Potential Impacts of Climate Change and Climate Variations on the Coastal Marine Fisheries of the South-West Indian Ocean Region

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Summary

Climate change poses a significant threat to global fisheries, with rising temperatures leading to the decline and disappearance of fish populations, particularly in tropical regions. Fish, a crucial protein source for 3.2 billion people, accounting for 17 per cent of the world's animal protein, is a lifeline for many developing countries, notably in the EA-SA-IO region, where fish contributes to 70 per cent of their nutritional needs. Despite the minimal contribution of these low-income and fragile nations to global CO_2 emissions, they confront existential threats.

Despite the commitments made during COP 21 - Paris Agreement on Climate Change in 2015, progress toward global decarbonisation and net-zero initiatives remains elusive. While the recent COP 28 in Dubai shows promises, several unresolved issues persist, putting the world towards a +2°C or worse scenario with potentially disastrous consequences, particularly for coastal and island states.

To counterbalance climate science's bleak outlook and uplift local fishing communities' spirits, ECOFISH actively facilitates proactive measures and no-regret policies to enhance their adaptive capacities and resilience. Against the backdrop of a comprehensive socio-economic assessment of the impacts of climate change and extreme weather variations on the coastal fisheries ecosystems, fish production, and the livelihoods and well-being of local fishing communities in the SWIO region, the programme aims to create a regional Fisheries – Climate Change Observatory. This scientific platform is comprised of the national maritime fisheries research institution led by the Mauritius Oceanography Institute. Instead of a one-size-fits-all approach, it aims to inform climate change adaptation, mitigation policies, and strategies within the local socio-ecological realities.

The platform will also help design projects eligible for the Green Climate Fund and other innovative financing mechanisms, such as Green and Blue Bonds. The challenges of climate change and environmental degradation are compounded in small-scale fisheries, predominantly subsistence and artisanal fishing operating in open–access and informal settings. The paper describes the potential climate risks for small-scale fisheries in the SWIO and the scope of adaptation measures and resilience-building. It also emphasises blue carbon projects and nature-based solutions that can generate new alternative sustainable employment opportunities in the local economies.

This paper details the potential climate risks small-scale fisheries face in the SWIO, highlighting the scope of adaptation measures and resilience-building efforts. Notably, it underscores the importance of blue carbon projects, nature-based solutions and resource mobilisation through innovative financing.

1.0 Introduction

Climate change is intensifying more rapidly than expected. The last five years have been the warmest on record; natural disasters are becoming more intense and frequent, while the previous years witnessed unprecedented extreme weather events worldwide. Alarmingly, *global temperatures are on track to increase by at least 3°C towards the end of the Century* – which is twice the limit to avoid the most severe economic, social, and environmental upends in the world's tropical regions. The near-term impacts of climate change will intensify the planetary emergencies, including loss of lives and livelihoods, extreme poverty, inequalities, and geopolitical instability. *Climate change mitigation and adaptation failure* is

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[2] *Based on the works carried out by ECOFISH, the technical paper contributes to the Region Multistakeholder Consultative Workshop for the official launching of a Fisheries-Climate Observatory for monitoring and anticipating the impact of global warming on the coastal ecosystems, fish production and the livelihoods and well-being of local fishing communities in SWIO countries" held in Mauritius on 6-7 February 2024.*

considered the No. 1 risk by impact and No. 2 by likelihood for the next 10 years[3]. Biodiversity loss has severe implications for humanity, from the collapse of functional services and health systems to the disruption of food webs. It is essential for maintaining human well-being, livelihoods, and wealth creation. The world's 7.6 billion people represent just 0.01% of all living creatures by weight, but humankind has caused the loss of 83% of all wild mammals and half of all plants. *Biodiversity loss and ecosystem collapse are among the top five global risks*. For example, clearing over 35% of the world's mangroves for human activities has exposed coastal people's habitats to risk from floods and rising sea levels. If today's mangroves were lost, 18 million more people would be flooded yearly (an increase of 39%), and annual damages to property would increase by 16% (US$ 82 billion). *Therefore, protecting and restoring natural ecosystems is vital to fighting climate change*. Nature-based solutions could provide 37% of the cost-effective CO_2 mitigation by 2030 to maintain global warming within 2°C[4].

Climate change threatens world fisheries. The significance of coastal fishing as "safety nets" for food and nutrition security and the livelihoods of local communities is high in Sub-Saharan Africa. As temperatures rise, fish populations will decline and disappear in some regions, especially in the Tropics. The challenges faced by the capture fisheries sub-sector are often underestimated or overlooked because researchers and policymakers tend to focus on agriculture as the primary source of food supply for the growing global population. However, *fish is an essential protein source for 3.2 billion people, providing 17 per cent of the world's animal protein*. It is a lifeline for many developing countries, including the Sub-Saharan African region, that rely on fish for 70 per cent of their nutrition. Improved fisheries management and setting aside climate-smart marine protected areas can provide a refuge for nurturing fragile fish stocks. A circular economy approach, i.e., the sustainable harvest and consumption of seafood, can increase the resilience of fish stocks. However, a drastic reduction of GHG emissions on a global scale must remain a top priority.

Various pathways and impacts of ocean warming and extreme weather events (EWE) on the coastal marine fisheries ecosystems are well-documented in existing scientific and peer-reviewed literature. These direct pathways include increased sea surface temperatures (SST), sea-level rise (SLR), change in rainfall patterns and intensification of tropical storms. The indirect drivers include ocean stratification and acidification changes in nutrients, currents, and salinity levels. *The intervention is to create a Coastal Fisheries-Climate Outlook Network to assess and predict the impacts of climate change and EWE on the productivity of the coastal marine ecosystems and fish production. It will also evaluate the cascading socio-economic consequences on fishing communities' fish market, trade, and national economies*. The most vulnerable or invisible groups and informal stakeholders, including children, women, and older people engaged in subsistence fishing and associated activities, require special attention.

Despite the significant progress in advancing global climate change science research, the conduct of viable *scientific and socio-economic impact studies* at the regional and national levels is lagging. There are still some severe data gaps and caveats to understanding the impacts of climate change and variations on the local socio-ecological environments. The local impacts differ significantly from the global and regional climate change averages. For instance, the first Marine Protected Areas established worldwide during the early 90s have focused mainly on biodiversity factors without integrating climate change. The refugia for aquatic resources in our region needs to be identified and documented. Though there is a correlation between extreme weather events and the impacts of climate change at the local level, it is not grasped by the fishing communities. Moreover, local communities tend to interpret extreme weather events as climate

[3] *World Economic Forum – Global Risk Report 2019.*
[4] *IPCC Ocean and Cryosphere Special Report, Sept 2019. Refer to Annexe 1*

change, which is not so. These shortcomings are partly responsible for the misunderstanding or scepticism of the impacts of climate change in the local communities.

There is a lack of adequate and reliable scientific knowledge and information on fish stocks and ecosystems supporting the major marine fisheries and the relative impacts of climate change pathways on the fish supply chains in the EA-SA-IO maritime region. Therefore, there is an urgent need for downscaled modelling to assess the potential impact of climate change on the fisheries economy of the region. *"We manage what we can measure"*. This intervention intends to build a set of indicators/markers of the Fisheries-Climate nexus for driving science-based climate-compatible fisheries policies, strategies, and management plans at national and regional levels.

2.0 Overview of the African Fisheries and Aquaculture Sector

In 2017, Africa produced nearly 12 million tonnes of fish, representing 7 % of the global catch of 173 million tonnes. This figure included 3.0 million tonnes from inland fisheries, 2.2 million tonnes from aquaculture and 6.7 million tonnes from marine capture fisheries. Over the same period, the African continent contributed about 3.4 % to the total value of global fish imports of US$ 146.3 billion) and 4.6 % to the value of global fish exports of US$ 156.5 billion[5]. The marine fisheries of the EA-SA-IO region hold a contrasting landscape where 90% of the coastal fisheries resources are harvested in the inshore waters on a small scale, mainly subsistence and traditional artisanal fishing. Generally, these fisheries are poorly regulated, open access and informal economy. The catch is for household consumption and any surplus sold locally. Africa's average per-caput fish consumption is less than 10 kg, i.e., less than half the global average, and it is projected to decline to 7 kg by 2030 if appropriate measures are not expedited. In some coastal countries, like Tanzania, Kenya and Sudan, inland fish production is much higher than the marine fisheries. The post-harvest physical and economic losses in subsistence and artisanal fisheries are severe socio-economic and ecological challenges, which regrettably do not receive sufficient policy attention.

