Climate Change Adaptation (CCA)

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Definition

The concept of adaptation originated from evolutionary biology in the 1970s and 1980s. It is often categorized as planned or autonomous, reactive, or anticipatory. It also involves process with goals to reduce vulnerability (Naess 2013). Since then it has been widely applied in both social and ecological systems to prepare for disasters and minimize risks. Below are some of the definitions that are widely used by various groups:

The IPCC Third Assessment Report defines adaptation as, “adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli, and their effects or impacts. This term refers to changes in processes, practices or structures to moderate or offset potential damages or to take advantages of opportunities associated with changes in climate” (McCarthy et al. 2001).

Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC TAR 2001).

Adjustment solutions take many shapes and forms, depending on the unique context of a community, business, organization, country or region. There is no ‘one-size-fits-all-solution’—adaptation can range from building flood defenses, setting up early warning systems for cyclones and switching to drought-resistant crops, to redesigning communication systems, business operations and government policies… It is a key component of the long-term global response to climate change to protect people, livelihoods and ecosystems (UNFCCC 2018).

Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects. (Zimmerman and Faris 2011:15)

The UN-Habitat (2011) defines adaptation as initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. On the other hand, the World Bank (2011) defines adaptation as the process of adjustment to actual or expected climate change and its effects in human systems. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate change and its effects.

The 2009 Copenhagen Accord recognized the need to cut global emissions and how it is
indispensable to sustainable development. It declared adaptation as a key measure to tackle climate change related impacts (UNFCCC 2010):

Adaptation to the adverse effects of climate change and the potential impacts of response measures is a challenge faced by all countries. Enhanced action and international cooperation on adaptation is urgently required to ensure the implementation of the Convention by enabling and supporting the implementation of adaptation actions aimed at reducing vulnerability and building resilience in developing countries, especially in those that are particularly vulnerable, especially least developed countries, small island developing States and Africa. We agree that developed countries shall provide adequate, predictable and sustainable financial resources, technology and capacity-building to support the implementation of adaptation action in developing countries. (p.6)

According to the Government of Japan (2010), adaptation measures are developed to achieve the following:

(a) Risk avoidance: As preventive measures against predicted impacts (disaster prevention facilities, and regulation of development in vulnerable areas).
(b) Reduction of negative impacts: It is designed to reduce the damage that may occur, especially in areas like disaster prevent to reduce the damages and assist in recovery.
(c) Risk sharing: These measures avoid the concentration of impacts by spreading their burden across a larger population and over time.
(d) Risk acceptance: It is okay to accept the potential of an event that has low likelihood to occur today by delaying the implementation of measures while monitoring the situation.

Introduction

Climate change is the biggest challenge facing humanity today. It will affect the biophysical systems, human health, agriculture, and socio-economic well-being. These impacts are not distributed equally; the poor, primarily, in the developing nations, will be disproportionately affected (Parry et al. 2005). As the temperature rises, sea level rises, ocean acidifies, and the entire environment changes from climate change, adaptation therefore becomes part of planning and development process (O’Brien 2017). Adaptation is the adjustment to actual or expected climate and its effects. Adaptation demands coordinated and complementary responses across all levels – individuals, policy-makers, nongovernmental organizations (NGOs), and the private sector. Adaptation approaches are linked to understand the causes of vulnerability. From the perspective of biophysical drivers of vulnerability, adaptations should be designed to minimize the impacts from climate change. Such adaptation is sectoral that focuses on water, agriculture, energy, health, or buildings. Most of these approaches are technical in nature, which could lead to a piecemeal solution that address only the symptoms without considering the systemic factors of vulnerability (O’Brien 2017). In addition, they could ignore cultural factors such as values, identities, and sense of place. The social approach to adaptation focuses on some of the underlying causes of vulnerability such as poor social services, education, and safety net. From this perspective, adaptation’s goal is to change social relations and address historical injustices which might be making poor people vulnerable to climate change. On the other hand, the resilience approach to adaptation looks at the complexity, feedbacks, linkages, flexibility, and adaptive capacity of socio-ecological systems. This approach looks at the incremental and transformative systems of change. One related approach is transformational adaption which goes beyond incremental adjustments or approaches and may include changes in form or structure through novel, large-scale actions (Park et al. 2012). Examples include shifting new types of agriculture or relocation people in response to sea level rise.

Adaptation to impacts of climate change consists of the actions that people take in response to or in anticipation of, anticipated or occurring change in climate, to reduce adverse impacts of climate change (Parry et al. 2005). Importantly, adaptation is not a “science” with a narrow view as a finite and technical-rational process with a beginning and a clearly identified milestones and
endpoints. It is more interdisciplinary with multiple ongoing processes across time and scale (Palutikof et al. 2015). No adaptation is not an option anymore. Rather adaptation is essentially a pragmatic response to a perceived present or future imbalance between climate and the societies and environments that it affects.

