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11. Climate-Smart Fisheries and Aquaculture Globally and in India

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11.1 Introduction:

Agriculture and allied sectors in the country are vulnerable to climate variability and change. The rise in temperatures and changes in precipitation patterns due to climate change is likely to have serious implications on water resource availability.

The manifestations of climate change have serious consequences on agricultural sector which will disproportionately affect poor and marginalized groups of people who are dependent on agriculture for their livelihoods (World Bank, 2017; Sikka *et al*, 2018).

The impacts of the accumulation of Green House Gases (GHGs) in the atmosphere and in the water affect the climatic parameters including gradual changes in water temperature, acidification of water bodies, changes in ocean currents, and rise in sea levels. These physical changes affect the ecological functions in aquatic systems both in freshwater and marine ecosystems (Cochrane *et al*., 2009). These also tremendously hamper fisheries and aquaculture sectors thereby affecting the spawning, survival of the juveniles, decline in primary productivity, population size, production, and yield (Tubiello and Fisher, 2007).

These can ultimately affect the livelihoods of many people who are engaged in fisheries and aquaculture activities for their primary and secondary sources of income as well as the food security of the country. Climate Smart Aquaculture is conceptualized from the concept of climate smart agriculture which is an integrated approach to managing landscapes—cropland, livestock, forests and fisheries to address the interlinked challenges of food security and climate change (FAO, 2010).

11.2 Importance of Fisheries and Aquaculture in India:

Fisheries occupy a unique position in the agricultural sector of the Indian economy. The sector contributes to the livelihood of a large section of the economically underprivileged population of the country. In addition to being a significant source of income and jobs, fisheries and aquaculture also help to grow a number of related sectors and provide access to low-cost, nutrient-rich foods (Ayyappan and Krishnan 2004). Fisheries is a complex enterprise that functions under an integrated network of natural resources, with other stakeholders that have forward and backward linkages with fisheries and other socio-political variables. Aquaculture is a rapidly growing sector in India that contributes immensely in the country's GDP. The major functions of the fisheries enterprises, including production, transportation, storage, and processing involve value additions from labor, capital, and management which greatly influence the rapid economic development of the country. Fisheries and aquaculture play a key role in the provision of food security and livelihoods of millions of people for their social, economic, and nutritional benefits. Trade has facilitated the sector's globalization, although output is concentrated in a few nations or areas, particularly when it comes to inland fisheries and aquaculture. Small-scale/artisanal fishermen and fish growers make up a large portion of the output and trade in developing nations, particularly in Asia.

11.2.1 Impact of Climate Change on Fisheries and Aquaculture:

The links between fisheries and their ecosystems are deeper and more significant than those that exist in common agriculture system. Climate change drives modifications in aquatic ecosystems and affects fisheries' productivity and food security. The amount of snow and ice has decreased, the ocean and atmosphere have warmed, and the sea level has increased. The uptake of additional energy in the climate system is caused by the increase in the atmospheric concentration of carbon dioxide (CO_2) and other greenhouse gases (GHGs). A range of scenarios for atmospheric concentrations of GHGs are used to model and project future climates; most of these scenarios indicate that a large fraction of anthropogenic climate change is irreversible for centuries to come even after the complete cessation of anthropogenic CO_2 emissions. Climate change is expected to have different typologies of consequences not only in fisheries but to the entire ecosystems. Due to its significant impact on employment, supply, income, and nutrition in those nations, fisheries and aquaculture can have a particularly significant impact on those nations that are more dependent on them. The distribution of various species is forecast to vary as a result of shifting conditions, which will also have an impact on the availability and circulation of items from aquatic industry. The accessibility of fish supplies, especially for small-scale fishermen, the fishing methods used, and consequently the dietary habits of the surrounding people, as well as the behaviors of producers, exporters, and consumers, may all be impacted by these species transitions. The changes in the distribution of fish resources can also put international fisheries agreements and governance under pressure. Trade and its patterns can also be affected, having consequences for countries who are more dependent on trade in fish and fish products for tax revenues and foreign exchange earnings, and with a potential impact on their food security. Consumption can also be affected by these shifts by making available on domestic markets fish species more or less favored by local consumers. The repercussions on consumption are expected to be more serious for communities dependent