Most fishers in the commercial, artisanal fisheries are fish workers. The fishing assets are owned mainly by fish traders and outside investors (shadow owners) without interest in sustainable fishing. The fishers, as the front liners are often blamed for overfishing and unethical fishing practices, whereas the real profiteers are officially unknown to the government agencies. The surplus profits are rarely reinvested in the industry. So, business-as-usual is not sustainable for the local fishing communities, the fisheries ecosystems, and the national economies. However, the governments do not invest in the hard and soft infrastructures or create a proper enabling environment for connecting the local communities to the economic mainstream. The open-access policy in the artisanal fisheries initially sought as a social safety net against endemic unemployment and food insecurity for the local population has failed and has become a politically sensitive issue. The nearshore fisheries are dwindling. The existing fishing capabilities (assets and technologies) and supply-chain ecosystems are insufficient to venture farther offshore. As a result, alternative sustainable livelihood opportunities are scarce in the coastal areas. Therefore, fishing communities are trapped in an existential threat, which is the cause of the growing disconnect between local communities and the Government. The remaining 10 % of the regional fisheries catch/landings comprise industrial value chains that target high-value fish species such as tunas, shrimps, and lobsters, mainly for the export markets. They are vertically integrated, locally-based foreign corporations that have obtained attractive economic and fiscal incentives from the coastal states. For instance, the landed value of the tuna fisheries in the WIO (FAO Fishing Zone 57) is approximately US$ 2 billion annually, and 34 % of it is attributed to the WIO states (US$

[5] *FAO. 2020. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome.*

684 million), which is composed of industrial tuna fisheries (US$ 231 million) and coastal small-scale tuna fisheries (US$ 433 million)[6]. The aggregated fisheries licence revenue is estimated at US$ 21 million annually. These industrial fisheries are relatively well-managed, but there is no record of their direct and indirect contribution to the national economies.

The Western Indian Ocean generates approximately US$22 billion of economic benefits annually, and the share of the marine fisheries is about 11%, i.e., US$ 2.4 billion[7]. Since the UN Convention on the Law of the Sea, 90% of fish resources and 55% of other natural renewable and non-renewable resources are located within the EEZ of the coastal states[8]. Blue Economy would provide the impetus for these developing coastal and island states to strengthen their marine economy amidst environmental risks, including climate change. Sustainably managed, the economic benefits derived from the marine fisheries can be enhanced by 2 to 3 times in the longer term. A recent study by the World Bank[9] shows that global marine fisheries are an underperforming asset, and the difference between potential and actual net economic benefits is estimated at US$ 88 billion per year, equivalent to half of the value of the global seafood trade. The share of WIO marine fisheries is about US$ 5 billion per year. If timely climate adaptation measures are not implemented urgently, the socio-economic benefits derived from the marine fisheries in the tropical region will decline significantly.

The marine fisheries sub-sector has the economic potential to support the cost of its sustainable development and management. As a rule of thumb, the foregone *economic rent or government revenue* in the form of direct and indirect taxes is currently estimated at US$ 240 million per year, and it can be increased progressively to US$ 480 million upon the sustainable rehabilitation and modernisation of the coastal fisheries. However, instead of fuelling economic growth and shared prosperity in those underdeveloped states, the financial resources are leaked out of the economic mainstream. It is a textbook example of the *paradox of poverty amidst plenty* that aggravates economic inequalities and multi-dimensional poverty in the coastal fishing communities. The root cause of the declining productivity of the coastal fisheries is population growth, overfishing and unethical fishing practices. In addition, land-based and marine pollution aggravates the direct and indirect impacts of ocean warming. *In other words, there is an urgent need for science-based policy-making and management actions[10] to ensure sustainable fisheries.*

The economic and social contribution of the fisheries sector is frequently underestimated in the national accounts. The outcome is both the cause and effect of a lack of disaggregated data on the different branches/segments of the sub-sector interacting with society and the economy. The information asymmetry may partly explain the ongoing political procrastination in managing this complex and politically sensitive sector. As a result, the Gross Domestic Product (GDP) does not reflect the development potentials of the industry in terms of net economic benefits or economic rents, its contribution to employment, food security and cultural diversity. An increase in GDP may result from increased fishing costs rather than raised productivity or net benefits. All may seem fine until a complete collapse of the fisheries. Therefore, these conventional macroeconomic indicators must be complemented by other meaningful measures, including their socio-economic impacts and environmental sustainability, such as the status of fish stocks and long-term profitability. Generally, the fisheries sector's contribution to national and regional economies is more

[6] *Sweenarain, S (World Bank - WIOFish 1, 2018). Cost-Benefit Analysis and Sustainable Financing of a Regional Fisheries Framework Agreement for the shared tuna fisheries resources in the Southwest Indian Ocean Basin.*
[7] *WWF 2015, Reviving the WIO Ocean Economy – Actions for Sustainability.*
[8] *Global Marine Atlas 2018.*
[9] *World Bank Group 2016, The Sunken Billions (revisited)*
[10] *Cf. FAO Fisheries Performance Analysis Toolkit, 2020*

significant than the official statistics. Commercial fishing constitutes the economic base for an extended value chain through processing, marketing, retailing, and the food service industry. In addition, subsistence fisheries are essential for food security and rural livelihoods. The economic measures do not fully integrate the economics of the informal sector.

Aligned with the earlier narratives, a new perspective is necessary to unlock the development potential of coastal fisheries, positioning it as a pivotal growth sector. The capture fisheries sector must be reformed to optimise economic performance, environmental sustainability and social equity. The proposed intervention will enhance objective policy coherence between the economic, social, ecological and governance imperatives for sustainable and inclusive fisheries. It will empower the national fisheries agencies to maximise cross-sector synergies to balance divergent policies for achieving a triple-win.

3.0 Potential Impact of Climate Change on Global Fisheries

Climate change is causing global warming. The scientific communities under the IPCC acknowledge with the highest confidence that human-induced greenhouse gas (GHG) emissions into the atmosphere are responsible for climatic change and *more frequent extreme weather events*[11]. However, the changes are not spread evenly across the world, and developing economies that have contributed the least to climate deregulation, namely the least developed and low–lying coastal countries and the Small Island Developing States, are affected the most. Therefore, *climate change is widening the existing economic inequalities* in the world[12]. According to the IPCC Global Climate Models (GCM), if the GHG emissions continue at the current rate, global temperature will increase by 2.6 – 4.8 degrees Celsius (°C), and sea levels will be 0.45 - 0.82 metres (m) higher than the present status by the turn of this Century. To save humankind from the predicted climatic Anthropocene, the UNFCCC recommends maintaining the average global warming since the pre-industrial times below *2°C and lowering it to 1.5°C soon*. According to IPCC AR 5, the world had already emitted two-thirds of the maximum aggregated quota of GHG to meet the threshold of 2°C in 2011. However, *the 2°C target is no less than the death penalty for the low-lying nations and the SIDS*, mostly in tropical and subtropical regions. They would be suffering from irreversible damages at 1.5°C. Therefore, limiting the effects of climate change would require an immediate and more stringent reduction of GHG from the world's largest economies/polluters. The oceans represent 70% of the planet's surface and provide vital services to sustain humankind, including providing food from fisheries and aquaculture. However, the ability of these marine ecosystems to maintain their productivity is reduced by the cascading effects of ocean warming.

