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IMPACT OF CLIMATE CHANGE ON SIDS. WHAT ENGINEERING SOLUTIONS?

Friday 04th March 2022

WORLD ENGINEERING DAY FOR SUSTAINABLE DEVELOPMENT

WFEO - SUSTAINABLE DEVELOPMENT GOALS

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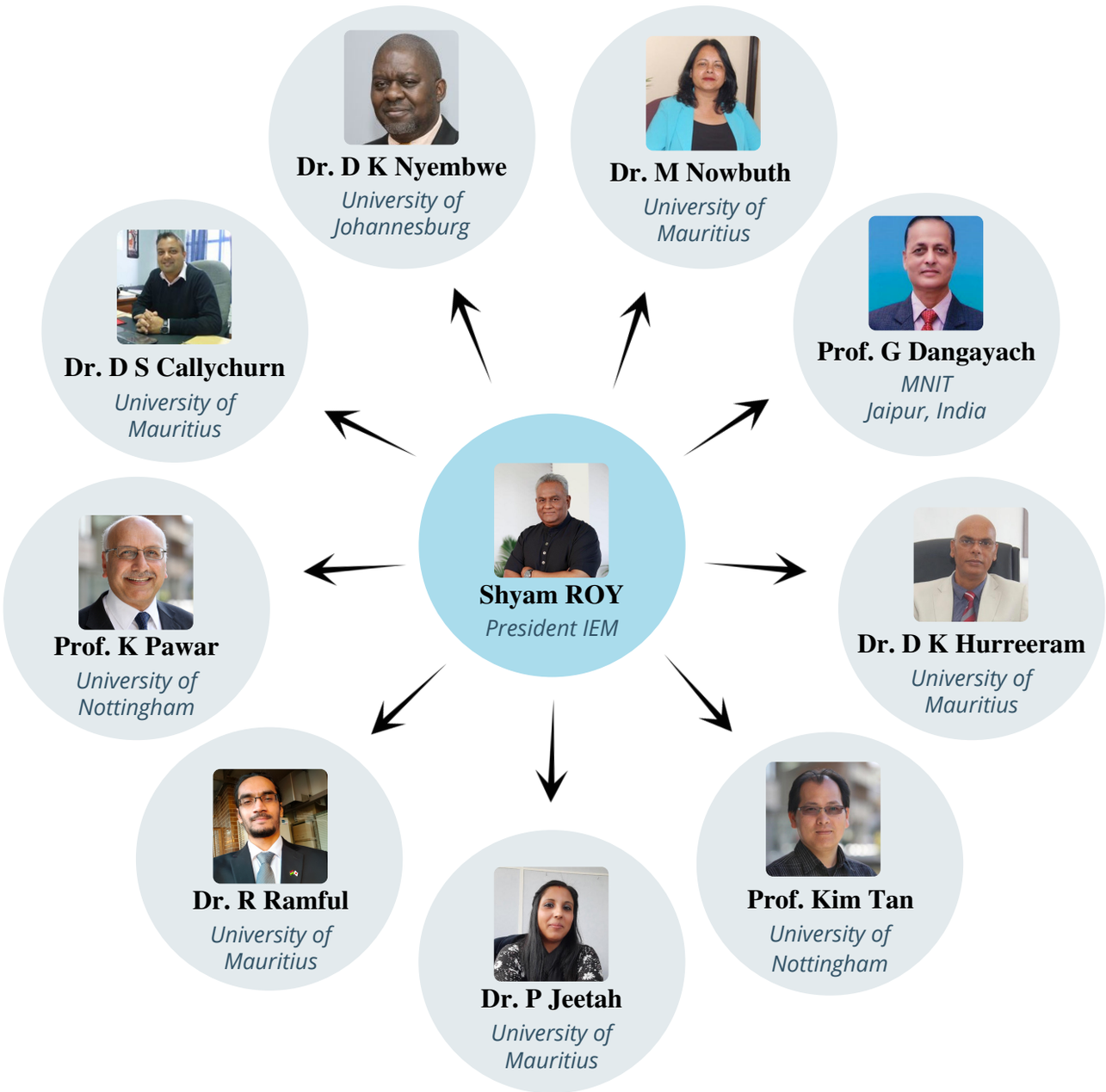

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INSTITUTION OF ENGINEERS MAURITIUS [IEM]

The Institution of Engineers Mauritius (IEM), was created on 26th February 1948, under the appellation Engineers Association of Mauritius, to represent the engineering profession and provide a forum for all engineers to come together for the advancement of the engineering profession irrespective of the engineering disciplines in which they specialised or practised, and had set itself the following objectives: to foster engineering science and its application in all engineering disciplines, ensure the highest standard of service in engineering, and improve the status and safeguard the interests of the engineering profession. Its name was changed to "The Professional Engineers Association of Mauritius" during a Special General Meeting held on 28th January 1965. Thirteen years later, on 1st Dec 1978, the association was restructured and adopted a new name "The Institution of Engineers Mauritius". The changes were approved by the Registrar of Associations on 19 January 1979.

The founder members desired to regulate the profession and the practice of engineering. The government of the day agreed on the regulation but by a different body. The engineers were nevertheless satisfied when a Council of Registered Professional Engineers Bill was pushed through the Legislative Assembly and was eventually approved. The Council of Registered Professional Engineers Ordinance was gazetted on 23 December 1965.

The IEM has remained an association of professional engineers, whereas the Council of Registered Professional Engineers (CRPE) is the body authorised to approve qualifications, leading to registration as Professional Engineers, and to register the holders of such qualification subject to their also meeting tie experience requirements. If at all the Institution has to intervene at the level of the Council, it does so through its two representatives on the council of the C.R.P.E.

In addition to serving on the council of the C.R.P.E. the Institution is active at the level of the Board of the Central Electricity Board and puts in its contribution at the Mauritius Standard Bureau, the University of Mauritius. The IEM has made requests to Government for the Institution to be represented on major Government committees and parastatal Boards concerned with the provision of services requiring heavy investment of engineering nature.

The IEM joined the World Federation of Engineering Organisations, (WFEO), as a Regional Member in 1981, and became a Full member of the Commonwealth Engineers Council (CEC) on 15 November 1985.

IEM's constitution was amended in October 2018 to create the Engineering Accreditation Board (EAB), in the context of the Washington Accord project. IEM's goal is to become full member by 2025. www.iemauritius.com

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Message from Mr Shyam Roy

President of Institution of Engineers Mauritius

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I am pleased to present to you the 2022 edition of IEM Journal (**Impact of Climate Change on SIDS: What Engineering Solutions?**) on the occasion of the World Engineering Day held on 4th March 2022. IEM is again very honoured to have a message page from Past President of WFEO Dr Marlene Kanga. I sincerely thank all authors for their efforts and valuable contributions to this Journal. Big Thanks also to the Members of the Editorial Committee for the long and tedious hours spent and to our sponsor Emtel Ltd. This Journal will be online on our website and available worldwide to create the awareness about Climate Change.

Every time disaster knocks at the door, such as the one in the Islands of Tonga recently, the whole world gets an abrupt wake-up call, only to slowly get back to their routine and lose the focus on urgent actions to be taken…. until the next Disaster.

Our small island can turn into a disaster place if we do not take immediate measures to safeguard the environment and to mitigate climate change-related disasters. However, 1.2 million people of this small island cannot on their own control the increase of temperature and all the gas emissions. It is the whole world that must be aware of the consequences and take urgent necessary actions.

If we want to leave a good legacy for our and future generations let's do something now.
Fellow engineers I urge you all to act promptly.

Wishing you Good Reading and a very Productive **World Engineering Day 2022.**

Thank you

Message from Dr Marlene Kanga

Past President World Federation of Engineering Organisations

Dr. Marlene Kanga AM FTSE HON. FIE Aust. Hon. FIChemE
President World Federation of Engineering Organisations 2017-2019
President, Engineers Australia 2013

My sincerest congratulations to the Institution of Engineers Mauritius and to all the contributing authors to this important book on the role of engineers in contributing to sustainable development. I am very pleased that the Institution and President Shyam Roy, has collaborated with engineers in Mauritius and internationally to capture the best of their work around the world to mitigate the risk of natural disasters and to demonstrate the work of engineers in addressing a wide range of the United Nations Sustainable Development Goals.

This volume is very timely, as in the past two years of the pandemic, the Republic of Mauritius, like many other Small Island Developing States, has been dealing with controlling the spread of the virus and its economic impact. The beauty of Mauritius attracts tourists from around the world. This industry which is the mainstay of the economy has been severely disrupted with the restrictions on travel. There has also been a loss of export income, such as seafood, textiles and sugar due to disruptions in global demand. In the post pandemic years, engineers will be needed like never before to build infrastructure including roads, water supply networks, communications systems and manufacturing and other facilities as the economy recovers.

The volcanic eruption and tsunami that followed in Tonga in January 2022, is a reminder to the world of the natural hazard risks faced by the Small Island Developing States (SIDS). The Republic of Mauritius is no exception, exposed to many natural hazards notably cyclones, tsunamis, torrential precipitation, landslides, and droughts. Mauritius is also highly vulnerable sea level rise, driven by the effects of climate change. Engineers have an important role to play in analysing the exposures to natural disasters and designing and implementing appropriate measures to manage these risks.

The pandemic has also severely disrupted education with school closures required to control the spread of the virus. Ensuring education at school and in colleges and universities will be essential for the future of Mauritius. This is particularly true for engineering education. There is a positive correlation between the number of engineers in an economy and economic development. The World Federation of Engineering Organisations is proud to be collaborating and supporting Mauritius to develop its engineering education system so that it has more engineers with the right skills for sustainable development.

The release of this important publication is therefore very timely. I am sure that many young people in particular will be inspired by the breadth of work of engineers that is showcased in this important publication and the positive impact that engineers have on their country and for sustainable development so that no one is left behind.

ASEAN National Policies and Strategies on Climate Change

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Abstract

In this paper, ASEAN National Policy, data, statistics, and implementation on Climate Change will be analysed and tabulated. The ASEAN National Policy on Climate Change serves as the framework to mobilise and guide government agencies, industry, community as well as other stakeholders and major groups in addressing the challenges of climate change in a concerted and holistic manner. Emphasis is on strengthening capacity of the nation to reduce its vulnerability to climate change whilst promoting mitigation responses that also enhance sustainable development. Particularly, Malaysia National Policy on Climate Change will be investigated. Priority should be given to the country's ability to adapt to the actual or expected impacts of climate change. Mitigation measures must also strengthen adaptation and sustainable development. The impact of climate change spans all levels, sectors, stakeholders and major groups, and requires coordinated global response measures. Only through cooperation and participation based on indigenous and scientific knowledge can the institutional capacity for implementation be made effective. Present strategy, implementation and results will be discussed in this paper.

Keywords - ASEAN, national policy, climate change

1.ASEAN Climate Change

Throughout the long term, ASEAN has exhibited obligation to tending to environmental change, including through multi-sectoral discourse and important exercises including key accomplices in different areas, like agriculture, disaster, forestry service, energy, transport, and economy.

The ASEAN Joint Statements on Climate Change to the 26th session of the Conference of the Parties (COP26) of the UN Framework Convention on Climate Change (UNFCCC) verifies our area's yearnings and recharged responsibilities to contribute towards worldwide environment targets.

In addition, under the chairmanship of Brunei Darussalam in 2021, ASEAN has recognized environmental change as one of its provincial needs. These drives have empowered ASEAN to encourage solid associations with provincial and worldwide accomplices to support building nearby limits, start supported environment ventures, and work with information and innovation trades.

In ASEAN, a lot of its rainforests are obliterated to make more land region to house the developing populace in metropolitan urban areas. The rainforest, being one the most organically different environments

- when annihilated can speed up environment changes. With widespread deforestation, we diminish the quantity of trees. With less trees, we have diminished oxygen supply, diminished downpour and expanded carbon dioxide in the air. These elements will prompt higher mugginess in the locale. As one prompts the other, this can increment a worldwide temperature alteration. As indicated by the ASEAN Biodiversity Outlook report (by ASEAN Center for Biodiversity, Philippines), the organic variety in the Philippines, Indonesia and Malaysia will be incredibly dissolved by 2100 assuming that the annihilation of the climate endures - where "the area is ready to lose 70-90% of living spaces and 13-42% of species in an additional 83 years".

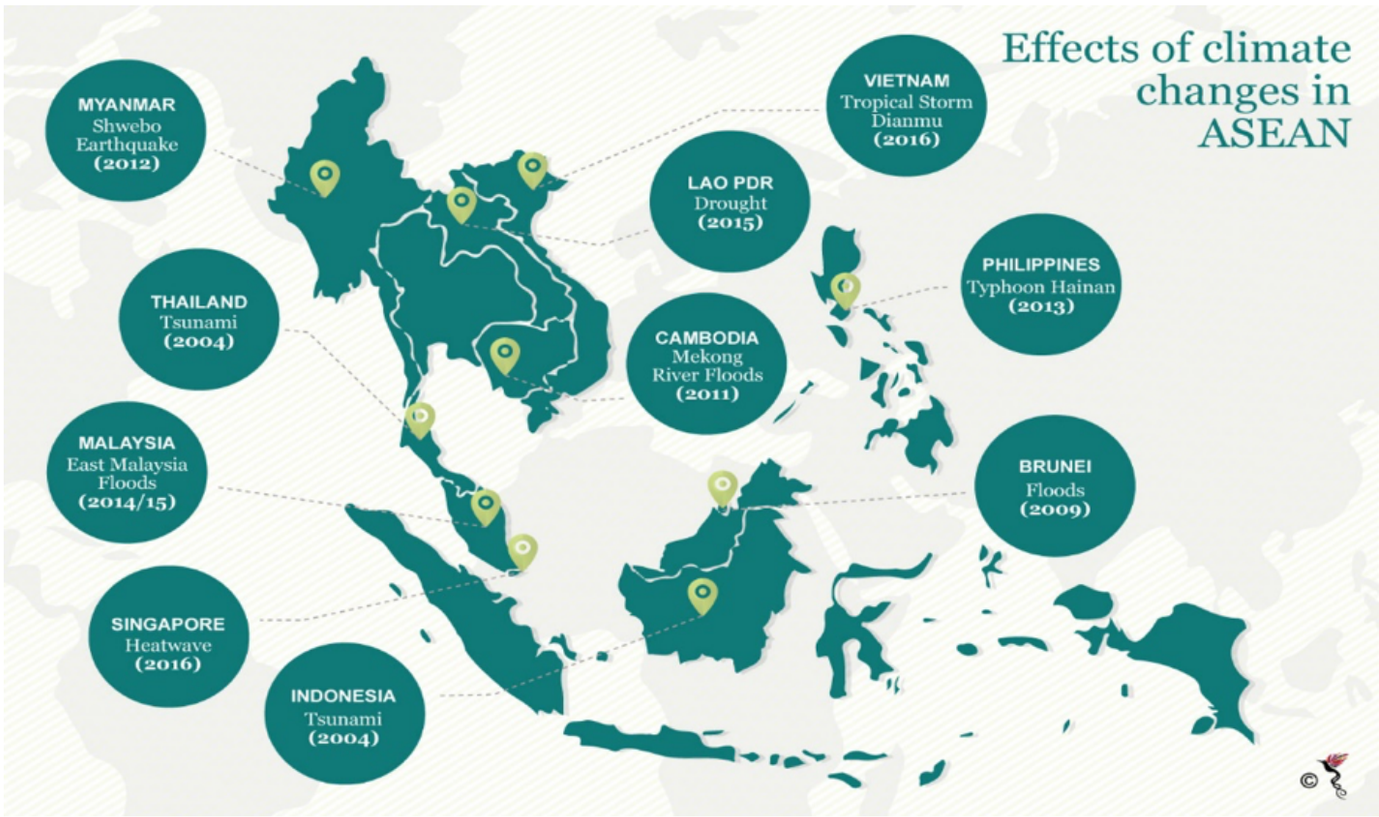

Figure 1: Natural disaster and climate change in ASEAN region [5]

ASEAN is additionally arriving at its pinnacle water - where we begin drinking clean water quicker than it very well may be recharged. For instance, the Mekong waterway which goes through Myanmar, Lao, Thailand, Cambodia and Vietnam is now intensely repressed - making the water assets go scant. However ASEAN has promptly accessible normal wellspring of water, quite a bit of it is dirtied or insufficiently cleaned. With worries for water shortage, we likewise face food security as agribusiness will similarly be impacted. Water is the essential impetus for solid and plentiful yields, other than different elements like daylight, soil and fertilizers.

2. ASEAN National Policies

The ASEAN region has already experienced significant impacts from climate change, with increasing intensity and magnitude of extreme weather events and increased economic, environmental and social damage. The future impacts of climate change undermine decades of development benefits, so the region should prioritize both resilience and adaptation.

The region is making steady progress in several areas related to climate change adaptation and disaster risk mitigation (DRR). Importantly, the ASEAN regional national policy and institutional environment related to Climate Change Adaptation (CCA) and DRR is at the forefront of this improvement and provides a good environment for the strong implementation of CCA and DRR. Progress at the political and institutional level of the country is commendable, but these advances must penetrate to the grassroots level.

In terms of science and technology, ASEAN countries have developed their national policies on climate change (Table 1). The initiatives are to strengthen climate science in relation to climate change forecasting, predictive downscaling, climate change risk assessment and vulnerability assessment, especially in priority areas such as water resources and agriculture. ASEAN countries that have made significant progress in climate change policies, risk assessment, adaptation planning, and climate smart agriculture are well suited to share this expertise with other countries. Table 1 identifies areas of collaboration in the region and the type of environment required for successful implementation.

Brunei Darussalam 1) Brunei Darussalam National Climate Change Policy (BNCCP) 2) National Forestry Policy of Brunei Darussalam 3) Forest Act (Chapter 46) Forest Rules	**Myanmar** 1) National Environment Policy (2019) 2) Myanmar Climate Change Policy (2019) 3) Myanmar Climate Change Strategy (2018-2030) 4) Myanmar Climate Change Master Plan (2018-2030) 5) National Waste Management Strategy and Master Action Plans (2020) 6) National Environmental Quality Emission Guidelines (2015) 7) Myanmar National Water Policy (2014) 8) Myanmar Action Plan for Disaster Risk Reduction (2017) 9) The National Forestry Master Plan (2001-31) 10) Community Forestry Instructions (2019) 11) National Adaptation Programme of Action 12) Climate Smart Agriculture Strategy (2015)
Cambodia 1) Cambodia Climate Change Strategic Plan 2014-2023 2) Climate Change Priorities Action Plan for Agriculture, Forestry and Fisheries Sector 2016-2020 3) Strategic National Action Plan for Disaster Risk Reduction in Cambodia 2008-2013 4) National Action Plan for Disaster Risk Reduction 2019-2023 5) 2015 Law on Disaster Management 6) National Adaptation Plan 2017	**Philippines** 1) National Disaster Risk Reduction and Management Law of 2010 2) National Climate Change Action Plan (NCCAP) of 2011
Indonesia 1) National Action Plan on Climate Change Adaptation (RAN-AIP) 2) Climate Change Adaptation Programme (ICCAP) 3) Proklim (Climate Village Programs)	**Singapore** 1) National Climate Change Strategy (2012) 2) Singapore's Climate Action Plan: A Climate-Resilient Singapore, For a Sustainable Future (2016) 3) Singapore's Long-Term Low-Emissions Development Strategy (2020) 4) Singapore Green Plan 2030 (2021)
Lao People's Democratic Republic 1) National Strategy on Climate Change (NSCC) (2010) 2) Forestry Strategy to the Year 2020 of the Lao PDR (2005) 3) Climate Change Action Plan of Lao PDR for 2013-2020 (2013) 4) National Adaptation Plan for Action (NAPA) 5) Strategic Plan on Disaster Risk Management (2020)	**Thailand** 1) National Adaptation Plan (NAP) 2) 2019 Community Forestry Law 3) Climate Change Master Plan 2015-2050
Malaysia 1) Eleventh Malaysia Plan 2) National Water Resources Policy (2012) 3) Water Services Industry Act 2006(WSIA Act 655) and National Water Services Commission Act (SPAN Act 654) 4) Environmental Quality Act 1974 5) National Agro-food Policy (2011-2020)	**Vietnam** 1) Law on Natural Disaster Prevention and Control (2013) 2) National Climate Change Strategy (2011) 3) National Target Programme to Respond to Climate Change (2008, 2012)

Table 1: National policies initiated by ASEAN countries [6].

3. Malaysia National Policy on Climate Change

Malaysia has always advocated sustainable development, taking into account economic growth, social welfare and environmental protection in its development plans. Sustainable development has always been the basis for the success of this beautiful country. Nevertheless, there is still much work to be done to fully realize the potential of the country. Climate change is no longer a remote possibility. Now, this is a scientifically proven reality that has affected all of us. Research conducted under the auspices of Malaysia's Ministry of Natural Resources and Environment gives us insight into future climate change scenarios and potential threats to our country's sustainability [4]. In addressing the challenge of climate change, we all have a role to play, but to be successful, we must work together. Therefore, the national climate change policy provides a framework to mobilize and guide government agencies, industries, communities, and other stakeholders and major groups to address the challenges of climate change in a comprehensive manner. National policies will allow us all to take concerted action and identify opportunities that will help guide our country towards sustainable development.

The strategic response is necessary to strengthen the country's resilience to the impact of climate change. These include:

- mainstreaming climate change;
- integration of balanced adaptation and mitigation responses;
- improvement of implementation institutions and capacities through coordinated policy responses.

Malaysia recognises the adverse effects and impacts of climate change and is committed to incorporating national response measures based on the following principles to consolidate economic, social and environmental development goals [4]:

P1: Development on a Sustainable Path

Advance on the path of sustainable development and incorporate response measures climate change in national development. Develop plans to achieve national goals and the desire for sustainable development.

P2: Conservation of Environment and Natural Resources

Strengthen the implementation of climate change actions that favor the protection of the environment and the sustainable use of natural resources

P3: Coordinated Implementation

Incorporate climate change considerations into the implementation of development plans at all levels.

P4: Effective Participation

Increase the participation of stakeholders and major groups to effectively implement climate change response measures.

P5: Common but Differentiated Responsibilities and Respective Capabilities

International participation in climate change will be based on the principles of common but differentiated responsibilities and respective capacities.

4. Malaysia Government's Approach to Climate Change Issues Outlined in MyCAC

According to the Ministry of Environment and Water Resources (KASA), the government will carefully conduct carbon trading to prevent such activities from affecting the country's greenhouse gas (GHG) emission commitments. This is one of the six methods outlined by the Malaysian Climate Change Action Committee (MyCAC) implemented by the government to address climate change issues [1].

The second approach is to formulate a "green recovery plan" agenda, such as the "Green New Deal", to make Malaysia a hub for green economy, services and technology, and to promote green lifestyles in all areas of life through ideas. The health of the earth is moving towards sustainable overall development.

The third way is to strengthen the country's climate change governance, involve all stakeholders, and implement various plans to advance the climate change agenda by mobilizing human resources and financial allocations.

In addition, it also involves the cooperation of all KASA stakeholders to fulfill the country's commitments under the United Nations Framework Convention on Climate Change.

MyCAC is the ultimate platform for determining direction, discussing climate change policies and actions, promoting green economic growth, and promoting green technology and low-carbon growth at all levels (especially federal and state governments). MyCAC meets twice a year to discuss issues related to climate change and the green development agenda. MyCAC also agreed to implement the 2021-2030 Low Carbon Mobility Development Plan.

Through this plan, greenhouse gas emissions are expected to be reduced by 165 million tons of carbon dioxide, saving RM 150 billion in fuel costs over 10 years and promoting greater use of electric vehicles and transportation. low carbon emissions.

In addition, the National Low Carbon Cities Master Plan will also serve as the guiding and directional basis for low carbon cities at the local and state level. Carbon market guidelines and carbon pricing policies will also be formulated to support the wishes of any party participating in the carbon market.

5. Malaysia's Third Biennial Update Report (BUR3) to UNFCCC 2021

Malaysia's third biennial update report (BUR3) has been submitted to the United Nations Framework Convention on Climate Change (UNFCCC). BUR3 highlights the estimates of anthropogenic emissions and removals in four sectors, namely energy; industrial processes and products used (IPPU); agriculture, forestry and other land use (AFOLU) and waste sectors, and time series estimates from 1990 to 2016 value [2].

We also reported on damage countermeasures and their effects in 2016. Estimates of greenhouse gas emissions avoided by these measures are determined in three sectors: energy, waste and forestry. It provides information on future mitigation goals and key impetus for implementation at the national and local levels.

The third biennial update report (BUR3) was prepared in accordance with Decision 2 / CP.17 of the United Nations Framework Convention on Climate Change (UNFCCC). The submission of BUR3 in 2020 is to fulfill Malaysia's obligations as part of the UNFCCC. The report is also the result of the UNDP Global Environment Facility (UNDPGEF) project. BUR3 contains the following updates:

a. National Conditions

In the past four decades, a trend has been observed to increase the temperature from 0.13°C to 0.24°C per decade. However, the long-term trend of rainfall is less obvious. The precipitation in Peninsular Malaysia and Sabah has a slight downward trend, while the precipitation in Sarawak has a slight upward trend. Forests are an important heritage and ecosystem of the country. In 2016, approximately 55.2% of the land was still covered by forests. Terrestrial biodiversity is concentrated in these forests, and the country is considered to be one of the rich countries in the world [2].

As of year 2021, the total population of Malaysia in 2021 is 32.7 million, with an annual growth rate of 0.2%. During the period 2005-2021, the population increased by approximately 21.5%. Approximately 94% of the population is under 65 years of age and the average life expectancy is 74.6 years.

To promote investment and economic growth, Malaysia launched an Economic Transformation Plan (ETP) covering the period 2010-2020 in 2010. The gross domestic product (GDP) (calculated at constant

2010 prices) has increased from RM659.6 billion in 2005 to RM1504.93 billion. Respectively 2021. [1]. The main contribution to GDP is the service industry (57.14%), manufacturing (24.59%), mining and quarrying (7.22%), agriculture, animal husbandry, forestry and fishery (7.26%) and construction (3.79%) (Malaysia GDP, 2021). Malaysia's 2016 primary energy supply was 93,396 ktoe, while final energy consumption was 57,216 ktoe (transportation sector (42.0%), industrial sector (28.0%), residential and commercial sector (14.1%)). , The agricultural sector (0.7%) and non-energy use (15.3%)) [2].

Sector	Emissions/ Removals (Gg CO_2 eq.)
Energy	251,695.02
Industrial Processes and Product Use	27,348.83
AFOLU – Agriculture	10,627.72
AFOLU – LULUCF (Emissions)	17,801.27
AFOLU – LULUCF (Removals)	-259,146.03
AFOLU – LULUCF (Sub-total)	-241,344.75
Waste	27,161.66
Total Emissions (without LULUCF)	316,833.23
Total Emissions (with LULUCF emissions part only)	334,634.51
Total Emissions (with LULUCF)	75,488.48

Table 2: The total greenhouse gas emissions in 2016 [2]

Development planning and implementation including climate change are negotiated and coordinated by the Economic Planning Unit of the Prime Minister's Office and various ministries. These are all carried out through the five-year development plan.

Since the submission of the second biennial update report to the UNFCCC in 2018, the UNFCCC's national focal point has changed, and the national focal point is currently located in the Ministry of Environment and Water Resources. Business issues related to climate change are guided and endorsed by the National Climate Change Steering Committee (NSCCC). A technical working group was established within the framework of the biennial update report and the national steering committee for national communications to prepare national communications and biennial update reports for the UNFCCC. In addition, the National REDD+ Steering Committee (NSCREDD) was established in 2011 to guide the formulation of a national REDD+ implementation strategy.

REDD+ is a United Nations-backed framework that aims to curb climate change by stopping the destruction of forests. REDD stands for "Reducing Emissions from Deforestation and forest Degradation"; the "+" signifies the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.

b. National Greenhouse Gas Inventory

The Greenhouse Gas (GHG) Inventory details anthropogenic emissions and removals in four sectors in 2016: energy; industrial processes and product use (IPPU); agriculture, forestry and other land use (AFOLU); and waste. The inventory also contains time series estimates for all sectors from 1990 to 2016, which have been recalculated to reflect updated activity data and emission factors. These greenhouse gas inventory estimates were obtained by following the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

The total greenhouse gas emissions in 2016 were 316,833 Gg CO2 equivalent (excluding LULUCF emissions) and 75,488 Gg CO2 equivalent (including LULUCF), as shown in Table 2 [2].

In 2016, in terms of greenhouse gas emissions, the energy sector continued to be the largest source of emissions, accounting for 79.4% of total emissions. The IPPU and waste sectors are closely followed, each of which accounts for approximately 8.6% of total releases. At the same time, the agricultural sector has the lowest emissions at 3.4% and LULUCF is the net sink. In terms of gases, CO2 emissions in 2016 accounted for 80% of total greenhouse gas emissions. CH4 emissions represented 17% of total emissions, while N2O and F- Gases emissions were 2%.

c. Mitigation Actions and Impacts

Malaysia's key strategy to mitigate greenhouse gas emissions is in the energy, waste and forestry sectors. Mitigation measures in other sectors, IPPU and agricultural sectors have not yet been quantified. The following Table 3 shows a summary of mitigation measures and their impact in 2016:

The report also outlines the future goals of mitigation actions and the key drivers of implementation at the national and subnational levels.

reporting obligations to the UNFCCC and implementing mitigation actions. Supported mitigation projects focus on energy efficiency in the construction, manufacturing, industrial, and transportation sectors. Clean and green technology is another key area, and the project is aimed at the development of small and medium-sized enterprises and low-carbon cities.

Sector	Sub-sector	Mitigation Actions	Emissions avoidance achieved in 2016 (Gg CO_2 eq.)
Energy	Renewable Energy (Power)	Feed-in-Tariff (FiT)	460.52
		Hydropower	6,570.15
		Other RE by public and private licensees	231.92
	Energy Efficiency	National Energy Efficiency Action Plan (NEEAP)	458.02
	Transportation	Rail based public transport	212.93
		Use of energy-efficient vehicles	90.65
		Use of palm-based biodiesel in blended petroleum diesel	1,127.34
		Use of natural gas in vehicles	114.77
Waste	Paper recycling		3,937.76
	Biogas recovery from palm oil mill effluent		2,377.84
Forestry	Reducing deforestation, Sustainable management of forest and Conservation of carbon stocks		20,307.50

Table 3: Mitigation measure and impacts [2]

d.The level of support received, constraints, gaps and needs.

In Malaysia's 11th plan, a large number of national resources have been allocated to strengthen a wide range of actions to combat climate change. These actions have also been supplemented by the international community's capacity development, technical and financial support to fulfil the country's obligations under the Convention, including the level of support for recording and dissemination.

The Global Environment Facility (GEF) is the main source of funding for climate change-related activities. The support received is mainly used to develop Malaysia's institutional and technical capabilities in

In this report, as far as possible the funds received by NGOs are reported. In addition, Malaysia has gained capacity building through participation in regional seminars.

Like the previous BUR, Malaysia also reported on its limitations, gaps and need to fulfill its reporting obligations and their implementation.

For greenhouse gas inventories, the challenge remains completeness and the shift to higher-level estimates. As far as mitigation is concerned, access to technological capabilities and clean technologies remains a major limitation. The use of assessment tools, big data and analysis are the identified needs for the development of a resilient Malaysia.

6. Conclusions

The national climate change policy is a long-term plan and commitment. Malaysia has made strong and ambitious commitments to reduce carbon intensity, in particular by 40% by 2020 (compared to 2005 levels) and 45% by 2030 (compared to 2005 levels). The situation of Malaysia is actually similar to other developing countries, Malaysia also faces the pressure of population growth and extreme poverty.

The challenge and barrier for Malaysia is to decarbonize the energy-driven economy. Interviews with public and private stakeholders have been conducted to examine how Malaysia began its transition to a decarbonized development path. According to our findings and analyses, we have identified the main drivers of progress, including behavioral changes, institutional changes, and the actions of a broad network of participants that have enabled Malaysia to begin decarbonization of the economy. At the same time, many barriers to federal friction, limited government capacity, lack of central government, lack of international funding, early environmental awareness and investment in renewable energy are strengthening carbon locks. I understand this. Based on the analysis, we can recommend other rapidly developing countries to gain experience from Malaysia's first successes and challenges.

In ASEAN region, an assorted arrangement of regional activities for transformation and alleviation are suggested, assembled into four classifications (“Acquaint”, related to transparency; “Integrate”; “Involve”; and “Motivate”, related to transformation), as focused by the ASEAN Member States (AMS) for the following ten years, while fundamental activities for 2030-2050 are likewise proposed.

Thus, ASEAN State of Climate Change Report (ASCCR) shows fundamental measures through 2030 and on to 2050, and on the off chance that these are joined with adequately upgraded limits, they would build the achievability to meet the e Paris Agreement (PA) objectives for variation and alleviation, counting by accomplishing net-zero GHG outflows as soon as conceivable in the last 50% of the 21st Century.

The difficulties going up against the ASEAN area as well as the flow responsibility of ASEAN to add to the Joined Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement (PA) are examined. Perceiving the difficulties to meet announcing prerequisites under the Enhanced Transparency Framework (ETF) and to gain ground towards the desire of the PA objectives of restricting worldwide normal temperature increment to well under 2 degrees Celsius (°C), ideally to 1.5°C, contrasted with pre-modern levels, this analysis has fostered a philosophy to evaluate the current advancement of activities and the need to reinforce them through 2030 and on to 2050 in light of the ideas of "transparency" and "transformation".

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Youth perspectives and engagement for climate action - an ACU COP26 research-to-action project for Mauritius

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Abstract

Climate change has progressively taken a global dimension since the industrial revolution that the annual UNFCCC Conference of Parties (COP) has become a pivotal event for all stakeholders, including leaders, NGOs, youth, civil society, industry and the public at large. Such has been the gravity of the consequences of climate change that the latest COP26 has seen unprecedented mobilisation of youth activists physically in Glasgow and around the world through social media platforms to voice their anger, disapproval and frustration against the lack of concrete action to tackle climate change to give them certainty for a more secure future. If the cause of climate change has been uncertain in the past, with the proponents for a modern, industrialised society at any cost, delegating climate change to a natural phenomenon, the latest IPCC report has been unequivocal in ascertaining that climate change is man-made, but man is and will not be the sole inhabitant of Earth to bear the consequences.

Although it is well-acknowledged and acclaimed that the needed, fundamental change in our society to nullify, if not reverse the doom and gloom of climate change, will occur through our younger generation, still literature reports little on what exactly our youth would like to see happening, in addition to advocating for climate action. In view of understanding the perspectives and aspirations of our youth in Mauritian, an online survey was carried out as part of an Association of Commonwealth Universities (ACU) research-to-action project in the build-up to COP26, in which 180 participants took part. The survey findings allowed to gain important insights into the level of awareness on the climate change phenomena itself, how it is impacting their communities and the extent to which our youth is conversant with important policy documents such as NDCs and IPCC reports. The survey was also focused on understanding the barriers for them to get into climate action activities at volunteering or business levels, based on which a range of training programmes were organised in collaboration with JCI Curepipe. The umbrella project was called Youth Voice to COP26, which culminated into a community engagement workshop on how each member of our community can be engaged in climate action at their household level in a highly effective way by improving the energy-water-materials nexus for their homes.

The workshop emphasized on demystifying the technical aspects of thermal comfort (using the passive solar design principles), water (using the regenerate natural systems pillar of the circular economy) and solid waste (using the keep materials in use pillar of the circular economy) to enable participants to have a

proper understanding of how their homes are contributing to climate change and amplifying its impacts, but on a positive note, how by understanding those impacts, they can take simple measures to make a difference. Whole the focus of the exercise was at localised, household level, the benefits can be amplified at neighbourhood and community levels. The workshop has seen the active engagement of our youth, who were left highly motivated by the take-away lessons, invigorated to learn that they can make a difference. The main outcome for this research-to-action project has been the need to make climate change teachings more accessible to the community at large, and more importantly, with clear and simple measures on what they can do practically. The academic, research and engineering community have the vital role to play in customising the scientific findings and solutions to the local context of communities with the people, and rendering the whole process easily understandable and demonstrable. As COP26 demarcated itself for its unrelenting focus on concrete climate action beyond just policies, the ability to engage the community in developing and co-creating these solutions will be of prime importance as well.