on fishing and aquaculture, which rely on fish for food and livelihoods (Barange *et al*., 2014) and in particular for those living near climate-sensitive environments like low-lying coastal areas. When specific species affected by climate change are used for export or consumption, the implications could be worse, especially if there is no help provided by focused policies on adaptation to climate variability and change. The availability of aquatic resources and the global supply, as well as the price of the items, infrastructure, and services needed for the production, processing, and distribution of aquatic foods, are all projected to change as a result of climate change. By 2050, it is predicted that the impact of anticipated changes in temperature and precipitation on food output will increase food costs worldwide (Porter et al., 2014). When compared to a no-climate change scenario in 2050, the highest emission scenario examined in the Intergovernmental Panel on Climate Change's (IPCC) fifth assessment report is predicted to increase food prices by two percent to 35 percent (Nelson et al., 2014). This may also apply to fish prices, particularly if there is a decrease in supply on local markets or as a result of shocks brought on by unanticipated catastrophic events. The demand for and consumption of these goods may decline as a result of higher fish prices, which might have a significant negative impact on food security and malnutrition, especially among the most disadvantaged households. Higher prices could decrease demand, especially among those who are less affluent consumers.in countries that rely heavily on imports for their consumption.

11.2.2 Climate-Smart Fisheries and Aquaculture:

Three primary important objectives are addressed by climate-smart initiatives in fisheries and aquaculture. The first objective, which includes aquaculture and the environmental, social, and economic elements of fisheries, including both commercial fleets and artisanal fisheries, is linked to the goal of developing sustainable food systems. The second goal focuses on the requirement to lessen the industry's sensitivity to the effects of climate change and increase the industry's resilience so that it can manage the effects that climate variability and climate change are projected to have on resource availability as well as natural disasters brought on by a rise in the frequency of severe weather episodes. The third objective is to enable the sector to contribute to the mitigation of greenhouse gases emissions during the harvest and production stages and throughout the entire value chain, which, given the high level of processing, transport and marketing activities involved in the sector, is extremely important. Climate-smart approaches in this sector are connected with most, if not all, of the major cross-cutting themes of sustainable development. As in other sectors, several issues need to be recognized and reconciled for climate-smart approaches to become the default pathway for development. Existing practices, such as ecosystem-based management, fall within climate-smart approaches. Climate change, climate variability, and their effects on resource distribution are projected to have some of the biggest effects on productivity and livelihoods in the fisheries and aquaculture sector. Each region has different climate change effects and response choices. To lead the industry towards a sustainable future, local context-specific, climate-smart agriculture solutions will be necessary. Climate-smart aquaculture aims to support food security taking into account the need for adaptation and the potential for mitigation. It addresses the challenges of building synergies between the related objectives of climate change mitigation, adaptation and productivity and income increase and minimizing their potential negative trade-offs. Climate-smart aquaculture requires the following:

a. Increasing the production of fish and aquatic meals while using less natural resources.
b. preserving the communities that depend on and depend on resilient aquatic systems so that the sector can continue to contribute to sustainable development;
c. Learning how to lessen the vulnerability of individuals who are most likely to suffer adverse effects from climate change.