Fisheries provide 3 billion people worldwide with about 20% of their average animal protein intake. Over 500 million people in Africa and Asia's poorest countries rely on marine fisheries for food and income[13]. Global warming affects the ecology of the coastal and oceanic ecosystems through the change in the food webs and biophysical features of the targeted fish species. Other induced effects of sea surface temperature rise, such as acidification, sea-level rise, algal blooms, and hypoxia, undermine the productivity of marine fisheries' habitats. Many coastal species are threatened by extinction due to the combined effects of climate change and other interconnected human and environmental stressors such as overfishing, unsustainable fishing practices, and land-based and maritime pollution. *Based on the +2°C scenario, the potential loss of global fisheries by 2050 is estimated to be between US$ 17 and 41 billion per*

[11] *IPCC, Fifth Assessment Report – Fisheries Summary 2014.*

[12] *It is a global moral indignation that the world largest polluters have systematically avoided the debate on climate compensation at the Paris Climate Summit 2015 to relieve the sufferings of the Low-lying coastal states and Small-Island Developing States that include most of least developed and fragile states of the Sub-Saharan African region. There is sentiment among these aggrieved nations that the International Community has failed deliver on Climate Justice.*

[13] *FAO World Fisheries Report, 2018*

year[14]. Coral reefs support 10–12% of all fish caught in tropical countries and 20–25% harvested by developing island nations[15]. Acidification will cause a decline in global reef fish and shellfish production between 2020 and 2060. Adaptation is possible in some cases but very difficult in others. *The estimated total cost of adaptation for fisheries globally from 2010 to 2050 is US$ 30 billion per year.*

3.1 Physical and Chemical Changes in the Ocean

Oceans absorb 30% of the global CO_2 emissions, lowering the pH of the water and causing *ocean acidification*. Bivalve molluscs such as mussels and oysters, corals and plankton that form shells from calcium carbonate are all at risk. Ocean acidification may also have direct effects on fish behaviour and physiology. Rapid changes in chemical and physical conditions in the oceans have already affected the *distribution and abundance* of marine organisms and ecosystems. Changes to the distribution of fish populations are affecting the *composition of catches*. For example, the range limits of many intertidal species in the North Pacific and North Atlantic have shifted by 50 km per decade. In the Indian Ocean, the migratory pattern of the tuna and tuna-like species is moving Eastward. These displacement rates are generally faster than land species and seriously disrupt the food webs, i.e., the prey-predator relationship. The potential impacts and risks include the following:

i) *Physical and chemical changes to the ocean lead to a loss of marine biodiversity;*
ii) *Changes in the level of seafood production, with initial decreases at low latitudes and increases at high latitudes;*
iii) *Potentially increased overfishing and unethical fishing practices (fishing down the web) due to a decline in the coastal fisheries resources and ecosystems.*
iv) *Degradation of tropical and cold-water coral reefs owing to decalcification resulting from ocean acidification;*
v) *Increased in harmful algal blooms, which threaten ecosystems and fisheries*

3.2 Changes in the Level of Seafood Production

From 1998 to 2010, *concentrations of chlorophyll – an indicator of net primary production* – in the Tropical oceans, including the Indian Ocean, decreased by about 10% due to climate change or weather variations. However, Climate change is projected to cause a further decline of 9% over the 21st Century in these open ocean regions. Rising temperatures reduce the ocean's oxygen-carrying capacity, limiting the maximum body size that large fish can achieve. As a result, *catches of smaller fish* are predicted for the future. In addition, the number of *'dead zones depleted in oxygen* is increasing, affecting coastal ecosystems and fisheries by inhibiting growth. The primary cause of dead zones in coastal regions is the nutrient run-off from land, exacerbated by warming water.

As seawater continues to warm, scientists are confident that the *productivity of many fisheries will change*. Due to projected warming, spatial shifts of marine species will cause high-latitude invasions and high local extinction rates in the tropics and semi-enclosed seas relative to 2005 levels and based on a global 2°C warming scenario. As a result, species intensity and catch potential are projected to increase, on average, at mid and high latitudes and decrease at tropical latitudes. *However, not all fish will adapt, and some stocks may die out*. Such changes are likely to increase the vulnerability of the coastal and island developing countries, which depend directly on fisheries for food and income and cannot target other stocks or extend the range of their activity due to financial or technical limitations.

[14] *IPCC Assessment Report (AR) No 5, Fisheries Summary, Page 5*
[15] *IPCC AR 5, Fisheries Summary, Page 8*

3.3 Collapse of some coastal reef fisheries

*When defining fishing opportunities, the migration of fish stocks will also pose new challenges to governments and regional fisheries management organisation*s. For example, changes in temperature, oxygen levels and food availability in the ocean will likely alter the distribution and abundance of top predator species such as tuna in the Pacific and Indian Oceans, with stocks in both oceans predicted to shift eastwards. These subtle changes undermine the fisheries economy, particularly the small-scale value chains of the island and coastal states of the Tropical and Sub-Tropical regions.

Under most climate change scenarios, more than half of the world's coral reefs are at medium or high risk of degradation. Reefs support high levels of biological diversity and provide critical habitats for fisheries. *Coral reefs support 10–12% of all fish caught in tropical countries and 20–25% captured by developing island nations*. However, many of these nations exploit their coral reef fisheries unsustainably.

3.4 Economics of Fish Redistribution

Fisheries yield is projected *to increase by 30–70% in high latitudes and fall by 40–60% in the Tropics and Antarctica, based on +2°C warming*. Large species, such as tuna in the Pacific and Indian Oceans, are likely to shift eastwards. *Global loss of landings is projected at USD17 to 41 billion by 2050*. The options are:

i) Undertake vulnerability assessments
ii) Strengthen coastal zone management
iii) Reduce aquaculture dependence on fishmeal

3.5 Dead Zones Are Becoming More Common

The extent of *oxygen-depleted 'dead zones'* in coastal waters is increasing. These are caused by high levels of nutrient run-off from land, exacerbated by higher water temperatures and ocean acidification. The extent of 'oxygen minimum zones (OMZs) caused by ocean warming also increases in the open ocean. These waters are oxygen-poor in the mid-layers and cannot support sizeable active fish. The options are:

i) Reassess and reinforce marine protected areas;
ii) Protect mangrove forests, sea-grass beds, and salt marshes.

3.6 Ocean's Chemistry is Changing at an Unprecedented Rate

Ocean acidification – the result of enhanced carbon dioxide uptake from the air – puts commercially important fish and shellfish at risk. *The ocean's pH has fallen by 0.1 since pre-industrial times, roughly corresponding to a 30% increase in acidity*. If CO_2 emissions continue to rise at the current rate, a further pH drop of 0.3 by 2100 is projected. Thus, the change in ocean surface pH by 2100 under the 'business-as-usual scenario: 0.6 more acidic.

3.7 Negative Effects on Shellfish

Shellfish are particularly vulnerable to ocean acidification and other changes in ocean chemistry. Therefore, if ocean pH continues to fall, the overall global production of shellfish fisheries will likely decrease. The main options are:

i) Reduce non-climate change-related stressors;
ii) Policies to reduce fossil fuel use across economies will affect the seafood industry.

3.8 Coral Reefs at Risk

Coral reef ecosystems are declining rapidly, with the risk of the collapse of some coastal fisheries. If CO_2 emissions continue to rise at the current rate, coral reef erosion will likely outpace reef building during this Century. Incidences of coral bleaching resulting from increasing temperatures are also likely to grow, with a consequent loss of support and habitat for fisheries and other marine creatures. As a result, coastal

protection, food resources, and tourism income are all at risk. Thus, the propagation of new habitats, such as artificial reefs, to act as nurseries in areas where coral destruction occurs is needed.