***Keywords**: Climate change, youth activism, community engagement, circular economy, circular homes, climate action*

1.0 Introduction

It is undeniable that climate change is well in our midst and has become a planetary concern for all nations around the world. The establishment of the annual Conference of Parties, commonly known as COP, in response to climate change, the latest being COP26 held in November 2021 in Glasgow is yet another indication of the gravity of the problem. There have been several grievances reported by various stakeholders participating in COPs both on the side of policy-makers and the climate activists as well as civil society organisations and the private sector companies, with the following salient points:

- Lack of engagement from governments to take concrete action in the fight against climate change;
- Lack of support for developing countries from developed countries, as the latter have been the prime cause of climate change, leading to the crucial topic of climate justice and loss and damage;
- Lack of concrete action beyond policies to make things happen in the real, at grassroots level.

All the issues concerned with climate change is in one or another related to economic development with admission of environmental degradation, which has reached a level beyond nature's ability to recover quickly, if not at all. The consequence of climate change has been experienced in different ways across the world, including forest fires, seasonal extremes, flooding and drought, sea level rise and changes in migration pattern. Not a single living entity on our planet has been spared by climate change, and with global warming bound to deteriorate and predicted to reach and exceed the 1.5°C threshold in a decade (IPCC, 2021), it is clear that the worse is yet to unfold, the next generation will have to bear the brunt of the action of past generations. This is indeed the concern of the growing number of youth activists around the world, claiming their rights of say on the legacy that will be left to them. The literature confirms the importance of youth participation in climate activism to voice out their concerns and lobby for the change they would like to see, yet a gap is observed in what concretely they would to see happening.

Martiskainen et al. (2020) studied the youth motivation in six cities, concluding that youth disagreement on climate policies is manifested through strikes, recommending more grassroots approach to climate action and the use of digital media tools, which the youth identifies closely with. Ballard et al. (2021) recommended positive youth development programme around climate activism, reporting an important increase in civic engagement skills as well as higher civic engagement score through such engagement for

equitable climate.

Haugestad et al. (2021) studied the #FridaysForFuture climate protests to understand why youth participate in climate activism. In their publication, they discuss environmental movements around the world from the perspective of the participants, highlighting the need to listen and integrate the perspectives of the youth to enable a broader discussion. Thew at el. (2020) observed that formal opportunities for youth voices to be heard in environmental governance are small, with the YOUNGO initiative from the UN Framework Convention on Climate Change (UNFCCC) providing one of the few opportunities for youth to share their perspectives. This confirms the lack of participation and opportunities for the youth to get their voice across and explains the frustration communicated during the last COP26. Thew et al. (2020) studied a UK-based case study organisation and long-established member of YOUNGO between 2015 and 2018. It was found that there has been a shift in the mandate of the youth from potential future risks caused by climate change to their generation towards solidarity claims for issues being faced by other groups in the present, which can act as a barrier to their initial cause for climate change affecting their generation in the future. Hahn (2021) studied the influence of childhood factors on environmental stewardship, and concluded that prior exposure to nature and environmental protection and habits from parents have a correction to children's environment engagement subsequently, with this inclination decreasing in adolescence. The research has pointed out a change in framework from one highlighting children as victims of climate change to one where they can be the positive needed.

Miller et al. (2021) relate to youth-led engagement as resulting from continuation of the work of previous generations of activists aiming to radically change our society. Wallis and Loy (2021) investigated the factors motivating young people to become climate activists by interviewing the Fridays for Future (FFF) movement participants. The results show that the main drivers for their engagement are: friends participation in the movement, identification with others engaging in climate protection, and personal principles and beliefs for climate action.

As a direct consequence of climate change is the loss of vital land for agriculture, and with it lower resilience for food security. However, Kabiri (2016) reported that incorporation of public participation in this sector can provide an opportunity to extend the dialogue for environmental governance in other sectors enabling governments to find local solutions to the pressing problem of food security, aggravated by the ongoing coronavirus pandemic. The agricultural sector can also be used as a key driver to encourage our youth to be engaged in food production, albeit using innovative and smart production technologies, while contributing to climate action.

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Macdonald et al. (2013) collected the climate change perceptions of youth between the age of 12 and 25 years old in the Inuit community of Rigolet, Nunatsiavut, Canada, where they carried 21 in-depth interviews. The feedback pertained to the following five categories: changing travel conditions and access to hunting; challenges to Inuit culture; a concern for Elder and senior well-being; strong climate-related emotional responses; and youth-identified potential adaptation strategies. The authors found that the youth

has valuable knowledge and views to offer, and recommended that the youth are meaningfully engaged in climate change work, research, dialogue and policy. MacDonald et al. (2015) went on to investigate the influence of how climatic and environmental change challenges the well-being of youth and Majeed and Lee (2017) looked at the impact of climate change on youth depression and mental health, a topic not thoroughly researched into, but with clear indication of adverse effects. Along this line, Vesely et al. (2021) investigated the interesting correlation between personal identity as an expression for climate action, and found links between pro-environmental intentions and behaviours to people's nature connectedness, confirming the key role of biophilic design in living environments on people's well-being and health.

From the brief review of key findings from literature presented above, it can be concluded that it is highly desirable to integrate the views and ideas of our youth to tackle the pressing challenges of climate change and use the potential of climate action to engage our youth to develop appropriate civic attributes and prevent social crises such as depression and frustration. Along this line, the research-to-action project proposed for Mauritius as part of the Association of Commonwealth Universities (ACU) Climate Research Cohort in the built-up to COP26 was a youth voice to COP26 project, organised in collaboration with JCI Curepipe, with aim and objectives described in the next section.

2.0 Research Scope and Objectives

Based on the clear lack of understanding observed in literature on what the youth wants to see happening in terms of climate action, the barriers they face in having their voice heard and in putting their ideas into practice, and how they can be engaged fruitfully to make beneficial use of their knowledge and skills, the youth voice to COP26 forum was organised with the following objectives:

- Design an online survey to invite feedback from our youth on their perspectives, apprehensions, observation and suggestions for climate advocacy and climate action;
- Through the survey, identify areas for capacity building and organise training programmes accordingly in the build-up to the COP26 conference;
- Evolve a community action programme over the course of the project to allow all layers of the society to be engaged and facilitate the creation of individual and common action plans based on their ideas.

3.0 Methodology

The online survey questionnaire was designed with open-ended questions to invite unbiased responses from the youth as well as guided questions using the Likert scale where participants were asked to rank the extent to which they agree or disagree to certain aspects of climate change. Given the findings showing the ability of our youth to propose creative solutions for climate action, a central goal of the project was to provide a platform through the survey, training programme and consultative workshop for the participants to brainstorm and propose concrete solutions to the problems they observe in their communities. The number of youth in the age range 18-40 years is estimated to be around 365,000 (Statistics Mauritius) in 2020 using the population pyramid provided. Using Slovin's formula:

$$n = \frac{N}{1 + Ne^2}$$

The number of participants for a 95% confidence interval is calculated to be around 400, but as discussed later, the number of participants was 180, bringing the confidence interval down to 92.6%. Further details on the components of the youth voice to COP26 project are given in the next sections, including the main survey questions presented along with the distribution of responses obtained. The format of the workshop

selected was a cognitive one, which cumulates the teachings from the online trainings offered prior to the workshop and further concepts presented on green building design, solid waste management and sustainable water use, the three pillars of the circular home concept, with a prime focus on presenting the principles in a non-technical language as far as possible to enable engagement of community members from all backgrounds.

4.0 Youth Survey

JCI Curepipe in collaboration with the University of Mauritius organised the "Youth Voice to COP26" with the objectives to give a stage to youth voices, raise awareness on climate change through training programmes, gather ideas to adapt to and mitigate the effects of climate change through consultative workshops and forge teams under common thematic areas to develop action plans for subsequent interventions to put the ideas in practice. Another key outcome of the forum was creating synergies with different stakeholders for concrete actions in the build-up to the COP26 conference and ongoing collaborations beyond. The focus of the Youth Voice to COP26 was to give the youth a platform to voice their ideas and views, to join forces, connect and construct synergies for concrete actions that can be taken to tackle issues related to climate change and unsustainable practices, broken down into the following six thematic areas:

1. Education and Gender Equality – empowering the community through awareness
2. Energy and Environment – access to energy and support of environmental-friendly practices
3. Livelihood and Skill Development – Empowering people to bring innovative, sustainable solutions.
4. Water and Sanitation – Improve quality of life by providing access to clean water and sanitation.
5. Waste Management and Infrastructure – Developing circularity in dealing with materials and resources.
6. Agriculture and Risk Management – using appropriate technology and methods improve agricultural practices.

Participation was open to young Mauritians aged between 18 to 40 years, and the first activity was an online survey to gather their feedback, which was a key step to decide on the remaining activities of the research-to-action project component in Mauritius. The main survey findings are discussed in the next section, based on which a series of online training programmes was organised with experts in the associated areas, ending with a consultative workshop centred on circular homes, which was conceived as a project to engage the community in climate action through non-technical knowledge as far as possible to allow members to understand their impacts and devise solutions at the level of their households. The circular home concept is described in Section 4.

5.0 Survey Findings

The survey was designed as an online questionnaire, which saw the participation of 180 youth. The background info about the participants is summarised in Figure 1. The ability of our youth to engage in groups to galvanise their efforts is crucial and the results illustrated in Figure 2 show that over 40% of them, despite keeping high interest to contribute to climate action are not associated with any organisation. Based on this, a training programme on youth advocacy was organised to provide information on existing youth platforms they can benefit from. Likewise, nearly 45% of them have not participated in climate activities so far, and around 12% have more than 3 years' experience in the field.

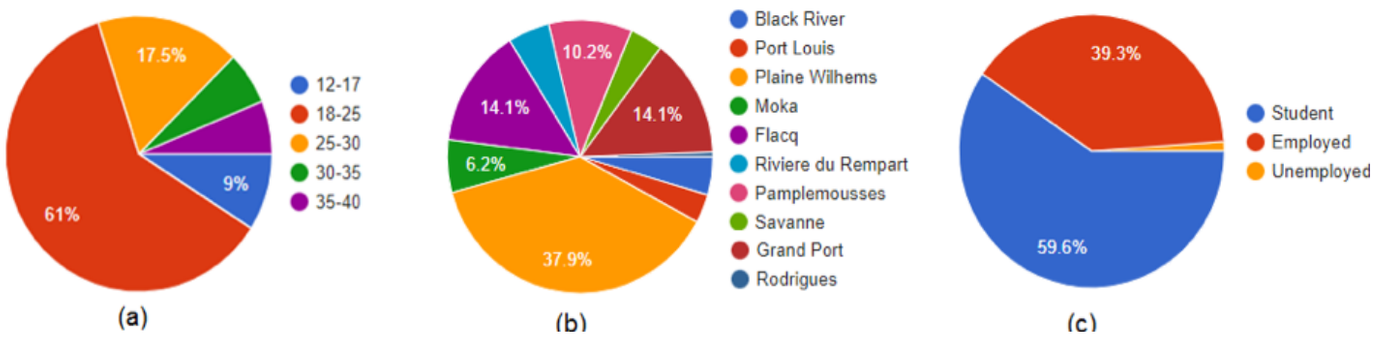

Figure 1: Background of participants (a) age range, (b) district and (c) occupation

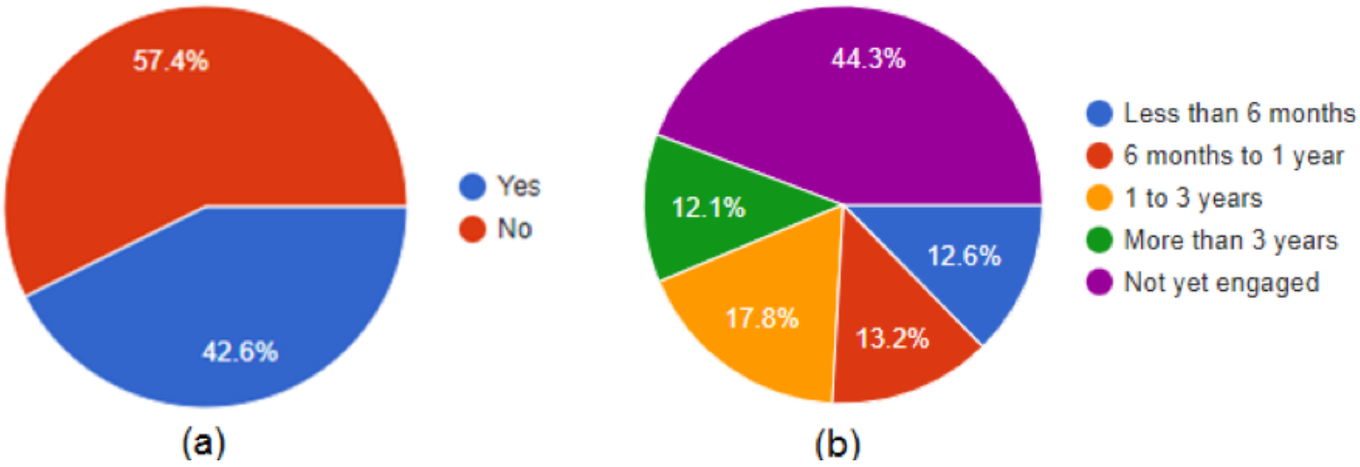

Figure 2: Involvement in climate action (a) associated with organisation, (b) experience with climate advocacy

The next figure (Figure 3) shows the level of awareness in the participants, with a high percentage in the high and very high categories, which actually does not represent the level of climate awareness in our youth in general, but rather showed that the participants in the survey had chosen to do so based on their keenness for the subject matter, and this in turn may point to the fact that the large majority of our youth are not conscious or do not keep abreast of the climate change topic. There is a need to ensure our youth are well acquainted on the subject matter through seminars and modules in educational programmes.

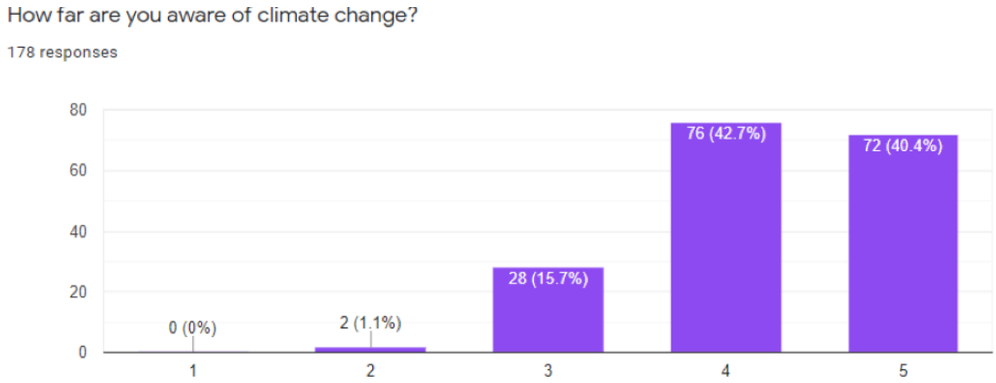

Figure 3: Climate change awareness

Figure 4 shows the distribution of responses on extent of impacts on livelihoods in communities.

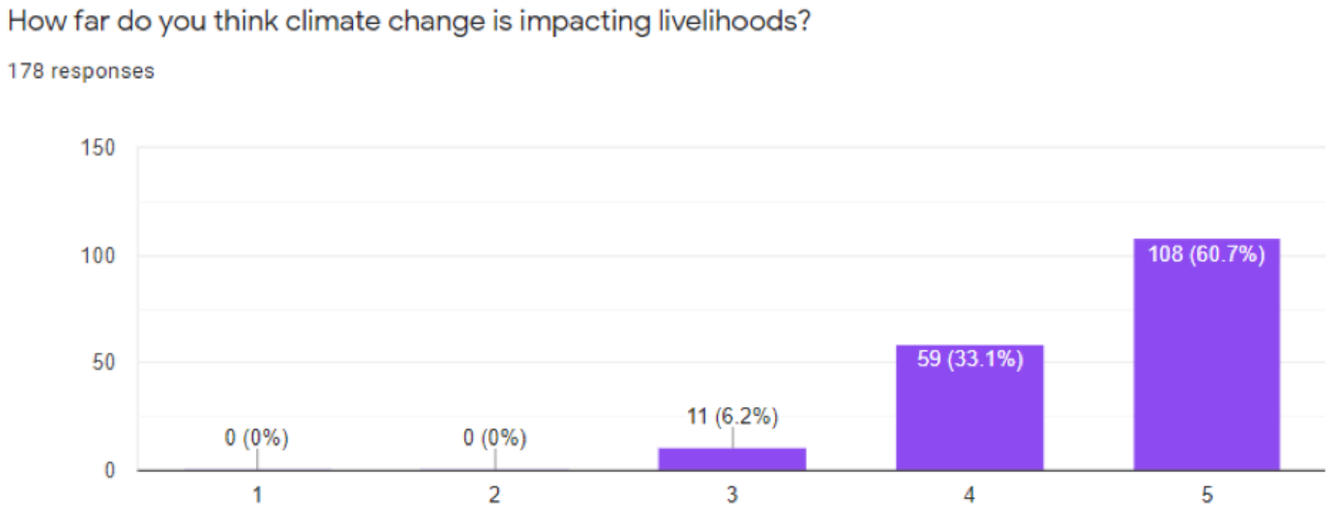

Figure 4: Impact on livelihoods

The results show that the participants were aware of the impacts caused by climate change, and that the impacts are on the high side. The latest IPCC report confirms, after decades of speculation, that indeed climate change has been caused by human activity, and that it can be tackled by reimagining the functioning of our society. Figure 6 shows the views of the youth on causes of climate change in Mauritius, with each cause ranked from low to high. Fossil fuels, destruction of green areas, rapid urbanisation and transportation were deemed to be the leading causes of climate change. Associated to the causes of impacts are the solutions, and Figure 7 shows that switching to renewable energies, greening of areas and buildings, coastal area protection and embarking on a circular economy are key areas our youth believe will help tackle climate change.

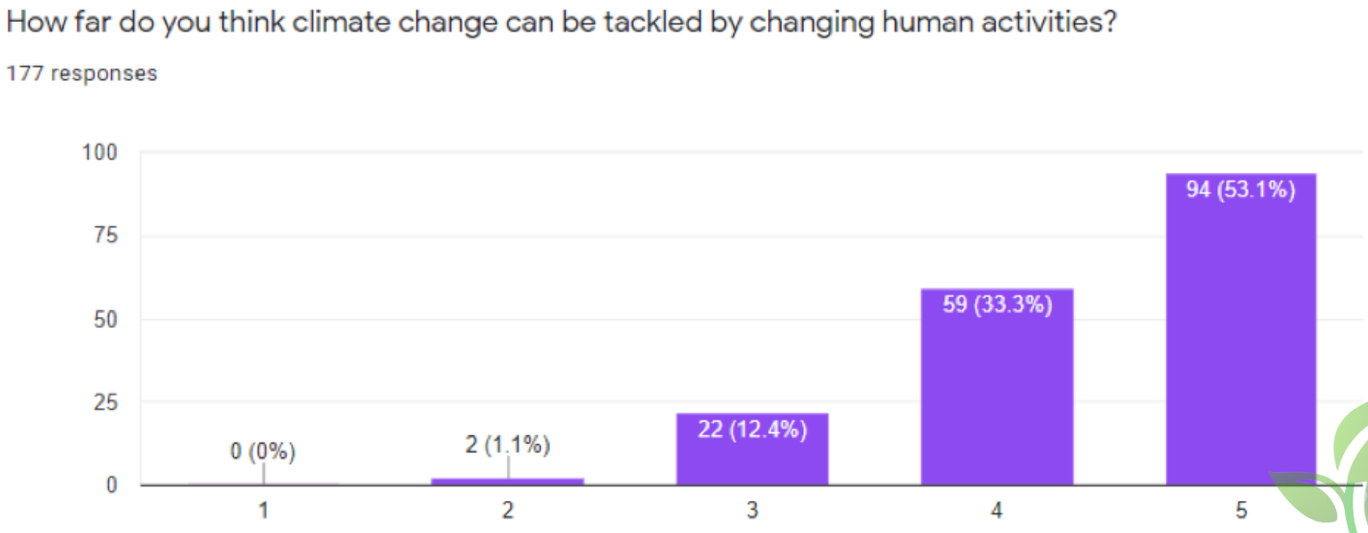

Figure 5: Human habits and climate change

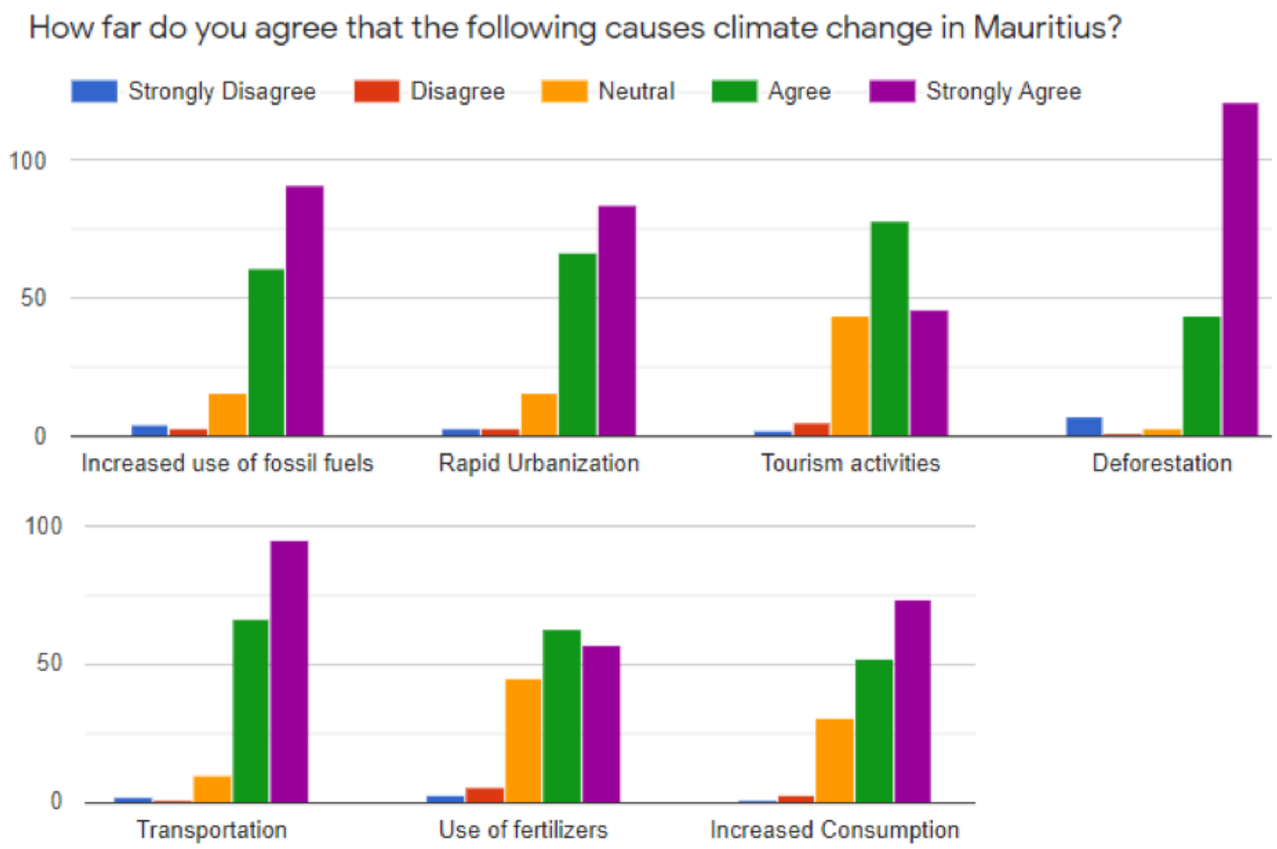

Figure 6: Causes of climate change in Mauritius

The next sets of responses (see Figure 8 and Figure 9) shed interesting results on awareness of our youth for climate targets and associated documentation and reports, for which a high incidence for the middle value range shows that there is less awareness for climate targets produced by the government, e.g. through NDCs or international reports on climate change. So there is a definite and ongoing education to do in this regard so that government strategies for climate change are effectively communicated to our youth and population in general. Figure 10 illustrates the responses for the impacts of climate change experienced or observed in local communities coastal and land erosion, extreme temperatures, flooding and frequency intense cyclones were the prime concerns. Figure 11 and Figure 12 depicts the results related to youth participation in consultation and involvement in setting policies for climate change, and as expected the distribution shows an unsatisfactory and uncertain level of youth participation, calling to be increased due to the high importance allocated to having the youth voice in policy-making.

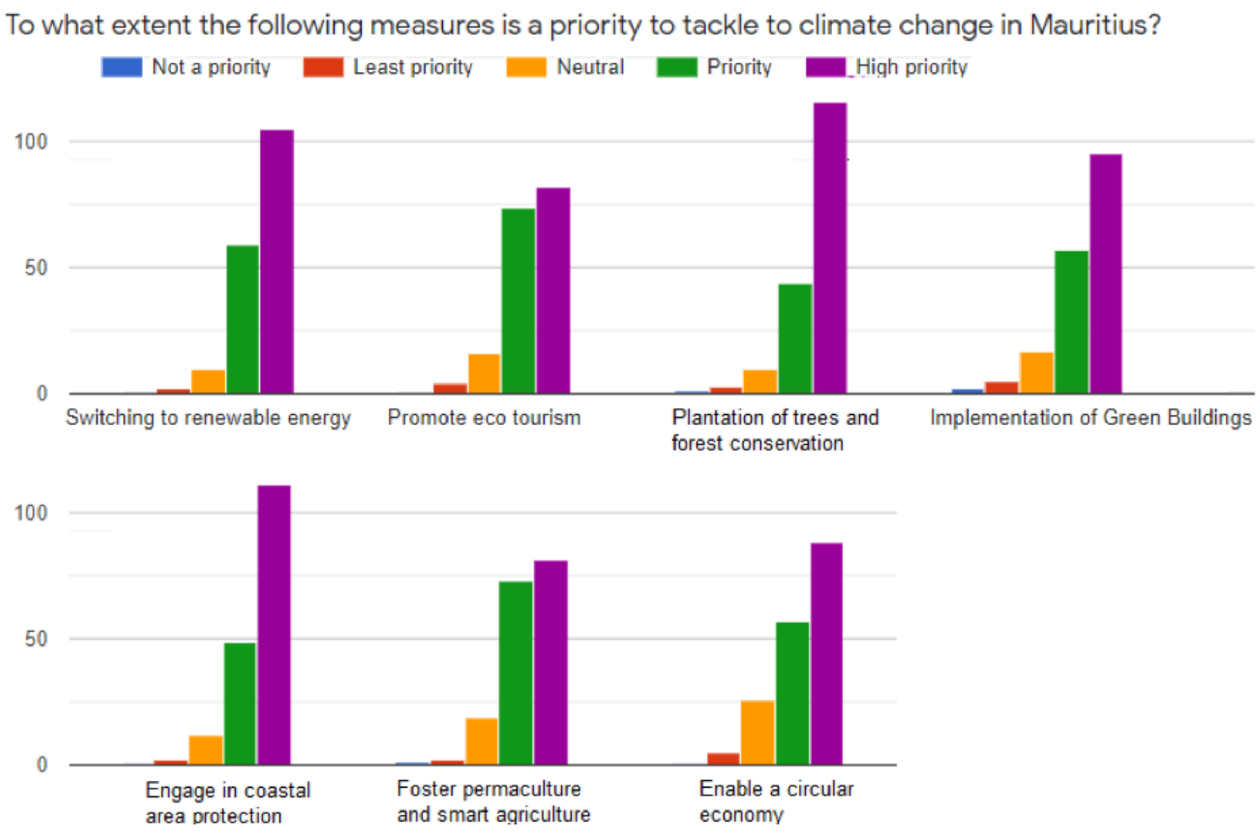

Figure 7: Climate action activities

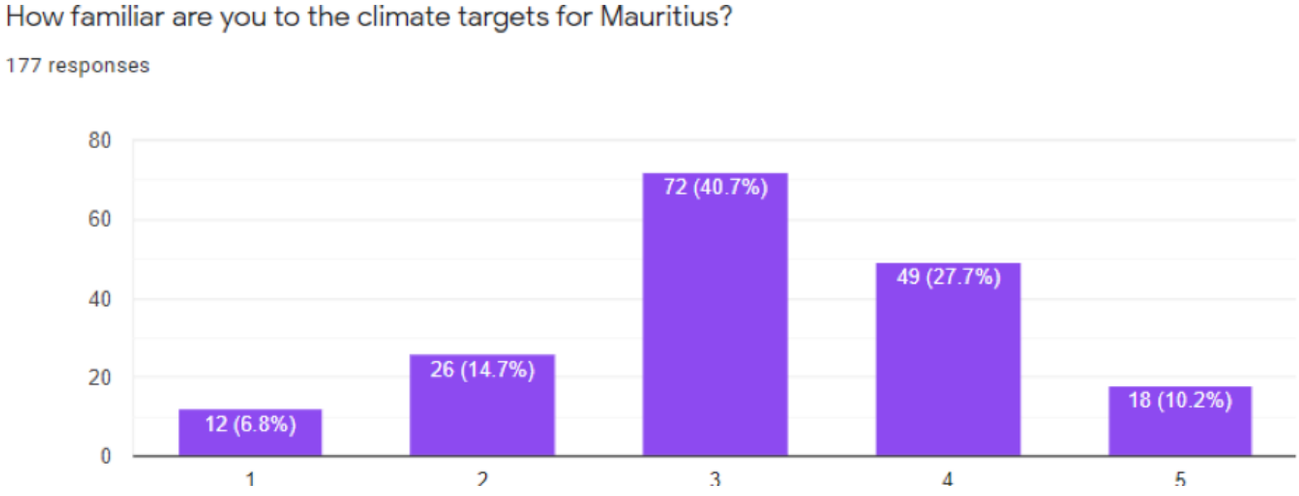

Figure 8: Climate targets

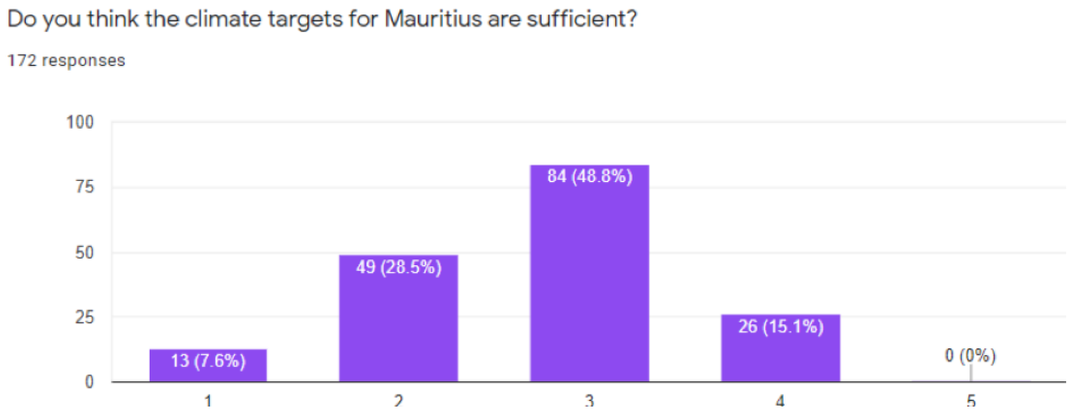

Figure 9: Adequacy of climate targets

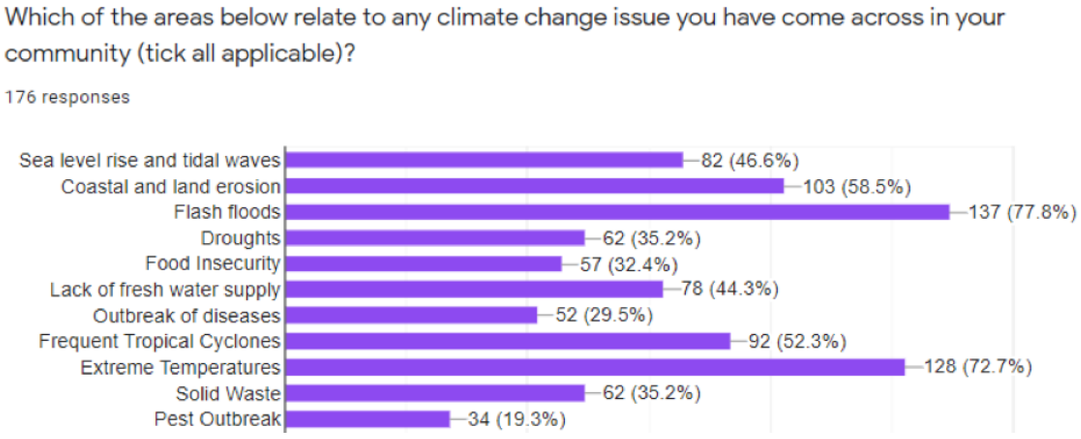

Figure 10: Climate change consequences

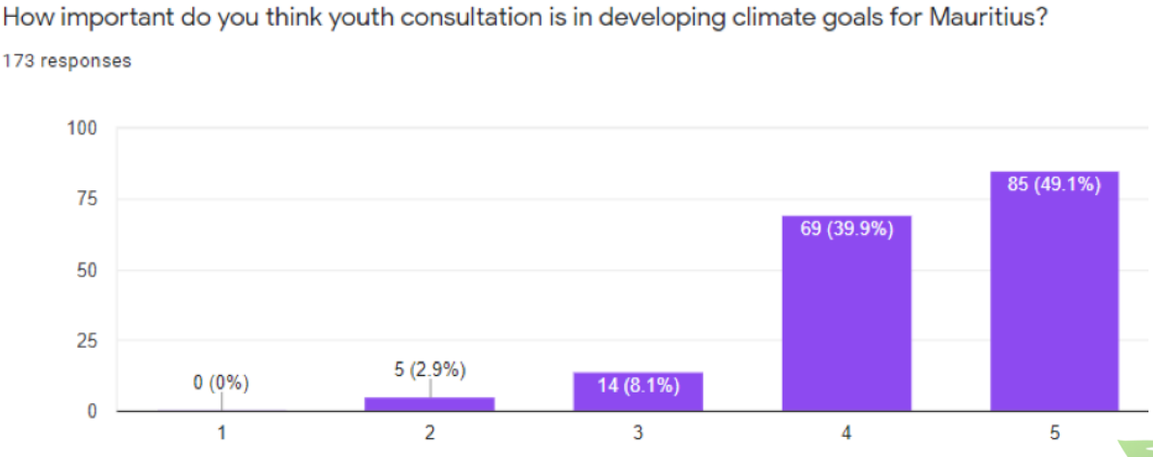

Figure 11: Youth consultation

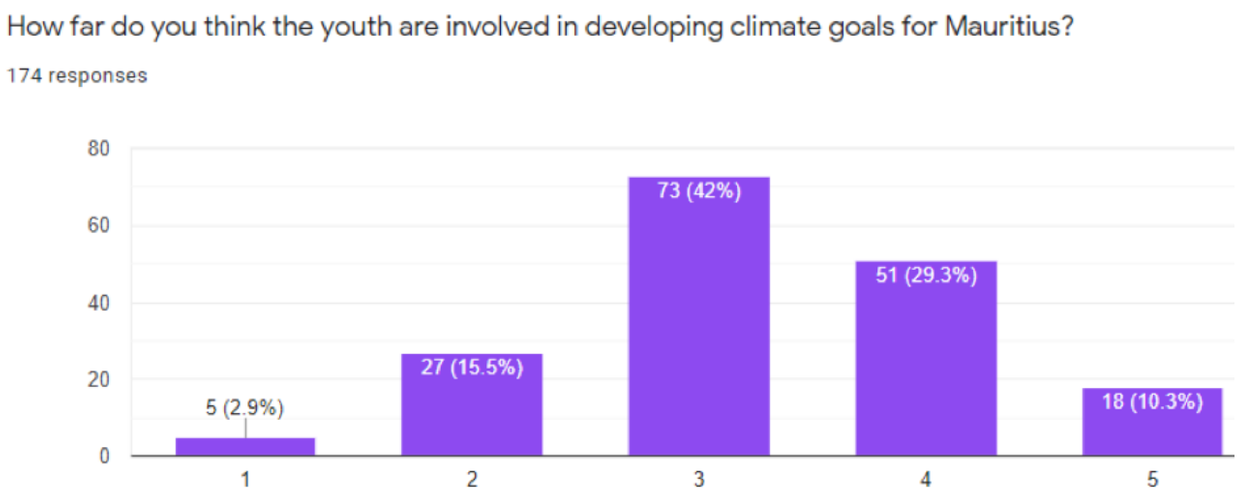

Figure 12: Youth involvement in climate goals for Mauritius

As shown in Figure 13, it is interesting to note the individual responsibility assigned to each one for climate action, on equal terms with government, as opposed to the private sector, NGOs and academia. As described later, the circular home community engagement is indeed an endeavour focused on empowering each individual household and members of that household to take responsibility for impacts at grassroots level and mitigate those impacts as far as possible using the energy-water-materials nexus.

