COVID-19 AND CLIMATE CHANGE:
PROSPECTS FOR A 'GREEN' RECOVERY IN THE INDIAN OCEAN REGION

Research Study Report

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List of Acronyms

ABC - Atmospheric Brown Clouds
COPD - Chronic Obstructive Pulmonary Disease
DCA - Document Cluster Analyses
EbA - Ecosystem-Based Adaptation
GDP – Gross Domestic Product
GoS – Government of Seychelles
GR - Green Recovery
ICT – Information and Communication Technologies
IOR – Indian Ocean Region
IORA – Indian Ocean Rim Association
LLR - Log-likelihood Ratio
LPG - Liquefied Petroleum Gas
LWMA - Landscape and Waste Management Agency
MCO - Movement Control Order
MS - Member State
NBS – Nature-Based Solutions
PAH - Polycyclic Aromatic Hydrocarbons
PET - Polyethylene Terephthalate
PM - Particulate Matter
PPE – Personal Protective Equipment
PRFs- Permanent Reserved Forests
PUC - Public Utilities Corporation
RE- Renewable Energy
RET - Renewable Energy Technologies
RMG - Ready-made Garment
SARS - Severe Acute Respiratory Syndrome
SDGs – Sustainable Development Goals
SIDS – Small Island Developing States
SWM - Solid Waste Management
UNESCO - United Nations Educational Scientific and Cultural Organization
USD – United States Dollars
VAT – Value Added Tax
VOC - Volatile Organic Compounds
WHO – World Health Organisation
WTE - Waste-to-energy

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Abstract

The COVID-19 pandemic that shocked the world from 2020 to 2022 was caused by Severe Acute Respiratory Syndrome (SARS) Coronavirus-2, which causes a highly infectious respiratory disease that led to lockdowns and movement control orders worldwide. This interfered with the movement of people and goods and thus impacted the economy and people's livelihood. The Indian Ocean Rim Association (IORA) countries were not spared and probably suffered more because of the hospital's unpreparedness, lack of social protection cover and high dependence on tourism and imports. The IORA launched this study to evaluate the impacts of COVID-19 on various sectors of the economy and the possibility of green recovery in the IOR region. This study involved a desktop analysis of literature, mainly peer-reviewed but also grey literature on the topics related to air quality and health, socio-economic impact, agriculture, sustainable consumption and production, energy generation and use, tourism, waste generation, and management, water quality in the aquatic ecosystem, aquatic biodiversity and ecosystem health and mangrove ecosystems and blue carbon.

The review showed that ambient air quality in the IORA region is below the recommended World Health Organisation (WHO) standard mainly because of high emission levels from poorly maintained vehicles, fossil fuel use, urbanisation, and agriculture. Many IORA countries have no continuous air quality monitoring programmes, so data is not readily available. There is a need to evaluate the disease impact due to indoor air pollution as many households in this region use biomass for cooking and heating.

Lockdowns due to COVID-19 affected many peoples' lives and livelihoods. In some countries, the governments injected funds to help cushion the households due to the loss of jobs. Education was interfered with, and because of the lack of proper infrastructure such as internet and power connectivity, gadgets, and trained human capacity, most students stayed home without contact with the teachers. Although most governments tried to cushion the citizens through cash transfers, this was very limited, with only a few beneficiaries, and very temporary. Only in Seychelles did such a scheme work to alleviate socio-economic challenges.

Lockdowns seriously hampered agriculture due to the high dependence on imports of inputs and external markets and lack of labour. This caused losses of produce that could not be harvested or reach the market in time, leaving the farmers at a loss and increasing food insecurity. On the other hand, the low supply of food made the food expensive to the consumer, while the farmers were at a loss. The market forces were reasonably favourable to the intermediaries and unfavourable to the producer and the consumer. This points to the need to evaluate the market forces to ensure that sustainable consumption and production (using less and getting more) is achieved at all supply and value chain levels and that overreliance on imports is curbed.

Without sustainable consumption and production, the environment will continue to be impacted by the production system. Sustainable consumption and production should be observed in all sectors of the economy, including energy generation and use, tourism, and waste management.

The energy generation in some of the IORA countries is sustainable, using green sources such as wind, water, solar, and geothermal with very little fossil fuel, like in Kenya. However, many other countries plan to go green, while others are yet to consider the possibility. Kenya has a mix of sources; one of the challenges is funding, as renewable energy technologies (RET) can be pretty costly, and the other is policy issues. Thus, IORA governments need to work on green energy policies to make them friendly to investors, and this can be part of these countries' nationally determined contributions.

Tourism is one of the essential economic activities ranking relatively high in most IORA countries, both international arrivals and domestic. The lockdowns severely impacted the economy of most countries, especially Seychelles, which has a high dependence on international arrivals. Besides, most tour companies are owned by foreigners, which could mean a lack of a fall-back during difficult times. However, the Seychelles Government cushioned all those who lost employment then.

Waste management is one of the problematic sectors in the IORA countries. Although there is legislation to guide waste management, there are still no sanitary dump sites in many countries, so waste is dumped in open dump sites. COVID-19 nearly doubled the waste generated because of the personal protective equipment (PPE), which littered the city streets and the environment (rivers, ocean, lakes), demonstrating the dire waste management issue. Some IORA countries like Seychelles and Bangladesh have plans to embark on a WTE project, but those plans were somehow slowed down during the pandemic. If such projects were started, they would offer these countries the opportunity for green recovery, which most countries have not yet embraced.

Review work published before and during COVID-19 showed that within the first three months of lockdown, the environment (water, mangrove ecosystem and biodiversity) started showing signs of recovery. This suggests that human activities impact these ecosystems most and that if these activities can be halted, ecosystem integrity and biodiversity can be restored. This, therefore, calls for the IORA governments to ensure compliance with the legislation for protecting the existing environment and develop new ones where necessary. Protecting and rehabilitating some of these environments, like the mangroves, offers an excellent opportunity for carbon dioxide sequestration while at the same time maintaining biodiversity and ecosystem integrity, the model of nature-based solutions. In no sector of the economy, did we identify green recovery project in IORA that has been launched post-COVID-19 except those that were already ongoing. Some of those planned projects, like waste to energy in Bangladesh and Seychelles, were shelved during the pandemic. Therefore, as the IORA governments start to consider post-COVID-19 recovery projects, they

should consider green recovery infused with nature-based solutions (NBS), and that puts into consideration sustainable consumption and production goals.

1.0 General Introduction

1.1. Background of the COVID-19 Pandemic

COVID-19 is an infectious and contagious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS CoV2) that emerged in December, 2019 in the Wuhan Province in China (Cascella *et al*., 2022). The World Health Organisation (WHO) declared the disease a pandemic in March 2020 (WHO, 2020). The highly infectious virus led to the infection of over 200 million people and the deaths of 4 million people by the end of 2021 (Pape and Delius., 2021). It stood at around 670 million infections and over 6.8 million deaths as of February, 2023 (WHO, COVID-19 dashboard, https://covid19.who.int/). Amid the pandemic, the disease overwhelmed health care systems in most countries all over the world (Pape *et al*., 2021) causing a strain in the health care systems that were unprepared to handle such high morbidity and mortality (Fitzgerald and Wong, 2020; Rana, 2021; Tesema *et al*., 2021). In some instances, the pandemic interfered with provision of other essential health care services such as post-natal services, health screening and admissions unrelated to COVID-19 (Kiarie *et al*., 2022; Baraza et., 2021).

1.2. The Climate Change and COVID-19 Interface

The COVID-19 pandemic ravaged the whole world, interfered with economic progress, compromised the economic gains made in the last few years and even caused postponement of the climate debate worldwide (Loureiro and Allo, 2021). The Paris Agreement, to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels in order to reduce the risks and impacts of climate change, was postponed.

Climate change and the COVID-19 pandemic are two significant global challenges that are similar in many ways but also different (Fuentes *et al*., 2020; Poortinga *et al*., 2022). Climate change occurs as a result of increased atmospheric greenhouse gases (GHGs) such as carbon dioxide (CO_2), nitrogen oxide (NO_2), ozone (O_3) methane (CH_4) and chlorofluorocarbons (CCl_2F_2) due to human activities, particularly the use of fossil fuels (Lamb *et al*., 2021). This leads to rising atmospheric temperatures and long-term changes in weather patterns which has been associated with spill-overs of zoonotic diseases including SARS CoV2 that caused COVID-19 (Gupta *et al*., 2021; Islam *et al*., 2021; Rodo *et al*., 2021; Zhu & Fang, 2021; Rupasinghe *et al*., 2022). Climate change and COVID-19 are similar in that they are caused by external factors whose correction is quite costly in economic terms. Climate change however, occurs slowly and has a long-term effect, while COVID-19 on the other hand, struck the world fast and required a quick response to reverse the situation and slow down the infections (Fuentes *et al*., 2020). The reversion of the disease status required concerted efforts both by individual and collective government's efforts including putting in place policies and guidelines for individual and collective behaviour (Wahaj *et al*., 2022). While people felt direct personal responsibility in halting the COVID-19 pandemic, it is different with climate change where people think that governments have the responsibility to help curb climate change. Therefore, governments will need different types of policies and framing

from those of COVID-19 to halt climate change progression (Poortinga *et al*., 2022). However, some of the strategies implemented to control COVID-19 could be applied in climate change mitigation efforts such as the global cooperation, information dissemination, and education to induce behaviour change as was witnessed in COVID-19 control (Fuentas *et al*., 2020).

In the absence of this kind of concerted effort to control climate change, emergencies and spread of other zoonotic spill-overs similar to SARS viruses will continue to be experienced (Rodo *et al*., 2021). Thus, the need for governments to collaboratively develop strategies for long term global decarbonisation focussing on sustainable consumption and production, green recovery and nature-based solutions and leveraging on sectors such as energy generation, food production, tourism industry, waste management and other sectors to achieve public and environmental health objectives (Khojasteh *et al*., 2022).

1.3. COVID-19 and its Impacts on Livelihoods and the Economy

The COVID-19 pandemic led to world governments taking unprecedented strategies such as lockdowns and night curfews, shutting down education institutions, restricting movement and social gatherings, and limiting the capacity in public spaces thus, impacting on socio-economic activities globally (Pape and Delius, 2021; Alamoush *et al*., 2022). As a consequence of these stringent measures, travel, including air travel, maritime transport, and border crossings, were interrupted (Kolahchi, *et al*., 2021; Millefiori *et al*., 2021). This interruption of transport created a crisis in the demand and supply chains (Moosavi *et al*., 2021) and thus lack of supply of essential commodities such as food, medicines, farm inputs, and industrial raw materials (Palakshappa *et al*., 2020). The stringent measures imposed affected socioeconomic activities such as farming, fishing, hospitality services, and supply, thereby exacerbating the unemployment crisis and socio-economic challenges. At the household level, reduced family income and inability to provide for the family's basic food and medicine needs were witnessed. Many rural as well as urban poor communities became even poorer and this had an impact on families wellbeing (Hossain, 2021). Within families the pandemic disproportionately impacted more women compared to men with more women losing employment than men, skipping meals, suffering domestic violence and sexual harassment, and foregoing essential healthcare services (Baraza *et al*., 2021; Pinchoff *et al*., 2021).

The COVID-19 pandemic revealed the vulnerability of communities in many IORA countries with precarious livelihood and no social protection. In response to the COVID-19 pandemic, communities developed various coping mechanisms such as food rationing, increasing the search for food, relying more on less nutritious foods and also developing kitchen gardening in urban areas (Tattan, 2020; Tabe-Ojong *et al*., 2022). To help alleviate the challenges many governments instituted temporary policies to inject funds to cushion the most vulnerable, e.g., in Kenya (Gikandi, 2020).

It is crucial to identify and document some of these coping mechanisms that families adopted to enable them to survive the difficult situation, in order to provide lessons for the future in the event of similar pandemics or other unfavourable occurrences. It is also essential to evaluate the policies instituted to inject funding into communities and their impacts in the different IORA member states

to identify lessons learned and a way forward. This study will identify synergies between smart adaptation, mitigation, and lessons learned from the pandemic towards novel pathways for the region's blue and green economic recovery.

The interconnections and interdependencies between agriculture, society, and the economy were brought to the fore by the lockdown during the COVID-19 pandemic revealing the vulnerability of agrifood production to external disturbances (Lioutas & Charatsari, 2021). Commercial farming suffered more during the restrictions on movement due to the over-dependence on inputs (fertilizers, seeds) from external sources and foreign markets for the products. Other challenges in the agricultural sector included interference with the production cycles, and undermining production capacity thereby jeopardising the gains made in SDG 1 on poverty and SGD 2 on food security (Pu & Zhong, 2020). On the other hand, subsistence farming was more resilient to the shocks, especially those produced for household consumption (Adhikali *et al*., 2021). However, extended disruptions leading to persistent financial stress affected even the small subsistence farmers (Boughton *et al*., 2021). This calls for governments in the IORA region to re-think policies supporting livelihoods and promoting economic growth and agrifood production without additional environmental burden. In this study we shall evaluate the response of communities and governments to crisis on food and farm inputs and marketing during the pandemic to provide lessons and identify policy gaps.

1.4. Prospects for a Green Recovery in IORA Region

As the world reaches the end of the pandemic that began three years ago, it is worthwhile looking back and assessing the damage, the lessons learned and the prospects of green/blue recovery as pathways to economic progress. The economic impact of COVID-19 was huge due to the public spending and debt governments incurred to provide health care services, cushion vulnerable families, and resolve socio-economic challenges related to the pandemic, such as unemployment (Lahcen *et al*., 2020). The world was already overburdened by the environmental challenges of climate change impacts, loss of biodiversity and ecosystem health and pollution even before the COVID-19 pandemic. In particular, activities concerning the Paris agreement to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels" had been shelved during the pandemic. World governments are now focussing on economic recovery while facing the ominous challenge of climate change. Therefore, a green recovery has been touted as the panacea for this dual challenge (economic recovery and climate change mitigation) (Vardon et a., 2023). Green recovery is a set of actions, strategies, and policies to sustainably accelerate economic recovery after the ravages of the COVID-19 pandemic without compromising human wellbeing and environmental health (air, water, soil) (Lahcen *et al*., 2020). Thus, post COVID-19 developmental projects are expected to be eco-friendly to boost the economy but at the same time mitigate against climate change and pollution through the sequestration of atmospheric carbon dioxide and reduction of toxic gases emissions (Lahcen *et al*., 2020). Some actors known to emit high levels of greenhouse and toxic gases include energy generation, manufacturing/industry, construction, transport, and agriculture, forestry and other land uses (Lamb *et al*, 2021). Thus, green recovery projects targeted in these sectors will help achieve the two prong results: economic recovery and reductions in emissions (GHGs and air pollutants).

However, focussing on decarbonisation alone without considering the environment has been found to have a weakness in that projects targeting CO_2 removal may compromise on biodiversity and ecosystem health. For instance, although it has not been used in situ, carbon dioxide removal techniques such as ocean alkalinisation technology (Butenschön *et al*., 2021) may be very effective in removing atmospheric CO_2 but has negative consequences to marine biodiversity and ecosystem integrity. Concerning natural CO_2 removal, projects have focussed on reforestation and afforestation of bare land without considering the original floral and faunal biodiversity. Regarding agriculture, the use of monoculture/plantations has been adopted primarily by commercial farmers which also tend to interfere with biodiversity conservation (Scherr and Jeffrey, 2008). The more recent approach is the adoption of nature-based solutions for carbon dioxide removal (Dafnomilis *et al*., 2022). In this review nature-based solutions will be reviewed in relation to GHG emission reductions for the IORA region and evaluate how they can be replicated to solve the CO_2 problem, improve biodiversity and ecosystem health and provide goods and services for the communities.

Nature-based solutions (NBS) are strategies designed to help address multiple challenges simultaneously and therefore, improve carbon dioxide removal from the atmosphere, while maintaining healthy ecosystems that support biodiversity and human needs. NBS provides avenues for decarbonisation, environmental conservation and maintenance of biodiversity therein (Seddon *et al*., 2020) by targeting nature capital. Natural capital is the renewable and non-renewable natural resources (such as air, water, soil and energy) that people directly or indirectly depend on (Vardon *et al*., 2023). NBS seeks to use and conserve these natural resources to slow down climate change impacts, support biodiversity and secure ecosystem services (Seddon *et al*., 2020; Sowińska-Świerkosz and García, 2022) and thus support the socio-economic system.

In relation to energy generation, strategies to reduce atmospheric CO_2 emissions include efficient and sustainable energy generation through renewable/green energy sources such as wind, hydro, solar and geothermal projects. These strategies will be reviewed including the landscape for transition from fossil fuel to renewable energy use in Kenya, Seychelles and Bangladesh in order to provide insights into the success of such approaches, the financial investments and policy interventions needed to aid in the transition from fossil fuels to renewable energy.

Sustainable consumption and production have been recognised as one of the key pillars for achieving the sustainable development goals (Akenji and Bengtsson, 2014) in all sectors of the economy including agriculture, energy generation, waste management, and tourism, among others. Unsustainable patterns of consumption and production are the key drivers of environmental degradation. For instance, one third of the food produced globally goes to waste at different levels of the supply chain including at the consumer level (Mozos *et al*., 2020). Yet food insecurity is experienced across the divide including up to 20% in developed countries (Polard and Booth, 2019). In developing countries, many urban dwellers, especially the poor living in informal settlements, do not get enough food (Faye *et al*., 2011). On the other hand, challenges of food safety vis-à-vis food storage in re-used single use plastics bags may pose a risk to the consumer (Kasza *et al*., 2022). Food safety issues and other plastics-related challenges arise due to the need to reduce plastic production especially, single-use-plastics which increased tremendously during the pandemic (Molly *et al*., 2022). Waste management through proper recycling should be implemented to reduce the cost of doing business, reduce energy waste, food losses, and carbon

footprint and thus, save the environment and biodiversity (Negrete-Cardoso, 2022). Therefore, strategies and policies to guide sustainable consumption and production must be developed and adopted in the IORA countries. This study evaluated the interrelationship between COVID-19, air quality and human health, the impacts of the disease on various sectors of the economy and the possibility of a green recovery.

1.5 Main Objective and Specific Objectives of the Research Study

The main objective of this research study was to evaluate the prospects of a green recovery of IORA countries from the impacts of COVID-19 on the economy, livelihoods, and environment, including climate change. This was done by drawing on case study countries examples from Kenya, Seychelles, Malaysia, and Bangladesh, with the expectation that future work will roll this out to other member states.

Specific Objectives

a) Evaluate the inter-relationship between COVID-19, air quality, climate change, and human health

b) Explore the impact of the Covid-19 pandemic on livelihoods and the response of governments of selected IORA member states.

c) Assess the impacts of COVID-19 on small-scale agriculture especially changes in food production and consumption during COVID-19 in the selected member states of the IORA region

d) Assess the appropriateness of waste management systems in Kenya, Seychelles and Bangladesh as examples of IORA countries

e) Review energy generation and use with a focus on the renewable energy mix across the three case study countries (Kenya, Seychelles and Bangladesh) in the IORA region

f) Evaluate the impacts of the COVID-19 pandemic on production and consumption with a focus on food production across the three case study countries (Kenya, Seychelles and Bangladesh) in the IORA region

g) Assess the impact of COVID-19 on the tourism industry and the possibility of recovery through nature-based solutions

h) Understand the impacts of COVID-19 on the water quality of the aquatic environment in the Indian Ocean Rim Region

i) Understand the impacts of COVID-19 on aquatic biodiversity and ecosystem health and the prospects of implementing nature-based solutions for a green recovery

j) Investigate the impacts of COVID-19 on Mangrove Ecosystems

2.0 General Methodology

2.1 Study Area

The study area was the Indian Ocean Rim Association (IORA) region. IORA is an inter-governmental organisation formed by countries surrounding the Indian Ocean whose main aim is to promote regional economic cooperation and sustainable development. The association was formed in 1997 with 14 member states at its inception which has now grown to a total of 23 countries including Australia, Bangladesh, the Comoros, France (Reunion), India, Indonesia, Iran, Kenya, Madagascar, Malaysia, Maldives, Mauritius, Mozambique, Oman, Seychelles, Singapore, Somalia, South Africa, Sri Lanka, Tanzania, Thailand, the United Arab Emirates and Yemen, and ten dialogue partners that include China, Egypt, Germany, Italy, Japan, Russia, Turkey, the Republic of Korea, the United Kingdom and the United States of America. The IORA focuses on six priority areas of economic development including Maritime Safety & Security; Trade & Investment Facilitation; Fisheries Management; Disaster Risk Management; Tourism & Cultural Exchanges; and Academic, Science & Technology Cooperation; and two cross cutting issues, namely Blue Economy and Women's Economic Empowerment.

For this study, a desktop review of relevant literature related to the main study topics and objectives was done by retrieving data from databases such as Google Scholar, Elsevier, Springer link, Harvard School of Public Health, Frontiers in Public Health and other public databases focussing on COVID-19 and each of the following: air quality and health, socio-economic impact, agriculture, sustainable consumption and production, energy generation, tourism, waste generation and management, water quality and marine biodiversity and ecosystem health.

The desktop study reviewed relevant available literature in general for all IORA countries and others outside of the region where published information was relevant to the study. This project was meant to introduce new IORA mechanisms for regional cooperation and strengthen the institutional research capacity and coordination on Blue Economy related issues. In connection with this, the countries selected to collaborate represented Least Developed (Coastal) Countries and Small Islands Developing States (SIDS) but also countries from different geographic locations around the Indian Ocean. The four IORA member states of Kenya, Seychelles, Bangladesh and Malaysia were used for specific case studies as indicated in the specific objectives (Figure 2.1).

2.2 The IORA member states

The SIDS and the Coastal States are more vulnerable to climate change impacts due to the environmental threats and socioeconomic complexity of their relationship to the ocean. However, these states have the opportunity to reduce negative environmental impacts and increase benefits to the local communities through good practices in tourism initiatives, such as ecotourism (Okech & Bob, 2009), and mitigate climate change through the conservation of natural ecosystems such as mangroves, seagrass beds, and coral reefs (McHarg *et al*., 2022). Furthermore, mitigating climate change requires adopting green/blue technology and nature-based solutions that IORA states (being Island and Coastal States) can adopt and implement given the right environmental

strategies and policies. Therefore, it is crucial to evaluate the relationship between climate change, environmental pollution (air quality) and COVID-19 in IORA regions to develop measures to break the cycle of pandemics and identify lessons learned that can be replicated in IORA member states. The blue economy and nature-based approaches offer a plausible green/blue recovery solution. Such options include the enhancement of carbon sequestration through conservation and restoration of mangrove forests, seagrass beds, and coral reefs; reducing the use of fossil fuels through green energy use; sustainable production and consumption through the circular economy and, consequently improving community livelihood.

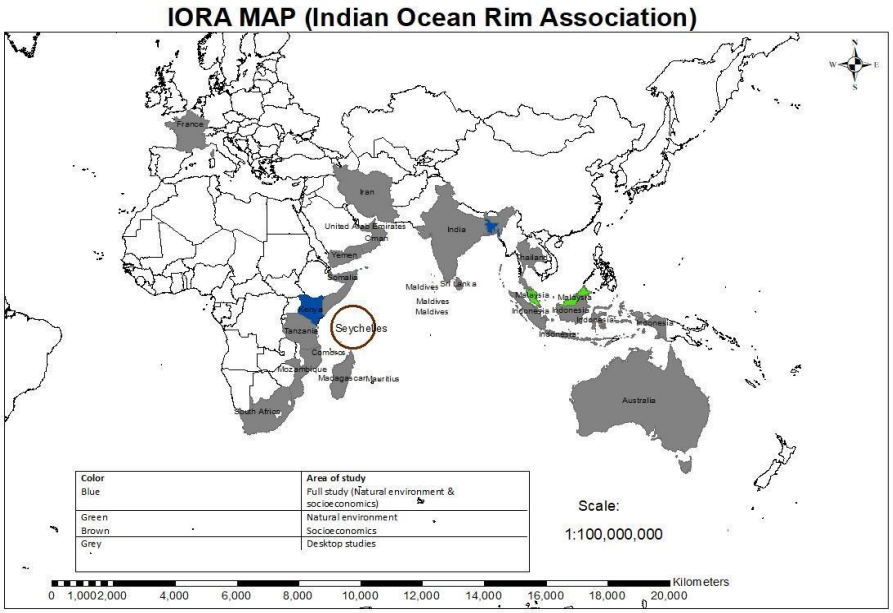

Figure 2.1: IORA countries showing in blue countries where all topics were covered, in green where environmental topics were covered, and in brown only socio-economic study.

To address the objectives stated above, this desktop study report has the following sub-sections:

- Interrelationship between air pollution, climate change and human health
- Socio-economic impacts of COVID-19
- Impacts of COVID-19 on agriculture
- Waste generation and management
- Energy generation and use
- Sustainable Consumption and production
- Tourism industry
- Water pollution in aquatic environments
- Aquatic biodiversity and Environmental Health
- Mangrove ecosystems and blue carbon
- Summary Conclusions and Recommendations, which brings the work together

3.0 Interactions of Air Quality, Climate Change and Human Health

3.1 Introduction

Air pollution and climate change are closely interrelated and often regarded as two sides of the same coin because most activities that emit gases that cause air pollution are the same that cause GHGs that impact on climate (UNEP, 2019). Air pollution is caused mainly by toxic gases such as nitrogen dioxide (NO_2), carbon monoxide (CO3), sulphur dioxide (SO_2), ozone (O_3), Volatile Organic Compounds (VOC), dioxins, polycyclic aromatic hydrocarbons (PAH), particulate matter (PM), and black carbon being emitted into the atmosphere. The pollutants with high public health concerns include PM (PM_{10} and $PM_{2.5}$), NO_2, O_3, CO and SO_2. PM is mainly inhalable particles composed of ammonia, sulphate, nitrate, black carbon, sodium chloride, and mineral dust or water (WHO, 2021). The PMs are a health hazard due to their capacity to infiltrate deep into the lungs and enter the bloodstream (Kinney, 2018; WHO, 2021). NO_2 is a gas that is soluble in water and a strong oxidant. At the same time, O_3 is a primary component of smog and is created through photochemical reactions with pollutants such as NO_2, VOC, and CO. CO is an odourless, colourless gas produced by the incomplete combustion of fuels with carbon, such as petrol, wood, coal, kerosene, and natural gas (WHO, 2021). SO_2 is a colourless gas soluble in water and predominantly produced from fossil fuel combustion (WHO, 2021). Anthropogenic activities are the primary producers of these air pollutants. Due to the rapid urbanisation, there has been an acceleration of emissions, way above the WHO recommended maximum levels (WHO, 2021) in developing countries (Hassan *et al*., 2016).

Air pollution can ameliorate or exacerbate atmospheric temperatures, thereby affecting warming. Air pollution caused by sub-micron-sized particles or aerosols can be transported across continents and oceans as atmospheric brown clouds (ABC). The ABCs tend to absorb and reflect sunlight, thereby causing surface atmospheric dimming, which can be enhanced further by aerosols when they nucleate more cloud droplets and thus reduce atmospheric temperatures. On the other hand, black carbon and particulate matter in the atmosphere act like GHGs by absorbing solar radiation from the earth and thus increase atmospheric heating (Ramanathan & Feng, 2009). In regions experiencing high surface ozone levels, high temperatures will lead to even further warming. At the same time, particulate matter and black carbon tend to decrease in high precipitation and increase where forest fires are frequent (Jacob & Winner, 2009).