4.0 Conclusion and Actionable Recommendations

The small-scale marine fisheries can be differentiated into two distinct segments based on their interconnectedness to the specific coastal fisheries ecosystems: sedentary and oceanic fisheries. The sedentary fisheries include the demersal and benthic aquatic marine resources such as the reef and herbivorous fishes, molluscs and crustaceans that live in the coral reef areas, mangroves, forests, sea-grass beds and shallow waters of the lagoons, estuaries, and wetlands. These coastal fisheries ecosystems are mostly over-exploited and polluted by land-based and maritime effluents in densely populated areas. The coastal oceanic or pelagic fisheries target tuna and associated large pelagic fishes in the nearshore open sea or around artificial fish aggregating devices. Some small pelagic fishes are also caught seasonally in the lagoon. The coastal tuna fisheries are not evenly developed in the region. The artisanal fisheries of Comoros and Reunion Island rely on coastal tuna resources due to the limited lagoon and nearshore continental shelves. Mauritius is also engaged in developing artisanal tuna fisheries as an alternative to relieve its lagoon from overfishing. Over the past decades, several countries, such as Kenya, Mozambique, and Tanzania, have tested coastal tuna fishing with FAD deployment but have not promoted it as a commercial fishery. Most of the SSF is impacted diversely by the different climate change pathways.

The Paris 21st Conference of Parties on Climate Change (COP 21) is committed to limiting global warming to +2°C and eventually down to +1.5°C to relieve the low lying least developed countries and the Small Island Developing States (SIDS) from unavoidable collateral damages by the turn of this Century. In the Indian Ocean, from 1998 to 2010, the Net Primary Productivity decreased by 10 % and is predicted to decline further. It will impact the presence and abundance of marine living aquatic resources in the region. The average SST and SLR in the WIO align with global trends. However, they differ significantly across the local coastal marine ecosystems, with diverse consequences on the productivity of the artisanal fisheries. The effects of climate change are still not understood as seasonal and inter-annual climatic variations by the coastal fishing communities. They have developed, over time, some adaptation strategies to cope with these changes. However, these measures are inadequate to establish proactive climate change adaptations and long-term resilience in the SSF.

Scientific evidence suggests positive interactions and mutually reinforcing systems between ocean warming and climatic variations, including the inter-annual phenomena such as El Nino and La Nina, that would further aggravate the conditions of the marine fisheries. Local communities relying on coastal fisheries for their livelihoods must be informed of the silent threats of climate change to fisheries ecosystems concerning their economic activities. A bottom-up approach is necessary to document the current effects of climate change and variations in the local socio-ecological environment. The mainstreaming of climate change adaptation measures has not fully been captured by the fisheries sector's national policy and institutional frameworks, particularly the SSF, because of a lack of reliable scientific and empirical observations on the potential climate risks.

The drivers of climate change disrupt the food chain and prey/predator relationship, directly affecting the productivity of the fisheries ecosystems and fish production. Fish stocks tend to move steadily towards cooler waters while heat-tolerant/pH-resistant species drive away from the endogenous fish species from their traditional habitats. The migratory pattern of tuna stocks is also changing subtly across the oceans. A peer-reviewed study showed that the surface tuna resources in the WIO are moving farther easterly at approximately one kilometre per decade. These climatic impacts will have severe socio-economic consequences on the coastal and oceanic fisheries of the region. Therefore, it is crucial to collect scientific and techno-economic information on the current and future climate impacts on the fisheries sector to anticipate policy actions at the national and regional levels.

The sustainability of the socio-economic benefits derived from the coastal fisheries in the WIO countries is seriously challenged by the poorly regulated open-access regime, lack of basic socio-economic and dedicated fisheries infrastructure; outdated fishing assets and fishing technologies; neglected fish value chains, value addition activities and market infrastructure and supply chain logistics, trained workforce as well as ineffective fisheries management and governance systems. The climate and non-climate (environmental and human-induced) factors are also culprits of the current situation, but they have not been adequately documented. Under the present business-as-usual scenario, the human and environmental stresses on SSF will intensify until they reach the tipping point. It will be a catastrophe for approximately 50 million people dependent on the coastal fisheries for livelihoods and food/nutrition security. A decrease in the fish stocks availability and accessibility or catchability generally observes the direct impacts of climate change and variations on inshore fishing.

A decline in the total catch, species mix, and spatial distribution of the marketed fish species affects fishing costs and revenue. The operating costs tend to increase because of a decrease in the landings and changes in the catch composition, an increase in the number of non-fishing days due to bad weather at sea, and extended fishing trips as more time is required for cruising to more distant fishing areas, increase in post-harvest losses in the absence of adequate preservation practices and higher cost of repair and maintenance. The market demand for fresh/chilled fish and seafood is driven by other factors such as the quantity and quality of the landed products, the purchasing power of the consumers, and cheaper substitutes, particularly from inland or farmed fish products. Though food prices, including fish, will increase worldwide, the escalating cost of fishing in the SSF coastal fisheries might not be fully compensated in developing countries. The confounding factors include the absence of organised primary markets, the low purchasing power of the consumers, widespread subsistence fishing and open access, poor value chains and marketing logistics and competition with cheaper imported fish.

The impacts of climate change will also hit fish and seafood exports in the WIO countries. However, the involvement of artisanal fisheries in regional and international trade is still insignificant in these countries. Except for Madagascar and Seychelles, artisanal fisheries production in these countries is destined for domestic consumption. It is a paradox that ocean states like Mauritius and Reunion Island are overly dependent on imported fish and seafood to satisfy their domestic consumption. Comoros, Madagascar, and Seychelles are self-sufficient, but their per-caput fish consumption varies significantly. For instance, in 2014, the per-caput fish consumption in Madagascar was 7.4 kg, much lower than the African average of 9.6 kg. Over 90 % of the fish production in Africa, including the Easterly countries, is harvested from the continental waters. With a per-caput fish consumption of 64 kg, Seychelles is the highest rating in the WIO. It has significant export potential for high-value reef fishes but is constrained by geo-economic factors common to the SIDS. The SSF of Comoros is overly dependent on tuna resources and is about to launch the first export-oriented vertically integrated tuna fishing and processing project. However, this development has not systematically anticipated potential climate risks. Small-scale actors are the main suppliers of affordable food and fish to the local population. Therefore, it is critical to proactively mainstream climate change adaptation measures into the fisheries management governance system. If appropriate measures are not taken promptly, it is most likely that the per-caput fish consumption will follow a downward-sloping curve. Since locally harvested marine fish would become scarce, these coastal countries might resort to imports and/or restrict fish and seafood exports to satisfy domestic demands.

The regional industrial tuna fishing and canning value chains, an extended segment of the European tuna markets, are under climate risks due to the observed subtle but steady change in the migratory patterns of the tuna stocks in the Indian Ocean. They are moving away from the traditional surface tuna fishing grounds of the WIO. The multi-million-dollar canned tuna industry is at stake as these environmental changes would affect its competitiveness at this critical time when the World Trade Organisation is challenging the ACP-EU Preferential Trade Agreement. It is most likely that the supply of raw tuna from the region will decline.