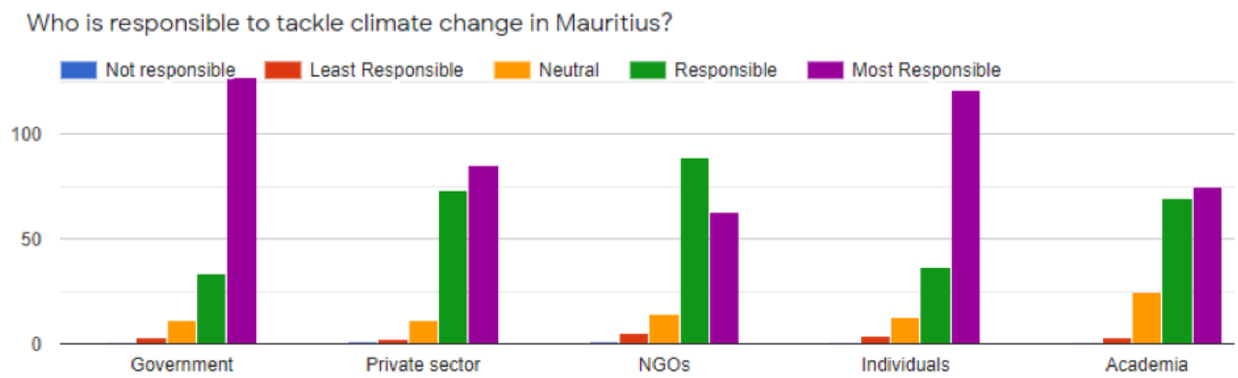

Figure 13: Responsibility to tackle climate change

The key barriers for youth engagement in climate action (see Figure 14) is a lack of funding to realise ideas, lack of consultation in policy decision on climate change and lack of guidance on how to go ahead to bring positive change. Again, the proposed circular home concept can pave the way to address the latter, and come up with innovative individual or community level project proposals that can be considered for funding by donor agencies.

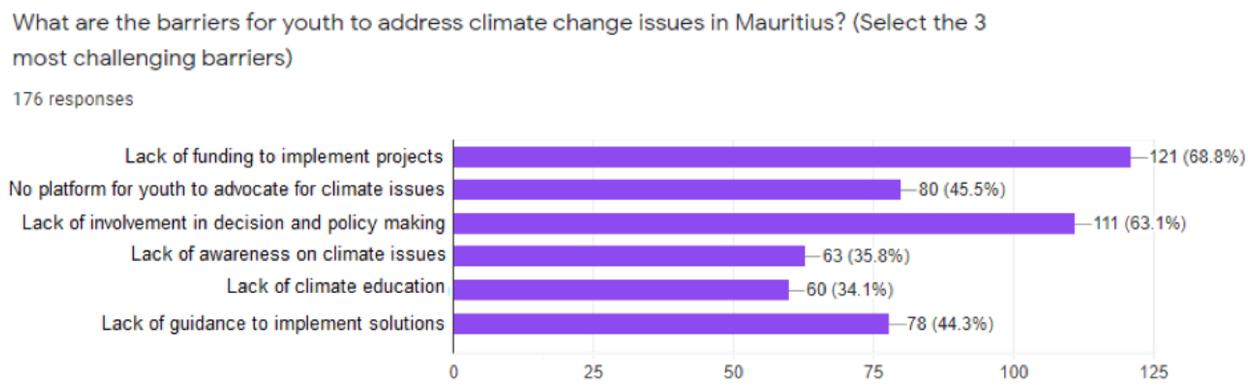

Figure 14: Barriers for youth climate advocacy and climate action

Finally, the areas where the youth would be interested to be trained to be able to better engage in climate action projects are presented in Figure 15 with the design of green buildings and smart cities used as an avenue for tackling climate change ranked highest, followed by smart agriculture and sustainability for businesses in addition to climate change principles. The keenness for agriculture is indeed a welcome proposition as there is tendency to think our youth is no more interested in engaging in agriculture, but they would be if backed with suitable innovative technologies such as mechanisation and AI solutions. The interest for sustainability for businesses is also a positive outcome to be built upon to encourage entrepreneurship for climate action offerings.

Figure 15: Capacity building for climate action

5.1 Open-ended questions

The participants were also offered the possibility to relate any further solutions they can think of to tackle climate change in the local context and the main areas recommended are as follows:

- Solid waste management of big appliances and commodities by government providing free service to transport these items to recycling points;

- Composting to properly deal with solid waste, and for this to be successful, run training programmes for the community;
- Carbon footprinting at individual level so that each one becomes aware of his or her impacts, and be able to mitigate same as much as possible;
- Stormwater management by upkeep of road drains in a proper state always;
- Promote green areas in all projects;
- Increased penetration of renewable energy on the grid by government providing incentives for green investments to the extent of having zero payback periods;
- Freshwater management by channelling rainwater appropriately for storage in our reservoirs;
- Changing mind sets by inculcating climate change education in curricula at primary and secondary levels to transition to a more sustainable lifestyle with less pollution and waste creation;
- Government setting the example to adopt sustainable practices in their projects.

6.0 Circular Homes for Community Climate Action

The circular economy (CE) framework, with its three pillars, illustrated in Figure 16, can be applied in a range of areas, including textile and fashion, food consumption, solid waste management and sustainable cities. These three pillars, namely (1) keeping out waste and pollution, (2) and for the sake of developing a circular, and (3) regenerate natural systems have deep and insightful meanings for thinking circular, and very much in line with climate action. It is for this reason that a circular economy framework has been found to be a great ally for climate change mitigation and adaptation. The circular homes concept has been conceived to engage the community members for climate action, by applying the CE framework to our homes, to which everyone attaches an emotional bond and which everyone will be keen to convert into a fundamental element of sustainable development and climate action.

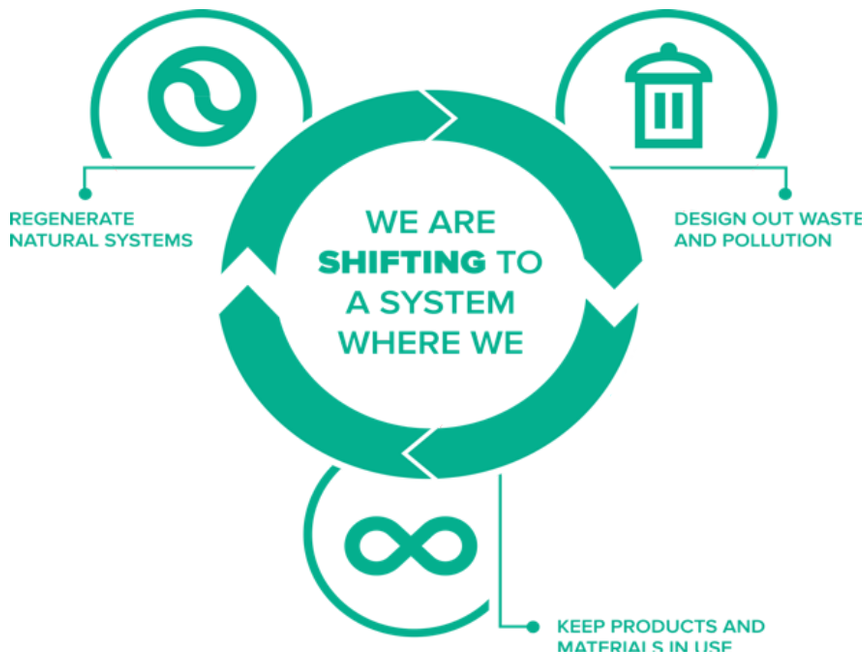

Figure 16: Circular Economy Framework (Source: Ellen McArthur Foundation)

It is with this goal that the home was selected as the basic building block for climate action in the community at grassroots level, a key requirement for success reported in literature. The workshop consisted of a general introductory session on climate change and presentation of the circular economy principles, followed by three focused sessions with associated assignments targeting the energy, water and materials dimensions, followed by a cognitive session to assimilate all findings and evolve concrete solutions for the impacts identified in households. Finally, the participants were required to identify one measure in each dimension they would be keen to bring forward, and this became the basis for potential synergy and concerted action. The activities of the workshop are detailed in the following sub-sections.

6.1 Energy dimension

The design out waste and pollution pillar was used as the basis for explaining the energy dimension, although the other two dimensions are also related. The key impact explained to the participants was the use of energy and the carbon emissions associated due to the burning of fossil fuels (rated at around 1 kgCO2/kWh). Therefore every means should be sought to reduce energy use in our homes, and the greatest potential lies in promoting thermal comfort without dependence on active cooling systems as in an air-conditioned building, air-conditioning can take more than 60% of the share of energy use, hence can become the major source of carbon emissions in our homes if no alternative sustainable solution is considered. In the current summer period we are living, there is an increased tendency for investing in the installation of air-conditioning units in homes, when the priority should be for implementing passive measures to eliminate or reduce the need for air-conditioning. Therefore the key is passive design and this is elaborately discussed in a non-technical manner in this part of the workshop. The participants were first asked to draw a rough sketch of their home for each floor, identify the nature of each space, the position of windows and doors and any adjacent building or tall trees around their home. This imaginative exercise is itself an introspection into understanding our homes and participants reported deep satisfaction in replicating their home spaces on paper.

Next key point was understanding the position of the sun, which is the prime natural element influencing heat gains and hence thermal comfort, for which the two solar angles, namely the azimuth and elevation angles were explained using a simple arm movement. The participants were all request to stand up and face the front of the room, and stretch their right and left arms horizontally and sideways. Imagining their heads are facing north, their right hands would in this position be facing the east and left arm facing west. The right hand would be generally the rising position of the sun and the left hand the setting position of the sun. They were then asked to move their right arm in a semi-circle, still horizontally to reach the left arm, and the angle they were sweeping is actually the azimuth angle. The participants were queried whether this is the position the sun takes during the day, and it was agreed that the sun actually also increase in altitude while sweeping from the right to the left arm, and now the participants were asked to modify the movement of their right arm to show the actual movement of the sun, and this allowed introducing the elevation angle. With this understanding, the solar path was introduced (see Figure 17) was introduced to show the equinoxes as well as summer and winter solstices.

Through illustrations like Figure 18 showing the position of the sun with respect to a building, the influence of the elevation was discussed. With this understanding, the participants were asked to show on their home sketch where the sun typically rises in the morning, and from there the participants were able to identify where there is likelihood of low angle sun occurring between East and North-East and North-West and West directions penetrating into the interior spaces and causing overheating through any glazed

openings along these orientations during summer periods. The participants were asked to cross check with their own experience living in their homes with what they predicted on their sketches, and it was generally found to match. With this simple exercise, they were able to understand the reason why they feel uncomfortable in certain areas in their homes, and therewith what can be done to control these heat gains. The efficacy of overhangs and eaves in the north direction (with high elevation sun) and the need for shading devices such as awnings louvres and shutters (see Figure 19) or tall trees in low elevation orientations became clear at this point. The constant exposure of the flat roof surface throughout the day and its major contribution to heat gains was also evident at this point, and with it the need to find means to shade the roof from direct solar radiation using simple canvas stretched over the roof, cool roofs, green roofs and extended roof terraces.

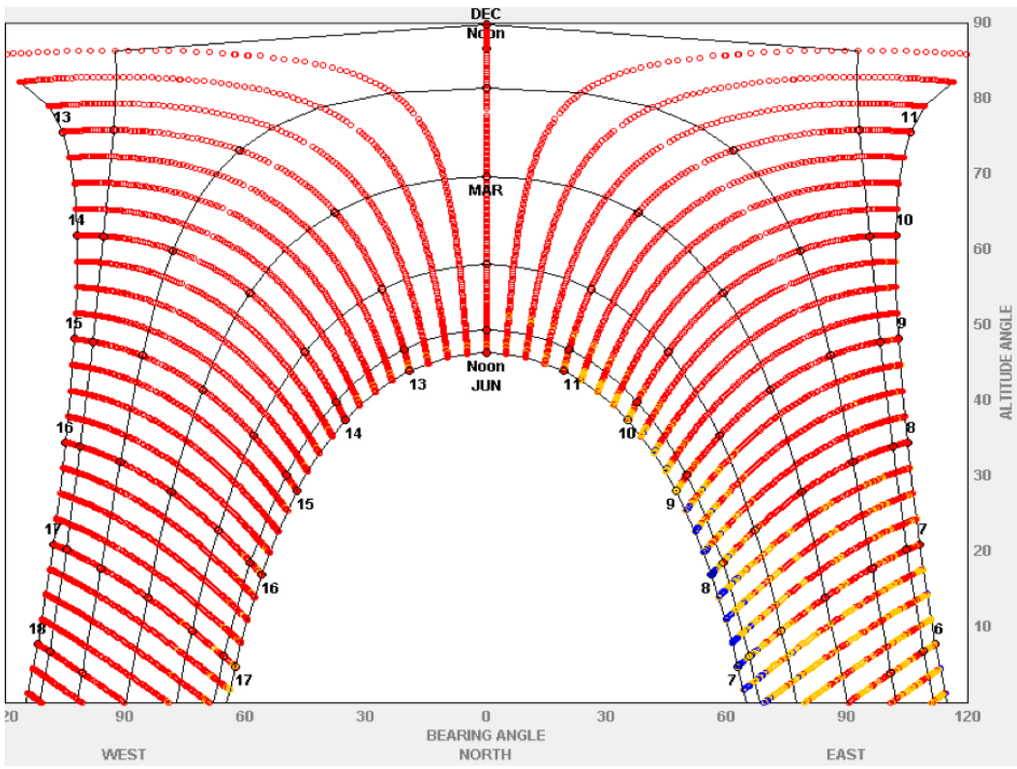

Figure 17: Solar Path for Mauritius with azimuth angle (horizontal axis) and elevation (vertical axis)

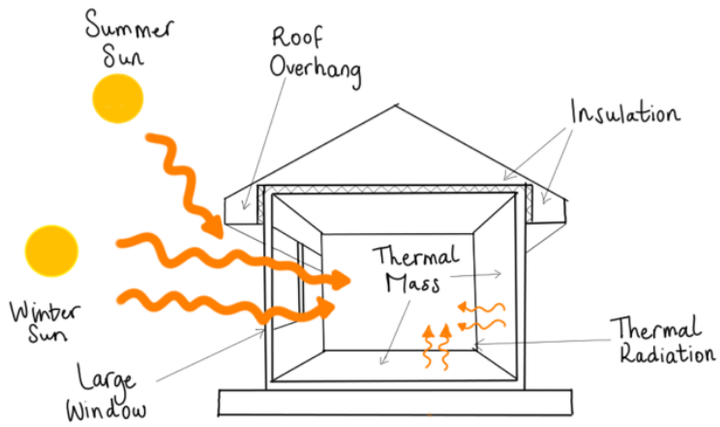

Figure 18: Coping with low angle and high angle sun using building envelope

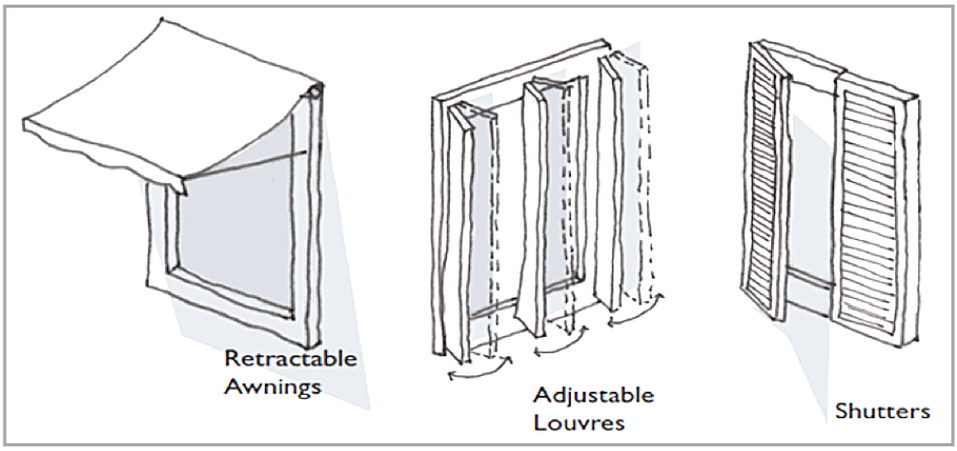

Figure 19: Adjustable external shading devices for low angle sun

With these simple and fundamental principles of passive solar design, the participants were well equipped to consider retrofits in their homes or design their future homes in a different way altogether to promote thermal comfort as passively as possible.

6.2 Water dimension

The water dimension would logically relate to the potable water demand, which is an important consideration, but the focus given in the workshop was a different one pertaining to rainwater run-off from the impermeable roof surfaces and with it, the regenerate natural systems pillar of the CE framework. The participants were invited to reflect on how their plot of land was before erecting their home building, especially in terms of the way rainwater would percolate into the ground to fill the underground aquifers without causing run-off, and the way their homes have now distorted this natural flow. With every household sending their roof run-off onto the road or into road drains, it became evident how increased urbanisation is causing accrued risk of flooding, which every Mauritian can now experience and since this undesirable water is sent to rivers and streams, and ultimately to the sea, it can also be understood why a situation can arise where flooding occurs but our reservoirs are empty.

The participants were directed through the assignment to think of the way their homes channel rainwater run-off, and what they can differently to make sustainable use of harvested rainwater for non-potable ends in their homes or at least store the run-off in retention tanks and allow the water to percolate slowly into the ground. With the more frequent occurrence of flash floods in Mauritius, it is clear that each household dealing with its rainwater run-off can contribute massively at neighbourhood level, providing improved resilience to adapt to short duration, high intensity rainfall patterns resulting from climate change, with which local authorities have had hard times predicting and attending to the consequences.

6.3 Materials dimension

The third and final dimension of the circular home is the materials dimension, which again can mean many things, including construction materials and insulation to regulate heat transfer, but the focus for the workshop was on solid waste management, which is poorly managed in Mauritius currently, leading to an annual waste amount of 500,000 tonnes sent to landfills, with significant environmental hazards, including worsening of climate change, when these materials are worth billions for our economy if dealt with properly. The majority of our waste is organic and come from the domestic stream, meaning households can have a huge impact on our solid waste management practices. Once the organic and inorganic streams are segregated from each other, the vast amount of possibilities over and above recycling were presented using the butterfly diagram (see Figure 20) with sharing, maintaining, reusing and refurbishing privileged before considering recycling on the right-side industrial cycle.

In addition to relying on central collection facilities to implement segregated waste collection, circular design practices involving materials innovation by local entrepreneurs and artists, and how these can lead to business and artistic opportunities were presented to the participants, as possibilities for them to consider at the level of their communities to divert maximum waste from landfills and feed into the materials loop of our economy.

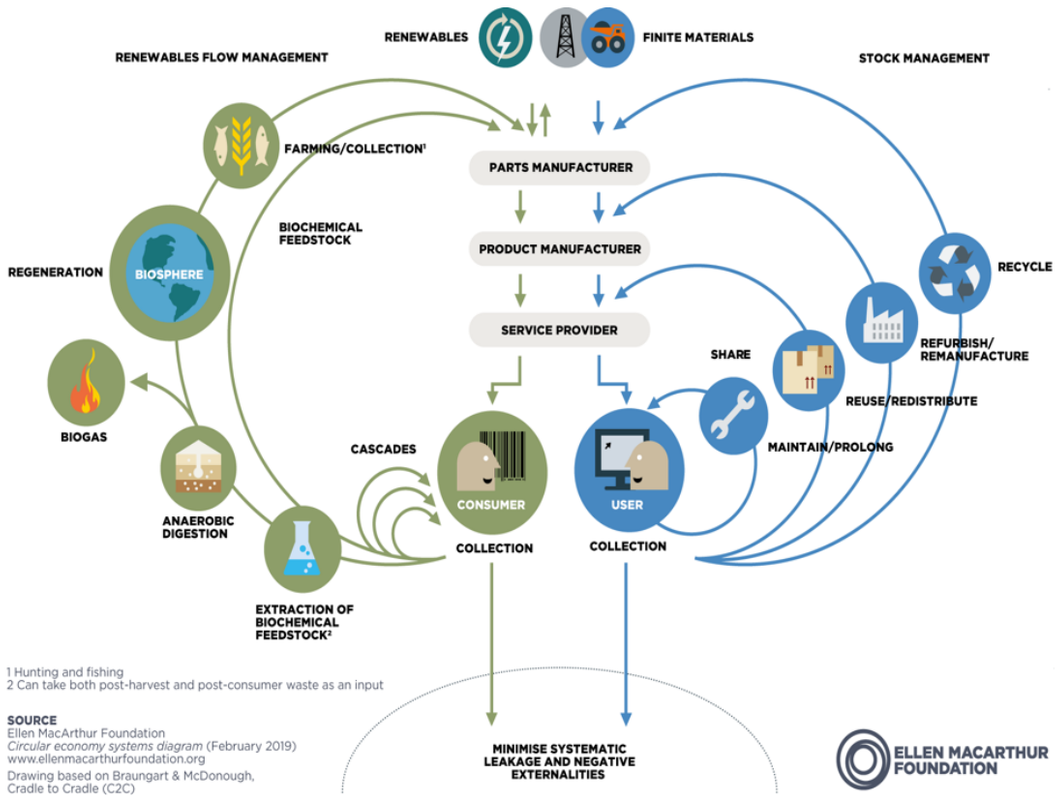

Figure 20: Industrial and Biological cycles for circular design (Source: Ellen McArthur Foundation)

6.4 Cognitive workshop component – ideation and sharing ideas

At this point, three groups were formed to brainstorm on strategies for homes under the energy, water and materials dimensions, each group spending 10 minutes on each topic, and a rapporteur staying back to brief the next group on deliberations so far and lead the discussion for new ideas for the next group. The three rapporteurs were finally asked to summarise deliberations taking place under their respective groups, and this was a fruitful experience of discussion and sharing for the participants.

6.5 Concluding the workshop – finding synergies for community action

Finally, the participants were provided with coloured post-its as per the colour scheme illustrated in Figure 21 for the three dimensions and a fourth dimension to suggest any additional idea they want to share, with each participant invited to write their name and town/village of residence on each coloured note and one main idea they consider as most impactful for climate action under each category. The post-its were stuck on a large sheet of paper placed in front of the room, and final the result was a board full of coloured notes and great ideas, which participants could then go through to find commonalities and possibilities for collaboration based on ideology or place of residence.

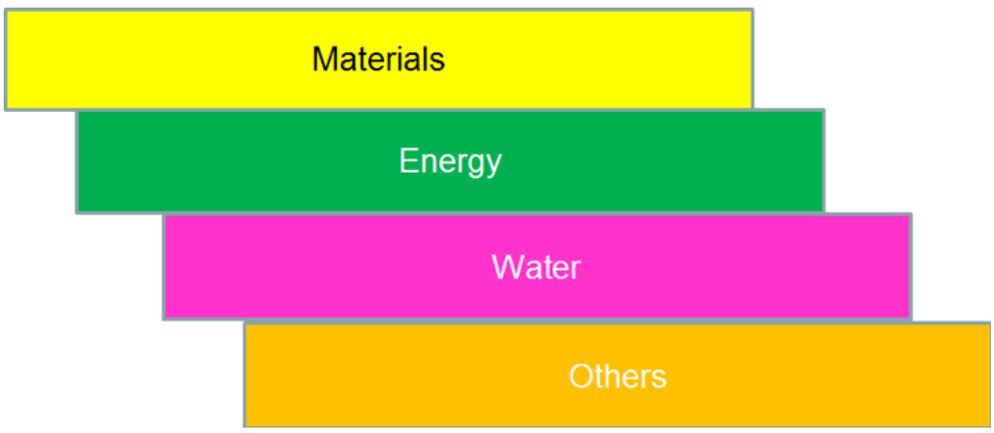

Figure 21: Gathering feedback from participants on dimensions of circular home and additional views

7.0 Discussion and Conclusion

The findings from literature and manifestation at the recent COP26 climate conference are unanimous on the expectations of our youth as the caretaker of our society in the near future, and their right to demand that the world handed over to them is a proper one. The close correlation between mental health and climate change has been shown by various studies as well as the key role climate action can play in developing the proper citizen attributes in our younger generations. Therefore, it does not serve anyone to keep alienating any generation or member of our society. The youth voice to COP26 project has revealed several insights of youth perspectives in the local context, although the participants were themselves already tuned to climate activism, which is confirmed by literature findings on the close link between personal upbringing and identify and environmental stewardship. Therefore, climate action can become a primary driver for developing proper civic values into the forthcoming generations, to lead to a better society on several fronts, including coping with climate change. Hopefully, the voice of our youth will be heard in time to make sweeping changes and avoid the doom and gloom predicted by leading scientists of the current generation.

The youth voice to COP26 has lived to the expectations through the feedback received from our youth, although a greater participation from all segments of our youth population would have given a better picture on climate change awareness. The responses received have been primordial in organising training workshop in the field of youth advocacy, NDCs (in collaboration with the Ministry of Environment, Climate Change and Solid Waste Management and UNDP Mauritius), water management, sustainability for businesses, culminating into a collaborative workshop on circular homes for community climate action. In reaching out to the community to co-create climate action solutions, the risk is to render the discussion too complex and technical, and academia has a key role to play to demystify their research findings into simple and easily understandable, readily implementable terms, which has been showcased through the circular homes concept, and which can act as a great start for community engagement for climate action while effectively raising awareness on the facets on climate change using real-life examples. Indeed climate action now needs to translate into the real-world through practical implementations to bring policies into life.

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Climate Change, SDGs and Revamping Engineering Education for a Circular Economy: Implications for SIDS

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Abstract

The 'linear economic model' which is generally, being followed is not sustainable. It is evident from the changing climate conditions in different parts of the globe. The United Nations (UN) has set seventeen Sustainable Development Goals (SDGs) for the member countries to achieve by 2030. Out of the 17 goals, ten need the direct involvement of engineers for their success. So, engineers have come to the centre stage of the development framework. In this background, the paper discusses measures taken by various stakeholders in different parts of the globe to sensitize engineering students towards SDGs and circular economy after a brief discussion on the concept of circular economy (CE) vis-a-vis green economy and bio-economy. As the concept of circular economy is new, reviews of literature and the case study method have been used to discuss the argument. So far, there are some online and MOOCs programmes on CE for particular industries, now it is time to develop such courses for specific geo-climatic conditions. The engineering community needs to develop CE courses on tourism and fishery for the SIDS as these sectors contribute significantly to the gross domestic product (GDP) of these economies.

Key Word - Circular Economy, Sustainable Development Goals, MOOCs, Greene economy

1. Background

All technological innovation impacts the economy but some revolutionise and whosoever takes the lead in adopting these technologies, reaps the benefit accrued over it. One such technological innovation was the development of 'technology for large-scale production' during the18th century. Europe adopted the technology and reaped the benefit too. They were producing more than their own requirements and the surplus was being sold by their traders in the African and Asian countries. The model may be termed as the development of Centre (Europe) at the cost of the periphery (Asian and African countries). In the process, some of these countries even became a colony of trading European countries. Even after the independence of these erstwhile colonies, they adopted the same development model. The pollution in the process of production was considered as a by-product of development which is evident in the process. It was Engineer Herbert Clark Hoover, the 31st President of the US, who discussed pollution as a matter of concern and advocated the need for a sustainable economic development model (Singh, 2009). If environmental degradation and pollution are considered as an unsustainable production process, climate change is the result. Since then, lots of water have been flown in the river. Many efforts have

been taken since then with limited results which is evident from the climate change status of last one year in different parts of the globe.

The United Nations has set seventeen Sustainable Development Goals (SDGs) for the member countries to achieve by 2030. Out of them around ten of them need direct involvement of engineers for its achievement. So, engineers have come at the centre stage of the development strategy. Engineers need to work on the concept of circular economy in place of the linear economy to achieve the UN's goal and for economic development with sustainable climate management. The philosophy of linear economy is to throw away a product (processed raw materials) after use.

2. Objective of the Study

In this background, the paper analyses the following:
i. What is a circular economy (CE) and how it is different from bio-economy and green economy?
ii. Engineers need to concentrate on achieving SDGs through CE and
iii. Measures have been taken by various stakeholders in different parts of the globe to sensitize engineering students towards SDGs and CE.

On the basis of discussion on these points, the type of the CE courses for SIDS economies has also been discussed.

3. Research Methodology

Studying education for sustainable development in information and communication technology (ICT) programs, Hilty and Huber (2018) consider that the sustainability concept which is still emerging is not yet ready for hypothesis testing. On the same logic, reviews of the literature and the case study method have been used in this paper to discuss the objectives of the study.

4. Analysis

The objectives of the paper have been analysed in this section as below:

4.1 What is circular economy and how it is different from bio economy and green economy

The concept of circular economy (CE) may be discussed as a regenerative system that uses minimum material input, waste, emissions, and energy over the entire lifetime of products (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Korhonen, Honkasalo, & Seppälä, 2018). This can be achieved by reducing material and energy input per unit of output during production, by designing products in a way that increases their lifetime, or by the repair, reuse, and recycling of products. The CE approach is crucial in greening the economy (Millar, McLaughlin, & Börger, 2019) and basic for achieving SDGs by 2030. The CE also helps in realising all three dimensions i.e. environmental, economic, and social of sustainable development (Korhonen et al., 2018; Schroeder, Anggraeni, & Weber, 2018)

The concept of CE is inspired by the article, "Economics of the Coming Spaceship Earth' written by economist Kenneth E. Boulding (1966). Boulding (1966) has discussed the group of inputs and outputs in open and closed systems, in the context of information system, matter, and energy. He has also questioned the suitability of Gross National Product (GNP) as an economic measure neglecting the future generational impact on environmental pollution (Cheong Fabrice, 2019). Boulding considered the earth as a circular system and argued that the economy and the environment need to coexist in equilibrium.

The concept of 'bio-economy' and 'green-economy' are very often also discussed to achieve sustainable development and are, very often, perceived as synonymous with 'circular economy'. Both these

terminologies are complex and multivariate. So, it is imperative to discuss them vis-a-vis circular economy. The bio-economy includes all sectors and systems that depend on biological resources of animals, plants, micro-organisms and derived biomass, including organic waste, their functions and principles. It includes and interlinks land and marine ecosystems and the services they provide; all primary production sectors that use and produce biological resources (agriculture, forestry, fisheries and aquaculture); and all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy and services. The European bio-economy is aimed to have sustainability and circularity at its heart to drive the renewal of its industries, the modernisation of primary production of systems, the protection of the environment and biodiversity (Eléonore Loiseau, et.al., 2016). For the last ten years, the notion of a green economy has become increasingly attractive to policymakers. Over the last decade, a frequent claim has been that the traditional economic models need to be reformed in order to address climate change, biodiversity losses, water scarcity, etc., while at the same time addressing key social and economic challenges. The global financial crisis in 2008– 2009 spurred this debate (Barbier E., 2021). So circular economy is basic and deals with the process to achieve sustainable development through bio-economy or a broader concept, green economy. So, there is a need to maintain environmental sustainability as well as, improve labour and capital efficiency through appropriate technology.

4.2 Engineers need to concentrate on achieving SDGs through CE

Engineers are capable of producing more output with the same input or the same output with less input. They are also capable of changing input mix as changing inputs which may be creating pollution with eco-friendly inputs. So, there is an urgent need to integrate the concept of CE in the engineering education curriculum and to take appropriate measures to sensitize engineering students regarding circular economy to prepare them for achieving SDGs by 2030. As per Table- 1, various SDGs need the attention of specific branches of engineering. To achieve Goal 2, agricultural and genetic engineering, as well as biotechnology courses, must have subjects relevant to achieve Goal-2. A civil and mechanical engineering curriculum must-have discussion on Goal-6, 9 and 12. Students of all branches need to adopt frugal innovation for their minor and major projects. The researchers have found that Artificial Intelligence (AI) could positively enable 93 per cent of the environmental targets, including the creation of smart and low-carbon cities; Internet-of-Things devices and appliances which may modulate their consumption of electricity, better integration of renewable energy through smart grids, the identification of desertification trends via satellite imagery; and combating marine pollution (WEF, 2021). there is a clear environmental need to improve efficiency in cement manufacturing also as according to the researchers of the Chatham House, cement accounts for about eight per cent of CO2 emissions and one tool to avoid so is to use Artificial Intelligence. (Khatry, 2021). So, special attention needs to be given regarding specific goals in the relevant branch of engineering.

Table1: Sustainable Development Goals and Branches of Engineering

SN	SDG	DESCRIPTION	RELATED TO BRANCH OF ENGINEERING
1	Goal-2	Zero Hunger	Agricultural Engineering
			Bio Technology
			Genetic Engineering
2	Goal-3	Good Health and Well Being	Bio-medical Engineering
			Genetic Engineering
			Bio-technology
3	Goal-6	Clean Water and Sanitation	Mechanical engineering
			Architecture
			Civil engineering
4	Goal-7	Affordable and Clean Energy	Electrical engineering
			Electronics
			Information Technology
5	Goal-9	Industry, Innovation and Infrastructure	Mechanical Engineering
			Civil Engineering
			Production Engineering
			For innovation- all branches of engineering
6.	Goal-11	Sustainable Cities	Information Technology
			Computer and Software Engineering
			Architecture
			Civil and Environmental Engineering
7	Goal-12	Responsible Consumption and Production	Production Engineering
			Mechanical Engineering
			Mechatronics Engineering
			Nanotechnology
8	Goal-13	Climate Action	Environmental Engineering
			Civil Engineering
9	Goal-14	Life Below Water	Bio-Technology
			Genetic Engineering
10	Goal-15	Life on Land	Bio Technology
			Genetic Engineering

Source: Singh, 2019

Engineering is the application of scientific theories for the welfare of society. Though scientific theories are place-neutral, if it is applied to make technology, it becomes a place and people subjective. As after transplantation of any organ in the human body, if the doctor says that 30% chances of success. It means there are only 30% chances that the natural body will accept the foreign body. Similarly, in an economy also, there are forward and backward linkages of technology with the society and if a technology is not able to establish these linkages, it is not accepted by the user. So, engineering students must be trained to take into consideration the socio-economic background of the people who are going to use a particular technology.

