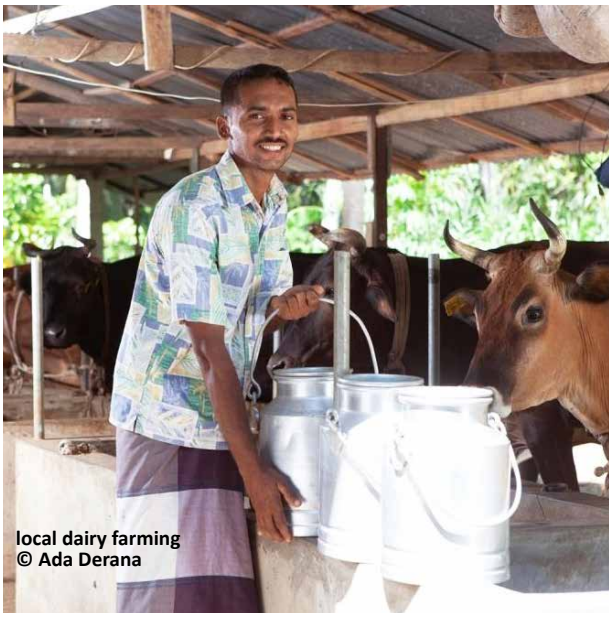
Conclusion and Recommendations

The SME sector being the main economic driver in the country, must be combined with the climate change adaptation process so that losses and damages are minimized. Again, such a step would advocate Sri Lanka's contributions to the Warsaw International Mechanism (WIM) for Loss and Damage associated with climate change impacts. Moreover, it would be necessary to revise the current SME policy to become disaster and climate-sensitive. While addressing some chronic issues related to SME administration and infrastructure, escalating climate risks must be a matter of concern. By making the SMEs linked to hazard information and climate-induced disaster risk information, would make the SMEs aware of disaster risk reduction and business resilience. Providing support to do business risk assessments leading to business continuity plans will be some vital steps to adapt SMEs to climate-induced disaster risks. At the same time, capacitating SMEs to search for information related to climate risks would create a pull factor, especially if it is perceived as their 'right' (to have climate & disaster risk information).

Risk transfers in the SME sector

When it comes to risk avoidance, 7% of the sample SMEs had property insurance including for natural disaster coverage. Though the majority of entrepreneurs were aware of climate change and that such change would increase disasters, multiple factors were distancing them from the option of insurance. The leading factor was the ignorance of the concept of 'insurance'. The entrepreneurs were expecting a return on insurance investment through cash as accumulated wealth. They were unaware of investing for climate-induced disaster risk transferring (or the risk-bearing investment was misunderstood). Moreover, the inability to understand the complex nature of insurance policies, high premiums, lack of customization and misconceptions about insurance repayments were some reasons that disconnected SMEs and insurance.

An example of a good effort for climate insurance for SMEs was the scheme of Sanasa Development Bank in which an Income Loss Insurance scheme was introduced to small and medium enterprises to cover property damages caused by disasters (Abeysinghe, 2014). For the agriculture sector SMEs an Index Insurance for Agriculture was introduced in 2018 by the Agriculture and Agrarian Insurance Board. However, sustaining such schemes would depend on the insurance knowledge and the interest of the beneficiary (Nilwala and Jayarathna, 2018). The study identified that the awareness of benefits is key to increasing the number of SMEs using insurance schemes; it was then identified that bringing down the insurance premium was another concern. Bringing down of insurance premia is one of the key factors of popularizing insurance (Wray *et.al*., 2021).



local dairy farming
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Planning for Business Continuity and exploring new business opportunities

When considering the hazard profile of the country (DMC, 2015), the threats and opportunities that each business encounter are different based on its geographical positioning or the climatic zone (Biodiversity Secretariat, 2017). The above study identified that there was a lack of information for risk-sensitive business planning. However, if the risk information is available in an understandable form the business plans would have developed methods to encounter shocks, which are commonly called the Business Continuity Plans (BCPs). As per IBM (2020) BCPs are the strategies that outline how a business will continue operating during an unplanned service disruption. It is beyond a disaster recovery plan and contains contingencies for business processes, assets, human resources and business partners. During the above study, it was evident that the SMEs were comparatively more flexible to quickly adapt to climate-induced disasters because they were with fewer protocols and legal complexities. Therefore, if risk information is adequately available, SMEs can adjust accordingly with some external technical support for risk assessment, disaster impact analysis and systematic planning (Castle, 2020). They may further identify the potential hazards that may affect business infrastructure, supply chain and movements, as well as consumers. Simultaneously, the SMEs could map their vulnerabilities and capacities based on their capitals, reserves, networks and technical expertise. However, most micro and small businesses would need technical support in this regard. Therefore, it is vital to develop the capacities of DMC, the National Entrepreneur Development Authority (NEDA) and similar agencies to support SMEs in BCPs.

Monsoon season floods
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The Importance of
Climate Emergency Response:
Special Reference *to* Sri Lanka

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Keywords

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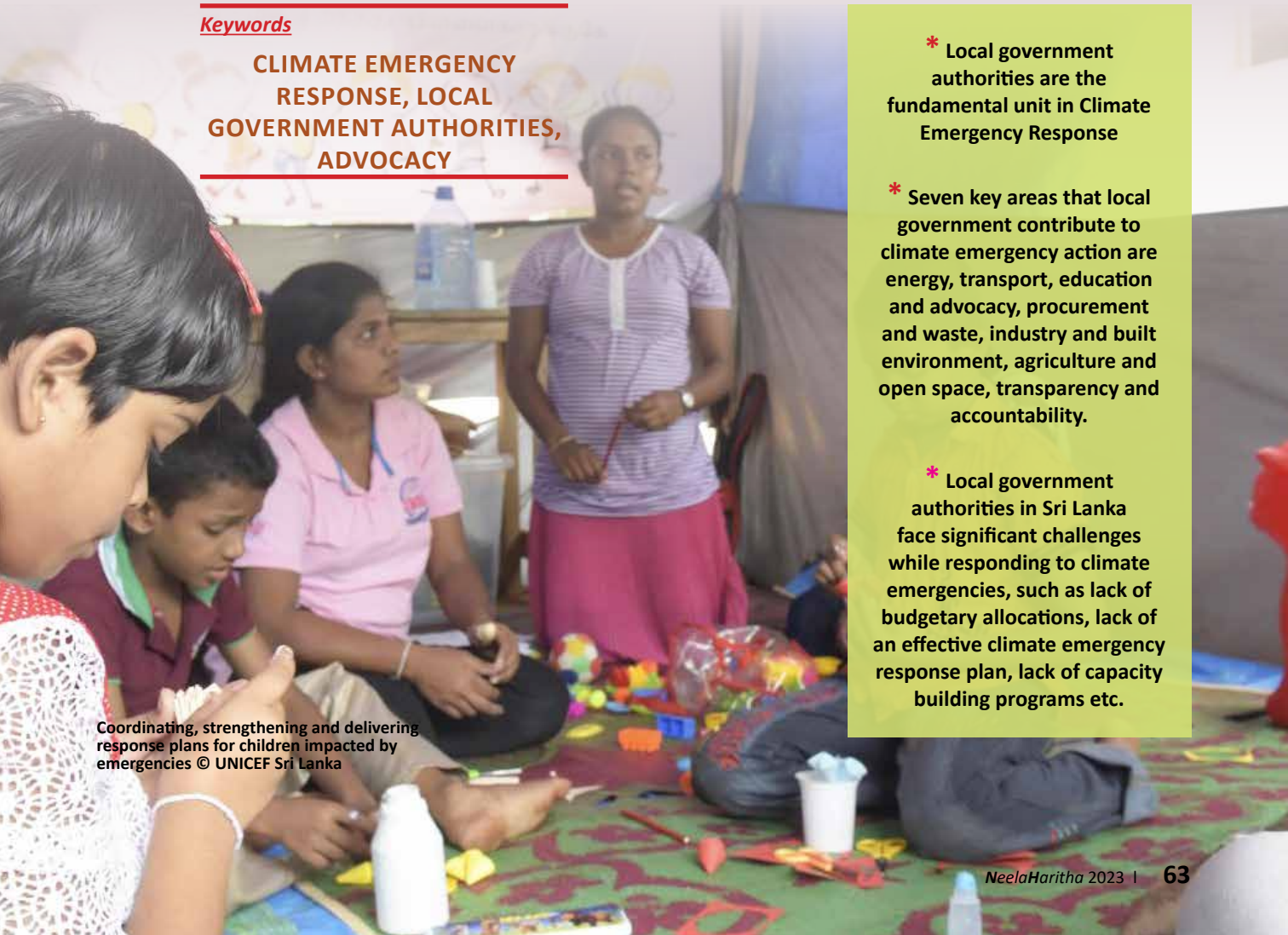

Coordinating, strengthening and delivering response plans for children impacted by emergencies © UNICEF Sri Lanka

* **Local government authorities are the fundamental unit in Climate Emergency Response**

* **Seven key areas that local government contribute to climate emergency action are energy, transport, education and advocacy, procurement and waste, industry and built environment, agriculture and open space, transparency and accountability.**

* **Local government authorities in Sri Lanka face significant challenges while responding to climate emergencies, such as lack of budgetary allocations, lack of an effective climate emergency response plan, lack of capacity building programs etc.**

Necessity of Climate Emergency Response for Sri Lanka

According to the Climate Change 2014 Synthesis Report (AR5), Climate Change (CC) refers to "a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer". Climate change has had frequent widespread impacts on human and natural systems. Therefore, it is well evident that climate change is one of the most urgent problems which may threaten all forms of life on earth. The exponential growth of the human population and level of economic development are some of the major reasons behind this threat. This is revealed by the clear human influence on the climate system and recent anthropogenic emissions of greenhouse gases, which at present are the highest in history. As a result, many environmental and socio-economic problems are increasing day by day in both the developed and developing countries around the world. The examples are, warming atmosphere and oceans, diminishing snows and ice caps, rising sea level, reducing economic growth and increased health issues (respiratory illnesses, cardiovascular diseases etc.), to name a few (IPCC, 2014.).

As an island nation exposed to tropical climate patterns a developing country like Sri Lanka is highly vulnerable to the effects of climate change. It is identified that climate change is a multidimensional phenomenon which not only impacts the environment but also affects the economy and society. With Sri Lanka in the 6th place among most affected countries by extreme weather events in the Global Climate Risk Index in 2018, the implications of such hazards are now evident (Eckstein, D *et al.*, 2020). The Disaster Management Centre of Sri Lanka estimated that nearly 3,386,466 people from 20 districts were affected and 509 people died due to landslides, heavy rains, lightning and strong winds in 2017 (Disaster Management Centre of Sri Lanka, 2017). Further, the average annual temperature in the country is expected to continue to rise by 1.08°C in 2030, and to possibly increase by 1.12°C in 2050 as evidenced in the rise in such hazards (USAID, 2015).

The climate change impacts are directly felt at the local level. For instance, more than one-third of Sri Lanka's population live in coastal regions that are highly vulnerable to potential sea level rise. Further, annual economic losses due to prolonged droughts are also common. Disaster Management Centre reported over 2,440,290 drought affected people across 11 districts in year 2017 (Disaster Management Centre of Sri Lanka, 2017). If these hazards occur continuously, the environmental, economic and social impacts will directly affect both local and national levels. Therefore, the attention of local authorities is necessary to address climate change impacts in Sri Lanka.

Climate Emergency Response and Key Processes in Effective Climate Emergency Response

According to 'Oxford Dictionaries' a Climate Emergency can be defined as a situation where urgent action is needed to reduce or halt climate change and prevent potentially irreversible damage to the environment resulting from it (Naaman Zhou, 2019). Even though urgent action is needed, we cannot tackle the impacts like global warming overnight, or even over the next several decades. However, action can be taken to slow the rate and limit the amount of global warming by reducing anthropogenic emissions of heat-trapping gases and other compounds. Therefore, it is obvious that some changes are required to make systems effective to face climate emergencies.

Climate emergency response © SLYCAN Trust

This study found that there are five key processes for effective climate emergency response for Local Government Authorities. They are:

I. Process one: Take leadership to declare a climate emergency

In this process, the local authorities are recognizing the catastrophic changes to the global climate resulting from human activities by declaring or acknowledging the climate emergency. Further, the council should also be committed to combat climate change by taking immediate actions to the extent and at a rate that will secure a safe climate.

II. Process two: Get house in order to embed climate emergency action in all council strategies, plans and actions

After declaring a climate emergency, the council should develop a Climate Emergency Plan (CEP). The CEP should outline any action the council will take to embed a climate emergency response into its operations. Actions should include, but not be limited to, switching to renewable energy, phasing out non-renewable energy sources like fossil fuels, implementing energy efficiency, moving linear economy to circular economy, educating and empowering the community to take actions, increasing community resilience to the impacts of climate change, etc.

III. Process three: Mobilize and build the climate emergency mandate to get the community active

Climate change is a global challenge and cannot be tackled by one nation alone. Therefore, instead of the blame game, everyone has a responsibility to take actions on climate change locally. In this process, the council should support communities to take individual actions such as switching to renewable energy, public transportation etc. This can be done especially through awareness and capacity building programs.

IV. Process four: Global movement building to reach out to other councils

A 'Climate Emergency Declaration' is an action taken by governments and scientists to declare that humanity is in a climate emergency. The initial declaration was made in December 2016 in Darebin, Australia.Since then, over 1,800 local governments in 33 countries have made climate emergency declarations. The declarations can be made at different levels. For example, climate emergencies can be declared at local, national and international level (City of Darebin and What, 2018). Therefore, it is important to reach out to peers locally, nationally, and globally. This will be an effective way of building the global movement for climate emergency action.

V. Process five: Advocate to national and sub-national government

Councils cannot do the work to respond to climate emergencies on their own. Sub-national, National and Global levels must work together to make a powerful impact on the climate emergency (City of Darebin and What, 2018).

The Role of Local Government in Response to Climate Emergency

It was identified that the local government authorities are the fundamental unit and the best place to start the government commitment in climate emergency response (City of Darebin and What, 2018). Therefore, the local government plays a critical role during a climate emergency. They can communicate the current and future impacts of climate emergencies, demonstrate climate adaptation and mitigation strategies, pilot and promote new technologies, work with local communities to reduce greenhouse gas emission etc. Energy, transport, education and advocacy, procurement and waste, industry and built environment, agriculture and open space, and transparency and accountability are the seven areas where local government can effectively contribute to climate emergency action. Suggestions and activities introduced under these seven areas should match with the level of urgency and ambitions of the climate emergency declarations. Moreover, they should lie within the

The supplies were delivered to families most in need following the flooding © SPRINT

power of local government, should be specific and measurable, and include time frames (Martin, 2020).

First step of the climate emergency response is that the local government should recognize the importance of climate emergency response, and they should acknowledge the need for all levels of government to act. As the transition is not fast enough, the local government should call for rapid action within the time frame. At first, when developing and implementing actions, local government should obtain deep community engagement. Second and foremost important action is to develop a climate emergency plan. Under this step, local government should set targets to reduce the emission within a time frame. Third step is ensuring that the council prioritizes the CEP in its strategic plan. Building the capacity of local government staff around CEP is the fourth step. The fifth and last step is to communicate the climate emergency approach to the community and obtain their support to implement CEP (City of Darebin and What, 2018).

Local Governments cannot solely maintain sustainable, effective and practical CEP. They cannot reverse global warming by themselves, but they can take steps to initiate to mitigate the impacts. Therefore, the most important action of the local government is to advocate the national government on emergency actions. National government policy, legislation and financial aid have the biggest impact on the climate emergency (Spratt, 2019).

Key Challenges for Local Government Climate Emergency Response

Significant challenges faced by the local government when responding to climate emergency include, politicians inadequately informed about climate emergency; lack of scale and efficiency in local government authorities when adapting to climate emergency response; inadequate funding facilities to incorporate and implement climate emergency response plan, difficulty to allocate time; knowledge, and resources for the response plan; and lack of expertise within the local government authorities to implement the response plan (City of Darebin and What, 2018).

Sri Lanka rushes aid to flood victims © DW

To overcome these challenges, it is essential to have existing policy changes and introduce governmental actions at national level. Further, an effective climate emergency response should be developed by experts in the field of climate change. According to the climate emergency, budget and resource prioritization is another mandatory requirement to deliver the essential services and to maintain the community support. Furthermore, operations and actions of the council should be transparent to the public for ensuring accountability, since it will figure the roles, responsibilities, strategies and goals of the CEP. In addition, educating the community is vital to creating public awareness of local issues and to gain public support. Therefore, awareness programs, workshops, forums, and discussions are required to build awareness regarding the need of CEP. Community mobilization is also important in getting the local community into track. Moreover, local governments should work with other levels of government to support CEP and partnerwith relevant authorities to obtain financial aid (City of Darebin and What, 2018; Martin, 2020; Spratt, 2019).

Conclusion

In conclusion, climate change is a global challenge, and it requires multi-sectoral actions. Local, national, and global level responses can be taken to respond to climate change impacts, in which local governments can play a vital role. Five key processes for effective climate emergency response was identified at the local government level. These processes are: taking leadership to declare a climate emergency, getting the house in order to embed climate emergency action in all councils into strategies, plans and actions, mobilizing and building the climate emergency mandate to get the community active, building a global movement to reach out other councils and advocating to Sub-national and National government. As a developing nation, Sri Lanka will face some barriers when adopting Climate Emergency Response mechanisms, such as financial and institutional issues, lack of an effective climate emergency response plan, lack of capacity building for the community and so forth. However, these challenges can be overcome through changing and introducing governmental rules and regulations, educating and creating awareness, providing funds etc.

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Sri Lankan villagers cross a landslide, Athweltota village in Kalutara. © CNN

ஐந்தடுக்கினாலான உணவுகாடுகளின் மூலம் காலநிலை மாற்றத்தின் தாக்கங்களை குறைத்து நிலைபேறான சுற்றுச்சூழலை உருவாக்குதல்

(Reduce the impact of climate change through five layer of food forests and to create a sustainable environment)

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மனிதனின் அறிவியல் தேடலிற்கு முற்பட்ட காலங்களில் பூமியானது தன்னை முற்றுமுழுதாக மூடிகொண்டிருந்தது வனாந்தரங்களாலும் அழகிய சூழற்தொகுதிகளாலும். மனிதனின் அறிவியல் அவா அதிகரிக்க அதிகரிக்க அந்த மூடியிருந்த இந்த பச்சை போர்வை மெல்ல விலக ஆரம்பித்து இன்று முழுமையாய் விலகிவிடும் நிலைக்கு தள்ளப்பட்டுள்ளது. இயற்கையோடு பின்னிப்பினைந்து அதன் ஓர் அங்கமாய் அதனுடன் வாழ்ந்த மனிதன் தனது அறிவியல் மாயையால் இயற்கையின் பின்னிப்பிலிருந்து விலகி தான் ஒரு இயற்கையின் அங்கமென மறந்து இயற்கையை தனக்காக மாற்ற நினைக்கின்றான்.

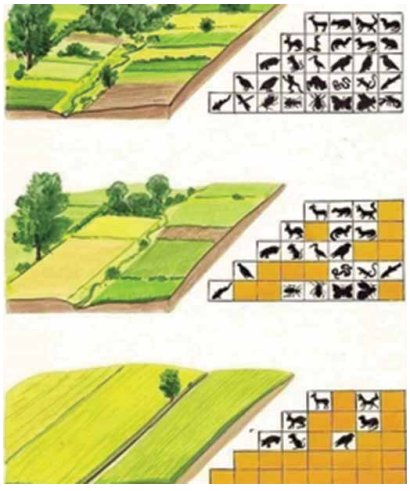
மனிதனின் வரையறை அறிவியலுக்கு அப்பாற்பட்ட இயற்கை மனிதன் தனக்காக இயற்கையை மாற்ற நினைக்கும் அல்லது மாற்றும் சந்தர்ப்பங்களில் இயற்கை தனது மௌன மொழியான அனர்த்தங்களாலும், சீற்றங்களினூடாகவும் தன்னை தானே சீர்படுத்தி மனித அறிவியலுக்கும் மனிதனுக்கும் மௌனமாக கூறி செல்கிறது இயற்கையின் ஓர் அங்கம் தான் மனிதன் என்று. இயற்கையோடு பின்னிப்பிணைந்து உயிருள்ள கூறுகளோடு வாழும்போது மனிதன் மனிதனாக இயற்கையோடு கூட்டாக வாழ்ந்தான் அறிவியல் எனும் மாயையில் அபிவிருத்தி எனும் பாதையில் மனிதன் காலடி எடுத்து வைக்கும் போதே இயற்கையின் பிணைப்பில் இருந்து அறுபட்டு இயற்கையை சுரண்டி கட்டிடங்களையே வானுயர போட்டிக்காக வடிவமைத்து உயிரற்ற கூறுகளோடு சுயநலவாதிகளாக தனியனாக வாழ்கின்றான்.

சுயநல போக்காளர்களாக மாறிய மனிதர்கள் குறுகிய தமது மனித கூட்டத்தை மட்டுமே கருத்திற் கொண்டு தமது மனித இனத்திற்கு கீழே தான் மற்றைய கூட்டங்கள் இருக்க வேண்டும் என எண்ணி இயற்கையை மாற்ற நினைக்கின்றனர், வாழப்பழகி கொள்கின்றனர். இதனால் மற்றைய கூட்டங்கள் அழிவுப்பாதைக்கு செல்ல நேரிடுகிறது. இதிலிருந்தே இயற்கைக்கும் மனிதனுக்குமான முரன்பாடு ஆரம்பித்து சூழற் சமநிலையின்மை குழப்பங்கள் உருப்பெருக்கின்றன. இந்த குழப்பநிலைகள் நாளடைவில் விரிவடைந்து தொகுதி சமநிலையின்மையாக மாறி இன்றையளவில் காலநிலை மாற்றங்களுக்கு காரணிகளாக அமைந்திருப்பதில் முக்கிய பங்காக காணப்படுகிறது இயற்கை சமநிலையில் ஏற்படும் சிறிய சிறிய மாற்றங்களே நாளடைவில் பெரிய மாற்றங்களுக்கு வித்திடுகின்றன.

நாம் தங்கியிருக்கும் எமக்காக வடிவமைத்த கட்டிடங்கள் முன்பு விலங்கு குடித்தொகை வாழ்ந்த காடுகளாகவோ, அவை நீர் அருந்திய ஏரிகள், குளங்களாகவோ காணப்பட்டிருக்கும். ஒரு குடித்தொகைக்குரிய வாழிடத்தை அழித்தே அல்லது சேதப்படுத்தியோ அவ் கட்டிடங்கள் வடிவமைத்துள்ளோம். அவ் குடித்தொகைக்குரிய விலங்குகள் வடிவமைத்த கட்டிடங்கள் நோக்கி வரும் போது அவை எமது எல்லை பிரதேசத்திற்குள் வருவதாக அவற்றை விரட்டுகின்றோம், எமக்கான எல்லைகள் என வெறுமனமே கொங்கறீற்று சுவர்களால் பிரிக்கின்றோம் இயற்கையை யாராலும் எல்லைகள் போட முடியாது அது ஒரு சிக்கல் தொகுதியாக இருப்பதனால் ஒன்றோடு ஒன்று இணைப்பிலே இருக்கும் இயற்கையானது எல்லா அங்கிகளுக்கும் பொதுவானது அவற்றுடன் வாழ பழகிகொள்ளாமல் அவற்றுக்கும் எமக்குமான முரன்பாட்டையே உருவாக்குகின்றோம். இப்படியான காரணிகளால் சூழலியல் குடித்தொகைகள் குழப்பப்பட்டு, சூழலியல் காரணிகள் சிதைக்கப்பட்டு குழப்பப்படுவதனால் சூழலியல் சமநிலையின்மை உருவாகின்றது. இது காலநிலை மாற்றத்திற்கு வழிகோலுகிறது.

படம் 02: ஐந்தடுக்கு உணவுக்காட்டின் உட்புற தோற்றம் (4மாதங்களில்)

சூழற்தொகுதியில் அந்த சூழலுக்கே உரித்தான உயிர்பல்வகமை சீராக காணப்படுமாயின் அந்த சூழல்தொகுதியானது சீரான சூழல்தொகுதியாகவும் காலநிலை மாற்றத்தை ஏற்படுத்தாத சூழல் தொகுதியாக அமையும். பல்வேறுபட்ட உயிரினப்பல்வகமை காணப்படுவதால் அவை ஒன்றினைந்த சூழல் தொகுதியாக சூழலுக்கு பாரதூரமான பாதிப்பை ஏற்படுத்தாத சூழல் தொகுதியாக அமையும். இவ்வாறு அமைந்த சூழல் தொகுதியில் ஏதாவது ஒரு மாற்றத்தை அல்லது சேதத்தை மனிதன் மாற்றியமைக்கும் போதோ அல்லது மாற்றமுனையும் போது இயற்கைக்கும் மனிதனுக்குமான முரண்பாடுகள் ஏற்பட்டு காலநிலை மாற்றத்தை ஏற்படுத்துமளவிற்கு காரணிகளாக அமைகின்றது.



படம் 01: பயிர்செய்கை கோலமும் விலங்குகளின் குடித்தொகையும்

மனிதன் சூழல் தொகுதிகளை குழப்புவதற்கு மிக முக்கிய காரணங்களில் ஒன்றாக அமைவது குடித்தொகை அதிகரிப்பினாலேயே இவ்வாறு நிலைமைகள் அதிகளவு நிகழ காரணமாக அமைகின்றன மனித குடித்தொகை அதிகரிப்பினால் உணவு தேவை அதிகரிக்கின்றன இதனால் குறிப்பிட்ட ஒரு சில உணவுக்கான தேவை அதிகரிக்கும் போது பல்படையிலான தாவரக்குடித்தொகை அழிக்கப்பட்டு தனிப்பயிர்செய்கை மேற்கொள்ள வேண்டிய நிலை ஏற்படுகிறது. ஒன்றினைந்த குடித்தொகை அழிக்கப்பட்டு சூழலுக்கு பாரதூரமான விளைவுகள் ஏற்படுகின்றன. உதாரண கூறுவோமாயின் ஒன்றிணைந்த சூழல் தொகுதியில் பறவைகள் காணப்படும் இவை அதிகமாகும் பூச்சி புழுக்களை உண்ணும் உண்ட உணவு கழிவுகளாக மாறி அவை மண்ணுக்கு உயிர்ப்பான உரமாக மாறும் அதிலுள்ள போசனை கூறுகளால் போசனையை பெற்று மரம் செடி கொடிகள் உயிப்பானதாகவும் பசுமை போர்வையாக பூமியின் மேல் காணப்படும். இந்த மரங்களின் பழங்கள் மற்றைய விலங்குகளிற்கும் பறவைகளுக்கும் நேரடி உணவாக மாறும். அந்த விலங்குகள் மரங்களின் விதைகளை இன்னோர் இடத்திற்கு எடுத்து சென்று காடுகளை உருவாக்க வழிகோலி இதுபோன்ற உணவு வலையினை உருவாக்கும். மனித தலையீடு அல்லது புறக்காரணிகள் காணப்படாதவிடத்து இது ஒரு தொடர்சியான வட்டமாக நிகழ்ந்து புவி மேற்பரப்பு பசுமையாகவும் மாற்றத்தை விளைவிக்காததுமானதாக சூழற்தொகுதியாகவும் இருப்பதோடு தன்னை தானே திருத்தியமைக்கவல்ல சூழல்தொகுதியாகவும் இருக்கும.

அதிகரித்து வரும் மனித குடித்தொகையில் உணவுக்கான தேவை இருந்து கொண்டே இருக்கின்றது உணவு தேவையினை நிவர்த்தி செய்யும் பொருட்டு அதிகளவில், குறுகிய காலத்தில் விளைச்சலினை பெறுவதற்காக மனிதனின் மிதமிஞ்சிய இயற்கைக்கு புறம்பான அறிவில் உருவான இரசாயன கிருமி நாசினிகள் இரசாயன உரங்களை பாவிக்கின்றனர். இதனால் பறவைகள் விலங்குகள் பெரிதும் பாதிக்கப்படுகின்றன. இங்கு சூழலுக்கான சமநிலை குழப்பப்படுகின்றது இங்கிருந்தே பெரிதளவிலான காலநிலை மாற்றத்திற்கு வழிகோலுகிறது. இன்றைய சமுதாய மக்கள் இயற்கை உணவினை பெருதும் விரும்புகின்றனர் காரணம் கிருமி நாசினிகள் பாவிக்கப்பட்ட உணவுகளால் தமது உடலுக்கு தீங்கு விளைவிக்கும் என்பதாலேயே அன்றி இயற்கையை பற்றி சிந்தித்து இயற்கை உணவினை விரும்பும் மக்கள் மிக குறைவு.