Air pollution has generally negative impacts on human health but more so in young children, people with chronic diseases and the elderly (Esposito *et al*., 2014). Respiratory diseases associated with air pollution include Chronic Obstructive Pulmonary Disease (COPD), asthma, bronchiolitis, and lung cancer (Manisalidis *et al*., 2020). COVID-19, also associated with the respiratory system, was more severe in people with pre-existing conditions (Treskova-Schwarzbach *et al*., 2021). Indeed, Ali and Islam (2020) found that exposure to air pollution particularly $PM_{2.5}$ and NO_2 contributed to significantly higher COVID-19 infections and mortality. However, people with chronic lung diseases and asthma using inhalers were less likely to get severe COVID-19 or die from the disease (Aveyard *et al*., 2021) due to the frequent use of steroids in the inhalers.

The impacts of climate extremes on air quality and associated health implications due to the COVID-19 outbreak are not well documented. Moreover, the responses to COVID-19, such as shutdown and reduced travel, led to a significant reduction of air pollution and GHGs (CO_2 and NO_2) emission in the atmosphere and thus reduced atmospheric heating, albeit in a small way (Amnuaylojaroen and Parasin, 2021; Usman *et al*., 2021). This may indicate that reducing human activities that cause emissions of atmospheric gases (GHGs and air pollutants) could positively impact on climate and human health.

Therefore, as the IORA countries start recovering from the COVID-19 pandemic effects, there is a need to rethink and re-engineer ways to spur economic growth for socio-economic development while at the same time reducing air pollution and GHG emissions and thus, mitigate against climate change impacts and human health.

3.2 Methodology

A desktop literature review of recent and emerging studies was conducted to determine the synergetic influence of air pollution and climate change on the risk of morbidity and mortality of respiratory diseases, especially COVID-19. The interrelation between air pollution and climate change and its influence on human health for individuals and communities in the IORA region was identified. The body of literature investigating the association or correlation between air pollution, climate change, and COVID-19 is nascent. However, reviewing these associations could be helpful in comprehensively informing future public health disease burdens in a changing climate. Through this review, the groundwork for future research on the topic, the complexities of the interaction between climate, air quality, and human health will be established, and outline promising strategies and regulatory frameworks.

3.3 Results

3.3.1 Interaction between air quality on human health

During the first WHO global conference on Air Pollution and Health, the WHO General Director, Dr. Tedros Ghebreyesus referred to air pollution as "the new tobacco" and a "silent public health emergency" (Manisalidis *et al*., 2020). Air pollution is the leading environmental cause of illness and premature deaths globally, causing an estimated 6.7-7.1 million premature deaths yearly (*Climate Explainer*, 2022; Fuller *et al*., 2022). Approximately 95% of these deaths happen in developing countries where people are exposed to indoor and outdoor concentrations of air pollutants multiple times higher than the WHO guidelines (Table 3.1) (Amnuaylojaroen & Parasin, 2021). Air pollution causes diseases such as ischemic heart disease, pneumonia, stroke, COPD, and neonatal disorders, depending on the scale of exposure (*Climate Explainer*, 2022). Short-term exposure to air pollution is associated with coughing, COPD, wheezing, shortness of breath, asthma, and increased hospitalisation rates (Manisalidis *et al*., 2020). Long-term exposure to air pollution is associated with pulmonary insufficiency, asthma, cardiovascular disease, and mortality. Local levels of $PM_{2.5}$ in the atmosphere have been shown to be closely interrelated with years of life lost (Juginović *et al*., 2022) and daily ranges of PM were shown to correlate with daily

mortality (Fang *et al*., 2013; Manisalidis *et al*., 2020). People living in urban areas are more prone to impacts of air pollution due to the higher exposure to the pollutants (Kinney, 2018). In infants and toddlers, air pollution causes several malign health effects such as mental perinatal, cardiovascular, and respiratory disorders that could lead to chronic disease in adulthood or infant mortality. For instance, in Dhaka, Bangladesh high levels of air pollution impacted pregnancy outcomes with as high as 20-36% low birth weights and 9-15% preterm birth pollutant concentration (Zhu *et al*., 2020).

Air Pollutants	**WHO Guidelines on exposure values**	
	Long term	**Short term**
$PM_{2.5}$	10 $\mu g/m^3$ annual mean	25 $\mu g/m^3$ 24-hour mean
PM_{10}	20 $\mu g/m^3$ annual mean	50$\mu g/m^3$ 24-hour mean
O_3		100 $\mu g/m^3$ 8-hour mean
NO_2	40 $\mu g/m^3$ annual mean	200 $\mu g/m^3$ 1-hour mean
SO_2	20 $\mu g/m^3$ 24-hour mean	500 $\mu g/m^3$ 10-minute mean
CO		4 mg/m^3 24-hour mean

Table 3.1: The guideline values for Air Pollutants according to the World Health Organization (World Health Organization, 2021).

The value of health damage caused by air pollution is estimated at USD 8.1 trillion yearly, translating to 6.1% of the global GDP (*Climate Explainer*, 2022). In India, 1.67 million deaths and economic loss of USD36.8 billion annually due to premature deaths and morbidity were attributed to air pollution in 2019 (IS-LDPC, 2021). The highest deaths associated with $PM_{2.5}$ were recorded in the country's northern region's more industrialised and densely populated cities (Zhu *et al*., 2020). In Bangladesh, Mahmood (2011) estimated that 15 000 people die every year and USD 200M-USD 800 million is lost annually due to poor air quality. In Malaysia, levels of PM_{10} were 80$\mu g/m^3$-100$\mu g/m^3$, way above the recommended WHO Air Quality Guidelines level of 20$\mu g/m^3$. In Kenya, although data is limited, the available data indicated that most parts of Nairobi experience levels of $PM_{2.5}$ and P_{10} higher than the recommended levels by WHO mainly due to emissions from vehicles (deSouza, 2020).

The situation in most other IORA states could be similar due to uncontrolled urbanisation, overpopulation, development and industrialization (Manisalidis *et al*., 2020). The rise of motorcycle use for transportation in rural and urban areas of developing countries, such as India and Kenya, is associated with increased emissions that further reduces air quality (Manisalidis *et al*., 2020). The use of wood fuel or biomass for cooking and heating, especially in low-income households, exposes individuals to indoor air pollution. It is estimated that more than three billion people worldwide use wood and solid fuel for heating and cooking (Household Air Pollution, 2022). Approximately 3.8 million individuals die yearly from smoke emitted by cooking fires (Household Air Pollution, 2022). Women and children seem to have the highest risk of developing COPD and lung cancer due to prolonged exposure to this poor indoor air (Manisalidis *et al*., 2020). Social disparities and lack of adequate information about the consequences of air pollution and lack of access to sustainable energy sources further exacerbate exposure to air pollution.

Shifts in climate, especially climate warming, may increase the susceptibility of vulnerable populations to the effects of air pollution, such as the elderly populations, thereby increasing the morbidity and mortality rate. Fine and ultrafine particulate matter can remain longer in the atmosphere in warmer drier conditions and invade deeper parts of human airways reaching the bloodstream more easily, thus, causing more severe ailments (Kinney, 2018; Manisalidis *et al*., 2020).

Unfortunately, research and information on air quality (CO and SO_2) and Covid-19 is limited (Amnuaylojaroen & Parasin, 2021). Thus, correlation between COVID-19 and air pollution is uncertain, as some studies have shown positive interactions, while others have shown negative interactions. Some studies indicate that air pollution exacerbated the rate of Covid-19 mortality, yet simultaneously, the lockdown led to reduced levels of air pollution (Amnuaylojaroen & Parasin, 2021). Recent evidence shows that exposure to higher pollutant levels such as PM_{10}, $PM_{2.5}$, NO_2, CO, and O_3 was associated with a heightened risk of Covid-19 infection (Amnuaylojaroen & Parasin, 2021; Mostafa *et al*., 2021). Zhu *et al.* (2020) observed a 15.11% increase in daily confirmed COVID-19 cases associated with $1g/m^3$ of CO in the atmosphere. Similarly, Zoran *et al.* (2020) found a positive correlation between daily maximum PM_{10} and average surface $PM_{2.5}$ on the one hand and recorded new cases of COVID-19 on the other. Sangkham *et al.* (2021) showed a negative correlation between COVID-19 cases and air pollution (NO_2, SO_2 and CO) in different parts of the world. Work on the correlation between air-pollutants and meteorological variables in four Italian cities showed that higher tropospheric ozone concentrations slowed down COVID-19 pandemic-related transmission (Lolli & Vivone, 2020).

Some studies have shown the indirect effect of COVID-19 lockdown on alleviating air pollution, especially in urban areas. Mostafa *et al.* (2021) found a compelling association between the COVID-19 lockdown in Egypt and a 5% reduction in CO and a 15-33% decrease in NO_2. In India, Kumari and Toshniwal (2022) found that the lockdown could have reduced SO_2, $PM_{2.5}$, PM_{10}, and NO_2 concentration by 19%, 49%, 55%, and 60%, respectively, in Mumbai and Delhi cities. Wetchayont (2021) corroborates these findings as he established that O_3, CO, PM_{10}, and $PM_{2.5}$ concentrations significantly declined in Bangkok, Thailand, during the COVID-19 pandemic due to containment measures. In Malaysia, Othman and Latif (2021) compared the levels of nine air pollutants, including PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, and CO, in nine cities before and during the movement control order (MCO) implemented during the pandemic. They found that pollutants had a higher hazard index before than during MCO (Othman & Latif, 2021). The COVID-19 lockdown reduced the levels of air pollutants primarily due to reduced movement of people and hence, reduced vehicular emissions. Consequently, the human health risk reduced tremendously due to reduced human activity demonstrating that reduction in activities that produce pollutant gases in the atmospheres can have a positive influence on human health due to reduced atmospheric air pollutants.

3.3.2 Policies guiding air quality in the IORA region

Many IORA member states have developed different types of legislation to deal with environmental degradation and air quality, Table 3.2. However, among the four selected IORA states only Malaysia has developed legislations that integrates air quality with other sectors of the

economy and has set standards for up to six main air pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO and O_3) and regularly carries out monitoring. The other countries have air quality policies anchored in their environmental management Aacts and no indication of integration of air quality control to other sectors of the economy such as transport, energy generation, and no regular monitoring. This lack of regular air quality monitoring and integration with other sectors of the economy exposes the populace to air pollution and diseases. Besides, many air pollutants, as has been pointed out, are also GHGs and thus continued air pollution continues to jeopardise climate change goals.

Table 3.2 Legislations on air quality in IORA member states

Country	Policies	Highlights	Source
Kenya	Environmental Management & coordination Act No. 8 0f 1999.	Sets out the legal and institutional framework for environmental management including air quality	http://kenyalaw.org/kl/fileadmin/pdfdownloads/Acts/EnvironmentalManagementandCo-ordinationAct_No8of1999.pdf
	The Environmental Management and Co-Ordination (Air Quality) Regulations, 2022	Provides allowable levels of emissions from different sectors	http://www.nema.go.ke/images/Docs/Regulations/Draft%20Air%20Quality_Regulations%202022.pdf
Seychelles	Laws of Seychelles Chapter 71 Environment Protection Act	Gazette any area as an air pollution control area in Seychelles	https://faolex.fao.org/docs/pdf/sey4585.pdf
	National Climate Strategy, 2009	Alternative energy sources other than fossil fuel	https://www.preventionweb.net/files/20091100_seychelles_climate_change_strategy_2009.pdf
Bangladesh	Air Pollution (Control) Rules 2022, established under the Bangladesh Environment Conservation Act 1995	Provides National Air Quality Control Plan, Air Pollution Prevention Plan, identify air pollution activities, establish standards for emissions from industry, automobiles, and projects	https://enviliance.com/regions/south-asia/bd/report_7939
Malaysia	National Ambient Air Quality Standards	AQS adopted measure for 6 parameters PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO and O_3	https://environment.com.my/wp-content/uploads/2016/05/Ambient-Air.pdf
	Clean Air Action Plan under the Dept Env.	Strategies and indicators for a roadmap to improve air quality	https://www.kasa.gov.my/resources/alam-sekitar/Clean-Air-Action-Plan.pdf
	National Air Quality Policies	Provides air quality policies from different sectors and the standards	https://wedocs.unep.org/bitstream/handle/20.500.11822/17046/Malaysia.pdf?sequence=1&isAllowed=y
	National Environmental Health Action Plan (NEHAP) Malaysia	Recognise the connection between air quality and human health	http://nehapmalaysia.moh.gov.my/wp-content/uploads/2021/04/Action-Plan-TWG-NEHAP-2016_2020-Final-Dis-2020.pdf

3.4 Conclusions and Recommendations

This literature review has found that ambient air pollution in most IORA countries is high and the governments have done little to deal with this issue especially in relation to public health. Some of the major drivers of air pollution are transport, energy generation, manufacturing and

urbanisation. There are no programs to help reduce air pollution and no regular monitoring in most countries. While air quality has a direct influence on health, especially respiratory diseases, there is little effort made to curb the air pollution and deal with human health. Indeed, air quality and pre-existing conditions, especially respiratory diseases, were found to exacerbate the impact of COVID-19.

Many households in developing countries, including in the IORA region, use biomass and kerosene for cooking, but this aspect was not investigated in this study. It would, therefore, be insightful to investigate indoor air pollution and health. Table 3.3. highlights recommendations that, if adopted, will help improve air quality and consequently public health.

Table 3.3: Strategies for IORA member states to adopt in order to reduce air pollution, mitigate against climate change and improve human health.

Sector	Pollutant	Recommendation
Transport	CO, SO_2, NO_2, black carbon and O_3	Transitioning from diesel-powered vehicles to electric vehicles. Establish a program for constant vehicular inspection and maintenance. Limit the age of imported vehicles and remove old ones from the roads. Provide efficient public transport systems to discourage personal vehicles.
Industrial	PM, VOC, NO_x, SO_x, PAH, toxins	Energy subsidies and incentives that phase out the use of fossil fuels. Policies that require the use of renewable energy by industries. Installation of electrostatic precipitators and scrubbers. Use of retrofitted technologies such as desulfurization and catalytic convertors by industries. Air pollution control fines and charges to offenders. Better building insulators for fire, thermal, and acoustics to reduce energy use.
Agriculture	Methane, NO_2, Ammonia, Nitrous Oxide	Phase out the use of nitrogen-based fertilisers. Improve manure and fertiliser management. Transition to renewable energy use in the agricultural sector. Improve livestock farming efficiency. Adopt sustainable agricultural practices such as drip irrigation. Carbon capture initiatives such as forest management, afforestation, and reforestation programs that improve carbon sequestration.
Energy	O_3, CO, SO_2, $PM_{2.5}$, PM_{10},	Phase out fossil fuels use in industries and power generation Introduce a carbon tax system to incentivize polluters to transition to more efficient energy sources. Adopt renewable energy sources such as wind, geothermal, and hydroelectric power. Adopt smart buildings such edge technology to reduce energy use.
Household	PM, CO, NO_x,	Investigate the impact of use of solid fuel (biomass), coal stoves and kerosene for cooking and the landscape to transitioning to cleaner energy like LPG.
Research and Data	N/A	Set up air quality measuring and monitoring stations in all states incorporating use of low-cost sensors, citizen science, and new technology. Set up air quality data collection, sharing, and forecasting and a repository, and capacity building and sharing among IORA scientists. Predictions of air quality using representative concentration pathway (RCP) scenarios for risk assessments and implementation of appropriate policies and mitigation measures.
Education	N/A	Comprehensive information dissemination to all stakeholders about air pollution, causes, implications on human health and appropriate actions to reduce emissions and disease burden.

4.0 Socioeconomic Impact of the Covid-19 Pandemic in the IORA Region

4.1 Introduction

Any contagious pandemic negatively affects individuals and society (Lai & Cavanagh, 1997). Likewise, the Covid-19 pandemic caused unexpected shifts in socioeconomic behaviour (Hua & Shaw, 2020; Lai *et al*., 2020; WHO, 2020). It severely affected Africa and Asia, hurting vulnerable people and causing severe problems for their social structures, economies and health. Bangladesh, Kenya and Seychelles were not spared from the adverse socioeconomic impacts. After the first detection of infection in Bangladesh on 8 March 2020, the highly contagious virus is still in circulation today. The first Covid-19 case was detected in Kenya on 13 March 2020. Two Covid-19 cases were detected in Seychelles on 14 March 2020. Since then, the number of cases has escalated. As of the 23rd of February 2023, Covid-19 infections had reached 203,777 among 169.4 million people in Bangladesh, 342,900 among 53.01 million people in Kenya and 50,665 among 99,982 people in Seychelles (worldometer.com). The unofficial death toll was more than the stated total because many people were not counted because they did not receive treatment and hid their sickness to avoid social stigma (Dubey *et al*., 2020).

At the outset, the Bangladesh government quickly implemented measures to contain the spread of the virus, such as social distancing, mandating face mask use and enforcing nationwide lockdowns from late March 2020 to July 2021. The Kenyan government imposed international travel bans and movement restrictions. Seychelles' government worked hard to stop its spread by applying travel bans and temporarily closing the island to cruise ships. Movement restriction measures severely disrupted the economies of these nations with varying degrees of economic progress, healthcare infrastructure and societal adaptability.

4.2 Methodology

We collected secondary data and information from legal national and international sources to report the socioeconomic influences of the Covid-19 pandemic on households in the IORA member states, namely Kenya, Seychelles and Bangladesh. These sources cover both electronic and printed research reports and publications. Since many scientific reports and journal articles exist, a selective exploration method was employed to select required documents related to this study. Various keywords were used to search in Google Scholar, such as 'Impact of Covid-19 + Socioeconomic', 'Covid-19 + Bangladesh + Socioeconomic', 'Covid-19 + Kenya', and 'Covid-19 + Seychelles'. Among the many suggested publications, articles were sorted based on the relatedness (e.g., economic, social and psychological impacts, healthcare infrastructure, policies and interventions related to Covid-19) and quality of the journal article (e.g., peer-reviewed article). Further refinement was accomplished following the title and abstract of the respective studies published in English.

4.3 Results

Bangladesh

Although Bangladesh did not have relevant health policies initially, it adopted the 'National Preparedness and Response Plan for Covid-19, Bangladesh' (IEDCR, 2020).

Health

After the first Covid-19 patient was identified in Bangladesh, the number of infected people rose significantly. The healthcare system was unprepared to deal with the outbreak. A critical aspect in Bangladesh was the paucity of physicians and nursing staff compared to other countries; on average, 0.7 doctors for every 1,000 persons. Critical patients and people with disabilities were denied access to necessary healthcare due to Covid-19. Healthcare personnel who treated patients during the pandemic were socially stigmatised (Hasan *et al*., 2021; Razu *et al*., 2021).

Bodrud-Doza *et al.* (2020) found that 62% of interviewees strongly recognised Bangladesh's poor healthcare system. They found a significant positive relationship between the trauma of Covid-19 casualty and the country's fragile healthcare infrastructure. Despite various flaws in the health systems, the government endeavoured to combat the pandemic. The government started a mass vaccination effort to immunise millions over several days - this percentage had increased to 68% after a year. The vaccinated population stands at 121.2 million, 71.6% as of March, 2023 (UNICEF, 2022).

Mental health

In Bangladesh, Hossain *et al.* (2021) revealed that 45% of their respondents experienced trauma due to the Covid-19 pandemic. According to Marzo *et al.* (2021), 44.3% of 503 respondents experienced average suffering, while 9.5% experienced extreme suffering due to COVID-19. Women were 2.435 times more distressed than men. Hossain *et al.* (2021) found that awareness was closely related to trauma, and family income was one of the strong predictors of awareness.

Education

The COVID-19 outbreak significantly affected the country's education system. On 16 March 2020, the education minister announced a sudden closure of schools, colleges and universities till 4 April 2020, and this date was extended as more infected people were recorded. Also, the ministry of education postponed all public examinations for extended periods. The government announced the continuation of classes at every level via an online platform and allocated funds towards this. Lack of handling experience with digital devices, limited internet access, and unavailability of digital content limited teachers' active participation during the pandemic (World Bank, 2020a; Dutta & Smita, 2020; Begum *et al*., 2020).

Economic impact

Throughout the last 14 years, Bangladesh has demonstrated consistent economic growth and made outstanding progress in all socioeconomic indicators, except for the brief downturn imposed by the COVID-19 pandemic. Due to the pandemic, the GDP growth of Bangladesh fell sharply to

3.45% in 2019-20 from 7.88% in the pre-pandemic year. Nevertheless, in 2020-21, GDP growth rebounded to 6.94% (Finance Division, 2022; BER, 2022, UNICEF, 2020).

The ready-made garment (RMG) sector had been severely hit. Due to the lockdown, many RMG employees lost their jobs. As of the end of April 2020, the loss of order cancellation was USD 3.16 billion. After the withdrawal of the lockdown, RMG sectors recovered because of stimulus packages and export incentives by the government, equivalent to USD 6.25 billion (BGMEA, 2020; Shammi *et al*., 2020). Due to the pandemic, export sectors suffered since the shipments were 83% lower in April 2020 and 66% lower in May 2020 compared to the same months the prior year. Although export revenues were substantially better in June 2020 than expected, overall exports for 2019-20 were 17% lower than the previous year. However, export revenue from goods reached USD52.08 billion in 2022, an increase of 34.38% by 2021 (Finance Division, 2022; Rahman *et al*., 2020). The decline in remittance flow from diaspora was another blow for Bangladesh due to COVID-19. Countries where Bangladeshi labourers work outside of Bangladesh were affected by COVID-19, hence, the availability of formal and informal jobs was reduced due to the shutdown of all economic operations (Lalon, 2020). Remittance flow stood at USD 21.03 billion in 2022, 15.12% less than in 2021 but 15.5% higher than in 2020. Therefore, it is evident that Bangladesh's economy has shown a good recovery from the pandemic's adverse effects due to the government's stable macroeconomic strategies (Finance Division, 2022).

Role of government

The Government of Bangladesh took numerous defensive actions to combat the disease outbreak, including identifying COVID-19 hotspots and implementing lockdowns, promoting public awareness through digital platforms, deploying more defence personnel, and hiring more healthcare professionals to limit the number of coronavirus outbreaks. The information and communication technology (ICT) division and the Directorate General of Health Services of the Government of Bangladesh launched the Corona Tracer BD application for smartphone devices that provided the most recent COVID-19 information, suggested nearby medical centres and screening facilities, updated incidence information (infected, death, recovery), and other relevant announcements. The government undertook incentive programmes to combat the economic impact due to Covid-19 (Economic Relation Division, 2021).

Kenya

Social impacts of Covid-19

With significant informal sectors and few social security measures, Kenya was heavily hit by COVID-19. Kenya's government proposed many economic stimulus measures to support people from various social groups, including tax cuts, VAT reductions, and income and company tax cuts (Were, 2020). The President formed the National Emergency and Response Committee on 28 February 2020 and implemented state-wide awareness campaigns. Kenya faced massive testing challenges, especially in locations with confirmed cases and high population density (Obonyo, 2020). The rate of adults vaccinated stands at around 37.2% (Ministry of Health of Kenya, 2023).

Kenya depended on outside help to implement health reforms, with government spending remaining at 6%, below the 15% worldwide average. Health services were inadequate and

sometimes absent in response to the COVID-19 pandemic (Kithiia *et al*., 2020). After the pandemic broke out, many household members required medical services, and access to medical care appeared as a barrier for both genders. The social limitations of COVID-19 created new risks for violence, with a particular emphasis on relationships and sexual assault against young women; some adolescents were lured into criminal gangs owing to economic pressures and police aggression against men. Moreover, it created many detrimental social and economic effects in rural areas, such as a sharp increase in teenage pregnancies, domestic violence, job losses and business failures (Barasa *et al*., 2022; Decker *et al*., 2021; Wangu & Githuku, 2022).

Upon hearing about COVID-19, most began following positive behaviour habits to avoid infection. They used masks (97.7%), reduced excessive travel (99.3%) and cleaned their hands more frequently (97.8%) (Karijo *et al*., 2021).

Education

The Kenyan government promoted remote learning while adhering to social isolation. The Education Ministry produced web content that students accessed via various channels to ensure they could learn from home. However, this had many challenges. School closures impacted students' capacity to communicate with teachers and lead to a decline in learner participation. Differences arose in the quality of learning engagement because underprivileged students could not afford to engaged in distance learning (online, radio and TV programs). Also, during COVID-19, females from low-income homes were less likely to learn remotely and reported spending twice as much time on domestic tasks than boys (MoE, 2020; World Bank, 2021).

Effects of Covid-19 on the economy

The harsh economic repercussions of the pandemic did not stop Kenya's economy from staging an impressive comeback. After contracting by 0.3% in 2020, the real GDP grew by 7.5 % in 2021, although the pandemic in general slowed Kenya's poverty reduction efforts. Poverty has decreased through 2021, although it remains higher than before the epidemic, with rural regions having a slower decline. Unemployment quadrupled, from 4% in the fourth quarter of 2019 to 16% in October-November 2020. The employment proportion of the working-age population reverted to pre-pandemic levels after falling from 80% to 71% between July and October 2021 and November 2021 to March 2022 (Mathenge *et al*., 2022; World bank, 2021).

As the pandemic started, household income from work in Kenya decreased by 33%, and at the same time earnings from gifts and remittances decreased by more than 33%. Urban livelihoods were notably harmed, while school closures restricted access and learning; this coincided with a significant increase in short-term poverty. Many Kenyans lost their jobs, and a sizable portion fell into inactivity. About 88% of respondents in Kenya who participated in qualitative phone interviews reported having a decreased income, with urban residents being the worst hit. In low-income rural Kenyan households, income from work fell by around one-third after the pandemic began (Janssens *et al*., 2021; Zollmann *et al*., 2020).

In jobs subject to disruption, females experienced job losses more than males, especially in the service and manufacturing industries (KNBS, 2020). Kithiia *et al.* (2020) revealed that 11% of women in self-employment could work from home, and none of the 28% of women in casual

employment could earn a living by working from home. Individuals who worked from home reported difficulties related to internet service access, reliability and affordability. Problems with the internet accounted for 31% of those who worked from home. Distractions were highlighted by 29% of respondents as another obstacle.

Kenya's labour market began to revive in the second part of 2020. The proportion of working-age people in employment increased throughout the year's second half, reaching more than 60% by the end of 2020. Men's employment improved steadily, but women's employment remained stagnant by the end of 2020; nonetheless, for both men and women, employment stayed lower than it was prior to the epidemic (World Bank, 2021).

Seychelles

Socioeconomic impacts

Seychelles is considered a high-income nation by the World Bank. Before the pandemic, Seychelles outperformed other African nations on numerous development indices, frequently placing first overall. However, the pandemic severely hit the country's macroeconomic performance. Seychelles immediately shut down public movement after identifying their first case of Covid-19 and removed most restrictions in June 2020. The nation's total fiscal balance, between -1.4% and 0.7% of GDP between 2016 and 2019, abruptly changed to a deficit of -19.5% of GDP in 2020. By the end of 2021, the public debt, which was 62.3% of GDP at the end of 2018 and was forecast to reach 87.7%, would be extremely high.

