Worthy of consideration also is the record of updated inventory of the amount of chemicals being used by each AMS, their application and assessment of the effect on the target objective of usage and the side effect to humans and the environment. Each AMS should have already adopted the ASEAN Guidelines for the Use of Chemicals in Aquaculture and Measures to Eliminate the Use of Harmful Chemicals (ASEAN, 2013). Nonetheless, competent authorities should be well-equipped with laboratory facilities and police powers for proper implementation.

6.5 Addressing Concerns Due to Intensification of Aquaculture and Climate Change

As the biggest producer of fisheries products both from capture and aquaculture, Asia has been considered the birthplace of aquaculture (FAO, 2016b; FAO, 2016c; Tacon *et al*., 1995). From 1950 to 2014 (**Figure 77**), Asia provided an average of 83% to the total world aquaculture production, with Southeast Asia contributing 9-31% to Asia's total aquaculture production (**Figure 78**). Indonesia and the Philippines contributed the most at 23-63% and 10-45% of the total, respectively (**Figure 79**). With the increasing demand for fish and fishery products and the dwindling supply of wild aquatic resources, aquaculture, considered a reliable solution to food security problems, is being intensified to compensate for the declining fisheries production. Aquaculture intensification has already caused aquaculture production to overtake the contribution of capture fisheries to the total world production at 51% in 2013 (FAO, 2016b).

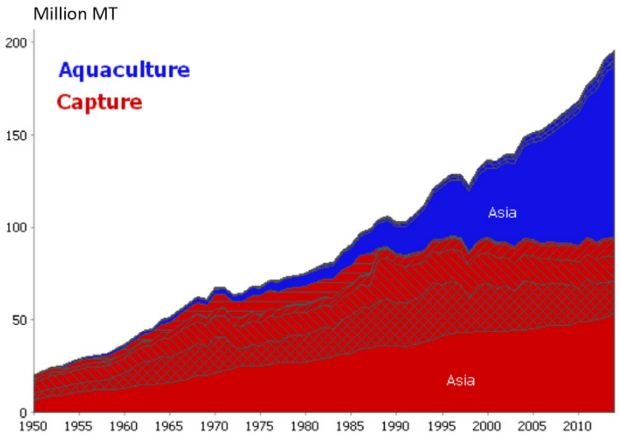

Figure 77. Total world capture (red) and aquaculture (blue) production from 1950 to 2014 by quantity; shaded areas with different patterns represent different continents and plain area represents Asia

Source: *FAO Database 2016*

However, as aquaculture production intensifies, a number of problems have been linked with it. The phenomenal growth of aquaculture in the recent years has caused modification, destruction or complete loss of habitat; unregulated collection of wild broodstock and seeds; translocation or introduction of exotic species; loss of biodiversity; introduction of antibiotics and chemicals to the environment; discharge of aquaculture wastewater, thus coastal pollution; salinization of soil and water; and dependence on fishmeal and fish oil as aquaculture feed ingredients, to name a few (Beveridge *et al*., 1994; Chua *et al*., 1989; Iwama, 1991; Naylor *et al*., 2000; Primavera, 2006). Thus, efforts have been done to balance the need to increase production and minimize the impacts of aquaculture on the environment.

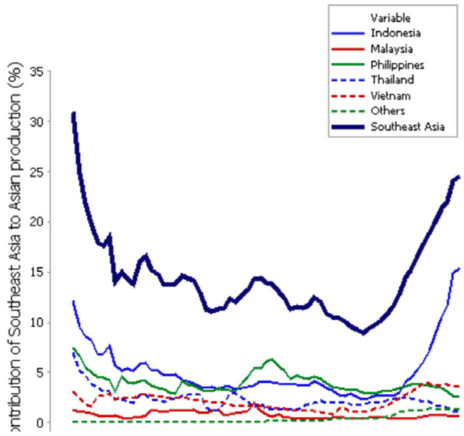

Figure 78. Contribution of Southeast Asian countries to aquaculture production in Asia, and top aquaculture producing Southeast Asian countries (1950-2014)