சுற்றுச்சூழலையும் பாதுகாத்து உணவுத்தேவையினையும் பூர்த்தி செய்ய வேண்டிய சூழ்நிலையில் இன்று நாம் இருந்து கொண்டிருக்கின்றோம். சுற்றுசூழலை பாதுகாப்பதற்காக வெறுமனமே மரங்களை நாட்ட முடியாது ஏனெனின் சூழலை பாதுகாக்ககூடிய இயற்கை சூழல் உருவாக்கப்பட்டாலும் உணவுக்கான தேவை இருந்து கொண்டிருக்கும். உணவுத்தேவைக்காக பல்படைகளை கொண்ட இயற்கை சூழலை அழித்து தனிப்பயிரையும் பயிரிட முடியாது (படம் 01) காட்டப்பட்ட படத்தில் உள்ளது போலே உயிரின பல்வகமை அழிக்கப்பட்டு சூழல் சமநிலை குழப்பப்படும் இதற்கு உணவு தேவைகளை பூர்த்தி செய்ய கூடிய காடுகளை உருவாக்குவதே சிறந்த முறையாக இருக்கும். அதன் ஒரு முறையாகவே ஐந்தடுக்கு முறையிலான உணவு காடுகளை முல்லைத்தீவு, மல்லாவியில் அமைந்துள்ள எமது இயற்கை விவசாய பண்ணையில் முன்மாதிரி துண்டமாக மாதிரி ஐந்தடுக்கு உணவு காட்டினை உருவாக்கி சிறந்த பெறுபேற்றை கண்டுள்ளோம். இது இயற்கையாகவே உருவான காடுகளிற்கு ஒப்பானதாக காணப்படுகின்றது. இங்கு உணவு தேவையினை பூர்த்தி செய்யும் மரங்கள் மற்றும் பயிர்கள் விதானத்திற்கு ஏற்றவாறு நாட்டப்பட்டன. புவியிற்கு முதன்மை சக்கி முதல் சூரியனாகும் இந்த சக்கி முதலினை பயன்படுத்தியே பயிர்களுக்கான ஒளித்தொகுப்பு நிகழ்கின்றது. ஓவ்வெரு பயிகளுக்கும் நிலத்திலள்ள போசனை சக்திக்கான போட்டியை விட ஒளிக்கான போட்டியே அதிகமாக காணப்படுகின்றது. இதனை கருத்திற்கொண்டே ஐந்தடுக்கு பயிர் செய்கையில் பயிர்களுக்கான இடைவெளி தீர்மானிக்கப்படுகின்றது ஒரு பயிரின் கீழ் இன்னெரு பயிராக அடுக்காக பயிரிடப்பட்டது. காற்றினால் மரங்கள் அசையும்போது ஏற்படும் சூரிய ஒளியினால் கீழுள்ள பயிர் ஒளியினை பெற்று அதற்கான தொழிற்பாடுகளை மேற்கொள்கிறது. இந்த முறையின் கீழ் 0.25 ஏக்கர் நிலப்பரப்பில் 15 வகையான பயிர்களை நாட்டப்பட்டது பல்லாண்டுப்பயிராக

கொய்யா,மா,பலா ஆண்டுப்பயிராக வாழை,பப்பாளி,முருங்கை போகப்பயிர்களாக மரக்கறிப்பயிர்கள் கத்தரி,மிளகாய்,வெங்காயம்,கீரை. மறுவயற் பயிராக உழுந்து, கொளபீ, கிழங்கு பயிர்களாக இராசவள்ளி, கரணைகிழங்கு மலர் பயிராக செவ்வந்தி போன்ற பயிர்கள் நாட்டப்பட்டது. ஐந்தடுக்குமுறை உணவுக்காட்டின் உட்புறமான தோற்றம் அருகில் படத்தில் உள்ளது. இதன் உட்புறத்தில் நுளையும் போது ஒரு இயற்கையான காட்டு சூழலிற்குள் நுழைவது போன்ற உணர்வையே எப்பொழுதும் கொடுக்கும். இதனினுள் உள்ள நிலத்தின் அமைவு காடுகளுக்கு ஒப்பானதாக அமைந்துள்ளதை காணக்கூடியதாக இருந்தது. ஏனெனில் உள்ளிருக்கும் தாவர கழிவுகள் எதுவுமே வெளியில் எடுத்து செல்லப்படுவதில்லை நிலத்திலேயே விடப்படுகின்றன. இவை தாமாகவே உக்கி சேதன படையாக மாறுகின்றன.

ஐந்தடுக்கு பயிர்செய்கை இயற்கை முறையிலே மிகவும் சாத்தியமானதாக இருக்கின்றது. இந்த முறையில் பயிர்செய்கை மேற்கொள்ளும் போது மேலே குறிப்பிட்ட போல் பயிர்களுக்கான பீடைத்தாக்கம் நோய்த்தக்கம் மிக குறைவானதாக இருக்கின்றது. பயிர்களின் மிகுதி கீழேயே விடப்படுகின்றது. இதனால் உக்கலடைந்து போசனையாக மாற்றப்படுகின்றது. இது ஒரு சுழற்சிமுறையிலான செயற்பாடாக தொடர்சியாக செயற்படும். இயற்கை காடுகளை போல் ஒத்திருப்பதால் பறவைகள்,தேனீக்கள் மற்றும் விலங்குகளின் நாட்டம் அதிகமாக காணப்படும்.இயற்கையாகவே உருவான காடுகளை கருதினால் அங்கு மேற்குறிப்பிடப்பட்ட விலங்குகளின் நடமாட்டம் சாதாரணமாகவே காணப்படும் ஏனெனில் அங்கு எதுவித இரசாயன பாவனையும் காணப்படாததினால் அவற்றின் நடமாட்டம் அதிகமாக காணப்படும் ஓர் சூழற்தொகுதி இயற்கையானதா அல்லது இரசாயனம் வீசப்பட்டதா என அறிவதற்கு இவை சிலந்தி, மண்புழு தேனிக்களின் குடித்தொகை அல்லது நடமாட்டத்தினை வைத்தே கணிப்பிடலாம். நச்சு இரசாயனத்திற்கு இவை உணர்திறன் கூடியவை நச்சு இரசாயனம் காணப்படுமிடத்து இவை குறைவாக காணப்படும் அல்லது இல்லாதிருக்கும் ஐந்தடுக்குமுறை உணவுக்காட்டில் தாமாகவே உருவான தேனீக்குடித்தொகை படம் 03 காட்டப்பட்டுள்ளது.

ஐந்தடுக்குமுறை உணவுக்காடுகள் இயற்கை காடுகளை ஒத்திருப்பதனால் இங்கு நீர் வட்டம், காபன் வட்டம், நைதரசன் வட்டம் போன்ற வட்டங்கள் சீராக காணப்படும் மற்றும் முழுவதுமாக தாவரங்களால் சூழப்பட்டிருப்பதனால் நிலைபேறான பச்சைவீட்டு விளைவு கொண்டிருப்பதோடு சீரான உணவுத்தேவை பூர்த்தியாக்கப்படும். இதனை விட இவ் செய்கைக்கு மற்றைய பயிர் செய்கை கோலங்களுடன் ஒப்பிடும் போது இதற்கான நீர்த்தேவை குறைவாகும். தேவையற்ற நீர்பாசணம் குறைக்கப்படுவதால் நிலத்தடி நீர் காக்கப்படும். காலநிலை மாற்றமானது ஒரு சூழற்தொகுதி தாக்கப்படுவதாலே அல்லது அழிக்கப்படுவதினாலோ ஆரம்பிக்கின்றது. ஆகவே எம்மை அண்டிய சூழற்தொகுதியை பாதுகாப்பதினாலும் அழிவிலிருந்து காப்பதினாலும் காலநிலை மாற்றத்திற்கான காரணிகளை குறைத்து காலநிலை மாற்றத்தை குறைப்போம்.

படம் 03: ஐந்தடுக்கு உணவுக்காட்டில் தாமாக வருகை தந்து குடியேறிய தேனி குடித்தொகை

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Healthy farming and Healthy soil to Combat Climate Change

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Key words:

SOIL-CLIMATE INTERACTION, MICROORGANISMS, SOIL CARBON SEQUESTRATION, BIOFERTILIZER

- **It is very important to understand soil-climate interactions through which changes in soil properties and processes will lead to reduce greenhouse gas emissions**
- **Detrimental effects of excessive use of agrochemicals on soil micro organisms**
- **Importance of introducing microbial inoculants to enhance carbon sequestration in agro-ecosystems to mitigate climate change.**

Climate change is a global crisis affecting living as well as non-living ecosystems on Earth. Anthropogenic emission of greenhouse gases, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), is the most significant contributors to climate change.

Due to the greenhouse effect resulting in global warming and melting of polar ice caps, alteration in biogeochemical cycles, altered rainfall, ocean acidification, eutrophication of lakes, imbalance in the ecological communities and extinction of some species, effects on soil fertility, changes in the metabolism at the molecular level of microorganisms can occur.

Plants and microorganisms act as a natural CO_2 filter. Several biomolecules, such as carbohydrates, proteins and lipids, are produced due to the biological carbon fixation process using photosynthesis. Diverse species of plants and microbes, such as bacteria, fungi, yeast and algae, are involved in atmospheric CO_2 fixation through photosynthetic pathways and some non-photosynthetic pathways.

Due to rapid growth of global population, in order to increase yield of crops, farmers tend to apply inorganic fertilizers and pesticides in large quantities, predominantly in developing countries. This puts not only human wellbeing at risk, but also environment health as well as the global climate.

Long-term excessive applications of chemical fertilizers in agriculture may result in adverse impacts on soil functions and may lead to increased nitrous oxide emissions. Nitrous oxide can contribute significantly to atmospheric warming because this greenhouse gas absorbs 300 times more radiation than carbon dioxide. It is also the most important stratospheric-ozone-depleting chemical emitted by human activities (Grace and Barton, 2014). Therefore, scientists are trying to identify strategies to reduce nitrous oxide emissions from agricultural soil.

There are a number of approaches, which can be used on a sustainable basis, to meet food requirements without compromising environmental health. Among these, use of microbial products is pivotal to ensuring food security in a changing climate (Timmusk *et al*., 2017). Microbial approaches can successfully be used for sustainable agricultural development. These

microbes can enhance plant growth by improving nutrient availability to crop plants through various mechanisms thus decreasing the dependence on chemical applications.

This article provides an overview of some literature on microbial inoculation as a way to either replace or reduce the use of agrochemicals and reduce impacts of climate change while increasing crop yield.

Soil Contributions to Mitigate Climate Change Impacts

The goal of the Paris Agreement is limiting global warming to less than 2˚ C above pre-industrial levels to avoid the adverse effects of climate change. According to the Intergovernmental Panel on Climate Change (UNEP,2022), achieving this will likely involve removing huge quantities of carbon dioxide from the atmosphere.

Capturing and storing the carbon emissions from biofuel-burning power plants, or planting new forests to absorb carbon, would require large areas of land, water and energy. But soil carbon sequestration is a process in which CO_2 is removed from the atmosphere and stored in the soil carbon pool. Currently, soils remove about 25 percent of the world's fossil fuel emissions each year.

Fertile soils produce more food, promote biodiversity, hold moisture better, and are less susceptible to erosion, floods, nutrient loss, and desertification. Microbes in the soil enable plants to grow deeper root systems that allow them to tolerate drought better, and be more resistant to pests. Enhanced carbon in soils improves soil and water quality increasing resilience to the impacts of climate change (Malhi *et al*., 2021).

Soil conservation
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Soil Climate Interaction

Soil is a key link in several global nutrient cycles. The carbon and nitrogen cycles are the most important contributors to soils and climate change interactions because carbon and nitrogen are important components of soil organic matter and because carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the most important long-living greenhouse gases.

The balance between carbon added to the soil and carbon emitted from the soil determines whether the overall carbon levels in a given soil increase or decrease. When carbon levels in a soil increase, that carbon is taken from the atmosphere, decreasing atmospheric levels, and when carbon levels in a soil decrease, that carbon is added to the atmosphere, increasing atmospheric levels.

Increased soil temperatures can result from warming of the ground once the forest canopy has been removed. Therefore, while soil carbon loss has contributed to increased CO_2 levels in the atmosphere, it also provides an opportunity to store some of this carbon in soil through reforestation (Malhi *et al*., 2021).

Soil Carbon Sequestration

Soil carbon sequestration is a process in which CO_2 is removed from the atmosphere and stored in the soil carbon pool. This process is primarily mediated by plants through photosynthesis, with carbon stored in the form of Soil Organic Carbon (SOC). In arid and semi-arid climates, soil carbon sequestration can also occur from the conversion of CO_2 from air found in soil, into inorganic forms such as secondary carbonates (Lal, 2004).

Natural method to sequester carbon involves plants and microorganisms, including bacteria, algae, fungi and yeast through two pathways. They are the photosynthetic and non-photosynthetic pathways Figure 1. Autotrophic and

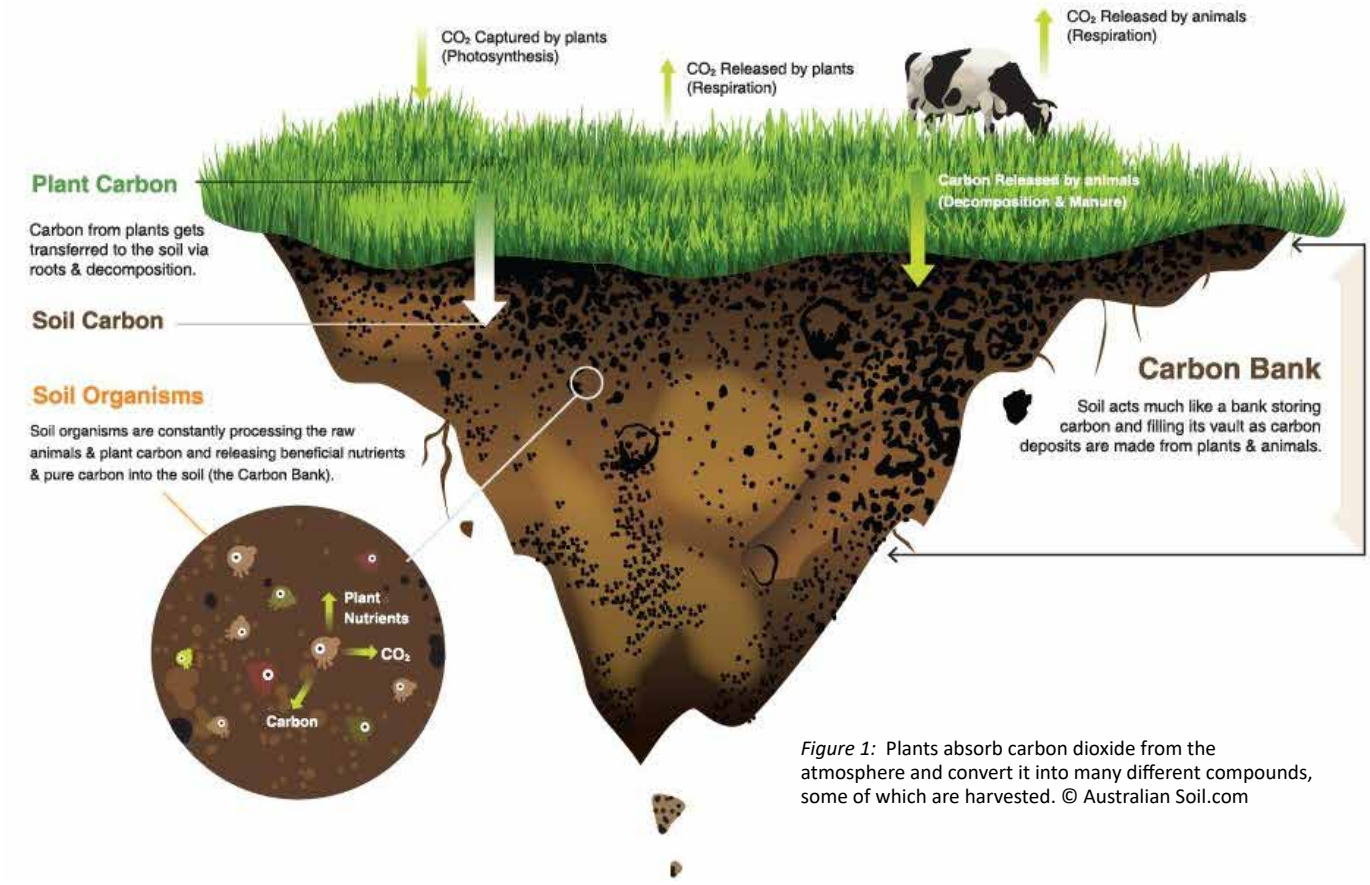


Figure 1: Plants absorb carbon dioxide from the atmosphere and convert it into many different compounds, some of which are harvested. © Australian Soil.com

heterotrophic organisms incorporate CO_2 into various organic carbon products such as cellulose, lignocellulose, chitin, hemicellulose, lignin etc (Lal, 2004).

Soil Microorganisms and their Contribution in Carbon Sequestration

The rhizosphere, which is the region of soil surrounding the roots, has the greatest concentration of microorganisms. This type of microbial communities depend on the root exudate. Manipulating the rhizosphere can change microbial diversity and could improve plant performance by influencing water dynamics and enzyme activities. A wide range of microscopic organisms inhabits the rhizosphere: bacteria, algae, fungi, protozoa and actinomycetes. Of these, bacteria is the most abundant and important group of microorganisms regarding plant growth and productivity (Bardgett *et al*., 2008). They either live freely in rhizosphere, or in inter and intracellular spaces of root tissues, forming symbiotic associations with plants (Nadeem *et al*., 2014).

Soil microorganisms have the ability to affect the organic matter quantity and quality, which can affect soil ecology and properties. By regulating different pathways, fungi and bacteria contribute differently in soil carbon sequestration such as possessing metabolic activities that can capture CO_2, the ability to sediment carbonates, the recalcitrant nature of their vegetative and products tissues, or the formation of stable forms such as soil aggregates that protect carbon in soil.

In a symbiotic relationship, the plant gains nutrients gathered from the greater soil volume explored by mycorrhizal hyphae, and the fungi obtains photosynthate carbon directly from the plant. Thus, the primary contribution of mycorrhizal fungi to carbon sequestration is as an additional source of carbon input to soil organic matter. This occurs, indirectly, through the generally positive effect of the mycorrhizal symbiosis on plant growth, particularly in low phosphorus soils.

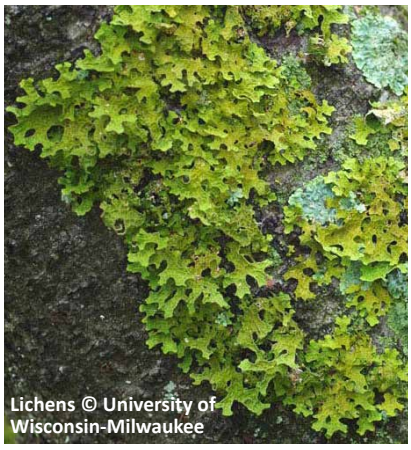
Fungi facilitate carbon sequestration in soil by forming organic humus and maintaining the carbon balance, thereby largely contributing to carbon capture and storage in the terrestrial ecosystem when compared to bacteria. There are three methods involved in soil carbon storage: incorporating recalcitrant biomass and their secondary products, producing soil aggregates and incorporating atmospheric CO_2 into fungal biomass. The mycelium acts as a storage site for the carbon. Thus, a large amount of biomass is produced by efficiently incorporating CO_2 at a higher percentage (Bardgett *et al*., 2008).

Effects of Fungal Mycelia, Proteobacteria and Algae on Carbon Sequestration

Fungi contribute to carbon accumulation and losses in soil through fungal biomass and by-products production as well as fungal necromass degradation. Carbon accumulation by fungi in soil varies depending on fungal species and fungal biomass content. Fungal mycelium is one of the vegetative tissues which grow and spread into soils in order to provide the fungi with the required water and nutrients. The production of extrametrical mycelium could reach hundreds of kilograms per ha per year. Since fungal mycelium is built up by carbon, the more fungal mycelia produced, the more carbon is captured in the soil. Therefore, fungal mycelia could be considered as a vital carbon sink to the soils.

For thermal adaptation, fungal hyphae (mycorrhizal fungi) and spores secrete glomalin protein. The glomalin is thick, sticky and acts as a recalcitrant to resist decomposition. Glomalin promotes carbon capture via two processes: making the fungal hyphae resist decomposition and endorsing soil aggregation. Thus, the carbon is ceased within the hyphae and soil aggregate for a prolonged period. Glomalin is found to be the principal substance responsible for the formation of stable soil clumps along with permeability to H_2O and air (Ahmed *et al*., 2019). Its hydrophobic nature protects the soil clump from microbial degradation and erosion. Hence, the organic carbon and nutrients located within the clump remain protected for more than 50 years. Thus, glomalin acts as a carbon sequester in the terrestrial carbon pool and promotes soil quality. Fungal species present in the following genera secretes glomalin protein; they are Entrophospora, Gigaspora, Acaulospora, Scutellospora, Glomus, etc.

Proteobacteria are large phyla which are capable of incorporating atmospheric carbon dioxide *via* various biological mechanisms such as the calvin cycle/



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reductive pentose phosphate cycle, TCA cycle/Krebs cycle and also directly in the cytoplasm.

Algae are the most efficient photosynthetic biofactories that incorporate CO_2 into biomass and energy. They range from macro to micro in size. Macroalgae produce high lipid content; hence they are directly used in the production of biodiesel (Ahmed *et al*., 2019).

Soil Microorganisms that Protect Plants, a Pioneer in Mitigating Climate Change

In the rhizosphere, plants continually secrete synthesized food through their roots, nourishing a diverse community of soil rhizobacteria, which in turn can strongly influence plant development by performing vital functions for the plant. They are allies of plants, governing several fundamental processes related to plant growth. One of the important functions of Plant Growth Promoting Rhizobacteria (PGPR) is phosphorus (P) solubilization in the soil (Nadeem *et al*., 2014). The dynamics of phosphorus in soils are complex. Its availability for plants is often totally dependent on Phosphate Solubilizing Bacteria (PSB). These are heterotrophic bacteria that secrete organic acids, which solubilize fixed forms of phosphorous and release available forms into the soil solution (He *et al*., 2002).

Endophytic bacteria are the plant beneficial bacteria that thrive inside plants and can improve plant growth under normal and challenging conditions. They can benefit host plants directly by improving plant nutrient uptake and by modulating growth and stress related phytohormones. Indirectly, endophytic bacteria can improve plant health by targeting pests and pathogens with antibiotics, hydrolytic enzymes, nutrient limitation, and by priming plant defenses.

(Afzal *et al*., 2019)

Heterotrophic bacteria have since been reported to be associated with almost every plant species. Their role in a plant's life is integral and their presence is considered as vital for plant function as nutrients, sunlight, and water.

Specific endophytes play an important role in plant protection against soil borne pathogens. Fungal pathogens are the most lethal to plants, but due to the antagonistic activity of hydrolytic enzyme producing bacteria their presence is rarely observed. Therefore, the application of bacteria as biopesticides could significantly reduce the use of agrochemicals for sustainable crop production. For example, in many crops, like sugarcane, tomato, and potato, inoculation by rhizobacterial

strains resulted in complete prevention of pathogenic development due to the production of antibiotic substances, resulting in Induced Systemic Resistance in crop species. Bacteria are known to produce hydrolytic enzymes and binding proteins in plants that efficiently control bollworms, mosquitoes, blackflies and beetles. Endophytic bacteria have been known to suppress competing weeds through allelopathy effect (Afzal *et al*., 2019).

Effect of Chemical Fertilizers on Soil Biota

Modern agriculture is largely dependent upon fertilizers of various types in the form of nitrogenous, phosphate, and potassium fertilizers. Continuous utilization of chemical fertilizers is responsible for the decline of Soil Organic Matter (SOM) content coupled with a decrease in the quality of agricultural soil. The overuse of chemical fertilizers hardens the soil, reduces soil fertility, pollutes air, water, and soil, and lessens important nutrients of soil and minerals, thereby bringing hazards to the environment.

Chemical fertilizer utilization has a negative effect on soil microorganisms. There is a huge possibility of changing soil conditions such as pH of soil. Formation of soil crust results in decreasing organic matter load, humus load and useful organisms. Continuous use of chemical fertilizers become responsible for the emission of greenhouse gases.

Application of bio-fertilizers

Biofertilizers are called bioinoculants as they are the preparations containing living or latent cells of microorganisms that facilitate crop plants uptake of nutrients by their interactions within the rhizosphere which is applied through seed or soil. It accelerates bound microorganism processes within the soil that augment the extent of conveyance of nutrients assimilated by plants. Use of biofertilizers has several other advantages as well. They are cost effective, eco-friendly and renewable sources of plant nutrients that form one of the important components of integrated nutrient management.

The application of bio-fertilizers that contain living microorganisms in agricultural practices can help to increase soil fertility in arable soils.

Application of Chemical Fertilizers © agrimate.org

How Pesticides Harm Soil Life

Herbicides, insecticides and fungicides: all chemical compounds are pesticides, designed to kill, each with their own targets and mechanisms of action. Many of the pesticides contain heavy metals. As little as 0.1 percent of an applied pesticide interacts with its targeted weed

How Pesticides Are Harming Soil Ecosystems © Civil Eats


Organic gardening © 2015 World Vision

or pest. The remainder contaminates the soil, air and water and can have significant non target effects throughout the ecosystem.

Toxicity issues can also be passed on from soil to humans through the food we consume. Elevated atmospheric CO_2 concentrations may lead to increased uptake of cadmium and arsenic in rice (Balbinot *et al*., 2021).

Contribution of Chemical Fertilizers and Pesticides to Climate Change by Affecting Soil Biological Process

Enhanced microbial production in expanding agricultural lands that are altered with fertilizers and manure is believed to be the primary driver behind increased atmospheric N_2O levels. As nitrogen fertilizer applications increase, denitrification and the generation of N_2O in the soil also increases. Emissions of N_2O are usually lower in organic farming systems than in conventional systems (FAO & UNEP, 2021).

The carbon and nitrogen cycles are key parts of the global climate system, and soils are an integral part of these cycles. Agriculture contributes a particularly large percentage of annual anthropogenic CH_4 emissions to the atmosphere. Agricultural management decisions have a profound influence on whether soils are net sources or sinks of the greenhouse gasses CO_2, CH_4, and N_2O, indicating that management systems have the potential to influence climate change.

Pesticides in the soil impact the non-target and useful microorganisms and their activities. The effect of pesticides on soil microorganisms and their activity depends upon the types and quantities of pesticides used and soil conditions (FAO &UNEP, 2021).

Overuse of pesticides;

a) Alter biochemical processes
b) Inhibit nitrogen fixation
c) Damage soil ecology

The application of pesticides such as glyphosphate affect the ecology of mycorrhizal fungi; affect the life cycle of earthworms; increase pathogenic microorganisms in soil, etc. Further, the application of a mix of pesticides are more harmful to the ecology and environment.

Especially, pesticides are a threat to the complex living community of the soil, and mounting evidence shows that overuse of pesticides is decimating pollinators and other insects that are central to a sustainable food system. Honey bees, butterflies, wasps and small birds are important in agriculture to enhance yields, because they are pollinators. Even soil-borne earthworms are threatened due to the heavy use of pesticides.

Researchers predict that over 40 percent of insect species may face extinction in coming decades, leading to widespread ecosystem collapse, because of our indifference in this regard. And the most comprehensive scientific assessment to date warns that loss of biodiversity is a global challenge on par with climate change. Along with the environmental costs of agricultural pesticides, the human health costs are "catastrophic" (IPBES, 2019).

Microbial Inoculants and Carbon Sequestration

Microorganism-based inoculants that enhance carbon sequestration, nutrient uptake, promote crop growth, or protect plants from pests and diseases can replace agrochemicals in food production.

Bacteria exist in large numbers in soil compared to fungi. Some bacterial strains have the ability to reduce CO_2 and could contribute to carbon sequestration and to mitigate atmospheric CO_2 levels. Bacteria could contribute to carbon sequestration through different pathways and metabolic activities. *Pseudomonas fluorescens* is a plant growth-promoting bacterium that could be a useful tool for carbon sequestration and climate change mitigation. These microbial inoculants increase plant productivity as well as having potential to mitigate high atmospheric CO_2 levels by increasing terrestrial carbon

sequestration, particularly in high-CO_2 ecosystems. Carbonate induction by some bacteria has the potential to capture atmospheric CO_2 and sequester carbon. *Bacillus mucilaginosus* produces carbonic anhydrase that first captures the atmospheric CO_2 and then fixes the atmospheric CO_2 through bacterial metabolism (Zhang *et al*. 2011). This process induces carbonate formation to form organic substances or carbonated minerals by fixing CO_2 from the atmosphere, which leads to decreased CO_2 levels and increased carbon sequestration in soils.

Fungi exist in a smaller population than bacteria, but they dominate the soil biomass, especially when soil is not disturbed. Fungi contribute more than bacteria to carbon sequestration, organic matter formation and stabilization in soil (Six *et al*. 2006).

Using microbial inoculants in agricultural practices could help achieve desirable characteristics in soil. Bio-sequestration is the process that includes the natural capture and storage of CO_2 by photosynthetic organisms as well as soil microbes. Microbial inoculants could be used to increase the level of carbon inputs and decrease the levels of carbon outputs in the soils. Soil microbial communities have important roles in carbon sequestration and soil carbon emission. Choosing the right microorganism with right mechanism for a specific land is very important in order to increase carbon sequestration in soils.

Carbon dioxide bio-mitigation could be enhanced through genetic engineering by CO_2 capture or transformation via carbonic anhydrase, with biological fixation of the captured CO_2 to participate in biomass generation. Microorganisms could be genetically engineered to overcome low efficiency of CO_2 capture and fixation. Then, these microbes could be further studied for their ability to be used as microbial inoculants for carbon sequestration in agricultural lands.

For all these benefits, microbial inoculant is the best solution to improve the fertility of agricultural lands and to address adverse soil conditions that directly or indirectly affect crop yield and quality.

Conclusion

Sequestering carbon in soils is a relatively natural way of reducing carbon dioxide from the atmosphere with fewer impacts on land and water, less need for energy, and lower costs. Better land management and environmentally friendly agricultural practices could enhance the ability of soils to store carbon and help combat global warming. It is a beneficial strategy that could mitigate climate change, enhance soil quality and soil health, increase carbon levels in soil, improve agricultural production and enhance food security.

Microbial inoculation is one of the major agricultural practices that has been used to gain desirable characteristics in the soil by improving soil ecological conditions to enhance crop production. This might be achieved by introducing environmentally friendly microbial formulations with carbon sequestering ability in the soil.

Different types and species of soil microorganisms could affect carbon sequestration and storage differently in soil. Some bacterial species have been reported to contribute in carbon sequestration and atmospheric CO_2 mitigation.

Fungi also have been proven to sequester more carbon in the soil than bacteria. Fungal microbes are good candidates to be used as microbial inoculants to increase organic carbon in soils.

Microbial interventions can also be used to clean contaminated sites from accumulated pesticides, heavy metals, polyaromatic hydrocarbons, and other industrial effluents.

The reviewed literature shows that microbial inoculants can be successfully used as biofertilizers and biopesticides by using diverse plant growth promoting traits.

Even in Sri Lanka there are small and large-scale organic farming organizations still doing organic “Hela” farming by understanding the contribution of soil micro organisms to improve soil fertility. Even non-arable lands are re-cultivated after converting them to fertile land by enhancing microbial activity. Integration of traditional knowledge to increase microbial inoculation in soil and modern methods to increase soil fertility and increase carbon sequestration will enhance food security while mitigating climate change.


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වියැදුණ පසට යළි පණ දෙන ජීව අඟුරු

රුචිර ශ්‍යාමන්ත ගුණතිලක
දෙරණ පදනම
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මූලපද:

ජීව අඟුරු, පාංශු කාබන්, කෘෂිකර්මය සහ කාබන් තිරකීරීම

- වියැදුණ ලක්දිව පස.
- ජීව අඟුරු යනු මොනවාද?
- ජීව අඟුරු පසට එකතු කිරීමේ තාක්ෂණික අතීතය.
- ජීව අඟුරු සහ ක්ෂුද්‍රජීවියෝ
- ජීව අඟුරු කෘෂිකාර්මික ජයග්‍රහණයන් සඳහා කෙසේ භාවිතා කළ හැකි ද?