The tourism, fishing, and shipping industries, which account for around 37% of all employment in Seychelles, were all adversely impacted by the pandemic. The pandemic harshly impacted the informal sector. The unemployment rate was 2.7% in 2019 and increased to 4.8% within six months (March to September) of 2020. The economy of Seychelles is enormously contingent on tourism and service industries, which the pandemic severely harmed. The tourism sector was paralysed by the travel ban that was in place from 23 March until 31 July 2020. Since February 2020, cruise ship trips were suspended permanently and postponed until the end of 2021 and again until the beginning of 2022.

Seychelles' Government implemented several stimulus plans to fend off COVID-19. For April, May, and June 2020, the government agreed to guarantee pay for all employees working in the private sector, and no redundancies were permitted during this time. Furthermore, the government provided more stimulus packages that included increased budget for social protection for monetary support to the informal sector's people; loan refunds condensed for six months; decreased electricity tariffs by 25 cents per unit and monetary support to small and medium entrepreneurs to safeguard their businesses from April to June 2020 (UNDP, 2020).

The tourism and fishing industries, which resulted in an enormous influx of foreign travellers and migrant workers, were reported as a significant element responsible for the virus's spread in Seychelles during the pandemic's start (Kousi *et al*., 2022). Despite a persistent increase in COVID-19 infections in Seychelles in 2021, the government made vital efforts to enhance its health system to respond successfully to the pandemic; this is reflected in the 0.38% case fatality rate. Beginning with a relatively small capacity, the country today has one fully-fledged Health

Laboratory and four PCR testing facilities. Being one of the few African countries with high immunisation rates, the government actively expanded vaccination, with 68% of people vaccinated by 2022; this facilitated its early reopening and rapid economic recovery (African Development Bank, 2022).

Although having sufficient nurses and doctors in Seychelles, they were under-prepared to tackle such pandemics as COVID-19. Many people's physical health was impacted by the pandemic, while countless more were psychologically impacted. Most of Seychelles' public schools and day-care centres remained closed during the lockdown period. The lockdown was expected to increase gender-based violence, but the government data showed no increase in recorded incidents. To stop the COVID-19 spread, Seychelles' Central Bank disseminated posters and booklets available in English and Creole. Furthermore, the telecommunication providers offered free browsing and free access to educational websites.

The Ministry of Education and Human Resource Development instructed the movement to online education. For improved communication and learning for school staff and students, telecommunications companies stepped up. Collaborating with mobile companies, the Seychelles Institute of Distance and Open Learning offered new mobile packages to all its teachers and students to help deliver classes and studies (UNDP, 2020).

4.4 Conclusions and Recommendations

The results reveal that the COVID-19 pandemic severely hampered the three countries' health, economy and society, albeit by varying degrees. The pandemic highlighted the weaknesses in these countries' healthcare systems and exposed their economies' vulnerabilities. In Bangladesh, the pandemic resulted in the closure of businesses and loss of jobs, with the garment industry being particularly hard hit. The healthcare system struggled to cope with many COVID-19 infected patients, although the government kept the mortality rate relatively low. In Kenya, the pandemic strained the weak healthcare system with shortages of medical supplies and equipment. The pandemic also led to widespread unemployment and reduced economic activity, particularly in informal sectors. Although Seychelles controlled the spread of the virus through strict border controls and lockdown measures, the tourism-dependent economy suffered a significant blow, with a sharp decline in tourist arrivals.

This study recommends tailored interventions and policies to mitigate the pandemic's impact in each country and the broader IORA region.

- IORA countries must construct inclusive and effective healthcare schemes, moveable and telepath health consultancy services and expanded lab amenities to promote disease prevention, early identification, treatment and containment; this will lower the number of fatalities in upcoming incidents and pandemics.
- Social safety packages should be enhanced to preserve livelihoods, lower household food insecurity and enhance effectual control processes like movement restrictions designed for lowering societal connections among neighbourhoods in IORA countries. Budget revisions for healthcare to improve disaster readiness, uninterrupted food chains, incentive packages and

low-interest loans for small and medium-sized enterprises all help lessen pandemics' economic effects.

- The countrywide contingency strategies should be fostered for increased sectoral and domestic preparedness in IORA countries. They should employ a holistic strategy to handle physical, medical and health needs covering social, psychological and emotional issues.
- IORA nations need to increase flexible work arrangements, including telecommuting, digitalisation, staff interchange and alternated hours so that staff can work from safe places in their home and students can take classes online.
- Social leaders should be aware and ensure that effective communication prevails among people in the local community so that they interact and exchange information on the pandemic's spread and essential precautions.
- Priorities in policy should gradually move toward decreasing environmental threats to human health. Natural ecosystems and biodiversity should be strictly protected to benefit human health. Investment in creating green and renewable energy can offer green/clean electricity that can improve air quality and climatic outcomes and benefit human health in the long run.
- Regional collaboration should be encouraged to allow the efficient cross-border flow of critical commodities and services, e.g., food, medicines, health equipment and necessities.
- Policies should be evaluated, priorities should be adjusted by removing subsidies for fossil fuels and putting them into green recovery, enhancing healthcare facilities, fostering economic growth and prioritising initiatives that reduce poverty and vulnerability.

5.0 Impact of Covid-19 on Agriculture in the IORA Region

5. 1 Introduction

The Covid-19 pandemic posed significant food and nutrition security hazards through food-production, distribution and access interruptions in addition to the effects on public health. Almost 2.5 billion people, one-third of the world's population, reside in the Indian Ocean Area (Javaid, 2020), and the region is still recovering from the impacts inflicted by COVID-19. There were significant financial, economic and social consequences of the COVID-19 pandemic. COVID-19 caused extensive negative impacts in the agricultural sector of IORA member states. Following this shock, numerous governments from IORA nations stepped forward to address the short- and long-term risks of COVID-19 by incorporating various policies for the economy, including agriculture. Besides reviewing the impacts of such policies, this chapter focuses on the changes in food production and consumption during COVID-19 pandemic period in three-member states, Bangladesh, Seychelles and Kenya, of the IORA region.

5.2 Methodology

The chapter is exploratory and descriptive. Peer-reviewed studies, grey literature, blogs, and research reports from governments and organisations were all screened for their important content using a critical review approach. Following Moher *et al.* (2009) for selecting the literature, four steps were followed: (i) Identification, (ii) Screening, (iii) Eligibility and (iv) Included. The literature on COVID-19, the IORA region, agricultural production, consumption, food security, agro-food system and government policy interventions in these countries was chosen through screening from the materials that had been identified. Finally, 34 documents were ultimately chosen for examination.

5.3 Results

5.3.1 COVID-19 pandemic and food production

Agricultural systems, particularly agro-food supply networks, were severely disrupted in the IORA region due to the COVID-19 pandemic. Although there may have been enough food in the supply chains at the start of the pandemic, scarcity and inconsistency in the food supplies were caused by panic buying by the public, who anticipated the potential of supply shortages during restrictions. Due to a scarcity of seeds, pesticides, capital and other essential agricultural inputs at the farmer level, agricultural production decreased in Bangladesh. As the government declared an official lockdown intending to decrease the spread of COVID-19, farm labourers were also restricted from moving from one place to another. As a result, farmers were unable to harvest their crops due to a lack of seasonal agricultural workers. Besides, the supply chain of agricultural products comprises many stages which require the transportation of farm produce from the producer to the ultimate consumer through several intermediaries. Nevertheless, this system was not smooth due to the

restriction imposed that adversely affecting agri-product availability throughout the country. Consequently, the production cost of agricultural products increased.

COVID-19 and government regulations were also found to have impacted the cost and availability of labour and agricultural inputs, distribution, and bean consumption in the Eastern African member states of Kenya, Mozambique and Tanzania (Nchanji *et al*., 2021). Government restrictions impacted on the labour-intensive operations like planting, plant management, harvesting, threshing, and storage since bean production requires much labour (Baudron *et al*., 2019; Nassary *et al*., 2020a, 2020b).

Farm inputs, supply timing and other hindrances significantly influence food production results (Ayanlade and Radeny, 2020). Studies carried out in IORA regions depicted that more than 70% and 20% of farmers, in Bangladesh and Kenya, respectively, faced difficulties getting different agricultural inputs like seed, fertiliser, pesticides, diesel for irrigation, sufficient labour and extension services (Babu *et al*., 2020; Hammond *et al*., 2022). Government action was necessary for Seychelles, one of the archipelagic states, to lessen the impact of imported agricultural inputs such as seeds, fertiliser, pesticides, animal feeds, eggs for hatcheries and day-old chicks (Rassool *et al*., 2020). More than 90% of Bangladeshi farmers reported a labour and equipment deficit during the rice planting, harvesting, and threshing seasons (Babu *et al*., 2020). Low supplies of insecticides and pesticides were limiting the efforts to protect the crops in Bangladesh affected initially, and as a consequence, the yield was reduced. According to Das *et al.* (2020), the yield of Boro rice production was lowered by 7%, as anticipated in 2020, accounting for roughly USD 438.9 million in national loss—farmers in need were forced to sell their produce at low prices to pay their bills. According to Babu *et al.* (2020), over 30% of farmers had trouble getting their products to market, and more than 50% blamed high transportation costs for the rise in product prices in Bangladesh.

Not only crop production but also the production of other agricultural sub-sectors, including livestock, fisheries and vegetable farming, was threatened in IORA states due to this disruption. Within the fisheries sector, the market price of fish decreased, and fish sales decreased from 100% to 56% in Bangladesh. Though the production and sales of cultured fish were drastically reduced, the amount of freshwater captured fish increased. As customers' purchasing power decreased, customer availability plummeted from 98% to 39% (Rahman *et al*., 2022). Due to the disrupted transportation and communication systems, export-oriented (i.e., shrimp) local businesses and import-based supply chains (i.e., onion, oil, sugar) were distressed in Bangladesh (Shoaib and Arafat, 2020). For instance, in 2020, 290 import orders of frozen fish were discarded at a value of around USD 54.2 million. The limitations on logistics, the closing of borders, and the lower demand in restaurants had a detrimental impact on the volume of fish that could be caught and the price at which it could be sold not only in Bangladesh but also in Kenya and Seychelles (Workie *et al*., 2020). Capture fisheries in Seychelles were sharply reduced from 628 tonnes in April 2019 to 368 tonnes in April 2020 following the onset of COVID-19, due to the suspension of commercial flights between Seychelles and the rest of the world, as well as a drop in demand for fresh tuna as Europe went into lockdown in April 2020 (Rassool *et al*., 2020). As fisheries are one of Seychelles' main exports, this sector faced difficulties, such as increased freight prices and fewer available international flights, due to COVID-19, resulting in a loss in revenue (Laurence, 2021).

In addition, as production costs climbed during the COVID-19 pandemic, cattle production fell by 30% to 40%. One of Bangladesh's top meat processing businesses claimed that beef and mutton sales decreased by about 20% in the consumer market and about 80% to 90% in the business market (Babu *et al*., 2020). In Kenya, while the COVID-19 pandemic did not significantly impact the output of dairy cattle due to the abundance of local fodder and low infection rates in milk shed locations, the sector was negatively impacted as the cattle markets were shut down, and travel across national and international borders was prohibited in 2020 for about three months (Griffith *et al*., 2020). This situation was mainly responsible for the reductions in herd size (Graham *et al*., 2021). Bangladesh's demand for poultry products dropped drastically from 90 metric tonnes to 25-27 metric tonnes. Egg production and its demand dropped noticeably at that time. A poultry meat price hike was observed in Kenya and Seychelles (Victoria *et al*., 2021; Rassool *et al*., 2020).

As with other agricultural products, the vegetable market was also impacted as farmers had limited access to the market. In Bangladesh, farmers suffered substantial losses in the production of vegetables, such as USD58.3, USD 683.3, USD130, USD625, and USD220.23 per acre losses in the production of brinjal, pointed gourd, cucumber, yardlong beans and bottle gourd at the time (Alam and Khatun, 2021). Similarly, COVID-19 had a detrimental impact on Kenya's production and trade of African indigenous vegetables. During the first stage of the pandemic, for instance, farmers' production and traders' overall sales decreased by 39% and 65%, respectively (Ogada *et al*., 2021). Likewise, exports of vegetables and fruits in Bangladesh plunged from 100 tonnes a week to 3 tonnes a week during the pandemic. The decreasing global demand trend and irregular air cargo shipments were mainly responsible for this disruption (Babu *et al*., 2020). Due to this reason, Seychelles faced a food crisis, due to it's high (80%) dependence on imported food. Likewise, the collapse of the tourism sector during the epidemic severely impacted agricultural sales. Generally, before the pandemic, farmers were accustomed to selling their produce, cattle, and fruits to hotels, restaurants, cruise ships, and charter boats, which was not possible due to the shutdown of tourism.

5.3.2 COVID-19 pandemic and food consumption

The prices of different food items increased during the COVID-19 pandemic due to the unavailability of agricultural inputs, labour scarcity, high transportation costs, product shortage, and market disruption. Fluctuation in food imports also made regional markets unstable, ultimately increasing food insecurity. For instance, many people in Kenya could not buy sufficient food due to the increased price of maize (Kansiime *et al*., 2021). In Bangladesh, the price of different rice varieties soared by 7% to 46%, whereas chicken, mutton, beef, and pulses prices climbed by 56%, 3%, 4%, and 24%, respectively (Rahman *et al*., 2022). Likewise, the Global Alliance for Improved Nutrition reported that Kenya had a 4.2% increase in food prices due to a production and import sources shortfall (Workie *et al*., 2020). Higher food prices during the pandemic resulted in a decrease in dietary diversity. As rice is the staple food of Bangladesh, people consumed rice even though its price had increased. However, they mainly reduced other essential foods to match their income and high prices. People's actual per capita intake of fruits, vegetables, milk and meat was below the recommended level. Those most affected by the issue of limiting daily food intake were those who were below the poverty line, followed by those who were above it but vulnerable non-poor households. In their study, Rahman *et al.*(2021) showed that although Bangladeshi

households could consume three meals a day prior to the pandemic, during the pandemic era, roughly 15% of rural households and 24% of urban households significantly reduced their food intake. Similarly, 20% of households in Kenya had to cut back on the amount and type of food they ate during the pandemic (Hammond *et al*., 2022), even though the effects on food consumption were the same in both rural and urban areas (Maredia *et al*., 2022). As a result of food price increases, unavailability of diverse food and inefficient supply chain, overall dietary diversity decreased (Harris *et al*., 2020). A survey conducted during the pandemic reported that about 70% of Bangladeshi families could not give their 6- and 23-months children various foods (Rahman *et al*., 2021). According to Thorne-Lyman *et al.* (2010), Bangladeshi families normally have a mean dietary diversity score of 10.3, but was only 6.22 during the pandemic (Kundu *et al*., 2021).

Households' monthly income decreased as household members lost their employment and jobs, which ultimately influenced their overall food security. A survey conducted in Bangladesh reported that about 78.1% of respondents' monthly income decreased (Kundu *et al*., 2021). Furthermore, food expenditure per capita dropped by 23% in rural regions and 28% in city slums in Bangladesh because of COVID-19. Household means food security was determined at 38.6 in 2009 in Bangladesh, but during the pandemic, it fell to 31.86 (Kundu *et al*., 2021; Saha *et al*., 2022). During COVID-19, more than half of respondents to a survey in Kenya reported eating fewer types of food and being unable to eat healthy, nutritional food. In contrast, only 30% of the participants had similar instances of food insecurity prior to the pandemic. The results showed that in Kenya, the number of households experiencing food insecurity soared by 38% over a regular period (Kansiime *et al*., 2021). The biggest obstacles to purchasing food were high market costs relative to limited cash availability, followed by access issues brought on by either closed markets or a lack of transportation choices. Contrarily, low agricultural product selling prices and enormous costs for acquiring food were also noted during the pandemic, which indicates traders' attitude to maintain buffers and market failures. However, the Seychelles government favoured non-market strategies to ensure the food security of its citizens (Pouponneau, 2021). The Seychelles Fishing Authority and the Ministry of Fisheries and Agriculture established new procedures to ensure food security during the lockdown. They provided the fishers with a guaranteed market by purchasing and stocking the excess catch of commercial species from artisanal boat owners and fishermen (Aquadocs, 2020).

5.3.3 Government policies to promote food production and food security during the COVID-19 pandemic

The governments in the IORA region took the following plans and policies to promote food production at the household level to alleviate food insecurity in this region.

Promotion of rooftop- and micro gardens to expand urban food production

Rooftop gardening grew during the COVID-19 pandemic as a sustainable healthy food source. Some people even started using it as a substitute for store-bought food. The Bangladeshi government encouraged 'micro gardens', also known as 'precision decision gardening', which are tiny farming areas that may be built on rooftops, balconies and other confined spaces. This form of gardening can grow leafy green vegetables and other high-value food crops due to their high

yields (NFNSP, 2021). The Kenyan government encouraged households to establish 'one million kitchen garden plans' nationwide to tackle the food crisis brought on by the pandemic (FAO, 2020). The Seychelles Ministry of Agriculture adopted a similar approach to encourage backyard farming and spread agricultural principles among young people; they introduced a ground-breaking programme called 'Every Household a Garden - Every School a Garden.' This program offered kids the necessary tools to develop their fruit and vegetable gardens at their local schools and encouraged them to bring seedlings home to support backyard farming (Rassool *et al*., 2020).

Leave no land uncultivated

The government planned to take every inch of uncultivated land under cultivation to grow food to fight against the food shortage in Bangladesh. Bangladesh had over 431,000 hectares of fallow land that could be utilised for agriculture in the fiscal year 2019–2020 (Chowdhury, 2022). Besides, at least 488,000 families planted their homestead lands under the Department of Agricultural Extension project named 'Pushti Bagan'. Likewise, the Seychelles Ministry of Agriculture established the 'La Semence-Youth Farming Enterprise' to encourage young entrepreneurs to work in agriculture to increase agricultural productivity. This programme involved leasing agricultural land to the youth (Rassool *et al*., 2020).

Automation of communication through hi-tech solutions

In order to assure massive yield and sustainability, the government of Bangladesh upgraded crop, soil, and natural resource management techniques, including mechanisation and 'high-tech' solutions. Customising equipment and machinery according to Bangladeshi farmers' requirements were encouraged. In Kenya, through collaborating with local digital technology start-ups, attempts were made to enhance producer-consumer communications, the supply of farm inputs, soil testing, and market connectivity (World Bank, 2020).

Maintaining the flow of essential inputs and outputs

The governments of the three IORA nations supported smallholder farmers by giving them access to loans, high-quality inputs, a market for their products, and temporary storage. For subsidising the costs of all necessary imported inputs, including seeds, fertiliser and pesticides, to farmers to keep up with pre-pandemic prices, the government of Seychelles deserves credit. The government also provided subsidies for the transportation of animal feed to Praslin and La Digue. Consequently, consumer prices for locally grown meat, fruit and vegetables stayed consistent because the Seychelles Agricultural Agency decided to forfeit its pre-COVID margin on inputs of 5-15% (Rassool *et al*., 2020). The Kenyan trade ministry waived the compulsory inspection charge for seed, insecticides, and animal health (FAO, 2020). Kenya established public-private partnerships to purchase and sell agricultural products and had an anticipated surplus of grains and dairy products during the pandemic (Agriculture KMo, 2020).

Protecting agricultural farms by providing financial support

The governments provided financial support for the agricultural sector, including agro-food processing. For instance, to increase agricultural productivity, the government of Bangladesh had granted BDT 5,000 crores (about USD 500 million) in soft loans to farmers in rural areas, bearing a 4% interest rate (Uddin *et al*., 2020). Kenya's government also announced in May 2020 a post-

COVID-19 economic stimulus package worth 53.7 billion shillings (USD 503 million) to aid pandemic-affected firms (Kansiime *et al*., 2021).

Government support for the final agricultural products

The governments adopted policies to support the agricultural producers by procuring or purchasing their products at guaranteed market prices. For example, the government of Bangladesh procured Boro rice during the pandemic at a reasonable market price. To help dairy farmers, the Kenyan government quickly supported the farm-gate milk price. The Kenyan Government had told their processor to pay farmers KES 33 (0.28 Euro) per litre for their milk (Vall *et al*., 2021). In Seychelles, the Seychelles Ministry of Agriculture reduced the cost of bait and ice to reduce fishermen's fish-catching and storage costs. They adopted the strategy of offering the fishers a guaranteed market at a fixed price through the processors, who would sell it to Seychelles Trading Company as the readily accessible market (Pouponneau, 2021).

Social safety net programs

The government of Bangladesh increased social safety net programs due to the COVID-19 crisis to target beneficiaries better and increase demand for agricultural products, which benefited both food producers and consumers (Babu *et al*., 2020). Similarly, Kenya declared the release of KSH 10 billion (USD 100 million) in April 2020 for its regular cash transfers, primarily benefiting the aged, the significantly disabled, orphans, and low-income households (FAO, 2020). Social assistance programmes, namely direct cash and in-kind transfers to households and waivers of utility fees, helped the wage earners' households whose earnings were lowered by restrictions (Miller *et al*., 2020; Ozili, 2020).

Encouraging domestic production

Due to the dependence on imports for essential foods, the governments explored ways of limiting importation by advancing domestic production. On mechanism for this was through increasing the import tax on some specific agro-products. For example, in the post-COVID period, Seychelles' Government raised the tax on imported chicken and pork. Additionally, the government was worried and thoroughly investigated the poor quality of several imported foods and the potential harm they could do to the local population's health (Rassool *et al*., 2020).

5.4 Conclusions and recommendations

Despite the devastating impacts of Covid-19 globally, countries of the IORA region did their best to fight against the situation with their limited resources as shown through the case studies provided by Bangladesh, Kenya and Seychelles. Initiatives included short-term and long-term policy changes, as the above sub-section illustrates. However, regarding green recovery, we observe limited initiatives across the region. So far, initiatives taken are encouraging domestic food production by rooftop gardening and micro-gardening, home-stead gardening and expansion of agriculture in fallow lands along with support to reduce losses and ensure actual prices of agricultural produce (crop, livestock and fisheries). Countries in the IORA region should be ready to tackle similar future shocks. Lessons learned and successful policy interventions implemented during COVID-19 will guide future short and long-term actions and policies. Furthermore, rural-

urban deviations, gender and class variation among the people should be appropriately addressed in the policies and interventions. This could include storage tanks and rainwater harvesting which should be encouraged for irrigation purposes in IORA regions to prevent the loss of groundwater. Agricultural extension and advisory services for technologies and farm practices, cutting-edge farm equipment and accessing agricultural inputs and markets should be enhanced, and crop diversifications, agro-innovations and agro-preneurships should be encouraged. Finally, awareness among farmers should be increased about the future crisis and their ability to adopt new technologies. Green recovery is not impossible and can be achieved through integrated participation and initiatives by Government Organisations, Non-Governmental Organisations, development partners, academia and civil society in the IORA region.

6.0 Sustainable Consumption and Production

6.1 Introduction

Sustainable Development Goal (SDG) 12 is about ensuring sustainable consumption and production patterns, which is critical for sustainable growth (Gasper *et al.*2019). On the other hand, unsustainable consumption and production patterns are the root causes of climate change, biodiversity loss, and pollution (Glavic, 2021). Reusing and recycling materials can minimise the use of natural resources and toxic materials on the environment (Glavic, 2021). Therefore, sustainable production and consumption in the report will focus on energy, waste, and food while integrating issues around emission reduction from transportation, agriculture, and manufacturing. The case study countries, which include Seychelles, Kenya, and Bangladesh, all depend on climate-sensitive livelihood activities such as agriculture, fisheries, and tourism.

The agricultural sector is a significant employer and contributor to the GDP of most developing countries, and those in the IORA are no exception. Its contribution to healthy food and livelihoods is crucial in achieving the SDGs. Most of those involved in the agricultural sector are smallholder farmers confronted with producing more with limited resources, and agricultural intensification is far from being achieved (Bachewe *et al*., 2018). Aside from agriculture, the fishery sector also plays a significant role in food and nutritional security, especially in developing countries (Temesgen *et al*., 2019). However, the Food and Agriculture Organization of the United Nations has increasingly reiterated that unsustainable fishing practices without mitigation actions will risk the long-term viability of fisheries and livelihoods of fishers and fishing-dependent communities (FAO, 2023). Management of bycatch, illegal, unreported, and unregulated fishing continues to challenge the long-term sustainability of the fisheries sector in the IORA countries.

Though per capita income and socioeconomic development can influence sustainable consumption and production, the COVID-19 pandemic impacted food production and distribution, waste generation and collection, energy and water use, healthcare systems, and, generally, the quality of life globally. Lessons learnt during COVID-19 offers an opportunity to develop recovery plans to reverse current trends and shift our consumption and production patterns to a more sustainable course. A successful transition will mean improving resource efficiency and considering the entire life cycle of economic activities (UN, 2019). This review will examine sustainable consumption and production across the core areas outlined above across the three case study countries.

6.2 Methodology

This chapter focuses on cross-cutting issues. Therefore, the review was based on peer reviewed publications, reports, news items, and policy documents across the case study countries – Seychelles, Kenya and Bangledesh. The search terms used were ‘sustainable consumption and production’ and ‘energy’ and ‘waste’ and 'agriculture’ and ‘COVID-19’ and ‘IORA’. A total of 57 documents were generated. These documents were screened based on the topic and 22 were used for this review in addition to seven news reports.

6.3 Results

6.3.1 Seychelles

Seychelles has 100% access to electricity (Wehner *et al*., 2020); over 90% of the energy is generated from fossil fuels. An energy transition will enhance sustainable development and climate resilience (Etongo and Naidu, 2022). Renewable energy stands at 5% in the energy mix, though an additional 5% was projected once the ongoing 5-MW floating solar power plant on Mahe Island is completed and operational (IRENA, 2019). The Public Utilities Corporation (PUC) provides the island nation's utility services, including electricity. According to a news report, hotels, as customers, bring in substantial revenue for the company. The closure of the International Airport because of COVID-19, and by extension, the tourism sector, had an adverse financial effect on the PUC (Seychelles News Agency, 2020). Though studies on household energy use are lacking, working and learning from home became the norm for three to four months in 2020 during the pandemic. Adoption of renewable energy such as solar PV among householders in Seychelles is relatively low (Etongo and Naidu, 2022). Some of the challenges identified by the same study include high initial costs, existing loans, infrastructural issues, and an inflexible payment arrangement in instalments which most households find inconvenient. To overcome these challenges and enhance renewable energy uptake among families, the PV democratisation project was introduced. This project aimed at increasing access to solar PV for households who cannot afford a rooftop PV system, access a low-cost loan or have a roof that is not conducive to installing a PV system. Phase one of this project was launched by Seychelles Energy Commission in 2018 with 500 low-income homes that benefited from the scheme (Seychelles Nations, 2018). Phase two of the project was launched in 2021 and experienced some delays due to the COVID-19 pandemic. All of these initiatives are to enable Seychelles to achieve low-carbon climate-resilient development.