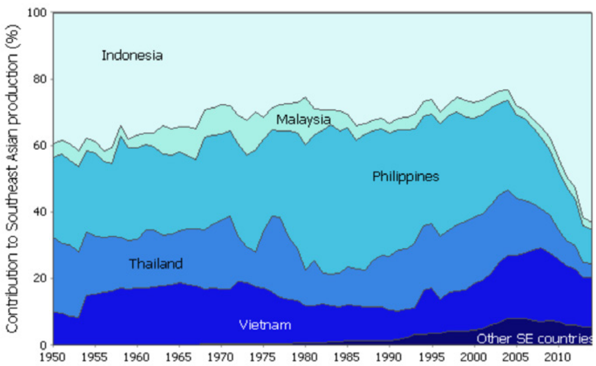

Figure 79. Contribution of Indonesia, Malaysia, Philippines, Thailand, Viet Nam and other Southeast Asian countries (Brunei Darussalam, Cambodia, Lao PDR, Myanmar, Singapore, and Timor-Leste) to aquaculture production in Southeast Asia from 1950 to 2014

Source: *FAO Database 2016*

Aside from aquaculture, the natural environment has also been greatly affected by extreme weather conditions brought about by climate change. Scientific evidence of the warming climate system is unequivocal and compelling. Extreme events, like numbers of recorded high temperature, numbers of intense rainfall, strengths of typhoons and storms, and the like, have been increasing since the 1950s (IPCC, 2007). Southeast Asia is not spared

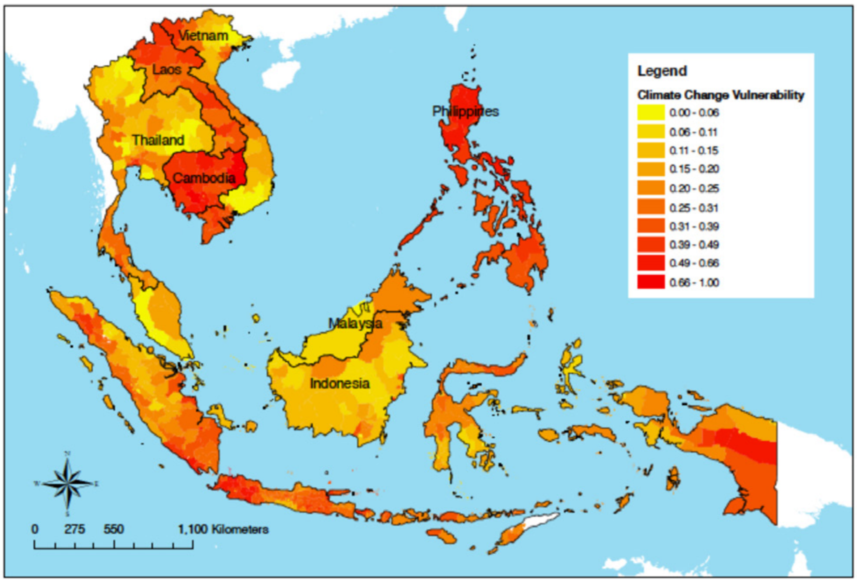

Figure 80. Climate change vulnerability map of Southeast Asia

Source: *Yusuf and Francisco, 2009*

from these impacts of climate change and of the countries in the region, the Philippines is the most vulnerable to the global changes (**Figure 80**) brought about by the changing climate (Yusuf and Francisco, 2009). The impacts of aquaculture coupled with extreme changes in climate could cause irreversible damage to the environment. Different sectors of the society have concerted their efforts to help mitigate the impacts of the fast changing climate.

6.5.1 Current Status of the Environment

In 2013, aquaculture became the major source of fisheries products after it has overtaken production from capture fisheries. Despite its own share of the problems that need to be addressed, the most important of which is its impact on the environment, the important role of aquaculture in food production provides a strong and credible argument for its continued implementation. Aquaculture continues to provide valuable food supply and economic support for many countries, especially in the Southeast Asian region. To limit the potential negative environmental impacts of aquaculture effluents, studies are conducted while policies and laws are formulated. There is also a joint effort of the scientific community, academe, policy makers, farm owners, and government authorities to come up with approaches that might help reduce production of aquaculture wastes or mitigate its impact. The specific strategy for mitigating the negative effects of aquaculture will depend on local conditions. Among the basics are choosing a location with high flushing rates and deep water, and using dry, easily digested feeds that will help reduce the potential negative impacts (Iwama, 1991). Tacon and Forster (2003) have suggested approaches for aquaculture farmers to follow to protect the environment (**Box 18**).