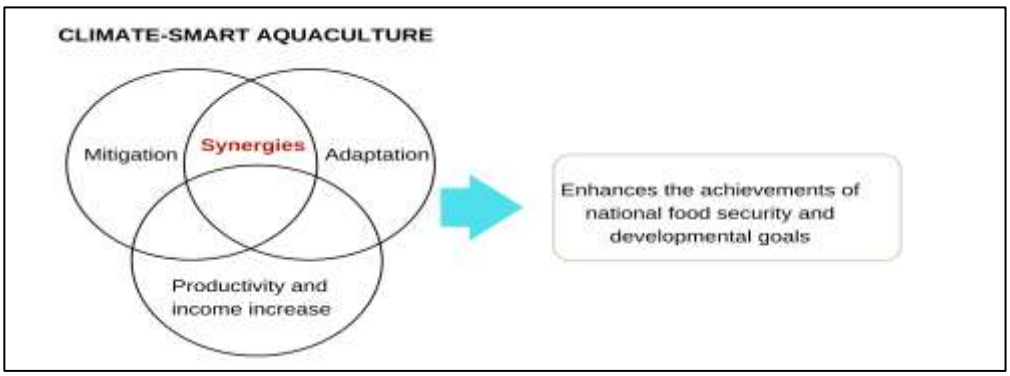

Figure 11.1: Components of Climate - Smart Aquaculture

Source: FAO, 2014

11.3 Fisheries and Aquaculture have Distinct Characteristics:

- Challenges specific to ecosystem complexity, including interactions at numerous scales across seascapes, watersheds, and landscapes, uncertainties regarding change and impacts, and the challenge of creating reliable and usable models;
- The potential hazards to productivity, stocks, and human health posed by the unusually quick interactions between pollutants and diseases in aquatic ecosystems, which are impacted by numerous factors of acidification and climate change;
- Lack of data, challenges in gathering data in complex, highly diversified social, economic, and ecological systems, and difficulty in getting stakeholders from these various systems and systems to agree on critical topics.
- The substantial degree of social and economic reliance on wild fish stocks in large- and small-scale ecosystems, which is connected to a variety of activities that exacerbate climate change;
- Socioeconomic problems associated with the utilisation of fishery resources in "last-resort" or emergency situations, as well as the prevalent social marginalisation and poverty in fishing villages along numerous supply chains;
- Aquaculture and capture fisheries have very little developed risk and insurance markets, and there are few options for community-based responses to less stable situations;
- Persistent governance problems, notably with regard to fisheries resources, such as significant IUU fishing and extensive fleet overcapacity;
- The political complexity of resource management systems, as well as the transboundary nature of key resource systems, encompassing places outside of national jurisdiction;
- The tropical regions' high concentration of aquaculture and their dense populations;

- The vital role small-scale fisheries play in ensuring food security and nutrition by producing fish at reasonable prices available and accessible to poor populations and are a key means for sustaining livelihoods in marginalized and vulnerable populations, compared to large-scale industrial fishing (HLPE, 2014).

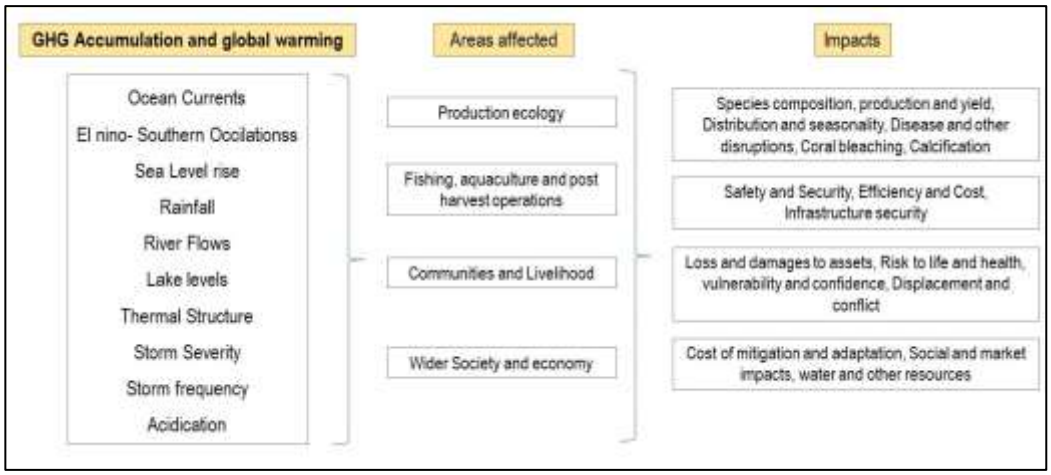

Figure 11.2: Potential Climate Change Impact Pathways for Fisheries and Aquaculture