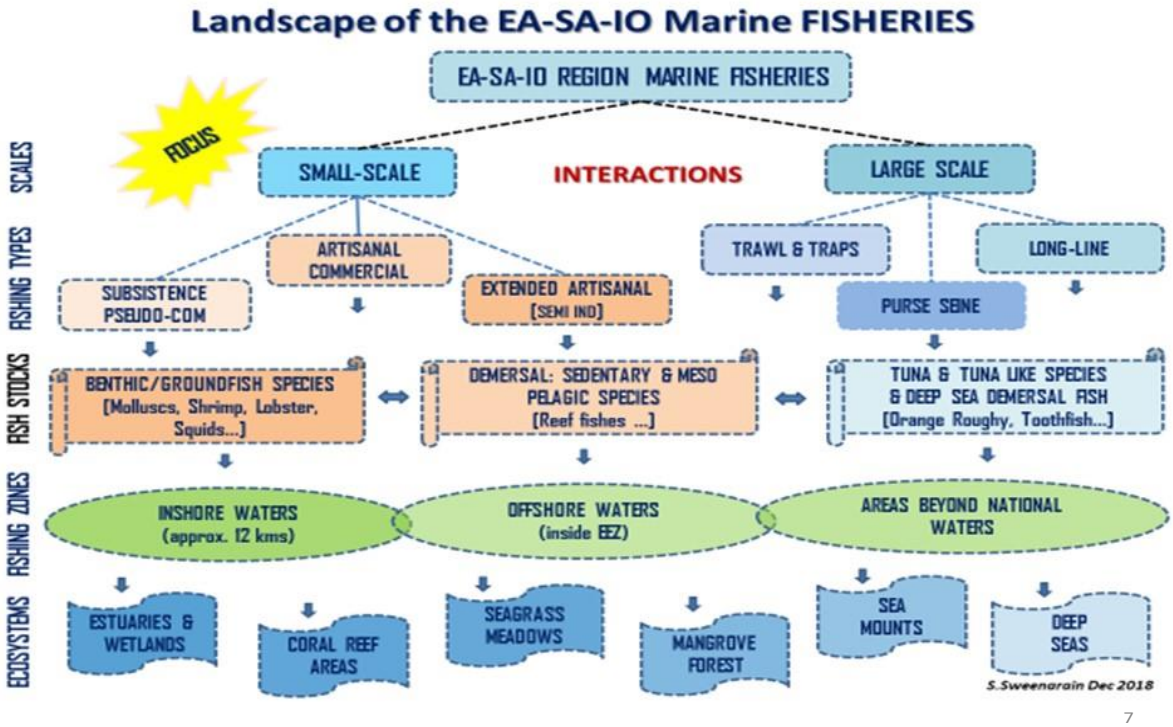
It will eventually impact the future Fisheries Partnership Agreement between the EU and the ACP countries of the WIO. Some tuna packers are shifting their operations to countries closer to emerging tuna fishing grounds, such as Bangladesh and Sri Lanka, to anticipate these long-term climate-induced changes and build their comparative advantage on export markets. As a result, fish and Seafood exporters of the WIO region might face tougher competition in their traditional markets from exporters from other regions whose fisheries are less affected by ocean warming and are managed more sustainably.

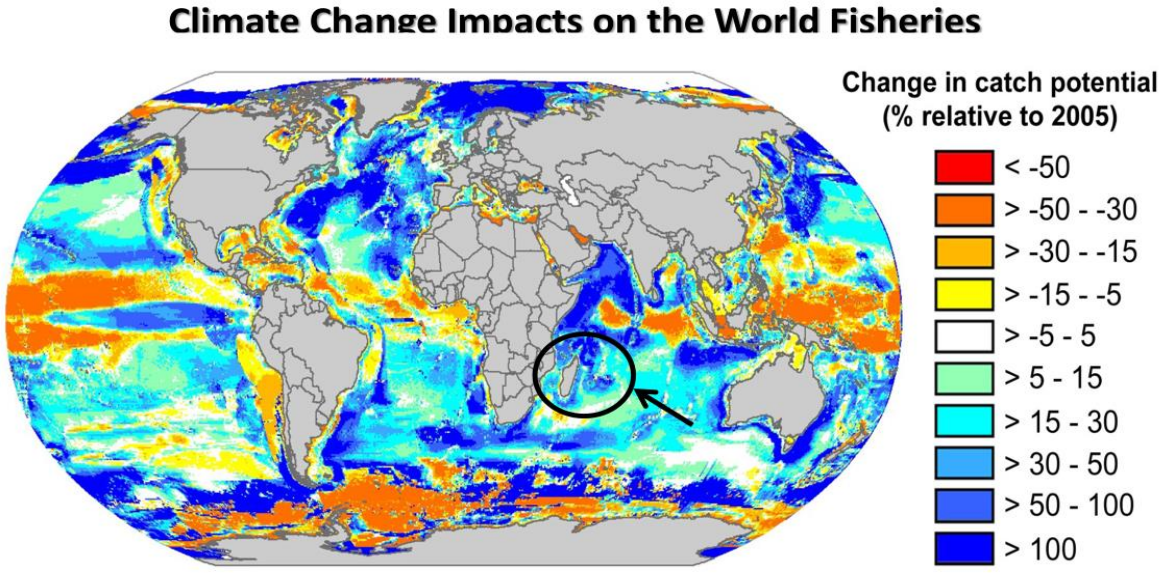
Over the past decades, the WIO countries have participated in over 30 regional and national climate-related programmes focusing on Research, Evaluation and Policy Formulation; Dissemination of Knowledge and Awareness building; Capacity building; and Community-based adaptation. In addition, most of them have undertaken a Vulnerability Analysis of their critical economic and environmental sectors. However, the national climate policies have focused more on the land-based sectors than their marine counterparts. Generally, the Ministries of Environment and Integrated Coastal Zones Management look after the social and ecological issues of the coastal and marine areas. However, these interventions have no direct interest in artisanal fisheries' environmental and socio-economic aspects. To cope with this policy gap, the relevant public agencies must integrate climate-smart strategies into the existing coastal marine fisheries policy and regulatory frameworks.

The combined effects of climate and non-climate stressors are wicked problems affecting the coastal marine fisheries' socio-ecological sustainability and long-term resilience. Some of those factors are internally manageable, while others are externalities. Therefore, relieving the coastal marine ecosystems from human-induced stressors, including overfishing and unsustainable fishing practices, including IUU fishing, maritime and land-based pollution, is critical. These environments can build natural adaptation and resilience against the drivers of ocean warming and extreme weather events. Climate adaptation strategies can be developed on a no-regret or triple-win approach when anticipated well in advance. Key components of any Climate Change Adaptation Strategy in coastal marine fisheries include:

i)	*Awareness building on the potential impacts of climate change and the possible proactive adaptation measures in the fishing communities;*
ii)	*Mainstreaming Climate Change Adaptation Strategy into the existing Regional Fisheries Policies and Management strategies at the EA-SA-IO level.*
iii)	*Improved communication and coordination among the various Environment, Sustainable Development and Ocean Governance policies and programmes at national, regional, and international levels*
iv)	*Participatory ecosystem-based management and governance in the coastal fisheries, with emphasis on the integrated coastal management that incorporates various interrelated multilateral environment agreements, including climate change and biodiversity protection, under the same umbrella;*
v)	*Smart Investments in climate-proofing fisheries infrastructure and fishing assets;*
vi)	*Development of smart aquaculture and fish farming projects to boost the supply of fish;*
vii)	*Social security and Insurance Scheme to protect the fishing communities;*
viii)	*Alternative/ Complementary Sustainable livelihoods for the fishing communities, such as blue carbon projects and environmental stewardship;*
ix)	*Science-Technology and innovation in leading the process of promoting climate-resilient fishing operations;*
x)	*Improved safety at sea through training and sharing of real-time weather information;*
xi)	*Review of Marine Protected Areas and Reserves strategies to integrate climate risks;*