Another crucial area for sustainable consumption and production is waste management since its impact on the environment can be overwhelming. In the case of Seychelles, a monthly estimate of 5000 tons of waste is generated, most of which comes from residential bin sites and retail shops (Ministry of Agriculture, Climate and Environment, n.d.). As a Small Island State, waste collection is well organised and disposed of at communal bins along the road. There are dedicated bin sites within the premises for businesses, schools, and offices. The Landscape and Waste Management Agency (LWMA) is the Agency responsible for administering waste management contracts for waste collection and landfill management. One of the leading contractors in Seychelles is waste management solution Seychelles (WASTEA). Waste is collected daily from all the bins and taken to the landfill site located at Providence. To further reduce solid waste, the Government of Seychelles (GoS) banned the importation, sale, and commercial use of plastic bags, cups, plates, and cutlery. Although WTE is yet to be operated in Seychelles, there is an ongoing project to produce clean and renewable energy through municipal waste combustion. This project, which is expected to be completed by 2025, can potentially reduce the amount of waste by 80%.

Seychelles is dependent on susceptible livelihood activities. Therefore, ensuring the delivery of water, energy, and food to the Seychellois population sustainably and equitably while concomitantly preserving the health of natural ecosystems would require a nexus approach. This

approach moves beyond traditional sectoral thinking to achieve overall security and sustainability of all resources, which is even more relevant as Seychelles, like other nation-states, strive to achieve the SDGs. Almost 80 - 90% of food consumed locally is imported (Seychelles News Agency, 2021a). The COVID-19 pandemic exacerbated the food crisis in Seychelles with the disruption in the supply of food items and also rapidly rising food prices. Local food production has gained traction in the island state to ensure food security. However, there are several challenges, including the just-ended pandemic. The shutdown of the tourism industry through the closure of the Seychelles International Airport between March and April 2020 (Seychelles News Agency, 2020a) significantly impacted agricultural sales. Before the pandemic, farmers in Seychelles had a more comprehensive range of customers and could sell their livestock, fruits, and vegetables to hotels, restaurants, and cruise ships/charter vessels (GoS and UNDP, 2020).

Having a predominantly mono-economy around tourism impacted families through massive job losses. An estimated 1,100 employees lost their jobs as of October 2020, most of which were in the tourism sector (Seychelles News Agency, 2020b). Loss of employment can affect the purchasing power of affected families, especially during the COVID-19 pandemic. However, the GoS put some mitigation measures in place through the Financial Assistance for Job Retention (FA4JR) scheme set up in March 2020. The purpose of this scheme was to serve as a mitigation strategy for those who lost their jobs during the COVID-19 pandemic (Seychelles News Agency, 2021b).

Home gardens, often called "backyard farming," are common in Seychelles, with over 500 households having a home garden that played a crucial role in food security during the pandemic. During the lockdown, most households devoted their time to working in the garden. Several families with larger land sizes expanded their cultivation during the pandemic since they had more time in the garden. This approach helped harness idle energy from family members in particular the youth and promoted food production to curb food insecurity. The pandemic was a wake-up call as promoting local food production has become a topical issue in Seychelles, which is less dependent on imports and also harnessing idle energy from unemployed members of the family to produce food in kitchen gardens (Etongo, 2023). In this regard, the Ministry of Agriculture is exploring ways of limiting the importation of essential foods, such as livestock products, by advancing domestic production. Despite being a tropical island with an average annual precipitation of 2330 mm (Etongo *et al*., 2020), agricultural practices depend on irrigation (Etongo *et al*., 2022). However, the Ecosystem-Based Adaptation (EbA) to climate change project in Seychelles has demonstrated that wetlands can be restored, providing farmers with water for irrigation. The EbA project is currently upscaled by the Department of Agriculture to other sites with degraded wetlands. The water-energy-food nexus has consistently been integrated into previous and ongoing Seychelles projects to enhance sustainable consumption and production (Etongo, 2022).

6.3.2 Kenya

Energy is essential for development. However, it has to be environmentally friendly and also sustainable. Biomass and petroleum products dominate Kenya's energy sector, corresponding to 68% and 22% of the total energy consumed (KNBS, 2020). Access to electricity across the rural

areas in Kenya stood at 63% in 2020, although fuelwood still constitutes a vital energy source for cooking, and serves as an alternative for liquefied petroleum gas (LPG). For example, Shupler *et al.*(2021) found a considerable increase in the use of wood and charcoal for cooking and a decline in LPG during the COVID-19 lockdown in the peri-urban community of Eldoret in western Kenya. The use of wood and charcoal for cooking has been identified among the drivers of deforestation and forest degradation. Charcoal provides more than 70% of the domestic energy demand for cooking and heating in Kenya, significantly contributing to the livelihoods of hundreds of thousands of people in rural areas. Using these types of energy sources for cooking also increases exposure to hazardous air pollutants, highlighting the health impact of smoke in tightly-packed homes (Weaver *et al*., 2019; Pedrosa, 2020).

Waste-to-energy (WTE) presents an opportunity for a win-win by reducing waste through a process that generates clean energy. Kenya, for example, generates an estimated 8 million tonnes of waste annually, with 40% of this figure in urban areas and organic waste contributing between 60%-70% of the total waste volume (Republic of Kenya, 2021). This same report indicated that the first WTE plant with a capacity of 45MW was set up in Ruai, Nairobi City, by the Government of Kenya (Republic of Kenya, 2021). If upscaled into other urban areas and, more importantly, in rural areas, such a project can enhance access to electricity from renewable sources. Such an approach will improve waste management as it will become a business with waste as raw material. Kenya also hosts the continent's largest grid-connected commercial biogas power plant. Situated in Naivasha, the plant has the potential to treat 50,000 tonnes of organic waste, serving up to 6000 rural homes with power.

As the largest sector in the Kenyan economy, over 70% of the workforce is employed in agriculture, with USD 1.37 billion in annual exports. In rural areas, the agricultural sector employs 70% of the population, compared to providing 40% employment in urban areas. Like other developing countries, the agricultural sector in Kenya has witnessed an increase in the workforce despite a growing ageing agricultural population (Yeboah and Jayne, 2016). For example, the average age of farmers in Kenya is 60 years. Such a figure might result from young people leaving the sector and older people moving in, raising concerns regarding this sector's long-term sustainability. The COVID-19 pandemic, on the other hand, also had a tremendous impact on food production and consumption. For example, the lockdown and travel restrictions resulted in farm labour shortages and disruption to access to agricultural inputs (e.g., fertilisers, improved seeds, crop chemicals, etc.), and extension and advisory services, resulting in a decline in farm productivity and yield levels (FAO, 2020; Ogada *et al*., 2021).

Without incentives to maintain agricultural inputs at pre-COVID prices, procuring these inputs came with an additional price tag. A study by Ogada *et al.* (2021) reported that 71% of farmers paid a higher price for the inputs between June and October 2020. Even land under lease agreement witnessed an increase of 27%. To mitigate the effects of rising prices on farm inputs, farmers have been cutting down on cultivated areas, ultimately making them more vulnerable.

As a mitigation measure, the Government of Kenya supported the farmers. In May 2020, the Government of Kenya announced a stimulus package of USD 503 million to support the sectors hit by the coronavirus pandemic. It covered eight areas, including agriculture (Ogada *et al*., 2021).

Of the USD 503 million, the government channelled USD30 million to supply farm inputs to cushion 200,000 small-scale farmers in 12 counties across the country in the first phase. Another measure was the e-voucher program, implemented in partnership with Kenya Commercial Bank (KCB) and Safaricom. The program aimed to reduce pilferage and promote farmers' purchase of farm inputs. Small-scale farmers with 5 acres of land or less were eligible for support through an e-voucher worth USD200 per acre. The government also allocated USD 15 million to assist horticultural and flower producers to continue accessing international markets.

6.3.3 Bangladesh

Given that fossil fuels still dominate Bangladesh's energy sector, the options to integrate renewable sources are minimal due to resource unavailability (Khan, 2018). Thus, energy efficiency offers an immediate practical opportunity as more than 50% of consumers are from residences. Ensuring sustainable consumption and energy production in a context such as Bangladesh would concomitantly ensure energy efficiency and the rollout of renewable energy technologies. Energy consumption was impacted during the COVID-19 pandemic. For example, Alavi *et al.* (2022) found an overall decline in electricity consumption during the 2020 lockdown in Bangladesh. A possible explanation provided by the same study for the decrease relates to shut down of all non-essential businesses, offices, industries, factories, schools, and universities. A 50% and 40% reduction in energy consumption was observed in the industrial and commercial sectors, respectively, whereas consumption increased by about 15% in the residential sector (FE, 2020).

Another critical area is waste generation, which impacts the environment. Solid waste management (SWM) is highly dependent on informal waste collectors, isn't properly regulated, and hardly factors in recycling (Roy *et al*., 2022). The lack of proper SWM systems has resulted in an estimated 55% of waste that hasn’t been collected (Islam, 2021). Waste sometimes ends up in the water or drainage systems, polluting the water, soil, and air (Islam, 2021), the essence of human survival. Population growth and urbanisation have also increased the amount of waste generated, especially in major cities such as Dhaka (Islam, 2021). About 206 tonnes of medical waste was produced in the capital due to COVID-19, which was on average 19 tonnes before the pandemic. However, some progress has been recorded through the WTE projects. For example, the Government of Bangladesh, in 2021, initiated the construction of a 42.5-megawatt WTE power plant at Aminbazar on the outskirts of the capital Dhaka. Additionally, a second WTE plant was launched in 2022 with a view to extending similar projects to rural areas in the country. The second power plant is expected to generate 6 MW of electricity from the garbage of Narayanganj city and adjoining areas (Dhaka Tribune, 2022).

Despite a steady increase in agricultural food production, Bangladesh faces persistent challenges in achieving food security. These challenges are mainly due to natural disasters and fluctuations in food prices from the influence of the volatile international market for essential food items. Bangladesh is confronted with climatic and non-climatic vulnerabilities, which impact the agricultural sectors that smallholder farmers in rural areas dominate. Crop production, for example, is affected by an extended drought period, affecting crop productivity in Bangladesh. The country relies on irrigated rice to ensure food security which is affected if droughts are more prolonged, which has become the situation under a fast-changing climate. Regarding land size,

Bangladesh is a small country compared to its population. The country's population is estimated at 165.28 million. Due to high pressure on farmland, the country is losing nearly 82,000 hectares of land annually, of which 55% is used by other land uses. Over the last three decades, about three million acres of agricultural land have gone to other sectors, including housing, infrastructure, and industrial (Rezvi, 2018). Despite these challenges, agriculture is Bangladesh's most significant economic sector and employs 62% of the population. The dependency on agriculture is higher in rural than urban areas, with 87% of the rural population relying directly and indirectly on agriculture.

However, the COVID-19 pandemic affected the agricultural sector with both production and consumption ramifications. These impacts occurred at the farm, value chain, and market levels (FAO, 2020), and COVID-19 has exposed the underlying risks and inequalities of food systems in Bangladesh (Talukder *et al*., 2021). Different players are involved in Bangladesh's food supply chain, including producers, consumers, transportation, and marketing services. This chain became dysfunctional due to the population's fear of infection by the coronavirus. Lockdowns and travel restrictions further decreased food availability and increased rates of food loss and waste (Roy, 2020). The lockdown, due to the COVID-19 pandemic, disrupted the whole agricultural system due to the stagnation in the transportation system. Farm produce did not just rot, but farmers had no choice but to sell their products at nominal prices. As the price of food and farm inputs rose, on the other hand, these farmers struggled to recover the cost of production. They were deprived of a fair price from which other key players within the food value chain, such as middlemen, brokers, and warehouses, benefitted.

6.4 Lessons learned and recommendations

Unsustainable consumption and production patterns are the root causes of the triple planetary crises of climate change, biodiversity loss, and pollution. Household energy consumption increased during the COVID-19 pandemic, of which most of the energy came from fossil fuels, primarily in the case of Bangladesh and Seychelles.

Using energy-efficient appliances can reduce energy consumption, which is recommended across the case study countries. Also, other IORA member states can adopt the communal approach to solar PV ongoing in Seychelles. WTE power plants operate in Kenya and Bangladesh but must be upscaled to rural areas.

Travel restrictions disrupted the food supply chain during the lockdown period of the pandemic, and farmers suffered considerable losses in crops that rotted or were sold at minimal prices. Embracing available technologies, Bangladesh's producer organisation established an ecosystem linking farmers with input suppliers and off-takers while complying with physical distancing. Through the virtual call Centres, farmers in Bangladesh could sell products worth more than Taka 34.4 million (USD 32,000) to buyers, including private companies. Investment towards value addition is crucial across the case study countries to reduce post-harvest losses of crops. Seychelles was most vulnerable due to its high dependence on imported food items. However, there are over 500 households in Seychelles with gardens or what is commonly known as "backyard farming." These householders spent more time growing food in their gardens during the lockdown. The

Government of Seychelles has emphasised the need for “one home, one garden” to ensure food security, especially for a country that depends largely on others to feed it. The home garden concept can benefit other member states in the IORA region and enhance food security within a household that can then only buy what they cannot grow. This concept is a program that member states could roll out within the IORA.

7.0 Energy Generation and Use in the IORA Region

7.1 Introduction

Nearly 1.7 billion people in the world do not have access to electricity and nearly 2.4 billion people use biomass fuels i.e., wood, agricultural residue and dung, for cooking and heating (EPA, 2009). Energy generated from fossil fuel sources is expected to increase, with a 50% projected growth rate globally between 2019 and 2050 under the normal energy consumption scenario (Doman, 2019). An increase in energy demand from population growth, higher standards of living, and changes in consumer behaviour, economic development, and industrialization is likely to occur this century (Oyedepo, 2012). In 2020, 9% of the energy generated in Africa came from renewable sources, with a firm reliance (6.8%) on hydropower, while over 80% of electricity generated across the continent is from fossil fuels (World Economic Forum, 2022). Development agencies have been promoting a transition from fossil fuels to renewable energy sources since energy-related carbon dioxide emissions represent two-thirds of all greenhouse gases (Von Stechow *et al*., 2016).

As such, the role of renewable energy in global energy transformation is at the core of the Paris Agreement and the 2030 Agenda for Sustainable Development (Gielen *et al*., 2019). Several studies have shown that access to reliable energy is a key driver that can contribute to the achievement of other SDGs (Von Stechow *et al*., 2016; Allen *et al*., 2016; McCollum *et al*., 2018; Nerini *et al*., 2017; Nilsson *et al*., 2016; Bowen *et al*., 2017). SDG 7 calls for global access to affordable, reliable, sustainable, and modern energy (Valickova & Elms, 2021). An estimated 3.8 billion people (over 40% of the global population), primarily in low- and middle-income countries in Africa, Asia, and South America, lack access to clean, modern, and affordable sources of household energy (Health Effects Institute, 2020). Some of these households, especially those residing in rural areas, depend on polluting fuels, including biomass (e.g., wood, charcoal, cowdung), coal, and kerosene, for cooking, heating, and lighting, which negatively affects their health and livelihoods, and the climate (Smith *et al*., 2014; Boateng *et al*., 2020; Anenberg *et al*., 2013).

Providing affordable and sustainable energy sources globally is undoubtedly important. In this study we review the types and sources of energy in three IORA states, as representative for the IORA region, the landscape to transformation in terms of policy and financial investment, factoring in the concept of "energy and environment" in defining the term energy (Legemza *et al*., 2020a).

7.2 Methodology

To achieve the objectives of the study in this section, the researchers undertook a comprehensive desktop review of journal articles, sectoral reports, grey literature and an analysis of relevant secondary data. The available information was synthesised to enhance the review and focus of in-country data. In addition, policy mapping was undertaken to demonstrate the policy landscape toward green energy and the share of national funds spent on developing green energy and the benefits in Kenya, Bangladesh and Seychelles.

7.3 Results

7.3.1 Literature review

Energy is an important factor in economies. Natural gas, coal and other fossil fuels are the most used fuels in modern economies. These are non-renewable resources while renewable energy (RE) resources include solar, wind, geothermal and hydroelectric all of which provide less than 10% of the energy needed in the world. Comparisons have found that most of the RE resources are less accessible than fossil fuels. The high prices of RE resources are partially attributed to their intrinsic nature, specifically their intermittent supply, low energy ratios, and being capital intensive. Unless externalities from the use of fossil fuels are accounted for (e.g., impacts to the environment and climate), cost reductions from new technology may not bring renewable energy processes into close competition with those of fossil fuels in the near future (Timmons et.al., 2014).

The modern era is one of tremendous energy use. Finding new sources of energy is crucial given the potential threat posed by depletion of non-renewable energy resources and the impacts on climate emanating from greenhouse gas emissions (Legemza *et al*., 2020a). Holechek *et al*., (2022) opined that fossil fuels will be critically depleted within 50 years at the current levels of use. It has been observed that at the global level, energy is quickly becoming one of the most significant issues. The world's economies are under threat from the rising price of oil, while on the other hand, climate change impacts attributable to use of fossil fuels are growing in importance globally (Mediavilla *et al*., 2008).

As the greatest threat to civilization, climate change is widely acknowledged to be a systemic issue that is closely related to population explosion and per capita energy needs that comes from non-renewable resources. The burning of fossil fuels causes a rise in GHGs emissions that cause global warming and modifies the climate (Holechek *et al*., 2022). Shifting from non-RE sources to RE source is the primary strategy for solving the climate problem (Rehman *et al*., 2022).

Over the past decade, deployment of renewable energy technologies (RET) has flourished. The continued rise in application of RET has been facilitated by a variety of policy interventions by governments such as decreasing cost of RET, changes in the price of non-renewable energy resources and the increased demand for energy (Edenhofer *et al*., 2012).

The latest report by the International Renewable Energy Agency (IRENA) shows that by the end of 2022, renewables accounted for 40% of global installed power capacity. 2022 accounted for the largest increase in renewable energy capacity, the world added almost 295 gigawatts (GW) of renewables, increasing the share of renewable power by 9.6% and contributing an unprecedented 83% of global power additions. This was attributed to the growth of solar and wind power, and the further decommissioning of fossil fuel power plants in several large economies. Solar power alone accounted for almost two-thirds of the renewable additions with a record 192 GW, while 75 GW of wind energy was added, slowing from the 111 GW of wind energy added in 2020 (IRENA, 2023).

7.3.2 Comparative analysis of uptake/development of renewable energy resources

There have been significant investments in harnessing RE resources globally. Data available from IRENA shows investments in RE in the world for the past 10 years (2011-2020). The data

indicates that a total of USD 225767.7million were invested in harnessing RE globally with 22% of the investments (USD 51126.79 million) going to Africa. A comparative analysis of the investments made in Kenya, Bangladesh and Seychelles indicates that Kenya, the leading RE user in Africa, invested about USD 3366 million, Bangladesh USD 1703.8 million and Seychelles USD1.83 million. The renewable energy sector has been on an upward trajectory for the last 10 years, apart from the few years that the world experienced the severe impacts of global recession compounded by impacts brought forth by economic disruption attributed to COVID-19 (starting from 2019 through 2020). The capacity to generate RE increased gradually over a period of 7 years (2014-2020) with an average of 9.5% increase annually. The RE generation capacity for the 7 years was estimated at 15666 GW.

7.3.3 Renewable Energy Sources in selected IORA member states

The RE sources in Kenya, Bangladesh and Seychelles were identified. Kenya has an interesting energy mix, with almost 73% (2,042 GW) installed capacity generated from renewable energy sources. Hydro (818 MW) and geothermal (678 MW) take a larger portion (59%) of the 73% renewables with the remaining being divided among wind (12%) and Solar (2%). Solar consists mainly of grid-connected (50 MW) and off-grid with an installed capacity of 0.7 MW. The wind is mainly grid-connected from Lake Turkana Wind Power (300 MW) and off-grid wind (0.6MW) (Ochieng & Kamau, n.d.).

Electricity generation from RE sources in Bangladesh is considered insignificant with an average contribution of 1.42%, disaggregated as solar (61.5%), hydro (37.8%), wind (0.5%) and biogas, to electricity. In 2020, RE accounted for 1.35% (19,580 MW) of the total installed power generation capacity (BPDB, 2020); of this, hydro power energy contributed 230 MW (1.17%) while solar energy contributed 35 MW (0.18%) (Yousuf *et al.*,2022).

Energy generated from renewable sources accounted for 3% of total energy supplied in Seychelles in 2019. The RE was disaggregated as follows: 80% from solar, 12% from bioenergy, and 8% from wind energy (IRENA, 2019).

7.3.4 Policy Mapping

Policy mapping was undertaken to demonstrate the policy landscape towards green energy and the share of national funds spent on developing green energy and the benefits in Kenya, Bangladesh and Seychelles. The investments made in RE in the three countries has been provided in section 7.3.2. The Government of Kenya has put in place the National Energy Policy effective from 2018 to guide promoting affordable, competitive, sustainable, and reliable supply of energy at the lowest cost. The policy recognises that RE has the potential to enhance energy security, mitigate climate change, generate income, create employment, and generate foreign exchange savings. Besides, the policy recognizes the importance of developing a sustainable source of energy for future generations anchored on careful planning and application of advanced technology. There are identifiable policy gaps in the Kenyan RE policy landscape. Power purchase agreements, feed-in-tariffs and government taxes have been a challenge jeopardising investment in RET. The government has not put in place comprehensive guidelines on power purchase agreements, feed-in-tariffs and applicable taxes. Recurring taxation and addition of taxes particularly Value Added Tax (VAT) on components of RET has created an unpredictable investment environment driving

away investors from Kenya. Analysis on the VAT regime on solar PV in Kenya in 2020 showed a lot of discrepancies with some of the components taxed while others were exempted (Ochieng & Kamau, n.d.).

Development of RE in Bangladesh is guided by Renewable Energy Policy of Bangladesh 2008. The major objective of the policy is to harness the potential of RE resources and dissemination of RET in rural, peri-urban and urban areas. The policy provides for establishment of a Sustainable Energy Development Agency, as a focal point for sustainable energy development and promotion of 'sustainable energy' comprising renewable energy and energy efficiency (GoB, 2008).

The policy set renewable policy targets of 5% by 2015 and 10% by 2020 in the national energy mix. The policy targets have not been realised; the development of renewables has not been up to the target. In the fiscal year 2015-16, the share of renewable-based installed capacity was only 1.86% whereas the target was 5%. Against the target of a 10% share by 2020, the achievement was only 1.63% (Fahad, 2022). The policy setback has been attributed to:

i. Lack of appropriate policy instruments which resulted in failure at the implementation, and not formulation (Rehman (2022).
ii. The policy was mainly formulated to help meet the target of energy security and not the global climate change commitments.

The Energy Policy 2010 for Seychelles set targets of RE consumption at 5% by 2020 and 15% by 2030. The Seychelles Sustainable Development Strategy 2012-2020 incorporated national priorities for sustainable development and formulated guiding principles for the energy and transport sector. A proposal to develop a 100% Renewable Energy Roadmap for Seychelles was adopted in April 2016 (Wehner *et al*., 2020).

The set targets have not been met. The policy challenges hindering attainment of 100% RE in the Seychelles have been identified as follows:

i. Lack of a legal and regulatory, financial, and technical framework.
ii. Lack of an enabling policy framework for Residential Resource Efficient Technologies.
iii. The current policy incentivizes electricity consumers to reduce their electricity costs by generating their own electricity using solar photovoltaics (Net-Metering Programme). However, due to grid constraints and limited experience the utility is limiting the up-take of electricity.

7.3.5 Impact of COVID-19 Pandemic on Energy Consumption

Research undertaken to examine cooking fuel usage in the peri-urban community of Eldoret in western Kenya showed a considerable increase in the use of wood and charcoal for cooking and a simultaneous decline in LPG during the COVID-19 lockdown (Shupler *et al*., 2021). The study found that changes in the use of primary cooking fuels occurred among 14% (n = 27) of households in response to the lockdown, with LPG users (26%) being three times more likely to switch their primary cooking fuel than kerosene users (8%). Previous LPG users switched to kerosene (4.7%) or wood (4,1%), and nine households previously using kerosene switched to wood. The prevalence

of wood being used as a cooking fuel in most communities increased during the lockdown, whereas there was a decline in LPG use for cooking (Shupler *et al*., 2021). Although some families that switched from LPG to kerosene or wood indicated cooking less frequently during the lockdown, the length of exposure to household air pollution from burning these fuels could still increase due to a longer time spent indoors in a cramped area and a 1-h longer median cooking time reported among households using wood rather than LPG (Shupler *et al*., 2021).

The PUC provides Seychelles with utility services, including electricity. According to the news report, hotels being part of the client-base contributed substantial revenue for the company. The surplus generated from tourism sales helped cross-subsidize domestic electricity consumers and water and sewerage customers. Therefore, the closure of the International Airport during COVID-19 pandemic, and by extension, the tourism sector, had an adverse financial effect on PUC (Seychelles News Agency, 2020). Though studies on energy use by households are lacking, working and learning from home became the norm for three to four months in 2020. Air conditioning systems at homes that used to be switched off during working hours were operational during the lockdown period. Utility bills, primarily electricity, increased as this is the primary energy source accessed by all in Seychelles through the PUC.

Alavi *et al.* (2022) demonstrated that the lockdown period in 2020 witnessed an overall decline in electricity consumption in Bangladesh. This was expected as all non-essential businesses, offices, industries, factories, schools, and universities were ordered to shut down as stay-at-home orders were imposed. The maximum reduction was about 14% in the afternoon, predominantly between 5pm and 6 pm (Khan and Sahabuddin, 2021). On the other hand, during evening peak hours, this reduction was within the range of 3%–5%. During the day's peak hours, the demand reduction was 4%–8%. In the industrial and commercial sectors, electricity consumption dropped by about 50% and 40% due to this pandemic, whereas consumption increased by about 15% in the residential sector (FE, 2020). More than half (57.02%) of the electricity demand in Bangladesh is from the residential sector (BPDB, 2020b). This also justifies the minimum demand reduction during the network peak hours in Bangladesh.

7.4 Conclusions and Recommendations

Clean energy has been identified as the solution in addressing adverse cumulative climate change impacts borne out of historic use of fossil fuels. The increase in GHGs, degradation of ozone layer and the global temperature increase are some of the climate change impacts affecting the world. Recently, prolonged droughts, irregular rain patterns, flash floods, increased frequency of tornadoes, typhoons/cyclones/ hurricanes and other abnormal occurrences have been linked to a changing climate. These calamities need to be addressed by reducing the GHGs emissions that will impact on warming and climate change.