Source: FAO, 2014

11.4 An Ecosystem Approach to Fisheries and Aquaculture:

A comprehensive method for managing catch fisheries and aquaculture that incorporates all of the ecological, socioeconomic, and institutional aspects of the industry is the ecosystem approach to fisheries and aquaculture. The strategy emphasizes management of fisheries and aquaculture, rather than just the development and management of commercially significant species. It takes into account the interconnections between the essential components of the productive fish system, the people who depend on them, as well as the other social and ecological components of the system.

It encourages the sector's contributions to more comprehensive multisectoral goals and is consistent with overall ecosystem approaches to development. The ecosystem approach to fisheries and aquaculture aims to direct planning, development, and management of these industries in a way that meets the many needs and aspirations of society without jeopardising the opportunities for future generations to benefit from the full range of goods and services provided by aquatic ecosystems.

By considering both the knowledge and the uncertainty about the biotic, abiotic, and human components of ecosystems and their interactions, the strategy uses an integrated management approach within ecologically appropriate boundaries and aims to balance various social objectives. The use of the ecosystem approach to fisheries and aquaculture must abide by the following guidelines in order to achieve progress towards the overarching objective of enhancing the wellbeing of communities and the ecosystem. (FAO, 2003):

- Apply the precautionary approach when faced with uncertainty;
- Use the best available knowledge, whether scientific or traditional;
- Acknowledge multiple objectives and values of ecosystem services;
- Embrace adaptive management;
- Broaden stakeholder participation with due consideration to gender;
- Ensure equitable distribution of benefits from resource use; and
- Promote sectoral integration and interdisciplinarity.

A broader and more comprehensive approach to analysis and management practises is required by the ecosystem approach. The method itself can help with tracking climate change and its effects. Using an ecosystem-based approach would enable the tracking of changes in aquatic ecosystems and the pathways via which they have an influence on fisheries and aquaculture systems.

The identification of issues that require management attention and the prioritisation of those issues through risk assessment are crucial steps in any ecosystem approach process. This must include all direct and indirect effects on supply chains, industry processes, and larger aquatic and coastal systems. The identification of problems that may be external to the management system is also a part of this process, including global demand, input prices, climate variability and change, that are affecting, or could affect in the future, the performance of the system and its management.