ජීව අඟුරු © Eater

හැඳින්වීම

ශ්‍රී ලංකාවේ සරු පසක් ඇති බව කවියන් කීව ද නිවර්තන කලාපීය රටක් වන අප රටේ පස එතරම් සරු නැත. නමුත්, මේ අපේ මහපොළොව නිසරු නොවේ. එය සොබාදහමට අවශ්‍ය පමණට සරුය. සිංහරාජ වනාන්තරය ඊට නිදසුනකි. ලෝකයේ පෙව විවිධත්ව උණුසුම් ස්ථාන ලෙස නම් කළ මුල්ම ස්ථාන 36 අතරට ද අපේ රට ඇතුළත් වූයේ වී නිසාය. නමුත්, ගොවිතැන ගත් විට මෙරට පස අපේ අපේක්ෂාවන්ට තරම් නිෂ්පාදනයක් ලබා නොදෙයි. එබැවින්, බාහිර යෙදවුම් මත ගොවිතැන් කටයුතු පවත්වාගෙන යෑම පසුගිය දශක කිහිපය තුළ සිදු විය. එහි ප්‍රතිඵලය වූයේ ගොවිතැනත් ගොවියාත් පිරිහීමයි. එහෙත් මෙම විනාශකාරී ගොවිතැන් ක්‍රමයෙන් එපිටට යාමට හා ලෝකයේ උසස් තත්වයේ ගුණාත්මක ආහාර නිෂ්පාදකයෙකු වීමේ හැකියාවක් මෙරටට පවතී. ලෝකයේ හොඳම තේ, හොඳම කුරුඳු, හොඳම ගම්මිරිස්, හොඳම කහ ආදී කෘෂිකාර්මික නිෂ්පාදන රාශියක් අපිට අපේ මහපොළොව ඇයිති කර දෙන්නේ ඒ නිසාය.

නමුත්, ඉහළ අස්වැන්නක් අපේක්ෂාවෙන් අබණ්ඩව යොදන්නට වූ බාහිර යෙදවුම් නිසා වූයේ පසේ ඇති ගුණාත්මකභාවය ක්‍රමිකව විනාශවීමයි. එබැවින් නැවතත් අපි අපේ පොළොව වටහාගෙන එහි යහගුණය වඩවමින් සාර්ථක කෘෂිකාර්මික සහ පාරිසරික ගණුදෙනුවක් සිදු කිරීම සඳහා කටයුතු කිරීම කාලීන ජාතික සහ ගෝලීය අවශ්‍යතා සමග ගැළපෙයි. එබැවින් උසස් අස්වනු ලබාදීම සඳහා පස සකස් කරන ආකාරය හා පුනරුත්ථාපනය කළ යුතු ආකාරය පිළිබඳ වඩා පැහැදිලි සහ තහවුරු වූ විද්‍යාත්මක ප්‍රවේශයක් හඳුනා ගැනීම වැදගත් සහ කාලෝචිත කරුණකි.

ජීව අඟුරු තාක්ෂණය පාරිසරික හා කෘෂිකාර්මික ප්‍රගමනය සඳහා වැදගත් වන තාක්ෂණයකි. ඒ පිළිබඳ මෙම ලිපිය වසර දහයක පමණ අත්දැකීම් සහ දැනුම පදනම් කරගෙන එහි සාර්ථකත්වය පිළිබඳව සාක්ෂි සහිතව සකස් කර ඇත. කලක් තිස්සේ විවිධ බලධාරීන් වෙත මෙම තාක්ෂණය ඉදිරියට ගැනීම සඳහා කරුණු ඉදිරිපත් කළ ද ඔවුන් අතර මෙම විෂය පිළිබඳව වූයේ ඇල්මැරුණු ආකල්පයකි. නමුත්, තිරසර කෘෂිකර්මයක් පිළිබඳ රටේ අවධානය යොමු වූ මෙම අවස්ථාව ජීව අඟුරු ක්‍රමවේදය පිළිබඳ නැවත විතාවක් සිතා බැලීමට කාලයයි.

ජීව අඟුරු නිෂ්පාදනය
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ජීව අඟුරු තාක්ෂණය පිලිබඳ හැඳින්වීමක්

දහනයට පත්කළ හැකි ජීව කොටස් අළු තත්ත්වයට පත්වන්නට නොදී අඟුරු තත්ත්වයෙන් ආරක්ෂා කරගෙන, පාලිත තත්ත්ව යටතේ සෙල්සියස් අංශක 400 සිට ඉහළ උෂ්ණත්වයක පවත්වා එය සිසිල් කොට ජීව අඟුරු සකස්කර ගැනේ. වර්ණායෙන් කළුපාට වන, එකිනෙක ගැටීමේ දී සියුම් නාදයක් නිකුත් වන හා ඝනත්වයෙන් අඩු පෙව නිෂ්පාදනයකි. බනිජ තෙල් සහ ගල්අඟුරු මගින් බලශක්තිය නිපදවා මිනිසාගේ සුබසිද්ධිය සඳහා සිදු කරනු ලබන කාර්යයේ ප්‍රතිලෝමය ලෙස සැලකිය හැකි ස්වාභාවිකව දිරාපත් විය හැකි ද්‍රව්‍ය අර්ධ දහනයකට ලක් කොට ජීව අඟුරු සකස්කොට පසට යෙදීම මිනිසාට, පරිසරයට ලබාදිය හැකි මහඟු දායාදයකි.

ජීව අඟුරු යනු අපට අලුත් අත්දැකීමක් නොවේ. එදා හේන් ගොවියා ස්වකීය හේන වියළි කාලයේ දී කපා මහවැසි එන්නට මත්තෙන් ගිනි තබන්නේ ස්වල්ප කාලයකට පසු වැටෙන වැස්සෙන් එකී හේන් නිවී යන පරිදිය. එවිට, අර්ධ ලෙස දහනය වූ හෙවත් අඟුරු බවට පත්වූ ශාක කොටස් රැසක් අපට එම හේන තුළ දැකගත හැකිය. එම හේන 'නවදැලිහේන' ලෙස නම් විය. මෙසේ හේන තුළ නිෂ්පාදනය කරගත් එම අඟුරු කාලාන්තරයක් තිස්සේ එම භූමිය ස්වාභාවිකව පෝෂණය කළේය. එහි තැනින් තැන ඉතුරු කරන ලද ගස් යම් කාලයක හේන් අත්හැර ගිය විට එහි නැවතත් ශාක ප්‍රජාවක් නිර්මාණය කොට තවත් කලකදී නැවතත් වතාවක් අඟුරු සපයා දීම සඳහා සූදානම් වෙයි.

මෙම අත්දැකීම් තවත් ආකාරයකින් භාවිත කළේ දකුණු ඇමරිකානු රතු ඉන්දියානුවන් ය. ඉපැරණි 'මායා', 'ඉන්කා' ආදී ගෝත්‍ර සිය සශ්‍රීක ශිෂ්ටාචාර බිහි කරන ලද්දේ මෙම ජීව අඟුරු තාක්ෂණය පදනම් කරගෙනය. වැසි සුලබ ඇමසන් වනාන්තරයේ අඟුරු සකස්කර ගැනීම ඉතා දුෂ්කර බැවින් ඇමසන් ගඟ ආශ්‍රිතව නිර්මාණය කරන ලද හෙක්ටයාර භාගයේ සිට තුනක් පමණ දක්වා වන ඉතා කුඩා ගොවිබිම්වලට දර පිටතින් ගෙනැවිත් ඒවා අඟුරු කර පසට යෙදීමත්, නිවෙස්වල භාවිත කොට ඉතිරිවන ගිනි පෙනෙලිවලින් අඟුරු නිෂ්පාදනය කොට ගොවිබිමට දැමීමත් සම්ප්‍රදාය කරගත් ඔවුහු මෙම ජීව අඟුරුවලින් ඔවුන්ගේ ගොවිබිම් සරුසාර කර ගත්හ. මෙම සම්ප්‍රදාය වසර තුන්දහසකට වඩා පැරණි බවට

ඇමසන් ගඟ ආශ්‍රිතව කෘෂිකර්මය සඳහා ජීව අඟුරු නිෂ්පාදනය © Humintech

පුරාවිද්‍යාත්මක සාක්ෂි ඇත. එබැවින් කෘෂි විද්‍යාඥයන් විසින් නිවර්තන කලාපීය පස සාපේක්ෂව නිසරු පසක් ලෙස අද හඳුන්වාදුන්න ද එම කලාපයේම හමුවන ඇමසන් ගංගා නිම්නයේ පවත්නා ඒ සුවිශේෂී වෙතිහාසික වගාබිම්වල පස ලෝකයේ ඉහළම නිෂ්පාදිතතාවයක් පෙන්වන භූමි භාගයන් ලෙස හඳුන්වා දෙනු ලබයි. මෙම මිනිසා විසින් තැනූ විශේෂිත පසෙහි ඇති කාබන් ප්‍රතිශතය ඒ අවට ඇති පසට වඩා 70 ගුණයකින් පමණ වැඩි බව පර්යේෂකයෝ තහවුරු කරති. ඇමසන් කළු පස නැතහොත් ඇමසන් මැපික් පස ලෙස හඳුන්වන මෙම පස ලොව පුරා ප්‍රචලිතව ඇත්තේ පෘතුගීසි බසින් එම අරුත් දෙන ටෙරා ප්‍රිටා (Terra preta) යන නාමයෙනි.

මෙම ජීව අඟුරු නිපදවීම සඳහා විවිධ මූලාශ්‍ර යොදාගත හැකිය. දහයියා, ලී කුඩු, පිදුරු, ගොවිපළ වියළි අවශේෂ, දර, කුකුළු පොහොර, ගොම, තෘණ වර්ග ඒ


ටෙරා ප්‍රිටා පස © Pacific Biochar

අතර වෙයි. මෙම අවශේෂ දහනය කිරීම සඳහා විශේෂිත අටළු යොදාගැනීම අවශ්‍ය වන්නේ, දර අළු බවට පත් නොවී අඟුරු තත්ත්වයෙන් ආරක්ෂා කර ගැනීමටය. මෙම ක්‍රියාවලිය තාපවිච්ඡේදනය (pyrolysis) ලෙස හැඳින්වේ. මෙම ක්‍රියාවලිය සිදු කළ හැකි අටලුවලින් පිටවන තාපය ආහාර වියළීම වැනි ප්‍රයෝජනවත් කාර්යයන් සඳහා යොදාගන්නා අතරම මෙම ක්‍රියාවලිය ස්වයංසිද්ධව සිදුවන පරිදි නිර්මාණය කර ගත හැකිය. සෙල්සියස් අංශක 400ක පමණ උෂ්ණත්වයක සිට ඉහළට මෙම තාපවිච්ඡේදන ක්‍රියාවලිය ආරම්භ වන අතර, උෂ්ණත්වය ලබා දෙන වේගය අනුව සෑදෙන ජීව අඟුරුවල ගති ස්වභාවය වෙනස් වේ. ගෙදරදොර භාවිත කරනු ලබන දර පෙනෙලි අවශ්‍ය කටයුත්තට පසු අළු වන්නට නොදී වතුර දමා නිවා ජීව අඟුරු නිපදවා ගත හැක. තාප විච්ඡේදන ක්‍රමවේදයන් සහ එහි ප්‍රතිඵලය පහත (වගුව 1) දැක්වේ.

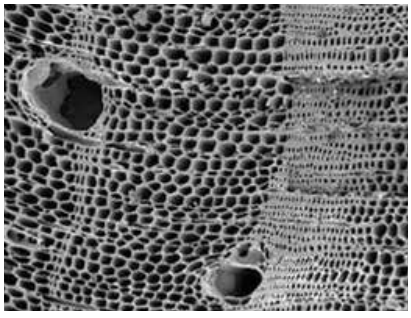
ක්‍රමය	රත් කරන වේගය	උෂ්ණත්වය	කාලය	අංශුවේ ප්‍රමාණය	නිපැයුම්		
					තෙල්	ගෑස්	අඟුරු
සෙමෙන් තාප විච්ඡේදනය	1-20°C මිනිත්තුවකට	400- 650°C	මිනිත්තුවේ සිට දිනක් දක්වා	1-200mm	ආසන්නව සමාන ප්‍රමාණයන්		
වේගවත් තාප විච්ඡේදනය	300°C < /තත්පරයට	700°C	තත්පරයක්	1mm	75%	5-15%	10-20%
වායුකරණය	1-100°C මිනිත්තුවකට	800°C <	මිනිත්තු 5 සිට 30 දක්වා	5-20mm	-	80%	10-20%

වගුව 1: තාප විච්ඡේදන ක්‍රමවේදයන් සහ එහි ප්‍රතිඵලය
මූලාශ්‍රය: Basic principles and practice of biochar production and kiln design.

ජීව අඟුරු හා ක්ෂුද්‍ර ජීවියෝ

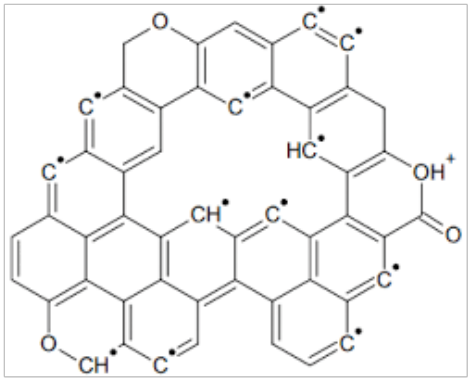
ජීව අඟුරු මගින් පසේ ජලය සුරක්ෂා කරයි. පසේ ජලය ප්‍රමාණවත් පරිදි ආරක්ෂා වීම නිසා පස අනවශ්‍ය ලෙස වියළීම වලකී. එම නිසා මෙම ජීව අඟුරු ආශ්‍රිතව ඉතා හොඳ බැක්ටීරියා සහ දිලීර ගහන නිර්මාණය වීමට හැකියාව ඇති වෙයි. මේ නිසා පසේ ක්ෂුද්‍ර ජීවී විවිධත්වය හා ගහනය සීඝ්‍ර ලෙස ඉහළ යයි. මෙම සාධකය පසේ ජීව ගුණය ඉහළ දැමීම සඳහා අවශ්‍ය මූලික කරුණකි. ප්‍රමාණවත් වසුනක් නොමැති, දැඩි හිරු රැසින් තදින් රත් වන මෙම ගොවි බිම්වල සීඝ්‍ර පදාර්ථ වියෝජනය සහ ක්ෂීරණය වීම ජීව අඟුරු මගින් නවත්වයි. එහි ඇති අධිශෝෂණ හැකියාව නිසා බොහෝ පාංශු පෝෂක පදාර්ථ ගිලිහී යා නොදී ඇද බැඳ තබා ගැනීමට ද ජීව අඟුරුවලට හැකියාව ඇත.

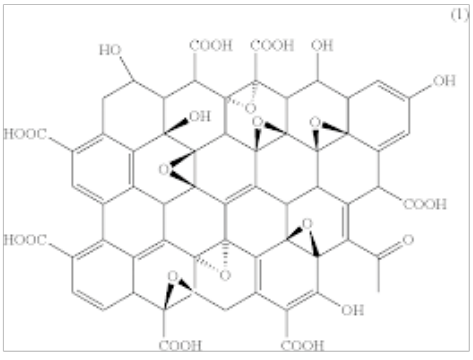
මෙම ජීව අඟුරුවල කාබන් ප්‍රතිශතය 65% කට වඩා වැඩිය. ක්ෂුද්‍ර ව්‍යුහයන් නිරීක්ෂණය කළ විට (ඡායාරූප 01) පෙනෙන කුඩා ක්ෂුද්‍ර කුටීර සිය වාසස්ථානය කරගත් බැක්ටීරියා ගහන පහසුවෙන් නිර්මාණය වන අතර (ඡායාරූප 02) අධික ලෙස සිදුවන වියළීම සහ සූර්යතාපයට නිරාවරණය වීම එමගින් පාලනය කෙරේ. එම නිසා බැක්ටීරියා ගහනයේ ආරක්ෂාව තහවුරු වෙයි. තව ද, දිලීර සහ බැක්ටීරියා අතර අන්තර් සම්බන්ධතා ද නිර්මාණය වෙයි. මේ අනුව අදාළ පරිසරයේ ජීවත් වන ක්ෂුද්‍රජීවීන් සඳහා ආහාර, ආරක්ෂාව සහ වාසස්ථාන සැපයීම මෙම ජීව අඟුරු මගින් සිදුවෙයි. මෙම ක්‍රියාවලියට අමතරව පසේ කාබන් ප්‍රතිශතය ඉහළ දැමීමට ද ජීව අඟුරු ඉතා ඉහළ මෙහෙවරක් ඉටු කරයි. එහි සුවිශේෂී හැඩය නිසා වැඩි කාබන් ප්‍රමාණයක් ස්ථාවර විශයෙන් රඳවා තැබීමට හැකිය. මෙහි කළු වර්ණය තාපය අවශෝෂණය කරන බැවින් පසේ උෂ්ණත්වය ඉහළ නැංවෙන අතර පාංශු ජෛව සහ මූලපද්ධතිවල ක්‍රියාකාරිත්වය වේගවත් වීමට ද එය හේතු වේ.



ඡායාරූප 01: ජීව අඟුරුවල ඉලෙක්ට්‍රෝන අන්වීක්ෂීය දර්ශනයක්. මෙහි ඇති කුඩා කුටීර වැනි ව්‍යුහ තුළ බැක්ටීරියා සහ දිලීර ජනාවාස පහසුවෙන් ඇති වේ. © healthyfields

වම් පස
ජායාරූප 02: ජීව අඟුරු මත නිර්මාණය වූ බැක්ටීරියා ජනාවාස ඉලෙක්ට්‍රෝන අන්වීක්ෂයෙන් පෙනෙන ආකාරය.
Chen Tu *et. al.,* (2020)





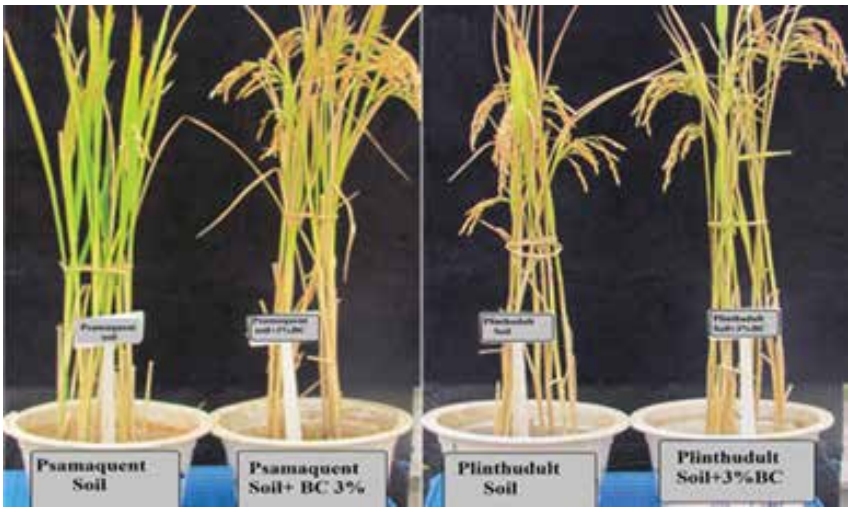
වම හා දකුණු පස
ජායාරූප 03: ජීව අඟුරුවල අණුක පදනම සංකීර්ණ ලෙස බැඳුන ඇරෝමැටික ව්‍යුහවලින් සමන්විත වේ.
මූලාශ්‍රය: Doctor-biochar. blogspot.

මෙම ජීව අඟුරුවල සුවිශේෂී අණුක ව්‍යුහය (ජායාරූප 03) නිසා වසර දහස් ගණනක් වුවද නොනැසී පැවතීමට හැකියාව ඇත. පසේ ඇතිවන පෝෂක බහුලත්වය හා තෙතමනය ආදී හිතකර ලක්ෂණ මගින් ශාකවල වර්ධනය ක්‍රමිකව වැඩි කිරීමට මේ මගින් පුළුවන. ඇතැම් විද්‍යාඥයන් විසින් කරන ලද පර්යේෂණවල ප්‍රතිඵලයක් ලෙස ඇතැම් භෝගවල අස්වැන්න 20% සිට 30% දක්වා ප්‍රමාණයකින් ඉහළ දමා ගැනීමට මෙම ජීව අඟුරු තාක්ෂණය භාවිතයෙන් හැකි බව තහවුරු කර ඇත. ඊට මෙම ජීව අඟුරුවල ඇති ශාක පෝෂක, එමගින් ඇතිකරන හිතකර pH පරාසය සහ පසේ වයනය මූලික වේ. ශාකවල වර්ධනය මනා ලෙස සිදුවීම නිසා එම ශාක කොටස් චක්‍රිය ලෙස නැවත ජීව අඟුරු බවට පරිවර්තනය කිරීම හෝ සත්ත්ව ආහාර ලෙස ලබා ගෙන අනතුරුව සතුන්ගේ වසුරු වෙන්ද්‍රීය පොහොර බවට පරිවර්තනය කිරීමට ද මෙම තාක්ෂණය හරහා වැඩි අවස්ථාවක් සැලසේ. මෙම ක්‍රමයෙන් වඩා වැඩි වාසියක් ලැබෙනුයේ ලංකාව වැනි නිවර්තන කලාපීය රටවලට ය. විහිදී සූර්යාලෝකය සහ උෂ්ණත්වයත්, වර්ෂාපතනයත් සැලකිය යුතු ප්‍රමාණයකින් ලැබෙන නිසා අපේ පොළොවේ හැදෙන ශාක වර්ග ජීව අඟුරු බවට පරිවර්තනය කිරීම තුළින් අපගේ පස ඉතා ඉක්මනින්ම ප්‍රතිඵලදායී තැනකට පත් කළ හැක.

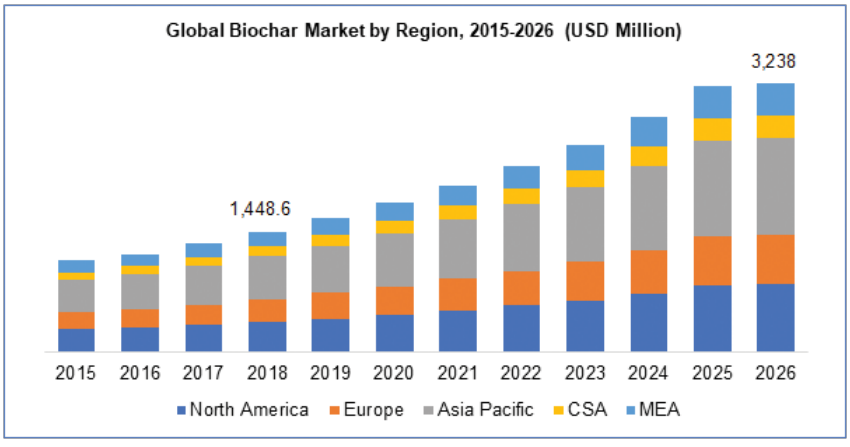
විශේෂයෙන්ම මෙරට පරිසරයට විශාල තර්ජනයක්ව පවත්නා ආගන්තුක ආක්‍රමණික ශාක ජීව අඟුරු නිෂ්පාදනයට යොදා ගැනීමෙන් මෙම ක්‍රමය හරහා තිරසර ලෙස පාලනය සහ මර්දනය කිරීම කළ හැකිය. මෙමගින් අති විශාල ආර්ථික වාසියක් අපට අත්කර දෙයි. එය දීර්ඝකාලීන ආර්ථික වාසියක් වන අතර දීර්ඝකාලීන පාරිසරික සත්කාරයක් ද ඇති වේ. එපමණක් නොව මෙරට කාබනික පොහොර නිෂ්පාදන අවශ්‍යතාවයට ද මෙමගින් 100% ක දායකත්වයක් ලබා දීමට පුළුවන. වනාන්තර එළි කර තනන නව වගා බිම් වෙනුවට පවත්නා වගා බිම්වල කෘෂි නිෂ්පාදිතාව ජීව අඟුරු තාක්ෂණය භාවිතයෙන් ඉහළ නංවා ගත හැකි නම් මෙරට වනාන්තර ආරක්ෂා වන අතර, ඉතා ඉහළ අස්වැන්නක් තහවුරු වීමෙන් ගොවියාගේ ආර්ථිකය ද ශක්තිමත් කර ගෙන රටේ ආහාර සුරක්ෂිතතාව ද තහවුරු කරගත හැකිය (ජායාරූප 04). මෙය ලංකාවට ජයග්‍රාහී සංවර්ධන මාවතකට එළඹීමට හැකි අවස්ථාවකි.

මෙම ජීව අඟුරු ලෝක මට්ටමින් ඉතා ඉහළ ඉල්ලුමක් ඇති ද්‍රව්‍යයක් බවට පරිවර්තනය වෙමින් පවතී. ගෝලීය ජීව අඟුරු වෙළඳපොළ 2026 වන විට ඇමරිකානු ඩොලර් මිලියන 3,238ක් වනු ඇතැයි ගණන් බලා ඇත. (වගුව 2) උතුරු ඇමරිකාව, යුරෝපය හා ආසියා පැසිපික් කලාපය තුළ මෙම වෙළඳපොළේ කැපීපෙනෙන ප්‍රසාරණයක් පසුගිය දශකය තුළ නිරීක්ෂණය විය. හොඳින් හිරු එළිය පවතින, හොඳ උෂ්ණත්වයක් පවතින ශාක වර්ධනයට අවශ්‍ය වන ජල පහසුකම් පවතින ලංකාව වැනි රටකට මෙම ජීව අඟුරු නිෂ්පාදනය අපනයන වෙළෙඳපොළ ඉලක්ක කරගෙන වුවද සිදු කළ හැකිය. අපේ පරිසරයේ ඉතා සීඝ්‍රයෙන් වැවෙන උණ ඇතුළු ශාක වර්ග යොදාගෙන කාර්මික නිෂ්පාදනයක් ලෙස ජීව අඟුරු නිෂ්පාදනය කළ හැකිය.


උණ ගස්වලින් ද ජීව අඟුරු සාදා ගත හැක © Santacol



ඡායාරූප 04: විවිධ පස් වර්ග සමඟ ජීව අඟුරුවල ක්‍රියාකාරිත්වය වෙනස් වන අතර, ඒ හැම පස් වර්ගයකම ඵලදායිතාව ජීව අඟුරු එකතු කිරීමෙන් ඉහළ දමා ගත හැක. *මූලාශ්‍රය:* Muhammad *et al.*, 2017



වගුව 1: ගෝලීය ජීව අඟුරු වෙළඳපල 2015 සිට 2026 දක්වා ලෝකයේ විවිධ කලාප අනුව
මූලාශ්‍රය: Polaris Market Reserch, 2019.

විශේෂයෙන් ගෝලීය උණුසුම පාලනය කිරීම සඳහා ජීව අඟුරු තාක්ෂණය අමිල මෙහෙවරක් කරනු නිසැකය. එනම් මෙම තාක්ෂණයේ දී ශාක තුළ තිර වන වායු-ගෝලීය කාබන්ඩයොක්සයිඩ්, නැවත පරිසරයට මුදා නොහැර අඟුරු වශයෙන් සැලකිය යුතු කාලයකට පොළොව තුළ ගබඩා කිරීමෙන් වායුගෝලයට නැවත එක්වීම වැලැක්විය හැකි නිසාය. මෙය සැලසුම් සහගතව කළමනාකරණය කළහොත් කෘෂිකාර්මික නිෂ්පාදනය ඉහළ දැමිය හැකි අතරම, ගෝලීය උණුසුම අවම කිරීමට සක්‍රිය ලෙස භාවිතා කළ හැක. එසේම කාබන් තිර කිරීම මඟින් කාබන් පියසටහන් ක්‍රමවේදි යටතේ ජාත්‍යන්තරයෙන් මුදල් ලබා ගැනීමේ හැකියාව පිළිබඳවත් අවධානය යොමු කිරීම මෙහි දී සලකා බැලිය හැකි වැදගත් ප්‍රතිපත්තිමය පියවර වෙයි. මෙවැනි ප්‍රායෝගික ක්‍රියාවලී තුළින් අපේ රටේ පාරිසරික. කෘෂිකාර්මික සහ ආර්ථික යන ක්ෂේත්‍ර ශක්තිමත් කොට මනා ජවයක් යටතේ ඉදිරියට ගෙන යා හැක.

බණිජ තෙල් යනු වසර මිලියන ගණනකට පෙර මිහිතලයේ ජීවත් වූ සත්ත්ව හා ශාක කොටස් වලින් නිර්මාණය වූ කාබනික පදාර්ථයකි. මෙම බනිජ තෙල් කැනීම් කොට භූ අභ්‍යන්තරයේ වූ සංචිත වලින් උකහා මිනිසාගේ ප්‍රයෝජනයට යොදවා එහි අතුරුඵල වායුගෝලයට කාබන්ඩයොක්සයිඩ් නිකුත් කරනු ලබයි. ඒ නිසා ගෝලීය උණුසුම ගෝලීය විපතක් ලෙස හිස ඔසවන අතර එම විපත අවම කර ගැනීමට ගත හැකි උපායක් ලෙස නැවත පසට ජීව අඟුරු එකතු කිරීම ප්‍රයෝජනවත්ය. එබැවින් ජීව අඟුරු තාක්ෂණය යනු භාවිත කිරීම අනිවාර්ය කළ යුතු තිරසර පාරිසරික සත් ක්‍රියාන්විතයකි.

ගෝලීය උණුසුම සෙල්සියස් අංශක එකකින් ඉහළ ගියහොත් ලෝකයේ සහල් නිෂ්පාදනය 3.2 ± 3.7% ප්‍රතිශතයකින් අඩු විය හැකි බව විද්‍යාඥයන් අනතුරු අඟවා ඇති තත්ත්වයක ජීව අඟුරු තාක්ෂණය යොදා ගතහොත් එසේ ඉහළ යාමට නියමිත පරිසර උෂ්ණත්වය අවම කිරීමටත් පහළ යාමට නියමිත නිෂ්පාදිතාව ඉහළ දමා ගැනීමටත් හැකියාව ඇත.

මේ අයුරින් ජගත් ප්‍රජාව ගෝලීය වශයෙන් මනා සැලසුමක් ඇතුව කටයුතු කළහොත් පසුගිය ශත වර්ෂය මුල් භාගයේ තිබූ හිතකර පාරිසරික තත්ත්වයට අපේ ලෝකය නැවතත් පුනරුත්ථාපනය කළ හැකිය. වායුගෝලයට එකතු වන කාබන් ඩයොක්සයිඩ් ප්‍රමාණය අවම කිරීම සඳහා ජීව අඟුරු තාක්ෂණය භාවිත කිරීම හා සංසන්දනය කළ හැකි තිරසර සහ කාර්යක්ෂම වෙනත් විකල්ප ක්‍රමවේදයක් මිනිසාට තවම හමුවී නැත.

එවිට ප්‍රභාසංස්ලේෂණය මඟින් වායු-ගෝලයේ කාබන්ඩයෝකසයිඩ් ඉවත්වීමේ ක්‍රියාවලිය පහත පරිදි විස්තර කළ හැක.