4.3 Measures taken by various stake holders in different parts of the globe to sensitize engineering students towards SDGs and CE

4.3.1 Compulsory Courses

Few universities across the globe may have a course on climate change. The same may be said for a compulsory course on environmental science which is much older among the academic circle as a compulsory six-module course on environmental science is being taught in all branches at the undergraduate level in India since 2014 (Ghosh and Dutta, 2019). The credit may go to the first and second UNESCO Engineering Report which deliberately discussed the crucial role of engineers in environment management and SDG achievement (UNESCO, 2010 & 2021). A study was conducted by the European School of Sustainability Science and Research (ESSSR) and the Inter-University Sustainable Development Research Programme (IUSDRP) on the inclusion of topics related to SDGs. Regarding the university and institutional involvement in external climate change projects, research was the most important type of involvement observed (76.7 per cent). Lower levels of responses were received for community-related programs (45.0 per cent) and merely 36.4 per cent of the respondents reported positively for teaching/ training programs. Other types of involvement mentioned were consultancy projects and events open to the public. About 41.9 per cent reported involvement to a moderate extent and 12.4 per cent of the respondents were not at all involved (M=2.9520, SD=0.99). When asked if they teach climate change-related aspects in a course at the university, 77.5 per cent responded positively but according to only 58.1 per cent of the respondents, climate change-related aspects are included in the course guidelines. As per the 16.3 per cent of the respondents, they do not teach the topic but 24.8 per cent reported that they include these aspects in their teaching, even though not having the course guidelines (Leal Filho, W., Sima, M., Sharifi, A. et al., 2021). The School of Engineering and Sciences at Tecnologico de Monterrey has four graduate (MSc, PhD) programs related to SDGs. The main research areas related to SDGs at the School of Engineering Sciences are no poverty, clean water and sanitation, affordable and clean energy whereas, in the programmes of the school of Nanotechnology, topics related to SDGs which have been addressed are no poverty, clean water and sanitation, affordable and clean energy. No poverty, zero hunger, good health and well-being, responsible consumption and production, life on land, industry innovation and infrastructure, sustainable cities and communities, climate action have been addressed at the School of Biotechnology and at the School of Computer Science, no poverty, quality education, sustainable cities and communities have been given priority (Ramirez-Mendoza et.al, 2020). So, in nutshell, universities across the globe have initiated though the level of adoption is differentiated. Even information among students is also limited. In a study conducted at the University of Extremadura, Spain, students of engineering and health sciences have limited knowledge about the SDGs (Francisco Zamora-Polo et. al., 2019). If the situation of SDG is so limited, one can imagine the universities acceptance or adoption for a compulsory course on the circular economy. It is hardly being offered at any university.

4.3.2 Online or part-time course on circular economy

At the University of the Basque Country (UPV/EHU), the students of civil engineering are being trained to evaluate each project on the basis of sustainability (Álvarez Irantzu et.al., 2021). A consortium of French agri-food engineering colleges has implemented sustainable development goals via the governmental Idefi-EcoTrophelia programme. The students are being trained to use their engineering and managerial knowledge for eco-design business models and to develop entrepreneurial capabilities to establish green ventures to commercialise food eco-innovations (Hiam Serhan & Gwenola Yannou-Lebris, 2021)). Table 2 gives a list of online courses on CE.

Table 2: Online CE programmes

SN	University	Programme on CE
i.	The Cambridge University Barkley Extension	A 6-week online programme on Circular Economy
ii.	Bradford University	There is 2-4 years distance learning programme on Innovation, Enterprise and Circular Economy (PGCert and MBA)
iii.	McMaster University	A professional certificate for a through via-a-variety of presentation and activity
iv.	Exeter University	A 6-weeks distance learning programme on Circular Economy
v.	Free MOOCS programmes	- Circular Economy: An Introduction - A Circular Economy of Metals Towards a Sustainable Societal Metabolism - Packaging in a Circular Economy
vi.	Ellen Macarthur Foundation	- Learning opportunity # Inside the circular economy - A programme for professional and Masters' students based in African #Inside the circular economy- an online global learning programme # From linear to Circular- A global Learning programme for professional and post-gradute students. - Learning pathways #What is the Circular Economy? #Make a circular economy pitch in your organisation #What can I do in my organisation? #Artificial Intelligence and the Circular Economy #Circular Design #Cities and the Circular Economy # Plastic and the Circular Economy #Fashion and the Circular Economy #Food and the Circular Economy #The Circular Economy in detail #Systems and the Circular Economy
vii.	Norwegian University of Science and Technology (NTNU)*	#a week online programme- IDS4004 - Circular economy and sustainability

Source: Ellen Macarthur Foundation, 2022; * NTNU website

These courses are not made particularly for engineering students but certainly, the content of these programmes have relevance for engineering students.

4.3.3 Annual Impact Rankings

To encourage institutions to adopt the sustainable processes to achieve the SDGs, the Times Higher Education ranks universities on the basis of 13 carefully selected variables to ultimately evaluate universities on four indicators i.e. research, stewardship, outreach, and teaching since 2020. It provides a ranking of overall SDG performance as well as on each of the 17 goals (THE, 2022).

4.3.4 Communication on Circular Economy

To encourage serious research, dissemination and discussion, Springer Nature has started publishing a journal titled, "The Circular Economy and Sustainability since June' 2021. It aims to bring different perspectives of the circular economy and sustainability at one platform as the topic has relevance for engineering, technology, environmental science, management, economics and society. They all have their own perspective and the circular economy needs to be studied by developing their relations, interactions and synergies to promote sustainable development goals and also to expand technological limits in order to solve diverse environmental problems and mitigate potential economic disturbances (Springer, 2022).

4.3.5 To sensitise civil engineering students at the Department of Humanities of Delhi Technological University, the circular economy has been discussed during the ongoing semester (even semester of 2021-22) under the subject of HU-302 Engineering Economics. During the previous two semesters, students were asked to prepare assignments on SDGs and the role of universities under the same subject.

5. Implication for SIDS

The Small Island Developing States (SIDS) are a distinct group of 38 UN Members and 20 Non-UN Members/Associate Members of United Nations regional commissions which face severe social, economic and environmental vulnerabilities due to climate change. The SIDS has experienced acute negative impacts at the time of every hurricane in past years which destroyed infrastructures such as communications, networks and energy as well as other physical capitals. These economies are living under the continuous threat posed by rising sea levels which is compounded by limited institutional capacity and scarce financial resources. Even though not being homogenous, the high dependence of these economies on their bio-diversity combines them together. Industries like tourism and fisheries constitute over half of their GDP. Not only that, the significance of their biodiversity goes beyond being the economic lifeline as, they are also integrated to the cultural and spiritual values (UN, 2022). Traditionally, these societies had evolved a system of co-existence of (wo)men and their biodiversity where they both take care of each other. However, the traditional sustainable system of existence has been purposely destroyed in the last two centuries or so by following the linear system of production, which has been aggravated in the neo-liberal world order. Now, the challenge before the people is to unlearn what has been learnt and follow a way of the circular economy to achieve sustainability.

Many initiatives have been taken so far to build resilience to the existing threats but very often these are criticised for being externally oriented, mostly rooted in international engineering and technical support and consultancy (Baldacchino, 2018). Therefore, it is imperative to search for solutions to these challenges in the local knowledge system. Lately, some initiatives have been taken in this regard by domestic engineers and scientists along with their international counterparts which have been discussed as below:

5.1 The World Federation of Engineering Organisations (WFEOs) along with its members in SIDS are playing a very important role to tackle SIDS specific problems such as the impact of disaster risk and climate change. In a joint project, UNESCO, the

World Federation of Engineering Organisations (WFEO), the Office of Climate Change Education (OCE), the Mauritius Institution of Education (MIE), the National Environment Agency Singapore (NEA), and the Institution of Engineers Mauritius came together for imparting training on climate change in a very effective and sensitive way to the primary and secondary school teachers in Mauritius. In 2021, two programmes were organised in June and November. The result of the workshops is very encouraging.

5.2 The University of Aruba along with the University of Leuven (KU Leuven) in Belgium has started a new academic programme as "Sustainable Island Solutions through Science, Technology, Engineering and Mathematics" (SISSTEM) which is funded by a project grant from the 11th European Development Fund with a focus on SDGs 7, 11 and 17. The SISSTEM project comprises a new Bachelor of Science program and 12 PhD projects, as well as a research and services centre. A Master of Science program is also in the pipeline (Government of Aruba 2019).

6. Conclusion, Suggestion and limitation of the paper

Now, it has already been realised that adoption of the process of the 'Linear Economy' [HD1] is not sustainable and engineers need to adopt the concept of 'Circular Economy' in their professional activities. Measures are being taken by many engineering colleges across the globe to sensitize their students accordingly.

Particularly for SIDS economies, the challenge before the engineering community is to develop technological solutions for the existing issues aligned with the philosophy of a circular economy. Some of them may be as below:

1. Developing courses such as (i). Tourism sector and the CE and (ii). Fisheries and the CE as many such courses have been developed by the Ellen Macarthur Foundation (refer to Table- 2) as these two sectors are the main constituents of their Gross Development Product (GDP). Different levels of these courses may be made compulsory to sensitise all irrespective of their educational background.

2. Use of Information and Communication Technology (ICT) as well as Artificial Intelligence (AI) can decrease waste creation in the production process. So, there is a need to carry out more research in the universities to take care of the different aspects of the production process.

3. Last but most important, engineers will have to study their traditional wisdom scientifically and will have to weed out if any product or process which is unscientific, has been integrated over time and will have to tell the world about the actual scientific process and their benefit in the present scenario.

The nature of the paper is based on secondary data, and cannot be applied to all member states of the SIDS as all these states are heterogeneous. However, it can be taken as a beginning point and research can be done separately for each member state.

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Climate Change adaptation and mitigation measures for Rodrigues Island and the role of engineers as valued actors.

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Abstract

Small Island States (SIDS) are among the nations most exposed to climate change (CC) and are characterized by a high degree of vulnerability. Rodrigues Island as a sub-national to the mainland of the Republic of Mauritius offers a unique case study example on how climate change impacts affect the livelihood of the resident. This paper addresses a perceived need to identify the role of engineers have to play to ensure better adaptation and mitigation measures to a rapidly changing climate. To this end, the study explores the climate change adaptation and mitigation measures that is currently being undertaken and maps the skill requirements to improve its intellectual capital that will support such measures in the near future. It uses an extensive review of the literature and analysis of policies and measures taken in response to the impacts of Climate change during the last decade. This research's findings showed that engineers have a major role to play in supporting the island's effort to cope with the threats associated with climate change. The engineering degrees programme dispensed locally must ensure that the educational objectives are aligned with the required skills for engineering professionals for better adaptive capacity. This study also concluded that, wider consultations among the engineering professionals with regards to strategic directions and planning are vital for a more sustainable Rodrigues island. Intergovernmental financial supports were instrumental in success of implemented climate change adaptation measures.

Keywords - climate change, Rodrigues Island, adaptation and mitigation measures, roles of engineers, SIDS.

1.0 Introduction

Rodrigues Island, forming part of the Republic of Mauritius, is a small island located in the South-West of the Indian Ocean. With a population of 44, 216, it is the smallest among the Mascarene Islands of the Indian Ocean (Statistics Mauritius, 2021). Rodrigues is 18 km long and 8 km wide and became autonomous in 2002. The economic pillars of Rodrigues include agriculture, tourism, fishing, small-scale industries, and export of handicraft. Small island developing states (SIDS) such as Rodrigues island, are in most cases, located across vast oceans and are particularly vulnerable to reverberations such as climate change. This is the reality of SIDS, even though they produce relative low greenhouse gas emissions as a group (Bush, 2018, pg. xi). Effects of climate change pose serious risks to SIDS such as Rodrigues Island. Such risks include an increase in the number of inequalities, unemployed, insecurity, and decreasing social protection and food security (Poorun-Sooprayen, 2021).

The warming of the climate and its effects on ecological and natural systems are already palpable. Temperature in Rodrigues has risen by 0.5 – 1.0 0C (Mauritius Meteorological Services, 2021). In recent years, the impacts of climate change have been observed in Rodrigues through events such as an increasing intensity and frequency of cyclones, and torrential rains, and flash floods. In February 2019, Cyclone Gelena crossed approximately 50 km southwest of Rodrigues with 165 km/hr gusts, resulting in flash floods that caused 259 people to be displaced. Damage to infrastructure, farms and private residences were also observed while the electricity network was severely affected (UNEP, 2019).

1.1 About this paper

This paper explores the various climate adaptation and mitigation measures developed for Rodrigues island and demonstrates the contributions of engineers to the development in this area over the last two decades. This is done by critically reviewing the sources of literature and by consultation with experts who had been involved in such activities. As a small island who has recently acceded to its autonomy, Rodrigues is an interesting case study with conveniently defined system boundaries and with a good record of data on the developments and statistics. This paper considers the relevance of such an assessment as the island steps embarks on a second phase of strategic development that will be aligned with the Sustainable Development Goals. The outcome of this work is expected to feed into the related efforts of engineering associations/regroupments and training institutions to better prepare the new workforce for adaptive and mitigation strategies towards the fast changing climate.

2.0 Climate change, land-use, energy and water nexus (CLEW)

The most basic human needs rely on the availability of key resources that include: water for drinking, domestic and health purposes, water and land for food production, energy sources for lighting, cooking and heating (Welsh et al., 2014). With the rapid changes in our climate, stresses related to the accessibility of the resources are exacerbated. Examples of such stresses are reductions in the rainfall, which in turn has an impact on the water available for domestic and agriculture thereby increasing the need for electricity generation for pumping of groundwater from wells and boreholes to maintain agricultural production. The rise in demand for clean energy for emerging sectors such as tourism sector (both in terms of transportation and energy for running of the small hotels) coupled with the increasing need for energy supplies for storage of agricultural produce are other emerging concerns.

Much of the water resources in Rodrigues is obtained from the rainfall. Rodrigues has a relatively dry climate, and annual mean evaporation exceeds precipitation. Yearly precipitation is ~ 1000 mm, mostly from January to April, related to the position of the intertropical convergent zone (ITCZ) (Zinke et al., 2016). Despite the water stress, the Rodrigues population have adapted well to the irregular water supplies by equipping themselves with high storage capacities. The younger generation would however desire a more regular access to water supplies so that they can enjoy facilities like electric showers, dishwashers and washing machines, which have all become a necessity for the working population more than just luxury. It has also been reported that inefficient design of the distribution system and persistently low investments, coupled with poor maintenance of water infrastructure, have restricted sustainability and safety of drinking water supply as well as adequacy of sanitation during the last decade. (SIDPR 2009).

Agricultural development was reduced to its minimum level in 1970 and 2003 (with an area cultivated falling from 1571 ha in 1989 to 173 ha in 2004) due to water shortages with direct socio-economic impacts (Bunce

et al.,2009). In terms of land-use and soil erosion management, the island is equipped with the necessary technology to perform close monitoring. A major shortcoming however is the poor ICT infrastructure and lack of human resource trained in geoinformatics field who can keep up with an increasing need for sophisticated data management, analysis and trouble-shooting skills. In all SIDS countries, geodatabase is considered as essential assets that can help in better decision making for policy makers with regards to developments for instance in the tourism sector and to cater for a more general environmental monitoring need that are pre-requisite to assess climate change impacts on SIDS.

Rodrigues as part of the Republic of Mauritius, is required to contribute to the reduction of GHG emission goals and faces constant challenges in rising up to the expectations of green energy transitions. According to the Central Statistics Office of Mauritius, the electricity energy mix (EEM) for Rodrigues island in 2018 was 93.5 % from non-renewable sources (principally diesel and fuel oil) and 6.5 % from renewable sources (solar and wind) as compared to a 79.3 % to 20.7 % non-renewables and renewable EEM for the mainland (Mauritius). The need to integrate more and more renewable energy in the EEM has long been recognized by the Government of Mauritius and streamlined in relevant national policies. UNDP is assisting Government of Mauritius in the implementation of the Green Climate Fund (GCF) "Accelerating the transformational shift to a low-carbon economy in the Republic of Mauritius" project. The USD 28 million grant (coupled with more than USD 162 million of co-financing) is assisting the Government of Mauritius to meet its target of using renewables to supply 40 % of the country's energy needs by 2030 through technical interventions on the electricity grid (to increase the grid absorption capacity) and through a subsidized approach to deployment of PV technology that will help democratize access to rooftop PV systems (UNDP, 2022). A new 200 kW-250 kW Solar Photovoltaic project farm at Grenade Rodrigues is underway and expected to reduce its dependency on fossil fuels (Ministry of Public Utilities Mauritius, 2022). With the increasing cost of fossil fuels, the utility provider for electricity is facing difficulties to maintain the current tariff for both domestic and industrial sector. While major decisions on strategic planning in the energy sector is still governed by the main land, the sub-national implementation is delayed due to poor consultations among stakeholders leading to unidentified barriers. A project carried out by The Mascara Renewable Water and Quadran Companies between 2018 and 2019 which provided the equipment and the expertise have demonstrated on Rodrigues Island that solar powered desalination systems may offer sustainable water and energy solutions. Despite being suitable and affordable for other remote communities on the island, the threats for equipment damage due to cyclones could still remain an important drawback (UN Report, 2019).

3.0 Beach Tourism as a cause and victim of impacts of climate change

In their study on SIDS and climate change adaptation, Leal Filho et al. (2021) explained that low-lying SIDS are even more vulnerable to the effects of climate change because they have relatively scarce natural resources and limited options for adaptation. As in most SIDS and developing countries, beach tourism remains the dominating market segment, constituting a key part of the economy. Low lying coastal and island destinations are highly vulnerable to direct and indirect impacts of climate change (such as cyclones, sea level rise, water shortages and water contamination), given that most infrastructure is located within short distance of the shoreline. Rodrigues islands has a special vulnerability which is coupled with a low adaptive capacity. The high tourist season over the island coincides with low water regimes in dry seasons, aggravating water management and environmental

issues. The impacts of climate change and global warming will vary greatly in the different coastal regions, and might bring opportunities as well. For example, extended summer periods and warmer summers, attracting more tourists. To counter effect the impacts, reafforesting of mangroves and reef protection campaigns are ongoing. Regulatory frameworks for tourism development, such as Environmental Impact Assessment for tourism infrastructure are well established. Being remotely located, Rodrigues islands depend on long-hauled flights. The local tourism authority regularly organizes training programs for the local tourist operators in an endeavour to raise awareness among the key actors. Tourist promotional campaigns targeting the visit of a group of Mascareign islands aims to reduce carbon footprint of travellers. Promotion of beach tourism needs to be accompanied by coastal ecosystem management measures often patroned by the main users of this precious resource i.e. the hotel industry.

4.0 Effects on Biodiversity due to climate change

Rodrigues island has an important marine biodiversity that has not been thoroughly studied. Poor understanding and poor monitoring of the ecosystem does not favour a complete assessment of the climate change impacts and other unsustainable practices such as overfishing. The western portion of the Indian Ocean Surface has experienced an increase in sea surface temperature (SST) of 1.2 0C over the last decade (Koll Roxy et al., 2014: cited in Zinke et al., 2016). The direct consequence of SST is a reduction in the fish stock (RRA, 2022). Strict policy measures have been adopted as early as 2012 to prevent risk of stock collapse (seasonal banning of octopus fishing from August to October). Impacted fishers sought for compensations from the local authorities due this unforeseen closure as these had impacts on their daily earnings (Yvergniaux Yann, no date). As an accompanying measure, awareness campaigns were conducted to sensitize the various stakeholders on the need to protect the fish stock. While the data gaps are evident, further studies on marine species could have served as indicators for assessing the environmental quality. For instance, the presence of an increased number of sea urchins could indicate unsustainable fishing practices and a high algeal diversity in the lagoon consequently qualifies the water for reduced turbidity. Timely research and regular environmental monitoring programs are essential to raise the alarm before reaching too close to the thresholds of irreversible environmental degradation. Despite its negative impact, a rise in the SST from the range of 20 0C to 27 0C to a range above 30 degrees Celsius is believed to promote coral growth. Other sustainable practices include mangrove re-afforestation to control soil sedimentation of the lagoon.

In order to preserve the surviving endemic species (the Rodrigues Fruit Bat and two other land invertebrates) four nature reserves have been established. Despite the existence of regulatory measure to preserve the ecosystem, more stringent enforcement of Fisheries Regulation, EPA Act and anti-erosive measures are urgently required.

5.0 Socio economic impacts of climate change (Employment, migration)

Implementation of the overarching goal of sustainable resource management will require an informed and skilled workforce. The capacity building for more local engineers to work as marine resource managers, environmental engineers and waste water engineers is viewed as critical in order to successfully transform the current situation. Rodrigues has a workforce of about 17,990, of whom 6,075, that is around 38%, are currently employed, in the agricultural and fisheries sectors. The economy of the island is mostly driven by micro, small and medium enterprises (MSMEs). Free education from primary to tertiary level has motivated the young generations to opt for a wider spectrum of

career opportunities ranging from educators, lawyers, accountants and engineers. Due to limited employability in their island, some young graduates prefer to migrate to the mainland for better job prospects and better quality of life. From 1991 to 2001 a net annual migration of 395 Rodriguans were recorded. Private sector is still not fully developed and considered unreliable and insecure as compared to the public sector. A concrete examination of the roles that graduate will be expected to play in the forthcoming years can better plan for post-secondary education and avoid mismatch between market requirements and course undertaken. Regular training needs assessment specific to Rodrigues is required with inputs from ministries/ departments and private companies in the relevant existing and emerging sectors. Preparing a separate list of priority fields for Rodrigues will ensure that the younger generation are well guided. The main goals for quality education is to empower and enable Rodriguans to develop the knowledge, skills and values necessary to participate in the decision making process to improve their quality of life. In his study on Luetz (2018) emphasized on the important role of education which is believe to accelerate climate change adaptation and related migration responses.

6.0 Methodological approach of this study

Two main approaches were used in this study. The first approach was an extensive literature search on climate change impacts for small island states with special focus studies conducted in Rodrigues Island. Search engines such as Science Direct and Google scholar were used with key words targeting impacts on water, agriculture and socio-economic effects. The web portals of local ministries, Rodrigues Regional Assembly as well as the online documentation platform of local universities were consulted for local publications such as national reports, policy papers, dissertation and relevant pieces of legislations. The second approach consisted of assisted interviews with local engineers with over ten years of experiencein their professions in the following fields: civil engineering, environmental engineering, mechanical engineering, electrical engineering and chemical engineering. In light of the research aims; combining both literary and grassroots-informed knowledge about the mitigation actions projected a better understanding climate change impacts faced by Rodrigues Island, the local measures adopted to address these impacts and the roles played by local engineers in support and implementation of the measures. Reports on previous stakeholder exercises were used to explore the meaning of 'sustainability' in the context of a remote sub national island such as Rodrigues Island. A review of engineering programmes offered by local institutions was also conducted to match the skills and expertise need under this assessment.

7.0 What does Sustainability implies for a small island such as Rodrigues?

The message that emanated from a series of consultative workshops in 2009 during the preparation of the first SIDPR was that achieving sustainability goals would clearly mean attaining the RRA goals of:

- Poverty reduction
- Employment creation
- Improving quality of life of local residents
- Environment protection

A set of eight goals and twelve targets were earmarked and clearly defined in a well stipulated action plan covering the recommendations for implementation over the short-term (2009-2011), medium term (2012-2015) and long terms (2015 -2025). (SIDPR, 2009)

An assessment year of 2015 was reckoned to reflect on the achievements. The progress would be measured against 60 clearly defined performance indicators under the responsibility of the Economic Planning and Monitoring Unit (EPMU) acting under the aegis of the Project Executing agency which is the executive council of the RRA. In June 2014, the Non-Governmental Organization (NGO) Mourouk/Anse Enfer Village Community developed a project with the

help of the GEF Small Grant Programme, to build resilience against coastal erosion and sea-level rise at Mourouk, a village located in the Southeast of Rodrigues. The projects resulted in the identification of causes and extent of coastal erosion, the preparation of a tailored strategy to combat erosion, and the launching of an anti-erosion and beach management campaign strategy, among others (GEF Small Grants Programme, 2012).

8.0 Recent strategies and measures to tackle climate change

Since the adoption of the SDGS in 2015, several other initiatives have been taken to tackle climate change in Rodrigues. In 2018, training on sustainability measures were provided to the key actors in the tourism industry through the project 'Greening the Mauritian Tourism Industry' under 'Switch Africa Green' flagship initiative. Another important initiative was the "Climate-smart agriculture for smallholders in Mauritius" whereby the Rodrigues Regional Assembly (RRA) received funding to address challenges of climate change faced by small planters by encouraging the adoption of climate-smart agriculture. It is expected that the project enhances the RRA (Commission for Agriculture)'s capacity to provide climate-smart agricultural advice to smallholders and to assess best climate-smart projects and practices (GCCA+, 2018). More recently, the government has released the Climate Change Bill, where provisions have been made for Rodrigues Island. Through this legislation, it is expected that an adaptation strategy and an action plan is developed for Rodrigues (Mauritius Assembly, 2020). The RRA, particularly the Commission for Environment and Others which is led by the Commission Payendee, has several climate ambitions for Rodrigues. The Commissioner stated during "COP 26: Climate voices and ambitions of Rodrigues" that his ambition was to make Rodrigues an ecological island. He also mentioned other initiatives that the island has already adopted namely the banning of single-use plastics, the closure of octopus fishing, among others. Future projects include promoting organic farming on the island (UK in Mauritius, 2021).

The Nationally Determined Contribution has been updated and this project was coordinated by the Department of Climate Change, of the Ministry of Environment Solid Waste Management and Climate Change. During this exercise various stakeholder's consultations were held both in the main land and in outer islands, notably Rodrigues. The islands national circumstances, challenges and opportunities for mitigation and adaptation were elaborated. Rodrigues Island of the Republic of Mauritius, a strong promoter of environment protection and sustainable development, has taken a new step towards achieving the United Nations 2030 Agenda. The RRA launched its Sustainable Development Goal Committee (SDG) on Tuesday 17 November 2020. Composed of the Chief Commissioner, the Chairperson and Honorable Members of the Rodrigues Regional Assembly (RRA), the SDG Committee will serve as an advisory and cross-party body to mainstream the SDGs as a development priority and coordinate their implementation across the different Commissions of the RRA (UNDP website undp.org). The year 2022 will be a determinant year as Rodrigues island will set off with the revision of its SIDPR which will be aligned with the 17 interlinked global goals intended to be achieved by the year 2030.

9.0 The role of engineers as valued actors in climate change adaptation and mitigation for Rodrigues Island

The engineering community present on the outer island supported by those attached to the main land, are working in close collaboration to provide technical knowhow in areas such as chemical, environmental, mechanical and civil engineering. The survey conducted among engineering professionals in Mauritius revealed that intellectual capital would be required in the following areas:

required in the following areas:

- Chemical, environmental, electrical and mechanical engineers: design of more efficient system for cooling and desalination;
- Chemical, environmental, mechanical and civil engineers: raising the standard of living and quality of life which Rodriguans are enjoying by significantly enhancing access to adequate water for domestic use and proper hygiene through appropriate water infrastructure planning and execution of water projects.
- IT engineers: GIS Training to computer engineers working as IT professionals, surveyors, civil engineers, hydrologists, land/marine resource managers and land planners, statisticians, environmental managers, climatologists, and market researchers.
- Chemical, environmental, mechanical, electrical and civil Engineers: undertaking further research on biomass (as agricultural waste mainly) as an energy source. This is considered as a crucial area for Rodrigues to adapt to climate change;
- Chemical, environmental, electrical and mechanical engineers: exploration of the potential of solar energy in both short and medium term plans for an increased solar powered penetration in the agricultural sector (for food storage and water irrigation) and for power production and desalination in the tourism sector.
- Mechanical engineers: promotion of mechanization in the agricultural sector
- Chemical, environmental, mechanical, civil and electrical engineers: design of appropriate storage facilities also appear to be lacking, causing significant post-harvest loss and affecting the quality of the product.
- Chemical, environmental and mechanical engineers: support to be provided to local planters and agro-processors to enable them to improve on their processing techniques of local products and to foster the adoption of new technologies in ecological agro-processing. To provide training and technical support on quality management, production systems, food preservation techniques, processing equipment and business skills.
- Environmental engineers: developing enterprise risk management plans for the MSMEs, conduct carbon footprint assessments, Life cycle assessment and material flow analyses
- Environmental engineers and climatologist: to improved provision of climatic information to the tourism sector through cooperation with national meteorological services for better impact management on climate change.
- Environmental and civil engineers: to improve the drainage and watershed management to reduce flood and erosion risks and to carry out re-design or redefinition of protected areas, for example revision of zoning of certain areas such as wetlands.
- Renewable energy engineers: to work on energy conservation and efficiency measures in buildings and tourist attractions.

This study also concluded that there is a need for more coordinated activities with regard to future strategic decision making exercises as far as the climate, land-use, energy and water systems are concerned. Government structures and the associated division of responsibilities and priorities do not favour the integrated approach required to capture these interlinkages. (Welsh et al, 2013). Carrying out strategic planning with proper consultations with a team of engineers regrouped under a professional structure such as the local Institution of Engineers can help assess the local situation with the desired optical lenses for a better understanding of the connections.

10.0 Concluding remarks

In this study, the climate change impacts for a small sub national island were examined. The various measures in response to the impacts as reported in

literature were identified. The responsibilities assumed by the engineers in several disciplines were investigated and matched against the educational objectives of engineering programmes offered on the mainland.

It was noted that engineers have been assuming important positions and supported extensively climate change initiatives in Rodrigues Island. More than ever their ingenuity and creativity are called upon to address the important crucial issues in the CLEW nexus. In most situations, local engineers are provided with sufficient 'marge de maneuver' to explore, assess and provide solutions for their communities and they express pride in their achievements. Schools, universities with the help of engineering companies need to market the field of engineering positively by extending the curriculum review to younger generations and offering more insights to green jobs. More young engineers' involvement is required to assist current experts in their combat to tackle climate change and in their quest to find locally adapted innovation solutions for recurring problems. Young engineers will thus gain more interest in the bright and important jobs such as renewable energy and environmental engineers as they are helping improve their lives and ensuring long term sustained planning and development while leaving no one behind.

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Climate Change: Can Conference of the Parties (COP) - UNFCC save the World

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"COP" stands for "Conference of the Parties" in the United Nations Framework Convention on Climate Change. The members of this committee are in charge of making choices that affect the entire organisation. The secretariat of the UNFCCC (United Nations Framework Convention on Climate Change) aids in the fight against climate change. Climate change is also known as the United Nations Framework Convention on Climate Change. As of this writing, 197 countries have signed up for the Convention. Both the 2015 Paris Agreement (signed in 2015) and the 1997 Kyoto Protocol (signed in 1997) are based on this agreement. Convention on Climate Change Adopted by the United Nations According to a 1992 treaty signed by every country, all nations are legally obligated to "prevent disastrous climate change" and develop solutions to reduce greenhouse gas emissions internationally in an equitable manner (United Nations Framework Convention on Climate Change, 2022). For the last three decades, world leaders have gathered annually to discuss how to address the climate catastrophe. An international agreement states that all countries must "prevent disastrous climate change" and devise methods to minimise global emissions of greenhouse gases in a way that is equitable to all. The Paris Agreement has two primary objectives. First objective is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below two-degree Celsius. Second objective is to make sure this century's global average temperature rise should be no more than 1.5 degrees Celsius above pre-industrial levels. The Kyoto Protocol was signed in 1997 as a result of the Kyoto Protocol's parent accord, the UNFCCC. All three UNFCCC accords aim to keep atmospheric concentrations of greenhouse gases to a level that is not harmful to the climate system, and to do so over a period of time that allows ecosystems to adjust naturally and allows for sustainable development. Despite its shortcomings, the COPs are the only forum in which the poorest countries, such as those in Africa and Asia, may be heard on an equal footing with the world's wealthiest nations. The only way to come to an agreement is if everyone is on the same page, which might be difficult. Even if Saudi Arabia may be able to stifle more ambitious action, COP choices have worldwide impact because they were made at the gathering. Pollution is increasing at an alarming rate in countries with no legal obligation to reduce it. Roads and coal-fired power stations have been erected in the years since the Paris Agreement was signed. There have been many more oil and gas fields discovered. Climate change is a growing source of anxiety for many people. As the urge to act on climate change intensifies, scientists must find a balance between study and advocacy. By 2100, the Earth is expected to warm by around 3°C,

with the majority of the heat being stored in the oceans. There is a need for ocean scientists to be familiar with the COP and the UNFCCC. These gatherings must be deliberate and self-reflective about how they transform the space they use, the solutions they promote, and how power is shared among those who attend in the future.

Keywords - COP, UNFCC, greenhouse gas, high-carbon infrastructure, methane emissions

Introduction

It is hardly hyperbole to refer to climate change as a "crisis." Along with increased mean temperatures, climate change brings with it more frequent exposure to extreme weather events: a greater risk of heatwaves, both terrestrial and marine; desertification in some places, and inundation and drowning in others; and desertification in certain areas. Climate change has the potential to alter the structure and function of practically every system on the planet, and it is critical that everyone work together to reduce the emissions that are trapping extra heat in our atmosphere and causing global warming. The United Nations Framework Convention on Climate Change (UNFCCC) has an important role to play in this regard because it facilitates supranational dialogue and consensus building. Aiming to "prevent dangerous anthropogenic interference with Earth's climate system," the United Nations Framework Convention on Climate Change (UNFCCC) works in collaboration with other UN departments and affiliate agencies to achieve relevant climate and humanitarian goals (for example, the "2030 Agenda for Sustainable Development"). An annual state-of-the-science and climate policy meeting, referred to as a "COP," is held by the United Nations Framework Convention on Climate Change (i.e., the Conference of the Parties; est. 1995).

Early on, the secretariat focused on helping governments work together on climate change. Today, it supports a complex structure of bodies that work to make the Convention, the Kyoto Protocol, and the Paris Agreement work better. The secretariat is a group of people who have a lot of technical knowledge. They help with the analysis and review of climate change information from Parties and with the implementation of the Kyoto mechanisms. It also looks after the registry of Nationally Determined Contributions (NDCs) that was set up under the Paris Agreement. This is an important part of the Paris Agreement's implementation. Between two and four negotiating sessions are held each year by the secretariat. The Conference of the Parties is the biggest and most important. It takes place every year and is held in different places around the world. It is the biggest annual United Nations meeting, with about 25,000 people there on average (Secretariat-United Nations Framework Convention on Climate Change, 2022). This isn't the only thing the secretariat does. It also organises a lot of smaller meetings and workshops all year long.

COP 26 – 2021 United Nations Climate Change Conference

The Glasgow Climate Conference officially began on October 31st, with a palpable sense of trepidation in the air as the event got underway. According to United Nation’s climate summit news, the United Nations Conference on Climate Change (COP26) will fail to make meaningful progress on climate action, and that time is running out. Collective global ambition and trust, on the other hand, continue to be woefully insufficient. National leaders are being challenged to take the necessary steps to decrease emissions, raise funds, and increase adaptation and resilience to the climate change impacts. As part of the Paris Agreement, governments are urged to submit aggressive 2030 emissions reduction targets that are consistent with the objective of reaching net zero emissions by the middle of the twenty-first century. It is essential that industrialised countries follow through on their pledge to raise at least $100 billion in climate money per year for developing countries by 2020 if

they are to fulfil these commitments (United Nations News, 2022). In addition, financial institutions from both the public and private sectors will be asked to contribute the trillions of dollars that will be required to achieve global net zero.

Parties to the Paris Climate Deal have been debating various articles of the pact, which establishes a goal of keeping global warming this century to less than 2°C while pursuing measures to bring it down to less than 1.5°C. Deliberations are taking place amongst parties to the agreement. Other topics covered by the "Paris Rulebook" will include loss and damage, transparency, and the finalisation of critical technological qualities. UN Environment Programme (UNEP) predicted that the United Nations Climate Change Conference (COP26) would result in increased global action in three important policy areas: mitigation, adaptation, and financing. In its pre-conference assessment, UN Environment Programme (UNEP) predicted that the United Nations Climate Change Conference (COP26) would result in increased global action in three important policy areas: mitigation, adaptation, and financing. It is necessary for each country to step up its efforts to reduce national emissions and adapt to climate change, referred to as Nationally Determined Contributions, in order for those efforts to be credible and translate into increased efforts on the part of each individual country (NDCs). Aside from that, agreement on critical technical issues, evidence of progress from private sector firms, and funding commitments from public and private financial institutions are required in order to carry the process further (Mahapatra & Ratha, 2016).

Global temperatures would climb by at least 2.7°C by the end of this century if new and revised climate commitments don't match the Paris Agreement goals, according to the UN Environment Program's (UNEP) newest Emissions Gap Report 2021: The Heat Is On. Although the report has been published for 12 years, countries have only decreased their estimated yearly emissions of greenhouse gases in 2030 by 7.5% compared to the previous round of promises, despite updating their Nationally Determined Contributions (NDCs) (United Nations Environment Program, 2021). Climate change mitigation efforts are required to meet 2°C and 1.5°C target reductions of 30 percent and 55 percent respectively **(Figure 1)**.