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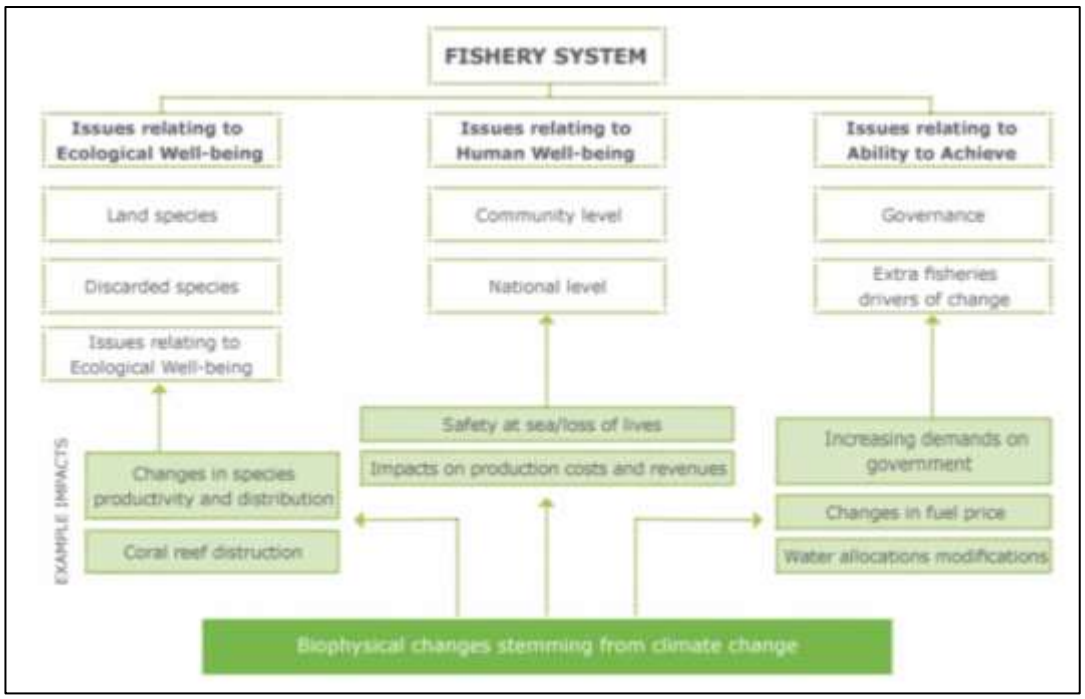

Figure 11.3: Ecosystem Approach to Fisheries issue identification process to identify climate change impacts (Source: FAO, 2017)

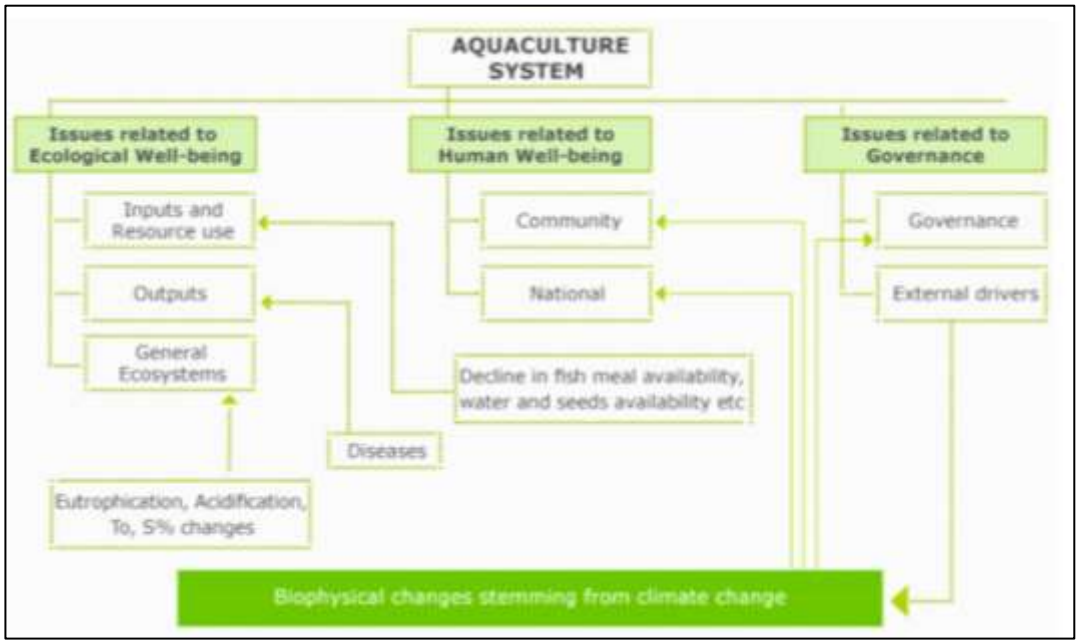

Figure 11.4: Ecosystem Approach to Aquaculture issue identification process to identify climate change impacts (Source: FAO, 2017)