$6CO_2$ + පාංශු $12H_2O$ * → $C_6H_{12}O_6$ + $6O_2$ + $6H_2O$ (* හිරු එළිය සහ හරිත පත්‍ර) Ref[6]

මෙහිදී කාබන් ඩයෝකසයිඩ් ($6CO_2$) වායුගෝලයෙන් ලබා ගන්නා අතර ජලය ($12H_2O$) මුල් මඟින් උරා ගෙන සෛලම පටක හරහා පත්‍ර වෙත ලබා දී ප්‍රභාසංස්ලේෂණය සිදු කරයි. හිරුඑළිය ඇති විට ශාක පත්‍ර තුළ මෙම ප්‍රභාසංස්ලේෂණ ක්‍රියාවලිය සිදුවෙයි.

වගා කරන සෑම ගොවිබිමක හෙක්ටයාරයට 50kg බැගින් ජීව අඟුරු යෙදීම අනිවාර්ය කළ හැකි නම් ගත වන සෑම කන්නයකම පාහේ කෘෂි අස්වැන්න 30% ක් දක්වා ක්‍රමිකව ඉහළ නැංවිය හැකි බවට විද්‍යාත්මක සාක්ෂි එහි ලෝක භාවිතය දෙස බැලීමේදී මනාව තහවුරුවේ.

කෙසේ වෙතත් අළු අවම අඟුරු උපරිම ජීව අඟුරු නිපදවන අටළු මත මෙම ක්‍රියාවලියේ කාර්යක්ෂමතාව රැඳී පවතී. වෙළෙඳපළේ ජීව අඟුරු කිලෝග්‍රෑම් එකක් රු. 50 සිට ඉහළට විවිධ මිල ගණන් යටතේ අලෙවි කරනු අපට දැකගත හැක. යොදාගත් අමුද්‍රව්‍ය සහ පාරිභෝගික ඉල්ලුම එකී මිල ගණන් මූලිකව හේතු වේ.

පහල වම් පස
කෘෂිකර්මය තිරසර කර ගැනීම සඳහා ජීව අඟුරු යොදා ගත හැක © ARC2020

පහල දකුණු පස
පොල් වගාවේදී පස තිරසර කර ගැනීම සඳහා ජීව අඟුරු භාවිතය © Ghent University

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Creating habitats for pollinators by the roadsides

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- Pollination is one of the most important ecosystem services.
- Globally, pollinator populations are shrinking.
- Habitat loss, climate change, heavy use of agrochemicals and invasive species are threats to pollinators.
- Conservation, creation, management and restoration of habitats for pollinators are key solutions to protect pollinator diversity and density.
- Irrespective of the type of roadside structures they can be maintained or transformed into thriving pollinator habitats by growing pollinator-friendly plants, integrated vegetation management and reduction of mowing while still providing safety for road users.

Key words:

POLLINATION, ROADSIDE STRUCTURES, HABITAT LOSS, AGROCHEMICALS


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Introduction

Bees, butterflies, wasps, moths, birds and bats are common pollinators that carry pollen from one flower to another and help to produce seeds and fruits maintaining natural plant population and genetic diversity. Pollination is one of the most important ecosystem services which contribute to 35% of global crop production (Klein *et al*., 2007). Food security, food diversity and human nutrition depend strongly on pollinator services. Bees, both honeybees and pollen bees, are considered the most common and important pollinators that pollinate a vast variety of flowering plants, contributing to pollinate an estimated 87% of the world's flowering plants (Hung *et al*., 2018). Sri Lanka records a high diversity, comprising 150 species of honeybees and pollen bees (Karunaratna *et al*., 2005). Butterflies are also common pollinators, and more than 200 different butterfly species are recorded in Sri Lanka.

Pollinator Decline

Climate change, habitat fragmentation, urbanization and excessive use of agrochemicals have largely attributed to the world-wide decline in pollinator abundance, diversity, distribution and plant-pollinator relationships (Hallmann *et al*., 2017). Especially, the decline in diversity of bees has been documented worldwide, for example, 40% in the United Kingdom and 60% in the Netherlands (Brunet, 2019). In California (USA), native bee populations are reported to be inadequate to pollinate tree species and almond tree growers import honeybees from other contries such as Australia to pollinate the spring flowers. European Union member countries reported a decline by about 75% of pollinator population since 1990 (Hallmann *et al*., 2017; Van Swaay *et al*., 2019).

A drastic reduction in bee and butterfly population in Sri Lanka during the past few decades has also been

observed. The legendary seasonal butterfly migration to Adam's Peak has decreased . The common reasons for this observation can be the change or loss of natural habitats of bees and butterflies due to human activities such as land-use intensification, overuse of agrochemicals, emission of pollutants, encroachment of certain wild habitats by invasive species and climatic changes, especially temperature increases and prolonged droughts.

Pollinator Conservation

Globally, several measures have been taken to address the problem of ever declining pollinator populations and at the same time to raise awareness among people on the role of pollinators in the environment. Policies, national conservation plans, urban planners and landscape architects play a major role in pollinator conservation.

In Sri Lanka, the Ministry of Environment established a 'Pollinator Advisory Group' and initiated the publication of the 'Pollinator Conservation Action Plan of Sri Lanka (2012)'; Flower - visiting fauna of Sri Lanka: An inventory of pollinators (2020) and the Butterfly Conservation Action Plan of Sri Lanka (2014) and has encouraged the establishment of 'Butterfly Gardens' in an effort to encourage to conserve the pollinator fauna of Sri Lanka.

Habitat conservation, restoration and creation of pollinator habitats

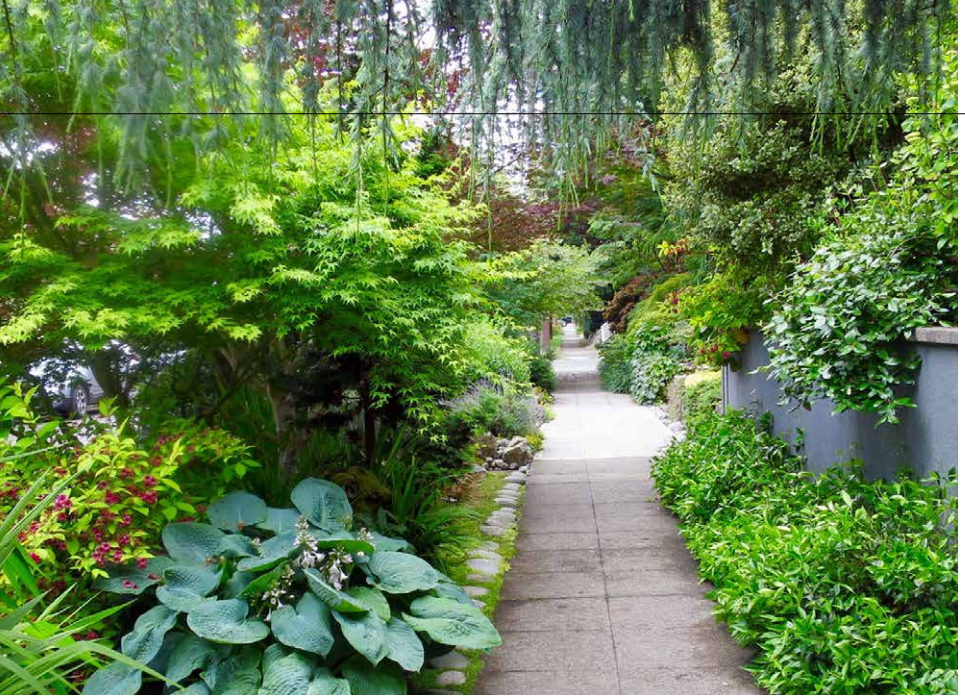
Pollinators need favourable natural habitats with flowering plants to live and forage for pollen and nectar. Efforts to protect existing natural pollinator landscapes are the preferred option. However, it is not always feasible to protect such natural habitats and, as an alternative, we must find ways to create new habitats. There are gaps in our knowledge on how to improve pollinator habitats and pollinator services in urban areas. European Union Pollinator Initiative (EUPI) established in 2018 addressed priority issues, namely improving knowledge on pollinator decline, tackling the cause of pollinator declines, raising awareness and engaging society to conserve pollinators and their habitat.

Protecting pollinators in agricultural settings is usually done during the planning phase of cultivation. Promoting pollinator-friendly spatial planning is an important concept. Fields and cropping systems e.g. alley cropping, cover crops and asynchronous planting, can be optimized to improve pollinator diversity and density (Figure 1).United States Department of Agriculture (USDA) conservation programs e.g. Conservation Reserve Program (CRP), encourage farm owners to create areas of pollinator-friendly plants, and award financial incentives. Cardamom farmers in India grow shade-trees e.g. coffee, in their fields to ensure continuous presence of pollinators. As another important strategy, these farmers grow a diversity of flowering tree species called 'sequential blooms' that can provide pollen and nectar resources for native bees around the year when neither cardamom nor coffee is blooming. In Colombia, farmers combine mixed cropping, herbal gardens and agroforestry systems which provide habitats on their farms for bees. Maintaining community gardens, home gardens and urban greenspaces benefit pollinator conservation (Figure 2). Designing and managing of urban spaces to create vibrant pollinator habitats have been initiated by many countries. Roadsides, hedgerows and field edges can be converted into thriving habitats for pollinators by facilitating with rich diversity of wildflowers and grasses that attract pollinators for nectar, pollen and nesting.

BELOW
Figure 1: Stripes of wildflowers across farmlands to enhance pollinator services (in England) © Rothamsted Research 2022

ABOVE TOP RIGHT
Figure 2: Community gardens-vibrant pollinator habitats (in Germany) © Tracey Byrne

ABOVE BOTTOM RIGHT
Figure 3:Lanes and paths grown with a variety of flowers to attract pollinators © John Gwynne



Roadsides as Pollinator Habitat

Creating or maintaining wild plant covers along roadsides is practiced in many countries as a popular and easy way of offering valuable habitat requirements for diverse pollinators. Roadside areas provide a range of nesting support and substrates such as leaf surfaces, pithy stems, small cavities in the stems, trenches and ditches, fulfilling different nesting requirements of pollinators. A small space or corridor along the roadside, whether a main road, a lane or a path leading to a house, can be grown with flower species of varied colour, shape, scent and differing times of bloom to support a different variety of pollinator species (Figure 3).

Growing native wildflower plants that are best adapted to a particular area will provide additional benefits like control of weeds and soil erosion, and attraction of more pollinators to native species. Neighbouring agricultural lands and wildlife ecosystems will benefit through improved pollination services.

Roadsides cover more than 10 million acres of land in USA. They have successfully managed roadsides to support, maintain and attract pollinators (Hopwood, 2014). State Departments of Transportation in USA improve pollinator habitat through Integrated Roadside Vegetation Management, especially by reduced mowing and strategic plantings of native shrubs and grasses and non-invasive plants (Galea *et al*., 2016) (Figure 4). This is one of the success stories of creating roadside habitat for pollinators, and counties organize competitions to maintain pollinator habitats and implement roadside maintenance practices that optimize necessary roadside activities (Galea *et al*., 2016).

North American Pollinator Protection Campaign has initiated pollinator-friendly roadside practices and offer Roadside Management Awards annually. One of the important criteria considered in awards is to demonstrate an exemplary long-term commitment to provide pollinator habitats along roadsides.

European Union (EU) Pollinators Initiative, commissioned in 2018, takes strategic actions to address the decline of pollinators in the EU and contribute to global improvement of pollinator habitats in urban areas including roadsides (Figure 5). A few examples are: Hannover, a city in Germany, viewed pollinators as a flagship species for biodiversity conservation and implemented action plans to restore and create roadsides as favourable habitats for pollinators (Region Hannover, 2016), integrated approach to biodiversity and pollinator conservation including potential roadside habitat development has been initiated by Edinburgh, UK, and Barcelona's Green and Biodiversity Plan 2020 describes the improvement of actions on the creation of pollinator-friendly habitats along roadsides for foraging and refuge.

Pollinator-friendly plant management practices and managing bee nest sites are feasible plans for enhancing pollinator populations.

Figure 4: **Wildflowers grown along expressways. Atlantic City (USA) © Expressway's wildflowers**

Figure 5: **Roadside meadows, wildflowers and grasses © the pioneer**

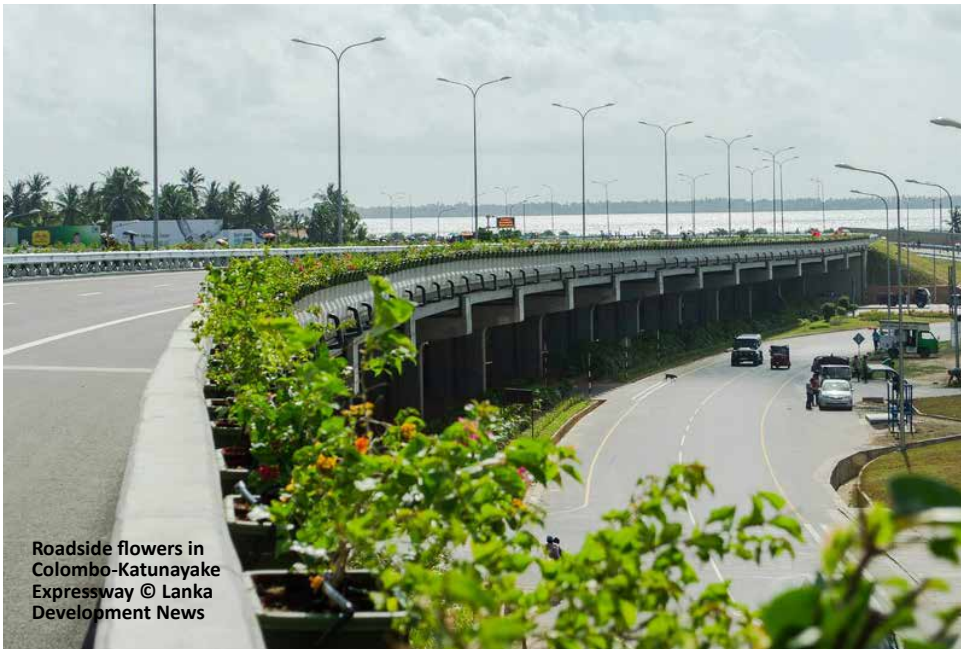
Recommendations for the Development of Roadsides as Pollinator Habitat in Sri Lanka

Sri Lanka, as a country that is concerned with drastically reducing pollinator diversity and density, can promote pollinator-friendly spatial planning. As one of the strategies, Sri Lanka can adopt a simple, cost-effective and environmentally friendly strategy of creating roadside pollinator habitats, especially in urban areas, to conserve and maintain our valuable pollinator insects and obtain their ecosystem services. Some of the recommendations are:

* grow flowering plants, preferably native/wildflowers and grasses, along roadside corridors and road-edge strips to attract pollinators.
* research on land management to increase pollinator activities, increasing diversity of plant communities, suitability study of flowering species to a particular site and appropriate density will be helpful in implementing and restoration of roadside habitat to provide greater benefit for diverse pollinators.
* create pollinator patches on selected sites.
* avoid growing invasive, ineffective and competitive pollinator species that exclude effective native pollinators from roadside vegetation.
* maintain and protect roadside corridors by mowing a narrow road-edge strip and reduce mowing when pollination activities are peaking, while considering the road safety concerns.
* use minimum or zero weediness to control weeds along roadside, and minimize broad herbicide application as a general vegetation control.
* educate the stakeholders involved in road development and environment protection
* raise awareness through community engagement and environmental education.

Conclusion

Urban areas can be a major refuge for many insect pollinators. As a step toward conserving and caring for pollinator services, people living in urban areas can easily contribute by planting and maintaining at least strips of flowering plants in urban gardens, field margins and narrow hedges in gardens. Providing shelter for bees can be done easily by making solitary bee houses/bee hotels. These simple methods can be introduced and promoted to the general public and incorporated in urban designs and plans of the public and private sector.



Roadside flowers in Colombo-Katunayake Expressway © Lanka Development News

Roadside meadows, wildflowers and grasses © staustell

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A Study on the variation of **Temperature and Rainfall Impact on** **Tea Production** *in the* **Central Province** *and* **Proposing Adaptive Measures**

(Comparison of the Years 2011 *and* 2019)

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Keywords:

ADAPTATION, CLIMATE CHANGE, RAINFALL, TEA PRODUCTION, TEMPERATURE

- **Tea production is highly vulnerable to the impacts of climate changes.**
- **The study aimed to analyze how tea production was affected by the variations of Temperature and Rainfall in the central province in 2011 and 2019.**
- **Appropriate adaptation methods have been suggested to deal with these climatic changes to improve tea production.**

Tea plantations © invite to paradise

Jayawardhana J.M.S.S


Heritance Tea Factory, Nuwara Eliya

Humanity has to face various types of climate change impacts with far-reaching consequences. Sri Lanka is one of the countries which is more sensitive to the impacts of climate change and a country where tea cultivation is common (Karunaratne *et al*., 2015). Tea is a cultivation that is very sensitive to climate change (IPCC, 2016). With this background, this study is aimed to analyze how tea production has been affected by the variations of temperature and rainfall in the Central Province in 2011 and 2019. It also aims to suggest suitable adaptation methods for the Central Province to cope with these climatic changes. This study was mainly based on secondary data, and the required data was collected from the Meteorological Department of Sri Lanka (Katugasthota station) and the Tea Research Institute of Sri Lanka.

On the Agro-Ecological map, Central Province belongs to the Mid-Country wet zone. About 15% of the total tea production in Sri Lanka, comprises Mid Grown Tea (Wijeratne, 2016). Accordingly, tea production of this area significantly contributes to the total tea production in Sri Lanka. In the Central Province, minimum and maximum temperatures are 20.3°C and 29.1°C respectively, with a mean temperature of 24.7°C (Karunaratne *et al*., 2015). Central Province records an average of 75–2900 mm of annual rainfall. This temperature and rainfall conditions are in the optimum range for tea cultivation in this region (Karunaratne *et al*., 2015). However, considering the Meta data, in the year 2011, the maximum annual mean temperature was 28.8°C, the minimum annual mean temperature was 21°C, and the annual rainfall was 1776.6 mm. In the year 2019, the maximum annual mean temperature was 30.2°C, the minimum annual mean temperature was 20.9°C, and the annual mean rainfall was 1543 mm. A comparison of these two years shows variation of temperature and rainfall over the last 8 years.

According to the data obtained from the Tea Research Institute of Sri Lanka, the total annual production of tea in 2011 was 52,590,795kg and in 2019 it was 48,493,985kg (in Central Province). Figure 1 shows higher tea production in the year 2011 and lower tea production in 2019. Figure 2 shows the annual rainfall variation for the years 2011 and 2019. The total rainfall in 2011 was more than the rainfall in 2019. Figure 3 shows the maximum annual temperature for the years 2011 and 2019 respectively. The temperature has a significant increase in 2019 when compared to 2011.

The comparison of these 02 years confirms that the tea production in the Central Province is more sensitive to rainfall and temperature fluctuations. There is a positive correlation between annual tea production and annual rainfall.

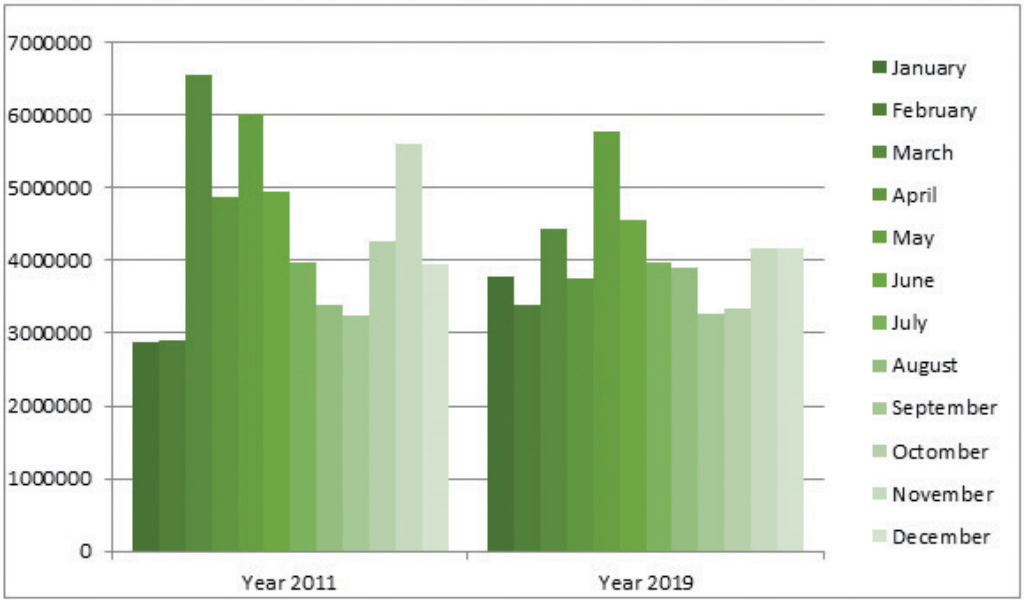

Figure 1: Variation in tea production (Kg) in the Central Province in 2011 and 2019 (with respect to 12 months).
Source: Tea Research Institute of Sri Lanka

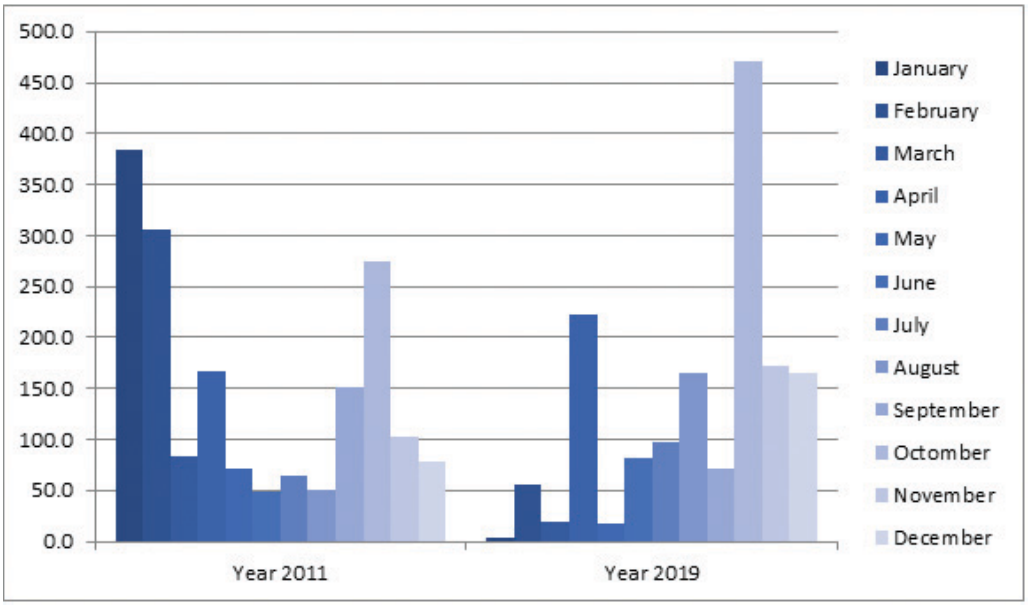

Figure 2: Variation in rainfall (mm) in the Central Province in 2011 and 2019 (with respect to 12 months).
Source: Meteorological Department of Sri Lanka

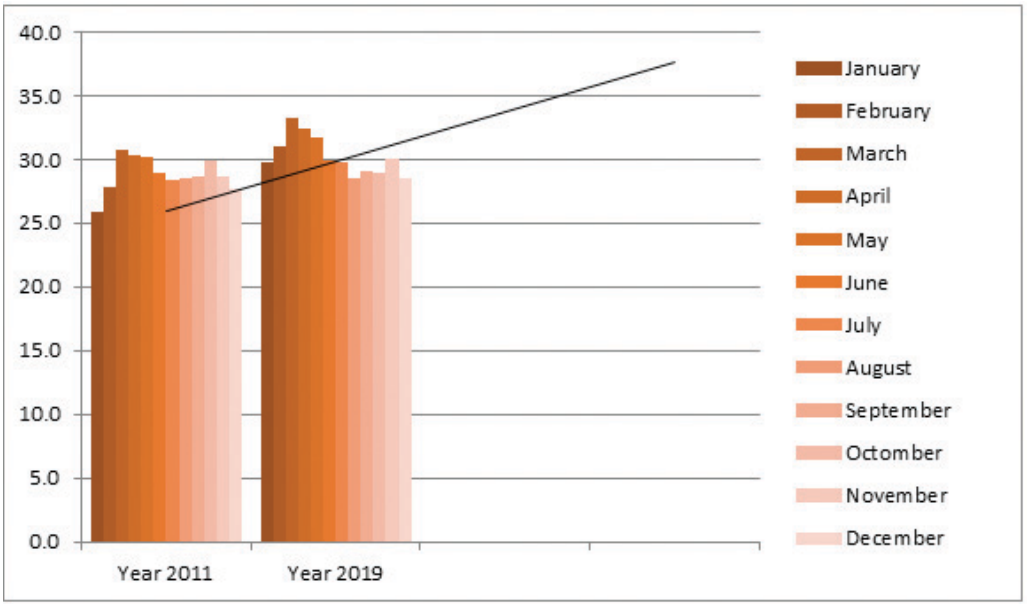

Figure 3: Variation in Maximum Temperature (°C) in the Central Province between 2011 and 2019 (with respect to 12 months)
Source: Meteorological Department of Sri Lanka

Months	Year 2011				Year 2019			
	Total Tea Production (Kg)	Monthly Rainfall (mm)	Monthly Maximum Temperature (°C)	Monthly Minimum Temperature (°C)	Total Tea Production (Kg)	Monthly Rainfall (mm)	Monthly Maximum Temperature (°C)	Monthly Minimum Temperature (°C)
January	2,880,223.1	383.20	25.9	19.3	3,767,130	3.60	29.8	18.5
February	2,909,750.33	305.80	27.8	20	3,391,721	55.099	31	20.6
March	6,551,728.9	83.20	30.7	20.3	4,441,894	20.00	33.2	19.9
April	4,874,784	166.70	30.3	21.2	3,760,269	222.89	32.4	21.5
May	6,005,293.9	70.70	30.2	22.1	5,764,378	17.90	31.7	21.5
June	4,938,661	47.90	28.9	22.3	4,560,392	81.99	29.9	22.2
July	3,978,810.8	63.60	28.4	22.3	3,983,081	96.79	29.8	21.3
August	3,390,775.2	49.80	28.5	22	3,887,641	165.79	28.5	21.7
September	3,245,540.8	150.80	28.7	20.8	3,268,112	71.99	29.1	21.2
October	4,261,603.9	275.10	29.9	21.2	3,349,151	471.19	29	21.1
November	5,609,791.5	102.30	28.7	20.7	4,160,108	171.29	30	21.1
December	3,943,831.5	77.50	27.7	19.9	4,160,108	164.39	28.5	20.7
Total	**52,590,794.9**	**1,776.6**	**(Mean value 28.8)**	**(Mean value 21)**	**48,493,985**	**1,543**	**(Mean value 30.2)**	**(Mean value 20.9)**

Table 1: Variation in total tea production (Kg), Total rainfall (mm), maximum and minimum temperatures (°C) in the Central Province between 2011 and 2019 (with respect to 12 months) ***Source:*** Meteorological Department of Sri Lanka

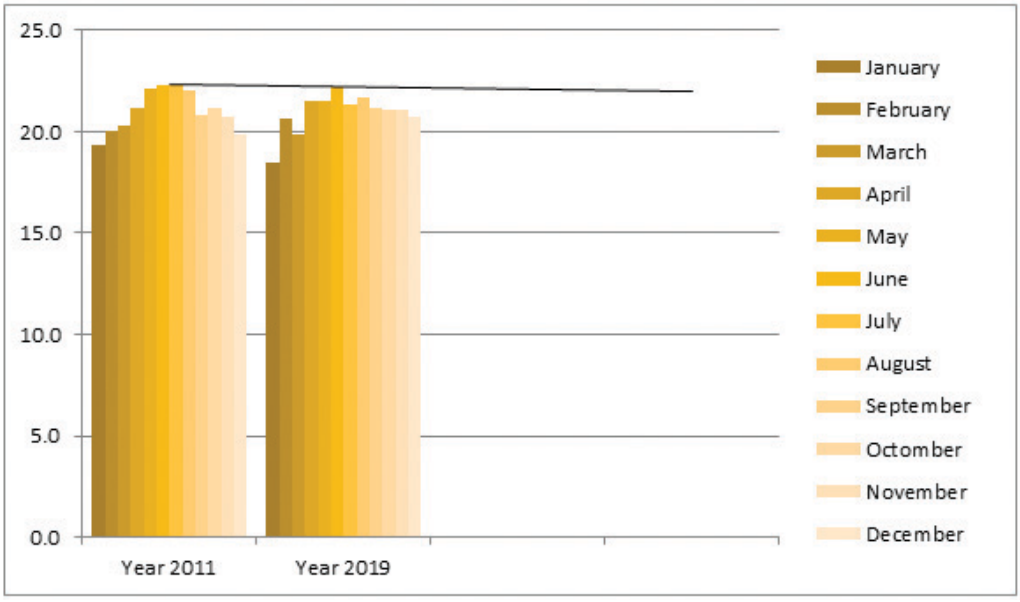

Figure 4: Variation in Minimum Temperature (°C) in the Central Province between 2011 and 2019 (with respect to 12 months).
Source: Meteorological Department of Sri Lanka

In the below mentioned comparison, the months of January, March, and May were found to have high rainfall variation (Table 1). In terms of spatial variations in mean temperature, tea grows well in the temperature range of 18–25°C, and it doesn't grow well in ambient temperatures below 13°C. However, if temperature continues to increase, it may cause for a decrease in the production of tea. Figure 4 above shows the minimum annual temperature comparison of 2011 and 2019. A significant minimum temperature change was not identified in the comparison of 2011 and 2019. (The minimum temperature seems to have no effect).

Tea Plantations © Flashpacking Family

Considering the climate variations, suitable adaptation methods to mitigate climatic impacts are cultural practices. Priority should be given to soil and soil moisture conservation and soil improvements (Wijeratne *et al*., 2007). In the mid-country, where the environment is comparatively dry, shade is also vital for tea (Jayasinghe and Kumar, 2019).

In addition to these key findings, the following measures can be suggested to increase the production of tea and to adapt to climate change. These are;

1. Drought-and Heat-Tolerant Tea Cultivars

- Tea cultivars, grafted plants, and enhanced seedlings that can endure harsh (dry) weather, heat, and poor soil conditions should be planted.

- As insect behavior and disease infestations are co-related with climate change, it's significant to have improved cultivars, particularly which are pest and disease resistant.