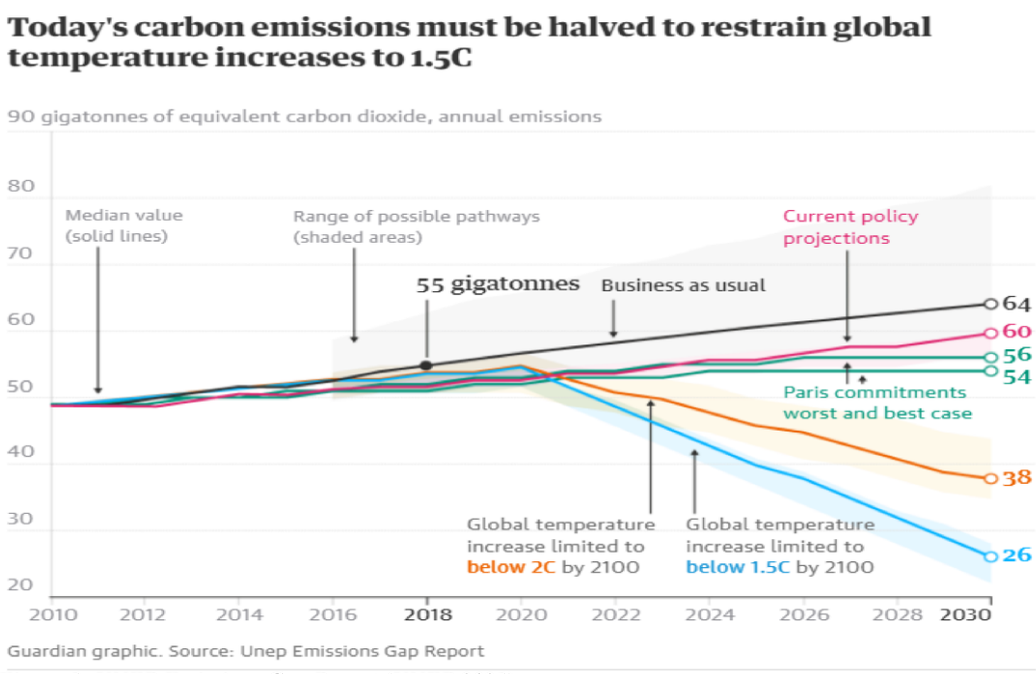

Figure 1: UNEP Emissions Gap Report (UNEP 2021)

Net-zero promises could have a significant impact, according to a new analysis released ahead of the UN Climate Change Conference (COP26) in Glasgow, the next round of climate discussions. There is reason to believe that even if these pledges are completely fulfilled, global temperatures could rise by just 2.2°C (Emissions Gap Report , 2021) allowing us to avoid the most catastrophic consequences of climate change. Pledges to achieve net-zero emissions are still largely speculative, inconsistent with the majority of 2030 NDCs, and sometimes even misleading. It's time to put climate change in the past." According to UNEP Executive Director Inger Andersen: "It's a now concern." "To have a chance of keeping global warming to 1.5°C, we have eight years to practically halve greenhouse gas emissions: eight years to formulate the plans, put in place the regulations, implement them, and finally deliver the cutbacks. "The time is running out," he moaned.

Why Methane is Important?

Every year, the Emissions Gap Report assesses the potential for certain industries to reduce their carbon footprints through cutting emissions. The topic of methane and market processes will be the focus of this year's conference. Making methane emissions from fossil fuel, waste, and agriculture sources more efficient can help bridge the emissions gap while also slowing the rate of global warming in the short term. Methane emissions, after carbon dioxide emissions, are the second most significant contributor to global warming after greenhouse gas emissions. If we look at it over a 20-year time horizon, the gas has more than 80 times the global warming potential of carbon dioxide (Environmental Defense Fund); it also has a shorter lifetime in the atmosphere than carbon dioxide – only twelve years, as opposed to hundreds of years for CO2 – so reductions in methane will slow global temperature increases more quickly than reductions in carbon dioxide (United Nations Environment Program, August 2021).

As per methane emission report by United Nations Environment Program (2022), anthropogenic methane emissions might be reduced by around 20% per year using just technological treatments that are currently accessible for free or at little cost. The implementation of all measures, in conjunction with other structural and behavioural initiatives, has the potential to result in a reduction of anthropogenic methane emissions by roughly 45 percent as per the report. Therefore, carbon markets have a potential to cut prices, thereby incentivizing more ambition in emission reduction goals. Carbon markets, on the other hand, will only be effective if the rules are clearly defined, transactions that reflect actual emissions reductions are recorded, and the markets are supported by structures that both measure progress and give transparency. Using the money generated by these markets, it is possible to fund climate change mitigation and adaptation strategies on a local level as well as in vulnerable nations where the consequences of climate change are the most severe (Ferrer, 2021).

According to the United Nations Environment Programme's Emissions Gap Report 2021: The Heat Is On, which was recently published, methane is crucial for short-term climate action. It has a global warming potential that is more than 80 times greater than that of carbon dioxide during a 20-year period, making it an extremely effective heat trapping agent. However, it only persists in the atmosphere for 12 years, which is a substantially shorter period of time than the carbon dioxide it replaces in the environment. If we look at the practical implications of this, reducing methane emissions can have a more immediate impact on global warming while also buying us some critical more time. In support of the Global Methane Pledge, which pledges governments to lowering methane emissions by 30 percent by 2030, more than 60 countries have signed on (European Commission, 2022).The report indicates that it is possible to achieve this goal at a low or no cost in a variety of industries, including the oil and gas, agriculture, and waste sectors, among others.

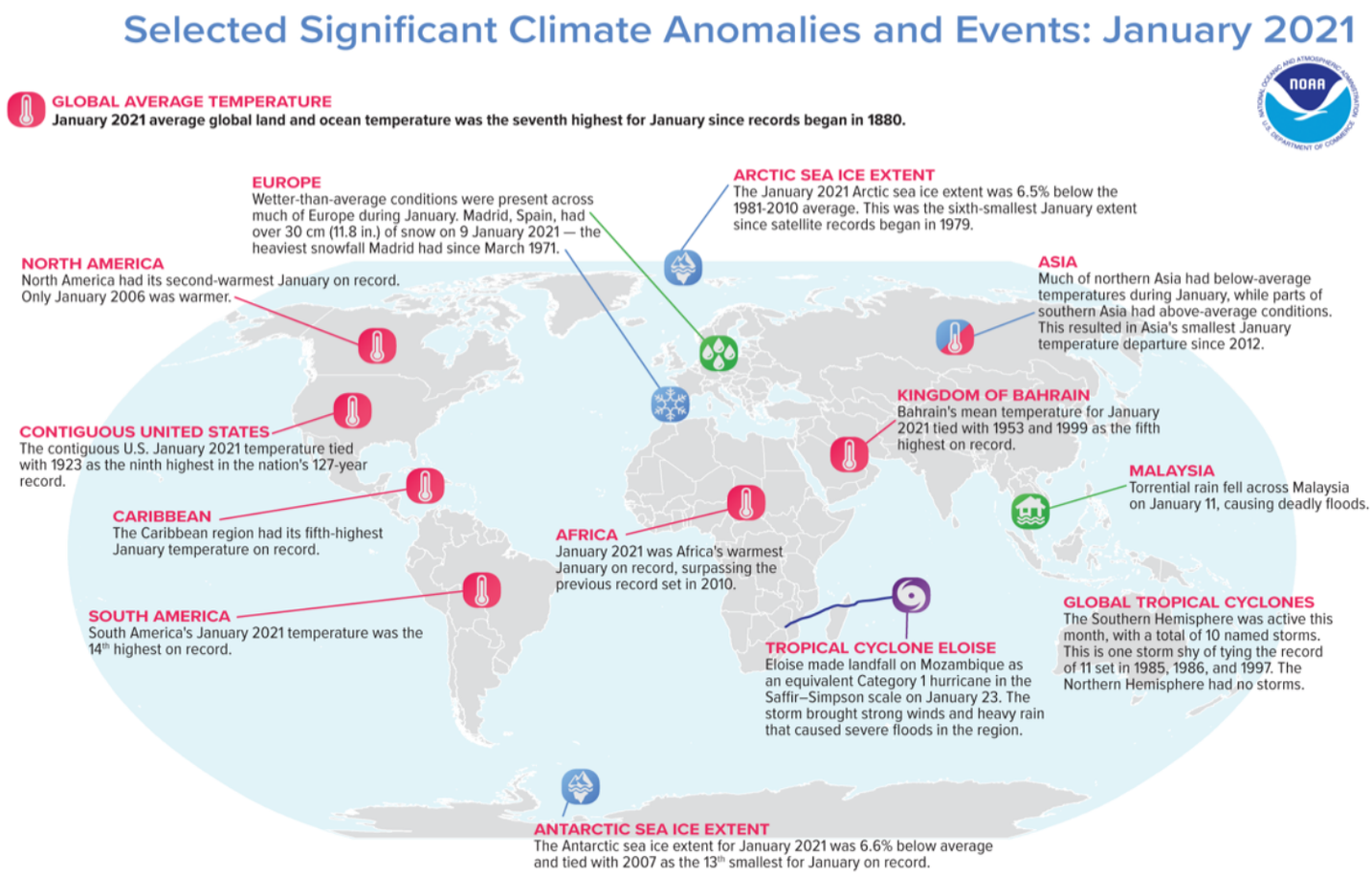

Figure 2: Climate Anomalies across the World (UNEP, 2021)

Discussion

New year, same old problems: COVID-19 epidemic, wildfires resurging, climate change crises persisting, loss of biodiversity, pollution and waste, among others. No matter how things look now, environmentalists may look forward to 2022 as a milestone year in their efforts, as a slew of high-level meetings and conferences are planned that aim to reinvigorate global cooperation and collaborative action. Next year will mark the celebration of not one, but two golden jubilees. International attention to environmental issues was given a major boost at the historic 1972 United Nations Conference on the Human Environment in Stockholm. The outcome of the summit was unanimous: governments, civic society, corporations, and politicians all agreed that environmental protection should be at the top of their priority lists, recognising the close relationship that exists between the earth, human well-being, and economic growth. To mark the event's 50th anniversary, the Stockholm+50 meeting in June 2022 will commemorate it and reflect on half a century's worth of global environmental action, as well as look to the future.

With its convening power and thorough scientific research, the United Nations Environment Program (UNEP) has coordinated a global effort to solve environmental issues. There will be a slew of events marking the UN Environment Programme's 50th anniversary in 2015. Around 2022, UNEP will implement a new "Medium-Term Strategy," which will

consist of seven interconnected subprogrammes for action: climate change, chemical and pollution, natural resource management, scientific policy and environmental governance; financial and economic transformations and digital transformations. United Nations Environment Assembly 5.2 will be held in February 2022, the fifth session of the United Nations Environment Assembly in 2021. Nature's role in achieving social, economic, and environmental sustainability will be emphasised as a key topic of discussion under the broad heading of "Strengthening Actions for Nature to Achieve the Sustainable Development Goals." Despite the fact that the history of environmental achievements shows what may be achieved with international cooperation, the science remains unmistakably clear. Unhealthy consumption and production practices contribute to the triple planetary calamity of climate change, loss of nature, pollution and waste disposal. UN Secretary-General António Guterres has warned that the triple crisis is humanity's greatest existential risk.

Conclusion

"A negotiated agreement was reached at COP26. It's a reflection of the world's conflicting interests, contradictions, and lack of political will right now. UN Secretary-General António Guterres said at the end of the summit that "not enough" had been accomplished. Although nearly 200 countries signed the Glasgow Climate Pact after two weeks of intense debate, it is unlikely that this agreement will have a major impact on the global climate change picture. In any case, it's a huge step forward in the right direction. Using recent IPCC findings as a starting point, it accepts that the world is facing a climate emergency, expressing "alarm and anxiety" about the fact that human activities have contributed around 1.1°C of global warming to date and that the impacts of these activities are already being felt in every region of the globe. Climate change impacts will be less severe at 1.5°C than at 2°C, and parties agree to keep working to keep the temperature increase below that level. Despite the fact that the accord reached was far from perfect, almost every country agreed that the alternative — walking away without an agreement — would be far worse. Even if the UN Conference on Climate Change (COP26) did not accomplish the full range of ambition required to tackle climate change, it did lay the basis for future action. COP26 was an important step forward. This is the hardest battle we've ever had to face in our lives. You should never give up on your dreams. Don't ever stop trying. Continually improve yourself. Is the COP 27 Conference on Climate Change going to save the planet?

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Storm Surge Vulnerability Assessment using CVI Case Study: Coastal Communities in Mauritius

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Abstract

Storm surge and sea level rise (SLR) cause damages to coastal residents since they are located on the forefront near the sea. The main aim of the study was to showcase the areas near the region of Rivière des Galets, most vulnerable to storm surges. In order to identify those areas, a coastal vulnerability index (CVI) analysis was carried out with respect to storm surges and sea level rise. The generation of the CVI was based upon the combination of several variables; coastal slope, coastal geomorphology, mean significant wave height, mean tidal range, mean sea level rise and rate of change of the shoreline. The variables used were compiled through literature, websites, as secondary data. The variable, rate of change of the shoreline, was derived using satellite imageries. First, the satellite image analysis index, the MNDWI, was used to extract the shorelines as from 2012 to 2018, and in the second part of the study, the Digital Shoreline Analysis Tool (DSAS) was used to analyse the rate of change of shoreline. The results of this analysis was classified into different categories based on their retreat, stability and accretion The CVI calculated ranged from 4.42 to 14.42 and these results were then reclassified into low, medium and high vulnerability. The results showed that the region deemed to be highly vulnerable was located at the cemetery of Rivière des Galets. A second method was used to identify the most highly vulnerable site. A 30m STRM digital elevation model (DEM) was used to prepare a coastal flooding map, based on wave heights and predicted SLR varying between 5m to 8m. While the CVI map illustrated the spatial variations in vulnerability levels, the coastal flooding map developed highlighted the need for more detailed field mapping. A survey with the community confirmed the sites most at risk to storm surges and SLR. The coastal flooding map derived with limited land elevation data, did not replicate this result. The CVI analysis on the other hand highlighted the governing parameters of coastal vulnerability at the study area, these were the geology and other physical process. Coupling coastal vulnerability index and coastal flooding, have the potential to contribute to the identification of areas where mitigation measures would be required. One of the main recommendations of the study was that coastal flooding can be predicted better with more detailed digital elevation models coupled with bathymetry data.

Keywords - Climate Change, Storm Surge, Coastal Vulnerability Index, Digital Shoreline Analysis, Satellite Imagery Analysis.

Introduction

Climate change refers to a change in the mean or variability of climate indicators (IPCC 2007). One of the thought that comes to mind when hearing about climate change is its nocuous effects such as (1) sea level rise (2) the melting of ice caps (3) intensified storms, and (4) storm surges that causes coastal flooding (Brown et al 2011). According to the Intergovernmental Panel on Climate Change (IPCC) the global temperature is expected to rise by 1°C in the coming years and will likely reach an increase of 1.5°C between 2030 and 2052 (IPCC 2018).

Coastal development, industrialisation and urbanisation have led to an increase in settlements along the coast creating coastal communities in lower geographic elevations. In many cases, these low elevation settlements are among the most densely populated ones as compared to those inland (Ye-Wu et al., 2002). Coastlines are subject to various challenges due to climate change effect. Statistics revealed that around 70% of the coastline around the globe are suffering from shoreline degradation and in the long run this will have a devastating effect on the coastal communities (Mansoori et al., 2016). These coastal communities are becoming highly vulnerable to storm surges, as they are usually the first ones being hit by disasters from the oceans, such as storm surges. Storm surges is a growing hazardous phenomenon that is affecting almost every island and continents around the globe, and they arise from cyclones, typhoons or hurricanes, and have recently intensified in magnitude owing to global warming (MEO, 2011).

Problem Statement

Global warming stands as a threat to coastal regions, for as the temperature rises so does the melting of ice caps, and with that comes the rising of sea level and intensified storms. Coastal regions are at the forefront when facing storms surges and they will most likely be affected by coastal flooding originating from the sea.

The resident's safety is at stake, therefore, there is the need to assess the vulnerability of the coastal regions in order to protect them or minimise the damages caused by this phenomenon.

The aim of the study was to assess the vulnerability of coastal communities to storm surge through the development of coastal vulnerability index map which can serve as a guide to cater for the future and current impact of both sea level rise and storm surge.

1.1 Study Area

Mauritius is a volcanic island located in the Indian Ocean bearing the coordinates (20°S 58°E) and an area of approximately 2000km2. The study was conducted in the southern part of Mauritius in the district of Savanne (Figure 1), at Rivière des Galets village.

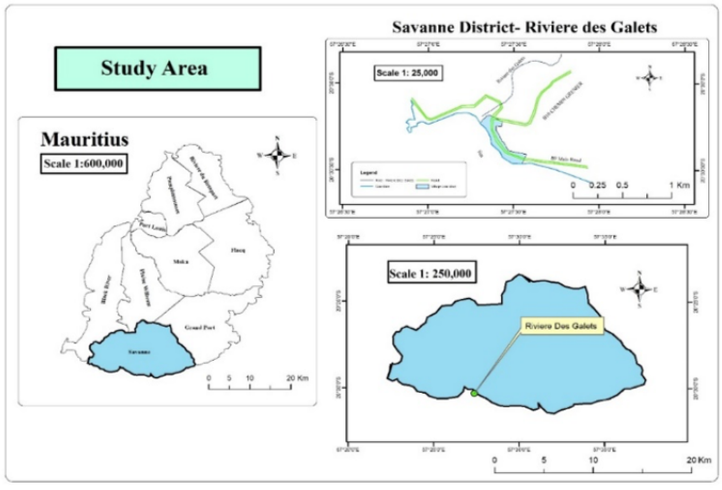

Figure 1: Location of the area under study

This village studied consisted of 318 coastal residents, 97 families and 50 houses (2019). It is bounded in the north by the river, Rivière des Galets, in the east by the coastal road B9, in the south by a cemetery and in the west by the seafront. The village (Figure 1) is under the influence of the following conditions:

- Regularly exposure to incoming waves and swells. The extreme weather events of May 1976, May

2007, caused a large amount of casualties in the selected study area. These events were caused by strong southern ocean swells.

- Lack of protection by natural resources such as coral patches. Even though there are corals at the selected site, those are being widened following storm surges events.
- Protection by hard structures, gabions. In order to reduce the effects and impacts from the disaster occurring in the area measures have been implemented to protect the coastal communities.

Literature Review

Human-induced activities have contributed to the release of gases; from the release of carbon dioxide gases through exhaust pipes of vehicles and chimneys, to the extensive use of chrofluorocarbon, are responsible for the greenhouse effect (IPCC 2014). This consequently is leading to a rise in ocean temperature, the melting of the ice caps and rising sea levels. According to the Intergovernmental Panel on Climate change (IPCC) report, the global mean sea level rose by 0.19 m between the year 1901 to 2010 (IPCC 2014) and it is estimated that by 2100 the global mean sea level would rise by approximately 0.26 to 0.77 m. Even though measures will be taken to reduce the temperature of global warming by 1.5 degree Celsius, sea level would continue to rise at an alarming rate beyond 2100 (IPCC 2018).

Sea level rise is particularly challenging to low lying islands and coastal regions such as the Maldives islands, the small island developing states (SIDS), the Mascarenes Islands, the Australian coastline, the African coastline and the coastlines of other continents. Mauritius being part of both SIDS and Mascarene Islands stands as a vulnerable island before this phenomenon. Mauritius is endowed with a coastline of 322 km, housing commercial, residential and recreational areas. The coastal areas are nowadays these are being threatened by the rise of sea level, with he island recording a mean sea level rise of 3.8 mm per year (Paula 2017). The Mauritius second national communication (SNC) indicated that there has been an increase in sea level in Port louis of 3.2 cm from the year 1988 to 2007 (SNC 2010). According to the National Climate Change Action Plan (2011), several coastal areas that will most likely be affected by sea-level rise in Mauritius were identified, namely: Mon Choisy, Cap Malheureux, Grand Gaube, Roches Noires, Poste de Flacq, Trou d'Eau Douce, Grande Rivière Sud Est, Anse Bambous, Anse Jonchée, Blue Bay, La Cambuse, Souffleur, Bénarès, Gris-Gris, Rivière des Galets, Baie du Cap, Macondé and Le Morne (MOE 2011). The expected sea level rise by the year 2050, 2080 and 2100 are 16cm, 35cm and 49 cm respectively (SNC 2010). With the 1m rise adopted by every country for the rise in sea level, there are bound to be projected damages to the coastal zones, that including the disappearance of 26 km of the beaches on the west coast of Mauritius (MEO 2011). The impacts associated with sea level rise are (1) loss of land as a result of erosion and inundation, (2) the increase in salinity in aquifers (seawater intrusion), (3) a rise in the coastal water table and (4) increased coastal flooding and storm surges. Therefore, there is the need to properly address the issues of sea level rise and coastal vulnerability, in order to protect coastal areas.

Coastal erosion, coastal flooding and rate of change of shorelines have been extensively researched upon in many coastal countries but few studies have been carried for the island of Mauritius. Nowadays availability of satellite imageries are opening new research avenues. The Digital Shore Analysis System (DSAS) coupled with remote sensing data have been used to analyse the dynamic movement of coastal erosion along shore line (Mansoori & Marzouqi, 2016; Kafrawyi et al, 2017). The DSAS is an extension from the ArcGIS Software, which mainly uses statistics such as regression rate, to assess the rate of change of shorelines of a given area. portraying whether there has been erosion or accretion (Hzami et al, 2018). Rate of change shoreline can be combined in coastal

vulnerability index mapping for a comprehensive analysis.

Materials And Methods

The analysis of the coastal vulnerability of part of the southern coastline of Mauritius was divided into three parts, namely; (1) questionnaire survey & analysis (2) use of a 30m STRM DEM for terrain analysis together with satellite imagery and (3) coastal vulnerability index assessment.

A. Questionnaire Survey

The questionnaire survey was used to gather crucial field data, such as location of people most at risk to the impacts from storm surge and to also analyse the emergency response effectiveness at the community/individual level. The questionnaire for the on-site survey composed of mixed method questions; close-ended, open-ended and statement questions which aimed at (1) assessing the knowledge that people of this coastal community have on storm surge and sea level rise, (2) locating areas at risk of coastal flooding as a result of storm surge or high waves, (3) identifying features present in the study area that would reduce the impact of ocean waves (4) assessing the level of preparedness and existing adaptation strategies, and (5) finding solutions to reduce the vulnerability to storm surge and sea level rise.

B. Terrain Analysis

The STRM DEM 30m resolution was used to model the areas that would most likely be flooded during a cyclone or during the storm surge. Storm surge height is usually based on high water marks or eye-witness accounts. For the modelling of storm surge impacts on the coastal area, the wave height obtained through the survey questionnaire was used, namely wave heights ranging between 4 to 7 metres. The modelling of storm surge impact was carried out in ArcGIS 10.4, more precisely with the tool, raster calculator. The model developed required the wave height as an input parameter and in this case, scenarios of 4m and 7m were used. Additionally, since sea level rise will have an impact on the level of water causing coastal flooding, and ought to rise by 1m by 2050. It was added in the equation for the modelling of storm surge. Thus the wave heights of 5m (4m + 1 metre sea level rise) and 8m (7m + 1 metre sea level rise), were used in the modelling of storm surge flood impact.

C. Coastal Vulnerability assessment

Coastal vulnerability index is an index that is widely used to assess the vulnerability of a coastline, there exist many variants of this methods, all of the variants originates from the main coastal vulnerability index method namely CVI by Gornitz, originally created to assess the vulnerability as a result of sea level rise and shoreline erosion or accretion (Marchant, 2017).

$$CVI = \sqrt[2]{\frac{a \cdot b \cdot c \cdot d \cdot e \cdot f}{6}}$$

Equation 1 Coastal Vulnerability Index (CVI)
(Source: Marchant,2017)

The Coastal vulnerability index used six physical variables as indicators of a coastline's vulnerability to the impacts of SLR: geomorphology, coastal slope, rate of relative sea-level rise, rate of shoreline erosion/accretion, mean tide range and mean significant wave height. The CVI uses a set of rankings to weigh the level of vulnerability of a given area prior to its variable, the table below shows the ranking adhere by Gornitz (Figure 2).

The parameters to be used in the coastal vulnerability Index were classified and ranked according to the table of ranking of Gornitz. All processing related to the coastal vulnerability index were carried out using ArcGIS 10.4. The variables were converted into raster layer where needed to and using the raster calculator the coastal vulnerability index for Rivière des Galets was computed.

	Ranking of coastal vulnerability index				
	Very low	Low	Moderate	High	Very high
VARIABLE	1	2	3	4	5
Geomorphology	Rocky, cliffed coasts Fiords Fiards	Medium cliffs Indented coasts	Low cliffs Glacial drift Alluvial plains	Cobble beaches Estuary Lagoon	Barrier beaches Sand Beaches Salt marsh Mud flats Deltas Mangrove Coral reefs
Coastal Slope (%)	> .2	.2 – .07	.07 – .04	.04 – .025	< .025
Relative sea-level change (mm/yr)	< 1.8	1.8 – 2.5	2.5 – 2.95	2.95 – 3.16	> 3.16
Shoreline erosion/ accretion (m/yr)	>2.0 Accretion	1.0 – 2.0	-1.0 – +1.0 Stable	-1.1 – -2.0	< - 2.0 Erosion
Mean tide range (m)	> 6.0	4.1 – 6.0	2.0 – 4.0	1.0 – 1.9	< 1.0
Mean wave height (m)	<.55	.55 – .85	.85 – 1.05	1.05 – 1.25	>1.25

Figure 2; Ranking for Coastal Vulnerability Index (Source: Marchant,2017)

D. Shoreline Regression analysis

The technique used to extract the coastline is the classification techniques, which uses spectral band ratios approach to classify land and water. The Modified Normalised Difference Water Index (MNDWI) (Mansoori et al 2016), demarcates the boundary between land and water. The resulting indices range from -1 to 1, where values greater than 0 represent water bodies (oceans, lakes, rivers) and values less than zero represent land. The MNDWI was calculated using the equation 2:

$$MNDWI = \frac{(Green - MIR)}{(Green + MIR)}$$

Equation 2: Modified normalised difference water index (Source; Mansoori et al., 2016)

Where the bands in Landsat imagery for
Green = Band3 and MIR = Band5.

Each satellite is characterised by spectral resolution which sets outs the various bands and its associated wavelength that can be used for Indexing-band ratio. The wavelength for the band 3 for Landsat 8 is 0.53-0.59 mm and that of band 5 is 0.85-0.88 mm. The wavelength for band 3 for Landsat 7 is 0.63- 0.69 mm and that of band 5 is 1.55-1.75 mm, Both Landsat 7 and Landsat 8 has a spatial resolution of 30m. Prior to carrying out classification, image pre-processing of each satellite datasets was carried out using the semi classification plugin in QGIS 2.18. The remaining operations were carried out in ArcGIS 10.4. The Digital Shoreline Analysis Tool (DSAS) is an extension that is used to analyse the changes in shoreline It depicts the rate of accretion and rate of erosion for a given area. The DSAS works on the basis of a baseline and transact which offset from the shorelines to analyse the rate of change of shoreline of a given area. The DSAS tool was used to analyse the shoreline changes, appointing the transect length as 100 and spacing 25 m. The rates mm/year obtained were then classified in the ranges below high erosion, Low erosion, No change, Low accretion and High accretion. The respective rate of change of shoreline were then digitise and reclassified to be used for the coastal vulnerability index.

Data Collection

The primary data collected for the study are the responses from the field survey carried out at a specific flooded region at Rivière des Galets to collect spot elevation data and from the questionnaires shared with inhabitants within the surrounding region. The primary data is of uttermost importance as it relates to the real aspects of the problem, those experience by the residents. The secondary data are the 30m spatial resolution STRM DEM and the satellite imageries.

The software ArcGIS have been used for the processing and analysis of data, such as generating the localised digital elevation model from spot elevation

data and for the creating the classification of land that shall be exposed to the assessed phenomenon. The Landsat and Sentinel satellite imageries used for remote sensing, and the STRM 30m spatial resolution DEM used for analysis were obtained from the website USGS earth explorer.

The data collected for the building of the coastal Vulnerability Index are as follows:

1. The coastal morphology was determined by the site visits at the village of the Rivière des Galets. The two types of coastal morphology identified were sandy beaches and rocky areas as a result of the rock revetment.
2. The mean wave height data was obtained from the Mauritius Oceanography Institute (2012-2014), long term ocean monitoring of the nearshore waters of the Republic of Mauritius.
3. The coastline coast UTM, mudflats and mangrove were obtained from the ministry of social Security, National Solidarity, and Environment and Sustainable Development (Environment and Sustainable Development Division).
4. The relative mean sea level was obtained through literature review more precisely from the publications coral reef of Mauritius in a changing climate (Paula 2017)
5. Tidal range was obtained from the website of the Mauritius Meteorological Services website.

Results & Discussion

A. Shoreline Extraction And Analysis

The shoreline extraction of Rivière des Galets was carried out using the Landsat imagery from USGS. The software's QGIS 2.18 and ArcGIS 10.4 was used for the processing. The software QGIS was used to carry out the pre-processing of the satellite imagery using the semi classification plugin. The remaining processing were carried out using the Software ArcGIS 10.4, the indexing band ratio, Modified Normalised Water Index was applied to the satellite imageries. In order to further distinguish the boundary of land and water, a particular threshold was chosen and classification was carried out. The threshold used for the classification was 0 and 0.1. Meaning that pixel having values ranging from -1 to 0 represented water and those having a value of 0.1 to 1 represented land. This classification helped to distinguish the boundary between land and water. The figure below shows the resultant map of the band ratio for the shoreline extraction of the Landsat imagery.

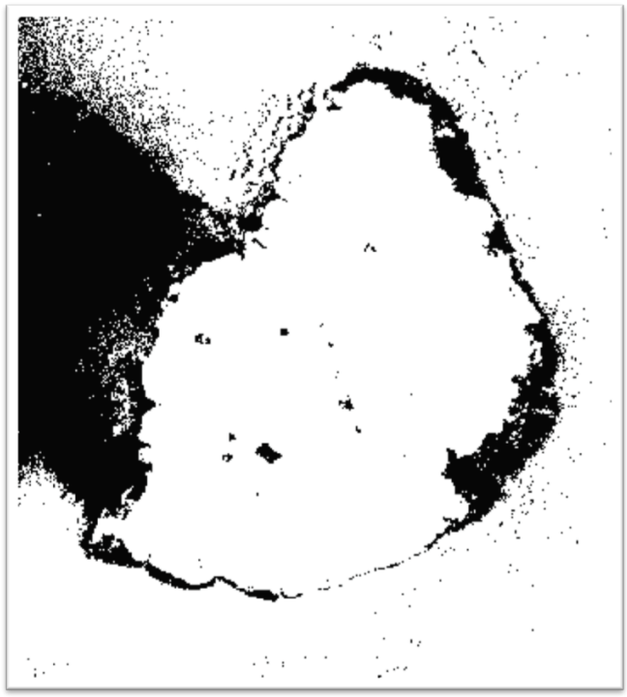

Figure 3: Map of MNDWI using Landsat Imagery 2018 for Mauritius

Once the boundary had been identified, the raster image was reclassified, leaving only one layer visible that is the water layer. The raster image was then converted into a polygon to aid in the identification and digitising of the shoreline. The coastal zone being a dynamic in nature, the challenge was to get an accurate extraction of the shoreline position due to the tidal changes during the day.

The process of shoreline extraction was repeated until the set of shorelines were obtained to be used in the

DSAS software for analysis of shoreline accretion or erosion (Figure 4). Since the satellite imagery used was of 30m.

An accuracy assessment was carried out using the UTM coast 2013 and the shoreline extracted 2013. Accuracy assessment worked on the basis of changes detected from the UTM 2013 coastline to the one being extracted that is the minimum distance between the extracted shoreline from the Landsat imagery and the UTM 2013 coastline. Figure 5 shows the UTM 2013 and extracted shoreline being superimposed to delineate the differences that exist between the two. The red vector line indicates the coast UTM 2013 shoreline while the blue vector line shows the extracted shoreline from the Landsat 7.

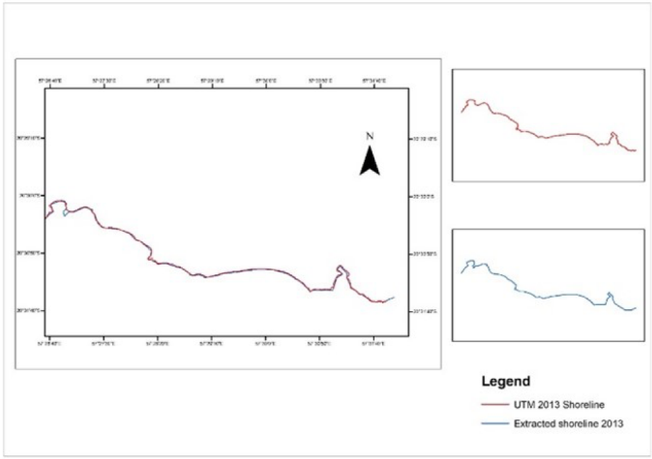

Figure 5 shows the extracted and actual shoreline of 2013

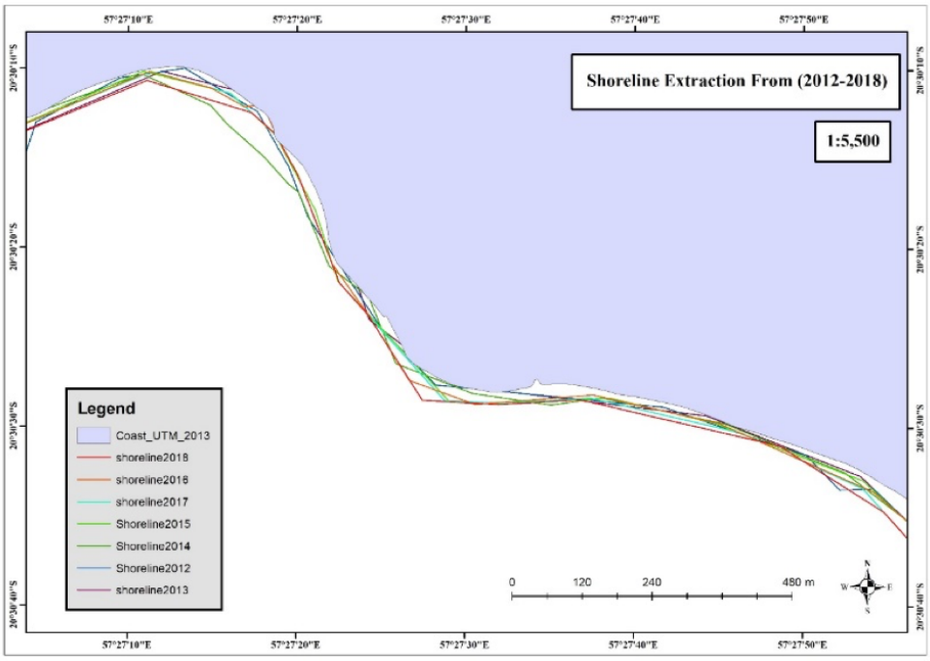

Figure 4 A comparison between the UTM coast 2013 and shoreline extraction

Visual inspection is a must when carrying out an accuracy assessment. From figure 5 it can be observed that the extracted shoreline from the Landsat imagery is depicted as blue, while the actual coast UTM 2013 shoreline is depicted as red. It can be seen from overlaying both shorelines that visually there are little variations between those two shorelines. They mostly corroborate with one another.

DSAS Analysis – Shoreline Change Rate

The DSAS tool was then used to analyse the rate of change of the shoreline. The process involved creating right-angled transects at 5 metre intervals as shown in Figure 6. A baseline has to be fixed for the analysis. The importance of the baseline is that it is helpful in the measurement of the amount of shift in the shoreline change. From this reference point it can be deduced if there has been any propagation or regression in the shoreline, which is denoted by positive and negative values respectively.