11.5 Climate Change Processes and Impacts:

The Intergovernmental Panel on Climate Change (IPPC) Fifth Assessment Report offers proof that global warming is happening and that it is having an impact on the seas, coastal regions, and inland waterbodies (FAO, 2016a). The number and distribution of fishery resources as well as the viability of some geographic sites for aquaculture systems are being impacted by climate change in addition to other factors that influence climate variability, such as El Nio-Southern Oscillation and extreme weather events. Rising carbon dioxide emissions are associated with physical and chemical changes connected to the climate. Aquatic systems are absorbing a significant portion of these emissions, which is leading to significant changes in aquatic ecosystems and impacting the crucial functions they offer for preserving food security and livelihoods (FAO, 2016b). changes in the climate that have an impact on how often and how ecological processes occur, changes in salinity and freshwater content, oxygen concentration, carbon absorption and acidification, temperature and thermal stratification, sea levels, ocean circulation, surface wind, storm systems, and waves all affect the severity and location of extreme weather events (Cochrane et al., 2009; FAO, 2016b). In fisheries and aquaculture, these changes are likely to have a variety of direct and indirect effects.

There is proof that the distribution of marine species is changing as a result of climate change. To find their perfect ecological circumstances, many species are moving towards the poles and deeper oceans. These alterations in migratory patterns alter the dynamics of interspecies interactions, trophic connections, and food webs. Several aquatic species are expected to experience changes in their size, reproductive cycles, and survival rates if migration is not possible. Depending on the area and latitude, both positive and negative

effects will be felt. New invasive species will probably fill the void left by some commercial species moving offshore and away from conventional fishing sites. There may be new livelihood opportunities in some areas if these novel species are suitable for ingestion by humans or other animals.

Ecosystem production is probably going to decrease in the majority of tropical and subtropical marine settings, seas, and lakes despite the incursion of species that are tolerant of higher temperatures and changes in the chemical composition of coastal waters. According to projected scenarios, capture fisheries productivity will rise in high-latitude systems while declining in low- and mid-latitude systems. Extreme weather events, hypoxic zones, rising temperatures, and acidification are all threats to coastal systems (FAO, 2016b).

Increasing sea levels have the potential to destroy a variety of agricultural methods in delta zones by displacing brackish and freshwater ecosystems. The productivity of freshwater fisheries and aquaculture is also impacted by the loss of coastal wetlands. Rising sea levels, nevertheless, might also open up new ecosystems and business prospects for the industry (e.g. through marine aquaculture and the expansion of mangrove forests). Sea level rise could directly threaten fishermen and communities that depend on fishing on coasts and at sea, as well as cause damage to housing, community facilities, and infrastructure used for fisheries and aquaculture. These factors include increased storm frequency and intensity, coastal flooding, coastal erosion, and saltwater intrusion. Aquaculture systems for marine shellfish are particularly susceptible to changes in carbon chemistry, which can influence how some species build their shells. For most species, the sensitivity to acidification and pathogens becomes greater when they are forced into habitats at the edges of their thermal ranges (FAO, 2016b).

It is anticipated that climate change would have a considerable influence on freshwater fisheries and aquaculture. The productivity of rivers, lakes, and floodplains will be impacted by the increasing variability in precipitation levels and changes in air and water temperatures. Higher temperatures and other climatic factors that affect inland ecosystems and species distribution are frequently made worse by non-climatic factors such invasive species, pollution, habitat destruction, and the damming of rivers. Freshwater reservoirs in the region will come under increasing pressure to supply the rising demand for irrigation. In general, places with severe water stress and intense competition for water resources will put inland fisheries at danger (FAO, 2016b). As a result of "gradual warming, ocean acidification, and changes in the frequency, intensity, and location of extreme events," aquaculture systems will be impacted by climate change (IPPC, 2014a). There will be certain production systems that need to be moved (IPPC, 2014a).