Box 18. Suggestions for aquaculture farmers to protect the environment

- treating farm effluents prior to discharge
- limiting the concentration of specific dissolved or suspended inorganic and organic materials and/or nutrients contained within the effluent discharged from the farm
- establishing maximum permissible amounts of specific nutrients (such as total nitrogen or phosphorus) that the farm is able to discharge over a fixed period of time
- limiting the total number of licenses that can be issued and/or size of farm, depending upon the vicinity of other farming operations and the assimilative environmental carrying capacity of the receiving aquatic ecosystem
- limiting or fixing the total quantity of feed the farm is able to use over a fixed period of time
- fixing maximum permissible specific nutrient levels within the compound feeds to be used to rear the species in question
- banning the use of specific potentially high-risk feed items such as fresh/trash fish and invertebrates and certain chemicals and antibiotics
- prescribing minimum feed performance criteria
- requiring the (i) use of specific Codes of Conduct, including appropriate Best Management Practices (BMPs) for farm operations; (ii) development of suitable farmor pond sediment management strategies for the storage and disposal of sediments; and/or (iii) implementation of an environmental monitoring program

At present, most fish farmers on one hand do not follow the said approaches but if implemented, only some of the approaches are followed, and as a result, the environment continues to suffer. On the other hand, the worsening climate has added its toll to the already suffering environment. Global sea level rose by about 17 cm in the last century with the rate in the last decade nearly doubled that of the last century (**Figure 81**) (Church and White, 2006). In 2008, extreme sea levels were high along the coasts of Southeast Asian countries, and low at most of the islands in the tropics (Peterson and Baringer, 2009). The global surface of the Earth, as shown by temperature reconstructions, has warmed since 1880. Most of this

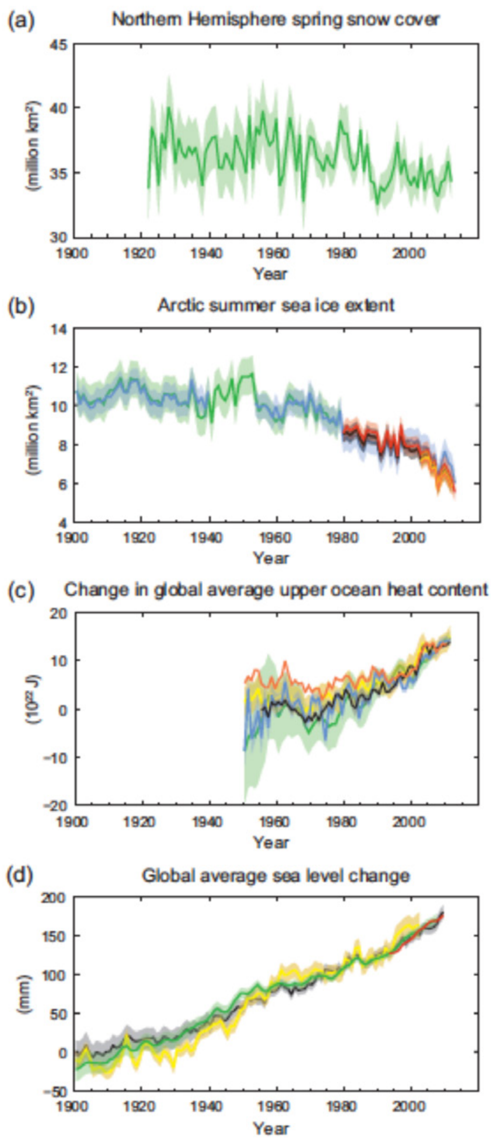

Figure 81. Observed indicators of a changing global climate from 1900-2012:
(a) Northern Hemisphere average snow cover for spring (March-April);
(b) Arctic average sea ice for summer (July-September);
(c) change in global average upper ocean heat content; and
(d) global average sea level change