The following recommendations will aid in harnessing RE generation and management of available RE resources, monitoring and evaluating of applicable RET and championing supportive policies and regulatory frameworks to enhance sustainable supply of accessible, adequate and affordable RE for conservation of the environment, mitigating climate change impacts and socio-

economic growth. The recommendations cut across the entire RE value chain, although they are not exhaustive, nor prescriptive, because the RE situations differs between IORA member states:

i. Mapping of all the available RE resources in the IORA region and compiling a RE resources map for the convenience of all interested stakeholders. The RE resources map shall be a consolidated database that will have all the necessary RE data and information in accessible formats; the database will serve as a one-stop-shop for all interested stakeholders and for ease of use by investors and other interested stakeholders. The database should be updated regularly to reflect the prevailing situation and trends;
ii. IORA member states should put in place supportive policies and regulatory frameworks to guide in harnessing RE resources and provide an enabling environment for investors in RE to accelerate development for the purpose of achieving sustainable development;
iii. The regulatory frameworks should put in place designated authorities (government agencies) with the mandate to:
    a. Regulate the production, conversion, distribution, supply, marketing, and use of RE;
    b. Collect and maintain energy data;
    c. To ensure, in collaboration with other relevant government agencies, that only energy-efficient and cost-effective appliances and equipment are imported into the countries; and
    d. To coordinate the development and implementation of national energy efficiency and conservation action plans.
iv. Comprehensive stakeholders mapping should be undertaken with the view of evaluating the available technical capacity and production capability factoring in skills levels for RET in the entire value chain inclusive of government, manufacturers of RE installations, technology experts and project management experts;
v. Regular monitoring and evaluation of the RE sector should be undertaken by a broad range of stakeholders to evaluate the performance of the RE sector in a country so that the strengths can be harnessed, areas that require strengthening can be identified, and the necessary recommendations made for actioning by the relevant entities;
vi. Formulation for roadmaps to zero fossil fuel energy dependence in a feasible period of time. The country-specific roadmaps should have clear pathways based on achievable targets, standards and financing. Central to the roadmaps should be a paradigm shift from a highly centralised energy sector to increasingly decentralised energy production; the roadmaps should contain actionable climate change and clean-energy targets premised on sustainable development and climate change management. The roadmaps should be supported by an enabling policy framework;
vii. The Technology Readiness Level and Commercial Readiness Levels for different RE resources in respective countries in IORA region should be evaluated with a view to identifying all the technology gaps and commercial opportunities that could be leveraged to harness RE resources;
viii. There is a need to create regional energy markets that will open up regional opportunities in harnessing RE. Extensive regional markets will offer swift energy transitions and accelerate the socio-economic benefits, promote a regional power grid that will facilitate seamless RE power flow in a region, and regional technical backstopping contributing to sustainable development in a region through the opening of many investments.

The IORA member states should endeavour to achieve the goals and targets set in the global intergovernmental based commitments such as access to affordable, reliable, sustainable and modern energy for all by 2030 (SDG7), the Paris Agreement and the UNFCCC (Article 4(f)) minimising adverse effects on the economy, public health, and the environment, in projects or measures undertaken to mitigate or adapt to climate change.

Development of the RE sector provides this opportunity to all countries in the IORA region and this is a noble undertaking that will suppress the negative impacts emanating from the continued use of fossil fuels.

8.0 Impact of Covid-19 on the Tourism Industry

8.1 Introduction

Tourism is one of the industries with the fastest and most significant growth globally. The United Nations World Tourism Organisation (UNWTO) estimates that tourism generates 30% of global service exports, 10.3% of all jobs (333 million), and 10.3% of global gross domestic product (GDP) at USD 9.6 trillion (UNWTO, 2018). Overnight tourist visits climbed by 4% contributing USD 1.5 billion in 2019 (UNWTO, 2019). Tourism has tremendous social, cultural, political and economic value. Targets 8, 12 and 14 of the SDGs on inclusive and sustainable economic growth, sustainable consumption and production, and the sustainable use of oceans and marine resources, respectively, stress the significance of tourism. Despite its negative impacts, tourism is considered an environmentally friendly method of economic development and the primary source of foreign exchange revenues in some developing nations (Postma & Schmuecker, 2017).

In Africa, international visitor arrivals increased by 4% before the Covid-19 outbreak, and the tourism sector supported 24.6 million jobs and generated 7.1% of the continent's GDP (ISPI, 2023; WTTC, 2020). According to GDP estimates, the Asia-Pacific has the most significant domestic travel industry, generating 15% of jobs (Travel & Tourism Competitiveness Index, 2019; Ingram, 2020). Although it is anticipated that tourism will continue to significantly contribute to economic growth in both developing and developed nations, it is also highly susceptible to various external shocks (Ritchie & Jiang, 2019). This was especially evident in 2020 during the Covid-19 pandemic, which caused the travel and tourism sector to experience unprecedented disruptions. International tourism declined by 74%, significantly reducing domestic travel (UNWTO, 2020). The tourism industry experienced the most considerable job losses, totalling USD 197.5 million globally (WTTC, 2020a). The tourism sectors of Kenya, Bangladesh and Seychelles are three nations that the pandemic severely impacted. This desktop study will examine the socioeconomic effects of COVID-19 on tourism and the various sustainable response measures undertaken in the Indian Ocean region, particularly in Kenya, Bangladesh, and Seychelles.

8.2 Methodology

This chapter follows a critical review of available and accessible relevant literature on the impacts of the Covid-19 pandemic, such as imposing social restrictions, on the tourism industry in the IORA states, focusing on three cases: Seychelles, Kenya and Bangladesh. The relevant literature is from local, national, and international scientific reports and publications, peer-reviewed journal articles, and government policy briefs. Only English literature is considered for writing this report chapter.

8.3 Results

8.3.1 Kenya

Kenya is well-known for its biodiversity and picturesque scenery, and tourism is a significant part of the economy. Kenya is the third most popular travel and tourism destination in Africa. Since 2015, the country has shown remarkable performance in the tourism sector. Kenya's tourism arrivals climbed by 3.9%, from 2.02 million visitors in 2018 to 2.05 million in 2019 (Standard Media, 2020). Given that tourism contributes 10% of the nation's GDP and 9% of all formal employment, the sector is regarded as one of the most important economic drivers in Kenya's coastal region (African Travel and Tourism Association, 2019). After the COVID-19 pandemic outbreak, the number of international visitors decreased by two-thirds, or significantly less than 500,000, in the first ten months of 2020 (World Bank, 2020). This caused a revenue loss of close to USD1 billion. Global domestic and international travel dropped to USD 2.7 billion in 2020 from 4.5 billion in 2019, representing a 60% decrease. This amounts to a predicted loss of USD 1.3 trillion in global tourism expenditures.

Through the Government of Kenya, the Ministry of Tourism and Wildlife undertook a study in 2020 which gathered information from significant stakeholders in Kenya's tourism industry to assess the impacts of the pandemic (Ministry of Tourism and Wildlife Kenya, 2020). This study showed that slightly more than 80% of these businesses had cut back on staff and that 31.9% had decreased salaries for the remaining workers by more than 70%. The government took several actions to address these problems through critical policy interventions categorised under seven broad themes: sustainable financial and fiscal incentives, public health or medical protocols, policy and regulatory framework, human capital development, tourism product and development marketing, and crisis management mechanism. In general, these themes outlined recovery measures in the form of financial support (loans, funds and subsidies) for different sectors, health and hygiene guidelines including compensation of sick pay, review of the tourism framework to adapt to changes, capacity-building for tourism businesses, diversifying revenue sources, enhancing the use of digital technologies for tourism marketing and building sustainable environmental, social and financial practices. According to Cottars (2015), existing tourism businesses charge a lease fee for wildlife protection, which is disbursed to local and rural people. The revenue from this fee was also used to advance wildlife conservation. However, through the COVID-19 policy recommendations, a temporary reduction in fees was introduced to encourage travel which would consequently impact positively on the indigenous people and wildlife conservation. Despite COVID-19 being primarily a health concern, Bitok (2020) reported that the Ministry of Health had noted that there was no reported progress on key policy reforms under the tourism pillar, such as the medical tourism strategy and that there was a need to develop and implement this strategy.

According to the German Commission for UNESCO (2020), Kenya was one of the eight African nations chosen to benefit from the UNESCO COVID-19 crisis response initiative to support tourism recovery, particularly around World Heritage Sites. Through this project, incentives were identified to promote sustainable tourism practices. These incentives included training and capacity building for critical sectoral stakeholders. Additionally, it included encouraging investments in the country's cultural heritage preservation and creating temporary job opportunities by utilising culture and heritage as a source of resilience. The community and young people were actively engaged to participate in order to ensure the project's viability. More recently,

in 2022, the Ministry of Tourism and Wildlife introduced the New Tourism Strategy for Kenya 2021-2025, founded on four strategic shifts based around branding, marketing, diversifying customer experience and developing enablers for alternative sources of funding and optimising the adoption of digital innovations and new technologies by the tourism sector. The new strategy is similar to the policy interventions introduced by the government at the beginning of the pandemic.

8.3.2 Bangladesh

Bangladesh is recognised for its rich history, heritage, and natural beauty. The tourism sector generated around USD 1157 billion in income from 2009 to 2019, contributing 4.4% to Bangladesh's GDP (Bangladesh-Contribution, 2019). Bangladesh was ranked the seventh "top ten best value travel destinations" in 2019, attracting 550,000 tourists on average (USAID, 2019; Chowdhury, 2020). Between 2011 and 2017, Bangladesh's travel and tourism business created around 2.23 million jobs per year, including formal and informal ones. The country has primarily relied on domestic tourism since its foundation, accounting for 96% of overall tourist spending, while overseas tourism accounts for only 4% (WTTC, 2020b). Despite its enormous potential, tourism in Bangladesh has yet to have a worldwide impact. This is due to the poor marketing of the country's attractive geographical features, rich culture, and cuisine. Another critical challenge to drawing international tourists to Bangladesh is political unrest (Murshed & Ahmed, 2018).

The pandemic exacerbated pre-existing challenges in the tourism sector along with the economy. The tourism industry of Bangladesh has been affected severely since many domestic and international visits have declined (Begum *et al*., 2020). Domestic tourists are crucial to Bangladesh's tourism business. Around 10 million domestic visitors travel yearly, with an annual revenue of approximately USD 250 billion. International tourist arrivals had also been gradually increasing. However, due to the COVID-19 crisis and travel restrictions, all tourism activities were halted (Deb & Shohel, 2020). The Bangladeshi hospitality industry, such as hotels, restaurants, resorts, and transportation, had come to a halt, which resulted in a decrease in income and significant job losses. Tourist locations in Bangladesh, such as Cox's-bazar, Saint Martin, Chattogram, Dhaka and Sylhet, are famous tourist destination sites. However, because of the pandemic, tourists who visited were highly impacted. All the country's tourism industry stakeholders needed to adjust to adversity (Hassan and Burns, 2014; Chowdhury, 2020). The travel and tourist industry adopted various crisis management strategies to deal with the situation. The government requested over USD 282 million in interest-free loans for three years and USD 47 million in financial help for foreign marketing to the Bangladesh Chapter of the Pacific Asia Travel Association (PATA, 2020). Sheikh Hasina, the Prime Minister of Bangladesh, developed specific instructions and policy actions to address the adverse effect of COVID-19 on the tourism industry. Since over 40% of the locals depend entirely on tourism, the pandemic affected the indigenous population more. Community-based tourism was one of the innovative initiatives by the Bangladesh Tourism Board to draw visitors back. Along with this, national tourism authorities maintained their relationship with international tourism authorities and promoted tourism destinations to emphasise the positive elements during the pandemic to aid the tourism sector in anticipating and responding to global health emergencies (Horaira, 2021).

Because of the outbreak, the country's GDP fell, and the tourism sector's input sharply declined. Despite some adverse losses, the pandemic also influenced the natural environment of the tourism geographies of Bangladesh positively. Considering both the positive and negative effects of the pandemic, it opened up the option of organising the tourist industries in Bangladesh sustainably (Bagchi, 2021).

8.3.3 Seychelles

Tourism is the central pillar of Seychelles' economy. The emerging growth of the tourism sector dates back to the opening of the international airport in 1971 and has been fundamental in sustaining state development plans after the country's independence in 1976. Tourism, directly and indirectly, generates about 72% of the GDP and about 70% of total foreign exchange earnings. According to the Seychelles National Bureau of Statistics (2022a), GDP growth rates are closely linked to tourism seasonality. Most recently, prior to the Covid-19 pandemic in 2019, the visitor numbers were 384,000 (National Bureau of Statistics, 2021), almost four times the size of the country's population, which is at only 100,477 (National Bureau of Statistics, 2022a). The tourism arrivals of 2019 had a 6.2% increase over 2018 and generated an income of USD 602 million. Notably, the wealth of Seychelles' people is inherently linked to tourism (McEwen & Bennett, 2010) as it also accounts for more than 30% of employment (National Bureau of Statistics, 2022b). During the pandemic, many people lost their jobs. Small tourism business owners in the hospitality industry had to temporarily close their businesses and find alternative jobs to support themselves. Due to this crisis, the government had to act quickly, particularly by offering financial assistance to the informal sector under the Unemployment Relief Scheme of the Agency for Social Protection (GoS & UNDP, 2020). Initially, the government made 100% job retention obligatory from April to June 2020. However, this policy was revised as the Covid situation worsened, and the private sector was allowed to negotiate redundancies with the Ministry of Employment. In July 2020, the government implemented the Seychelles Employment Transition Scheme to assist all employees who had lost their jobs by ensuring they would continue receiving their monthly salary until 31 December 2020. This scheme also catered for self-employed individuals. To further support the population, the Minister of Finance postponed payment of taxes until September 2020 and budgeted SCR 1.1 billion to secure the jobs of 37,000 employees in the private sector. Following the implementation of the Covid-19 relief scheme, the Government of Seychelles had to approach its creditors to discuss the possible restructuring of its international debt (Ministry of Finance, National Planning and Trade, 2020).

The prevalence of foreign-owned transnational hotel chains is a disadvantage to the national economy as it promotes economic leakages and overpowers local entrepreneurship (Ioannides & Holcomb, 2003, p. 43). This may have profound adverse effects on Seychelles' economic sustainability. Other identified areas that need to be developed and improved are the ICT sector, which potentially have long-term benefits and is a sector where the pandemic has highlighted the need to increase national investments in terms of international support. Seychelles, like Kenya,

also received funds from UNESCO under the #SOSAfricanHeritage project. The UNESCO project trained staff and other key stakeholders to use the new technologies.

8.4 Conclusions and Recommendations

COVID-19 had varying effects in different IORA states, which required specific tailor-made interventions due to the magnitude and other variations like geo-political settings, resource availability and social make-up in these countries, including existing socio-economic issues. Research on the impact of COVID-19 is still in its primary stage. There are many areas where no light has been shed yet to evaluate the impacts of COVID-19 on, for example, the businesses run by different nationalities and different models of tourism business to compare business resilience and recovery. Dedicated studies should explore these areas to devise effective interventions to compensate for the losses and restructure policies to include short- and long-term solutions to such issues. Through policy development, the government must customise financial instruments based on national demands and priorities. Some recommendations are stated below:

Local ownership of tourism businesses

In Seychelles, most transnational hotel chains are foreign-owned, including cruise ships which offer all-inclusive packages to tourists. This is the case in several IORA countries, meaning that international tourism does not benefit the host country entirely. Therefore, there is a need for countries, particularly SIDS, that are not endowed with natural resources to diversify their economy either into fisheries or agriculture and for the government to invest in and support locally owned tourist businesses. The government also needs to provide training for community-based tourism and other self-supporting businesses.

Improve tourism infrastructure

In Bangladesh, where domestic tourism arrivals exceed international tourism, there needs to be an investment in tourism infrastructures and marketing to maximise the full potential of the tourism sector.

Increase skills capacity to run local tourism businesses

Each country needs to move towards more digitised ways of conducting various types of businesses and interactions. Kenya is an excellent example of how this can be achieved through its engagement with indigenous people to promote cultural heritage and nature conservation. Such practices could be facilitated further through training and stakeholder involvement whereby the government could partner with the private sector to invest in skills upgrading programmes that will protect the national workforce. These initiatives should include vulnerable groups such as women, the youth and persons with disabilities.

Promoting domestic tourism

International travel restrictions were typically maintained for extended periods during the pandemic, but domestic travel could resume. Domestic tourism should become a short-term goal

for countries that do not have large domestic tourism markets because it is relatively easy to promote and more resilient to certain external factors.

Travel bubbles

Travel bubbles are agreements between countries to let travellers from a partner economy or economies through their borders. Travel bubbles may be for both business and leisure travel. Regulations frequently include requirements for health precautions to be taken when entering and departing the region.

Diversifying tourism offerings

All three case study countries are known for their natural beauty, wildlife, and cultural heritage. They can also investigate new tourism services to draw on a broader range of tourists with different interests and preferences. For example, they can promote outdoor activities like hiking, mountaineering and water sports. They can also focus on eco-tourism, where visitors can experience the local environment while contributing to conservation efforts.

Emphasising sustainable tourism

Sustainability is becoming more critical in tourist decisions. To encourage sustainable tourism, states can act by lowering plastic waste, protecting natural resources and helping local communities. These nations can stand out from other travel destinations and draw tourists who value ethical travel by emphasising sustainable tourism.

Exploring new markets

Even though international travel might take some time to rebound, MS can look into new markets to draw tourists. MS can, for example, target tourists from neighbouring countries or emerging markets. Furthermore, they can market their locations as attractive and secure for digital workers looking for new locations to conduct remote work.

Utilising technology

Tourism management and promotion are two areas in which technology can be beneficial. MS can use social media and other online platforms to advertise travel destinations and interact with potential tourists. They can also create targeted marketing campaigns using data analytics to better understand visitor preferences and behaviour.

Strengthening industry partnerships

Many stakeholders are involved in the tourism industry, including airlines, travel agencies, tour operators and hotels. MS can fortify their alliances with these parties to create joint marketing campaigns, provide package deals, provide training and exchange best practices. All such arrangements could increase demand for their tourist attractions and improve the visitor experience.

9.0 Impact of COVID-19 on Waste Generation and Management Systems

9.1 Introduction

Waste management has continuously been overlooked, a situation that could have devastating effects on economies (UNEP, 2015) and have negative environmental impacts (Sawant *et al*., 2021). Uncontrolled and ill-managed waste could have damaging repercussions on human life. In particular, solid waste may either find its way into groundwater and compromise its quality through percolations of leachate or lead to the emission of poisonous gases that will compromise human health (Sawant, *et al*., 2021). Waste generation and management have always been a challenge for many countries (Abedin & Jahiruddin, 2015; Afroz *et al*., 2011; Eckelman *et al*., 2018; Gakungu *et al.*, 2012; Islam, 2016; Krutli *et al.*,2018; Lai *et al*., 2016; Paruta *et al.*, 2020).

Weary of the potential threats that mismanagement of waste can bring about, the waste management industry has evolved from just treating waste and disposing it, to an industry that is looking into various ways of adding value and converting this waste into avenues for energy production. Given that municipal solid waste through WTE mechanisms can be used as biomass or biogas for energy generation, it can substitute the importation of foreign oils and offer opportunities for green recovery with regards to waste management (Varjani, *et al*., 2022).

9.2 Methodology

Against this backdrop, this report chapter reviews waste management literature (i.e., published research and policy documents) in the context of Seychelles, Kenya, and Bangladesh and seeks to (a) establish the management of waste; and (b) evaluate the appropriateness (capacity and efficiency) of waste management systems. Moreover, through policy mapping, data was collected to illustrate the share of national resources used in waste management (especially COVID 19 waste) and the prospects of processing solid waste for energy generation as a way of managing solid waste.

9.3 Results

9.3.1 Seychelles

In Seychelles the Ministry of Agriculture, Climate Change and Environment is responsible for the development of drafting and implementing the waste management policy. Waste disposal and transportation are also guided by the Basel, Stockholm and Rotterdam conventions. Working in conjunction with the ministry, is the Landscape and Waste Management Agency (LWMA). This body is in charge of cleaning and beautifying Seychelles. They issue waste management contracts, and monitor and supervise all waste collection contractors on the Island. There are some private waste collection and management agencies. The biggest one of these is WASTEA, which offers skip services, liquid, solid and commercial waste collection, high water pressure and cleaning (WASTEA, n.d.)

The Island generates around 5000 tonnes of waste each month, of which one third is from residential bin sites and retail shops (Ministry of Agriculture, Climate and Environment, n.d.). Waste generated is usually in most cases disposed of at communal bin sites and later transported by waste collectors and disposed of at a landfill site in Providence.

Primary data on the impact of COVID-19 on waste generation and management in Seychelles is lacking and hence there is the need for such studies. However, like every other country, lockdown and restrictions in Seychelles meant that most offices and schools were shut and people had to stay home. With many spending more time at home, there was a likelihood of an increase in waste generation that in turn put pressure on waste collection systems (Filho *et al*., 2021). The sanitation sector was the third most hit after water and electricity. This was very evident as over-spilling bins were clearly visible. The LWMA was overburdened with waste collection and had to put on hold the second phase of its household and polyethylene terephthalate (PET) waste sorting and collection project, an initiative which was being piloted at the time (Seychelles News Agency, 2021).

Lai *et al.* (2016) reported that a review of official government documents, waste management reports and semi-interviews indicates that most households performed some sorting of their waste and were willing to go further by separating their organic waste. However, a joint initiative between the government, Seychelles Brewery Limited and Seychelles Marketing Board aimed at reducing waste pollution by setting up plastic collection centres across various locations to encourage people to trade in the PET soft drinks and mineral water bottles from Seychelles for a fee (Seychelles Nation, 2007) had only been utilised by informal waste collectors (Krutli *et al*., 2018; Lai *et al*., 2016), who patrol the island in search of these bottles. Households have not utilised these collection schemes as much because they simply do not know where these centres are or they are located in unsuitable areas (Krutli *et al*., 2018).

Though the current Seychelles National Waste Management Policy 2018-2023 has not been published and efforts to gain access have not been successful, the policy aims to ensure that 'Waste is managed in a sustainable manner, following the set guiding principles and approaches, in order to protect the integrity of the environment and improve the quality of life in Seychelles' *(*Ministry of Agriculture, Climate Change and Environment, nd). Despite documented challenges to the implementation of previous waste management policies *(*Lai *et al*., 2016; Talma & Martin, 2013), there are systems that currently pre-process different types of solid waste, including scrap metal, beverage cans and PET (Krutli, *et al*., 2018). Krutli *et al.* (2018) established that there was a potential for Seychelles to produce and increase its quota of RE through two waste treatment alternatives (i.e., anaerobic digestion and incineration). Hence, the Seychelles Government's idea to introduce a WTE plant within the next two years, which will generate and produce RE and reduce waste by 80% (Seychelles News Agency, 2022), is in line with this proposal. As it stands at the moment, it is not clear what type of plant will be established, however, according to Krutli *et al.* (2018) both plants (anaerobic digestion and incineration) could have positive effects for Seychelles. They assert that while an anaerobic digestion plant can produce energy to meet about 10% of the national electricity needs, an incineration plant can also contribute up to 15% of the entire energy production. Moreover, an anaerobic digestion plant can be used to produce fertiliser for local use and export (Krutli *et al*., 2018).

Given that the COVID-19 pandemic and subsequent restrictions caused a rise in unrecyclable and organic waste and presented a challenge to waste management authorities (Werikhe, 2022), the governments' investment in a WTE plant is a sustainable initiative that will help counter potential risks that come with improper waste management and ensure the country is better prepared for future crisis. Moreover, better incentives that encourage people to recycle their bottles may go a long way in reducing waste.

9.3.2 Kenya

In Kenya, the drafting of the waste management policy and all other corresponding legal documents that regulate waste is overseen by the Ministry of Environment, Climate Change and Forestry. The National Environment Management Authority is responsible for the implementation of policies drafted by the ministry (Ministry of Environment, Climate Change and Forestry, n.d.).

Waste generation and management has been a challenge in Kenya. It's been reported that most counties have challenges that range from lack of infrastructure, governance mechanisms, and finance, with only 40% of the population of most urban cities having access to waste collection services (Republic of Kenya, 2021). Other studies in Kenya support this claim, with similar challenges across the board. For instance, a study into solid waste management in the city of Nairobi had disturbing outcomes. Findings show low solid waste coverage, uncontrolled dumping, inefficient public services, unregulated and uncoordinated private sector assistance and lack of key solid waste management infrastructure (Njoroge *et al.,* 2014). Njoroge *et al.* (2014) found that of the 4,016 tonnes of waste generated, only 33% of this was collected, leaving around 2,690 tonnes uncollected. This statistic is very worrying, given the potential pollution and negative health implications that unattended waste can cause.

Kenya has made some strides with regards to drastically cutting down on GHG emissions by 30% by the year 2030, to align with pledges made at the COP-21 in Paris (Dianati *et al*., 2021). The country houses the largest grid-connected commercial biogas power plant on the continent. Situated in Naivasha, the plant has the potential to treat 50,000 tonnes of organic waste, serving up to 6000 rural homes with power. Many cities across Kenya have such plants. Moreover, through the Africa Biogas Partnership Program 27,000 households in Kenya, Tanzania and Uganda had biogester installations from 2009 to 2017, with Kenya having the highest number of household installations (Dianati *et al*., 2021). Despite the relative successes by the Africa Biogas Program, and the potential to provide biogas for over a million households, there are still documented challenges that include lack of credit facilities, lack of policy support, and maintenance related issues. Consequently, a lack of policy support caused the abandonment of around 30% of biogas plants (Robinson, 2023).

Lack of policy support towards waste management in Kenya has been documented (Dianati *et al*., 2021; Robinson, 2023). However, the government has made some efforts with regards to waste generation and management. For instance, the National Guidelines for Management of COVID-19 waste served as a good guide for waste management during the pandemic and lockdown. Medical waste was separated from other waste and handled with more care (National Environment Management Authority, nd). The guide made some recommendations at various waste generation levels. For instance, at public, community and household levels, management or owners of gated

communities, residential areas, factories, institutions and office blocks were to provide medical waste pedal bins with biohazard bin liners. These managers/owners were also expected to liaise with licensed waste handlers to collect and deposit waste at designated sites (National Environment Management Authority, nd). Similarly, recommendations were made for the Ministry of Health to do the same for waste generated in hospitals, clinics and other health facilities.

Moreover, the launch of the National Sustainable Waste Management Bill (2021) in a period when the country was recovering from effects of COVID-19, was a step in the right direction. The policy aims to 'protect public health and the environment, as well as drive job and wealth creation, by creating an enabling environment for sustainable, integrated waste management and the minimization of waste generation, to contribute to a circular economy' (Republic of Kenya, 2021). The Bill placed emphasis on moving away from the traditional way of waste management in favour of a more contemporary framework which guides and advocates for the segregation of waste at source, proper transportation, closure of dumpsites, sanitary landfill, proper guidance towards recycling, and conversion of waste for renewable energy purposes (Parliament of Kenya, n.d.). The policy, if implemented well, can guide Kenya towards a better recovery from the effects of COVID-19. This remains to be seen as policy implementation in developing countries has always been a challenge.

9.3.3 Bangladesh

The Ministry of Environment, Forest and Climate Change is responsible for policy formulation on waste generation and management. Over the last few decades Bangladesh has seen a significant growth in waste generation with up to about 55% of the waste not being collected (Islam, 2021). Most of the uncollected waste tends to end up in the water or drainage systems. Consequently, polluting the soil, air and other surfaces and putting human life in danger (Islam, 2021). Waste, particularly hazardous medical and electronic waste pose huge challenges to the waste management system in the country. An increase in urbanisation has caused a rise in waste generation in big cities such as Dhaka (Islam, 2021).

Between 2008 and 2018, the urbanisation rate increased from 28.97% to 36.63% (Mostakim *et al*., 2021). This put a strain on waste management with a large proportion of the waste being left unattended to and potentially impacting negatively on the environment. Waste management has proven to be a problem not only in Dhaka. In Khulna, for instance, despite a daily waste generation rate of between 550 and 600 tonnes, the local authority is constrained and lacks the required logistics and capacity and hence, only collects around 400 tonnes (Islam, 2021). In Gazipur the 2,500 tonnes of waste collected daily is carelessly deposited close to the highway. This is attributed to systematic waste dumping (Islam, 2021).