Climate change may have a substantial impact on post-harvest operations, production processes that add value, and the delivery of fish to regional and national markets in the fisheries and aquaculture sector. Changes in the availability of other crucial inputs, such as electricity and water for processing, as well as changes in the location and fluctuation of supply, are also possible. These climate-related changes will all take place concurrently with additional national, regional, and international socio-economic pressures on natural resources. It will increase the impacts on food security and nutrition, habitation and social stability.

11.6 People, Communities and Vulnerability:

The IPCC has amended its theoretical risk framework in its Fifth Assessment Report to better understand how to promote the adaptation process of natural and human systems to climate-related changes by acknowledging that "climate change is not a risk per se" (IPPC, 2014a, p. 1050). Only in systems that are unable to handle it does climate change become a risk.

a. The probability of climate-related events or changes (such as sea level rise, acidification, and increasing water temperatures)
b. how much of the system is exposed to the risk (for example, the number of coastal communities in the area where the climate event happens, the number of commercially significant fish species in a lake, or the presence of coral reefs);
c. as well as the system's flaws (e.g. the lack of an early warning system, overfished resources, undiversified practices and livelihood strategies).

The effects of climate change put hundreds of millions of people who depend on fisheries, aquaculture, and fish processing for their livelihoods, food security, and nutrition at danger (FAO, 2016a). Extreme occurrences (such as hurricanes and cyclones) and sea level rise pose a particular hazard to fishermen, coastal communities, and sector-related infrastructure. In its Fifth Assessment Report, the IPPC noted that one model predicts a 21 percent annual decline in the value of marine fish landed in West Africa, a nearly 50 percent decline in employment related to fisheries, and an overall annual loss of US$ 311 million to the region's economy compared to 2012. (IPCC, 2014b). Several research have looked into how climate change can affect fisheries and aquaculture. Allison et al. (2009) examined how vulnerable national economies are by looking at how climate change has affected their fisheries. Bell et al. (2011) examined tunas, feeding habits, coral reefs, mangroves, freshwater habitats, and fishing operations in the context of the vulnerability of species, food webs, and ecosystems tropical Pacific islands.

The sensitivity of coral reef systems to climate change was incorporated into measures relating to the vulnerability of fishing communities that depend on coral reefs by Cinner et al. (2012) in order to capture the connections between human activities and aquatic systems. By combining the expected effects of climate change with the reliance of economies and food systems on fisheries, Barange et al. (2014) argue that these implications will be most concerning in South and Southeast Asia, South West Africa, Peru, and several SIDS in the tropics. Cambodia and Viet Nam are two of the nation’s most vulnerable to the effects of climate change on fisheries in the Lower Mekong Delta of Asia (IPCC, 2014b).

According to the Fifth Assessment Report, Colombia and Peru are the South American nations whose fisheries are most at risk from the effects of climate change. The combined consequences of actual and predicted warming trends, species transitions, productivity changes in oceanic upwelling systems, the relative importance of fisheries to country economies and diets, and their limited ability to adjust to associated risks and opportunities have made them vulnerable (IPCC, 2014a). Climate change is likely to have a negative effect on nations that border semi-enclosed oceans and/or significantly rely on their inland fisheries.