Source: *IPCC, 2013*

warming has occurred since the 1970s with all 10 of the warmest years occurring in the past 12 years (Peterson and Baringer, 2009). In turn, the oceans have absorbed much of this increasing heat, warming the top 700 m by 0.302°F (~0.17°C) since 1969 (Levitus *et al*., 2009). Satellite observations reveal that the amount of spring snow cover in the Northern Hemisphere has decreased over the past five decades with the snow melting earlier. Since the beginning of the Industrial Revolution, the acidity of surface ocean waters has increased by about 30% resulting from increasing carbon dioxide (CO_2) emission into the atmosphere and hence more are being absorbed by the oceans. The amount of CO_2 absorbed by the upper layer of the oceans is increasing by about 2 billion metric tons per year (Sabine *et al*., 2004). In 2008, the most extreme land precipitation events have greatly affected Japan and the Southeast Asian countries. Regional *La Niña* impacts included above-average rainfall across much of the Maritime Continent (*e.g.*, Indonesia, Philippines, Malaysia, and Borneo) extending to northernmost portions of Australia (Peterson and Baringer, 2009). The impacts of climate change in forms of different weather disturbances are not limited only to a few places but everywhere. The daunting reality is that through the years these disturbances intensify causing excessive casualties to the natural environment.

6.5.2 Issues and Constraints

6.5.2.1 Intensification of aquaculture

Modification, destruction, or complete loss of habitat: Among the coastal ecosystems, mangroves are the most greatly affected by aquaculture since most aquaculture ponds were constructed in mangrove areas. Southeast Asia has the widest and the most diverse mangroves in the world but between 1980 and 2005 it suffered a decline of 26.46% (Spalding *et al*., 2010). Most of these losses were due to conversion into milkfish and shrimp ponds (Naylor *et al*., 2000), resulting in loss of goods and ecosystem services generated by mangroves—plant and wood products, provision of nursery habitat, coastal protection, flood control, sediment trapping, and water treatment (Bandaranayake, 1998; Ewel *et al*., 1998; Macnae, 1968). Aside from losing these goods and services, converting mangroves into aquaculture ponds transforms an open access fisheries with multiple users to a privatized farm resource of few wealthy individual investors and business enterprises.

Loss of biodiversity: The impacts of aquaculture on biodiversity are rarely positive, sometimes neutral, but usually negative to some degree (Beveridge *et al*., 1994). Loss of biodiversity is one of the consequences of habitat modification or its complete destruction to give way to aquaculture ponds. Globally, mangrove biodiversity is highest in the Indo-Malay Philippine Archipelago, with 36-46 of the 70 known mangrove species occurring in this region. However, the region has one of the highest rates of mangrove area loss at an estimated 30% reduction in mangrove area since 1980 (Polidoro *et al*., 2010). Although mangrove species diversity may be low, faunal, microbial, and other associated species diversity can be high (Alongi, 2009). Thus, losing mangroves means losing a highly complex system that serves as nursery or permanent residence for a range of organisms, both from the terrestrial and the aquatic environments (Alongi, 2002; Macnae, 1968). Unregulated collection of broodstock and wild seeds for use in aquaculture facilities also threatens the wild population. The same may happen to fish species harvested for use in fish meal and fish oil production. Regardless of purpose, indiscriminate harvesting of wild stocks has negative impact on biodiversity.

Discharge of aquaculture wastewater and introduction of antibiotics and chemicals to the environment: Aquaculture has heightened public concerns about pollution, water quality degradation, health, and other violations of the public trust (Costa-Pierce, 1996). Aquaculture wastewater outputs and loads vary widely, depending upon the species cultured, farming system, and aquatic environment employed (Tacon and Forster, 2003). Aquaculture wastes are mostly derived from excess feeds and fecal matter. Continuous discharge of wastewater without treatment may result in a chain of undesirable events, *e.g.* serious oxygen deficit caused by the decomposition of organic substances, sedimentation, eutrophication or algal bloom caused by the accumulation of organic nutrients like nitrogen and phosphorus, changes in energy and nutrient fluxes, changes in pelagic and benthic biomass and community structure and fish stocks, low productivity, sometimes disease outbreaks. Moreover, the inadequate handling of wastewater has serious consequences on human health, the environment, and economic development (Cao *et al*., 2007). Aside from wastewater, aquaculture also introduces various chemicals to the environment in the form of therapeutants, disinfectants, water or soil treatment compounds, algicides and pesticides, fertilizers, and feed additives. Too much use of these chemicals can result in toxicity to non-target populations, human consumers and wild biota, and the accumulation of their residues (Primavera, 2006). Antibiotics (tetracycline, oxytetracycline, oxolinic acid, furazolidone and chloramphenicol) are also used excessively and may lead to the development of resistant bacterial populations (Hoa *et al*., 2011; Tendencia and de la Peña, 2001).