- New tea cultivar suggestions should be made based on the soil and climatic characteristics of Agro-Ecological zones (Wijeratne, 2016; Menike and Keeragala Arachchi, 2016).

2. Crop Diversification

- Only suitable lands with better soil conditions should be replanted with tea, whereas fields with more soil degradation should be diversified into other economic uses.

- Tea plantations can be inter-cropped/mixed-cropped with other perennial tree crops such as rubber, coconut, fruit, and Spices when soil and environmental conditions favor their cultivation. Likewise, low-yielding tea lands with marginal soil conditions can be diversified into fuel wood (energy plantations) or timber plantations (Menike and Keeragala Arachchi, 2016).

- Convert unproductive tea lands into "thatch banks" or plant rehabilitation grasses such as Mana or Guatemala, which contributes to the generation of green manure or compost (Wijeratne, 2016).

3. Irrigation and Soil Enhancement

- Compost generation by growing green manure crops in vacant patches and along fences, etc.,

- Adoption of soil conservation measures (drains, terraces, bunds, etc.)

- Mulching in young tea lands.

- Irrigation of tea during dry weather (Wijeratne, 2016).

4. Shade Tree Planting and Management

- Planting and management of high and medium shade trees to lower temperatures can alter the microclimate (Wijeratne, 2016).

5. Forecasting Seasonal Weather

- Weather forecasting technologies have improved. Therefore, tea growers can protect their tea cultivations from unfavorable climatic changes by using seasonal weather predictions (Wijeratne, 2016).

Finally, it could be concluded that the lack of understanding of climate change and its consequences has contributed to a lack of response to climate change mitigation and adaptation. Given the tea industry's economic and social importance, increasing awareness on climate change impacts and providing financial assistance to tea growers will almost certainly increase the rate of adoption of those well-known Good Agricultural Practices (GAP) that are often referred to as "No-regret strategies", which can reduce the negative effects of climate change on tea.

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Addressing climate change challenges *in the* water sector through restoration of irrigation structures

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Keywords:

PROLONGED DROUGHTS, CANAL, WATER OPTIMIZATION, IRRIGATION

- **Agricultural productivity depends on the availability of sufficient water**
- **Maximizing the water carrying capacity of tanks and reservoirs contribute to optimization of water**
- **Innovative methods for the irrigation sector to enhance water storage capacity and distribution are described here**

Paddy field in Agbopura
© REUTERS /Devjyot Ghoshal

Introduction

In Sri Lanka, prolonged droughts and increased frequency and intensity of floods are some of the adverse effects of climate change. Flood and droughts inflict damages to the agricultural economy of the country and the normal lifestyle of the communities living in marginalized areas. Therefore, climate change mitigation and adaptation actions need to be introduced for the marginalized areas in all aspects as much as possible. In the agricultural sector, water resources play a critical role. A sufficient volume of water is required to have a good harvest, and that directly links to the country's agricultural productivity. Therefore, sustainable management of water resources is an important subject and a challenging task with increasing variability of rainfall. Water management in drought conditions is indeed a challengeable issue, and new methodologies and engineering technologies need to be applied simultaneously to mitigate the impacts.

In the context of climate change adaptation, conservation of limited water resources come into the picture. The focus of the Integrated Watershed and Water Resources Management Project (IWWRMP) of the Ministry of Irrigation is to maximize the water carrying capacity of tanks and reservoirs and to support to restore water distribution canal networks. Essentially, this project focuses on enhancing the functionality of water infrastructure. Dam safety comes under this context too. Strong dams support to store water, and well-established and regulated distribution networks (distribution canal systems) help to distribute water without waste. This article describes some of the major interventions under the IWWRM in the irrigation sector to enhance water storage capacity and distribution.

Water Optimization in the Irrigation Sector

The irrigation sector in Sri Lanka mainly comprises major and medium irrigation schemes, and small tanks. The major and medium irrigation schemes provide water for more than 650,000ha. There are more than 350 major and medium irrigation systems in the country. The irrigation tanks are mainly scattered in the dry-zone, and some of them are linked in a cascade, providing water for about 320,000ha.

Other than irrigating crops, water from canals and reservoirs are used for livestock watering, fisheries, industries, and domestic purposes like drinking, bathing, and laundering.

In the irrigation sector, there is surface water as well a ground water. But this article only focuses on the water optimization of the surface irrigation sector.

In the irrigation sector, main methods used to enhance water optimization are,

1. Enhance water carrying capacity of tanks and reservoirs, and
2. Strengthen and rehabilitate water distribution canal networks.

Water-Efficient Agriculture
© Global Opportunity Explorer

Figure 1: **Chilli Farming © Agri Farming**

Enhancing Carrying Capacity of Tanks and Reservoirs

Desilting, rehabilitation of dams, increase of dam height, strengthening of sluice gates, increasing of spillway heights are directly supported to increase water carrying capacity of the reservoirs. These activities should be done under detailed study and close supervision. Especially increase of dam heights and spillways can create unexpected environmental and social issues due to new inundation areas. Therefore a, comprehensive environmental and social management plan should be established before commencing this type of actions.

Some tanks of the country have been specially constructed to provide water for Other Field Crops (OFC) such as green gram, Undu, groundnuts, chili, etc. (Figure 1). Some tanks located in the northern province (MoI, 2020a; MoI 2020b) show this character, and the soil type and climate of the area are also compatible with these crop varieties and cultivation system. The utilization of Other Field Crops in designated areas will support obtaining a good harvest, and it is ideal for overcoming the adverse impact of climate change.

The OFCs can generate comparatively more income for the community than paddy cultivation in the same area. Cultivation of OFCs supports reducing hunger and enhance the nourishment of the nation, and it provides some job opportunities for the communities too. Therefore, rehabilitation of tanks and schemes support to store rainwater as an adaptation to adverse effects of climate change (MoMD&E, 2016). Strengthening and re-establishment of farming schemes designed for OFCs are directly supported to enhance food security and economic development and increase resilience to climate change (MoI, 2020a; MoI 2020b).

Rehabilitation of Canal Network

Rehabilitation of dilapidated main canals (Figure 2), feeder canals, and distribution canals support to optimize water utilization by controlling waste through transporting from tank to agriculture fields. The establishment of new sluice gates or repairing of existing sluice structures, laying concrete for distribution canals, removing barriers in canals is mainly supported to increase the water transportation efficiency. However, implementing agencies need to re-think of sustainable environmental benefits of downstream areas while establishing sluice gates and other regulatory structures upstream. Allowing sufficient amount of environmental flow and providing opportunities to support ground water recharge should be considered in this activity.

Concrete laying for canal systems support to avoid water waste in transportation and obtain the maximum benefit of water. This also helps to reduce water volume that needs to be released during the cultivation season and support water conservation. Normally, irrigation schemes have a long canal network and some places would be damaged and need to have immediate restoration. Therefore, identification of dilapidated canal systems is an important activity, and repairing of dilapidated canals and hydrology structures support to increase the resilience of climate change (Figure 3).

BELOW LEFT
Figure 2-1: Rehabilitation of dilapidated main canals © Daily News

BELOW MIDDLE
Figure 2-2: Dilapidated D canals © Flickr

BELOW RIGHT
Figure 3: A dilapidated canal, now functioning as a naturalized canal that provides habitats for biodiversity and as a newly rehabilitated canal © Sri Lanka Red Cross

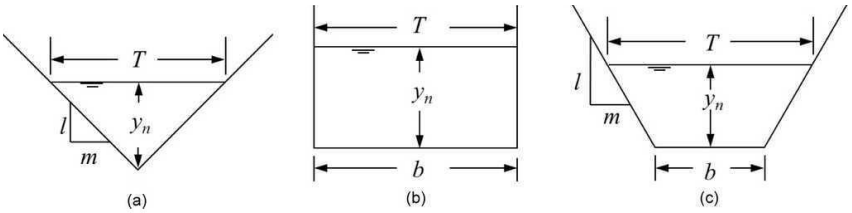

Figure 4: Trapezoid shaped canals. © Journal of Applied Research and Technology. JART

Trapezoidal drain © YouTube

Canal systems which have been dilapidated for 2-3 decades play a role as naturalized ecosystems. Most of these canals are shallow, with slow flow of water and the riparian vegetation is rich. Therefore, most of the dilapidated canal systems provide habitats for biodiversity and sustainability of the adjacent environment. Further, this system supports groundwater recharge and sustenance of ecosystem services. Therefore, in the rehabilitation of canals, we need to consider the sustainability of ecosystem services too. Application of green design in engineering activities will support to fulfill this requirement. The inclusion of green concepts into engineering designs also supports to overcome some environmental and social issues of the target communities.

In engineering aspects, the change of the shape of canal structures will also support to enhance the water flow rate of the canal and helps to transport water to longer distances. Here, square-shaped canals are transformed into trapezoid-shaped canals (figure. 4). This is normally a simple engineering method but provides more benefits in water resources optimization and climate change. Incorporation of green designs for these changes will generate eco-friendly results. Green designs consider the sustenance of eco system services and support for the survival of adjacent biodiversity (e.g. establish holes in concrete layered canals to support ground water recharge, establish suitable steps on canals banks at relevant places for animals to drink water, establish escape structures for animals (this is for large canals). If an animal accidently falls into the canal, these structures will assist its escape).

Conclusion

At present, restoration of irrigation structures in the country are directly linked to climate change adaptation. These restoration activities should be done under comprehensive studies which addresses environmental and social issues. However, water is the limiting factor. Therefore, conservation and restoration of the upper watershed is a major task that leads to sustainability of water resources. Watersheds provide water to rivers and canals and finally large and small tanks and reservoirs. Healthy watersheds directly link the continuous water supply to rivers. When considering the current status of watersheds, there are some threats to watersheds like on-farm and off-farm soil erosion, degradation of soil productivity, deforestation, reduction of river flow, low quality of river water, siltation etc. Therefore, watershed restoration is more important and a priority action which supports the sustainability of water resources.

Canal network rehabilitation is an important activity in the irrigation sector and it supports to optimize the utilization of water resources. Concrete layering is the most common technique that is practiced in canal rehabilitation. Under this rehabilitation, we have to re-think on the potential of ground water recharge.

Restoration of upper watershed areas directly affects the sustainability of water flow of the downstream areas. Therefore, proper restoration actions need to be established with the support of stakeholder agencies. Crop diversification is another agricultural practice that can be used to enhance income generation in climate vulnerable areas. Therefore, rehabilitation of delapidated canal network ensures the function of watersheds and introduces new agricultural practices that can be applied simultaneously for climate change adaptation.

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Designing a Climate Smart City for Kurunegala

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• Cities are emitters of greenhouse gases, and unplanned cities face damage and loss due to the adverse impacts of climate change

• A city can transform into a 'Climate Smart City' by adopting nature-based solutions, blue-green infrastructures, and integrating low-carbon development technologies.

• The key components of a Climate Smart City are reduction of greenhouse gas emissions, water conservation, waste management, energy efficiency and being resource wise.

• An adaptation and mitigation assessment were carried out for the Kurunegala City, and the issues identified were water scarcity, heat stress, waste management and traffic congestion.

• Potential applicable recommendations were made to reduce heat stress and water scarcity, and technologies were proposed to reduce greenhouse gas emissions.

***Keywords*:**

KURUNEGALA, CLIMATE SMART CITY, ADAPTATION, MITIGATION, NATURE BASED SOLUTIONS

Background

Anthropogenic greenhouse gas (GHG) emissions accelerate climate change. The primary catalyst is the burning of fossil fuels. Global warming which is the result of increase of GHG is evidenced in global temperature rise, droughts, floods, coastal erosion, ocean acidity, shrinking of ice sheets and increasing extreme weather events.

Global warming makes cities warmer and rapid urbanization intensifies this process. Urban Heat island (UHI) generation and aerosol radiative forcing are two such processes that make cities unlivable. Estimates suggest that cities are responsible for 75% of CO_2 emissions, with transport and buildings being the biggest contributor. Therefore, it is essential that cities be made a part of the mitigating efforts to control climate change.

Further, city populations are expected to rise up to 60% globally as people flock to cities for employment opportunities and services. However, around one-third of the world's population lives in cities at risk of cyclones, floods, droughts, earthquakes, landslides or volcanic eruptions (UN DESA, 2018.) Climate change further exacerbates these risks with more frequent and intense floods, droughts, sea level rise, heatwaves, landslides and storms (WMO, 2021).

In the 2030 Agenda for Sustainable Development, countries have committed to engage in systematic follow-up and review of progress towards the goals and targets, using a set of global indicators. Sustainable Development Goal 11 (SDG

Kurunegala © A.Savin, http://WikiPhoto.Space

11) formulates the ambition to make cities and human settlements inclusive, safe, resilient and sustainable.

Rapid urbanization is resulting in a growing number of slum dwellers, inadequate and overburdened infrastructure and services (such as waste collection and drinking water and sanitation systems, roads and transport), worsening air pollution, and unplanned urban sprawl. Thus, the environment is intrinsic to SDG 11, which puts forward the need for critical urban infrastructure to be low-emission, resource efficient and resilient. Better urban planning and decision-making which strive to decouple, decarbonize and detoxify our cities are crucial strategies to achieve SDG 11.

A **Climate Smart City** contains infrastructure and built environment that is resilient to climate change impacts and adopts low carbon technologies that reduce greenhouse gas emissions, ensuring a comfortable, healthy living for the urban population. Climate Smart Cities help find integrated solutions for their complex urban sustainability challenges. Further, they are necessary to protect citizens and businesses from negative climate change impacts.

This article describes the activities and components of a Climate Smart City designed for the city of Kurunegala in Sri Lanka. The design of Climate Smart City for Kurunegala is based on the intervention of Climate Technology Centre and Network (CTCN). On the request of the Kurunegala Municipal Council (KMC), CTCN provided *pro bono* Technical Assistance (TA) through the facilitation of the Climate Change Secretariat of the Ministry of Environment to design a 'Climate Smart City' for Kurunegala. The key objectives of the programme were to,

a) Identify the key climate issues and provide adaptation recommendations.

b) Identify 10 climate technologies to potentially reduce the greenhouse gas emission (mitigation) of the city.

Ethugala of Kurunegala © Nick Dowling

Introduction: Kurunegala City

History

Kurunegala was the fifth Kingdom in Sri Lanka. It was ruled by King Buwanakabahu the Second in 1293 A.D. followed by King Parakramabahu the Third. This period was known as the 'Golden Era' of literature. In the 16th century, the Kurunegala city was used by the Portuguese as a centre to collect cinnamon and pepper, whilst in the 17th century the British established it as the main administrative centre for *Sath Korale*. The town/city area was said to be a planned area during that period. Along with time, the town has expanded to become the highly populated urban centre it is today.

City design

Kurunegala City is 11km^2 in extent and is situated in the Kurunegala District located in the North Western Province of Sri Lanka. Kurunegala City is one of the most intensively developed economic and administrative cities of the North Western Province. This city can be considered a hub which connects a number of major cities: Colombo, Kandy, Dambulla, Negombo, Anuradhapura, Trincomalee and Kegalle. Its main economy is service and industry (GOSL, 2018). The population of Kurunegala City was 24,833 (Census, 2012) with a daily commuter population of over 300,000 (UDA, 2019). The population growth estimate for KMC is 8.5% from 2012-2017 (GoSL, 2018).

The Kurunegala City is situated in the plains of the intermediate climatic zone bordered by Ethugala, a large granite outcrop. Kurunegala City displays a ribbon development which has progressed to an urban sprawl. The land use of the city comprises of 65% built environment and 35% green space. Municipal services cover 13.9% of all land use (GoSL, 2018).

Climate

The city's climate which is hot throughout the year is made intense by the surrounding rock outcrops. These rocks retain heat during the day. The built up environment increases the heat distribution. Moreover, with the daily floating population of approximately 30,000 people and traffic congestion, the heat is exacerbated further. During April, the temperature increases to over 35°C leading to decrease in water in reservoirs and the Deduru Oya which supplies water to the city. In general, the monsoons from May to August and October to January provide rain. The average annual rainfall is approximately 1750mm-2000mm. During the last decade, Kurunegala experienced prolonged droughts annually.

Kurunegala has been experiencing prolonged droughts in the past thirty years (MoE,2011). According to Punyawardena *et al*., 2013, Hambantota district has the highest exposure to

climate change followed by Kurunegala and Anuradhapura. This, they have stated, can be attributed to higher number of days (in a year) with daytime maximum temperatures greater than 34C° and increased frequency of drought during recent times.

In the 'Status of Sri Lanka's Cities (GoSL, 2018), Kurunegala City has been identified as one of the cities that has a high risk of exposure to droughts.

This type of prolonged drought leads to water scarcity and heat stress in cities.

Globally, too the challenge of water scarcity in cities is growing. Recycling, water conservation technologies, designing Water Cities, Climate Smart Cities, reduction of non-revenue water, technologies to reduce water leakages, reduction of water contamination in agriculture and improvement of sewage systems are some of the actions that can solve water scarcity and cool cities.

Through designing a Climate Smart City for Kurunegala, it is expected that the recommendations, when implemented, will increase the resilience of the city in the face of droughts.

This article strives to highlight the key climate issues faced by the Kurunegala City and summarize the recommendations presented through the CTCN programme, to develop resilience and reduce greenhouse gas emissions through a Climate Smart City design.

Brief Methodology

Stakeholder consultations, expert opinions, qualitative analyses in the form of questionnaires, literature, and, wherever possible, quantitative surveys were done to obtain information and provide recommendations (CTCN website). From the climate adaptation perspective, water scarcity and heat stress were identified as key issues that needed to be addressed in the Kurunegala City. From the mitigation perspective, technologies to reduce greenhouse gas emissions and the need to assess the current greenhouse gas emission status were identified.

Waste Water Treatment plant , Kurunegala
© Thilina Dissanayaka

Current Status of Kurunegala City

Water availability

In ancient times, Sri Lanka used traditional micro watershed management systems, which were referred to as Tank Cascade Systems (TCS), to irrigate the vast dry zone plains. This system utilized a unique channel technology. This system provided water for human consumption as well as supported the local livelihood of agriculture, irrigation and moreover supported biodiversity and provided ecosystem services (Geekiyanage and Pushpakumara, 2013).

Kurunegala in ancient times also boasted a cascade system. However, with population increase and urbanization, the tanks were silted and the channels were blocked. The main sources of drinking water in Kurunegala City are Deduru Oya, Wendaru Wewa and, during water shortage, the Kurunegala Tank. The National Water Supply and Drainage Board (NWSDB) treats the water and the Kurunegala Municipal Council (KMC) purchases the water in bulk and distributes the water to the city at a subsidized rate.There are two water treatment plants in operation. Those that do not have pipe-borne water use wells and tube wells (ground water). Community wells are available for washing and bathing. The present water sources are not adequate to meet the demand of the burgeoning population and the increase in commercial use. Another challenge faced by the City is the high rate (45%) of Non-Revenue Water (NRW). This may be attributed to leakages in the transmission and distribution systems and in the service reservoirs, illegal water consumption, production and consumer metering errors and administrative errors.

Currently, the water demand of the city is about 8000m^3 per day. It is estimated that the demand will increase to 19,000m^3 per day by 2030 (NWSDB).

The Greater Kurunegala Water Supply and Sewerage Project which commenced in 2018 was initiated to provide clean water for households, government and private institutions, schools, hospitals, tourist hotels and the daily floating population. It provides the disposal of waste water for 3,500 domestic and commercial institutions with its sewerage network. A capacity of 300m^3 of sewerage per hour is treated daily. The treated effluent (24,000m^3) is released to the Beu Ela that flows in to the adjacent paddy fields. Compost is made from the remaining sludge which is used as a fertilizer in plantations.

The case study on Kurunegala City and the recommendations provided are those that can be applied for any city considering its climate related issues. Some of these recommendations, especially on adaptation, can be adopted even in homes.

Heat stress

Unplanned rapid urban growth, traffic congestion, overcrowded urban public space with concrete buildings and lack of green space and predominant granite rock in Kurunegala city exacerbates heat. Impervious surfaces such as buildings, parking lots, roads and interlocking brick pavements add to the increase of surface temperature.

Urban Heat Island (UHI) is a result of rapid urbanization. There are two types of UHIs which includes Surface Urban Heat Island (SUHI) and Atmospheric UHI. Atmospheric UHI is observed based on air temperature and SUHI is measured based on land surface temperature (Ranagalage *et al*., 2017).

Rapidly increasing UHI results in degradation of living environments, elevated ground level ozone, increased mortality rate, elevated emission of air pollutants and greenhouse gases, compromised human health and comfort, and increased hospitalization of children and elderly people (Ranagalage *et al*.,2017).

A study by Ranagalage *et al.*, in 2020 on the Kurunegala City based on data gathered from 1996-2019 indicates that the rapid increase in urbanization, loss of vegetation cover, increase in built-up areas and congested road network resulted in the increase of Land Surface Temperature (LST). The study specifically indicates that the increase was evident from 2008-2019. They, (Ranagalage *et al*., 2020) further observe that the increase in overall average in LST in Kurunegala urban area from 1996-2019 was 5.5°C which may have been caused by the rapid urbanization and increase in impervious surfaces of the area.

Health authorities do not have documented data on heat stress associated with climate change. However, there are reports of dehydration and fainting in school children which may be attributed to heat stress.

Transport

Kurunegala City is a highly traffic congested city. Due to the administrative and service facilities in Kurunegala City, many people commute for jobs, commercial and administrative services, health services, schools and tuition classes. Of the land use, nearly 10% is set aside for roads. Considering the road network, there are main roads which branch off into narrow roads and dead ends. There are no sign boards for by- passes. Heavy vehicles go across the town without using alternate roads due to lack of signages. During peak hours, it takes 35 minutes to drive a 2km distance. There is a lack of parking space and only 1,310 slots are reserved as private vehicle parking spaces. Therefore, this causes vehicles to be parked on either side of the pavement resulting in traffic congestion. Highest traffic congestion is seen during school and office opening and closing times (UDA, 2019).

Waste

Solid waste management of the city is the responsibility of the Municipal Health Department which ensures the overall collection of waste and keeps the city clean. The Solid Waste Management Division of the KMC manages the composting and disposal treatment of solid waste and waste water at the Sundarapola Waste Management site located just outside the city boundary. The Sundarapola site manages waste collected both from the KMC as well as the Kurunegala Pradeshiya Sabha area. The site is 12.5 acres and of this the operational area is 5 acres and around 4 acres consist of an open dump containing mixed waste. The Sundarapola final disposal site was established and has been in operation since 1920. The discharged solid waste amount is approximately 38 tonnes/day from the Kurunegala Municipal Council, approximately 10 tonnes/day from the Kurunegala Pradeshiya Sabha and is estimated at approximately 48 tonnes/day in total (CTCN, 2021a).

The screw type composting machine was installed in Sundarapola waste disposal site with the capacity of 50 tonnes/day in August 2019. The major raw materials to make the compost are organic domestic garbage collected by separate collection which was introduced to households in 2010. However, the plant did not run at its full capacity due to technical operational issues in the previous years. The plant processes 3-7 tonnes of wastes daily. There are studies being carried out to assess the quality of the fertilizer. In Sundarapola, only 2 tonnes/day of solid waste can be accepted at the compost yard due to a shortage of workers. Further, there is an issue as to finding solutions to clear the mixed waste dumping hill (landfill site). Various recommendations (i.e; selling the mixed waste to a recycler, sorting the waste manually, etc) have been made in order to manage this mixed waste hill. However, it is still in the same condition. The KMC carries out an extensive programme to promote segregation of waste at source. With the floating population, it is very difficult to manage this and there are many instances of mixed waste accumulation (CTCN, 2021a). It is necessary to rehabilitate this mixed waste dump.

Study, based in the KMC compost plant © IWMI

Recommendations

Water scarcity and heat stress

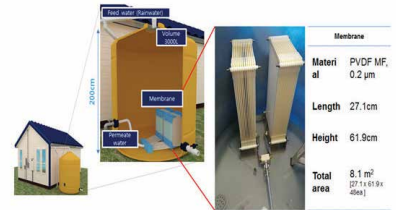
The use of an integrated approach using Nature Based Solutions (NBS), Blue Green Infrastructure and Low Impact Development (LID) can bring about climate resilient communities (Liao *et al*., 2017 and CTCN, 2019).

The following are a list of recommendations that could be utilized to increase climate resilience and transition to a cooling city. These recommendations can be adopted not only for KMC but also for other cities in Sri Lanka.

1. Treated sewerage effluent (which is currently being sent to paddy fields) can be used for construction purposes without the need to use potable water.

2. By connecting all household sewerage systems to the Sewerage Treatment Plant, the contamination of ground water does not take place, leaving the wells to be used for drinking water.

3. If it is necessary for water to be boiled (using firewood) before consumption there is much carbon dioxide being released. The use of Gravity Driven Membrane (GDM) to filter water will reduce air pollution. This system can be used in small scale as well as large scale for community water projects or for schools. The membrane purifies contaminated water using only gravity without additional energy consumption. It can remove more than 99% of particulate contaminants and bacteria in water using micro-pores. Heavy metals in water can be filtered by using a nano membrane (this was demonstrated at a workshop in Kurunegala). This eco-friendly technology can be used for rain water, sources of contaminated water etc.



4. Rain water harvesting: Offices, schools and households can have rain water harvesting barrels. This reduces metered and ground water consumption.

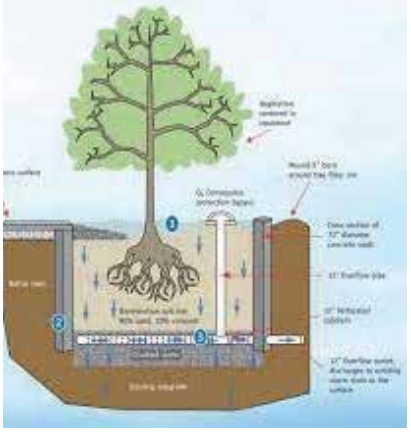
5. Infiltration trenches: Instead of using open concrete drains, the bottom of the drain (without concrete) contains a layer of pebbles and sand while the water infiltrates to the soil below, the top of the drain remains dry.

6. Rain gardens: This is a vegetated shallow depression designed to treat stormwater runoff from nearby impervious spaces. These can be adapted in front gardens of offices, schools, homes, round-a-bouts, etc.

7. Retaining a percentage of permeable surfaces in offices and houses: Instead of concreting walkways and gardens, retain a percentage of ground area for vegetation. The KMC has already included this as a by-law within the KMC area.

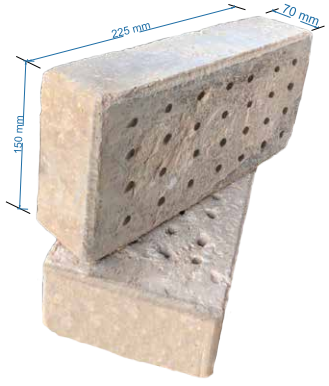
8. Bioswales: Similar to rain garden, this is a vegetated channel used to convey rain water and treat it prior to its entry into a water body. It provides bio-retention facilities. This can be most often applied along streets and in parking lots.

9. Tree box filters, planter boxes: These can be used in pavements where the pavement is sloped so that rainwater flows from impervious surfaces to the tree box.



10 Constructed wetlands: This is designed mainly for water quality treatment in a controlled environment. In this subsurface flow wetland, a gravel and sand-filled basin planted with vegetation is used to treat domestic, municipal and industrial waste water. Here, the pollutants are removed through several mechanisms which include plant uptake, microbial biodegradation, physio-chemical adsorption, mechanical filtration and sedimentation.

11 Permeable bricks: These clay based porous bricks can replace the cement inter-locking stones used in pavements and parking areas. These encourage filtration of rain water which seeps in and recharges ground water.



© Gayanath. Eco Bricks

12 Cement blocks and grass pavements: These include intermittent cement blocks and grass which helps filter rain water.

13 Green and shade curtains: Vines can be grown along the walls with the support of a mesh. These provide a green visual as well as assist to keep the area cool, and in addition provide a habitat for fauna. If the vine is an edible plant, it also provides an additional food source.

The above systems encourage purified filtration of rainwater, increased ground water recharging, reduce storm water wastage, reduce atmospheric temperature and help to cool the city. In addition, by recharging ground water and having a layer of water in the sub soil layer there is an increase in water availability during drought periods.

Energy &Transport

According to the Kurunegala Town Development Plan (2019-2030), the proposed Central expressway, Kurunegala Dambulla Railway line, Transit Oriented Development Centre, multi -storey vehicle parks and the promotion of alternative road connections for main roads will assist to reduce traffic congestion and create a healthier environment in the city (UDA, 2019). Further, the promotion of e-buses for short distances within the city (circular routes) will reduce emissions. The promotion of solar street lights, conversion of buildings to energy efficient buildings through the use of energy efficient lighting, efficient air conditioners and solar roof tops will reduce the use of fossil fuel. The encouragement to use LED display boards in the city will reduce visual pollution, while reducing power consumption.

Waste

The waste management site needs to be upgraded to support the daily waste generated. The composting facilities need to be improved and the quality of compost needs to adhere to standards specified for cultivations. Frozen biodegradable food blocks can be supplied to pig farms. Trees that are cut or cleared after storms can be used as wood chips for furnaces of factories. Segregation activities and recycling rate of wastes can be increased. Feasibility for a waste management programme which can be upgraded to an Internet of Things (IoT) programme which can accommodate the waste from not only the municipality but also the surrounding Pradeshiya Sabha areas is possible. If a venture is to be started for a Waste to Energy programme it should be for the entire North Western Province. Solar roof top and solar lighting in the premises will reduce electricity consumption. It is also beneficial to retain part of the forest area within the site for carbon sequestration purposes.

Greening Kurunegala

Emissions and removals are part of any city. It is necessary to increase the green cover in Kurunegala City to absorb the greenhouse gas emissions released. The Rajapihilla Park and the forested area around Ethugala rock are the remaining greenery at KMC area. It is necessary to make part of the Rajapihilla Park into an urban forest. It is also necessary to plot out areas where space is available to accommodate trees and increase the greenery of the KMC. Urban Forests serve as carbon sequestrators and perform ecosystem services and conserve both soil and water resources.

Proposed low carbon technologies to transform KMC to a Climate Smart City

The greenhouse gas emission assessment conducted by the National Cleaner Production Centre indicated 58,797 tonnes CO_2eq in 2012-2013 to 82,562 tonnes CO_2eq in 2016-2017 of greenhouse gas emissions considering energy, waste and transport sectors for

the Kurunegala City. The rate of increase was 40.42% from 2013 to 2017 (NCPC In: CTCN, 2021a).

Stakeholder consultations were held and 22 low carbon emission technologies were assessed. Out of these 12 were further shortlisted as potential technologies to reduce greenhouse gas emissions and propel the KMC towards a transition to a Climate Smart City (CTCN, 2021 b). Short listed technologies are in (Table 1).