The distance between the transects, shoreline, and the baseline were used to calculate the rate of change of shoreline using the weighted least squares regression (WLS) which takes into consideration the uncertainty for each shoreline positions.

The shoreline linear regression rate ranges from -3.83 to 5.93 m/year. With most negative values being perceived as erosion and most positive values as accretion. Thus the linear regression rate was classified into four categories namely high erosion, erosion, stable, low accretion and high accretion. The negative values ranging from -1.99 to 1 and were classified as high erosion, the values ranging from -0.99 to 1.00 were classified as erosion, the values ranging from 1 to 2 were deemed as being stable, those ranging from 2 to 5.93 were classified as being of low accretion and those ranging from 2 to 5.58 were classified under the high accretion category.

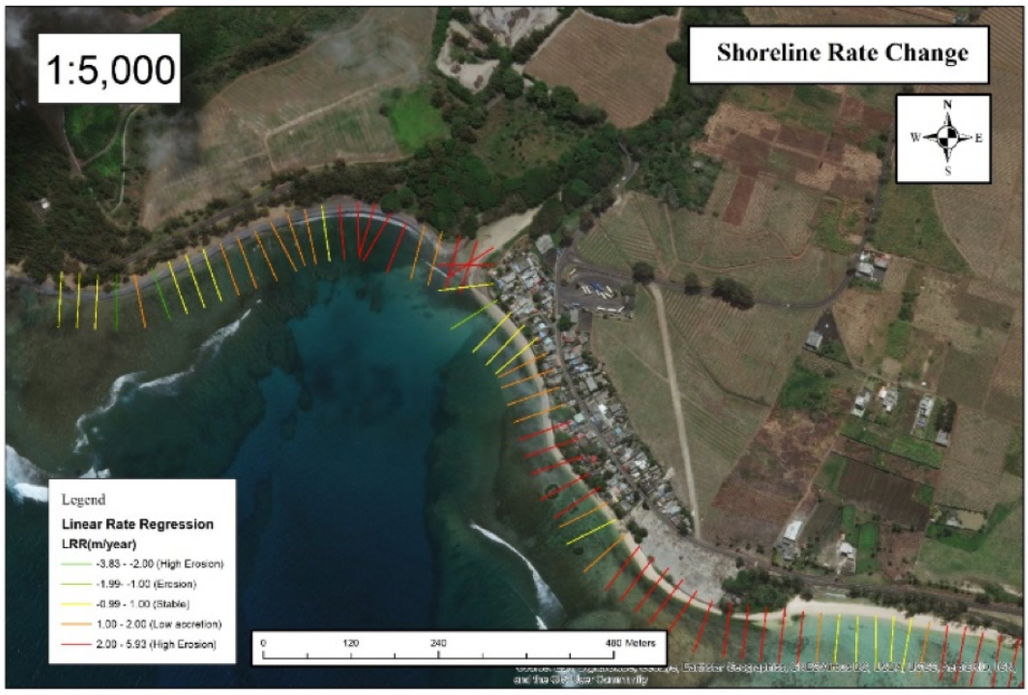

Figure 6 shows the rate of shoreline change at Rivière des Galets

Figure 7 depicts the linear regression rate of the shoreline at Rivière des Galets and its surrounding. The linear regression rate is in line with the transect distance used for the analysis. The study area spread from Ilot Sancho (0m) to St Felix beach (130m). From the graph (Figure 7) it can be seen that there are at least four peaks that fall below zero in the linear regression rate, it means that those three peaks reflect the level of erosion and they are at transect 0 to 5 and at transect 30. The peak is more more prominent at this transect which is located near Ilot Sanchot. Rivière des Galets being a village which is renowned for being affected by strong waves from the southern oceans, it was expected that the results of the rate of change of the entire shoreline in this region would reflect major erosion processes. However, the results obtained indicated that the only some regions suffer from major erosion, the region around Ilot Sanchot at the start of the village. The results highlighted that wave movements are not the only cause of shoreline retreat, urbanisation, infrastructure development and increased population are aspects that will accelerate the rate of shoreline change.

The regions having the most accretion rate are depicted by the orange to red indicator, with the orange colour reflecting a low rate of accretion and the red colour, a high rate of accretion (Figure 7). The deposition of sediment that causes accretion would be part of the process of erosion on one side and accretion on other sides where the waves are deflected by either the shape of the shoreline or presence of hard coastal structures.

The area near the cemetery yielded a high rate of accretion. This result was confirmed visually on site where significant accretion was noted.

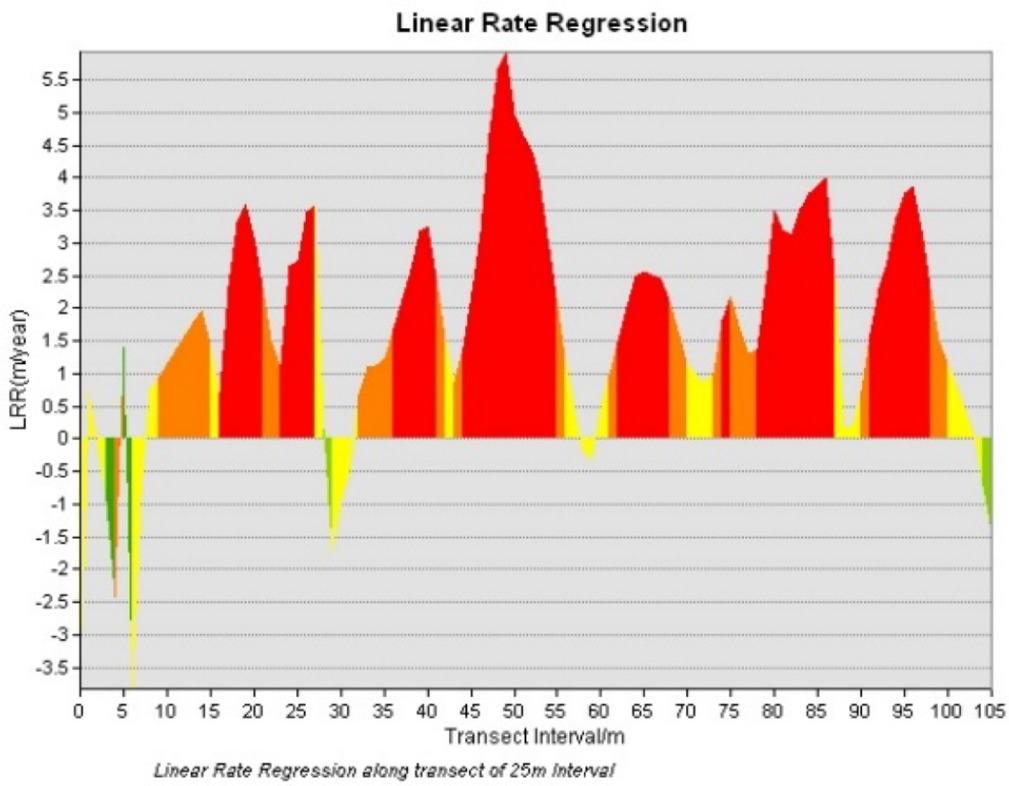

Figure 7 shows the linear Rate regression graph for Rivière des Galets

B. Dem Terrain Analysis

The 30m STRM DEM was used to develop a coastal flooding map. The DEM was reclassified based on predicted sea level rise (1m) and observed wave height (4m to 7m) and based on the coastal elevation data. The results obtained did not match reality. The resulting coastal inundation map showed that the whole village on either side of the main road would be inundated in case of storm surge flooding, which is not the case in real time. From the questionnaire answers and walkthrough surveys, the respondents stated that the region which are more likely to be flooded are located within the 25m frame from the barrier at Rivière des Galets, that is the seawall and rock revetment. A coastal slope map was generated for further analysis. The coastal slope clearly showed that the gradient of the slope increases along the village and gradually decreases via the end edge of the village (Figure 8). Hence there is a low probability that the coastal water will flow to the other side of the village. The validity of the 30m DEM for this analysis was questioned, and the spot elevation data confirmed that a higher spatial resolution DEM would be needed for a more accurate analysis.

Ideally, the use of LIDAR based DEM of the study area would have been ideal tools when portraying the level of flooding. The limitation attached with the use of DEM is that it cannot be used on its own to model the effect of storm surge in our given study area due to its geological process, perhaps in other countries where the gradient of slope is low along the shore, the DEM only can be used.

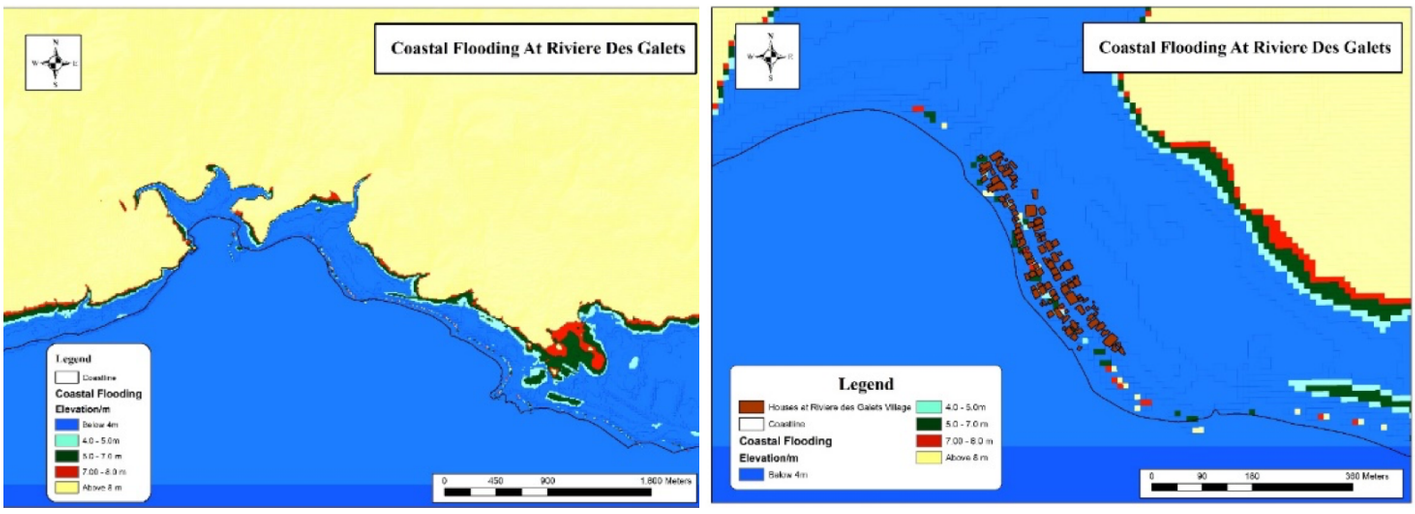

Figure 8 shows Coastal Flooding obtained using the 30m spatial resolution DEM

C. Coastal Vulnerability Index

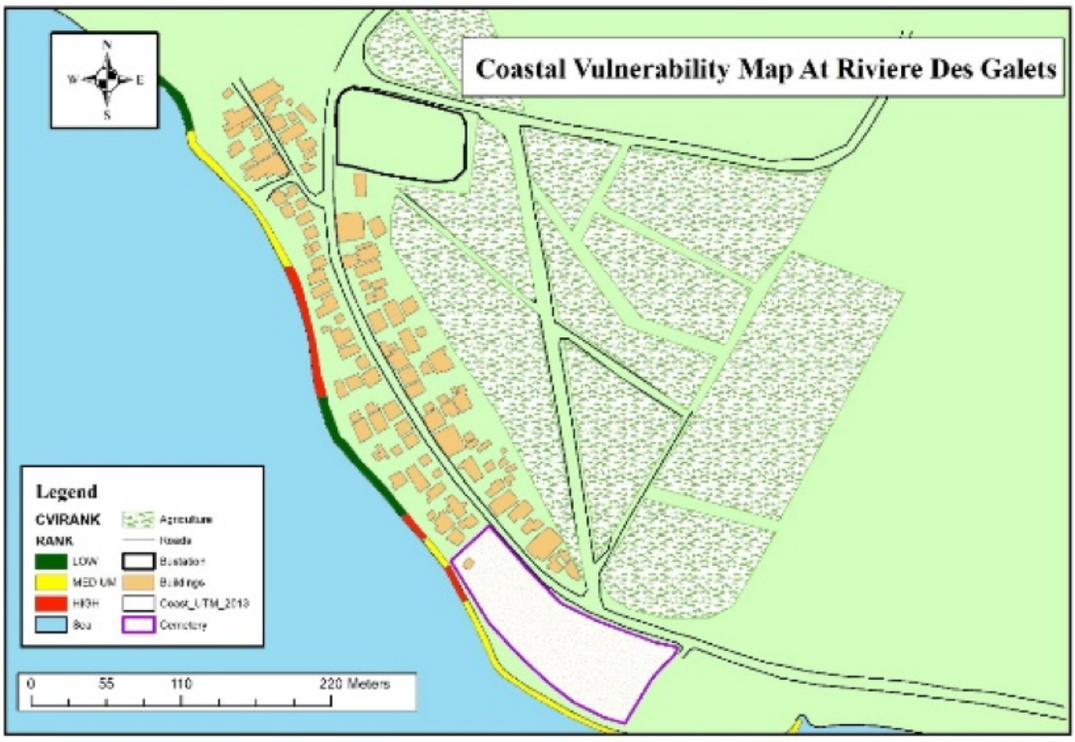

Figure 9: Coastal vulnerability map at Rivière des Galets

The CVI obtained at Rivière des Galets ranges from 4.47 to 14.42. The mean value was 7.92, and the standard deviation 2.47. The CVI was reclassified into three categories namely Low, Medium and High vulnerability (Figure 9). The classification was based on the quartile ranges and visual inspection of the study area and using the mode and median as well. The CVI values falling below 4.47 were classified as being low, those values ranging from 4.47 to 7.86

were classified as medium vulnerability and the value above 7.86 were considered as being highly vulnerable. Figure 10 shows the percentage of shoreline and their relative vulnerability. As can be noted from figure 10, a large percentage of the area is at high risk to storms surges.

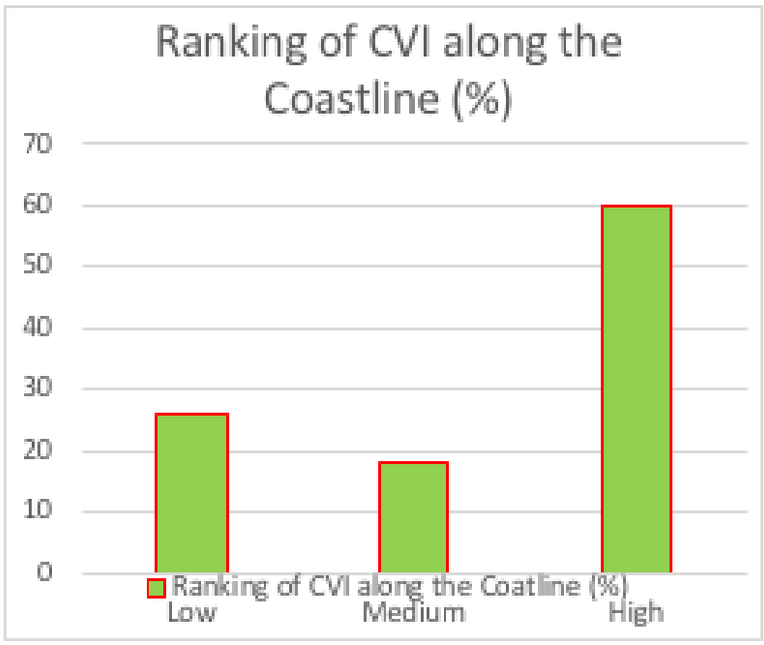

Figure 10: Ranking of CVI along the coastline

The Coastal Vulnerability Index method takes into consideration the physical features and geological processes along the coast so that the region having the most changes can be identified. The geological components play an important role in the CVI namely the coastal morphology which in the case at Rivière des Galets is divided as rock revetment and Sandy beach. The coastal morphology layer protects the coastline by opposing the force with which the wave hits the shore, for instance the rock revetment will absorb the energy from the waves and cause minimum disturbance. Coming to the sandy beaches, part of the sediments on the shore will be washed away due to the movement of the waves, a wave having high energy is proportional to the square of the wave height that comes hits the shore. Hence a wave having a high height will disturb or displace the sediments along the coast leading to erosion. Most of the layers were casted as having a high contribution in the CVI, the only aspect which differentiate the extent of vulnerability were the coastal morphology, the coastal slope and shoreline rate change at the given sections. The classified vulnerability are low, medium and high vulnerability explained below.

Those regions were located with the frame of the newly built rock revetment. This barrier protects the coastal residents against strong storms, high tides and reduces the probability that this region can be affected by flood. This is all because the rock revetment absorbs energy and oppose energy coming from the waves. This reduces the risk of erosion, by reducing the amount of energy that is sent back to the sea. Even though layers such as sea level rise, tidal range and wave significant wave height are casted as having a high contribution in the level of vulnerability or causes of physical changes along the coast. Moreover, the coast has a slope of high gradient which reduces the risk by which flood can reach the residents by being on a high terrain. The areas associated with medium

vulnerability are those subsections where there is a high probability that they will incur damage if coastal flooding were to occur. The region adhere to high vulnerability is located at the cemetery at Rivière des Galets, there the sandy beach can easily be eroded by waves of significant height which are quite high and there is a high probability that this area will be flooded by storm surges or bad weather as compared to those areas in the low or medium classification.

The cemetery at Rivière des Galets falls within the areas that are highly vulnerable as compared to the region located at the mouth of the river. Typically, Rivière des Galets village would have been considered as being lowly vulnerable due to its low value for CVI 14.42 as compared to other studies that were conducted abroad which yielded values up to 162 (Pantusa,2018). However, the ways in which the layers have been ranked are different from other countries, meaning that each country may have its own estimates based on the CVI due to the difference in physical features and location.

Conclusion

Storm surges are dangerous to coastal communities due to the increase in sea level rise, resulting from global warming. There is thus an urgent need to undertake detailed assessment and evaluate the extent to which coastal communities are vulnerable to storm surges.

The risk coastal flooding predicted using the DEM was intended to portray the extent of damages that can be caused by waves occurring from storm surges. However, using DEM is not adequate, as the prediction did not match field information. Additional factors need to be analysed in combination with elevation data.

The Coastal Vulnerability index gave an indication of the level of coastal vulnerability at Rivière des Galets. A low CVI vulnerable rank reflects a zone which will be able to withstand the forces acting upon them while the highly vulnerable areas located more precisely at the cemetery will incurred damages during strong weather events. Be it of low or high vulnerability, the probability that this event will affect the likelihood of the coastal communities still exist. The coastal vulnerability index can act as a guide to locate areas that require more care. It can also act as a guide in the assessment of changes that may occur in the future as a result of sea level rise and processes such as shoreline rate change. The coast being a dynamic environment will continue to change over the years, global warming will accentuate the way in which the coasts are changing, exposing it to the forces from the sea.

Thus continuous assessment must be done to evaluate the extent of degradation of the coastline. Knowing both the vulnerability index of the coasts and the flooded area help to address the coastal changes that may occur in the near future and effectively plan evacuation system which can be of utter importance to the citizen.

This research portrayed the level of damages and losses that can occur as a result of coastal flooding. Hence highlighting the sites which require further investigation regarding types of coastal protection measures.

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"Impact of Climate Change on SIDS. What Engineering solutions?"

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Abstract

The United Nations 2030 Agenda for Sustainable Development, with its 17 Sustainable Development Goals (SDGs) and 169 targets, provides a universally accepted and comprehensive framework addressing all aspects and dimensions of sustainable development globally, which can be applicable from small communities to large economic powers.

FAO, UNESCO and WFEO are committed to advancing the UN Sustainable Goals in their work. The collaboration between agronomists and engineers from various disciplines, is expected to result in new innovations that could offer new technologies and approaches for sustainable agriculture the technical capacity of engineers, scientific knowledge in a sector such as the industrial one, would guarantee concrete results in a short time, with the application of methodologies capable of being applicable even to small territorial areas for example: in the SIDS

Acronyms and Abbreviations

CAC	**Central American Agricultural Council**
CSA	**Climate Smart Agriculture**
FAO	**Food and Agriculture Organization of the United Nations**
GHG	**Greenhouses Gases**
SDG	**Sustainability development Goals**
SICA	**Central American Integration System**
SIDS	**Small Island Development State**
UN	**United Nations**
UNESCO	**United Nations Educations, Scientific and Cultural Organization**
WFEO	**World Federation Engineering Organization**

Introduction

The relationship between The Climate Smart Agriculture (CSA) and SDG Agenda 2030

Climate-smart agriculture (CSA) may be defined as an approach for transforming and reorienting agricultural development under the new realities of climate change (Lipper et al. 2014). The CSA is an integrated approach that seeks to promote sustainable food production, adaptation to climate change and mitigation in the agricultural sector. CSA addresses climate change contrary to conventional agricultural development, CSA systematically integrates climate change into the planning and development of sustainable agricultural systems (Lipper et al. 2014).

To introduce the three main objectives, the so-called CSA Pillars below we propose an approach to classify and identify potential synergies and trade-offs of CSAs in a structured way, already defined by FAO through research studies, each pillar has been divided carried out in each CSA pillar has been divided into subsets of three objectives, in order to present a more nuanced picture of the possible interconnections between the objectives within and across the three pillars. Our fundamental objective is to present a direct relationship with some engineering sectors such as energy, environment and production, what would that mean?

The three pillars of CSA

- **Productivity**: CSA aims to sustainably increase agricultural productivity without negatively impacting the environment.
- **Adaptation**: The CSA aims to reduce farmers' exposure to short-term risks, while strengthening their resilience by strengthening their adaptability and prosperity in the face of long-term shocks and stress.
- **Mitigation**: Where and when possible, CSA should help reduce and / or remove greenhouse gas (GHG) emissions. This implies that we reduce emissions for every calorie or kilogram of food, and fuel we produce.

The three Pillars of the CSA launched by FAO, have a connection from an engineering point of view. It is essential to identify and understand the interconnections between these, with concrete solutions, which would help governments and the political world, intergovernmental organizations to inform and support strategic decisions that can improve synergies and reduce compromises to obtain better results for investments in climate-smart agriculture.

CSA Pillar 1: Sustainably increasing agricultural productivity and incomes		
1.A	**Increasing agricultural productivity** Any improvements in the productivity or efficiency of food production systems; expressed as food production per unit area or per unit of a specific input.	Productivity
1.B	**Increasing food producers' incomes** Any improvements in incomes or profitability at household, farm or product level; expressed as household income, net revenue per unit area, internal rate of return, etc.,	Income
1.C	**Social and environmental sustainability**[5] Based on the aim of CSA Pillar 1 to achieve increases in productivity and incomes 'sustainably'. While economic sustainability is represented in Objectives 1.A and 1.B, this objective captures relevant aspects of social and environmental sustainability, e.g. food security, social equality, biodiversity and ecosystem services.	Soc./Env. sustainability

Fig. 1: Pillar 1 CSA: Sustainable increase in agricultural productivity and incomes

CSA Pillar 2: Adapting and building resilience to climate change		
2.A	**Improving climate risk mitigation strategies for food producers' livelihoods** Any improvements in livelihood resilience to climate impacts derived from mitigation strategies such as diversification or microinsurance; expressed as income stability, change in unsustainable coping strategies, etc.	Livelihood resilience
2.B	**Adapting food production systems to current and expected future climate change** Any technical or agronomic adaptation measures that aim to reduce exposure and sensitivity to physical impacts of climate change, as well as to exploit opportunities offered by changing climate conditions, e.g. use of improved varieties, adoption of irrigation, change of crop or livestock species or construction of dykes; expressed as yield stability, area under irrigation, etc..	Production system adaptation
2.C	**Increasing the resilience of agro-ecosystems** Any improvements in the resilience of food production systems to climate impacts derived from the enhancement of ecosystem functions and services, e.g. species diversification, increasing structural diversity and natural habitats or improving soil health; expressed as yield stability, damage from climate-related disasters, etc.	Agro-ecosystem resilience

Fig. 2: Pillar 2 CSA: Adaptation and construction of resilience to climate change

CSA Pillar 3: Reducing and/or removing greenhouse gas emissions, where possible		
3.A	**Increasing carbon stocks in soils and biomass** Any measures to conserve or enhance terrestrial or marine carbon sinks at field, farm, landscape or seascape level; expressed as carbon stock per unit area, area reforested, area of carbon-rich ecosystems conserved, etc.	Carbon stocks
3.B	**Reducing emission intensities of agricultural products** Any improvements in GHG emission per unit of product or unit area at product, field, farm, landscape or national level; expressed as emissions of individual GHGs per unit or emissions of carbon dioxide equivalent (CO_2eq), i.e. global warming potential (GWP) per unit.	Emissions
3.C	**Replacing fossil fuels with renewable energies** Volume of renewable energy production, as far as related to agriculture. This includes, for example, renewables that are integrated in agricultural systems (e.g. solar-powered irrigation), or bioenergy and/or bioenergy feedstock that are derived from agriculture. It may also concern the production of renewable energy outside the agriculture sectors, where agriculture competes for the same resources (e.g. hydropower versus irrigated agriculture); expressed as energy production at river basin level, energy content of bioenergy feedstock, biomass yield, etc.	Renewables

Fig. 3 Pillar 3 CSA: Reduction and / or removal of greenhouse gas emissions, where possible

In the CSA there is a direct correlation between the Pillars and some engineering sectors, such as energy, for example Pillar 3 "Replacing fossil fuels with renewable energy", it is possible to use Renewable Energy, through the production of energy with the use of photovoltaic panels, and at the same time leaving room for agricultural cultures, the so-called Agrovoltaic system, also developing agrovoltaic Hangars and Agrovoltaic Greenhouses, a system already patented at an industrial level. This is an example that could also be used in geographical areas where there are of the limitations of land as in the islands. Each process must be seen as a single system and it is also necessary to make an assessment from the point of view of the environmental impact, of the quality of life, with the use of more innovative systems from the production point of view, which allows a healthier style of life and above all to be able to reach everyone on a global scale.

In the study published by FAO in 2019 Climate -smart agriculture and Sustainable Developments Goals, "The mapping of interconnections, synergies and trade-offs and guidelines for the integrated implementation

between CSA and SDG to Agenda 2030" were created. This is a complex study that considers all 17 goals of the Agenda analysing, from different perspectives, through two important concepts: Synergies and Trade-off. However, by going deeper and looking at more direct interconnections, with action "keys" from a methodological point of view of processes, the interlinkages between CSA pillar and SDG can be seen more clearly. With the implementation of innovative and technological tools, it is possible to reach a faster result with the introduction of engineering systems.

In its report Rabobank's contribution to the UN Sustainable Development Goals, Rabobank (2018) provides an overview of many of the synergies between climate-smart agriculture and the Sustainable Development Goals, based on the work that the multinational bank supports. Rabobank sees CSA as directly supporting SDGs 2, 8, 9, 12, 13, 15 and 17, and indirectly supporting SDGs 1, 2, 5, 7, 8, 9, 10, 13, 15 and 16. Both these studies assess the linkages at goal level, and distinguish between direct and indirect links to the SDGs, but neither provides descriptions of the methodologies used to identify the linkages.

A clear example of the interaction between CSA and SDG is the study published by SICA and CAC "The Clime Smart Agriculture" Strategic for the SICA Region 2018-2030"[1], where small territorial realities the Latin Americans including the island of the Dominican Republic, operate through 3 strategic axes which are:

- **Strategic Axis 1**: Efficient productive systems for sustainable livelihoods
- **Strategic Axis 2**: Integrated risk management and climate adaptation
- **Strategic Axis 3**: Sustainable low emission agricultural landscapes

Where there is a direct, indirect and enabling correlation in relation to the 17 SDGs of the 2030 Agenda as shown in fig. 4

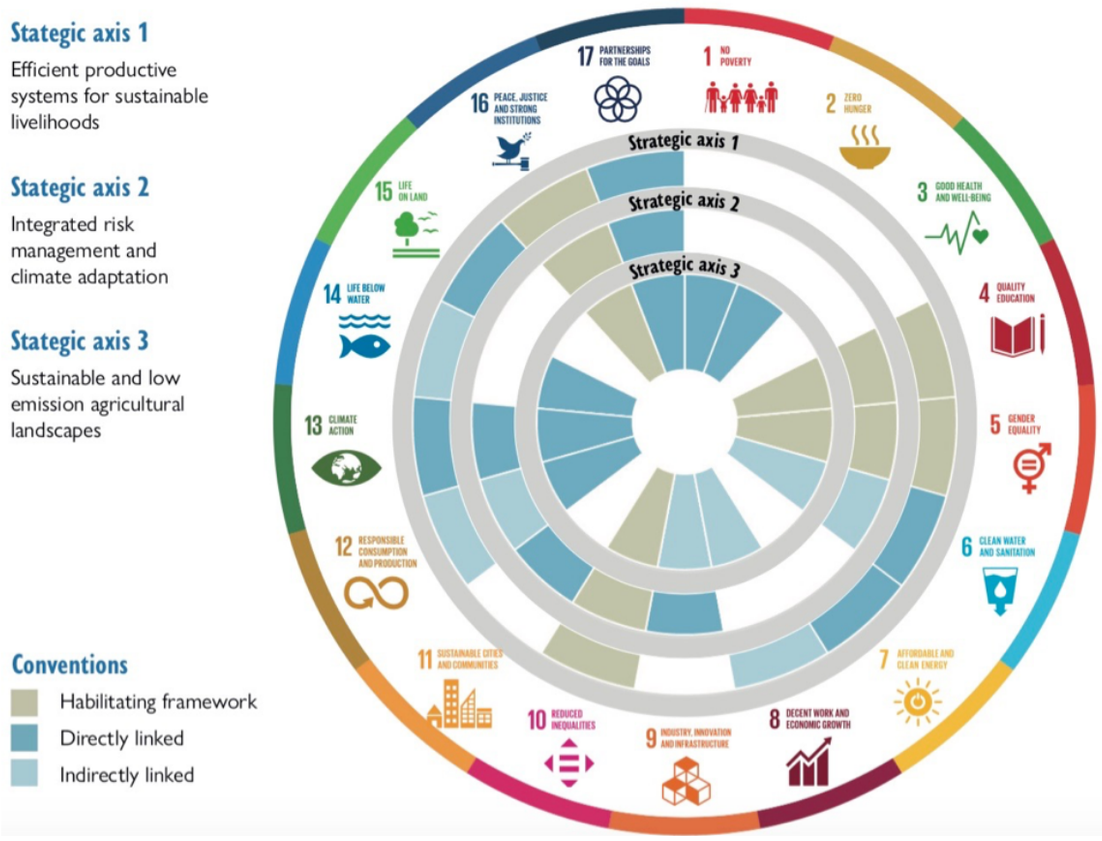

Fig. 4 SICA Visualization of the relationship between CSA and SDG / Agenda 2030

The Central American Integration System (SICA in Spanish: Sistema di Integracion Centroamericana) is constituted by eight countries: Belize, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Nicaragua and Panama.

From the study presented, SICA countries will be able to find a complete solution through Climate Smart Agriculture (CSA) to improve income and productivity, increase resilience and adaptability to climate change. However, it is believed that in the strategic lines defined in the study and the measures for each, can give rise to real engineering projects, promoting technology, innovation with the use of a standardized methodology. It would be desirable to create specific programs for each axis, which provides for monitoring to facilitate evaluation and its improvement in time.

Methodology

More strategic indicators in the Framework FAO (2022-2031)

Since FAO has been developing a strategic plan for years that will guide the main interventions through previous research. Now there are new elements recognising the effects of COVID-19 and the 2030 Agenda, in line with the new FAO Strategic Framework 2022–2031, where green and climate-resilient agriculture are part of FAO's aspirations for better production, better nutrition, a better environment and a better life, leaving no one behind. It is linked with several programme priority areas (PPAs) such as green innovation, climate change, mitigating and adapted agri-food systems, bio-economy, biodiversity and ecosystem services for food and agriculture, reducing food loss and waste, resilient agri-food systems, and scaling up investments.

Fig. 5 The "four betters"

FAO's Strategic Framework seeks to support the 2030 Agenda by transforming towards MORE efficient, inclusive, resilient and sustainable agri-food systems for better production, better nutrition, a better environment and a better life, leaving no one behind, with the " introduction of the Best Four represent an organizing principle of how FAO intends to contribute directly to SDG 1 (No Poverty), SDG 2 (Zero Hunger) and SDG 10 (Reduced Inequalities), as well as supporting the achievement of the agenda broader than the SDGs.

FAO's new approach is based on a much broader global vision than previous approaches, adopting a system that has a more substantial economic, social, environmental and quality of life impact. All of these elements are represented within the objectives of the 2030 Agenda, and are outlined in the different goals of the SDG.

In my opinion an important additional element to this new analysis is the introduction of the so-called "accelerators" which are:

- Technology
- Innovation
- Date
- Complements (Governance, human Capital and Institutions)

As reiterated by FAO, in its Strategic Plan the "accelerators" recognise the need to reduce physical inputs and improve the way we optimize their use, that is, assign them more efficiently to get more from each unit of input.

Fig. 5 The "four betters"

On this point it is necessary to underline what was recalled previously when analysing the CSA and the 3 Pillars, through the engineering of the processes, with the use of systems for the reduction of pollution with the help of renewable sources for the production of energy. Sustainable agriculture could be developed, with this new approach. Through the introduction of "accelerators" Engineering is facilitated through its 3 fundamental sectors (civil-environmental, industrial and ICT).

The synergy between skilled engineers, can provide solutions quickly with a methodological and monitoring approach through the areas of intervention to reach the SDG not only from the point of view of green agriculture, but also considering the four betters: better production, better nutrition, better environment, better life.

However, it is a system that of accelerators within the new FAO Strategic Framework, which will have to be implemented according to the SDGs, also given the considerable technological changes and above all climate change, a fundamental element of this system are women, bearers of innovations also for young people. It would be essential to think in terms of the project, grouping the SDGs and considering the CSAs.

Results

What Engineering solutions?

Globally, food and agriculture can highly benefit from the fourth industrial revolution (or specifically in agriculture referred to as agriculture 4.0) which is driven largely by large sets of data (big data) with innovative digital technologies in convergence with science and technology. This creates an unprecedented opportunity move towards an agriculture sector that produces more with less, needing less water, land and energy, saving biodiversity and reducing carbon emissions. Agricultural innovation is broader than technology, and is the process whereby individuals or organizations bring new or existing products, processes or ways of organizing into use for the first time in a

specific context, to increase effectiveness, competitiveness and resilience with problem- solving goal. Innovation also encompasses modernization of policies and business models for agri-food systems.

The "accelerators" are valid tools from an engineering point of view which can give a new model for the design of plants that introduce digital intelligence to supervise industrial workflows and as a key for research and product innovation and service.

The optimization of production layouts and connectivity between machines, systems and intralogistics handling, in order to customize products more and make processes more flexible and efficient thanks to the introduction of the CPS - Cyber-Physical System (hardware tools able to connect to the network and interface with information technology) within factories, would increase control over processes, enhance automation mechanisms and finally improve collaboration between people, machines and software.

To achieve the efficiency objectives, operations must necessarily be optimized through the principles of lean smart production, which allow the minimization of lots and the just-in-time management of materials, orders and supplies, minimizing stocks and ensuring greater flexibility to meet the needs of the market.

The reorganization of processes as a prerequisite of Smart Manufacturing also involves the collection, management and distribution of data, which must be reorganized to allow streamlined, fast and functional information flows. It is therefore necessary to identify the key parameters and the indications necessary to refine the decision-making process at every level of the production process, ensuring timely communication between people with the right tools.

The introduction of biodegradable materials in product packaging processes, the introduction of smart supply chain management in transport logistics processes with the use of a fleet that can use intelligent transport systems would all facilitate the reduction in the consumption of energy.

The introduction of the blockchain in agriculture with the aim of simplifying each phase, from cultivation to food distribution, offering all interested parties a single certified source of information from the entire supply chain.

The use of agricultural systems to limit soil consumption, taking the opportunity to produce clean electricity, giving space to agricultural crops especially in the peninsular areas.