6.5.2.2 Climate change

Solar irradiance: Studies have shown that solar variability has played a role in past climate changes. A decrease in solar activity is thought to have triggered the Little Ice Age between approximately 1650 and 1850, when Greenland was largely cut off by ice from 1410 to the 1720s while glaciers advanced in the Alps. Since the sun is the fundamental source of energy that drives our climate system, it is just reasonable to assume that changes in its energy output would cause the climate to change. However, the current global warming could not be explained by changes in energy from the sun. Since 1750, the average amount of energy coming from the sun either remained constant or increased slightly. If warming was caused by the sun, the atmosphere is expected to be warmer in all layers. However, a cooler upper atmosphere and a warmer surface lower atmosphere were observed. Greenhouse gases are the ones trapping heat in the lower atmosphere making it warmer than the upper atmosphere (IPCC, 2007).

Greenhouse effect: Most climate scientists agree that the main cause of the current global warming trend is human expansion of the "greenhouse effect," as human activities are changing the natural greenhouse. Over the last century, burning of fossil fuels like coal and oil has increased the concentration of atmospheric CO_2. Clearing of land for agriculture, industry, and other human activities have also increased the concentrations of greenhouse gases. Industrial activities that our modern civilization depends upon have raised the atmospheric CO_2 levels from 280 ppm to 400 ppm in the last 150 years. Among the consequences of changing the natural atmospheric greenhouse include warming of the earth, warming of the oceans, melting of glaciers, increased sea level, and increased evaporation and precipitation (IPCC, 2007; NASA, 2016).

6.5.3 Outlook and Future Perspective

Habitat rehabilitation or restoration: In the case of aquaculture, habitat rehabilitation or restoration is more focused on mangroves which suffered most because of pond construction. In the review paper of Ellison (2000), he cited that although most of the objectives of restoration projects were for forest products, coastal protection and stabilization, two Southeast Asian countries set their goals for maintenance or sustainability of fisheries (Malaysia) and provision of habitat for wildlife (Viet Nam). Rehabilitating nursery habitats is also effective in restoring populations of naturally occurring species and considered as one of the approaches in enhancing fisheries (Welcomme and Bartley, 1998). This has been observed in mud crabs, *Scylla* spp. in the reforested mangroves in Kalibo, Aklan, Philippines (Walton *et al*., 2007) and mangrove recolonized in an abandoned pond in Dumangas, Iloilo, Philippines (Lebata-Ramos, unpublished data).

Stock enhancement: Stock enhancement using individuals reared in aquaculture facilities is becoming a popular method of supplementing depleted stocks (Bert *et al*., 2003). Bell *et al*. (2006) discussed two of the most successful stock enhancement initiatives—the augmentation of scallop fishery in Hokkaido, Japan causing a four-fold increase in annual harvest. Success in stock enhancement depends on setting the management goals and identifying the right species for release. It can be a very effective tool if accompanied with habitat restoration because it will be of no effect in situations where recruitment is limited due to lack of sufficient nursery areas (Bell *et al*., 2006). Although stock enhancement activity may change the status quo of the ecosystem, given the substantial damage these ecosystems have suffered due to anthropogenic activities and the depletion of fishery resources due to overfishing, the impact of adding juveniles aimed at improving production of target species should not be a cause of great concern, provided that this activity is conducted responsibly and that this will not cause further degradation to the ecosystem and its diversity (Lebata, 2006).