Table 1: Proposed low carbon technologies for Kurunegala city

01	Organic waste composting
02	Rooftop photovoltaic generation system
03	Water heating system by solar energy
04	Bulb replacement to LED
05	Green buildings
06	Park and ride system
07	Rainwater recycling
08	IoT based Smart City
09	Electric car and ESS (Energy Storage System)
10	HEV (Hybrid Electric Vehicle) taxi
11	IoT based waste recycling system
12	Electricity generation by incineration of Municipal Solid Waste

Recommended Policy Initiatives

As urban populations grow, a considerable amount of funds will be spent in expanding and renewing urban infrastructure. Therefore, supportive national and regional policies need to be in place to ensure that their policies are well aligned to support city-level action. Building environmental goals and incentives into national policies, identifying national policies that conflict with or prevent local climate action, investing in low-carbon, climate resilient urban infrastructure that has low incremental costs and provides multiple local benefits, mobilizing private capital for green urban infrastructure projects and encouraging private sector investments are some of the initiatives to be incorporated into policy framework.

Conclusion

The case study on Kurunegala City and the recommendations provided are those that can be applied for any city considering its climate related issues. Some of these recommendations, especially on adaptation, can be utilized even in homes. It is necessary for urban planners to shift from standard built grey environment concepts towards more blue-green concepts. It is also necessary for municipalities to demonstrate some of the actions and set an example for other municipalities. Further, there are some actions that can be addressed through the implementation of by-laws.

It is also necessary for municipalities to have a good baseline and a database and build their own Greenhouse Gas Inventory (GHGI). The inventory will assist to monitor the low carbon development pathway taken by the city and assist to balance development projects with carbon sequestration activities.

This initiative is further emphasized in the National Policy Framework: Vistas of Prosperity & Splendour where chapter 7 (New approach in National Spatial System) and chapter 8 (Sustainable Environment Policy) highlight actions such as establishing Kurunegala and other cities as national cities, introducing urban forests, green belts, encouraging waste segregation and waste management systems and introducing water storage mechanisms for houses and water scarce areas to recharge ground water to name a few. It is further endorsed under the Theme 8: Environmental Management in Cities and Human Settelement in the National Environment Action Plan (2022-2030) (MoE, 2022) as well as the UN Sustainable Cities programme.

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Kurunegala_Lake
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Sunset at Kurunegala Lake
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ප්ලාස්ටික් කළමනාකරණය සහ දේශගුණ විපර්යාස

සුජීවා ප්‍රනාන්දු
පරිසර දූෂණ පාලන හා රසායන ද්‍රව්‍ය කළමනාකරණ අංශය, පරිසර අමාත්‍යාංශය
sujeewaf@gmail.com

මූලපද:
ප්ලාස්ටික්, ක්ෂුද්‍ර ප්ලාස්ටික්, රෙගුලාසි, ප්ලාස්ටික් අපද්‍රව්‍ය කළමණාකරණ ජාතික සැලැස්ම

■ සැහැල්ලු බව, මිල අඩුවීම, නම්‍යශීලී බව, බර අඩුවීම ජලය සමඟ ප්‍රතික්‍රියා නොකිරීම ආදී ගුණාංග නිසා ප්ලාස්ටික් භාවිතය අද වන විට ප්‍රචලිතවී ඇති නමුත් අවභාවිතය, සහ නිසිලෙස බැහැර නොකිරීම නිසා පාරිසරික සෞඛ්‍ය ව්‍යසනයක් බවට පත්වී ඇත.

■ වසරකට ප්ලාස්ටික් මෙට්‍රික් ටොන් මිලියන 350 ක් නිෂ්පාදනය කරන අතර එයින් 9% ප්‍රතිචක්‍රීකරණය කරන අතර 12% පරිසර හිතකාමී ලෙස පුළුස්සා දැමේ (incinerate). **එමෙන්ම 8% පමණ සාගරයට මුදා හැරේ.**

■ පර්යේෂණවලට අනුව 2019 වසරේ ප්ලාස්ටික් දහනය නිසා හරිතාගාර වායු ටොන් මිලියන 850 ක් පරිසරයට මුදා හැර ඇති අතර, 2050 වනවිට එය ටොන් බිලියන් 2.8 ක් පමණ වනු ඇතැයි ගණන් බලා ඇත.

■ මිලි මීටර් 5 ට වඩා විශ්කම්භයෙන් අඩු ප්ලාස්ටික් ක්ෂුද්‍ර ප්ලාස්ටික් ලෙස හඳුන්වන අතර අද වනවිට මෙම ක්ෂුද්‍ර ප්ලාස්ටික් වාතයේ, ජලයේ සහ පසෙහි ඇති අතර සතියකට ප්ලාස්ටික් ග්‍රෑම් 02 ත් 05 ත් පමණ එක් පුද්ගලයකුගේ ශරීරයට ඇතුළුවීමට හැකි බව සොයා ගෙන ඇත.

■ ප්ලාස්ටික් භාවිතය අවම කිරීම සහ බුද්ධිමත්ව භාවිතා කිරීම, විකල්ප භාවිතය ප්‍රවර්ධනය, භාවිත කර ඉවතලන ප්ලාස්ටික් ප්‍රතිචක්‍රීකරණයට යොමු කිරීම සහ පරිසර හිතකාමී ලෙස බැහැර කිරීම මඟින් මෙම ව්‍යසනය අවම කරගත හැක.

හැඳින්වීම

ප්ලාස්ටිකොස් යන ග්‍රීක වචනය ඇසුරින් ප්ලාස්ටික් යන වචනය සැදී ඇති අතර මෙහි අරුත, බිඳී යාමකින් තොරව වෙනස් කළ හැකිය යන්නයි. ප්ලාස්ටික් ෆොසිල ඉන්ධන නිෂ්පාදනයේ අතුරු ඵලයක් වන අතර, ලොව පුරා ෆොසිල ඉන්ධන භාවිතය වැඩිවීමත් සමගම ප්ලාස්ටික් නිෂ්පාදනය ද වැඩිවේ. ප්ලාස්ටික් ප්‍රධාන වශයෙන් 99% පමණ සාදනු ලබන්නේ බොරතෙල්වලිනි. මෙහි ප්‍රධාන වශයෙන් කාබන් සහ, ඔක්සිජන් යන මූලද්‍රව්‍ය අඩංගුවේ. මෙයට අමතරව, සල්ෆර් නයිට්‍රජන් ආදී මූලද්‍රව්‍ය ද අඩංගු විය හැක. ප්ලාස්ටික් ප්‍රධාන වශයෙන් වර්ග 02 ට බෙදේ. එනම් තාප ස්ථායි ප්ලාස්ටික් (Thermosetting) සහ තාපස්ථායි නොවන ප්ලාස්ටික් (Thermoplastics) වේ. තාපස්ථායී නොවන ප්ලාස්ටික් ප්‍රතිචක්‍රීකරණය කල හැක.

ප්ලාස්ටික් නිෂ්පාදනය සඳහා ස්වාභාවික වායු, ගල් අඟුරු යොදා ගනු ලබන අතර, පෙව ප්ලාස්ටික් (Bio Plastic) නිපදවනු ලබන්නේ ශාකමය ද්‍රව්‍ය උපයෝගී කරගෙනය. උදාහරණ ලෙස එළවලු තෙල්, පිටුරු, මඤ්ඤොක්කා, ලී කුඩු ආදිය මේ සඳහා යොදා ගනී.

ප්ලාස්ටික්, වර්තමාන ලෝකයේ ඉතා බහුලව භාවිතකරන අතර එයට හේතුව, කල් පැවැත්ම, මිල අඩු වීම, සැහැල්ලු බව, ජලය සමඟ ප්‍රතික්‍රියා නොකිරීම ආදී ලක්ෂණයි. ප්ලාස්ටික් වලට වර්ණක, ස්ථායිකාරක සහ ආකලන ආදිය යොදා විවිධ ගුණයන්ගෙන් යුතු ප්ලාස්ටික් නිෂ්පාදනය කරනු ලැබේ.

1907 බේක්ලයිට් නමැති ප්ලාස්ටික් වර්ගය එකල ආශ්චර්යමත් සොයාගැනීමකි.

මේ වනවිට ලොව පුරා, ප්ලාස්ටික් ටොන් මිලියන් 350 ක් පමණ වසරකට නිපදවන අතර මෙම අගය 2050 වන විට තුන් ගුණයක් පමණ වන බව ගණන් බලා තිබේ. නිෂ්පාදනය කරන ප්ලාස්ටික් වලින් 9% ප්‍රතිචක්‍රීකරණය කරන අතර 12% පරිසර හිතකාමී ලෙස පුළුස්සා දැමේ (Incinerate). එමෙන්ම 8% පමණ සාගරයට මුදා හැරේ. අනෙත් ප්ලාස්ටික් බොහොමයක් අනිසි ලෙස බැහැර කෙරේ.

අද වන විට ප්ලාස්ටික් භාවිතය ඉතාම අධික වී ඇති අතර ලොව පුරා ප්ලාස්ටික් ව්‍යසනයක් බවට පත්වී ඇත. මෙයට හේතුව අනවශ්‍ය ලෙස සහ අධික ලෙස ප්ලාස්ටික් භාවිත කිරීමත් භාවිතයෙන් පසු නිසි ලෙස බැහැර නොකිරීමත්, ප්ලාස්ටික් ප්‍රතිචක්‍රීකරණය අවම මට්ටමක පැවතීමත්ය.

ප්ලාස්ටික් බෝතල් නිශ්පාදනය
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ප්ලාස්ටික් නිශ්පාදන කර්මාන්ත ශාලාවලින් ඇතිවන වායු දූෂණය © Giles Clarke/Getty Images

ප්ලාස්ටික් සහ දේශගුණ විපර්යාස

ප්ලාස්ටික් දූෂණය සහ දේශගුණ විපර්යාස ඉතා තදින් බැඳුනු අංශ දෙකකි. දේශගුණ විපර්යාස පිළිබඳ අන්තර්රාජ්‍ය සභාවෙහි (Intergovernmental Panel on Climate Change) පර්යේෂණවලට අනුව 2019 වසරේ ප්ලාස්ටික් දහනය නිසා හරිතාගාර වායු ටොන් මිලියන 850 ක් පරිසරයට මුදා හැර ඇති අතර 2050 වනවිට එය ටොන් බිලියන් 2.8 ක් පමණ වනු ඇතැයි ගණන් බලා ඇත.

එමෙන්ම ප්ලාස්ටික්වල ජීවන චක්‍රයේ සියලුම පියවරවලදී හරිතාගාර වායු මුක්තවීම සිදුවේ. මෙලෙස ප්ලාස්ටික් සෑදීම සඳහා අමුද්‍රව්‍ය ලෙස බොර තෙල් පොළොවෙන් ලබාගැනීමේදී, ප්‍රවාහනයේදී සහ නිෂ්පාදන ක්‍රියාවලියේ දී හරිතාගාර වායු නිකුත් වේ. එබැවින් ප්ලාස්ටික් නිෂ්පාදනය සහ භාවිතය දේශගුණ විපර්යාස ඇතිකිරීමට සෘජුව බලපායි.

ක්ලෝරීන් අඩංගු ප්ලාස්ටික් පිලිස්සීමෙන් ඩයොක්සින් සහ ෆියුරාන් නම් පිළිකාකාරක වායු නිපදවෙන අතර, ප්ලාස්ටික් අපද්‍රව්‍ය පිළිස්සීම මගින් පරිසරයට කාබන් 38% මුදා හැරේ. එබැවින් ප්ලාස්ටික් අපද්‍රව්‍ය පිළිස්සීම වෙනුවට ප්ලාස්ටික් අපද්‍රව්‍ය පරිසර හිතකාමී ලෙස පරිසරයට බැහැර කිරීම සඳහා ක්‍රමෝපායන් යොදා ගැනීම වැදගත් වේ. පිළිස්සීම හැර වෙනත් පරිසර හිතකාමී ක්‍රම යොදා ගනිමින්, ප්ලාස්ටික් බැහැර කිරීමෙන් පරිසරයට කාබන් මුදා හැරීම 1/3 කට අඩු කළ හැක.

ජාත්‍යන්තර පාරිසරික නීතිය පිළිබඳ මධ්‍යස්ථානය (Center for International Environmental Law- CIEL) පවසන අන්දමට ප්ලාස්ටික් නිෂ්පාදනය දේශගුණ විපර්යාසයන්ට ඇතිකරන බලපෑම ගල් අඟුරු බලාගාර 189 ක් මගින් පරිසරයට ඇතිකරන බලපෑමට සමාන කර ඇත. පුරෝකතනය කර ඇති ලෙස 2050 දී ප්ලාස්ටික් නිෂ්පාදනය තුන්ගුණයක් වූ විට එය ගෝලීය කාබන් විමෝචනයෙන් 13% කට සම කළ හැකි අතර එය බලශක්ති බලාගාර 615 ක් මගින් පරිසරයට ඇතිකරන බලපෑමට සමාන බව පැවසේ.

2015 වන විට ලොව පුරා, නැවුම් ප්ලාස්ටික් මෙට්‍රික් ටොන් මිලියන 8,300 ක් නිපදවා ඇති අතර මෙයින් 2/3 මේ වනවිට පරිසරයේ පවතී. මෙසේ පරිසරයේ පවතින ප්ලාස්ටික්, විශේෂයෙන්ම පොලිතින් සූර්ය විකිරණවලට නිරාවරණය වීමෙන් මීතෙන් සහ එතිලින් යන සෘජු සහ වක්‍ර ලෙස හරිතාගාර වායු පරිසරයට මුදා හැරේ. මෙය දේශගුණ විපර්යාස තීව්‍ර කිරීමට හේතු වේ.

ප්ලාස්ටික් නිෂ්පාදනය වර්ධනය වීමත් සමඟම එය නිෂ්පාදනයට අමුද්‍රව්‍ය ලෙස බොර තෙල් ප්‍රමාණය වැඩි වන අතර දේශගුණ විපර්යාස සඳහා වන දායකත්වය ද වැඩි වේ.

දාහකය (Incinerators) © Lanka Refractories Limited

ප්‍රතිචක්‍රීකරණය කල හැකි පොලිප්‍රොපීලීන් සුභුරු

ස්වාභාවික වායු සුලභ වීමත් සමගම ෆොසිල ඉන්ධන සඳහා ඇති ඉල්ලුම යම් රටවල්වල අඩුවීම හේතුවෙන්, මෙම ෆොසිල ඉන්ධන නිෂ්පාදනය කරන කර්මාන්තශාලා බොර තෙල් භාවිතයෙන් ප්ලාස්ටික් නිෂ්පාදනයට පෙළඹී ඇත. මෙය ඉතාම භයානක තත්ත්වයක් වන අතර ඔවුන් ප්ලාස්ටික් නිෂ්පාදනය සීඝ්‍ර වර්ධනයක් කර ගෙනයාමට ද යන්න දරමින් සිටී.

සුපිවා ප්‍රනාන්දු

පැසිපික් සාගරයේ ඇති විශාලතම අපද්‍රව්‍ය එකතුව
© Ocean Cleanup

සාගර ප්ලාස්ටික් අපද්‍රව්‍ය වල බහුලවම ඇත්තේ මාළු දැල්ය
© Jackson Mcmuldren/ Ocean Voyages Institute

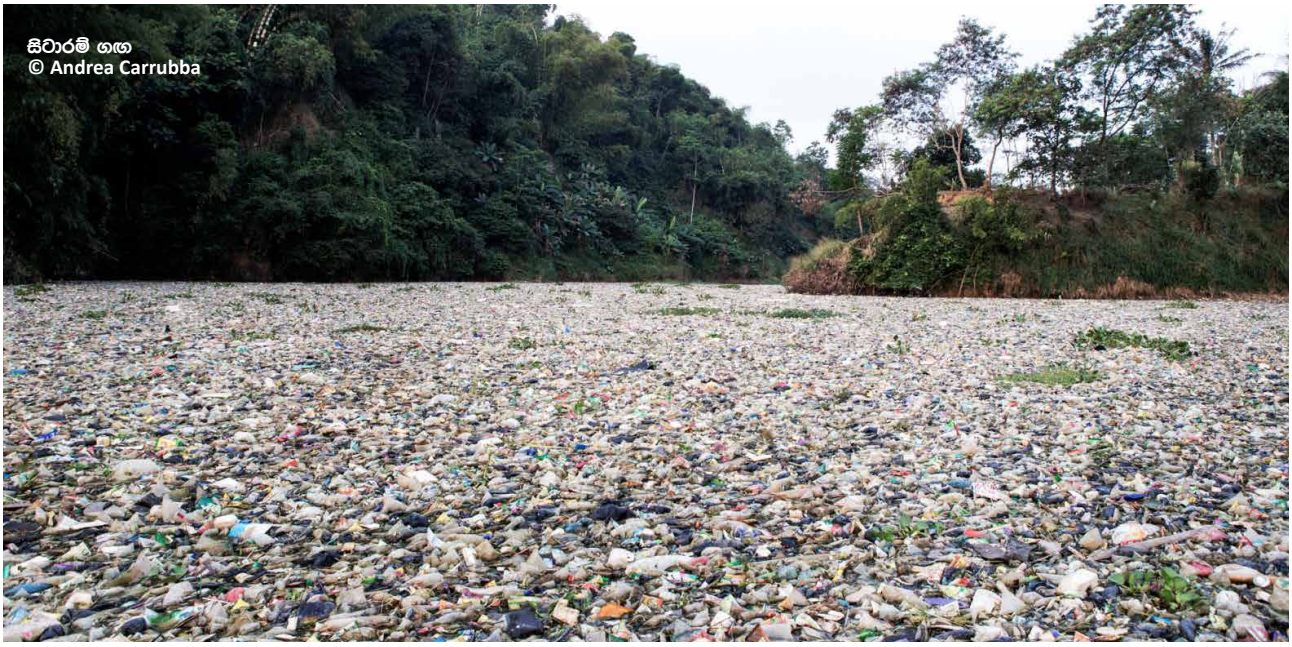
ප්ලාස්ටික් දූෂණය සහ සාගරයට ඇති බලපෑම

අද වන විට සාගරය විශාල ලෙස ප්ලාස්ටික්වලින් දූෂණය වී ඇති අතර, කිලෝ මීටර් 11 ක් ගැඹුරු මරියානා ආගාධයෙහි පවා ප්ලාස්ටික් තැන්පත්ව ඇත.

පෘථිවියට අවශ්‍ය ඔක්සිජන් ප්‍රමාණයෙන් 65%-80% පමණ ප්‍රමාණයක් නිපදවන්නේ සාගරයේ ඇති ශාක ප්ලවාංගයන්ය. ඔවුන් ප්‍රභාසංස්ලේෂණ කාර්යාවලිය සඳහා කාබන් ඩයොක්සයිඩ් 30%-50% උරාගන්නා අතර, ප්ලාස්ටික් නිසා සාගරය දූෂණය වීමත් සමගම ශාක ප්ලවාංගවල වර්ධනයට හානි පැමිණේ, එවිට කාබන් ඩයොක්සයිඩ් උරා ගැනීමේ හැකියාව අඩුවේ. මෙය දේශගුණ විපර්යාස වැඩි වීමට බලපායි.

මේ වන විට පැසිෆික් සාගරයේ ප්ලාස්ටික් අපද්‍රව්‍ය එකතු වී දුපතක් සෑදී ඇත (Great Pacific Garbage Patch). මෙහි ප්ලාස්ටික් කැබලි ට්‍රිලියන 1.8 ක් පමණ ඇති අතර ප්ලාස්ටික් ටොන් 80,000 ක් ඇතයි ගණන් බලා ඇත. මෙහි බහුලවම ඇත්තේ මාළු දැල්ය.

මේ වන විට ලොව වටා ප්ලාස්ටික් අපද්‍රව්‍ය එකතු වී දුපත් 05 ක් සැදෙමින් පවතී © Tomra



සිටාරම් ගඟ
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ලොව ඇති දූෂිතම ගංගාව ලෙස සැලකෙන්නේ ඉන්දුනීසියාවේ ඇති සිටාරම් ගඟයි. මෙහි බහුල වශයෙන් ප්ලාස්ටික් අපද්‍රව්‍ය දැකිය හැක.

මුහුදු පත්ලේ ප්ලාස්ටික් තැන්පත්වීම නිසා මුහුදු ශාක වලට මෙන්ම සත්ත්වයන්ගේ ජීවිතවලට හානි පැමිණේ. සමහර මුහුදු ජීවීන් ප්ලාස්ටික් මලු ජෙල් ෆිෂ් (Jelly Fish) යයි වැරදි ලෙස වටහාගෙන ආහාරයට ගනී.

ප්ලාස්ටික් නිසා සතුන්ගේ ජීවන චක්‍ර හා ජීවන රටාවන් වලට විවිධ හානි සිදුවේ.

නොදැනුවත්වම, කසළ බිම්වල ඇති ප්ලාස්ටික් ආහාරයට ගන්නා සතුන්: ප්ලාස්ටික් මොවුන්ගේ ආහාර මාර්ගය අවහිර කිරීම නිසා, මෙම සතුන් ජීවිතක්ෂයට පත්වීමට හැක.

ප්ලාස්ටික් නිසා සතුන්ට ඇතිවන හානිකර තත්ත්වයන්
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ජෙලිෆිෂ් වැනි සතුන්ගේද ප්ලාස්ටික් අපද්‍රව්‍ය හමු වේ
© Alexander Semenov

ප්ලාස්ටික් පිළිබඳ දැනගතයුතු කරුණු

- වසරකට ප්ලාස්ටික් බෑග් - බිලියන 500 ක් ලොව පුරා භාවිත වේ.
- වසරකට ප්ලාස්ටික් ටොන් මිලියන 13ක් සාගරයට එකතු වේ.
- වසරකට ප්ලාස්ටික් සැදීම සඳහා තෙල් බැරල් මිලියන 17 ක් අවශ්‍ය වේ.
- සෑම විනාඩියකටම වරක් ප්ලාස්ටික් බෝතල් මිලියන 01 ක් මිල දී ගැනේ.
- වසරකට මුහුදු ජීවීන් 100,000 ක් පමණ ප්ලාස්ටික් නිසා ජීවිතක්ෂයට පත් වේ.
- ප්ලාස්ටික් දිරාපත්වීමට වසර 100ක් පමණ ගත වේ.
- 90% පානීය ජල බෝතල්වල ප්ලාස්ටික් අංශු අඩංගු වේ.
- 83% නල ජලයේ ප්ලාස්ටික් අඩංගු වන බව සොයාගෙන ඇත.
- 50% නිෂ්පාදන වික් වරක් පමණක් භාවිතා කරන ප්ලාස්ටික් වේ.
- මිනිසුන් ජනනය කරන කසළ වලින් 10% ප්ලාස්ටික් වේ.
- නිෂ්පාදනය කරන ප්ලාස්ටික්වලින් 50% වික්වරක් භාවිත කර ඉවතලන ප්ලාස්ටික් වේ (single use plastics).

ප්ලාස්ටික් සහ පොලිතින් යන සියල්ල ප්ලාස්ටික් කාණ්ඩයට අයත් වේ

ආහාර ඇසිරීම සඳහාම නිර්දේශ කරන ලද ප්ලාස්ටික් හඳුනාගැනීමේ ලාංඡන
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ප්ලාස්ටික් වර්ග

1. පොලි එතිලින් ටෙරෙප්තැලේට් (PET)
2. වැඩි ඝනත්ව පොලි එතිලින් (HDPE)
3. පොලි වයිනයිල් ක්ලෝරයිඩ් (PVC)
4. අඩු ඝනත්ව පොලි එතිලින් (LDPE)
5. පොලිප්‍රොපිලින් (PP)
6. පොලිස්ටයිරින් (PS)
7. මිශ්‍ර ප්ලාස්ටික්

ප්ලාස්ටික් වර්ගවලින් සමහර ප්ලාස්ටික් විෂ සහිත වේ. එම නිසා ආහාර ඇසුරුම් සඳහා භාවිතා කළයුත්තේ ආහාර ඇසිරීම සඳහාම නිර්දේශ කරන ලද ප්ලාස්ටික් (Food Grade Plastic) වේ. එනම්, PET, HDPE, LDPE සහ PP යන වර්ගයි. PVC හෝ PS සහ මිශ්‍ර ප්ලාස්ටික් ආහාර ඇසුරුම්වලට යොදා ගැනීම සුදුසු නොවේ. Food Grade Plastic හඳුනාගැනීම සඳහා "වයින් වීදුරුව සහ ගෑරුප්පුව" යන සලකුණ භාවිතා කෙරේ.

ප්ලාස්ටික් වර්ග 07
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ක්ෂුද්‍ර ප්ලාස්ටික් © SciTechDaily

ක්ෂුද්‍ර ප්ලාස්ටික් (Micro Plastics)

ක්ෂුද්‍ර ප්ලාස්ටික් යනු මිලි මීටර් 05 ට වඩා කුඩා විශ්කම්භයකින් යුත් ප්ලාස්ටික් කැබලි වේ. මේවා තවදුරටත් කැඩී මයික්‍රෝ මීටර් 0.1 වඩා කුඩා වූ විට "නැනෝ ප්ලාස්ටික්" නම් වේ.

ක්ෂුද්‍ර ප්ලාස්ටික් ප්‍රාථමික සහ ද්විතීයික ලෙස නම් කළ හැක. මිලිමීටර 5 ට වඩා කුඩා ලෙස කාර්මිකව නිෂ්පාදනය කරන ප්ලාස්ටික් ප්‍රාථමික ක්ෂුද්‍ර ප්ලාස්ටික් ලෙසත්, අධික හිරු එළිය, වැස්ස වැනි බාහිර සාධක වලට මුහුණ දෙනවිට ප්ලාස්ටික් භාණ්ඩ කැඩී බිඳී යාමෙන් ඇතිවන ප්ලාස්ටික් ද්විතියික ක්ෂුද්‍ර ප්ලාස්ටික් ලෙසත් හැඳින්වේ.

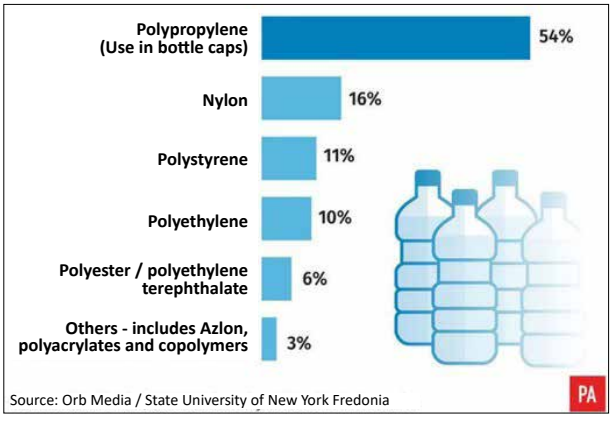
- ක්ෂුද්‍ර ප්ලාස්ටික් - Micro beads, දන්තාලේප, රූපලාවන්‍ය ද්‍රව්‍ය, ඇඳුම් සහ නොයෙකුත් ප්ලාස්ටික් නිෂ්පදානවල ඇත.
- මෙම ද්‍රව්‍ය අවසානයේ අපජලය සමඟ එකතුවී අපජල පද්ධති හරහා ජලාශවලට හෝ මුහුදට එකතුවේ. මුහුදට යාමෙන් සතුන් ආහාරයට ගැනීමට පෙළඹේ.
- සමහර ප්ලාස්ටික්වල විෂ රසායනිකයන් අඩංගු වේ (ක්ලෝරින්/බිස්ෆීනොල් A වැනි). මෙම රසායනික ද්‍රව්‍ය ශරීරයට අහිතකර වන අතර, සමහර සංයෝග අන්තරාසර්ගි වියවුල්කාරක (endocrine disruptors) වේ.

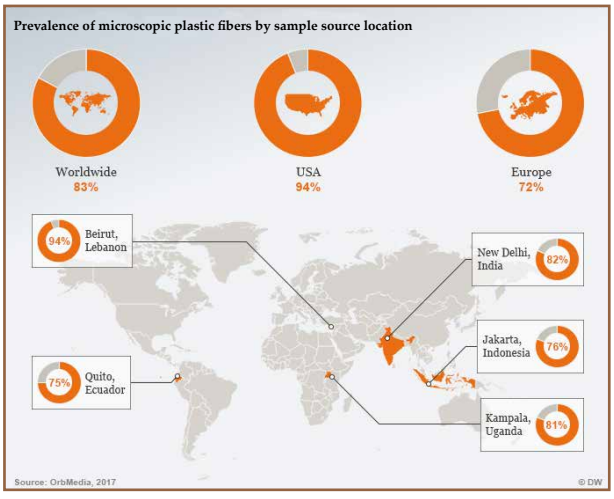
මෙම නිෂ්පාදනය කරන ප්‍රාථමික ක්ෂුද්‍ර ප්ලාස්ටික් රූපලාවන්‍ය නිෂ්පාදනවල, දන්තාලේපවල දැකිය හැක.

නොයෙකුත් ප්ලාස්ටික් නිෂ්පාදන ගොඩ ගැසී ඇති කසළ කන්දක් © EJAtlas

තැන තැන කසළ දැමීමෙන්, එහි ඇති කුඩා ප්ලාස්ටික් කැබලි හෝ ප්ලාස්ටික් භාණ්ඩ දිරාපත්වීමෙන් ඇතිවන කුඩා ප්ලාස්ටික් කැබලි වාතයේ, ජලයේ සහ පසේ දැකිය හැක.

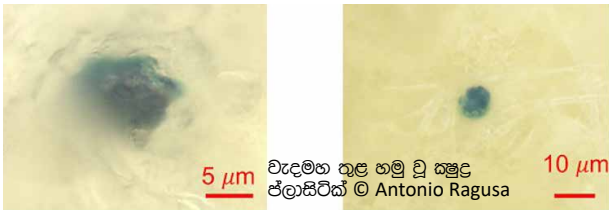
අද වනවිට පස, ජලය සහ වාතය ක්ෂුද්‍ර ප්ලාස්ටික්වලින් දූෂණය වී ඇති අතර සතියකට ප්ලාස්ටික් ග්‍රෑම් 02-05 ක් පමණ ප්‍රමාණයක් මිනිසකුගේ ශරීරගත වන බව සොයාගෙන ඇත. නල ජලයේ හා බෝතල් ජලයේ ක්ෂුද්‍ර ප්ලාස්ටික් දැකිය හැක.