Annexe 1 – Fisheries Climate-related PPT Slides





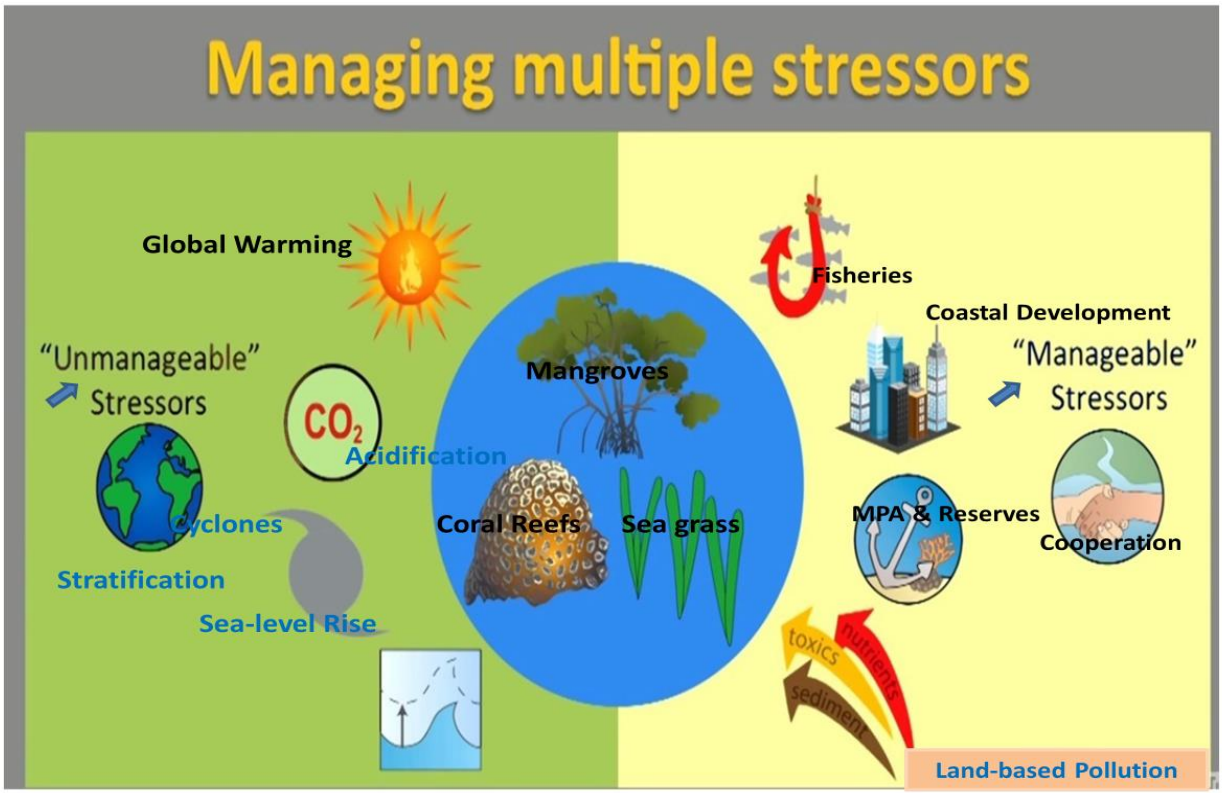
Predicted change in the potential of fisheries, given the distribution range shifts induced by global warming and a relationship linking distribution and potential catches. Insert show some countries predicted to gain, and to lose from such changes (from Cheung et al. 2009b). Note that these predictions do not ac-count for change in oxygen distribution in, and acidification of the oceans, and hence represent an optimistic scenario

Source: Daniel Pauly – Sea Around Us (2009)

Potential Climate & Non-Climate Impacts on Small-Scale Fisheries

CLIMATE DRIVEN STRESSORS				NON-CLIMATE DRIVEN STRESSORS			
CORAL REEF DECALCIFICA-TION	RISE IN SEA SURFACE TEMPERATURE	MANGROVE FORESTS REDUCTION	SEAGRASS BEDS ALTERATION	LAND-BASED & MARITIME POLLUTION	POP GROWTH COASTAL URBANISATION	OVERFISHING AND IUU (POUCHING)	DEFICIENT GOVERNANCE MANAGEMNT
CLIMATE CHANGE IS STRESS MULTIPLIER AND AMPLIFIER ON THE CONDITION							
Destruction of Coral Reefs and Crustaceans...	Ocean Currents Seal level Rise Acidification	El-Nino La –Nina Salinity	Storms frequencies & Severity	Run-offs of Sediments , & Chemicals	Alien Invasive species Dom. Wastes	Unsustainable fishing practices	Tragedy of the Commons
THE EFFECTS OF THE CLIMATE AND NON-CLIMATE STRESSOR ARE SPINNED-OFF							
FISH PRODUCTION		**FISHING OPERATIONS**		**COMMUNITIES LIVELIHOOS**		**SOCIETY & ECONOMY**	
Species Composition, Diversity & Distribution		Fishing Costs and Revenue Net Income		Damage /Loss - Fisheries Infrastructure & installations		Loss / Damage of private assets (Houses, household eqts)..	
Decline in Fish Production & Yield		Safety at Sea / Loss of lives		Damage / Loss – Fishing Assets		Risk to Public health & lives	
Displacements & Conflicts over resources		Conflicts over resources & fishing grounds		Food & Nutrition Insecurity & Poverty		Market Impacts Foreign Trade	
CLIMATE ADAPTION MEASURES							
- Post harvest losses - Marketing & Value addition - Smart aquaculture development - Improved MPA & Reserves - Research & Development		- Diversification & Alternative livelihoods - Improve fishing assets & technologies - Insurance Scheme - Social assistance / Compensation		- Improved food safety and quality management - Education & Awareness building - Migration - Improve Early Warning System		- Improved Governance - Ecosystem –based Mgmt - Climate Proofing Policies at Sector and national level - Climate Adaptation Investments - Regional Cooperation	

Source : S. Sweenarain, 2016



Annexe 2 - COP 28 Outcomes

Summary

COP28 witnessed significant strides in addressing climate change, underscored by the inaugural Global Stock Take (GST). This mid-term review assessed UN member states' progress towards the goals set in the 2015 Paris Agreement, culminating in the UAE Consensus—a milestone for multilateralism and climate diplomacy. The key takeaways are as follows:

Course Correction Urgency: COP28 was a critical platform for nations to recalibrate climate action through the GST. Despite positive outcomes, the sobering reality of rising global emissions highlighted the need for a rapid transition from fossil fuels to meet the 1.5°C goal, necessitating deep and sustained reductions in greenhouse gas emissions.

Renewable Energy and Efficiency Surge: A substantial effort to meet energy transition goals was evident in commitments to triple global renewable energy capacity by 2030 and double the annual rate of energy efficiency improvements. With an estimated $4.5 trillion investment by 2030, the private sector pledged significant support for renewable energy projects in emerging markets.

Revamping Agriculture for Sustainability: COP28 introduced the Emirates Declaration on Sustainable Agriculture, supported by 134 countries. It committed to including emissions from agriculture in national climate action plans, with the First Movers Coalition for Food stimulating demand for sustainably produced agricultural commodities.

Nature-Climate Nexus and Funding Initiatives: Emphasising the interdependence of climate and nature agendas, COP28 launched initiatives with an initial commitment of $1.7 billion, concurrently addressing climate and biodiversity goals. Efforts to fund ocean action, including the Mangrove Breakthrough, mobilised over $2.5 billion to bridge funding gaps for nature conservation and restoration.

Adaptation and Loss & Damage Mitigation: The Global Goal of Adaptation by 2030 outlined seven targets to enhance resilience. COP28 operationalised the Loss and Damage Fund, securing over $726 million to assist severely affected countries. However, funding levels fall short of requirements, highlighting the challenges ahead.

Despite progress, challenges persist, with the non-binding nature of the UAE Consensus requiring a roadmap for effective GST implementation. Mobilising over $85 billion in financing is commendable but falls short of rebuilding trust and translating the GST into tangible actions. The emphasis on enhanced Nationally Determined Contributions, transitioning from fossil fuels, and ensuring a just transition sets the stage for future revisions and collaborative efforts leading to 2030.

As COP28 concludes, leaders are urged to leverage multistakeholder events like the upcoming World Economic Forum Annual Meeting to propel global momentum and enact meaningful change. With NDC revisions by 2025, these gatherings are critical for steering the world towards a resilient 1.5°C future, leaving no one behind in pursuing sustainable climate action.

Overview of COP 28

Significant progress was made at COP 28, but many issues remain unresolved, and new technology cannot solve all challenges ahead. Despite positive signs, COP 28 outcomes leave space for loopholes and lack a clear plan to transform into reality. Some progress was made regarding food systems. Despite the conference in Dubai, UAE, an oil-producing country, there are positive shifts in a vast majority of countries agreeing to phase out fossil fuels. After 14 days of negotiations, nearly 200 countries agreed to transition away from fossil fuels to avert the worst effects of climate change. The language in the final text of COP28 demonstrates that many states and interests are still hesitant to shift away from oil and gas. India's position has shifted from an obstructionist to a positive global contributor for transitioning to renewable energies.