Aquasilviculture: Mangroves and aquaculture are not necessarily incompatible (Primavera, 2006). Marginal coastal sites such as denuded and overexploited mangrove areas and unproductive or abandoned fishponds can be made productive and economically profitable through aquasilviculture. The integration of aquaculture with silviculture, known as aquasilviculture refers to the harmonious co-existence of aquaculture species and mangrove trees (de la Cruz, 1995). This mangrove-friendly aquaculture technology had been applied in shrimp ponds (Primavera *et al*., 2007) and mud crab pen culture (Primavera *et al*., 2010; Triño and Rodriguez, 2002) in the Philippines; shrimp-mangrove farms in Viet Nam (Binh *et al*., 1997); and milkfish pond culture, milkfish and shrimp polyculture (Fitzgerald and Savitri, 2002), and shrimp pond culture (Shimoda *et al*., 2006) in Indonesia. Using the concept of mangrove resource rehabilitation and livelihood provision, the Philippine Bureau of Fisheries and Aquatic Resources recently implemented the National Aquasilviculture Program to help address climate change, food security, and poverty among municipal or artisanal coastal fisherfolks (Dieta and Dieta, 2015). Aside from integrating aquaculture into the mangroves, aquaculture species (*i.e.* seaweeds, mussels, oysters, and fish) are also being reared in mangrove waterways.

Integrated aquaculture: The concept and practice of integrated aquaculture is well-known in inland environments in Asia, but much less reported in the marine environment. In the recent years, the idea of integrated aquaculture has been often considered a mitigation approach against the excess nutrients and organic matters generated by intensive aquaculture activities particularly in marine waters. Integrated marine aquaculture can cover a diverse range of co-culture and farming practices, including integrated multi-trophic aquaculture (IMTA) and aquasilviculture. IMTA explicitly incorporates species from different trophic positions or nutritional levels in the same system for bioremediation and economic returns (Soto, 2009). Integration can be directly beneficial to farmers either through additional valuable products, improving water quality, preventing diseases, habitat conservation, or increasing allowed production volumes through waste reduction (Troell, 2009). Neori *et al*. (2004), for example, reported that annually, a 1-ha land-based integrated sea bream–shellfish–seaweed farm can produce 25 metric tons of fish, 50 metric tons of bivalves, and 30 metric tons fresh weight of seaweeds or 55 metric tons of sea bream or 92 metric tons of salmon, with 385 or 500 metric tons fresh weight of seaweed, respectively, without pollution. In coastal fishing communities in Guimaras, Philippines, SEAFDEC/AQD has successfully introduced the concept of IMTA through the combined pen culture of milkfish *Chanos chanos*, with sandfish *Holothuria scabra*, and seaweeds *Kappaphycus* sp. Funded by Japan International Research Center for Agricultural Sciences (JIRCAS), the project aimed to demonstrate the potential of IMTA in mitigating the impacts of excess nutrients from uneaten milkfish feeds and milkfish feces while obtaining additional income from other non-fed species.

Modern integrated systems are bound to play a major role in the sustainable expansion of world aquaculture. IMTA seems to be the direction of aquaculture in order to make it economically and environmentally sustainable.

Proper feeding management: Most aquaculture wastes are usually dietary in origin. Aquaculture feeds and feeding regimes can play a major role in determining the quality and potential environmental impact of fish and crustacean farm effluents (Tacon and Forster, 2003). Optimized local feed management together with further development of fish feed in terms of increased digestibility of feed components will lead to greater profitability to the farmer and also minimize aquaculture wastes (Kolsäter, 1995). Boyd (2003) suggested the Best Management Practices (BMPs) that pertain to feeding management (**Box 19**).

Box 19. Suggested Best Management Practices (BMPs) pertaining to feed management

- use fertilizers only as needed to maintain phytoplankton blooms
- use high quality, water stable feeds that contain only the required amount of nitrogen and phosphorus than necessary
- apply feeds conservatively to avoid overfeeding and to assure that as much of the feed is consumed as possible

Feeding may also be improved through the use of automatic feeder and by employing compensatory feeding. Feeding regimes may be manipulated in such a way that feed inputs to the environment may be minimized without sacrificing production.