Extreme climate events can have a particularly negative impact on cities and nations around the coast as well as those near large rivers and lakes. According to an FAO estimate undertaken between 2003 and 2013, the agriculture sector in developing countries, including fisheries and aquaculture, absorbs about 22% of the economic damage brought on by medium- and large-scale natural disasters. The effects of climate change and climate variability tend to be more severe for SIDS, whose economies are heavily dependent on fisheries and where the industry is crucial for food security and employment (FAO, 2015a). Supply and value chains are likely to be affected by changes in temperature and humidity. For example, traditional food processing in the Arctic (e.g. the drying of fish) is at risk due to increasingly wet conditions. Evidence of rising rates of food-borne illnesses, such as ciguatera fish poisoning, are heightening concerns about the impact of climate change on food safety (IPCC, 2014b). Along with its impacts on food security and safety, climate change may also threaten human health by increasing the incidence of other types of diseases. The impacts are likely to affect infrastructure in all sectors, as well as social services, causing displacement of communities and subsequent migration and/or conflict. Small-scale fishermen are particularly vulnerable to climate change because they rely so largely on inland and coastal fishing. Almost 47 million people are employed by small-scale fisheries, with 12.5 million of them directly involved in fishing and another 34.5 million working in post-harvest activities (IPCC, 2014b). These fisheries, particularly in tropical nations, are frequently at risk because of a variety of issues, such as the great degree to which low-latitude regions are exposed to the effects of climate change, subpar governance and management systems, and scant or no information on fish stocks (IPPC, 2014a). The majority of aquaculture production takes place in the tropics, which also have large people populations, making the industry particularly vulnerable (De Silva and Soto, 2009).

Adaptation and Mitigation Strategies:

By preserving or boosting adaptive capacity and system resilience, adaptation is described as actions that "increase the resilience of human or natural systems to the consequences of climate change and climate-related threats."

Adaptation Strategies:

a. Addressing the causes of vulnerability Increase household income diversity
b. Take part in income stabilisation programmes Implement social protection programmes
c. Encourage community-based risk management strategies to deal with production failure and product price fluctuations
d. Create novel risk financing and insurance instruments to lower climate-related risks
e. Developing reaction capability, protecting genetic resources, and putting co-management procedures in place.
f. Handling the Climate of Disasters

Mitigation Strategies:

In addition to "technological advances that minimize resource inputs and emissions per unit of output," mitigation supports initiatives to lower or restrict greenhouse gas emissions or to improve greenhouse gas sequestration.

The following are the main options to reduce climate change:

a. Lowering emissions by implementing better aquaculture management
b. Removing or avoiding emissions

decreasing post-harvest losses, using fishing methods in accordance with the code of conduct for responsible fisheries, removing emissions, and replanting mangroves in aquaculture areas are some of the objectives.

Constraint to Climate-Smart Fisheries and Aquaculture:

a. Initial costs that are higher; formal and informal tenure systems that have unstable tenure;
b. cultural barriers including community norms and rules;
c. Limited information and accessibility to extension services
d. Restricted access to inputs in the local market, no credit or insurance markets.

11.7 Conclusion:

A climate wise approach is necessary because it combines adaptation and mitigation in a way that will improve sustainable fisheries production in the face of climatic change. Climate change is a severe challenge for the entire world. The climate wise strategy is also not widely known.

A greater understanding of climate-smart fishing techniques has the potential to improve food security and farmers' ability to make a living over the long term. Farmers and scientists alike are working around the clock to ensure cleaner and more effective methods of processing fish in India. Improved and modern fishery/aquaculture techniques are required to adapt to the changing climate as well as reduce the release of GHGs from processing activities into the atmosphere.

A fundamental strategic and operational issue is to provide quick and efficient solutions to climate change in the fisheries and aquaculture sector, and to mainstream climate-responsive practises within broader development goals. Within established fields and situations, conventional methods for constructing and validating evidence might not always be workable. It will be necessary to develop experience through an adaptive management method based on action learning with widespread stakeholder participation and information exchange. Also, more research will need to be done on how vulnerable people are to climate change. To ensure that the most vulnerable states, production systems, communities, and individuals have the ability to design and apply solid climate-smart methods, practical measures must be established. To expand information technology and modelling of climate change data, it will be important to create conveniently accessible regional, national, and local depositories for climate and related data. To respond to expected changes in rainfall and temperature, appropriate adaptation and mitigation measures should be site-specific. Regeneration of fish stocks and ecosystems would require models for sustainable fisheries management and the preservation of aquatic resources.

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