Six major cities in Bangladesh produce around 7,690 tonnes of waste every day (Mostakim *et al*., 2021). Despite this, management of solid waste is highly dependent on informal waste collectors, and is not properly regulated and hardly factored in recycling (Roy *et al*., 2022). The lack of proper SWM systems has resulted in creating a situation where there is low budg*et al*location, lack of technical advancement and a lack of coordination between various stakeholders. With regards to electronic waste, there is a general lack of awareness and understanding of the potential risks this poses to the environment (Islam, 2016). Another major challenge to waste management in

Bangladesh is that even though 9 out of the 12 city corporations have allocated dumping sites for solid waste, most of these are open air and lack the proper sanitation arrangements (Islam, 2021). Though landfills are usually created far away, a rapid growth in population means over the years people get closer to these sites and are at risk of getting health complications. Moreover, plastic waste, which constitutes the majority of solid waste and has a huge economic value, has not been fully utilised (Roy *et al*., 2022).

Medical waste is also not well managed in Bangladesh. As of 2019, there were around 645 public and 288 private hospitals, laboratories, and diagnostics centres. All these facilities produce some hazardous waste and if not managed well can pose health risks. In Bangladesh around 5.7% of hospital waste ends up in uncovered bins, buried in the ground, by the roadside or in open water bodies. About 59% of such waste end up in bins without being sorted and separated (IPEN, 2021).

COVID-19 impacted on waste generation and management in Bangladesh in a number of ways. A large amount of potentially infectious medical waste was generated during COVID-19. About 206 tonnes of the medical waste was produced per day in Dhaka due to COVID-19 as opposed to an average of 48 tonnes per day prior to the pandemic (IPEN, 2021). During the first three months of the lockdown period, the country produced 14500 tonnes of hazardous waste (IPEN, 2021). Also, during this period, more than half of the country's population made use of single-use synthetic surgical masks, while around 30% of people in cities used gloves and hand sanitizers (IPEN, 2021). Moreover, used containers from hand sanitizers contributed around 900 tonnes a month of waste, while the capital city contributed around 3076 tonnes of plastic within the first quarter of the lockdown period (IPEN, 2021). Overall, during the lockdown period, there was a surge in the production and usage of hazardous medical apparel. Given that Bangladesh already struggles to manage waste efficiently, the unexpected surge in waste during COVID-19 lockdown further exposed the deficiencies in the waste management systems (IPEN, 2021).

COVID-19 also had an effect on waste treatment and on disposal facilities. During the lockdown, many organisations who were initially committed to sustainable waste generation and management practices showed a lack of commitment (IPEN, 2021). Again, an increase in the volume of waste posed a further threat to healthcare and waste collection.

Recently, the Bangladesh Government has come up with various strategies to rid the city of Dhaka of waste. The government, under the Department of Environment, came up with a plan to pilot the 3R strategy (i.e., reduce, reuse and recycle) in 2012 at a cost of USD 2.5 million (Kengo, 2022). The intention behind this strategy was to ensure that household waste was processed for biogas, while inorganic waste was to be recycled. This initiative failed as a result of a lack of motivation and awareness amongst some stakeholders (Islam, 2021). Also, the Solid Waste Managed Bill (2021), besides stressing the need for a 3R strategy, also stresses the need for a collaborative approach to dealing with waste, with responsibilities for waste generators, consumers and users defined. Provision is also made in the policy for treatment of solid waste for energy generation and imprisonment for up to two years or a fine of not more than 200,000 takas for those who violate the law (Kengo, 2022).

Going forward the government has announced that it has awarded a contract to the China Machinery Corporation (CMEC) to implement a 42MW WTE plant to be situated in Aminbazar

by 2024 (The Business Standard, 2021). This giant step by the Bangladesh Government can help increase the country's share of renewable energy, to fall in line with the Paris Agreement. Moreover, as the country recovers from the effects of COVID-19, it is imperative that it adopts sustainable approaches to managing the country. The implementation of a WTE plant is one way of achieving that.

9.4 Conclusions and recommendations

The review of waste generation and management amongst the three IORA states (Seychelles, Kenya and Bangladesh) offered some insights. Firstly, in the case of Seychelles, studies on waste generation and management before, during and after COVID-19 are very scarce. In the case of Kenya there are a few studies on waste generation and management before COVID-19, however, there is not much on the subject during and after the COVID-19 lockdown. On the other hand, there are quite a number of studies on waste generation and management before the lockdown and a few during the lockdown in Bangladesh. However, there are not many studies focussing on the recovery period. It is recommended that further studies on the impacts of COVID-19 on waste management, particularly on the recovery period are conducted. Secondly, the size of the various countries means that the primary data collection strategies will differ. Kenya and Bangladesh are far bigger than Seychelles. For instance, while waste collection data from waste collectors may be easily accessible from a single source in Seychelles, this may differ in Kenya and Bangladesh due to various divisions.

Again, a key observation while reviewing the literature was that Kenya seems to be advanced with regards to the processing of biogas for renewal energy. While there are plans to construct WTE plants in both Seychelles and Bangladesh by 2024, Kenya already has some of these plants and plays host to the biggest commercial biogas plant in Africa that has the potential of treating 50,000 tonnes of organic waste.

Despite the potential gains from recycling and processing waste for energy generation, there has been a lacklustre approach by governments of the member states involved in the study to act on it with urgency. For instance, amongst all three countries, studies have shown that Bangladesh has struggled the most in dealing with waste, yet it is only recently that they have awarded the contract for a Chinese company to construct a waste to energy plant; Seychelles has also struggled in dealing with waste, hence the delay in investing in such a plant is surprising; Kenya on the other hand made some in-roads with regards to processing waste into biogas for energy generation, however a lack of policy support meant that stakeholders were not committed to invest in it.

Though efforts have been made towards the adoption of better waste mechanisms amongst the three countries, it is evident that there is more work to be done in. There is the need for a more integrative approach that involves all stakeholders to achieve green recovery, particularly post COVID-19. Better incentives that encourage recycling could help curb the waste menace. Above all a circular economy approach to waste generation and management will aid green recovery. Circular economy approaches in this regard encourage waste reduction through reusing, repairing, refurbishing and recycling. In Germany the closed cycle approach, an integrative policy aimed at achieving a circular economy tasks manufacturers and product distributors with waste disposal

responsibilities (Morscheck *et al.*, 2016). This has created the awareness among the populace to separate waste, leading to the innovation of advanced disposal technologies as well as increased recycling capacities. To complement the closed cycle management policy, the German waste management program that started in 2013 offers support and incentives to encourage recycling. Under the Closed Cycle Management policy, uniform recycling bins are introduced in all communities and households are tasked to dispose of packaging and other waste material. In relation to waste disposal and recovery, the Closed Cycle Management approach makes it illegal to landfill organic waste without it undergoing some treatment. Moreover, waste paper recycling is highly recommended and in force. For instance, about 80% of graphic paper in Germany is recycled (Morscheck *et al.*, 2016). The approach also advocates for the usage of bio waste for renewable energy. Approximately 12 million tonnes of biodegradable waste are processed through biogas installations. Aside from renewable energy, bio waste can be treated and used as fertiliser which can be used locally or exported for revenue (Morscheck *et al.*, 2016).

10.0 COVID-19 Impacts on Water Quality in the IORA Region

10.1 Introduction

The lockdowns due to COVID-19 that took place in 2020, detrimentally affected the socio-economic welfare of individuals across the globe, and the containment measures presented multifaceted implications to the water quality of the aquatic environment. While most studies have reported positive impacts of lockdowns on the water quality of the aquatic environment, several studies have shown negative implications caused by COVID-19 on the aquatic environment in IOR countries such as Bangladesh, India, Indonesia, Iran, and South Africa, which were mainly due to excessive white pollution. Interestingly, a few studies have shown both negative and positive impacts of the pandemics towards the water bodies such as those in Dhaka Lake in Bangladesh (Haque *et al*., 2021; Rahman *et al*., 2021), Buddha Nulla stream (Das *et al*., 2021), Chennai city (Robin *et al*., 2021), Sabarmati River (Aman *et al*., 2020; Kumar *et al*., 2021), and Yamuna River (Patel *et al*., 2020) in India, and Zarioub River in Iran (Haghnazar *et al*., 2022).

Notably, the aquatic environment contributes valuable resources to countries within the IOR, especially the highly populated countries. Given that the COVID-19 pandemic demonstrated bidirectional influence of human intervention on water bodies, further exploration of COVID-19 impacts on the water quality of the aquatic environment across the vast IOR region is of vital importance. In recent years, scientometric studies have made significant contributions to the assessment and analysis of research fields ranging from natural to social sciences (Kim & Zhu, 2018). Scientometric studies could identify emerging research fields and their development (Chatterjee & Dethlefs, 2021). The primary objective of this study is to identify the research and publication trends that have emerged in the field of water quality and aquatic environment impacted by the COVID-19 pandemic in the IOR region. The result from the present study will provide insights into the network pattern and research topic hotspots associated with water quality and aquatic environment affected by COVID-19 pandemic in the IOR region.

10.2Methodology

10.2.1 Data sources and literature search strategy

A literature search for scientometric analysis was conducted for articles published from January 2019 until 31st December 2022 using the subscribed materials from the network of Web of Science, Core Collection (WoSCC) database by Clarivate Analytics. We used the Science Citation Index Expanded (SCI-EXPANDED) part of the WoSCC, and modified the search string to match the most important keywords for this study ("COVID-19", "Water environment", AND "IOR region"). While the "COVID-19" keywords were focused on the pre-, during, post-COVID term and the common name, short form and scientific name of COVID-19 was included, the keywords "Water" and "IOR region" were the "Exposure" terms. The "IOR region" keyword was focused on the water bodies within countries in the IOR. Only original peer-reviewed journal articles which were written in English were considered for subsequent analysis, while those from conference

proceedings, review papers, book and book chapters, protocol papers, letters, editorial material, commentaries, short communications, news and abstracts were excluded.

10.2.2 Scientometric Analysis

CiteSpace version 5.8. R1 for 64-bit Windows along with MS- Excel spreadsheet was utilised for the visualisation and knowledge graph analysis that generates numerous bibliometric networks that permits multiple research area analyses (Chen & Leydesdorff, 2013). Threshold of "Top 50N" was fixed per slice, which selected, displayed and ranked the top 50 high occurrence research articles to construct a network using selected input value and different node types. Co-citation analysis was conducted to evaluate the status of scientific development and structural changes by examining the cluster of journals, in which a co-citation occurred when two sources were cited simultaneously in a single article (Chen & Leydesdorff, 2013; Aryadoust & Ang, 2021). The variable's quality was estimated based on the values of degree, centrality, and sigma (Chen, 2022). Document cluster analyses (DCA) was used to identify research clusters in focal areas. CiteSpace's text mining and keyword analysis algorithms were used to create cluster labels. Log-likelihood ratio (LLR) was used to automatically extract and name the cluster labels as they could provide the best coverage and uniqueness. The modularity Q index, average silhouette metric and centrality values were used to assess the quality and homogeneity of the DCA and detected clusters (Chen *et al*., 2009, 2010; Chen *et al*., 2019).

10.3 Results and discussion

10.3.1 Global publication trends

The scientometric analysis based on Web of Science Core Collection (WoSCC) database identified a total of 489 articles published with the research scope of "Impact of COVID-19 on water quality of the aquatic environment in the IOR region" between years 2019 till 2022, since the outbreak of the pandemic in 2019 (Figure 10.1). While an exponential surge was observed in the number of publications related to this research domain in the years since 2019, the decreased number of published articles in 2022 may be due to reduced interest in researching the post-pandemic impacts, following the pandemic recovery period. Notably, the number of authors (2,838) and affiliations (1,270) have suggested that the impact of this pandemic on the water quality within the IOR was one of the popular topics of interest among scientists. In fact, the prevailing interest of research domains have also been extended globally, given that numerous related studies have been published by countries such as USA, China, United Kingdom, and Australia (Surulinathi *et al*., 2021; Mare *et al*., 2023, Nyika & Dinka, 2022). There were 90 countries with relevant articles, with the top three accounting for 61.96 % of the total number of articles for "Impact of COVID-19 on water quality of aquatic environment in the IOR region". India produced the highest number of publications (173), followed by the United State of America (78 publications), and Australia (52 publications). The other countries which have profusely contributed to the publications within this research domain were Bangladesh (40 articles), England (35 articles), and Iran (34 articles). Out of a total of 2,838 authors, only 344 authors (12.12%) have published more than one article. Interestingly, half of the top 10 most productive authors were affiliated with India. Kumar Manish with his co-authors, Bhattacharya Prosun and Joshi Madhvin had the highest contribution of

publication related to SARS-CoV-2 surveillance in the wastewater around India (Kumar *et al*., 2020; Kumar *et al*., 2021b; Kumar *et al*., 2021c).

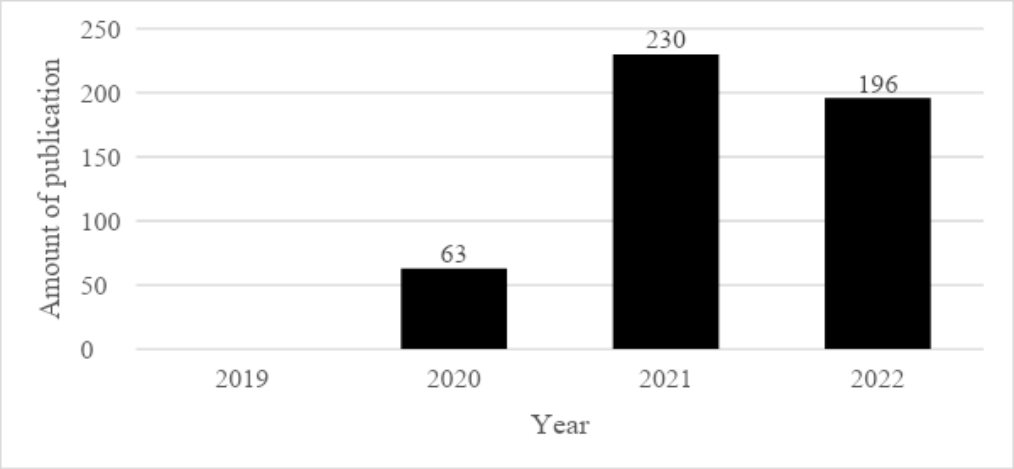

Figure 10.1: Research articles, relevant to the Indian Ocean Region and water quality, published annually since 2019.

10.3.2 Global collaborative networks

In co-citation analysis (Figure 10.2), Arora Sudipti was the most influential author with the highest centrality score (0.32). During the pandemic, she researched on the epidemiology of COVID-19 in India based on wastewater surveillance (Arora *et al*., 2020; Jiang *et al*., 2022). The second most influential author, Garg Vaibhav monitored the water quality of the most polluted river in India, the Ganges River, during the pandemic by satellite remote sensing. Garg V. had discovered that the water quality parameters, particularly turbidity level along Ganges river had declined during the pandemic lockdown, signifying improved water quality (Chander *et al*., 2019; Garg *et al*., 2020). Besides, Mahato Susanta also discovered positive meteorological changes during COVID-19 pandemic, and had published 3 articles on the improvement of air quality in India (Mahato *et al*., 2020; Mahato & Ghosh, 2020; Pal *et al*., 2021). Based on our document co-citation analysis, three review articles (Bogler *et al*., 2020; Naddeo & Liu, 2020; Quilliam *et al*., 2020) that were related to SARS-Cov-2 in water were highlighted in Figure 10.3. These articles emphasized that the prevalence of SARS-CoV-2 in wastewater could be used as a proxy for viral prevalence surveillance. Mani *et al.* (2020) reported an improvement of water quality in Ganges River following the reduction of economic activities during pandemic lockdown. The remaining two highlighted articles (Dogliotti *et al*., 2015; Luis *et al*., 2019) utilized satellite remote sensing for water turbidity surveillance which was designed on the basis of inaccessibility of sampling sites by researchers during pandemic lockdown.

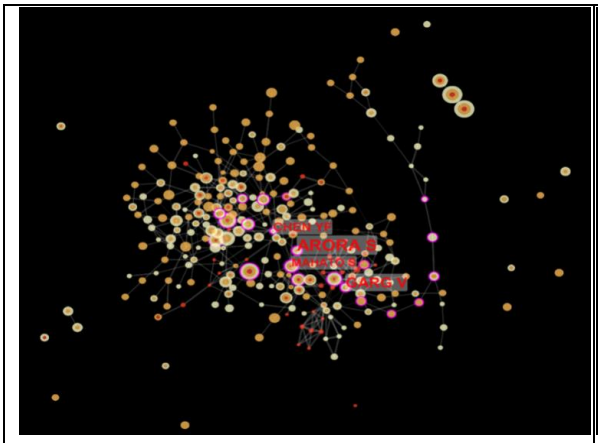

Figure 10.2: The network of co-citations between authors, where coloured circles represent author nodes and lines represent their connections.

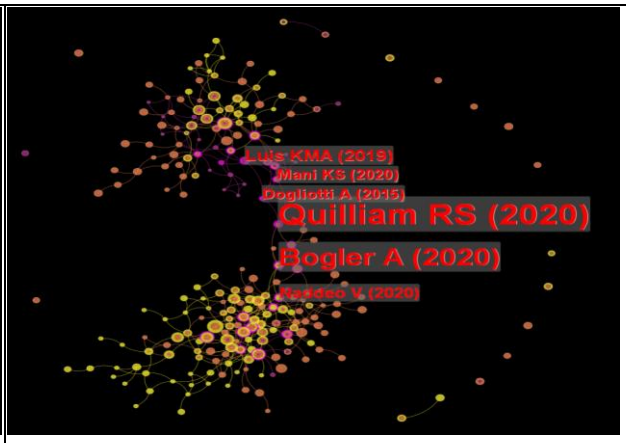

Figure 10.3: The network of document co-citation analysis, where coloured circles represent article nodes and connecting lines represent connections between the articles.

Based on the summary generated from DCA, the document cluster elements (Figure 10.4) were classified into two major groups, "impacts of COVID-19 towards environment" and "COVID-19 epidemiology in wastewater". The former group consists of cluster element #0 sustainable development goal, #4 air quality, #6 COVID-19 lockdown, and #8 lake water quality; while the latter group consists of cluster element #1 variant dynamic, #2 wastewater-based epidemiology, #3 COVID-19 lockdown, #5 COVID-19 lockdown, and #7 CoV-2 RNA. In Figure 10.4, we observed a decreasing "cited" trend of publications between year 2019 to 2022 which are represented by the number of nodes. The most cited articles from cluster #1 variant dynamics (Wurtzer *et al*., 2020) and cluster #2 wastewater-based epidemiology (Randazzo *et al*., 2020) and cluster #7 CoV-2 RNA (Rimoldi *et al*., 2020) have suggested that the presence of COVID-19 virus in wastewater can be used as a proxy for viral prevalence monitoring. Cluster #3, #5, #6 Covid-19 lockdowns constantly appeared as keywords for all the cited articles. The most cited article (Yunus *et al*., 2020) observed improvement of water quality parameters (reduced turbidity level by 16%) following decline of anthropogenic impacts due to implementation of pandemic lockdown. It is not unexpected that cluster #0 sustainable development goal (2020-2022) represents the cluster with the highest number of cited articles, due to common findings from these articles which have proposed that reduced anthropogenic activities during pandemic lockdowns has enabled environmental recovery which gear towards achieving a sustainable environment.

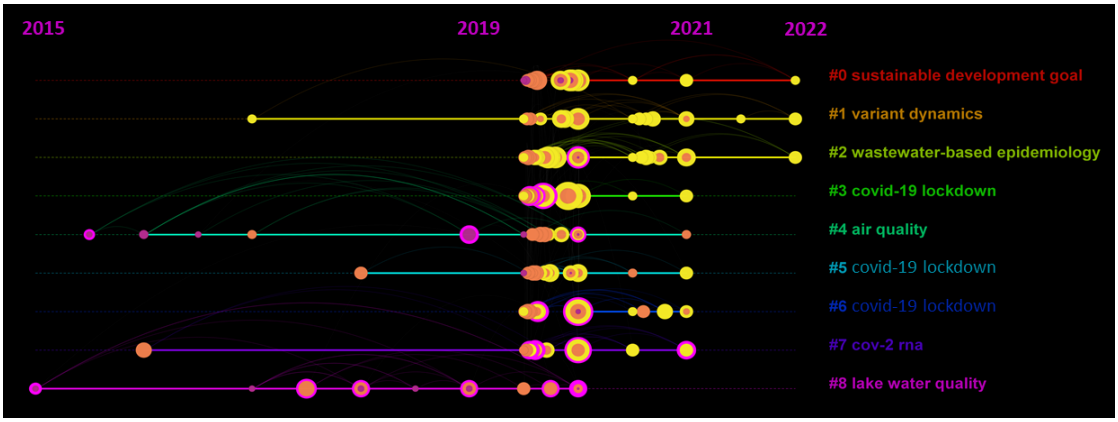

Figure 10.4. The summary of identified cluster lifetimes generated from DCA network in "Impact of COVID-19 on water quality of the aquatic environment in the IOR region" research studies between 2019 to 2022.

The impactful keywords with larger size which were found to consistently appear in 489 citing articles (Figure 10.5), include words related to the "environment" aspect such as water, wastewater, atmospheric, climate, city, environmental, air, coastal, and river. In keywords cluster analysis as shown in Table 10.1, most of the citing articles contains keywords which were categorized under the following cluster element such as cluster #0, #6 COVID-19 case study, cluster #1 surface water quality, cluster #2 resilient strategies, cluster # 4 hand hygiene practice, cluster # 8 pre-existing condition and cluster #9 pollution. Keywords in cluster #0 #6 COVID-19 case studies were used by citing articles which researched the coronavirus in the sewage water. Keywords in cluster #1 surface water quality were commonly used in heavy metal pollution related studies within the citing articles. Keywords in cluster # 8 pre-existing condition refers to citing articles with research focus on impacts of COVID-19 on the groundwater quality towards public health, during and post COVID-19 pandemic. Cluster #2 resilient strategies involved research on the development of environmental management models following COVID-19 pandemic. Cluster #4 hand hygiene practice emphasized the importance of COVID-19 self-hygiene practice to prevent transmission of this infectious disease. Lastly, cluster #9 pollution has raised the concern regarding post-pandemic emergence of white pollution due to poor management of PPE waste.

Table 10.1: Top 10 cluster analysis based on the given keywords of the "COVID-19 impact water of the aquatic environment in the IOR" research.

ClusterID	Size	Silhouette	Label (LLR)	Average year
0	27	0.912	COVID-19 case study	2021
1	27	0.851	surface water quality	2020
2	26	0.91	resilient strategies	2021
3	24	0.794	Rohingya refugee	2020
4	15	0.845	hand hygiene practice	2021
5	14	0.912	meteorological parameter	2020
6	14	0.874	COVID-19 case study	2021
7	12	0.935	food pattern link	2020
8	9	0.851	pre-existing condition	2021
9	6	0.949	pollution	2022

Figure 10.5: The distribution of keywords generated by the Pro Word Cloud by Microsoft PowerPoint 2019.

10.3.3 Bidirectional impacts of COVID-19 towards the water quality of the aquatic environment in the IOR

Disinfectants such as sanitizers and detergents which were widely used during COVID-19 pandemic have contributed to increased water consumption and chemical pollution in the aquatic environment (Wang *et al*., 2020; Campos *et al*., 2021; Chirani *et al*., 2021; Dobson *et al*., 2021). Excessive use of these disinfectants did not only overburdened wastewater treatment systems by altering the wastewater quality, but also increased the potential risk of releasing untreated wastewater into natural water bodies (Bogler *et al*., 2020; Wang *et al*., 2020; Dobson *et al*., 2021; Elsaid *et al*., 2021; Kataki *et al*., 2021). Haghnazar *et al.* (2022) revealed an increase of 23-50% of wastewater pollution during pandemic lockdown in the Zarjoub River, Iran. Similarly, wastewater pollution caused by domestic household effluents and untreated sewage was also reported in Indian water bodies (Das *et al*., 2021; Khan *et al*., 2021). In fact, the excessive usage of these drugs and antimicrobial disinfectants were reported to promote the dispersion of anti-drug resistant microbes in sewage areas and their surrounding water bodies, which could potentially expose humans to the risk of water borne disease (Kumar *et al*., 2021). In addition, white (plastic) pollution which was driven by wide use of PPE such as facemask, wet-wipes and gloves during and post-COVID-19 pandemic further intensified pollution level at riversides, beaches, and eventually the ocean within the IOR, which were reported in Jakarta Bay in Indonesia, the coast of Kenya, and the southeast coast of India (Rume & Islam, 2020; Okuku *et al*., 2021; Robin *et al*., 2021; Abedin *et al*., 2022; Cordova *et al*., 2022; Gunasekaran *et al*., 2022). Poor management of PPE waste may be highly detrimental to the aquatic environment and ecosystem in the long run, as the ageing PPE may leach pollutants such as heavy metals (e.g., Cd, Pb), organic contaminants, plastic additives (phthalate esters), and micro/nanoplastics (MPs/PNPs) (Kutralam-Muniasamy *et*

al., 2021, Sullivan *et al*., 2021). While potentially contaminating water bodies with the coronavirus when these PPE waste serve as hosting medium for microbes and viruses (Tran *et al*., 2021), the leaching of the pollutants during the waste degradation may further exacerbated the ecotoxicological effects along the trophic levels from the aquatic to terrestrial ecosystem (Kim *et al*., 2021).

Despite the negative effects of household effluents and poor management of PPE on the water quality, reductions in anthropogenic activities in the industrial, tourism, and fisheries sectors were observed to have positive effects on the aquatic environment (Ormaza-Gonzaìlez *et al*., 2021). The COVID-19 pandemic and subsequent lockdowns led to a decrease in industrial activities, resulting in the reduction of industrial wastes such as organic matter, chemical pollutants and heavy metal discharge into the water bodies (Das *et al*., 2021; Jawad-Ul-Haque *et al*., 2023). It is evident that the reduction of discharged industrial effluents during the lockdown of less than 6-months interval, resulted in significant improvements in the water quality of the world's most polluted river, the Ganges River, and its tributary, the Yamuna River (CPCB, 2020; Das, 2021; UPPCB, 2020; Yashvardhini *et al*., 2021). The water quality of Kartova river in Bangladesh had improved by 59-62% during lockdown (Jawad-Ul-Haque *et al*., 2023), while most rivers and tributaries in India exhibited increase of 30% in their water quality levels (Patel *et al*., 2022; Chakraborty *et al*., 2021). Lockdowns also drastically impacted the operation of many industrial activities which consequently stopped the release of excessive nutrients and heavy metal into water bodies in Bangladesh (Jawad-Ul-Haque *et al*., 2023), India (Patel *et al*., 2020; Selvam *et al*., 2020; Chakraborty *et al*., 2021; Singh *et al*., 2022), and Malaysia (Akhtar *et al*., 2022). The restricted human activities in many urban areas in the IOR resulted in reduced industrial pollutants and organic matter in the water sources, which helped to reduce pathogenic bacterial (*Escherichia coli* and *Vibrio* sp.) count and retard the eutrophication process which deteriorate water quality and deplete dissolved oxygen in the aquatic ecosystem (Li *et al*., 2017; Zhang *et al*., 2021; Karunanidhi *et al*., 2021; Panja *et al*., 2022; Sahoo *et al*., 2022).