බෝතල් කළ ජලයේ හමුවන ප්ලාස්ටික් වර්ග හා විවිධ රටවල් වල නල ජලයේ ඇති ප්ලාස්ටික් ප්‍රතිශතය

එමෙන්ම, වසරකට මිනිසකුට ක්ෂුද්‍ර ප්ලාස්ටික් කොටස් 50,000ක් පමණ ශරීරගත වේ. නවතම සොයා ගැනීම් අනුව කාන්තාවන්ගේ දරු ප්‍රසුතියේදී වැදුමහ තුල ක්ෂුද්‍ර ප්ලාස්ටික් ඇති බව සොයා ගෙන ඇති අතර, එමගින් කුඩා දරුවන්ට නොයෙකුත් බලපෑම් ඇතිවිය හැක. මෙම ක්ෂුද්‍ර ප්ලාස්ටික් පොලිප්‍රොපිලින් ලෙස හඳුනාගෙන ඇති අතර, හඳුනා නොගත් ප්ලාස්ටික් වර්ග ද හමුවී ඇත.



වැදුමහ තුළ හමු වූ ක්ෂුද්‍ර ප්ලාස්ටික් © Antonio Ragusa

ශ්‍රී ලංකාව තුල සිදු කළ පර්යේෂණවලින්, මුහුදු මත්සයන්ගේ සහ ආහාරයට ගන්නා ලුණුවල ක්ෂුද්‍ර ප්ලාස්ටික් ඇති බව තහවුරු වී ඇත. එමෙන්ම වෙරළ තිරය ද ක්ෂුද්‍ර ප්ලාස්ටික්වලින් දූෂණය වී ඇති බව සනාථ වී ඇත.

එක්වරක් පමණක් භාවිත කරන ප්ලාස්ටික් (Single Use Plastics /SUPs)

මෙම ප්ලාස්ටික් එක්වරක් පමණක් භාවිතා කර පරිසරයට බැහැර කෙරේ. උදාහරණ ලෙස යෝගට් කෝප්ප, ෂොපින් බෑග් - සිලිසිලි මලු, ප්ලාස්ටික් බීම බට, කෝප්ප, පිඟන්, හැඳි, ගෑරුප්පු ආදිය දැක්විය හැකිය. ලොවපුරා භාවිතවන ප්ලාස්ටික් නිෂ්පාදනවලින් 50%ක් එක්වරක් පමණක් භාවිත කරන ප්ලාස්ටික් වේ.


එක්වරක් පමණක් භාවිත කරණ ප්ලාස්ටික් © MRW

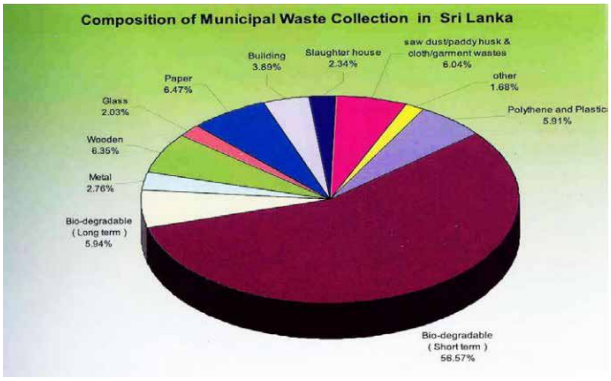
ශ්‍රී ලංකාව තුළ ප්ලාස්ටික් කළමනාකරණයේ වර්තමාන තත්ත්වය

ශ්‍රී ලංකාවේ ප්ලාස්ටික් ආනයනය, භාවිතය සහ පසුභාවිත කළමනාකරණය සම්බන්ධ වූ පරිසර විගණන වාර්තාව අනුව 2012 සිට 2018 දක්වා කාලය තුළ දී ශ්‍රී ලංකාවට ආනයනය කරන ලද ප්ලාස්ටික් ප්‍රමාණය (අමුද්‍රව්‍ය, නිමිද්‍රව්‍ය, ගෘහ භාණ්ඩ හා සෙල්ලම් බඩු ඇතුළත්ව) කිලෝග්‍රෑම් මිලියන 3,353.9 ක් පමණ වේ.

අප රටට 2019 සහ 2020 ආනයනය කරන ලද ප්ලාස්ටික් අමුද්‍රව්‍ය සහ නිමි භාණ්ඩ, පහතින් දැක්වේ.

වර්ගය	2019	2020
අමුද්‍රව්‍ය	342,703 MT	288,806 MT
නිමි භාණ්ඩ	101,281 MT	118,015 MT
මුළු ගණන	**443,984 MT**	**406,821 MT**

නගරසභා මගින් එකතු කරන කසළවල සංයුතියෙන් වැඩි ප්‍රමාණයක් දිරාපත් වන අපද්‍රව්‍ය වන අතර 2005 වසරේ ප්ලාස්ටික් අපද්‍රව්‍ය 5.9%ක් පමණ වූ අතර එය දැන් 9%ක් පමණ වේ.



නගරසභා මගින් එකතු කරන ලද කසල වල ඇති සංයුතිය (Database of Municipal Solid Waste In Sri Lanka -2005 – Ministry of Environment & Natural Resources)

ඇස්තමේන්තු කර ඇති ලෙස දිනකට ප්ලාස්ටික් අපද්‍රව්‍ය මෙට්‍රික් ටොන් 938.12ක් ජනනය වන අතර එයින් එකතු කරනු ලබන්නේ මෙට්‍රික් ටොන් 300.30ක් (32%) වන අතර, මෙට්‍රික් ටොන් 638.12ක් (68%) එකතු කරනු නොලැබේ.

විවෘත කසල බිම්වලට මෙට්‍රික් ටොන් 261.82 (27.9%) ක් ද පුද්ගලිකව මෙට්‍රික් ටොන් 139.82 (14.9%) ක් ද නීත්‍යානුකූල නොවන ලෙස මෙට්‍රික් ටොන් 70 (7.5%) ක් ද, ජලයට මෙට්‍රික් ටොන් 8.45 (0.9%) ක් ද බැහැර කෙරෙන අතර, විවෘත දහනය මගින් මෙට්‍රික් ටොන් 419.47 (44.7%) ක් ද විනාශ කෙරේ. ප්‍රතිචක්‍රීකරණය සඳහා යොමුවන්නේ මෙට්‍රික් ටොන් 38.48 (4.1%) ක් බව ඇස්තමේන්තු කොට ඇත.

දිනකට ආහාර ඇසුරුම් (Lunch sheet) මිලියන 15ක්, පොලිතින් මලු (Shopping bags) මිලියන 20 ක් සහ කුඩා ඇසුරුම් (Satchet packet) (තහනමට පෙර) පැකට් මිලියන 01ක් පරිසරයට මුදා හැරෙන අතර, මසකට යෝගට් කෝප්ප මිලියන 45ක් පමණ ද පරිසරයට මුදා හැරේ. (National Post Consumer Plastic Waste Management Project, Central Environmental Authority-2013).

මධ්‍යම පරිසර අධිකාරියේ ලියාපදිංචි වූ ප්ලාස්ටික් ප්‍රතිචක්‍රීකරණ ආයතන 200ක් පමණ ඇත.

ප්ලාස්ටික් පිලිබඳ රෙගුලාසි: මධ්‍යම පරිසර අධිකාරිය මගින් පරිසර පනත යටතේ ප්ලාස්ටික් කළමනාකරණය සඳහා රෙගුලාසි පනවා ඇත. පිළිවෙලින් 2006 වසරේ රෙගුලාසි 01 ක් සහ 2017 රෙගුලාසි 06ක් සහ 2021 රෙගුලාසි 06ක් පනවා ඇත. මින් සමහර රෙගුලාසි ඉතාම සාර්ථක වූ අතර, අනෙකුත් රෙගුලාසි අනෙකුත් ආයතන සහ ප්‍රජාව සමග සහයෝගයෙන් කටයුතු කරමින් සාර්ථක කර ගත යුතු වේ.

කසල වෙන්කිරීම සඳහා වර්ණ වර්ගීතරණය © Daily News


එකතු කරන ලද ප්ලාස්ටික් බෝතල්

2006.10.10 දින අංක 1466/5 දරන ගැසට් නිවේදනය යටතේ පළ කරන ලද ආඥාව

මයික්‍රෝන 20ට අඩු පොලිතීන් හෝ පොලිතීන් නිෂ්පාදන භාවිතය තහනම් කිරීම.

2017.09.01 විස්තරය

2034/33
2017/09/01 පොලිතින් හෝ යම් පොලිතින් නිෂ්පාදනයක් මයික්‍රෝන 20 හෝ ඊට අඩු ඝනකමින් නිෂ්පාදනය තහනම් කිරීමේ නියෝගය.

2034/34
2017/09/01 පොලිතින් ආහාර දවටන (ලන්ච් ෂීට්) නිෂ්පාදනය භාවිතය හා වෙළඳාම තහනම් කිරීමේ නියෝගය.

2034/35
2017/09/01 වැඩි ඝනත්ව පොලිඑතලීන් (HDPE) වලින් නිපදවන ෂොපින් බෑග් හා ග්‍රොසරි බෑග් නිෂ්පාදනය, වෙළඳාම හා භාවිතය තහනම් කිරීමේ නියෝග.

2034/36
2017/09/01 ප්ලාස්ටික් ද්‍රව්‍ය හා අවශේෂ විවෘත දහනය තහනම් කිරීමේ නියෝග.

2034/37
2017/09/01 උත්සව සැරසිලි සඳහා පොලිතින් ආශ්‍රිත ද්‍රව්‍ය භාවිතය තහනම් කිරීමේ නියෝග.

2034/38
2017/09/01 ප්‍රසාරිත පොලිස්ටයරීන්, කෑම පෙට්ටි නිෂ්පාදනය වෙළඳාම හා භාවිතය තහනම් කිරීමේ නියෝග.

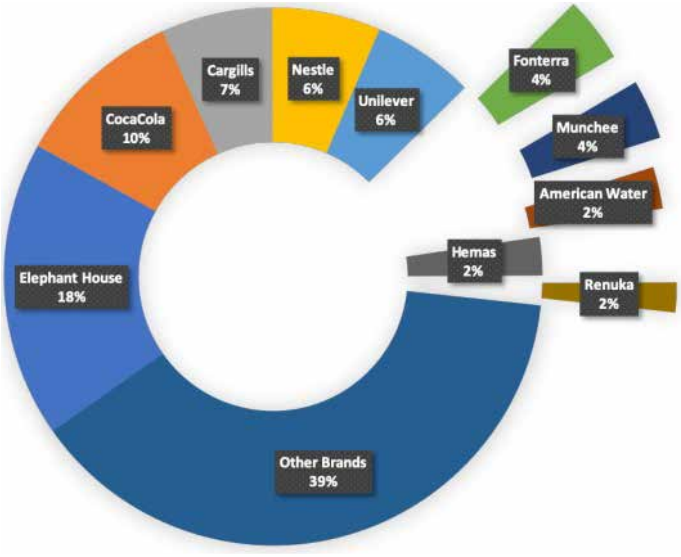
ප්ලාස්ටික් පිලිබඳ රෙගුලාසි - 2021.03.31

1. කෘෂි රසායන PET සහ PVC ප්ලාස්ටික්වල ඇසිරීම තහනම් වේ.
2. මිලි ලීටර 20 හෝ ග්‍රෑම් 20 හෝ ඊට අඩු සැශේ පැකට් තහනම් කිරීම (ආහාර සහ ඖෂධ හැර)
3. හුලං පුරවන සෙල්ලම් බඩු තහනම් වේ (පිහිනුම් තටාක උපකරණ හැර)
4. ප්ලාස්ටික් බඳ සහිත කොටින් බඩි තහනම් වේ. (වෛද්‍ය කටයුතු හැර)
5. ප්ලාස්ටික් වර්ගවල කේත අංක (1-7) දක්වා සඳහන් කිරීම අනිවාර්ය කෙරේ.

පරිසර යුක්ති කේන්ද්‍රය විසින් නොයෙකුත් නිෂ්පාදකයින් අලලා සිදුකරන ලද ප්ලාස්ටික් විගණනය (Brand Audit) – 2019

යම් ස්ථානයක එකතු වන ප්ලාස්ටික් අපද්‍රව්‍ය විශ්ලේෂණය කිරීමේදී එක් එක් නිෂ්පදාකයන් පරිසරයට මුදාහරින ප්ලාස්ටික් ප්‍රමාණය ප්‍රතිශතයක් ලෙස හඳුනාගත හැක. එහිදී වඩා අපද්‍රව්‍ය ජනනය කරන්නේ, කුමන නිෂ්පදාකයා දැයි හඳුනාගත හැක.

මෙහිදී මෙම නිෂ්පාදකයින් තම නිෂ්පාදන නිසා පරිසරයට සිදුවන හානිය අවම කිරීමට කටයුතු කිරීමට පෙළඹවීම සඳහා නිසි ක්‍රමවේදයක් සකස්කර නිෂ්පාදකයින් ඒ වෙත යොමුකලයුතු බැව් වැටහී යයි. මේ අනුව ඉදිරියේදී පරිසර අමාත්‍යාංශය විසින් "නිෂ්පාදකයාගේ විස්තීරණ වූ වගකීම" (Extended Producer Responsibility) සංකල්පය යොදා ගනිමින් නිසි ක්‍රමවේදයන් සකස් කිරීමට යෝජිතය. මෙහිදී මෙම නිෂ්පාදකයින් යම්කිසි මූල්‍යමය දායකත්වයක් දරා පරිසරයට මුදාහරින ප්ලාස්ටික් බෝතල් ප්‍රතිචක්‍රීකරණය කිරීමේ ක්‍රමවේදයක් සකස් කලයුතුවේ.



ඉහළ
යම් ස්ථානයක එකතු වන ප්ලාස්ටික් වර්ග විශ්ලේෂණය කිරීමේදී දැකගත හැකි ප්ලාස්ටික් වර්ග නිෂ්පාදකයන් (Brand) වශයෙන් හඳුනා ගැනීම.

වම
ප්ලාස්ටික් වෙනුවට භාවිත කළ හැකි විකල්ප.

පහළ දකුණ
ඉවතලන ප්ලාස්ටික්වලින් සාදන ලද විසිතුරු භාණ්ඩ.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ප්ලාස්ටික් අපද්‍රව්‍ය කළමනාකරණ ජාතික සැලැස්ම (2021-2030)

ප්ලාස්ටික් අපද්‍රව්‍ය කළමනාකරණ ජාතික සැලැස්ම, අඩු කිරීම (Reduce), නැවත භාවිතය (Reuse) සහ ප්‍රතිචක්‍රීකරණය (Recycle) චක්‍රිය ආර්ථිකය සහ ප්ලාස්ටික් අවසන් බැහැරලීම මත පදනම් වී ඇත.

1 ප්ලාස්ටික් භාවිතය අඩු කිරීම (Reduce) (මෙහිදී ප්ලාස්ටික් භාවිතය අඩු කිරීම, අනවශ්‍ය ලෙස ප්ලාස්ටික් භාවිතය හෝ අව භාවිතය වැළැක්වීමට පියවර ගැනීමත්, ප්ලාස්ටික් වෙනුවට විකල්ප භාවිතය ප්‍රවර්ධනය කිරීමත් වැදගත් වේ.

2 ප්ලාස්ටික් නැවත භාවිතය (Reuse): ප්ලාස්ටික් නිෂ්පාදන නැවත භාවිත කළ හැකි සෑම අවස්ථාවකම එය අපද්‍රව්‍ය ලෙස ඉවත් නොකර නැවත භාවිත කිරීම වැදගත් වේ.

3 ප්ලාස්ටික් ප්‍රතිචක්‍රීකරණය (Recycle): භාවිත කර ඉවතලන ප්ලාස්ටික් නැවත ප්ලාස්ටික් නිෂ්පාදනය සඳහා යොදා ගැනීම මගින් බලශක්තිය ඇතුළු අනෙකුත් සම්පත් සංරක්ෂණයට උපකාරී වේ.

4 වික්වරක් පමණක් භාවිත කරන ප්ලාස්ටික් භාවිතයෙන් වැළකීම (Disposable Single Use Plastic items)

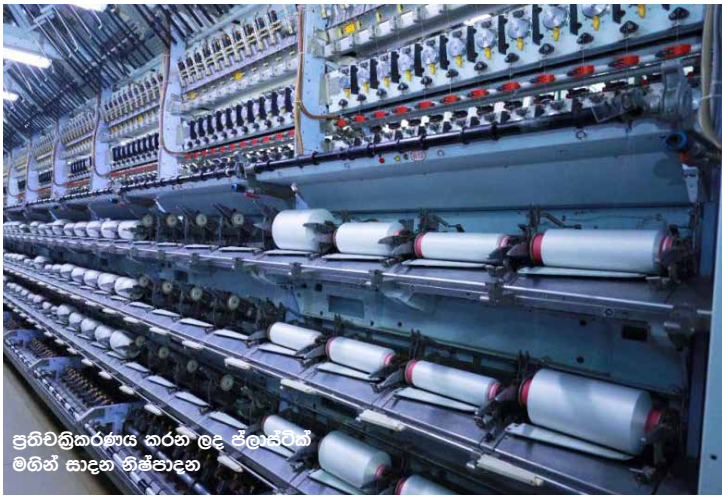
5 ස්වාභාවික ද්‍රව්‍යවලින් නිපදවන ප්ලාස්ටික් භාවිත කිරීම. (Edible/ Bio Plastics).

6 ප්ලාස්ටික් /පොලිතින් අනිසි ලෙස බැහැර කිරීමෙන් වැලකීම

7 පරිසරය පිරිසිදුව සෞඛ්‍ය සම්පන්නව පවත්වාගෙන යාමට දායක වීම.

ප්ලාස්ටික් අපද්‍රව්‍ය කළමනාකරණ සැලැස්ම අරමුණු 16 ක් ඉලක්ක කොටගෙන සකසා ඇත. මෙහි අරමුණු ප්ලාස්ටික් ඉන්වෙන්ටරියක් සැකසීම, ප්ලාස්ටික් අවම කිරීම, නැවත භාවිතය, ප්‍රතිචක්‍රීකරණය, පුහුණු කිරීම්, දැනුවත් කිරීම සහ පර්යේෂණ, ප්‍රතිපාදන ලබාගැනීම, ප්ලාස්ටික් අපද්‍රව්‍ය කළමනාකරණය කරන්නන් සඳහා ජාතික ඇගයීම් ක්‍රමවේදයක් සැකසීම, ප්ලාස්ටික් නිෂ්පාදන, ප්‍රතිචක්‍රීකරණය සහ අපද්‍රව්‍ය හසුරුවන්නන්ගේ සෞඛ්‍ය සහ ආරක්ෂණය, ප්‍රජා සහභාගිත්වය යන අංශ ඔස්සේ සකසා ඇත.

සංක්ෂිප්තව දැක්වුවහොත්, ප්ලාස්ටික් නිෂ්පාදනය සහ භාවිතය නිසා දේශගුණ විපර්යාස සඳහා ඇතිවන බලපෑම අඩු කිරීම සඳහා ප්ලාස්ටික් භාවිතය අඩුකිරීම, විකල්ප භාවිතය ප්‍රවර්ධනය, ප්ලාස්ටික් ප්‍රතිචක්‍රීකරණය වැඩි දියුණු කිරීම, ප්ලාස්ටික් විවෘත දහනය අවම කිරීම සහ පරිසර හිතකාමී ලෙස බැහැර කිරීම සිදුකළ යුතු වේ.



ප්‍රතිචක්‍රීකරණය කරන ලද ප්ලාස්ටික් මගින් සාදන නිෂ්පාදන

ස්වභාවික ද්‍රව්‍ය වලින් නිපදවන නිෂ්පාදන

පාරවලට තාර සමග මිශ්‍ර කර දැමීම
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මූලාශ්‍ර

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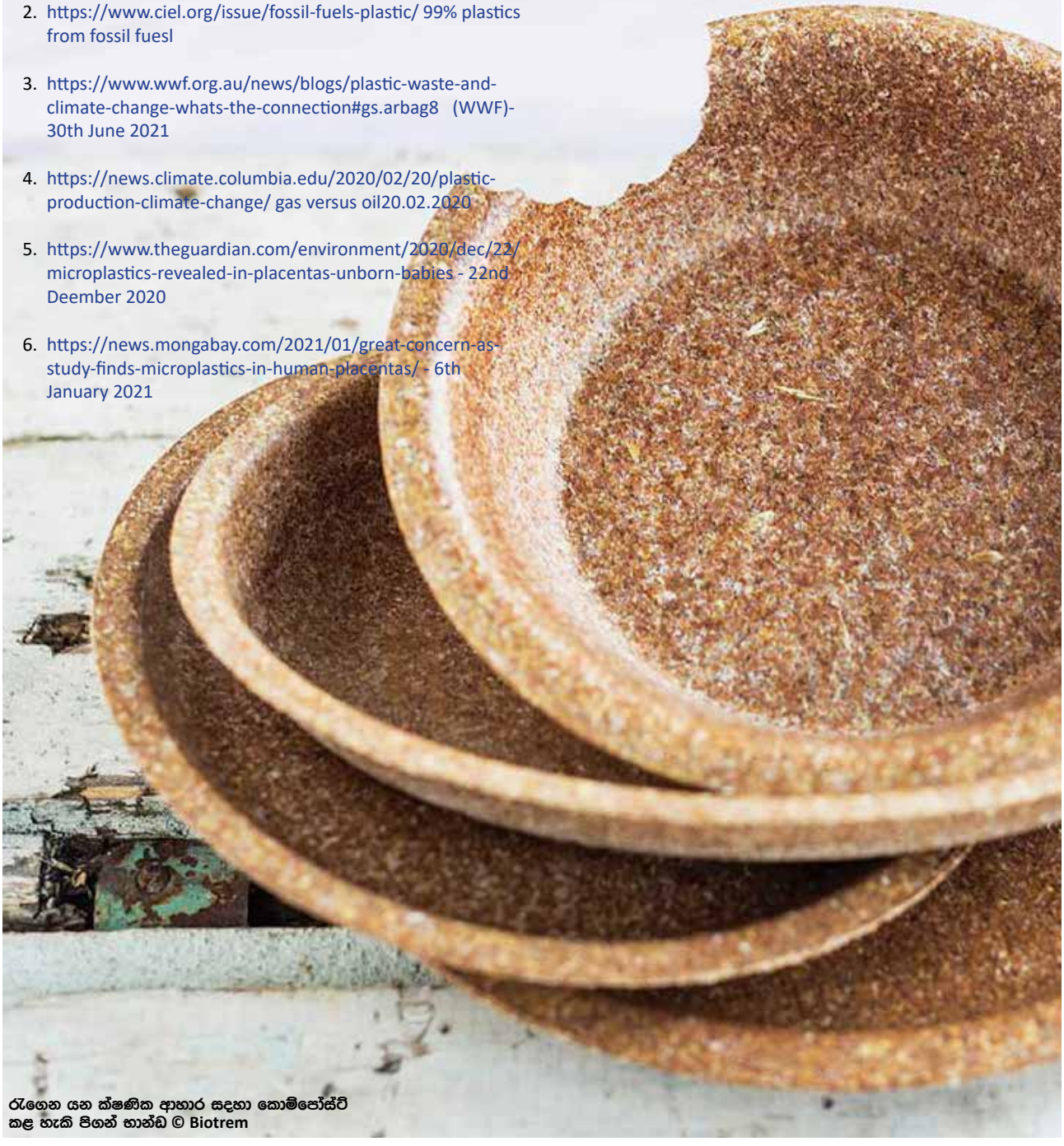

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Climate Change Mitigation and Anaerobic Digestion Technology for Agriculture Industry:

On-Farm Biogas Systems

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Keywords:

BIOGAS, ANAEROBIC DIGESTION TECHNOLOGY, AGRICULTURE and MITIGATION

- **Biogas technology decomposes organic matter by groups of microorganisms in the absence of oxygen inside a manmade vessel under controlled conditions that results in production of methane and digestate.**

- **Organic wastes can naturally generate large amounts of methane as they decompose where appropriate conditions prevail. Methane is a greenhouse gas with high Global Warming Potential (GWP) contributing to global warming and climate change.**

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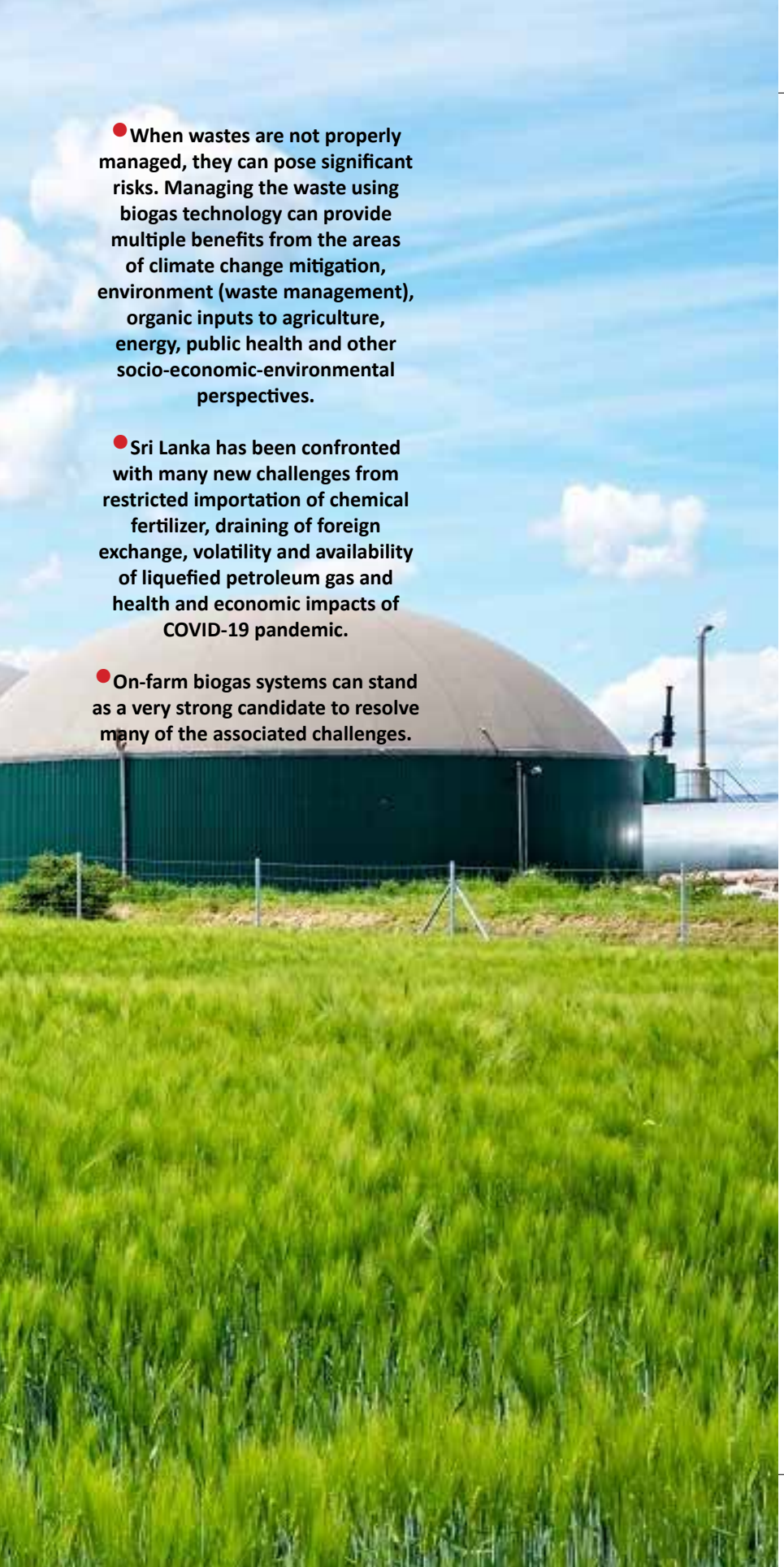

- **When wastes are not properly managed, they can pose significant risks. Managing the waste using biogas technology can provide multiple benefits from the areas of climate change mitigation, environment (waste management), organic inputs to agriculture, energy, public health and other socio-economic-environmental perspectives.**

- **Sri Lanka has been confronted with many new challenges from restricted importation of chemical fertilizer, draining of foreign exchange, volatility and availability of liquefied petroleum gas and health and economic impacts of COVID-19 pandemic.**

- **On-farm biogas systems can stand as a very strong candidate to resolve many of the associated challenges.**

Introduction

Biogas technology refers to decomposition of organic matter by groups of microorganisms in the absence of oxygen. The resultant is a mixture of gases and a digested organic matter in the liquid or a semi- liquid form, which is called the digestate. This mixture of gases primarily consists of methane (50%-70%) and carbon dioxide (30%-40%). Commonly used raw materials in biogas systems include livestock and agricultural wastes, other manure, municipal wastes, agricultural residues, plant material, sewage, industrial organic wastes, industrial waste water and food wastes etc. While biogas can refer to the gas produced naturally or industrially, biogas technology facilitates the organic material to digest inside a man-made vessel under controlled conditions called a reactor (biogas digester) system through the fermentation of the biodegradable organic materials.

The biogas generation process consists of four biochemical reactions, and performance of different groups of microorganisms are responsible for the conversion of organic matter into biogas and digestate. The final phase of this conversion process is called methanogenesis. Two groups of microorganisms, i.e.acetoclastics and hydrogenotrophes are involved in this phase. They belong to one of the oldest groups of living organisms on earth. These microorganisms were first observed in wetlands, responsible for producing marsh gas (Musafer, 2021). These organisms are also commonly found in the gut of ruminants, such as cattle, and in their dung. As these microorganisms are naturally found in nature and the places where biodegradable organic matter is largely found, such as farm yards, dairy farms and open dumping sites, they generate biogas wherever appropriate environmental conditions prevail.

Biogas contains methane which is one of the key gasses contributing to global warming. Its Global Warming Potential (GWP) is between 28-36 times more

than that of carbon dioxide, considering its impacts over a time frame of 100 years, and 84-87 times over a 20 year time frame (IEA, 2021). While leaving the organic matter unattended can lead to generation of methane, capturing and using methane through anaerobic digestion can significantly reduce greenhouse gas (GHG) emissions from manure systems, mitigating the impacts of climate change. An on-farm biogas system can reduce methane emissions from manure storage, handling, and processing, and thereby reduce the climate impacts by a ratio of 28:1 times to 36:1 times over a 100 year time frame.

Evidence suggests that biogas was first used to heat baths in Assyria nearly 3,000 years ago (Primmer, 2021) while biogas has been identified as a clean fuel since the late nineteenth century. This technology was first tested in Sri Lanka in 1973-1974 at a time when its importance as a source of energy was felt significantly, with the global energy crisis. Thereafter, the governmental institutions initiated research and development activities and installed biogas systems across the country. The role played by the Department of Agriculture, Department of Animal Production and Health and the Universities of Peradeniya, Ruhuna and Moratuwa in this regard is commendable. This phase was followed by the non-governmental organizations and the private sector with support from the provincial councils and development agencies. By the year 2014, it was estimated that about 7,000 biogas systems had been installed in Sri Lanka (Musafer, 2015; 2019) in households as well as in the institutional and industrial sectors where Sri Lanka Sustainable Energy Authority, Lanka Biogas Association and Sri Lanka Standards Institute played a catalyst role. After 2015, some internationally supported projects boosted biogas activities with provincial councils while the private sector invested in medium to large scale biogas systems to manage their own institutional and industrial organic waste.