Finally, the “Accelerators” can make the difference in reaching the SDGs faster because the climate change underway, on our planet, is evident. We do not have a planet B!

Recommendations:

1.Sustainability: Sustainability is an urgent and universal concern. We can no longer postpone our efforts to combat the climate crisis. The time to act is now, for companies, even those in the agricultural sector, the challenge is that of sustainable transformation is to balance the need to keep the business moving by making changes to achieve your sustainability ambitions.

2.**Technology**: The use of technology through digital agriculture is distributed throughout the agro-industrial chain (supply chain), with applications and technologies from cultivation, to industrial transformation, to packaging, to sales, passing from logistics to the final consumer, it is necessary to take care of these. challenges with continuous scientific research, aiming at the use of biodegradable materials, the inclusion of agrovoltaic systems, an approach in industrial processes through "lean production", producing what we consume, zero waste!

3.Big Data To address the growing challenges of agricultural production, it is necessary to better understand the complex agricultural ecosystems, it is necessary to implement modern digital technologies that continuously monitor the physical environment, producing large amounts of data at an unprecedented rate, the analysis of these big data would allow farmers and companies to extract value from it, improving their productivity.

4.Collaboration Develop new professional collaborations capable of funding specialized project teams to face the new challenges of climate change from a specialist point of view, together with engineers, agronomists, geologists, architects, urban planners we can make a scientific and concrete contribution to the new challenges for achieving of the 2030 Agenda SDGs

5.International Organization To work so that all the work carried out in these years of research on the SDGs is made available to the community, it would be desirable to work in synergy with organizations such as: FAO, UNESCO and WFEO to weave the new strategies and be protagonists and influence with prize proposals capable of find technological solutions to deal with this climate change.

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Overview on Disaster Management that Happened from The Recent Tragedies Nature Disaster Events in Malaysia

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Abstract

From year 2020, there is the battle of Coronavirus (COVID 19 disease) between humans, which is still happening presently and affecting our lifestyle with the practices of new norms as compared to the past. Meanwhile, in getting to reduce the infection rate of COVID 19, there are few obstacles and challenges that have been faced by the Malaysians from Peninsula and East Malaysia recently. The incidents of landscape and heavy flood that caused the tragedies happened at different states of Malaysia in these past few months before the coming year 2022. These multiple incidents had caused the loss of 41 lives, evacuated over 125, 000 victims, estimation of total loss could be up to RM 20 billion from the households and private property that impacts our country's economy. Thus, it is important that the implementation, prevention and awareness of disaster planning requires before and after the devastating impacts carried by the natural disaster, in order to prevent the next occurrences of tragedies worldwide. This review is more emphasizing on disaster planning from the aspect of government policy, social responsibility or global perspectives and other factors that are related to the topic of climate change in Malaysia.

Keywords - Nature disaster, Covid, Flood, Tragedies

i. Introduction

Topic of climate change has been discussed in global response over years and years with various implementations and prevention of getting worse on the Earth, and in giving a better environmental impact to the current and future generations. However, the impact of extreme weather is massive changes on weather patterns that affect every country, including the human health, ecosystem, socioeconomic and other related sectors (Taib et al., 2016 & Yusoff et al., 2018). For example, the disasters such as the bushfires in Australia (January till March 2020), severe flood in Henan province, China (July 2021), Earthquake in Harti (August 2021) and the recent happening in Hunga Tonga Hunga Ha'apai volcano on volcanic eruption. This is an undersea volcano in the Pacific Ocean, just 40 miles away to Tonga that happened on 15 January 2022, with a massive volcanic explosion because of the degassing of magma. The amount of energy released is equivalent to 5 Megaton of TNT in estimation. Meanwhile, it released the volcanic ashes and dust after the eruption that formed the ash cloud into the sky, causing the concern of air and water pollution in Tonga. This eruption also triggered the tsunami and severe flood to Tonga, and across the Pacific Ocean to North and South America such as California and Peru. Multiple countries had issued warnings to the coastal regions about the tsunami risk

such as Japan, Fiji and New Zealand.

Moreover, the classification of the disaster has been classified into natural, human induced or hybrid, carrying along the devastation to the people, environment and society. The victims might experience high stress levels, loss of properties and lives, psychological issues after the traumatic events (Taib et al., 2016). According to the European Commission, the root cause of climate change is the greenhouse effect with the emission of greenhouse gases (GHG) that traps the heat in the atmosphere of the Earth. For example, the GHG includes the Chlorofluorocarbon (CFC), Methane (CH4), a hydrocarbon gas that highly contributed approximately 25 times of global warming potential (GWP) than the carbon dioxide, and causing the effects of thinning ozone layers, global warming, rise in temperature as well. Hence, the highlighted consequences of climate change, including the formation of heat waves, heavy rainfall, tropical cyclones or diminishing of sea ice, snow cover on Arctic and Antarctic regions. Those disaster events could happen in the way of human induced disaster due to the practices of daily activities.

ii. Relate Works On Disaster Management & Climate Change

Disaster management has divided into four actions with the timeframe on before, during and after the disaster events happened. The process included mitigation, preparedness, response and recovery with different strategies that would be implemented. The purpose of disaster management is to reduce the loss and damage of the properties, lives and livelihoods (Lin et al., 2021 & Yusoff et al., 2018). Moreover, the planning stage of disaster management is important to prevent the huge losses during the next disaster events and minimize the effort on the disaster relief. Thus, it is required to be attentive and put more effort on this stage (Yusoff et al., 2018). Figure 1 shows the cycle of disaster management with the sequence of mitigation, preparedness, response and recovery. For the activities on disaster preparedness, it is termed as 'dimension' that constructs of the disaster related works, is tangible and measurable action to achieve the goals of the disaster preparedness (Hisham et al., 2019). Several approaches on the study of preparedness had proposed aspects to social, economic, environmental and physical by using area or flood vulnerability indicators. Meanwhile, the study of calculating the possibility of the occurrences of flooding and flood control capability or the safety assessment techniques to identify the potential risk of the disaster might happen (Lee et al., 2020). This is because of increased land areas for the developments of industrialization and urbanization in those large population areas. Rasch analysis, based on the theory of items response in planning of the preparedness such as the routine monthly meeting as discussion on the planning of emergency, recovery, training programme or site visit on high-risk hotspot areas that presented in one dimension of measurement. These actions are measured by the mathematical function in probability of success on such planned preparedness activities, and could vary on the difficulty of the planned task and ability of action taken from the related parties (Hisham et al., 2019).

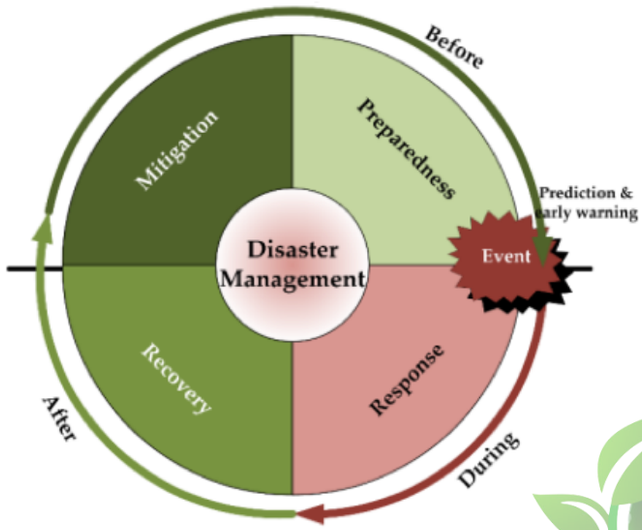

Fig.1 The cycle of disaster management (Lin et al., 2021)

Moreover, framework of Integrated Catchment Modelling (ICM), a measure of the flood mitigation that was implemented on the disaster planning which proposed the use of hydrodynamic modelling with the flood hazard maps in evaluating the existing development of the structure plan to an area. This methodology is to investigate based on the flow data along the river system, in order to improve the structure of the river channels that try to reduce the floodplain and minimize the damage to the affected areas. The advantage allows the study of the mapping that the flood happened previously, to identify the causes and run off control. This also provides the improvements that get the protection against the flooding based on the analysis from the catchment of hydrodynamic model, with the predicted value of Average Recurrence Intervals (ARI) in years (Shahrulnizam et al., 2020).

A. Preparedness on Disaster Planning

The preparedness on the disaster management cycle is implemented before the disaster happens and it is required to prepare the emergency or contingency plans that are useful for the prevention from the disaster, such as the use of the monitoring and detection systems before and throughout the events. For example, the implementation of the disaster warning system, an earthquake early warning system (EEW) used in Japan and Taiwan by using the seismic sensors networking for sensing the location of the waves before the earthquake hits the country. This is because their geographical location is located on the path of Circum-Pacific Belt that surrounds the Pacific Ocean, known as Ring of fire, and is having the active volcano and vigorous earthquake activities due to convergence of the plate tectonics on Eurasian and Philippine. Thus, the monitoring and announcement system is useful to alert the authorities and make announcements to the public with the integration of IoT applications. According to the Taiwan's Central Weather Bureau (CWB), they are having hundreds of seismic stations such as the Central Weather Bureau Seismographic Network (CWBSN), Taiwan Strong Motion Instrumentation Program network (TSMIP) and Taiwan Geophysical Network for Seismology (TGNS) in monitoring the motion of the strong waves, in order to prepare the next earthquake and respond according with the corrective action (Central Weather Bureau Seismological Center, n.d.).

B. Structural and Non-Structural Mitigation

Structural defines as the measures that used the physical changes to prevent disasters from happening and reduce the loss from the events. This mitigation is required to apply the scientific and engineering principles or geographical location in order to mitigate the disaster events (Mhatre et al., 2021) For example, the construction of the seawalls or concrete that minimize the damage when a strong wave hits at the coastal areas by using the design of the curved seawalls to weaken the waves by deflecting them upwards and back to the sea, without reaching land. Furthermore, non-structural involves the use of regulation to limit human activities and society by planning and providing the policies and guidelines. This is to improve on the disaster response and management planning during the disasters that happen. The methodologies have included the awareness campaign and education program to convey the information on safety and survival during the occurrence of natural disaster, in order to raise the public awareness (Saravanan, 2016). When rapid urbanization and industrialization take place nowadays, the emission of CO2 and GHG is required to reduce their emission that protect our environments but still reserve the rights for the business economy sectors. Hence, the policy on the emission mitigation such as 'The Paris Agreement' which limits the global temperature increased by 1.5°C, be more sustainability and more solution to decarbonize our economy.

C. Response and Recovery from Disaster Event

From the past disaster events, the post disaster activities for recovery are giving the timeframe in

reconstruction on the affected area. Those response actions that were planned during the mitigation and preparedness stages would be evaluated and analysed on the disaster events. All response action and operation should be reacted immediately with the proper planning and strategies for the rescue of the affected victims. From the examples in the incident of the Japan Earthquake and Tsunami that happened at Tohoku region in March 2011, the rescue teams, fire crews and other volunteers of Red Cross were providing medical assistance, setting up evacuation centres, and emotional support for the victims and survivors. At the same time, the effect of the earthquake had triggered a tsunami to Fukushima and 3 nuclear reactor plants were damaged and it was causing the leakage of the highly radioactive radiation to the environment and surrounding area. Before this tragedy happened, the seismologist warned that it was a large earthquake and tsunami might happen but it is a small possibility that it hits the coastal region. Some of the critics claimed that this tragedy happened because of the lack of preparedness from the response of the government and Tokyo Electric Power (TEPCO) in such an event, and fails to meet the safety requirement. Even though Japan's government had set a 10 years' timeframe for the recovery and reconstruction of Fukushima, the fear of radiation is still implanted into the mindset of the Fukushima's residents. The government also tried to change the perception and rebuild the image of Fukushima during the Tokyo Olympics 2020 with its concept of "Hope Lights our Ways" that appreciates the efforts made from those nations that are trying to reconstruct the disaster affected area (International Olympic Committee, 2021). Thus, the Olympics organizer had implemented in the way of tourism, art and culture programme and set up the opening ceremony's torch relay in Fukushima as the recovery effort to this tragedy.

iii. Implementation on Urban Flood Event

Malaysia, one of the Southeast Asia countries located at latitude of 3∘ 8' in North and longitudes at 101∘ 41' in East. A tropical country near the Equator and its weather is almost always hot and humid in a year. Total coverage area of Malaysia is about 329,847 km2 in west and east Malaysia and it is rich in natural resources with the minimum number of natural disasters happening in a year. During the monsoon season, there is some severe flood at the central and east coast of Peninsula Malaysia and minor areas in East Malaysia. Malaysia's Agensi Pengurusan Bencana (NADMA), a government disaster rescue department, will set up and prepare the flood operation over the east coastal area for the evacuation and coordination of the rescue to the public. However, on the day of 17 December 2021, a heavy rainfall over the Peninsula Malaysia, with the effect of a tidal surge that struck Malaysia, in resulting the occurrence of urban flood, especially the west coast area including the city of Kuala Lumpur, Selangor, Negeri Sembilan. Urban flooding is a very rare and unusual event that happens in Malaysia, by comparing the last severe urban flood was about 26 years back, in Year 1995, the flooding happened at Taman Sri Muda, Selangor. Meanwhile, the public were stuck in offices or roads because the blockage of high levels of rainwater blocked the roadways and the public cannot be homed during that heavy rain Friday night. At the same time, the occurrence of the water cut, electricity disruption and lack of food and rescue impacted the flood victims, especially the high-density population in KL and Selangor with continuous rain in 3 days. The flooding was further affected into different states with continuous rain within 2 weeks and it was across over 8 states.

A. Response Action from Government and Society

According to the emergency plan of action from the International Federation of Red Cross and Red Crescent Societies, the rescue operation has cooperated with our government Malaysian Civil Defence Force (APM), Social Welfare Department (JKM), National Disaster Management Administration (NADMA) in providing the hygiene kits, emergency medical

assistance and local fundraising activities (Reliefweb, 2021). From our official government authorities, they conducted the rescue of the trapped flood victims and transported them to the evacuation centre, cleared the muddy road and reconstructed the damaged properties. Furthermore, the government of Malaysia also set up a financial fund for the affected flood victims, by providing compassionate aid, with a total fund of RM 100 million to the public for the repair of houses and infrastructure damaged by the floods. However, the opposition parties claimed that the leading government was incapable of handling the flood event because of the shortage of manpower, lack of assets (rescue boats) and slow response action and planning. Example, the incident of the flood victim has broken into a hypermarket for taking the food supplies and other valuable items, without getting any assistance from the official authorities after 2 days of this urban flood. Previously, the weather forecast predicted that the only east coast states will get affected by the northeast monsoon surge.

Unfortunately, the statement from the Malaysian meteorological department had been made that the monsoon hit over the west coast and the rainfall was getting worse with the extended rain warning over the west coast. The Prime minister claimed that the warnings of continuous heavy rains had been ignored by the certain parties including Selangor's disaster management. Meanwhile, 6 bad weather warnings had been issued out from the meteorological department but neglected, in causing the chaotic situation that occurred on the first day flooding in Selangor that failed to take the response on rescue and planning immediately after the formation of this sudden and unexpected flood.

Fig. 2 Situation on urban flood in Selangor

From the non-governmental organization (NGO), plenty of work had been done by them during the urban flood in achieving the flood relief efforts. Example, the Buddhist Tzu Chi Foundation, in providing the cleaning activities, food and cloth packs for the flood victims that affected the most in Hulu Langat district and Taman Sri Muda in Selangor. Moreover, other organizations like Yayasan Ikhlas, Kembara Kitchen, Gurdwara Sahib Petaling Jaya contributed the food kits and fundraising for helping the affected flood victims as well. During this period of flooding, a new hashtag of '#DaruratBanjir' and '#KitaJagaKita' movement is spreading virally again, showing the spirit of Malaysians for helping each other regardless of the races during this difficult time. This situation is similar to the White flag initiatives with the hashtag of #BenderaPutih during the peak of Covid-19 infection cases in Malaysia in July 2021. However, some of the affected victims still have not gotten any assistance from the government for the reconstruction of their home, even though the flooding had passed over 2 weeks.

B. Activation of SMART Tunnel

The development of SMART tunnel is an underground tunnel, 9.7 KM in total that is linked from the city centre of Kuala Lumpur to Southern gateway (includes the KL-Seremban Highway, Sg. Besi Highway). It has been designed and developed into 3 different levels, with the structure of first upper and middle lower decks for the unidirectional roadway, in order to reduce the congestion that diverts the traffic flow in or out from the KL city. Moreover, a waterflow channel is located under both decks to divert the excessive river water from the Sungai Klang, and bypass the upper and lower decks of the roadway to the Sungai Kerayong (Isah & Ali, 2015). Four different operations from the SMART tunnel will be reacted accordingly depending on the seriousness of the flood events. Under a normal condition without the occurrence of flood, both roadways are allowed to be used as traffic pathways for the public, whereas for second operation, the roadways are still able to be used when there is a mild rainfall with the detection of flow rate within 70 till 150 m3/s of the waterflow. If that is the overflow at the Sungai Klang, the installed automated water gate will be closed and let the rain water flow into a holding pond as a temporary water storage. For the third and last operating modes as the severe rainfall, in leading to the occurrence of flood event, the SMART roadway tunnel is fully closed and the upper and lower decks become the water tunnel for the pathway of excessive flood water, and transferred from the holding pond to the attenuation reservoir that located at Taman Desa. Before the diverting of flood water, these 2 operation modes are required to evacuate the road users from the SMART tunnel before the closure of the tunnel and the situation needed to be declared that the flowrate of flood water is exceeded 150 m3/s by the Department of Irrigation and Drainage (DID) from Ministry of Environment and Water. Hence, the flood water will continue to flow to the Sungai Kerayong if that is still overflowing from the attenuation reservoir.

Figure 3 shows the various operation modes of the SMART tunnel that diverted the excessive flood water and bypassed the SMART tunnel.

According to the Syarikat Mengurus Air Bandar dan Terowong Sdn Bhd (SMART), it declared that this urban flood that happened on mid of December 2021, 5 million m3 of flood water had diverted from the Sungai Klang to the Taman Desa reservoir after the SMART tunnel has been activated and operated about 22 hours due to the high rain intensity in Kuala Lumpur on that day. Meanwhile, the volume of the flood water that diverted from this urban flood event exceeded the capacity of the SMART tunnel, 3 million m3. The operation of the pump houses was operated at the maximum capacity and closure of the tunnel for inspection and clean-up activities. Even the KL city area such as Masjid Jamek was experiencing minor flooding but the trapped flood water drained faster than the other states because of the operation of SMART tunnel that diverted the flood water from the city. There is approximately 45 % of the flood water that had been mitigated by the SMART tunnel in reducing the seriousness of the flooding at Klang Valley. The conceptualization of this SMART tunnel has been discussed by the parliament, as suggesting the construction of another tunnel around the region of Shah Alam, Selangor to mitigate the flood events in future.

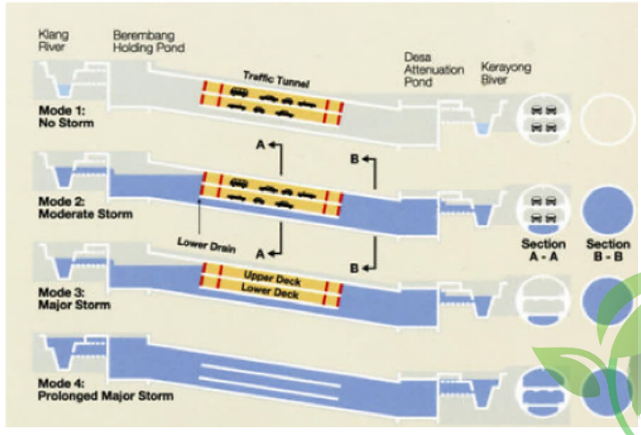

Fig. 3 Mode of operation of the SMART Tunnel

C. Weather Monitoring and Announcement system

For the monitoring and announcement system, it has responsible by the Malaysian Meteorological Department (MetMalaysia) under the department of ministry of environment and water, its role is to forecast the weather, real time monitoring on the earthquake, tsunami, thunderstorm, tropical cyclone and heavy rainfall from Malaysia and other countries. From the report of the weather outlook, the weather forecasting from October till December 2021, is predicting the rainfall is slightly above the average, that over the states of Northern, Western Perak, East Coast, Sarawak and Sabah by using the modelling of seasonal forecaster such as the NCEPCFSv2, JMA Ensemble Prediction System. Before the rainstorm started, a "Borneo Vortex" had been identified by the weather system that was moving towards the Peninsula Malaysia on 14 December 2021. The MetMalaysia had issued the warning of the continuous heavy rainfall at the east coast of Malaysia on 15 December, and further announced the warning to the entire Peninsula as the storm intensified in the next 3 days. In Selangor and Kuala Lumpur, the recorded rainfall was about 363 mm on 18 December 2021. This amount of rainfall is more than the recorded average rainfall for December in Selangor, 250 mm. This rainfall just happens about a day. Figure 4 showed the weather announcement on 18 December 2021, 10.30 pm, and indicating the yellow, orange and red colours of the continuous rainfall with the extended warning announcement.

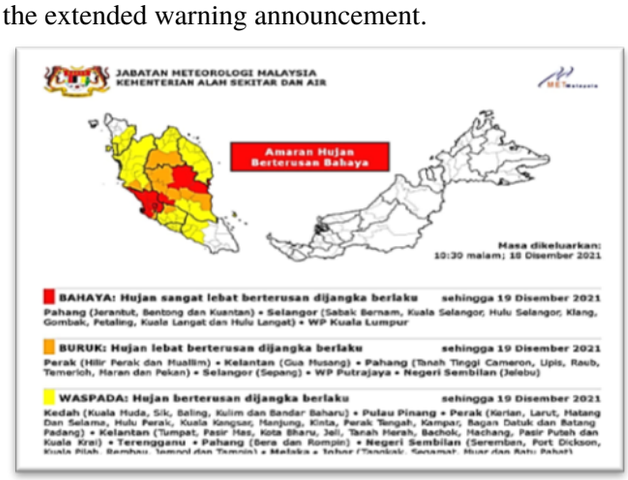

Fig. 4 Weather Announcement in Malaysia on 18 Dec 2021 (Eco Business, 2021)

iv. Discussion

The response action from this urban flood event, the disaster management is not satisfied by the affected victims because of the slow response and lacking on any proper planning in rescuing and recovery. This is because the flooding was not a new disaster that happened in Malaysia. Hence, it is reflecting the response from all of the government agencies should be more emphasizing on disaster planning before the actual disaster comes and be prepared for the worst case, instead of trying to neglect and mitigate the responsibility, or ignoring the risk of every single disaster. Thus, it should be tried to figure out the root cause of such disaster events such as the construction of drainage systems, reduction of rubbish and gases emission that affect our environment. At the same time, the government should be educating the nations on safety measurement when there is an emergency situation of disasters in order to gain the awareness of the public. This is because the disasters cannot be avoided and should not underestimate its effect because of the massive changes in weather patterns nowadays. Furthermore, a complete set of planning, assets, equipment and manpower are required with the updated guideline from time to time for the references to the public and future use. Overall, the flood tragedies that happen in Selangor, supposedly can be managed better and avoided by the authorities. The challenges on prevention in future include the gain of awareness, good coordination in responses from organizations and community with preparation and mitigation planning in advance. For the suggestion on constructing a new mitigation tunnel, its cost is around 1.88 billion ringgits, which mitigates the flood water level effectively from the city to another places. However, this is not a total solution that kept constructing the tunnels as the planning of flood preparedness due to its high cost, long duration of construction and it is not efficient that serves as disaster planning. It should be more focused on the rapid development of construction or infrastructure, and the concept of sustainability in order to reduce the

potential risks from the disasters. At the time, the cooperation on disaster planning should be based on the effort from every community, with the involvement of bottom-up approaches, rather than the top-down approaches that the decision making is done by the government or related authorities.

iv. Conclusion

The concept of urban resilience should be taking action in order to plan, prepare and act for the responses, and protect people's lives and property. This requires a lot of effort from the stages of planning and implementation, with the positive impacts for today and in future. Even though the measures of disaster preparedness and mitigation from the existing government have been implementing the planning activities and providing the support and aid during the recovery phase. The improvement can involve the cooperation and awareness from the communities to discuss the issues on the flood management with the expertise, in getting better coordination and responses when the disaster happens. Furthermore, the future work can include more related disaster modelling approaches in obtaining different degrees on the flood extents and elongate the value of ARI.

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Assessing the Vulnerability of Infrastructure to climate related disasters using Disaster Resilience Scorecard method

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Abstract

While the impacts of climate change have been increasing yearly, so have the frequency and intensity of natural hazards such as tropical cyclones and flood type rainfall events. Many countries and cities are finding it challenging to manage these natural hazards as they turn to disasters and cause destruction of property, loss of financial resources, and at times loss of lives. Mauritius is a tropical country which has been regularly been experiencing tropical cyclones and flooding events during the wet summer season. For the past few years, the negative impacts of these events have been growing. To better handle these natural disaster events, the need for the country to adopt the concepts of a resilient city, similar to practices at international level, is strongly being felt. A resilient city is a city which is able to bounce back quickly to its original operation state after a major disturbance. The approach towards building resilience of a city to natural hazards has been proposed by the UNDRR in the form of a disaster resilience scorecard method(UNDRR, 2017; UNDRR, 2020a). This method has proved to be very beneficial as it allowed users to develop a baseline measurement of current level of disaster resilience of the city while creating awareness and understanding of resilience challenges that the city faces. In addition, a methodology proposed by the UNEP, the community risk profile (CRP) is another method which provides a city an approach to developing a risk profile analysis. The CRP helps cities to understand how their vulnerability to different natural hazards varies. In this research project, the study area chosen was Réduit owing mainly to the prevailing activities, which is mixed use, including residential and commercial. While the CRP tool highlighted how the intensity and frequency of the natural disasters, flood and cyclones, were affecting the study area, the UNDRR disaster resilience score card method focused on the highlighting the vulnerable zones of the study area. The most vulnerable areas in the Réduit village were noted as well as the need to map similar information at village level. Identification of the highly vulnerable sites was followed by the identification of appropriate mitigation measures needed to reduce the vulnerability of the study area to climate related disasters and increase its resilience. The recommendations were for a different approach to the design of the drainage system, dikes alongside the rivers and a holistic approach towards flood management that will include sustainable urban drainage systems.

Keywords - climate resilient infrastructure; disaster resilience score card; small islands; hydrometeorological hazards; resilient cities, SUDS.

Introduction

Climate change is becoming a challenging factor that will increase the flooding events and hence sites at risk to floods, in the near future. The main cause of the climate change is obviously the greenhouse effect. NASA (2016) reported that the average surface temperature has increased about 0.9 degrees Celsius and 2016 was the warmest year. The oceans which cover 71% of the Earth surface have also recorded an increase in its temperature by 0.4F. Another evidence of the rapid growth of climate change is the rising level of the sea and the high occurrence of extreme events in many countries (PNAS, 2018). Many countries have been witnessing a large number of extreme rainfall events throughout the year. Climate change has been having increasing the severity of floods and droughts occurring in some countries while increasing the strength of hurricanes, tropical cyclones and tornadoes.

It is fully appreciated that natural hazards such as cyclones, torrential rains, tornadoes and earthquakes cannot be prevented, but good planning can help to minimise their impacts. Floods are one of the natural principal hazards that goes beyond boundaries touching a large part of the society. Floods severity are determined by different factors such as the rainfall characteristics, the water use and also the presence and the carrying capacity of stormwater drainage networks. The rise of flooding events in many countries is also contributed by the increase in urban sprawl and inappropriate land use management and development. The increase in population promotes the migration of rural areas into urban areas. Urban sprawl (Serre & Heinzlef, 2018) refers to the quick extension of geographic extent of cities and in some areas has caused an increase from 10% in the 1990s to 50% in 2010. So, this quick extension of cities is very detrimental as the cities do not have enough equipment and facilities to manage the natural hazards and their risks. This problem is nowadays being addressed in a more holistic manner, that of resilient cities. Resilient cities (Gonçalves, 2018; UNDRR, 2020b) are being promoted at international level, as they can the impact of disasters better, hence protect human life, absorb the impact of economic, environmental and social hazards and ensure sustainable growth. Since cities are complex and dynamic systems comprising of buildings, recreational areas, services, road networks and institutional departments, applying the concept of resilient cities is also a complex and involves several stages. This stage wise approach is a necessity as it will ensure that cities are able to foresee problems areas and address same in the development management plan so that the city can eventually operate in harmony while accommodating the failure of any component of the complex system. In this research project, we are going to determine the resilience of a community to climate related disasters and to propose some new measures in order to strengthen the resilience of the community.

This research study aimed at assessing the level of resilience of a complex and mixed use developed area which houses important educational and commercial institutions, by using the disaster resilience scorecard and the CRP method. The study had as objectives; to assess the strengths and weakness of the area in the context of climate resilience and propose adaptation and mitigation.

Literature Review

Natural hazards such as tropical cyclones, landslide, volcanic eruptions, floods and earthquakes can cause significant damages to a country. The impacts of climate change has been growing over the past few years, with the increase in the intensity and frequency of natural hazards. During the last few years, many countries in different parts of the world have been experiencing increasing flood problems due to climate change. A recent study by the World Resources Institute (WRI, 2020) reported that by the end of 2030, almost 147 million people will be affected by pluvial and fluvial flooding and that damages sustained will range from $174bn to $712bn per year.

Early 2020, the capital of Indonesia, Jakarta was flooded and this resulted in loss of lives, 53 death cases (Karmini, 2020). The main reason for this flooding was the lack of an effective drainage system. The situation returned to normal after some days, and this resulted in major disturbance of life in the region. Similarly, around 150 people have died in Brazil due to flooding and landslides in the year 2020 (Claudia & Melgar, 2020). It can be said that global warming has been contributing a lot to increasing extreme events in the country. Each summer, monsoon rains destroy Brazilians with floodwaters flooding the streets and landslides afflicting poorer neighborhoods and favelas constructed on steep slopes, mostly without adequate drainage or sanitation. In Guarujá, Brazil, it was recorded that there was 282 mm of rainfall in just 12 hours, more than the long term monthly average rainfall of the month of March. The main reason for the increased amount of flooding events in Brazil is due to the urban sprawl and the lack of effective drainage systems. As a result of flooding, landslides also occurred in some areas in Brazil. In the past few years, the island of Mauritius has been experiencing flood problems (Defimedia, 2022) and this has caused a lot of damage.Though Mauritius has been investing heavily to construct protective infrastructure such as drainage system, yet there are still flood problems in the island. Similarly, globally infrastructural losses and socio-economic losses are significant from flood and consequent landslides events, and the need for mainstreaming climate change in infrastructural development is getting wider consideration over time.

Infrastructures are the backbone of the development of a country and loss of infrastructure implies economic losses. This explain why there is a move towards building resilient infrastructures in particular critical infrastructures. The term resilience (UNISDR, 2015) has been defined as the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. To clearly understand the concept of resilience, we need to know what a critical infrastructure is. Critical infrastructures (UNISDR, 2009) are defined as the primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a society or community, both in routine circumstances and in the extreme circumstances of an emergency. These critical infrastructures are very important for the proper functioning of a community. And the potential destruction of these infrastructures can affect the whole community by weakening its defense and its economic organisation. Critical infrastructures vary from communities to communities and include the following systems:

1. Transport systems. (Airplanes, Ships)
2. Water and Wastewater systems
3. Health care systems. (Hospitals and clinic)
4. Emergency services. (Police and fire station)

Resilient infrastructures reduce the risk of cascading negative impacts. As the communities are interconnected, so when one part of the system fails, this can affect the systems of another community. The cascading effect normally increases the impacting areas and generates secondary effects which can affect the whole country. In practice, there are 3 factors which are used to design a good infrastructure system: integration, coordination and sequencing. Instead of doing large projects, a good infrastructure system should consist of smaller and interconnected parts, a system which take into consideration the welfare and comfort of the community they serve. Urban resilience is a term used to highlight the response of a city to climate related disturbance. On one hand, a resilient city is designed so that it has the capacity to maintain functions during crisis and on the other hand the design of the city has to ensure the capacity of the city to reconstruct itself after disturbance. A proper strategy of urban resilience has these 3 capacities: Resistance, absorption and recovery, namely;

• **Resistance**: Resistance capacity is used to analyse the physical damages caused to a community. Firstly, for this capacity, the focus is on the risk management and actions which are being used in the community to accommodate for potential damages of a system. Serre & Heinzlef (2018) estimated that the more the technical system is damaged, the greater is the possibility of a malfunction of the system and the more it will be difficult to restore it to service.

• **Absorption**: For this capacity, it is expected that when the infrastructure systems in a community have failed, they will provide potential alternatives to help the community. So, we should analyse the systems configuration so as to characterize its redundancy.

• **Recovery**: Recovery is the capacity of the city related to the time required to restore a damaged system to the normal service. When the system has returned to normal service, it can find a new mode of operation.

As a support to the international communities, the UNDRR devised a methodology to build climate resilient cities, the disaster resilience scorecard method for cities. This tool was launched in May 2017 by the UNDRR. It allows the local authorities to assess the disaster resilience of a city and also integrates the implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030 United Nations, 2015) in the process of building resilient cities. This tool provides for several benefits:

1.It gives measurement of the current level of disaster resilience.

2.It allows communication and collaboration between key stakeholders.

3.It increases the knowledge and perception of resilience challenges.

4.It helps to develop a resilience strategy.

The scorecard tool helps cities to deal with risk by considering the city‘s hazards and risk ranging from ‗most probable‘ to ‗most severe‘ risk scenarios. It provides a set of assessment to assess disaster resilience structured around the new 10 Essentials for Making Cities Resilient. Essential 1 to 3 covers the city governance factor, essential 4 to 8 covers the integrated planning factor and essential 9 to 10 covers the response planning factor and this is illustrated in Figure 1.

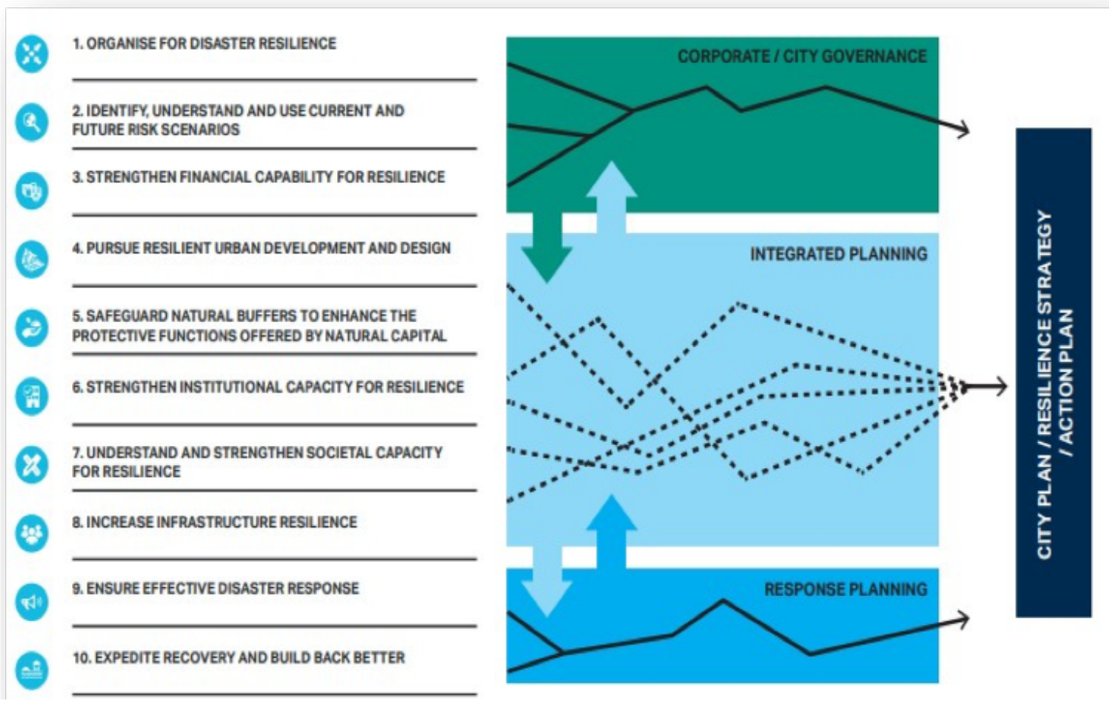

Figure 1: The 10 essentials for Making Cities Resilient (Source: www.unisdr.org)

The disaster resilience scorecard has two different level of assessment namely the preliminary assessment and the detailed assessment. The preliminary assessment has in total 47 questions each with a score of 0 to 3, whereas as the detailed assessment has in total 117 questions each with a score of 0 to 5.