During lockdown, the aquatic ecosystem in the IOR also underwent a temporary "recovery" period (Ormaza-Gonzaìlez *et al*., 2021). The short-term suspension of non-essential business such as tourism and fisheries during lockdown provided an improved water quality and rejuvenation opportunity for the aquatic organisms (Somchuea *et al*., 2022; Sarkar *et al*., 2021). Indeed, reduced noise and light pollution, as well as fishing pressure, accelerated the recovery of aquatic resources and population stocks such as fish, whales, and sea turtles (GeoNoise, 2020; Lombrana, 2020; Mantur, 2020; Khan *et al*., 2020). Dolphins and sea turtles were discovered around coastal area in Cox's Bazar beach and Saint Martin island, Bangladesh, indicating that the improvement of water quality index and reduced anthropogenic interruptions invited these ecologically sensitive organisms to their nesting or "playing" grounds (Rahman *et al*., 2021).

10.4 Conclusion and recommendations

The majority of published research (489 articles) was devoted to two topics: implementation of containment measures and social-environmental impacts. From cluster analysis, COVID-19 pandemic had caused a bidirectional effect to the aquatic environment: 1) reduced human

intervention, which resulted in less harmful pollutants being released, and ii) mismanagement of PPE waste induced white pollution. Lockdown and other containment strategies for the COVID-19 pandemic provided aquatic environments with a "recovery gap" from the adverse effects of anthropogenic activities including the discharge of industrial effluents and untreated wastewater. By knowing the impacts of the COVID-19 pandemic on the aquatic environment, sustainable management systems could be developed by researchers, government and relevant stakeholders.

Anthropogenic activities within industrial, tourism and households should be reassessed and revised to reduce their negative environmental impacts. Proper wastewater and effluent treatment process should be conducted prior to their release into water bodies. The emergence of white pollution as a result of excessive use of PPE should be eliminated by educating individuals on proper waste disposal or by inventing environmentally friendly materials as a substitute for dangerous substances used in the production of PPE and disinfectants. Governments across nations within the IOR should coordinate their efforts to raise public awareness about the importance of safe PPE waste disposal and to impose regulations and heavy penalties on any negligent industries that contribute to water or white pollution in the aquatic environment. Governments in the IOR should provide funding for the research and development of eco-friendly products and water pollution-reduction technology, as well as subsidise the industries that are involved in their productions. Environmentally friendly products are market-oriented items that cause minimum environmental damage, and their manufacture is associated with a product development process that is designed to consider environmental implications throughout the product's life cycle. Tourism and industrial activities could also be suspended for brief intervals by the local government in order to decrease human interference and permit the recovery of water quality and aquatic ecosystems. For example, tourism industries in Malaysia, are temporarily shut down for 3 months during monsoon season, where the closure time will be utilised for renovation and maintenance work. However, to compensate those involved in these industries during the temporary closure period, local governments could introduce incentives to venture into other businesses such as hand-craft or online business.

11.0 Impacts of COVID-19 on Aquatic Biodiversity and Ecosystem Health in IORA Region

11.1 Introduction

The Indian Ocean region (IOR) is a very diverse region situated between Africa, Asia and Australia. This area is home to various atolls, archipelagos, and islands, including Java, Madagascar, Sri Lanka Sumatra and smaller island groupings like the Comoros Islands, Maldives, and Seychelles. The Indian Ocean extends across 30% of the global ocean with nine marine ecosystems and about 34,986 species (Wafar *et al*., 2011). Marine ecosystems constitute rocky shores, sandy beaches, mudflats, seagrass beds, coral reefs, mangroves, estuaries and the open water. Coral reef ecosystems and mangroves occupy an area of approximately 200,000 km^2 and 40,000 km^2, respectively. Sandy and rocky beach ecosystems occupy around 3,000 km^2. The region has 246 major estuaries, as well as many small estuaries, coastal lagoons, and backwaters (Wafar *et al*., 2011).

Ecosystems are intricate systems made up of both living things and the physical environments they occupy, as well as the interactions that take place both within as well as between the two elements. Ecosystems provide crucial products and services for human survival such as cultural, material and regulatory services for the welfare and human well-being. Xu and Mage (2001) defined ecosystem health as the ability to realize the functions desired by society and maintain them over a long period of time. It integrates environmental conditions with the impacts of anthropogenic activities in habitat destruction, proportion of sedimentation, mobilisation of contaminants and climate change (IOC, 2007).

The IOR has a rich marine biodiversity, that peaks within the East Indies Triangle and levels down in East Africa (Alpers 2014). Marine biodiversity is affected by terrestrial anthropogenic activities such as changes in land use, altered hydrological patterns, and nutrient loading via sediment transport, runoff, and sediment reduction through rivers and natural oceanic occurrences including weather, tsunamis, wave patterns, and coastal and ocean (Ayyam *et al*., 2019).

Despite a massive amount of institutional efforts and expeditions to study the region, our understanding of its biodiversity is still incomplete, particularly in smaller taxa, the continental shelf and deep-sea ecosystems. This is due to inadequate human, institutional, and technical capabilities in some countries. Furthermore, habitat loss, uncontrolled developmental activities, overexploitation, and pollution pose threats to the region's biota, especially in countries with weak environmental regulations.

The majority of countries in the IOR have high population densities and high poverty rates. Over 50 % of people living in the Indian Ocean rim reside within 100 km of the coast. Poor management of limited resources in overpopulated coastal regions is likely to lead to significant negative repercussions on the marine ecosystem. Anthropogenic impacts on the oceans are extensive, with 87-90 % of the world’s ocean surface affected (Halpern *et al.*2015; Jones *et al.*2018). Since 1970, the number of marine fishes has decreased by 38%, and the size of some coastal marine habitats, like seagrass beds and mangroves ecosystems have shrunk by more than two-thirds.

11.2 Methodology

A desktop literature search was done through databases such as Google Scholar, Web of Science, and ResearchGate to retrieve peer-reviewed publications related to marine biodiversity, ecosystem health, COVID-19 impact, biodiversity challenges, and marine ecosystem services broadly, in the IORA region.

11.3 Results

11.3.1 Marine Ecosystem goods and services

Coastal ecosystems provide services such as tourism, building materials, fisheries, medicine, and protection from storm waves and coastal erosion, regulation services and cultural services (Harvey *et al*., 2017: Pondolf *et al*., 2011; Kuok & Tong, 2020). Seafood, such as crustaceans, molluscs and fish are important sources of protein to human beings. Around 20% of the average person's animal protein consumption worldwide comes from fish (FAO, 2010), the percentage being higher in many underdeveloped nations. Almost 20% of the world's demand for tuna, amounting to approximately USD 6.5 billion daily, is from the Indian Ocean. In 2010, 11.3 million tons of fish, roughly 14.6% of the global catch, were produced by marine capture fisheries in the Indian Ocean (FAO, 2010). For many of the coastal states around the world, the fisheries that produce this catch are a significant source of employment. Small-scale fishermen capture a significant share of the global catch. This has improved the lives of coastal communities and people working in fish related industries. Oceans are crucial for maintaining the hydrological and climatic balances of the world on a broader scale. Through the biological process of ocean photosynthetic pump, which removes the atmospheric GHG (CO_2), the ocean helps regulate the Earth's temperature. Coral reefs provide ecosystem services valued at hundreds of billion dollars annually (Costanza *et al*., 2014: Fisher *et al*., 2015; Rodgers at al., 2015) or about USD 350,000 annually per hectare of coral reef (De Groot *et al*., 2012).

Coastal wetlands include saltmarshes, mudflats, estuaries, freshwater tidal wetlands, coastal peatlands, high intertidal forested and scrub wetlands and mangroves. They are sinks for carbon dioxide (CO_2) from the atmosphere by the standing biomass and 1% root and rhizome organic matter in sediments. Mangroves are important components of nutrient, carbon, water and oxygen cycles, and provide fibre, firewood, access to recreation habitats, shoreline protection and water filtration (Lin *et al*., 2020; Xia *et al*., 2021). Build-up in soil surface with the rising sea level and burial of organic material beneath saturated soils gradually increase the carbon pool. Seagrass beds support significant sequestration of carbon in sediments, below ground biomass and within the surface, and water borne plants and animals (Duarte *et al*., 2017). Sediments below sea grass beds or mats hold up to 40% of carbon reflecting a significant role in climate protection. Carbon rich soils are deep, and may hold up to 65,000 tons C per km^2 for every meter depth of soil (Craft, 2007; Middleton *et al*., 2008). Mangroves are highly efficient carbon sinks and can store large amounts of carbon in their biomass and sediments thereby assisting with mitigating climate change (Alongi, 2014). In the Western Indian Ocean region, 14% of the gross marine product, or USD2.9 billion annually, is provided by carbon sequestration (WWF, 2017). Recently the economic value

of carbon sequestration has been recognized, and interest is growing in understanding these processes as the urgency of addressing climate change throughout the world grows.

Coral reefs, estuaries, lagoons, mangroves are some of the most biologically productive ecosystems on the planet. They provide a unique and diverse habitat for marine life, providing a vast array of biodiversity, including numerous rare and endangered species (Bryant *et al*., 1998). Some ecosystems, like reefs and mangroves, are breeding grounds and nurseries for marine organisms. The sandy beach ecosystems support a unique biodiversity. They provide habitat for certain species of vegetation, benthic fauna such as shellfish, decapods, worms and seabirds which are unique to the environment. They also serve as nesting and feeding grounds for migratory seabirds and sea turtles (Defeo *et al*., 2009; Hassan *et al.* (Eds.), 2005).

Sandy beaches are also one of the attractions for coastal tourism. They provide options for a variety of social and leisure activities, including walking, sports, access to the water, and sunbathing. In addition, beaches are beautiful locations that contribute significantly to the aesthetic attractiveness of coastal landscapes (Doody, 2013). The physical assets of the coastline and beaches as well as functional and healthy marine and coastal ecosystems are both crucial to tourism. Employment in this industry can be found in a variety of secondary businesses, including stores, restaurants, tour operators, and transportation, as well as establishments ranging from five-star resorts to budget hotels. In 2016 alone, 1.2 billion people were reported to have visited countries in the IOR. For many of these countries', growth is primarily driven by tourism especially for the SIDS like Seychelles where 70% of foreign currency earnings is from tourism (Andrew & Senaratne, 2019).

11.3.2 Challenges to biodiversity and ecosystem health

Overharvesting of marine resources

Most coral ecosystems in the Indian Ocean are threatened, ranging from critically endangered in the Islands, to vulnerable in the continental coastal countries as a result of fishing pressure (Obura *et al*., 2022. Several of the world's coral reefs are facing the serious issue of overfishing, which has led to the depletion of some reef fish populations (Sadovy, 2005; Berkes *et al*., 2006; Newton *et al*., 2007). Over-exploitation of herbivorous fish can lead to the proliferation of algae and a change in the dominance of the coral condition (Hoegh-Guldberg *et al*., 2007), and a collapse of the reef ecosystem that can significantly affect fisheries' earnings and food security for local communities (Payet *et al*., 2004). Regulations governing fisheries management need to be properly enforced to avert these problems.

Unsustainable fishing practices

The excessive use of destructive fishing methods such as trawling, use of dynamites, spears and seine nets has caused severe depletion of fish stocks and habitat destruction, preventing their recovery. Tanzania, for instance, has been heavily involved in dynamite fishing, killing all life stages of fish stocks and causing severe depletion (Liddick, 2014).

Sharks, rays, and chimaeras are highly vulnerable to the negative effects of overfishing and by-catch due to their slow growth, late maturation, and low reproduction rates. By-catch is a

significant issue in commercial fishing as well, with high levels of by-catch and discards in the industrial tuna fishery in Seychelles and industrial prawn trawling in Kenya (Payet *et al*., 2004). This has led to death of non-target species, reducing their numbers tremendously.

Habitat degradation and modification

Habitat loss and degradation brought about by human actions such as pollution, coastal expansion, and modifications of habitats are significant threats to biodiversity and ecosystem health. These actions can lead to smothering, microbiological contamination, sedimentation loading, and changes in water quality due to the addition of contaminants. In the end, habitat loss may result in an ecological shift where dominant species that provide structure, including corals, seagrasses, and mangroves, are replaced. This shift can cause a loss of biodiversity as habitat quality decreases, leading to a decrease in species richness and abundance in various marine ecosystems. In particular sediment loading can decrease the ability of reefs to recover after mass bleaching, therefore increasing coral mortality (Fabricius, 2005; Hoegh-Guldberg *et al*., 2007). Clearing mangroves to make room for structures, roads and mariculture farms is another form of habitat modification. In Malaysia, the clearance of mangroves has significantly weakened their ability to protect coastlines from climate change impacts and provide nurseries for juveniles of marine fauna communities. Similarly, in Indonesia, half a million hectares of mangrove cover were lost in the 1990s due to the expansion of brackish-water shrimp and fish farms (Ismail *et al*., 2018). The coastlines of Kenya, Tanzania, and Mozambique have also experienced notable losses of mangrove forests for decades due to unmonitored logging. The destruction and alteration of structurally complex habitats have resulted in loss of marine biodiversity in IORA countries and elsewhere. For instance, sand mining for construction from coastal sandy beaches interferes with the coastal communities and the biodiversity and other ecosystem functions (Doody, 2013).

Pollution

Pollution of marine environments occurs mainly through domestic sewage, agricultural runoff, and industrial effluents. Excess nutrients from sewage and runoff cause eutrophication and hypoxia, leading to the death of marine flora and fauna. Industrial pollutants have a direct harmful effect, impairing metabolism and increasing death of marine animals (Gray, 2002). Since 1960, the number of eutrophication-related dead zones has been growing dramatically, and the IOR now has roughly 10 such zones (Thrush *et al*., 2006).

Climate Change

The ocean absorbs about a third of carbon emissions from the atmosphere (Dlugonkeneky & Tans, 2017). The introduction of GHGs by humans is causing climate change, which poses a serious threat to marine flora and fauna abundance and diversity. Increased carbon emissions have lowered ocean pH by 0.1 unit causing ocean acidification, and it is predicted to decline further by 0.3-0.4 by 2100 (Feely *et al*., 2009). The high levels of atmospheric CO_2 have led to higher atmospheric and sea surface temperatures. According to the IPCC Fourth Assessment Report, the effects of global warming on coasts are negative and certain to be overwhelming. These impacts include sea level rise, flooding, erosion, and ecosystem loss. Extreme events like storm surges, hurricanes, cyclones, irregular rainfall patterns, and ocean acidification make coasts highly vulnerable and negatively impacting the biota. Coastal erosion removes beach areas and protective barrier islands,

interferes with near shore currents, and changes drainage and irrigation patterns, which redirect the movement of sediment and nutrients into coastal waters.

Climate change's effects on coral reefs is a significant threat due to their sensitivity to changes in ocean temperature and acidity (Rodgers *et al*., 2015: Spalding & Brown 2015). Even small temperature increases above the average can lead to stress and eventually death of corals. Coral cover has already declined globally due to repetitive occurrences of mass coral bleaching, which is expected to continue as ocean temperatures rise further (Hoegh-Guldberg, 2007). It is predicted that by 2050 coral reefs will erode faster than they can build causing net reef dissolution (Silvermar *et al*., 2009).

The major factors that cause degradation and loss of seagrass beds are sediment or nutrient inflows, while impacts of climate change like rising sea levels, warmer coastal waters, and extreme weather like storms can make these stresses worse.

It is expected that, in a business as usual scenario, by 2150, 90% of the coastline will have been impacted by development, and 2-5% of coastal wetlands will be lost to rising sea level by 2080s (Saunders *et al*., 2013). With no interventions to stem the loss, by 2100, coastal wetlands will decline to narrow strips, or be completely lost globally (IPCC Climate Change, 2013) exposing coastal communities and livelihoods to the dangers of marine hazards and losing carbon dioxide sequesters like mangrove and seagrass ecosystems. Furthermore, low resource capacity and lack of awareness of monetary worth and significance of sea grasses are impeding conservation levels.

Sea level rise and climate change are likely to result in accretion, migration inland or habitat loss in coastal wetlands and mangroves. Up to a certain point, mangroves may adapt to changes in sea level by vertically accreting silt. Nonetheless, habitat loss may occur in areas where sea level rise is greater than the rate of accretion. The distribution, composition, and structure of the forest community may alter as a result of adaptations by various constituent species (Pallewatta, 2010). Warmer temperatures have increased the threat to Asian wetlands in recent years. Wetlands in major delta regions of Bangladesh, Pakistan, China, and India have dried up, severely degrading their ecosystems as a result of droughts and decreased precipitation. The mangrove forests in the Indus Delta and Bangladesh which were about one-third of all mangroves worldwide have disappeared over the past 50 years as a result of human activity. By 2025, it is predicted that mangroves would continue to decline in developing nations by another 25%, with significant nations like Indonesia expected to lose up to 90% or more of their mangroves in some regions (Pallewatta, 2010) seriously affected by reduced freshwater flows and saltwater intrusion.

Impact of COVID-19 on aquatic biodiversity and ecosystem health

The COVID-19 lockdown resulted in a decrease in fishing effort and fishing-related employment in the IORA region (UN-FAO, 2020). This reduced activity led to many species, both terrestrial and aquatic, returning to their natural habitats, enjoying the reduction in noise and water pollution. The significant decrease in fishing effort during the pandemic caused a substantial decline in fishing mortality, though temporary, providing a positive impact on recruitment success, particularly for species with short life spans and fast growth rates (Thakur *et al*., 2021). The reduced fishing pressure had a positive impact on the biodiversity of marine ecosystems.

In the Maldives, absence of tourists' activities led to an increase in sharks, dolphins, baleen whales, manatees, and toothed whales' populations (Green *et al*., 2020). Other important wildlife sightings reported included seabirds and shorebirds, elasmobranchs, marine turtles, and invertebrates. However, reduced tourism and diving activities in the coral reefs led to decreased coral reef monitoring and conservation efforts (IUCN, 2020).

Reduction in activities led to improved water quality in the oceans, rivers and other water bodies, due to a decrease in the entry of hazardous and chemicals as a result of closure of industries and reduced transportation, that led to decreased input in nutrients, waste water, crude oil, heavy metals and plastics (Hader, 2020; Yunus *et al*., 2020; Dey *et al*., 2020).

Reduction in ocean activities such as oil and gas exploration and exploitation, and cruise ships reduced the ocean noise pollution tremendously and helped lower stress levels in certain marine organisms, especially the whales (Rolland *et al*., 2012) and reduced deaths of marine organisms normally caused by collision with boats (FWC, 2020).

There was, however, an increase in marine debris resulting from increased use of PPE, such as protective suits, gloves, masks, sanitiser bottles, etc. (Chakraborty *et al*., 2020; Sing *et al*., 2020; Ashraf *et al*., 2021) that were observed along the beaches in many developing and developed countries, such as Bangladesh, India and Italy (Yunus *et al*., 2020; Cocca *et al*., 2021).

11.4 Conclusions and recommendations

The lockdown demonstrates that through reducing human activities that interfere with ecosystems, organisms can reclaim their habitats and spaces. It is possible to make preliminary reflections, even though research findings and thorough direct and indirect socioeconomic impact measurements and ecological repercussions have not yet been presented.

1. It is evident that the environment can quickly respond to reduced interference as was observed within the first months of the pandemic; there was a positive response to global reduction in human activities by both terrestrial and aquatic creatures.

2. To have a significant impact on nature, significant reductions in pollution and human movement in identified important ecosystem areas (e.g., marine protected areas) would be required. This is not achievable if we continue to violate the set policies and guidelines. Therefore, strict observance and compliance of regulations is necessary to achieve biodiversity conservation and environmental health.

3. The response to COVID-19 at individual level demonstrated the power of behavioural change in achieving communal good through national social education programmes. IORA states need to invest in adult education in order to improve biodiversity conservation and environmental health.

4. The pandemic's impacts on societies and economies reinforced the need to acknowledge how closely connected and reliant healthy ecological systems are to the success of human activities. Reduced human activity can have significant negative social and economic effects if it is abrupt, severe, and unplanned since it can seriously disrupt existing value chains and leave people without

other options. Future planning should take into consideration potential pandemic events to reduce negative social and economic impacts.

The interdependencies between anthropogenic impacts and the natural world must consequently be understood, acknowledged, and communicated to achieve SDGs (Griggs *et al.*2013, UN 2016).

IORA states should adopt (NBS) for climate change mitigation, biodiversity conservation and maintenance of a healthy ecosystem by establishing, restoring and protecting marine environments through the following:

i. Establishing and maintaining Marine Protected Areas;
ii. Restoring and protecting coastal and marine ecosystem including mangroves, seagrass beds and coral reefs, etc;
iii. Cultivating macroalgae for carbon dioxide sequestration;
iv. Education (at all levels) and community involvement in environmental conservation projects;
v. Collection and curation of environmental data by both researchers and communities (citizen science) and making the data available for societal benefit/use;
vi. Development of environmental protection and conservation policies and ensuring compliance of the already existing ones;
vii. Financial investment in environmental protection and conservation.

12.0 Impact of COVID-19 and Climate Change on Mangrove Ecosystems

12.1 Introduction

Mangrove ecosystems play a major role in the provision of goods and services to humans and for marine biodiversity. Mangroves are rated as the most carbon rich forests in the tropics, storing an estimated 1,023 Mg carbon ha^{-1} (Donato *et al*., 2011). World mangroves occur in sheltered tropical and subtropical coastlines in 118 countries and territories (Giri *et al*., 2011). Bunting *et al.* (2018) reported a global mangrove cover of 137,600 km^2, with the highest proportion of 53,278 km^2 (38.7%) of the global total being in Asia. However, mangrove cover loss has been on the increase with global cover loss estimates of 35% by the end of the 1990s (Valiela *et al*., 2001). Bhowmik *et al.* (2020) reported a decline of world mangrove coverage of 8,600 km^2 (1990-2020), with 3,870 km^2 decline occurring in South and Southeast Asia. Eleven mangrove species were identified as threatened, of which *Sonneratia griffithii* and *Bruguiera hainesii* were reported as critically endangered species.

Mangrove loss has mostly been attributed to human activities and natural losses (Lagomasino *et al*., 2020). An interaction between natural and anthropogenic drivers has been reported where aquaculture and agriculture were ranked as the major drivers of global mangrove deforestation and climate change through rise in sea-level, changes in precipitation patterns, increase in temperatures, coastline erosion, salinity intrusion and acidity ranked as the second major group of drivers (Bhowmik *et al*., 2022). Indonesia and Thailand have been reported as mangrove forest loss hotspots as a result of conversion to aquaculture and agriculture despite some areas being partially or fully designated as protected (Hagger *et al*., 2022). In India seismic activities, climate change, land reclamation, agricultural activities and pollution have been identified as important causes of mangrove deforestation (Chakraborty *et al*., 2020). Loss of mangroves contributes to more carbon dioxide emissions to the atmosphere, loss of carbon stocks, in addition to loss of biodiversity and associated benefits. As the world continues to experience varied effects of climate change and due to their role in carbon removal from the atmosphere, mangrove ecosystems are receiving increased attention in terms of conservation as they stand out as a significant blue carbon storage ecosystem. Lagomasino *et al.* (2020) notes that loss of mangroves from anthropogenic activities declined from 2000-2016 resulting from increased awareness for conservation and lack of mangrove forests for further conversion. Richards *et al.* (2020) reports an increase in mangrove forestation between 1996 -2016 translating to a carbon storage of 118.2 Mt. The objective of this study was to (1) investigate how climate change and the COVID-19 pandemic have affected mangrove ecosystems and biodiversity in the IORA countries, (2) carry out a policy mapping to establish the gaps in policy and legal frameworks on mangrove conservation, and (3) establish and give recommendations that can be adopted by IORA countries for a blue/green recovery.

12.2 Methodology

A desktop literature search for information and metadata such as, published papers, annual reports and any other relevant data was analysed, sorted and compiled to have the most inclusive and

relevant information for the region on: mangroves ecosystems cover and loss in the IORA, impacts of COVID-19 and climate change on mangroves in the IORA, mapping for policy and legal frameworks for countries in the IORA, potential for NBS, and the role of blue carbon ecosystems for economic and green recovery.

12.3 Results

12.3.1 Status of mangrove ecosystems in the IORA region

Countries within the Indian Ocean basin account for 50% (~76,275 km^2) of the world's mangroves (Andrew *et al*., 2019). Indonesia, Malaysia, Bangladesh and India have been listed among the top ten countries with high mangrove extents of 26,890 km^2 (19.5%), 5,201 km^2 (3.8), 4,163 km^2 (3.0%) and 3,521 km^2 (2.6%) of global percentage respectively (Bunting *et al*., 2018). However, increases and decreases in mangrove cover has been reported in the Indo-Malayan countries (DasGupta & Shaw, 2013). Bangladesh mangroves are one of the richest in the world it terms of species richness and contribute 41% of the country's total revenue, and ~600,000 people's livelihoods are directly or indirectly dependent on the mangroves. In addition, 45 % of timber and fuel wood is derived from mangroves and is a habitat to many species of mammals (45%), birds (42%), reptiles (46%) and amphibians (36%) representing a large proportion of the country's biodiversity (Hoque & Datta, 2005). Malaysia has a mangrove cover of 627,567 ha of mangroves in 2017, a decrease from 648,984 ha in 1990 representing an average rate of mangrove deforestation of 793 ha yr^{-1} or a 0.13% annual loss (Omar *et al*., 2018). The Western Indian Ocean Region has a mangrove cover of ~6,200 km^2 (620,000 ha) representing a 4.1 % of world's mangrove area of which the largest cover is found in Mozambique (3,054 km^2) followed by Madagascar (2,059 km^2) (Fatoyinbo & Simard 2013). Mangroves in Kenya cover an area of 61,271 ha (GoK, 2017). There are variations on mangrove loss in Kenya with some areas reporting an increase in net mangrove loss and others a decrease (Hamza *et al*., 2022).

12.3.2 Impact of climate change on mangrove communities and biodiversity in the IORA

Sea level rise is reported to be the greatest threat to mangroves from climate change, especially for mangroves in area where elevation of mangrove sediments accretion does not match sea level rise (Gilman *et al*., 2008). Indonesia and India are projected to experience mangrove loss in river deltas due to low tidal ranges, subsidence, and lack of accommodation space, whereas an expansion of mangroves is likely to occur in Malaysia and Thailand (Alongi, 2022).

Bangladesh is experiencing adverse effects of climate change through sea level rise, droughts, floods, cyclones, land erosion, salinity intrusion and epidemic disease. It is also prawn to cyclones of which 93 major disasters were reported between 1991 and 2000 causing high fatalities and socio-economic effects that lead to unsustainable livelihoods and social tension. The Sundarban shared between Bangladesh (60%) and India (40%) constitutes various species of vascular plants (350), fishes (250) and birds (300), in addition to many planktons, microorganisms, benthic invertebrates, reptiles, amphibians and mammals (Gopal & Chauhan, 2006).

Mangroves in Bangladesh Sundarbans are threatened by sea water intrusion through sea level rise from climate change which puts the rich mangrove biodiversity at risk including *Panthera tigris*

the only tiger population in the world, that exclusively lives and is adapted to the mangrove ecosystem (Loucks *et al*., 2010; Asiz & Paul 2015). The Sundarban mangroves are also threatened by overexploitation and over dependence on the resource (Das, 2022).