Currently, the interest in biogas technology is in a renaissance because of inter-alia the rapidly growing threat of human induced (anthropogenic) global warming and climate change. The attention has been driven to restrict the unproductive generation and release of methane into the atmosphere. It is because methane is considered to be responsible for a considerable amount of global warming. As a result, biogas technology is effectively deployed in the capture and management of naturally generated or industrially produced methane. Treatment of organic waste from different origins using biogas technology helps in reducing overall methane emissions. Further, waste management and resource recovery using this technology has gained wide acceptance in the context of circular economy.

Sustainable biogas systems are multifunctional. They serve as a waste treatment process; environmental protection; for conversion of low-value material to higher-value material; production of heat and electricity; upgraded into a natural gas or Liquid Petroleum Gas (LPG) substitute, and boosts public image. Electricity generated from biogas systems are dispatchable, and as such, can facilitate intermittent renewable electricity, unlike in the case of other sources of renewable energy, such as wind and solar energy. Further, use of biogas as an alternative source of energy could reduce the emissions associated with the exploration, extraction, refining and transportation of non-renewable fuels including LPG. The multiples benefits of biogas systems are depicted by the following figure 1.

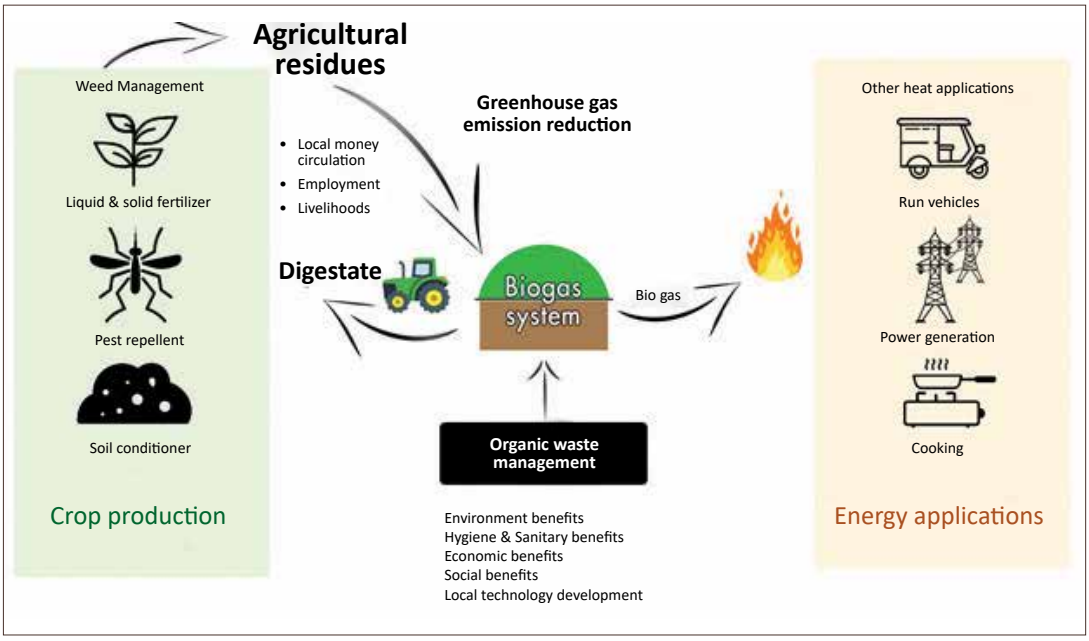

Figure 1: Biogas systems and their multiple benefits

Humans and human activities, directly or indirectly, generate tonnes of organic wastes. If the organic waste is poorly managed or unmanaged, the rotting waste would release methane and other greenhouse gases directly into the atmosphere as the waste decomposes. Once the waste is recycled through biogas technology, potential emissions into the atmosphere can be mitigated and the wastes can be turned into valuable green resources, such as biogas which comprises mainly bio-methane, carbon dioxide (CO_2), natural fertilizers and other valuable bio-products. Even when biogas is used as a fuel, the release of CO_2 will have a less potent impact (Primmer, 2021).

Biogas technology provides multiple benefits from the areas of environment (waste management), agriculture and energy (Musafer *et al*., 2017). Biogas also can be used as a substitute for LPG, being an alternative energy solution. This technology has been used as a green technology in Sri Lanka for many years. However, Sri Lanka is currently confronted with three major challenges where biogas technology could ease the circumstances.

1 As a policy measure, Sri Lanka had restricted importation of chemical fertilizer. Such restrictions can help in reducing negative health effects on the populace due to chemical pollution, and can make some foreign exchange savings from nearly US$ 400 million spent annually on importation of chemicals. Importation and use of chemical fertilizer lead to foreign exchange drain while resulting in negative implications on people's health and ecosystem sanitation.

2 The volatility of availability of LPG, which is used by households as a cooking fuel. Relying on imported LPG threatens the energy security of the country while it leads to foreign exchange drain as well as greenhouse gas (GHG) emissions from their use and from transportation.

3 The health and economic impacts from the Covid 19 outbreak and the necessity to 'build back better'by leading the country toward accelerated development.

Under the contemporary circumstances, the attention given to biogas technology as a multi-faceted solution has grown substantially. The prominence of it as a technology to effectively handle organic waste and as a sustainable energy solution has extended to look into the dimension of biogas systems in agricultural inputs.

On-farm Biogas Systems

There is a growing demand and amazing opportunities for development of farm-based biogas systems in Sri Lanka (Figure 2). These biogas systems represent a significant opportunity in capturing additional value from agrifood products and by-products while treating manure to reduce odour and pathogens. As farm-based clean energy becomes a new on-farm product, more farmers may look for ways to finance and establish biogas systems in their farms.

One of the main products from the biogas systems is the 'digestate' or 'natural fertilizer'. It is the remaining part after the degradation of substrate (feedstock, input material) originally fed into the biogas digesters and treated, and the extracted energy in the form of biogas. Digestate contains water, nutrients and organic carbon, which are suitable for soils. This may be used as a bio-fertilizer and applied to agricultural lands as 'whole digestate', composted, or separated into liquid and solid fractions before being applied to land (Jain, 2019). Further, elemental fertilizers may also be extracted from the digestate which can be used for more targeted applications.

Nutrient Recovery and Applications in Agriculture

The biogas digestate is rich in organic matter and nutrients such as nitrogen, phosphate and potash, and can be applied to land for the recirculation and return of nutrients and carbon to the soil. Recycling organic wastes through biogas technology is also a nature-based solution that is part of the natural carbon lifecycle (Primmer, 2021). The nutrients in the digestate become more available for plant absorption. Further, the anaerobic digestion of food waste and sewage can recover the nutrients that otherwise would have been lost to landfills or water bodies. As the quality of soil in many parts of the world is shown to be at risk of depletion of organic carbon, replenishment of nutrients and carbon to soil by applying digestate into the soil can bring in additional benefits (Jain, 2019). Quite frequently, the

Figure 2: **Inlet and bio-gas outlet of the underground bio-gas unit © Sri Lanka Red Cross Society**

Figure 3: **Application of digestate ensures a sound source of nutrients © Daily News**

nutrient recycling benefit of anaerobic digestion can possibly be underestimated in current literature.

The diluted digestate could be successfully used as a hydroponics media for leafy vegetables, and as an insect repellent (Weerasinghe *et al*., 2009). The digestate also can be used to create an efficient bedding for fish tanks. Further, Indian researchers have demonstrated the enhancing solubility of rock phosphate after being treated with the biogas digestate. These findings open-up a prominent pathway for efficient usage of Eppawela phosphate to support the organic drive in Sri Lanka.

The composition of the fertilizing agents in a digestate can vary significantly, depending on many external factors including the substrate type that is input into the biogas system and the weather conditions to a large extent. This means that the composition of digestate varies substantially subject to the composition of the substrate,and based on the operational parameters of the biogas digester. In most applications, the digestate produced by the biogas systems is found to be a sound source of nutrients, including more readily available nitrogen which is vital for crop production (figure 3). However, higher availability of nitrogen can also lead to nitrogen losses along the supply chain, the links being storage and handling as well as application through volatilisation and leaching (Drosg *et al*., 2015).

When substrates as human wastes and animal manure are anaerobically digested at higher temperature (thermophilic phase at around 55°C), it facilitates destroying weed seeds and prevents many pathogens from entering the watersheds. This helps in protecting both animal and human health. The digestion process also removes odour compounds from the raw substrate, leading to maintaining a pleasant environment.

It is also found that anaerobically digested slurry contains higher concentrations of plant hormones (Li *et al*., 2016). Another main use of digestate is its use as a soil conditioner. It improves moisture retention capacity of the soil due to high organic content and protects the soil against soil erosion.

The nutrient-rich by-product of the digestate generated as a result of anaerobic digestion of input substrates is a key to economic benefits for the farmers from the perspectives of cost savings. The farms can benefit from reduced commercial fertilizer requirements and related costs by recovering and transforming lost nutrients into soil amendments (any material applied to the soil in order to improve the soil) by applying the digestate on the soil. Compared to the raw manure, the conversion of the nutrients into more accessible form for the plants uptake could boost soil health to increase the crop yield.

An on-farm biogas system can economically help the farms in generating an additional income. The farms may have to spend money on disposal of their waste unless there is an internal use of the organic waste or the farms are linked to an internal or external waste management system. Having an own biogas system to manage organic waste offers the opportunity to avoid payment of tipping fees or incurring related costs where applicable. This would boost a farm's revenue in terms of reduced expenses. If there is no internal use or the internal requirements are less than the production, the farms can directly sell or further process and sell the digestate, generating opportunities through off-farm sales. As a nutrient enhanced by-product, digestate can fetch a good market value, catering to non-chemical agricultural input demands and yielding an additional income.

Generating heat and electricity from the biogas systems (separately or as combined heat and power – CHP), biogas being a source of sustainable energy would lessen the farm's dependency on grid electricity or fossil fuels. The generated energy can be used in many energy applications including for own use or to sell electricity by feeding into the national electricity grid at a reasonable price. The feed-in tariff for the electricity generated from biogas and fed into the national grid can be quite competitive even if no preferential tariffs are paid. On the other hand, biogas can be used for heat applications, such as cooking, producing hot water or heating buildings. It can be a substitute for LPG, natural gas, electricity or fuelwood. Besides these applications and if sale of biogas or electricity is not lucrative, the biogas or electricity could also be shared with neighbouring farms. Further, farms with on-farm biogas systems could also be energy independent and reap benefits from reduced heating and electricity costs. The heat also can be used for the purposes such as heating incubators, greenhouses, and grain drying, while the biogas can directly be used in water pumping, agricultural machinery and operating vehicles [similar to the use of Compressed Natural Gas (CNG) and lighting (illumination). Converting organic waste into biogas can even be considered as a risk mitigation strategy to increase the farm's resilience in the face of some of the supply chain issues and market volatilities.

Capturing of and using methane through biogas systems can significantly reduce greenhouse gas emissions from manure systems, while mitigating the impacts of climate change. Management of organic waste using biogas technology by the farms would reduce the environmental footprint of the farms and enhance their environmental stewardship and agronomic value as well.

Biogas in Circular Economy

Circular economy focuses on minimizing the resource use as inputs while reducing the waste creation, carbon emissions and pollution, etc. Routing organic waste through biogas systems offers the opportunity of reaping the benefits of the 'circular economy' (Fagerström *et al*., 2018). These systems attempt to keep the material, products, equipment, and infrastructure etc., to be used for a prolonged time period. Such a system facilitates the linking up of different phases of material extraction, transportation, manufacturing, usage of products, after-use and closing the loop, deviating from the previously practiced linear economic processes of channeling organic waste to dump yards or landfills, following a take, make and waste (cradle to grave) approach (figure 4,5). Biogas technology handles the waste in a sustainable and circular manner recovering the nutrients and other ingredients helpful in agriculture and food production, as well as contributing to the reduction of energy consumption, while extending the product and service lives in a sustainable, environmentally friendly manner.

Figure 4: **Food waste into green energy © Robert Barker / Cornell University**

Figure 5: **Organic waste into liquid fertilizer and high-quality biogas, Kuliyapitiya © Green Energy Champion**

Industrial Symbiosis and Biogas Systems

There is a potential to integrate biogas systems in industrial symbiosis as well. Industrial symbiosis can be seen as a subset of industrial ecology, where different wastes of one industry is used as an input raw material in another industry. Many such arrangements within a close proximity can lead to a network of different organizations working together, inter-dependent, for mutually profitable transactions thereby reducing the environmental footprint of the relevant industries. Some research and modelling are underway on industrial symbiosis between biogas systems and nutrient deficient industrial wastewater treatment plants.

Greenhouse Gas (GHG) Abatement by Biogas Systems

Quantification of methane emissions related to the biogas sector is a new topic. This can be of significant interest to the scientific and industrial communities in pursuit of assessing the contribution by and the sustainability of biogas systems. Further, the methodologies for quantifying methane emissions from biogas systems have also been developing over the recent years. Several methods are being used for this purpose with a variety of data sets provided by different international teams. Accordingly, the results given in literature have large differences. Therefore, the methods used and the documentation and reporting of the results need to be harmonized in order to obtain comparable and representative results in the future. Hence, it is quite difficult to provide general and average numbers for methane / GHG emissions from components or complete biogas systems (Liebetrau *et al*., 2017). There is a tremendous quest from the practitioners and researchers to obtain a one-time emission factor for general wastes. However, as emission factors can significantly vary as per the circumstances, it is quite difficult to declare a common value.

Despite the above constraints, the United Nations Framework Convention on Climate Change (UNFCCC) has published a methodological tool for calculating project and leakage emissions from anaerobic digesters under the Clean Development Mechanism (CDM). According to the tool, the methane emissions from biogas systems include the unused biogas (can be defined as leakage) and emissions from storage of the digestate (Note: this tool is not applicable to other systems where waste may be decomposed anaerobically such as stockpiles, solid waste disposal sites or un-aerated lagoons). The emissions accounted for in this tool include CO_2 emissions from consumption of electricity and fossil fuels associated

with the operation of the biogas system, methane emissions from the digester itself and from flaring of biogas. The emissions from the digester include the emissions during maintenance of the digester, physical leaks from the roof and side walls, and release of biogas through safety valves due to excess pressure in the digesters.

The sources of leakage emissions accounted for in this tool include methane and Nitrous oxide (N_2O) emission from composting of digestate and methane emissions from the anaerobic decay of digestate disposed in solid waste disposal sites or those subjected to anaerobic storage, such as in a stabilization pond. This tool provides two different procedures to determine the quantity of methane produced in biogas digesters. The large scale are to monitor, measure and determine the mass flow of a greenhouse gas in a gaseous stream, while the small scale biogas system can adopt the same procedure or use a default value for the fraction of methane in the biogas associated with the measured flow of the biogas. These measurements are the quantity of methane produced in the digester and the amount of biogas collected at the digester outlet. Use of the default value corresponds to the type of digester used in project activity which shall be identified by manufacturers' information (UNFCCC, 2012).

Considering the above discussions, it can be summarised that biogas systems can contribute towards abatement of GHG emissions by subjecting organic waste streams to anaerobic digestion in a number of ways such as avoiding emissions from fossil fuel burning, manufacture of inorganic fertilizer, landfill emissions from food waste digestion, manure management and burning of crops (Jain, 2019). At the same time, it is important for the designers and operators of the biogas systems to minimise the associated project and leakage emissions of methane from anaerobic digestion (figure 6).

Carbon Neutrality of Biogas Systems

Anaerobic digestion is simply the natural process that takes place when biodegradable material is broken down in an oxygen free environment in the presence of some anaerobic microorganisms. When the rotting wastes are channeled and recycled through biogas technology, methane emissions from these are trapped and the fossil fuel use is displaced, and the need for artificial fertilizers is curtailed. Moreover, the biogas CO_2 can be used in the applications of industrial processes or permanently stored using carbon capture, utilisation and storage technology. When all these emission reductions are accounted for, anaerobic digestion can be considered as a carbon negative technology versus business-as-usual scenario (BAU) (Primmer, 2021). Accordingly, biogas technology contributes to curtailing of climate change mitigation (reduction of GHG emissions) (figure 7).

Nationally Determined Contributions

Sri Lanka has submitted its updated Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change in July 2021. Although it has remained a low-carbon-intensive country in terms of low per capita carbon emissions, it is ranked among the most vulnerable countries to climate change-induced hazards. Despite these, in its revised and updated NDCs, Sri Lanka presents an ambitious 4% unconditional and 10.5% conditional reduction of greenhouse gas emission commitments compared to the Business-As-Usual (BAU) scenario for the period of 2021-2030 from six sectors: power (electricity generation), transport, industry, waste management, forestry, and agriculture. Biogas technology could be a strong technology candidate in delivering these national obligations to the global community (MoE, 2021).

Figure 6: Using waste vegetables and fruits to produce biogas © Roshini Muthukumar

Figure 7: Cerbon neutral Biogas plant
© Reecon aqua green technologies

Capabilities of Biogas Technology

Energy: Biogas, as a renewable fuel, can replace the need to extract fossil resources for energy.

Fertilizer: Biogas digestate is a renewable fertilizer rich in key nutrients, nitrogen, phosphorus, and potassium (NPK), recovered from the nutrients of the substrate - input organic material. This reduces the need to produce non-renewable mineral fertilizers.

Waste management: Organic wastes can rot and release potent GHGs, such as methane, directly into the atmosphere unless properly managed. By treating them through biogas technology instead, these otherwise harmful GHGs are converted into valuable bio-resources.

Agricultural crop residues: Typically, most of agricultural wastes are either left to rot resulting in releasing of CO_2 and methane or burnt, releasing harmful particulate matter into the atmosphere. Biogas technology can avoid these emissions while delivering ecosystem services.

Livestock manure and slurry: Often, farmers spread raw manure such as pig manure directly to land untreated. This practice emits vast quantities of methane, ammonia, and nitrous oxide, gases with high global warming potential worse than CO_2. Biogas technology reduces these direct emissions while returning the nutrients and valuable organic matter available in manure back to the soil.

Food waste: If the organic wastes are not separated out from other municipal wastes, this valuable bio-resource is often sent to landfills. This can lead to generate methane and emit to the atmosphere while producing toxic chemical leachate that can seep into nearby waterways.

Sewage and industrial wastewater: Raw sewage can emit GHGs, pollute ecosystems and spread disease. Biogas technology can prevent all these negative impacts, while supporting health, economy and social status of the local communities.

Bio-CO_2: Many industrial processes such as food and beverage manufacturing require pure carbon dioxide. The CO_2 content in biogas can be captured at such industries with bio-CO_2.

(Primmer, 2021)

Sri Lanka also commits to achieve 70% renewable energy in electricity generation by 2030, carbon neutrality in electricity generation by 2050, Carbon Neutrality by 2050 and adding no additional capacity of coal power plants. Further, Sri Lanka has launched some major initiatives such as restricting the importation of agro-chemicals and chemical fertilizer, promoting application of organic fertilizer and organic farming, adoption of Colombo Declaration on Sustainable Nitrogen Management with an ambition to halve the nitrogen waste by 2030 and promoting circular economy (MoE,2021). There had been many planning interventions that took place in the country aimed at realizing these commitments by many government and other agencies. (Ex. Ninth Biennial Sri Lanka Conference on Science and Technology organized by National Science and Technology Commission, which paid special attention to biogas technology) (NASTEC, 2023). These could also help realize ambitious NDC targets, where biogas technology could be one of the appropriate options (MoE, 2021).

Out of the six sectors identified for mitigation NDCs of Sri Lanka, biogas technology can directly and comprehensively contribute to five sectors, namely, electricity (power), transport, industry, waste management and agriculture NDCs. This document identifies the adoption of biogas technology where composting is not practically applicable under the waste management sector, and introducing biogas digesters for large scale livestock, poultry, dairy processing and abattoirs under adopting renewable energy for livestock applications in the agriculture sector. This document also states about efficient and effective waste to energy systems, which can include biogas technology. A detailed and a complete analysis and exercise in revising the NDCs may have captured a prominent role for the biogas technology in Sri Lanka's development endeavours.

Figure 8: Cooking with bio-gas
© Sri Lanka Red Cross Society

Challenges Encountered by On-farm Biogas Systems

Despite many benefits biogas systems offer to the farming community (figure 8), there are some significant challenges the Sri Lankan farmers need to overcome in developing on-farm biogas systems. The prevailing environmental laws and regulations have some restrictions in applying digestate directly into soils or water bodies. The lack of clear standards and guidelines pertaining to biogas digestate as an agricultural input makes it hard to select what is allowed and what not to apply. Further, the lack of good analysis of different available types of digestate makes it hard for the decision makers and regulators to make clear cut decisions. Due to this reason or others, there are no proper guidelines and regulations applicable to biogas digestate. Lack of localised research and analytical information prevents the formulation of science -based decisions.

The other barriers to on-farm biogas systems are the low level of agricultural or livestock concentration in a particular area and economies of scale. As the prevailing farms are quite fragmented and most of them are small in scale, the manure cannot be processed in an economically viable manner. Further, there are no favourable financing schemes or promotional programmes for biogas systems in the country in place at the moment. Therefore, the farms have to rely on conventional sources of financing. As there are only a few on-farm biogas systems, even the decision makers of the financial institutions tend to adopt a risk aversive approach due to lack of proven evidence.

Some of the biogas systems, especially the low rate biogas systems can also leak methane into the atmosphere as discussed above. These systems have to be constructed without leaving provisions for any such leaks. While emergence of any leak should be continuously monitored in case such a leak is detected, leakages have to be fixed to mitigate the negative impacts of this technology. As methane is a combustible gas, leaks can lead to fire hazards, and necessary precautions must be installed to prevent fire related accidents.

National Biogas Standards

Sri Lanka Standards Institution initiated the setting of national standards related to mid-size farm and institutional biogas systems about a decade ago. It occurred after establishing the national standards for domestic (household type) biogas systems of 6-12m^3 of capacity in the year 2006 (SLSI, 2006). Availability of such standards could help the farmers to decide on establishing their on-farm biogas systems with confidence, supported by sound quality assurance and after-installation service.

Analytical Data and Quality Assurance

Reliable data collected from good chemical and physical analysis of the substrates and digestate are strongly required for Sri Lanka. Providing some indications on the suitability of different types of digestate and their applications as an agricultural input can boost their confidence. Therefore, quality control and assurance of the substrate is vital in ensuring a quality end product digestate. The content and composition of the arriving substrate have to be characterized on-site as thoroughly as possible before being input into the biogas system.

Operational and Monitoring Aspects of Biogas Technology

In the Sri Lankan context, instability or failure of biogas systems are reported particularly because of the low rate anaerobic digesters used for organic solid waste treatments. The reasons for such can be attributed to the changes in composition of substrates (mainly due to seasonal variations), adverse operational and environmental conditions, and inhibitions due to toxic substances etc. Lack of proper pretreatment of substrates too can lead to failures of biogas systems. If the experts are not involved in designing, construction and operationalizing and maintenance of biogas systems, these can lead to failures resulting in gas leaks and not reaching designed volume, flow rate and pressure of the biogas. Further, lack of making arrangements to measure required parameters and inadequate knowledge of personnel also affect in not quantifying or poor quantification of biogas generation and use. This makes it impossible to estimate the related GHG emission reductions.

To popularise and disseminate the biogas technology among farming communities, these challenges must be overcome and a more efficient, lower cost, easily operable biogas reactor systems must be introduced. It is paramount to operate the biogas systems at the optimal conditions so as to produce high quality organic fertilizer (Figure 9).

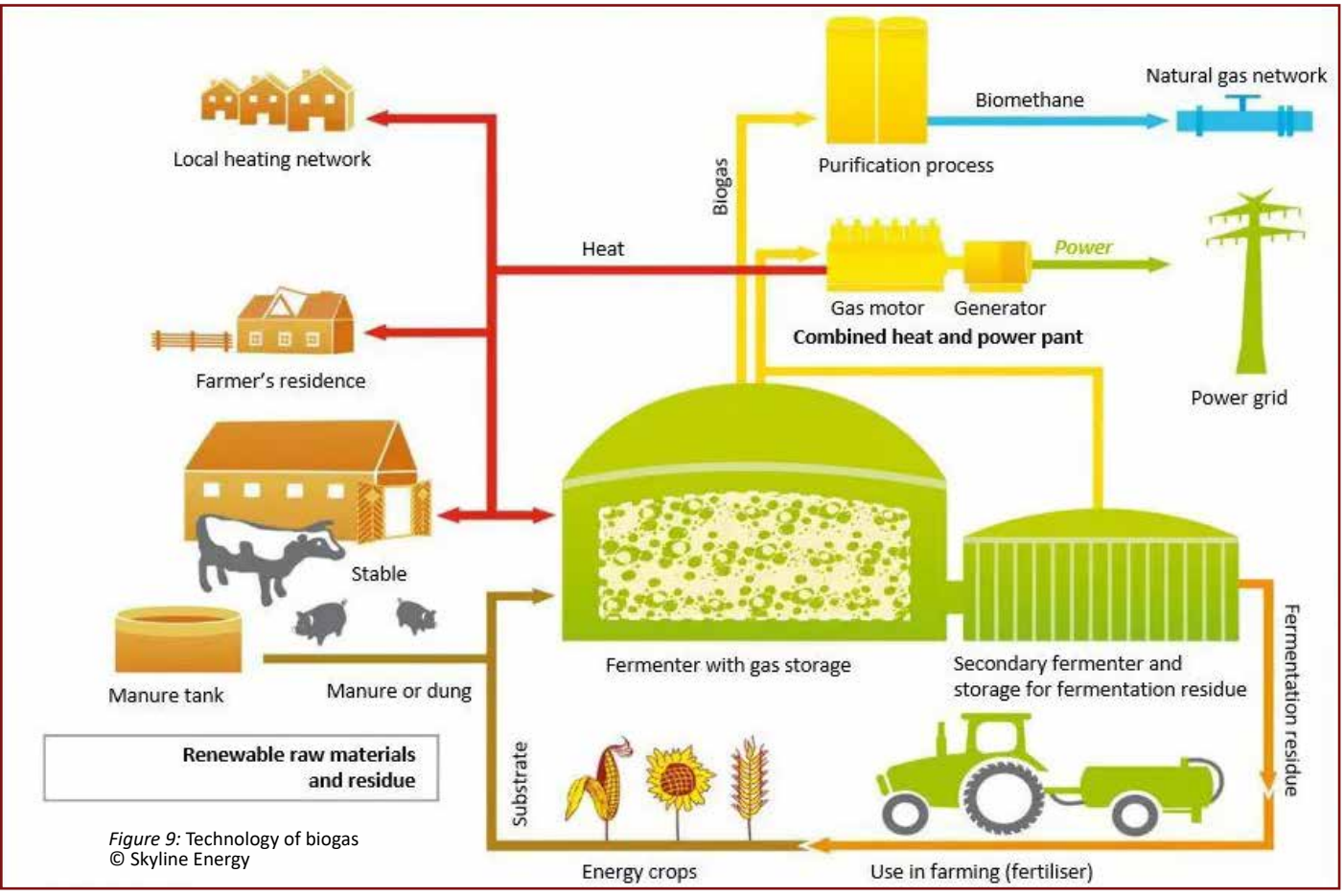

Figure 9: Technology of biogas
© Skyline Energy

Enhancement of Performance Efficiency of Existing Farm-scale Biogas Systems

It is vital to provide conditions favorable for the anaerobic microorganisms. Due to lack of proper mixing of the content inside the biogas digester, the production of biogas can be reduced by even up to 40%. To enhance mixing, mechanically operated impellers can be installed inside digesters. Also, to improve hygienisation, the content inside the biogas digester can be heated using hot water generated by burning the biogas produced by the same biogas system. Co-digestion (digestion of multiple organic wastes in one digester) is another way to increase favourable conditions for microorganisms and improve production of biogas, by adding additional material to substrate to enhance its composition favourable for biogas systems. All these measures can lead not only to produce more biogas, but also to produce more organic fertilizer of higher quality.

Modification and Enrichment of Digestate

Sound recommendations from the experts as to how to modify and enrich the digestate to suit different crops, soils and seasons should add further value to the farmers (Figure 10). If an authorized competent body can stipulate relevant specifications and quality standards, then the direct or processed digestate can be marketed in large scale with branding to be bought over the counter from different parts of the country in bulk or retail where there is a demand. In order to cater to on-farm community and a wide range of customers, the existing biogas industry in Sri Lanka may have to deviate from conventional biogas systems and adopt specifically designed biogas systems for *in situ* medium to large scale and high-rate biogas systems, where some of them have to operate in the thermophilic range, to reduce space requirements, reach economies of scale, produce the digestate and biogas quicker, and make the process efficient and useful to all concerned.

Conclusion

The interest in biogas technology is in a renaissance of interest, because of, *inter alia*, the rapidly growing threat of anthropogenic global warming and climate change. The attention has been driven to restrict the unproductive generation and release of methane into the atmosphere from the farmland (livestock and crop agriculture) which is considered to be responsible for a considerable amount of global warming. There is a growing demand and greater opportunities for development of farm-based biogas systems in Sri Lanka where importation of chemical fertilizer is restricted as a policy measure. The biogas digestate is rich in organic matter and nutrients such as nitrogen, phosphate and potash, which can be applied to land for the recirculation and return of nutrients and carbon to the soil. Recycling organic wastes through biogas technology is also a nature-based solution that is part of the natural carbon life cycle. The digested slurry contains higher concentrations of plant hormones while biogas digestate is used as a soil conditioner, improving moisture retention capacity of the soil while protecting the soil against soil erosion. On-farm biogas systems also can be a part of circular economy and industrial symbiosis, reaping multiple benefits. There are many methodologies developed to quantify methane emissions from biogas systems with a variety of data sets. However, the methods used and the documentation and reporting of the results need to be harmonized in order to obtain comparable and representative results. While biogas systems can demonstrate carbon neutrality, and contribute to achievement of Nationally Determined Contributions, detailed and a complete analysis and exercise in revising the NDCs have captured the prominent role the biogas technology could play in Sri Lanka's development endeavours. National standards on farm-scale biogas systems, collection of analytical data, quality assurance systems and improvements to the performance efficiencies, operational, monitoring and maintenance aspects can take biogas technology to further heights. Biogas, being a multi-faceted technology, brings many advantages from different dimensions. However, it has its own limitations and challenges as well and, therefore, appropriate actions should be taken to overcome them to reap the benefits.

Figure 10: Organic farming using digestaste
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