Climate change adaptation and mitigation: The fast changing climate is inevitable and to survive this irreversible condition, adaptation and mitigation measures have been formulated. Adaptations are adjustments in natural or human systems in response to climatic changes (IPCC, 2007). It involves adjusting to actual or expected future climate. The goal is to reduce our vulnerability to the harmful effects of climate change like sea-level encroachment, more intense extreme weather events or food insecurity. It also encompasses making the most of any potential beneficial opportunities associated with climate change (NASA, 2016). Adaptation measures are needed to protect livelihoods and food security in many developing countries that are expected to be the most vulnerable, even under moderate climate change and the impacts of the change are likely to be lower the sooner the mitigation activities begin. The overall challenge of climate policies is to find the efficient mix of adaptation and mitigation solutions that will limit the overall impacts of climate change. Adaptation is necessary to limit potential risks of the unavoidable residual climate change now and in the coming decades. Examples of this adaptation measures are shown in **Box 20** (IPCC, 2007; NASA, 2016; Tubiello, 2012).

Box 20. Examples of adaptation measures on climate change

- expanding rainwater harvesting, storage and conservation techniques and water reuse and desalination
- adjusting cropping periods both for agriculture and aquaculture and shifting to species or areas more productive under new climatic conditions or developing culture techniques for new species which are more resilient to climate change
- relocating residents from storm and surge-prone areas to safer locations
- designing standards and planning for roads, rails, and other infrastructure to cope with warming
- using renewable sources and reducing dependence on single source of energy

On the other hand, mitigation is reducing climate change by reducing the flow of heat-trapping greenhouse gases into the atmosphere, either by reducing the sources of these gases or enhancing the "sinks" that accumulate and store these gases. The goal of mitigation is to avoid dangerous human interference with the climate system, and stabilize greenhouse gas levels in a timeframe sufficient to allow ecosystems to adapt naturally to climate change, ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner (NASA, 2016). Mitigation actions involve direct reduction of anthropogenic emissions or enhancement of carbon sinks that are necessary for limiting long-term climate damage.

The benefits of adaptation choices will be realized almost immediately but will matter most under moderate climate change. However, benefits of mitigation may only be realized decades from now.

6.5.4 Way Forward

Aquaculture may be the ultimate solution to the problem of reduced fisheries production. However, in view of irresponsible practices by many, aquaculture has negatively affected the environment. To compensate the diminishing fisheries production and meet the demands for fisheries products as human population continues to grow, aquaculture must be redesigned to minimize its impact on the environment and make it more environment-friendly and at the same time economically sustainable. Scientific studies on how aquaculture destroyed habitats, polluted the waters, threatened non-target species, and a long list of others; and how aquaculture should be done to make it sustainable and environment-friendly are readily accessible. But despite the easy access to such information, aquaculture continues to degrade the environment. Scientific findings should be properly and widely disseminated to fish farmers, hatchery operators, feed suppliers, policy makers, and government agencies to make them understand that protecting the environment is not the task of just one person but should be a joint effort of everyone producing from it, using it, and living in it. Science should be strongly supported by policies that are strictly implemented in order to achieve the goal of having a better and cleaner environment in the future.

While climate change is a global issue, it is strongly felt on a local scale. In areas where the environments are badly damaged, the impacts of climate change may be greatly experienced. When Typhoon Haiyan hit the Philippines, storm surges caused heavy casualties and damages in communities where mangrove areas have been converted to ponds or other uses. As anthropogenic activities continue to destroy the environment and as weather disturbances worsen, the impacts of climate change on the society become more catastrophic. Adaption and mitigation measures are in place but the capacity to adapt and mitigate is dependent on socio-economic and environmental circumstances and the availability of information and technology. In the absence of national or international climate policy directions, cities and local communities around the world have been focusing on solving their own climate problems. They are building flood defenses, planning for heat waves and higher temperatures, installing water-permeable pavements to better deal with floods and storm water, and improving water storage and use. Moreover, efforts are also into managing the increasingly extreme disasters we are seeing and their associated risks, protecting coastlines and dealing with sea-level encroachment, managing land and forests, dealing with and planning for reduced water availability, developing resilient crop varieties, and protecting energy and public infrastructure (NASA, 2016). Unfortunately, those with the least resources are the most vulnerable to, and the least able to adapt to, climate change. As such, it is important to protect and rehabilitate the environment as a mitigation measure to the fast changing climate. In the end, it is still the condition of the environment that defines the condition of the earth.