Some theme-based adaptation targets have made a breakthrough. Overall, there is now momentum for real progress.

The Kunming-Montreal Global Biodiversity Framework, which links climate and biodiversity, was referenced in the final text. Establishing a Loss and Damage Fund is welcome, but there is a long way to go in operationalising it, and more money is needed to prevent loss and damage in the first instance. The most compelling aspect of the COP was the mobilisation of all sections of civil society to defend the 1.5-degree threshold. The science community was tasked to explain Carbon Capture and Storage (CCS) and Carbon Dioxide Removal (CRD)- technology solutions essential to transition away from fossil fuels. It must be more precise about the uncertainties about the technological inventions of CCS and CRD as solutions instead of fossil fuel phaseouts. Another risk with the agreement is focusing on lower carbon emission fuels, such as fossil gas, to bridge the energy transition into renewable energy. Transition fuels can play an important role, particularly in countries from the Global South with a high dependency on coal and oil. However, there is a risk that investments that should be directed to renewable energy get directed to transition fuels. It may result in fostering the same type of infrastructures that support the production of other fossil fuels with higher emissions, maintaining the status quo.

There is still a huge implementation gap between the current Nationally Determined Contributions and the actual climate policies implemented. Vulnerable countries have not yet received the promised pledges on climate finance that would allow them to achieve their nationally determined targets for the current period (2020-2025). With the ambition to increase emission reductions, it is critical to increase climate funding and the mechanisms that make it accessible to places and communities where it is most needed. However, the finance gap is large and predicted to increase if current trends continue. Yearly pledges for adaptation funds will need to double during this decade to meet the needs of the most vulnerable countries. Money is not the only factor for the expected transformative change. Even if climate finance substantially increases, it is essential to underline the contribution of science, technology, and innovation to leverage knowledge and best practices for financing and enabling transformation across different sectors and regions within their socio-ecological contexts.

Agriculture was also in the limelight at COP 28 as its presidency organised a ministerial dialogue on building food and water resilience to launch a two-year partnership hosted by the UNFCCC's Climate-Resilient Food Systems Alliance. It will support countries and non-state actors in better integrating water and food systems management – for both adaptation and mitigation – in the National Climate Plans of COP 30. It is a breakthrough in recognising the environmental impacts of food imports and the global supply chains. It is essential to put food and water systems resilience at the centre of the COP agenda. However, it is worrying that many ministerial interventions overemphasise technology and drought-resistant seeds as silver-bullet solutions for climate resilience in food systems. Such solutions reinforce the status quo instead of driving people-centred transformative change. The issues of justice and equity in food distribution were overlooked, although these are at the core of resilience and food and water security. Therefore, there must be a shift in the dominant narrative on what resilient and sustainable food and water systems are needed.

It is essential to recognise that the resilience of food and water systems is inherently intertwined with social-ecological dynamics, encompassing a variety of perspectives, values, and cultures guided by principles of equity and justice. Despite positive signs, the COP28 outcomes leave space for loopholes and lack a clear plan for how ambition will become a reality.

Annexe 3- Notes

a) Africa Climate Summit – September 2022

The Africa Climate Summit, which wrapped up in Kenya last September, was an effort to forge a harmonised approach to the continent's negotiating stance on climate diplomacy ahead of the United Nations COP28 Climate Change Conference in November. Hosted by Kenyan President William Ruto, the current rotating leader of the Committee of African Heads of State and Government on Climate Change, the summit produced the Nairobi Declaration, now viewed as Africa's defining response to the climate crisis.

The manifesto, titled *"Driving Green Growth and Climate Finance Solutions for Africa and the World*," delineated Africa's critical priorities in addressing the crisis, to which it contributes the least of all the world's regions but from which it suffers the most. These included calls for urgent global climate action to reduce greenhouse gas emissions, new global taxes on carbon emissions and ramped-up investment in clean energy to leverage the continent's vast natural assets in critical minerals for the green transition. Addressing Africa's urgent need for predictable climate financing, the summit urged wealthy nations to pay their "climate debts." At the same time, it called for an overhaul of multilateral financial systems to restructure the debts of insolvent nations that, staggering under the burden of repayment, cannot redirect scarce resources toward addressing climate shocks.

b) Loss and Damage Fund

Small Island Developing States (SIDS) have had considerable success in getting climate-induced loss and damage onto the international policy agenda, as evidenced by the decision at COP27 to create a specific Loss and Damage Fund. However, the challenging task of harnessing adequate support to address loss and damage hinges on being able to calculate what constitutes 'loss' and 'damage', both retrospectively and prospectively. This paper contributes to that conversation. It presents estimates of the impacts of extreme weather events due to climate change in SIDS over the past 23 years and projections of expected loss and damage by the year 2050.

Using information from extreme event attribution (EEA) analysis, this paper finds significant loss and damage attributable to climate change in SIDS: from 2000 to 2022, a total of 10,113 deaths associated with extreme weather events were recorded in SIDS, of which anthropogenic climate change was responsible for 38%. Annual economic losses of US$1.7 billion can be attributed to climate change, representing 0.8% of SIDS's collective gross domestic product (GDP) every year. For small, undiversified SIDS economies, this is highly significant. On average, SIDS suffer higher levels of loss and damage than non-SIDS across all income groups. For instance, SIDS experience five times more climate change-attributable deaths (per million) than non-SIDS in low- and lower-middle-income countries.

Floods and storms will produce cumulative climate change-attributable loss and damage of $56 billion in SIDS under a 2°C warming scenario by 2050. It would represent an 11% higher average annual loss and damage over the next 23 years (2023–2045) than over the past 23 years (2000–2022). These projections likely underestimate the potential loss and damage that may occur in SIDS because of limited data and indirect economic impacts (e.g. loss of GDP, loss of revenues) and loss and damage due to slow-onset events have not been included in the analysis.

More research is needed to help inform the development of adequate financial mechanisms, including the Loss and Damage Fund, for coping with these seemingly inevitable impacts of climate change on SIDS. Firstly, mechanisms to address loss and damage must focus on loss and damage under a 2°C+ scenario.

Additionally, there needs to be a more precise articulation and calculation of the indirect costs of climate change, which could be significant. And finally, data gaps need to be filled urgently, including through more attribution studies in SIDS and other highly vulnerable countries.

d) Climate Economics

Adaptation and Mitigation: The world faces a two-front battle to halt global warming and address the effects of climate change. Imagine your boat has sprung a leak. To keep from sinking, you must address the source of the problem. That means plugging the holes. But what about all the water already rushing in? To stay dry, you grab a bucket and start bailing. To stay afloat and prevent damage to your boat, you must address both issues simultaneously. Humanity must similarly act on two fronts simultaneously in the face of climate change. Mitigation efforts require measures to address the underlying problem by slowing or stopping the rise in fossil fuel emissions, which could irreversibly raise the Earth's temperature. Adaptation is needed to help people and governments withstand and minimise the ravages of climate change already here. Scientists and economists mostly agree on what must happen in the next 30 years to mitigate climate change. The dilemma for policymakers lies in determining effective strategies to encourage and disseminate clean technologies for powering vehicles, generating electricity, and diminishing the economic appeal of fossil fuel usage.