Methodology

The objectives of the study were to conduct a holistic evaluation of the study area, Réduit Village, based on prevailing facilities, existing legislation, and risk of torrential rainfalls, to map its level of resilience to climate change. From a detailed literature the most comprehensive and adapted method was the UNDRR disaster resilient assessment framework, the UNDRR was identified. This method is based on a score card method and is complex addressing several factors which in combination contribute to the vulnerability of a region to climate change. This method is tailor made to the local authorities and is two staged. The first one being a preliminary assessment and the second one, the more detailed assessment address the internal commitments towards building a resilient community by the local government.

First a site visit and a field survey was carried out. By inspecting the study area clearly, information was gathered and noted. All the elements such as the existing protective infrastructure, buildings and water bodies on the site were identified. While carrying the site survey, the direction of water flow was noted at different places of the study area by approximating the slope via visual inspection. This preliminary analysis was used to develop a first vulnerability map, highlighting the high risk and low risk areas of the study area.

Next the more holistic approach, the UNDRR disaster resilience scorecard method was used to assessment the study area. Before using the scorecard method, all the relevant stakeholders were identified. By using the preliminary analysis, we had to answer and rate all the questions indicators for the 10 essentials for making cities resilient on a score of 0 to 3. For some essentials, appropriate data and information was gathered online to answer the questions and for other essentials, assumptions were made since the required data and information are not available online. After properly answering and rating all the question indicators, the scorecard method tool automatically produces the results in form of a matrix which is helpful in analysing the results.

Next, the community risk profile assessment was used to conduct a risk profile analysis of the study area. As the community risk profile tool was not available online, the tool was created on excel by using the guidelines provided by UNEP. For this method, there were some surveys which were carried out on site so as to know the opinions of people which visits frequently and lives in the study area.

Since we are concerned with climate related disasters in this research project, only tropical cyclones and flooding have been considered. The community risk profile assessment is based on the following factors: the presence, the intensity and the frequency of the hazard; the elements at risk, the vulnerability of each group, the knowledge of risk and finally the prevention, protection, emergency preparedness and resilience strategies prevailing.

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The results of the three analyses were combined to produce and interpret the vulnerability map to flood events in the village of Réduit. The actual level of resilience of the study area was mapped and the

strength and weakness of the area were highlighted. This was definitely useful in identifying and applying mitigation measures.

Data Collection & Data Analysis

The village of Réduit covers an area of around 55.67 Hectares, out of which 23.2 % is under agriculture, 8.6 % is under forest land, scrubs and grazing lands, 0.9 % under reservoir, ponds, swamps and rocks, 10.2 % is under infrastructure such as road and footpath and 57.1 % under built-up areas. It can be observed from Figure 2 that the built-up areas and the road and footpath account for 67.3% of the total area. So, it can be said that with a relative large percentage of the total land surface, being under impervious area, the study area will be prone to flood problems. The area is characterised by the intermediate lava series which has given rise to a water body in the region. Normally during the summer season, Réduit has an average rainfall amount of 100 mm, but in 2019 the average amount of rainfall was 308.5 mm

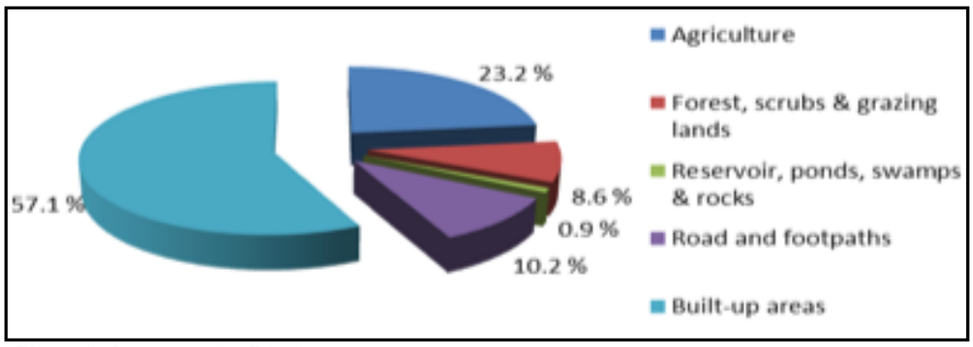

Figure 2: Land uses for Réduit.

Based on the landuse patterns of the study area, for the purpose of the analysis the area was divided into 6 parts namely Area 1, 2, 3, 4, 5 and 6 as shown in Figure 3. For the purpose of this paper, data collection and analysis in one of the zone (Zone 1) only has been presented and discussed.

Figure 3: Sub division of the study area (based on landuse)

Field Survey

Table 2 is an example of data collection during the site survey in Zone 1:

Site Survey For Research Project		
Site: Réduit Area 1		
Ref: SS01		
Features Present:	**Yes/No**	***Comments***
Roads	Yes	There are 4 roads which the residents use.
Buildings	Yes	Around 50 houses, 4 shops, 3 religious buildings, 1 school and a stadium are present
Protective structure on buildings	No	No protective structures found on buildings
Existing protective infrastructure	Yes	Only drains are present in certain places.
Constructing protective infrastructure	Yes	Drains are being constructed in certain places
Infrastructure affected by flooding	No	None
Water bodies	Yes	Grand River North West is present near the site
Assessment of damage	20%	
Nearby emergency services	Yes	Quatre Bornes fire station is about 7 minutes away, Moka police station is 5 minutes away and Victoria Hospital is about 10 mins away.

Table 2: Area 1 and its features

While carrying out site survey in Zone 1, it was noticed that the only existing protective infrastructure against flooding was the drainage system and it was only available in certain places. Some drains were even in bad conditions and in some places, drains are now being constructed. All the water run-off normally goes to the nearby river, GRNW. As illustrated in Figure 4, in Zone 1, there are 3 high risk areas:

- The road near the Maryse Justin Stadium: Whenever there is high amount of rainfall, there is flooding at this particular region of the road. This is due to the fact that the road has the lowest elevation at this particular region and all water is accumulated. There is also a poor drainage system present.
- The road near Tamil league: As described by the residents, there is sometimes water accumulated at this particular region when there is heavy rainfall. On site, it was noticed that there was drains but they were in bad conditions.
- Residential area to the north of school: Water is accumulated in this place as it is the lowest point of the region. Where there is heavy rainfall, water comes from higher elevation (denoted by blue arrow) and stays stagnant at this place. This is due to the fact that there is no drainage system present and on site, it was seen that there was on-going construction of drains.
- The assessment of damages was considered to be 20 as there are flooding of locally important roads and flooding of residences.

Identification of high risk and low risk areas:

The data and information collected during the site surveys was analysed to identify all the high risk and low risk areas of the community. The zones highlighted in red area the high risk areas. The blue arrow illustrate the path of surface runoff in the particular area.

Figure 4: Identification of high risk and low risk areas for Zone 1

Disaster Resilience Scorecard Method:

For this method, the whole study area was analysed at once since the ten essentials for the six different areas of the study area are the same. Secondary information were compiled from existing sources and from those interviewed in the region. The information required to address the ten essentials of the UNDRR Scorecard method (United Nations, 2015) are as highlighted in Table 4:

Table 3: UNDRR Scorecard 10 Essentials

UNDRR SCORE CARD	INFORMATION REQUIRED	STATUS FOR ZONE 1
1	Organise for Resilience	At country level Climate Change, DRR and Climate Resilience policies have been promulgated. At Institutional level the NDRRMC overlooks DRR and climate resilience issues. However at institutional level the concepts are not well developed and mainstreamed.
2	Identify, Understand and Use Current and Future Risk Scenarios	The study revealed the general public and technical officers are fully aware of climate related risk elements in particular floods and cyclones. However, it was noted that adequate working documents were still missing. The link between climate related disasters and infrastructural losses are yet to be fully developed.
3	Strengthen Financial Capacity for Resilience	While each organisation has a dedicated for contingencies, this is not considered as adequate.
4	Pursue resilient urban development	Mainstreaming climate change in decision making including building of resilient systems is not yet fully appreciated.
5	Safeguard Natural Buffers to Enhance the Protective Functions Offered by Natural Ecosystems	The potential for using natural ecosystems exist but is not being fully exploited at this stage.
6	Strengthen Institutional Capacity for Resilience	Training facilities do exist at local level, but is yet to reach all the different expertise involved in decision making.
7	Understand and Strengthen Societal Capacity for Resilience	The community works a lot with NGOs and the NDRRMC for awareness raising.
8	Increase infrastructure Resilience	Much remains to be done with regards to building more climate resilient infrastructures.
9	Ensure effective disaster response	The area is served by an efficient early warning system with support from a well structure institutional set up, which also includes drills. There is however high dependency on support services.
10	Expedite recovery and build back better	After a disaster, often the system goes back to normal within 2 to 3 days, but building back better based on experience is financially more demanding.

The Réduit city scorecard results are shown in Figure 5, indicating a total scoring of 92/141, with the highest scoring achieved for Essential 6 (Strengthen Institutional Capacity for Resilience), 8 (Increase Infrastructure Resilience) and 9 (Ensure Effective Disaster Response). The graph above shows all the strength and weakness of Réduit. While the blue colour of the graph shows the actual level of resilience of the city, the grey colour shows the required level of resilience that the city must have. We can observe that the city do not have the required level of resilient and it does not have the ability to bounce back and recover quickly from the impacts of the worst disaster scenarios. To achieve the required level of resilience for the city, we should apply all the following measures which we have mentioned above for all the ten essentials.

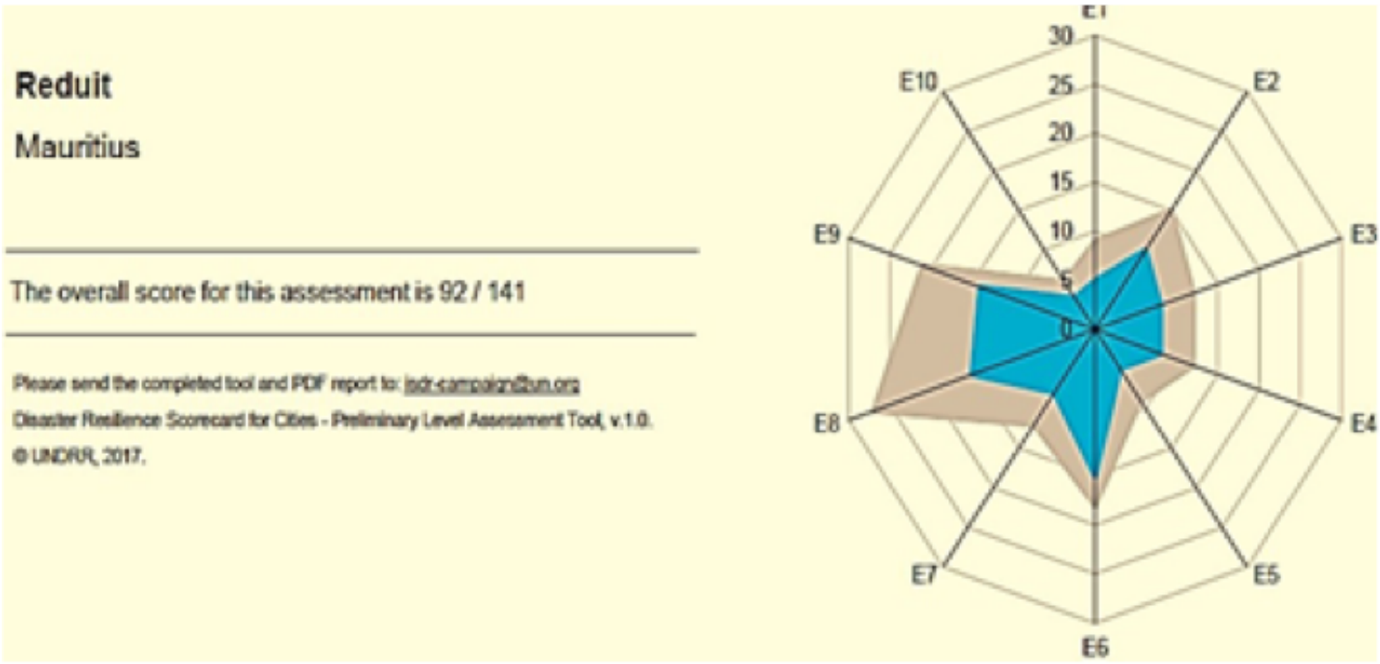

Figure 5: Graph obtained for all the ten essentials

Community Risk Profile Assessment (CRP)

After collecting data and information in the first two stages of the study, the field survey and the secondary data compilation or the UNDRR resilience scorecard, same were used to assess the study area using the CRP tool, with respect to resilience to cyclones and resilience to floods (Figure 6).

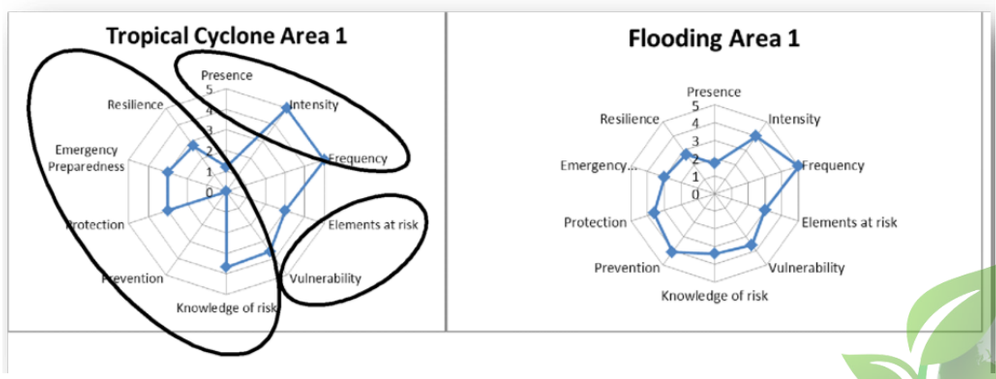

Figure 6: CRP for zone 1 of Réduit village (Cyclones and Floods)

The computed scores and the graph of tropical cyclone and flooding for zone 1 are as follows:

The community risk profile analysis is analysed based on the 3 main areas of the graphs:

- The upper right portion, indicating the characteristics of the hazard in terms of the presence, intensity and frequency of a dangerous phenomenon.
- The lower right portion, giving an indication of the vulnerability of the community to the hazardous phenomenon.
- The remaining portion, the entire left half of the CRP, covering risk control activities.

This is illustrated as in figure 6. The two sources of hazards considered for the community in this study were tropical cyclone and flooding events.

With regards to resilience to cyclone from Figure 6, it can be noted that the surface area of the upper right portion of the graph is large. So, it is confirmed that the community is subjected to tropical cyclone during the year. And we can also see that the hazard has a high intensity and frequency as it occurs many times during a year. The surface area of the lower right portion of the graph is sufficiently large. So it has some elements and regions at risk and the vulnerability of the community which has a score of 4, is high enough. The entire left half of the graph has a medium area. This is good for the community as it explains that the community has a relatively good protection, emergency preparedness and a good level of resilience. However, these criteria need to be improved as the scores obtained in this analysis was 3 and they required one for resilience is a score of 1.

With regards to the resilience to flooding, for zone 1, there are mainly residential houses and no green spaces and this is one of the reasons why this area has a score of 5, thus a high intensity of flooding. The surface area of the upper right portion of the graph is large. So, it is confirmed that the community is subjected to flooding during the year. We can also see that the hazard has a high intensity on area 1. The surface area of the lower right portion of the graph is medium sized. So it has different elements and regions at risk and flooding makes the community becomes vulnerable as the vulnerability criterion has a score of 4. During the site survey, the regions at risk at the different areas of the study area were identified and appropriate measure will be taken in order to reduce the vulnerability of these regions. The entire left half of the graph has a relatively large area. The overall score for the left half of the graph can be seen to be 4 and this explains that the community does not have a great protection, prevention, emergency preparedness and a great level of resilience against flooding.

Overall, from the community risk profile analysis carried out at Réduit (Zone 1), it was found that the community is subjected to risks and impacts from both tropical cyclones and flooding events. To successfully overcome the risk and impacts of these natural hazards, the level of resilience of the community must be increased.

Proposed Migitating Measures

This study noted that both structural and non-structural measures can be considered to increase climate resilience in the study area, for example:

- There is a need to review the existing drainage system with new designs, that will reduce the volume of surface runoff that reaches low areas as well as reduce the rate at which the surface runoff reaches the vulnerable zones.
- Dikes along banks of rivers will need to be considered to protect the residential zones from fluvial flooding, caused by overflow of river banks.
- At zones where no drainage system can be constructed, detention basins in the form of dry basins near the two roundabouts near the Auditorium, small-scaled detention basins can be considered.
- More holistic approached to flood management such as sustainable urban drainage systems should form part of the surface runoff disposal system at catchment levels, to reduce the volume and rate at which flooded water reaches vulnerable zones.

Conclusion

The growing impacts of climate change are making it difficult for countries and cities to manage disasters caused by natural hazards. In addition to economic losses, loss of livelihoods and the move towards achieving the SDGs are challenges. Mauritius is one of the countries which are subjected to natural hazards such as tropical cyclones and flooding events yearly. It is estimated (UNEP, 2019; UNIDSR, 2015) that Mauritius experiences a combined loss of $139 million annually from tropical cyclones and flooding events. The risk profile assessment by the CRP method highlighted how the level of resilience is high with regards to cyclones but low with regards to flood events. This method which is applied at community level, provides detailed insight of the vulnerability of a community to different natural hazards. The applications of the UNDRR disaster resilience scorecard allows users to undertake this assessment in more depth, highlighting for this study area, organizing the development of a city based of the concepts of resilience is low, the use of nature based solution to mitigate impacts of climate change is low and similarly the approach of build back better is low. These points reflect the low appreciation of the need to build more resilience cities. The technical approach of climate resilience assessment coupled with a visual display in the form of maps, are strong working tools that can consolidate awareness of the relative vulnerability of a community to climate change. This study concluded that spatial analysis of study areas at community level, do provide more accurate information regarding high risk areas while helping authorities to identify specific local solutions. This research also strongly highlights the need for concerned authorities to undertake climate resilience assessment at community level, for them to be able to address climate resilience in their respective development plans of concerned local authorities.

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Resilient Transport in Mauritius

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1. Introduction

The theory for resilient cities is based on anticipation, mitigation, and reduction of physical, economic, and social effects of natural or man-made disasters in a city. Therefore, by derivative, the resiliency of a city can be defined as its capacity to survive, adapt and grow (Fitzgibbons and Mitchell, 2019); and to provide rapidity in its use of resources to recover and withstand the degradation from any stress that may occur.

The transport sector plays a big role in the proper functioning of any country, and its efficiency and ability to withstand and bounce back any stress is of utmost importance. Transport encompasses the transfer of goods and services to the movement of personnel throughout a city's roads. With the growing menace of the results of climate change, our roads are in uncertainty to allow the free-flowing of resources to all its parts.

During the last two decades, Mauritius has seen itself become an example of economic growth in the African continent. The ratio of the length of road to the number of vehicles per kilometre of road has increased from 18.1:1 in 1996 and 12.3:1 in 2016. At the end of December 2019, 580,629 vehicles had been registered at the National Land Transport Authority, compared to 384,115 vehicles in 2010 (StatsMauritius, 2019). Just over these nine years, the number of cars registered in the country has nearly doubled. This shows that Mauritians are depending more and more on the transport network to maintain their livelihood and lifestyles.

But being a tropical island, Mauritius is prone to adverse turbulence in its weather patterns. This phenomenon is being exacerbated with climate change. In recent years, the increasing frequency and intensity of cyclones, torrential rains and flash floods have also threatened people's livelihoods in the islands (Mauritius Meteorological Services, 2021). From droughts and dry seasons, and high winds coming from the ocean, to flooding issues, Mauritius must account for and build its infrastructure accordingly. Infrastructure built to evacuate excess water to appropriate discharge areas, while maintaining mobility of vehicles and access to locations is why infrastructural resiliency is the primary concern before the construction and design phases.

Every year, some areas become inaccessible due to the submersed access points, affecting access to emergency services, and is responsible for cause thousands of dollars of property damage. Therefore, to be able to plan resilient cities and infrastructure, planning and design must be done accordingly such as allows for passage water and their canalisation to

appropriate discharge areas. Creating natural barriers and the increased use of plants and natural resources to make cities both sustainable and more resilient to such events.

In this ever-changing and ever-evolving world, where cities worldwide are not safe from unpredictable events such as natural disasters or most recently, proven by the Covid-19 global pandemic, public health crises; we must all account for five of the most important sectors – transport, construction and infrastructure, energy and power, water management, urban planning, disaster management, and food security.

Due to the above reasons, a study was carried out to assess the resiliency of cities in the Mauritian context, the focus being on the transport sector. A review of the existing literature was carried out in order to identify the main issues and problems in this sector. Recommendations were then made to improve the resiliency of the transport sector.

2. The Transport Infrastructure

The transport infrastructure has become an important factor for economic and social development across the globe (World Bank, 2019). The transport infrastructure helps in linking people to work, education, health facilities, food distribution, and others (World Bank, 2019). There exist several types of transportation systems, used across the world namely:

1. Road Transportation (car, motorcycle, bicycle, truck, cargo truck, and others).
2. Rail Transportation (trains, monorails, and others).
3. Maritime Transportation (boat, yacht, cruise ship, cargo ship, submarine, and others).
4. Air Transportation (planes, helicopters, and others).
5. Telecommunication (satellites, communication vehicles, and others).

The increasing availability and convenience of personal transport rather than public and mass transportation also plays a big role in the setup of a resilient and sustainable city. An increase in the number of vehicles without any changes in the road networks and traffic management systems can lead to traffic congestions. Traffic jams are one of the main contributors to air, noise pollution in urban environments as their locations are usually localised and repetitive. Congested traffic also accounts for the slow movement of goods, increased travel time between destinations, and slow response time from emergency services(Yao and Wang, 2020).

To combat traffic congestion and future possible traffic blockades, smart cities are implementing traffic management systems that use past and real-time traffic monitoring data to predict and help mitigate the possible occurrence of traffic congestion, and traffic accidents and collisions (Majumdar et al., 2021). Traffic prediction and data analysis are useful tools being promoted by traffic engineers to reduce commute time, thus saving fuel, and causing less pollution, and reducing road traffic. This is so as they help drivers avoid busy roads and promote better traffic flow and pollution management, despite being a very practical instrument to increase the resiliency of any city. (Majumdar et al., 2021). As traffic prediction is still in its infancy due to the lack of information, and vehicular data and relies on complex factors which do not operate on a linear model, it is still early to see its applications on Mauritian roads.

Countries with a good road infrastructure system are in a better position to obtain benefits from the trade domestically and internationally, improving their economic conditions as well. The following factors are vital for a good road infrastructure:

- properties of roads
- materials
- layout
- dimensions

2.1 Properties of Roads

Streets and roads are built in ways that they relate to each other in networks and each one of them has a

different impact on their surrounding environment and buildings. They also affect the aesthetic and functional success of a neighbourhood.

As street networks support a wide range of urban processes, they attract attention from scholars in many disciplines, including transport and urban planners, architects, geographers, environmental psychologists and, recently, physicists. Street network studies include investigations into network structure, connectivity, centrality, circuity, traversal, hierarchy, typology and evolution (e.g., Courtat et al. 2011; Crucitti et al. 2006). They must therefore be built and maintained in a future-proofing manner, as they will be used daily and cannot easily be changed.

2.2 Materials

When building and planning road networks, their properties are essential. Some examples to consider should be as follows (Davis and Huxford, 2009):

Paved roads may be sub-divided into those surfaced with a bituminous surfacing (asphalt or spray seals) and those with non-bituminous surfacing (concrete, block paving, cobblestones, paving slabs, etc.). Their respective performances under wet and hot conditions can differ and they are thus dealt with separately in terms of their adaptation measures.

On the one hand, when considering roads with flexible surfaces (cobblestones and bricks), subsurface moisture conditions play a big role in its performance criteria. Subsurface moisture conditions depend on both precipitation and drainage on such roads. These types of roads are more likely to develop faults in situations of excess rain or lack of water in the soil (Davis and Huxford, 2009).

Whereas, on the other hand, non-flexible surfaces (bitumen and concrete) tend to be non-porous and do not rely upon subsurface properties to affect their performance criteria. Instead of allowing water penetration into the soil, they can be used to direct the flow of water to desired locations or cause flooding in case of blocked drainage systems. One other disadvantage of such materials is that they are affected by temperature, Increased temperatures may lead to potential problems and need to be considered in their design applications (Davis and Huxford, 2009).

Despite each of their advantages and disadvantages, each material is mainly considered due to its cost of application, ease of maintenance, load capacity, and road safety

2.3 Layout

The road layout is of utmost importance as it allows traffic flow to be optimised and road safety to be maximised. Common layouts are (Hughes and Healy, 2014):
1.Rectangular grids, and
2.Concentric grids.

Rectangular grids have their roads and streets arranged perpendicular and parallel to each other whereas, in concentric grids, the roads and streets are arranged in circles, with different diameters, having a common focus and interconnected by equidistant tangent and perpendicular lines.

Road layouts depend on the geographical landscape properties of a region and can therefore not be easily updated. This is the reason why they must be carefully considered.

Some criteria of road planning to avoid are as follows (Davis and Huxford, 2009; Hughes and Healy, 2014; Temmer and Venema, 2017; Duy, Chapman and Tight, 2019; Ledwell, 2020; Mahdavi, Bhouri and Scemama, 2020): unsafe road layouts, lack of security measures, poor drainage in case of rainfall and inadequate infrastructure for public use.

2.4 Dimensions

Road dimensions play a big role in their safety qualities and ease of use. Especially in Mauritius, where available space is restricted, we must maximise the efficacity of every square meter to provide the best experience to Mauritian road users. But, updating road dimensions allow for room for adaptability and diversity in a location to prosper, and with good road networks, locations can see a spike in property value, accompanied by an increase in the quality of life (Davis and Huxford, 2009; OpenData Mauritius, 2018; Statistics Mauritius, 2019).

3. Evolution of the Mauritian Transport Sector

Until the advent of the Light Rail Transit system in Mauritius, the land transport sector has solely consisted of roads with a network of 2502 km as of 2016 (OpenData Mauritius, 2018). Table 1 gives a preview of how the road network has evolved from 1996 to 2016. Although the ratio of the length of road to the number of vehicles per kilometre of road has changed from 18.1:1 in 1996 and 12.3:1 in 2016. These show that despite the increase in the road network over these last 20 years, traffic congestion and traffic flow are becoming more and more of a problem.

According to Statistics Mauritius, at the end of December 2019, 580,629 vehicles had been registered at the National Land Transport Authority, compared to 384,115 vehicles in 2010 (Statistics Mauritius, 2019). Table 2 contains more information on the various types of vehicles registered in Mauritius from the year 2010 to 2019. Over these 9 years, the number of cars has nearly doubled.

These alarming facts mean that our land transport networks are of the utmost importance for the daily routine of Mauritian citizens as a lot of them depend on such services, prompting the subject of transport resiliency to be taken into consideration.

Length and density of road network	Length of roads, as at end of year (km)	Motorways (km)	Main roads (km)	Secondary roads (km)	Other roads (km)	No. of Vehicles per km of road	Density of total road network in km per sq km
Year 1996	1905	31	902	582	390	105	1.02
Year 2015	2428	99	1,131	716	482	200	1.3
Year 2016	2502	100	1,137	756	509	203	1.34

Table 1. Length and Density of road network in Mauritius from 1996 to 2016 (OpenData Mauritius, 2018)

Types of vehicle	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Car	127,363	136,225	147,733	160,701	173,954	188,299	202,696	218,976	235,598	251,973
TOTAL	384,115	400,919	421,926	443,495	465,052	486,144	507,676	531,797	556,001	580,629

Table 2. Types of vehicles registered in Mauritius from 2010 to 2019 (Statistics Mauritius, 2019)

4. Main issues

The main issues identified in the Mauritian context after site surveys and site observations were carried out are:

- *Poor road and building layout*

One example of poor road and building layout is the regular thefts that happen on D'Artois Street. D'Artois street is a commonly used road, located within 200m from Dr.AG Jeetoo Hospital, Port Louis. Due to the presence of high-rise buildings and a lack of such security measures, crimes are committed in an open public space.

- *Road dimensions*

- Amount of parking spaces available, especially in urban spaces is affected when the roads are enlarged

- During the last few years, some locations in Mauritius have had a complete overhaul of their environment. Places like St Pierre and Moka have seen increased traffic flow due to the expansion of commercial zones along those regions. Having roads previously not built for such traffic density, these locations are usually witnessing traffic congestions.

- *Out-of-date roads provide a reduced driving experience and drivability.*

- This is so as modern vehicles have larger turn circles and require more space to function properly. The fact that Mauritius is home to larger and larger cars and double-decker buses is of concern if future-proofing our roads is to be judged as they cannot drive under certain bridges or do certain regular public transport routes.

- Also, out-of-date road infrastructure (such as bridges, roundabouts, and culverts) cannot accommodate modern vehicles.

- Such out-of-date roads also affect traffic flow, as on some bridges only 1 vehicle can pass at a time and have a weight restriction or have height restrictions which have not been updated for modern vehicles: thus, responsible for difficult traffic movement.

- Usually roads do not have proper road signs to indicate changes in the geographical landscape of a location.

- Speed limitations in some regions have not been revised to accommodate modern roads and modern vehicles and with an increased number of vehicles in Mauritius, are a source in the slow movement of traffic.
- Every year, Mauritius suffers from an accumulation of excess water on our roads, not being processed by the drainage systems as they are either not maintained or non-existent (Lexpress.mu, 2021d).
- Non-respect of construction laws. The implications result in flooding or roadblocks, making roads unusable. Some of the guidelines (unedited from the original document), required to be followed by builders are (Ministry of Local Government and Outer Islands, 2017):

- Building line of 6m from roadside boundaries.

- Building line of 4.5m from any other road or 3m from lightly trafficked roads.

Building line of 0.9m from the sides and rear boundaries (other than coastal zone) for Building comprising of Ground Floor and First Floor and not exceeding 7.5m in height.

Also, following the fact that these guidelines have not been satisfied results in the lack of space to allow the construction of roadside drainage systems. In some places, despite the presence of a drainage pit, water is no longer infiltrating the soil as the subsurface porous layer of the pit has become saturated (Lexpress.mu, 2021c).

5. Recommendations

The main recommendations of this study, based on literature review and site surveys are:

1. Create elevations and angles between foot pathways and roads, to allow ease of flow of water and the use of gravity water drains.
2. Use permeable materials to build surfaces, instead of impermeable ones to allow water to replenish subsurface aquifers.
3. Use of plants for evapotranspiration properties, as

a low maintenance means to remove soil moisture, along roadsides.

4. Produce design standards for road drainage networks to efficiently adapt to other regions. The standards would be based on the development of drainage systems following environmental assessments.

5. Emergency sensors can be installed at key points to warn of road usability and flooding. This would allow emergency services to warn and guide road users to their destinations as rapidly and safely as possible.

6. Conclusion

Resilience is an important property of transport infrastructure networks. Roads and road networks that are built to be climate resilient can tremendously enhance the adaptive capacity of a country like Mauritius. Climate resilient roads can help in providing people a route to reach safety during calamities and ensure adequate service levels of the road network under extreme weather conditions. As such, it is very important to invest in infrastructure more resilient to weather extremes and climate change.

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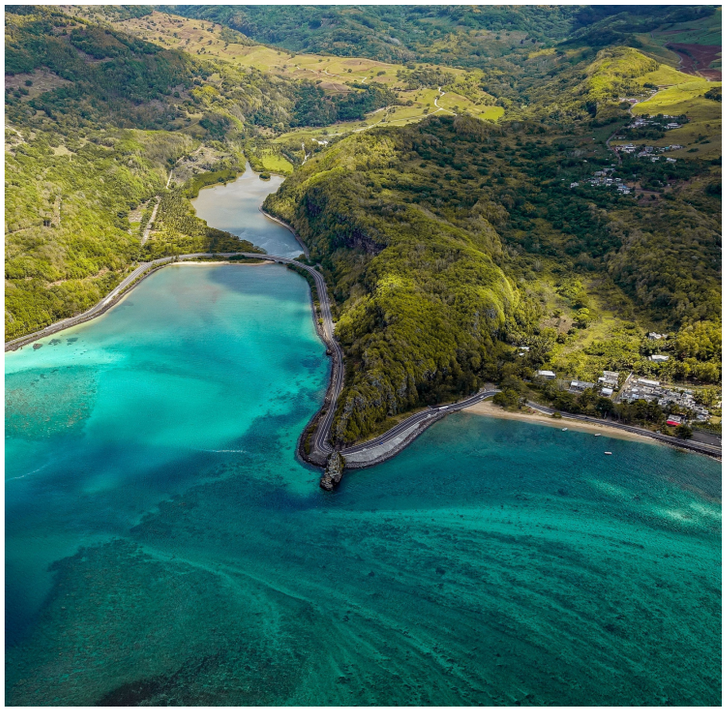

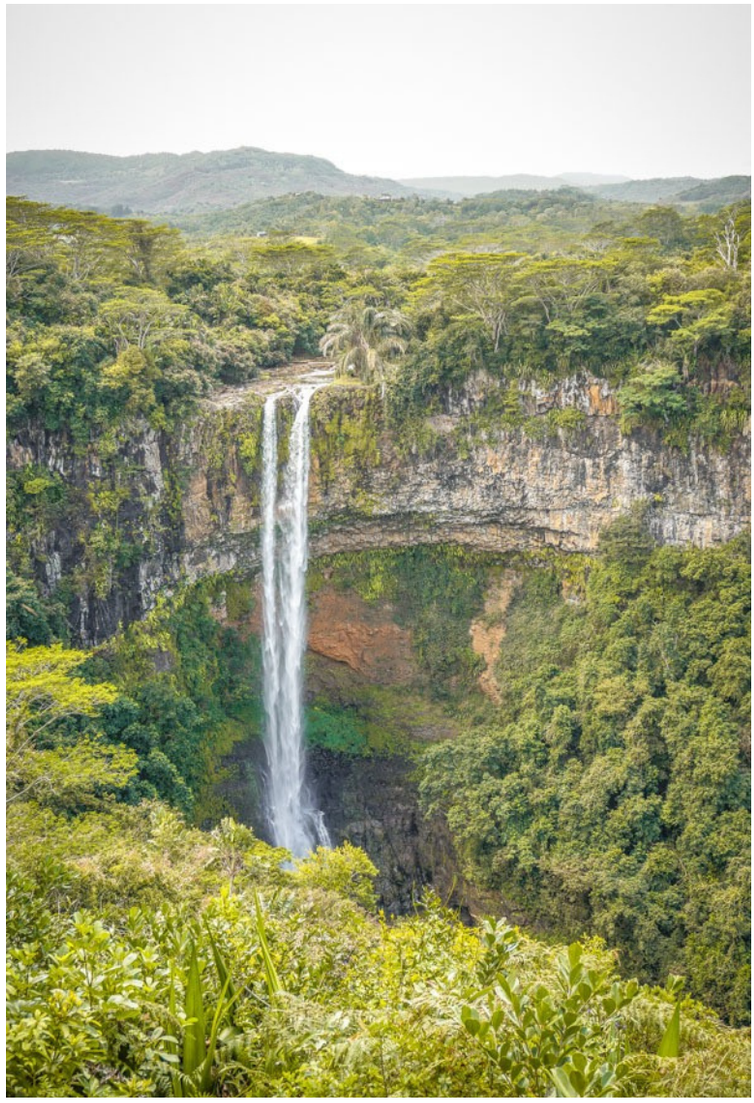


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