In Malaysia mangrove ecosystems support high biodiversity and are home to endemic marine species estimated at 20% of the world's animal species (CBD, 2019). A loss of 22% of mangroves has been projected from a 1m rise in sea level in Pantai Acheh, Penang (a low-lying coastal zone) which will also lead to groundwater salinization affecting water supply for domestic use and crop cultivation which may jeopardise the achievement of SDGs 2 and 6 (Kh'ng *et al*., 2021).

In Kenya, a mangrove dieback was reported during the 1997/8 El Niño phenomenon due to sedimentation and prolonged flooding from abnormally heavy rainfall (GoK, 2017). Mangroves in Lamu and Kwale continue to record net loss in mangrove cover, more so in areas exposed to coastal hazards (Hamza *et al*., 2022). Between 1990 and 2019 a total of 1,739 ha of mangroves were lost due to anthropogenic activities. This translates to 140.1 Mg C ha^{-1}; 30,840.1 Mg CO_2e yr^{-1} carbon emissions (Kairo *et al*., 2021). Sea level rise, salt water intrusion, flooding and sedimentation are other major threats (GoK, 2017).

12.3.3 Policy mapping

In regard to legislative aspects of mangrove conservation, most of the countries in the Indo - Malayan region of the IORA appear to have a substantive legal framework for mangrove forest conservation (Table 12.1). However, Thailand, Malaysia and Indonesia lack specific legislative policies to address certain aspects of mangrove conservation and management (DasGupta & Shaw, 2013). Kenya on the other hand has legal frameworks and policies in place to address the issues on mangrove conservation and management as documented in the National Mangrove Management Plan as shown in Table 12.2. Challenges appear to be in the implementation of the policies and law enforcement to curb mangrove loss (GoK, 2017).

DasGupta & Shaw (2013) pointed out a deficiency in the existing legal framework and recommended the strengthening of the existing legislative framework. Identified gaps include; a) The lack of legal sanctity of Community Based Mangrove Management (CBMM) and when communities are involved, they take up a secondary role; b) Existing legislation on mangroves is not well developed and is contradictory (one side is promoting conservation while the other is doing the contrary; c) Poor policy implementation and monitoring in all South and Southeast Asia countries; d) Lack of suitable legislation to control shrimp farming that is a major contributor of mangrove loss through conversion of virgin mangrove land to shrimp farming especially in Indonesia, Thailand and Malaysia; e) Deficiency in the implementation on legislature for coastal zoning despite the existence of policies on coastal zoning and integrated coastal zone management; f) Lack of coordination of mangrove management activities among government agencies and departments; g) Low success rates of restoration efforts due to lack of knowledge among government officials in species and site selection; h) Lack of sustainable economic development of coastal areas; and i) Lack of strong regional transboundary management of shared mangrove ecosystems.

Bhowmik *et al.* (2022) indicated that governments of Indonesia, Malaysia and Bangladesh need to put in place strong monitoring and conservation measures to curb any further mangrove loss.

The gazetting of the remaining state land forest as Permanent Reserved Forests (PRFs) has been recommended as the most effective way of conserving mangroves in Malaysia; it is recommended that any social-economic developments in PRFs should be prohibited or implemented with serious caution (Omar *et al*., 2018).

12.3.4 Effect of COVID- 19 pandemic on mangrove ecosystems and biodiversity in the IORA

Bertucci *et al.* (2023) reported higher densities of juvenile and adult fish in bare and mangrove ecosystems in French Polynesia during the first COVID-19 lockdown (May 2020) in comparison to April 2019 and the numbers were still high two months after the end of the lock down (July 2020). A decline in tourism activities in the Indian Sundarban recorded a positive impact on the mangrove faunal biodiversity. In addition, restriction of anthropogenic activities also positively impacted the environment of the Indian Sundarban region (Chaudhuri & Bhattacharyya, 2021). Transmigration of the workforce from other states created employment problems as other workers could not obtain transport to urban areas which negatively created a strain on the Sundarban Biosphere Reserve area which resulted in an increase in illegal activities. This also caused an increase in COVID-19 infections and pollution from solid waste PPE. Negative COVID-19 impacts (overexploitation, deforestation, and degradation of natural resources) were reported for the Sundarbans mangroves which increased because of lower surveillance during the pandemic, more so during the lockdown (Roy *et al*., 2022).

In Bangladesh ~222 ha of mangrove forest was cleared between January and October 2020 which was 8% higher than that reported for the whole of 2019. Despite reports of free movement of wildlife due to decreased tourism, 112 animals were killed, 28 times more than 2019 (Rahman *et al*., 2021).

Bangladesh and India reported an increase in illegal activities in the mangrove forests, overexploitation, deforestation and degradation of mangroves in addition to increased unemployment, a decline in tourism and surveillance; in India a positive impact was reported on faunal diversity (Chaudhuri & Bhattacharyya, 2021; Roy *et al*., 2022). In Kenya there was a decline in surveillance activities in mangrove areas and an increase in sea turtle deaths, whereas unemployment increased during the COVID-19 pandemic (Okuku *et al*., 2021; Lau *et al*., 2021; Makre & Katana, 2022). Only in Malaysia did forest vegetation cover improve (Nordin *et al*., 2022). It is thus evident that negative impacts from COVID-19 outweigh the positive impacts.

12.3.5 Nature-Based solutions (NBS) for a greener recovery in IORA Member States

The impacts of Covid-19 and climate change are evident on mangrove ecosystems in IORA countries. It is thus important to identify solutions geared towards easing the impacts and provide a blue-green recovery of the member states. NBS have been advocated for and received a lot of interest recently as providing solutions to challenges of climate change and biodiversity loss, while supporting sustainable development. However, the implementation pathways are still not clear (Sowińska-Świerkos & Garcia, 2022; Seddon *et al*., 2022). For example, tree planting for carbon sequestration is being promoted as a NBS to mitigate against the adverse effect of climate change, however, there is a feeling that it is casting a shadow on the need to focus on phasing out the use of fossil fuels and protecting existing functional ecosystems. It is also seen to promote forestry at

the expense of other carbon rich ecosystems and local community resource rights (Seddon *et al*., 2022).

Despite the contentious issues, Kenya, Bangladesh, India and Madagascar have rolled out successful blue carbon projects that offer climate change mitigation services through carbon sequestration, conservation of biodiversity and improving the livelihoods of coastal communities (Wylie *et al*., 2016). Kenya is implementing two projects in Vanga (South coast) and Mtwapa (North coast). India Sundarbans Mangrove Restoration Project (in India and Bangladesh) has also been successful despite some challenges with benefits to the community and the environment with CO_2 sequestration rate exceeding what was projected. Studies have shown that coastal ecosystems despite having a global coverage of 2%, have a huge potential for carbon sequestration, rated at ten times more on both per area basis per year than boreal, temperate, or tropical forest combined and store ~223 T g Cy^{-1} of global carbon burial (McLeod *et al*., 2011). Maintenance and protection of these ecosystems is neutral in terms of carbon valuation, whereas restoration of degraded ecosystems has a positive effect as opposed to degradation or destruction of habitats (Hilmi *et al*., 2021).

While analysing 229 NBS in Malaysia, Chee *et al*., (2020) observed that some efforts achieved their anticipated outcomes, while others were faced with challenges such as, communication, institutional uniformity, community engagement, partnerships and collaborations, knowledge, funding, and management, which in part or collectively, affected the actual outcomes of each effort. Wylie *et al.* (2016) proposes actions that can be taken up to ensure the success of current and proposed carbon projects.

For NBS to provide sustainable benefits and offer solutions to societal, environmental and biodiversity challenges, Seddon *et al.* (2022) proposed four guiding principles that policymakers, practitioners and researchers can apply. They include, 1) recognition that NBS cannot substitute the need to phase out of fossil fuels; 2) NBS are comprised of varied ecosystems on land and in the sea and not exclusively forest; 3) NBS are implemented with the full engagement and consent of Indigenous Peoples and local communities and respects for their cultural and ecological rights is key in the implementation of NBS; and 4) NBS should be designed in such a way that they provide measurable benefits for biodiversity.

To enhance the uptake of NBS globally, improving the evidence base and informing adaptive management, Chee *et al.* (2020) proposes key action points, including increasing education, training, and knowledge sharing; rationalising cooperation across jurisdictions, laws, and regulations; enhancing environmental monitoring; leveraging on existing policies; enabling collaboration and communication; and implementing sustainable finance instruments.

12.4 Conclusion and recommendations

Despite their importance, the world mangroves continue to decline and more so in IORA states threatening humans, the environment and biodiversity. These ecosystems are impacted by socio factors of disease outbreaks which further exerts more pressure on them. Understanding the socio-economic impacts of anthropogenic, climate change and COVID-19 pandemic will help to design

and implement NBS that are geared towards a blue/green recovery and ensure sustainable utilisation of blue carbon ecosystem resources and at the same time improve the livelihoods of coastal communities, achieve biodiversity conservation, and mitigate against climate change impacts. We observe that anthropogenic activities and climate change remain the major threats to mangrove ecosystems and the recent COVID- 19 pandemic escalated mangrove degradation even further. It is evident that blue carbon projects, though faced with challenges, have accrued benefits by achieving mangrove forest conservation, restoration, as well as improving the livelihoods of local communities, in addition to climate change mitigation, and still remain a good choice for a blue/green recovery post COVID-19. However, lack of effective legal frameworks and policies, and stringent implementation and enforcement strategies for the existing policies, continues to impede the already implemented projects and negatively impacts the designing and implementation of additional blue carbon projects, further derailing the realization of the full potential of blue carbon ecosystems in the IORA. IORA member states need to strengthen their collaboration as they relook, re-strategize and devise ways of addressing these challenges owing to the vast coverage of mangrove ecosystems in the region and their potential for CO_2 sequestration and climate change mitigation.

Recommendations for IORA member states

To achieve a blue/green recovery from impacts of COVID-19 pandemic and climate change we recommend the following:

a) Preservation and restoration of carbon sequestering ecosystems

The first line of action to a blue/green recovery process is preservation of existing healthy and restored ecosystems (mangroves, seagrasses and salt marshes) through formulation of new policies, and implementation and enforcement of existing policies and relevant legislation, in the conservation and management of these ecosystems. Avoiding further degradation will cut CO_2 emissions from the buried pool. Preservation, restoration and conservation of blue carbon ecosystems will also create more opportunities for the blue economy. Gazettement of remaining state land forests as PRFs will strongly help implement this recommendation.

b) Implementation of blue carbon projects

This is a NBS that can help achieve the preservation of both healthy and restored mangrove ecosystems, in addition to restoring degraded mangrove ecosystems through reforestation. The positive outcomes of these projects are evidence that these projects can navigate through challenges and achieve their objectives.

c) Creation of strong policies and legal frameworks for conservation of blue carbon ecosystems

There is a deficiency within the IORA countries for relevant policies and legal frameworks to enact strong monitoring and conservation measures. There is the need to strengthen existing legal frameworks and policies and formulate new ones to address major challenges facing blue carbon ecosystems. Lack of clear legal frameworks, waters down any conservation efforts and also contributes in the loss of any accrued gains. Though most projects have made efforts for inclusivity, there is need to strengthen policies and legal frameworks that ensure inclusion and

active participation of the local community as stakeholders. Training the community also ensures acceptance and sustainability of the projects.

Table 12.1: Comparative analysis of legislative aspects of mangrove conservation in select IORA countries *(modified from Das Gupta & Shaw, 2013)*

Legislative aspects of mangrove conservation							
Country	**Main governing department**	**In-situ conservation of natural resources**	**Community participation in mangrove management**	**Control of shrimp farming**	**Coastal zoning/integrated coastal zone management**	**Marine/coastal environmental protection**	**Legislative provisions of coastal greenbelt development**
India	Ministry of Environment and Forest	Forest Conservation Act, 1980 and Wildlife (Protection) Act, 1972	Joint Forest Management Initiatives adopted by National Forest Policy, 1988	Coastal Aquaculture Authority Act, 2005	CRZ Notification, 1991 (rev.2004) under the Environmental Protection Act of 1986	Environmental Protection Act, 1986, Water Prevention and Control of Pollution Act, 1974	No specific legislative arrangement
Bangladesh	Ministry of Environment and Forest	Forest Act, 1927 (Amendments in 1989)	Forest Policy, 1994 allowing community participation	Environmental Regulations, 1997	Coastal Zone Policy, 2005	Environmental Regulations, 1997	Coastal development strategy
Thailand	Royal Forestry Department and Ministry of Natural Resources and Environment	National Forest Reserves Act, 1964	Community Forestry Bill, 2007	No specific legislative arrangement	Land Development Act, 1983	Enhancement and Conservation of National Environment Quality Act, 1992	No specific legislative arrangement
Malaysia	Department of Forestry (Provincial Government)	National Forestry Act 1984 (revised 1993)	No specific legislative arrangement	No specific legislative arrangement	9th Malaysian Plan (2006–2010)	Environment Quality Act, 1974 and Merchant Shipping (Oil Pollution) Act of 1994	9th Malaysian Plan (2006–2010)
Indonesia	Ministry of Forestry	Presidential Decree 32 (1990)/Law no.5 (1990)	2004 amendments in Law no. 32/41	No specific legislative arrangement	Law no. 27 (2008)	Major Provisions in Law no. 32 (2009)	400 m greenbelt as per Decree no. H.1/4/2/18/1975

Table 12.2: Policy and legal framework for mangrove conservation and management in Kenya (GoK, 2017).

Legislative aspect of mangrove conservation	**Policy and Legal framework**
Main governing department	Kenya Forest Service (KFS) in partnership with Kenya Wildlife Service (KWS) in Marine Protected Areas (MPAs); Ecosystem Conservator (county)
In-situ conservation of forest resources	Constitution of Kenya Article 60 (1) (e); Article 69 (1); Forest Policy (2014); Forest Conservation & Management Act (2016); Kenya Forest Service (KFS) Strategic Plan (2014/2017); Vision 2030; National Climate Change Response Strategy (NCCRS)
Community participation in mangrove management	Environmental Management & Coordination Act (EMCA) of 1999; Participatory Forest Management Plan (PFMP); Community Forest Association (CFA)
Control of industrial developments and other conversions	Article 11(1) of Land Act (2012); County Governments Act, 2012; Coast Development Authority (CDA) Act, Cap 449; Physical planning Act of 2012, Cap 286
Coastal zoning/integrated coastal zone management	Proclamation No. 44 of 30th April 1932, Legal Notice No. 174 of 20th May 1964; Environmental Management and Coordination Act (EMCA) of 1999; Integrated Coastal Zone Management (ICZM) Policy and Action Plan
Marine/coastal environmental protection	Water Act, No. 8 of 2002

13.0 Summary, Conclusions and Recommendations

Air quality is closely linked to human health, especially respiratory diseases such as asthma, lung cancer, heart disease, etc. COVID-19 was also linked to air quality and respiratory diseases, especially pre-existing conditions such as asthma, lung cancer, and heart disease. Air quality is influenced by human activities such as energy generation, transportation, urbanisation, mining that emit pollutants such as particulate matter (PM), SO_2, CO, O_3, yet, in many IORA countries, many of these activities are not regulated in terms of emissions and policies touching on them are in passing. Regular monitoring of ambient air quality should be instituted in order to help curb air pollution from all sources of pollution in IORA countries and help reduce the disease burden, loss of life, loss of revenue and be on track in terms of the Paris Agreement in relation to climate change. Besides, through continued emissions and the related atmospheric warming, the world could end up with more pandemics in the future. We recommend that IORA countries should put in place policies that will ensure regulation of emissions by all activities, regular monitoring of air quality and education of the populace on the impacts of poor air quality on health, and atmospheric GHGs on climate change, and the individual and collective actions to help curb the emissions.

Many IORA countries use biomass (firewood, charcoal, coal) for heating and cooking and this is known to pollute the environment with fine particulate matter. Indoor air pollution has serious impacts on health (respiratory impacts) especially those exposed for longer periods of time. This study has not focussed on this aspect but it needs to be done in order to inform policy development.

In relation to socio-economic impacts of COVID-19 many countries were impacted by the disease to the extent that the healthcare facilities were overwhelmed at the beginning of the pandemic, while some countries took advantage of the opportunity to improve their health care facilities such as diagnostic laboratories, ICU and specialised wards for COVID patients' isolation facilities. Education was generally affected because of lack of infrastructure such as internet connectivity, hardware and software and trained capacity. Most countries in IORA started investing in internet connectivity and training staff for online delivery of education but also meetings and other businesses. IORA countries need to invest in the last mile internet connectivity in order to remain in business and curb losses in employment in future, and interference with education.

High economic losses occurred due to the high dependency on external sources for business such as tourism, export of garments and import of farm inputs. Policies to improve inter-border relationships between IORA countries to improve cross-border business and also improve on local markets and domestic tourism. Governments should have policies in place to support and cushion the vulnerable people in society in circumstances such as those observed during the COVID-19 pandemic through the provision of food and/or cash transfers, mental health support, and support for the youth and women.

Agriculture production and supply suffered in IORA states because of the dependence on external sources for inputs and markets, transport challenges and labour uncertainty during the COVID-19 pandemic. This led to shortages in some areas and oversupply in other areas and variations in

prices. Governments in IORA states should develop policies that will ensure future similar incidences do not lead to lack or loss of agricultural products by having proper storage facilities, ensure that supply chains for raw materials, labour and markets are not interrupted, but should remain open as much as possible. The encouragement of communities to start kitchen gardening for vegetables should be upheld as part of a long-term solution to food insecurity rather than a short-term solution.

In relation to consumption and production patterns, unsustainable consumption and production are the root causes of the triple planetary crises of climate change, biodiversity loss, and pollution. The COVID-19 pandemic and subsequent national lockdowns provided incentive for countries like Seychelles to open idle lands for home production and make use of idle members of the family to produce food for home consumption and curb food insecurity. Other areas of the economy that can be harnessed to promote sustainable consumption include waste management, through converting WTE, and transitioning from fossil fuel to green energy sources such as solar and hydropower where possible. Food wastage and loss of crop production can occur when supply chains are interrupted by whatever reason, as was demonstrated by COVID-19 pandemic. The longer the supply chains the higher the risk of losses. Therefore, IORA countries need to evaluate the supply chains for various commodities to ensure that losses will not be experienced in future unnecessarily, especially for perishable commodities such as food.

Energy generation in most IORA countries uses non-renewable energy sources even though the negative effects to human health and the environment are known. The ease of using fossil fuel and the investment required to develop and install RET has discouraged many IORA countries from expanding RE programmes, especially during the COVID-19 pandemic. Apart from Kenya, which was already on the path of RE development, most other countries, as demonstrated by Seychelles and Bangladesh, have the plans and the targets for RE set out but have not been able to achieve this. Some of the reasons identified for this failure are to do with policies that do not explicitly provide guidance on the process but also information on the financial requirements. Since RET requires more investment to develop and install compared to non-renewable energy, IORA governments must look beyond financial implications for RET, but also consider the human and environmental health that will be achieved, and the climate change impacts that will be resolved in the long term. Packaged in that manner, governments are likely to be convinced of the need to invest in RET.

The tourism industry was one of the worst hit businesses all over the world due to travel bans and it was even worse in the IORA countries that heavily depend on it, as reflected on in the reviews of Seychelles, Kenya and Bangladesh. The impact on tourism and employment was further exacerbated by the fact that even domestic tourism could not occur. That implies a lot of job losses and loss of livelihood because a lot of these employees do not have any savings as they have low pay. For countries like Seychelles, where most tourist facilities are owned by foreigners, impacts on the economy and on families was high. IORA governments need to come up with policies that can cushion employees during adverse times, such as compulsory saving of a certain portion of the salary that can be contributory by both employer and employee. There is also a need to diversify

sources of livelihood and employment not to focus too much on tourism, such as the case of Seychelles. Other forms of livelihoods that can be promoted include fishing and farming.

Solid waste management offers a good opportunity for a green recovery projects that countries in IORA can adopt. So far SWM is a sector that has many challenges in most IORA countries as is demonstrated by all three countries that were studied. Many of these countries did not have sanitary landfills or recycling plants and so waste was dumped in open landfills and still some of the waste was not collected at all and thus became a health hazard. Seychelles, which has a better organised collection system, still struggled with waste management during the first few months of the COVID-19 pandemic. The country plans to start a waste to energy project by 2025. Kenya, that has been able to convert bio-waste into biogas, has been unable to expand this to all parts of the country, citing policy issues that are discouraging investors. Thus, most waste is disposed of in open landfills and the rest is not collected at all. On the other hand, Bangladesh is set to start a WTE project by 2024. Waste management offers the best opportunity for green recovery projects that most IORA countries can adopt.

The COVID-19 pandemic and the lockdowns had a two-way impact on the aquatic environments (rivers and the oceans). The lockdowns, which slowed businesses including manufacturing and tourism, led to reduced effluents and thus improvement of the water quality in terms of water clarity and reduced chemical pollution, reduced noise and light. This resulted in improvement of fish stocks, more sightings of key aquatic fauna like whales and dolphins, etc. However, the use of PPE and the poor disposal of the waste led to their accumulation along the beaches and in the water bodies. This finding provides hope that with the right incentives for people to stop polluting the environment, it is possible to witness recovery of biodiversity and ecosystem health.

Coastal and marine ecosystems are important resources for IORA countries as they provide crucial resources for human well-being including material such as fish, for building, services such as carbon sequestration, tourism, culture and aesthetic. The ecosystems are however degraded because of the uncontrolled human activities, leading to loss of ecosystem integrity and biodiversity, climate change and poor productivity. The COVID-19 pandemic and lockdowns demonstrated that ecosystems can quickly respond to an improved environment, including recovery of biodiversity. Therefore, the IORA governments, working together with all stakeholders should endeavour to install mechanisms that will help recovery in all environments. The COVID-19 pandemic demonstrated the impact of human behavioural change in achieving a shared objective and the importance of information sharing, communication, and education to stakeholders to achieve the objective. If such a model would be used, then the degraded environments would be reversed in a very short period of time.

Mangrove forests are one of the ecosystems known to sequester and store large amounts of carbon both above and below ground. Yet, these ecosystems continue to be lost in many parts of the world due to climate change impacts, land conversion for shrimp farming and other economic developments. The IORA region hosts at least 50% of the world forest cover and therefore provides an opportunity for mangrove ecosystem rehabilitation for climate change mitigation and human well-being. In a few countries where mangrove ecosystems have been rehabilitated and protected for carbon sequestration, the results indicate success. For instance, in Kenya, mangrove forest

rehabilitation has successfully traded in the international carbon markets for the benefit of communities. Such projects should be increased in IORA countries for a green recovery.

Th green recovery model has been adopted to help in the countries' recovery from the economic impacts of COVID-19, without compromising on climate change goals but also embracing NBS to ensure biodiversity and ecosystem health are maintained. IORA countries have, however, not quite embraced the green recovery model yet. Apart from countries that already had plans to implement projects like green energy in Kenya, and WTE projects in Bangladesh and Seychelles, some of which stalled during the pandemic, no new projects were identified in the region. Instead, most countries sought a quick-fix economic recovery model through injecting funds to support vulnerable communities and struggling businesses to recover. The issue of climate change, biodiversity loss and pollution are still not a priority in the region. Therefore, for IORA countries to get back on track in terms of climate change mitigation and environmental conservation, the governments need to make deliberate efforts to identify suitable projects and pursue their implementation.

Those projects need to follow the model of NBS and sustainable consumption and production. IORA governments need to proactively identify and support such projects but also regulate the development of projects to ensure their compliance to the green recovery model. Greenhouse and toxic gases emissions as well as human health should be regularly monitored (Figure 13.1).

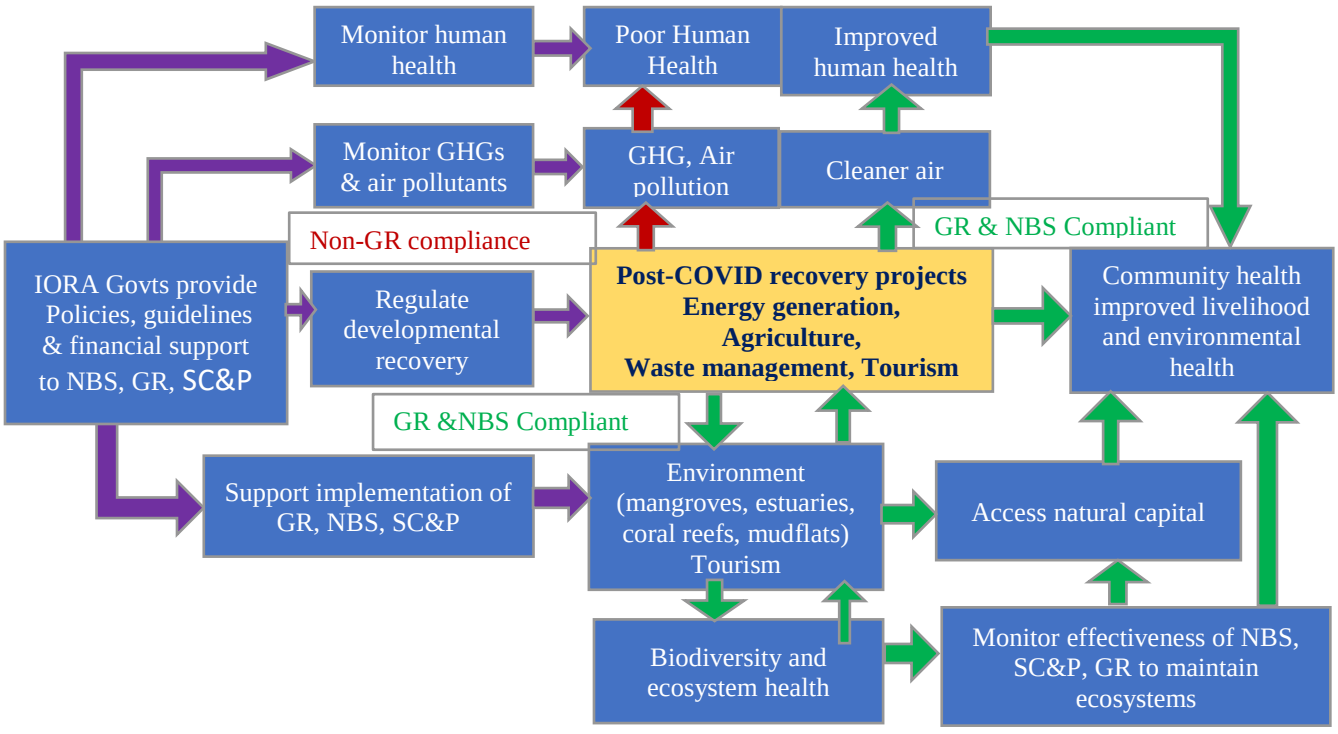

Figure 13.1: The role of IORA governments in the implementation of Post-COVID Green Recovery-NBS compliant projects and the impact on human and ecosystem health.

NBS can be applied in many sectors of the economy such as energy generation, waste management, tourism, agriculture, among others, to guarantee economic recovery, while at the same time promoting CO_2 removal, socio-economic growth, biodiversity protection and environmental health. Through the strategies of green recovery targeting and leveraging on SDG 12 on sustainable consumption and production, the IORA region will be able to recover economically without compromising climate change mitigation, the environment and the people.

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