Carbon pricing: Reducing carbon emissions from burning fossil fuels like coal, oil, and gas won't happen without some prodding. Just as you might pick the cheaper of two similar items when shopping, people are less likely to choose fossil fuels with an added environmental cost if cleaner alternatives are cheaper. Pricing carbon is calculating the cost of releasing another ton of carbon dioxide (CO_2) into the air. Using fossil fuels may create jobs and commerce, but they enjoy an implicit subsidy: users don't have to pay for environmental damages. In economic terms, this is known as a "market failure", in which the price of a good or service doesn't fully reflect all the costs. When a power company decides between investing in a new wind farm or a coal-fired power plant, the decision should consider the cost of pollution on top of the costs of both technologies. Policymakers may consider two primary approaches for carbon pricing:

Carbon tax: This sets a direct tax on coal, oil products, natural gas, and other fossil fuels in proportion to their carbon content. The tax is passed from suppliers to consumers through higher prices for electricity, gasoline, heating oil, and other products and services that rely on fossil fuels.

The cap-and-trade system sets allowances on the total carbon emissions released each year, creating a market-based system in which allowances can be traded from less carbon-intensive to more carbon-intensive sectors.

The best form of carbon pricing depends on a country's circumstances, but a carbon tax has been identified as the most effective way to change behaviour. Carbon taxes are appealing because they can be added to existing gasoline and other fuel taxes and help countries meet pledges to reduce emissions under the 2015 Paris Agreement. They can also provide an additional revenue stream for governments, allowing them to cut burdensome taxes or fund development. Beyond direct carbon pricing, regulatory measures can minimise carbon emissions. Governments can set a renewable portfolio standard, which mandates producing a certain amount of energy from renewable sources like wind and solar. However, carbon pricing has an advantage over regulatory approaches because it forces a more rapid and broader behavioural shift in the type and amount of energy used. Electricity providers, manufacturers, and consumers will seek cleaner, lower-cost energy sources, adopt more efficient technologies, and reduce their energy demand to save money. The goal is to reduce emissions enough to limit global warming to 1.5°C– 2°C above pre-

industrial levels—the point of likely irreversible changes in sea level rise, extreme weather, availability of water, and other significant shifts.

An international carbon price floor is increasingly viewed as the way to get the world's largest CO_2 emitters to reduce emissions enough to keep global warming below the 2°C target. Concerted action can alleviate concerns that one country's energy-intensive or trade-exposed sectors will be less competitive or that companies will flee to countries with lower or no carbon prices. *The IMF has found that it will take a $75 a tonne price on CO_2 worldwide by 2030 to limit warming to 2°C. The world has far to go. Four-fifths of global emissions are not priced, and the global average emissions price is only $3 a tonne*.

There's a reason for slow action: such measures have costs in absolute terms and political decision-making. At $75 a tonne over ten years, electricity prices would rise, on average, by 45 per cent and gasoline prices by 15 per cent. Pursuing a just transition is vital. The revenue raised through carbon taxes will be necessary to compensate low-income households that struggle to afford higher energy costs and to support people who currently rely on coal, petroleum, and other fossil fuels for their livelihoods.

Adaptation: Yet the world is already facing increasingly severe weather. It affects government budgets worldwide, especially in poorer countries struggling to provide essential services. Adapting to climate change with more resilient infrastructure, securing water resources, improving crop production for dryland farming, protecting coastlines, and other measures can pay a triple dividend. Countries will suffer less from future climate shocks, enjoy greater productivity and growth, and reap social and environmental benefits. Adaptation can take many forms beyond direct government financing of infrastructure. It involves encouraging the private sector to adapt, social protection after disasters, and a holistic strategy for budgeting and planning those factors in climate change.

Adaptation is smart: According to a Global Commission on Adaptation report, every $1 invested in adaptation could yield up to $10 in net economic benefits, depending on the activity. The benefits of adaptation measures are apparent and save money in the long run, but they require up-front costs that are a struggle for many developing economies.

Some are caught in a vicious circle: limited fiscal space hinders their ability to adapt to climate change, and worsening climate shocks raise their risk premiums, increasing the cost of borrowing in global financial markets. When debt costs are higher, adaptation measures are less feasible.

Helping countries sustainably finance these investments is critical for adaptation and will help public finances in the long run. Reducing climate vulnerability by investing in resilience can reduce climate risk premiums. But too little climate financing is still available to prevent this destructive cycle. *Financing for adaptation totalled $30 billion on average annually in 2017 and 2018. Annual adaptation costs in developing economies alone are estimated at nearly $70 billion and are expected to rise to $140–$300 billion by 2030.* The world can meet its climate targets, but more work must be done on mitigation and adaptation. Unlike our metaphorical boat, there is only one Earth: our efforts to keep it afloat are a task of existential proportions.

e) Green Finance

Around the world, "green finance" is in hot demand. Europe leads the way, with over half its financial assets under management- 7 trillion out of 12 trillion euros invested in green funds or strategies. In the US, one-eighth of financial assets under professional management, or $8.4 trillion out of $66.6 trillion, is invested in funds with some sustainability criteria. Nine of ten asset owners in the Asia-Pacific region said they had "implemented" or "evaluated" sustainable investment in their strategies in 2022. The surge in investor

demand for green finance is good news for the environment, representing a potential reservoir of urgently needed funds to stabilise the climate. *According to a United Nations report, $125 trillion of climate investment is needed to meet the "net zero by 2050" emissions goal set by the Paris Agreement. McKinsey put the number substantially higher, at $275 trillion, an average of $9.2 trillion annually, or $3.5 trillion more annually than today.*

A global carbon price floor holds the potential to expedite the global shift towards sustainable energy solutions without compromising the competitiveness of individual nations. Escalating food and fuel costs, exacerbated by the surge in energy prices following Russia's invasion of Ukraine, underscore the urgency of moving away from vulnerable energy sources. Concurrently, the war has heightened concerns about food security due to crop failures and extreme weather events, amplifying the need for an accelerated transition to green energy. While carbon pricing emerges as a potent tool for redirecting investments from polluting to eco-friendly alternatives, many countries hesitate to implement it, fearing adverse effects on their competitiveness in high-emission sectors. *Addressing this dilemma, the International Monetary Fund (IMF) proposed an International Carbon Price Floor (ICPF) agreement, suggesting that major emitters pay a minimum carbon price of $25-$75 per tonne based on their economic development.*

f) Nuclear Fusion

Nuclear fusion happens in the Sun and other stars and involves joining two atomic nuclei to make one larger one. At COP 28, US Special Climate Envoy John Kerry announced an international plan to boost nuclear fusion as an emissions-free technology following a scientific breakthrough necessitating more public investment to scale the technology. He launched He was launching an International Engagement Plan – involving 35 countries – to boost nuclear fusion through research and development. The initiative will also focus on regulation and safety and reduce supply chain issues. Emissions-free nuclear fusion technology could be a game-changer in the fight against climate change if it can be scaled up.

Our current nuclear power stations use nuclear fission – essentially splitting an atom's nucleus. Nuclear fusion happens in the Sun and other stars and involves joining two atomic nuclei to make one larger one. Both reactions release large amounts of energy, but with nuclear fusion, there is a very high energy yield and very low nuclear waste production.

Fusion occurs when two light atoms bond or fuse to make a heavier one. The total mass of the new atom is less than that of the two that formed it; the "missing" mass is given off as energy, as described by Albert Einstein's famous $E=mc^2$ equation. There are several "recipes" for cooking up nuclear fusion, which rely on different atomic combinations. Today's most promising combination for power on Earth is the fusion of a deuterium atom with a tritium one. The process, which requires temperatures of approximately 72 million degrees Fahrenheit (39 million degrees Celsius), produces 17.6 million electron volts. Deuterium is a promising ingredient because it is an isotope of hydrogen. In turn, hydrogen is a vital part of water. A gallon of seawater (3.8 litres) could produce as much energy as 300 gallons (1,136 litres) of petrol. While nuclear fusion power offers the prospect of an almost inexhaustible energy source for future generations, it has also presented many so-far-insurmountable scientific and engineering challenges. In the Sun, massive gravitational forces create the right conditions for nuclear fusion in the star's core, but they are much harder to achieve on Earth. Fusion fuel – different isotopes of hydrogen – must be heated to extreme temperatures of around 50 million degrees Celsius, kept stable under intense pressure, and dense enough and confined for long enough to allow the nuclei to fuse.