Adaptation needs vary across geographical scales (local, national, regional global), temporal scales (coping with current impacts versus preparing for long-term change) and must be addressed in complex and uncertain circumstances. Responding to this process requires interdisciplinary and multiple expertise at the local and international level. Researchers and practitioners in climatology, ecology, economics, and the management of natural resources, including agriculture, forestry, watersheds, and fisheries, will have to join forces with those from public health, engineering, business, disaster risk reduction, community development and social services. (Parry et al. 2005:4)

**Adaptation-Related Terms**

Adaptation Assessment – The practice of identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency, and feasibility (IPCC TAR 2001)

Adaptive Capacity – The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC TAR 2001)

**Types of Adaptation**

Adaptation can be categorized along three dimensions (Bosello et al. 2012):

1. Based on the subject of adaptation like who or what adapts
2. From the object of adaptation such as what they adapt to
3. The way in which adaptation takes place such as how they adapt (process)

Most common types of adaptation include anticipatory, autonomous, community-based, ecosystem-based, evolutionary, incremental, mal (adaptive), physiological, planned, private, public, reactive, and transformational (Palutikof et al. 2015).

There are two kinds of adaptation based on who implements it – autonomous or market-driven and planned or policy-driven. Autonomous adaptation can be defined as “adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems” and planned adaptation as “adaptation that is the result of a deliberate policy decision based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state” (McCarthy et al. 2001). In addition, adaptation can be differentiated based on the timing of adaptation actions, anticipatory or proactive adaptation, and reactive or responsive adaptation.

On the other hand, adaptation can be private or public. The Intergovernmental Panel on Climate Change (IPCC) defines private adaptation as “adaptation that is initiated and implemented by individuals, households or private companies. Private adaptation is usually in the actors’ rational self-interest” (IPCC 2001) and public adaptation that is “adaptation that is initiated and implemented by governments at all levels. Public adaptation is usually directed at collective needs” (McCarthy et al. 2001).

Depending on how adaptation programs are implemented, they could be top-down or bottom-up. The top-down adaptation is a scenario-driven approach where policy-makers provide the information about the likelihood of impacts of climate in different region and work to raise awareness across levels. However, they do not share the information with local decision-makers to make localized decisions. On the other hand, the bottom-up or vulnerability-driven approach to adaptation involves assessment of past and current climate vulnerability, existing coping strategies and how to modify them to the changing climate. This approach overcomes uncertainties associated with
the top-down approach by increasing the capacity of communities and government to cope and adapt to the local changes. In a real world, both approaches complement each other for the best results (Parry et al. 2005).

Park et al. (2012) identified two types of adaptation based on the end goals.

1. Incremental adaptation – maintaining the essence and integrity of an incumbent system or process at a given scale.
2. Transformational adaptation – a discrete process that fundamentally (but not necessarily irreversibly) results in change in the biophysical, social, or economic components of a system from one form, function, or location (state) to another, thereby enhancing the capacity for desired values to be achieved given perceived or real changes in the present or future environment.

Sometimes adaptation could be specific to a single component or service sector of the society. For example, in many cities in the United States (USA), adaptation initiatives include the following localized actions (Zimmerman and Faris 2011):

1. Infrastructure service adaptations – Protection against sea level rise because of the low elevation, heavy use, and overuse of infrastructure. In New York City (NYC), transit system improvement is of priority to the city.
2. Stormwater management – Since stormwater is related to sea level rise, and/or extreme storms or precipitation, adaptation strategies aim at increasing water storage capacity, promoting drainage, controlling land and soil movement, and building more infrastructure.
3. Urban trees – Cities in the United States have adopted planting trees for many adaptive benefits like absorbing CO2, increasing the absorptive capacity of soil for water and reducing heat through shading.
4. Land use planning and policy – Climate change adaptation is widely included in cities’ land use policies. For example, King County aggressively included climate as a fundamental consideration in all land use planning and policy discussions.

Finally, based on the timing of the programs, adaptive responses can be categorized into three types: anticipatory adaptation, reactive adaptation, and adaptation research and development (Bosello et al. 2012).

- Anticipatory adaptation – Here the society builds a stock of defensive capital, which it can use when the damage materializes. The stock depends on economic inertia to invest in defensive program that can protect capital after some years. It is usually undertaken before the damage occurs.
- Reactive adaptation – This includes all actions undertaken in response to climate change damages that were not addressed by anticipatory adaptation.
- Adaptation research and development – It deals with investing in R&D and knowledge to build adaptation system that is effective. It is widely applied in agriculture and health sectors in trying to discover new crops and vaccines to reduce vulnerability to climate change.

Overall, adaptation can be broadly categorized into four types: reaction, planned, public, and private (Table 1).

## Approaches to Adaptation

Basically, there are two approaches to adaptation: short-term and medium- to long-term adaptation (Gov. of Japan 2010). Governments can use one or both approaches based on their policy goals, resource availability, and in response to the disaster.

1. **Short-term adaptation**: Initiatives that encourage urgent response to prevent or mitigate short-term impacts that are happening or likely to occur from climate change. Examples include:
(a) Crisis management arrangements and improvements in early warning systems, to deal with sea-level rise and with rising damage in confined areas and from intense rainfall events.

(b) Installation and augmentation of independent electrical generation equipment for water purification plants to respond to power outages caused by the increase of natural disasters.

(c) The introduction of heat-resistant crop varieties and promotion of appropriate cultivation methods, to address the declining crop quality and yields.

2. Medium- and long-term adaptation: Response measures to enhance adaptive capacity to prevent and mitigate possible impacts, by assessing the risks of impacts that may occur in the medium and long term and by controlling the impacts, reducing vulnerability, and strengthening resilience. Examples include:

(a) Adaptation measures in individual sectors: These are measures implemented with the intention of adapting to estimated impacts in specific sectors. New construction and functional improvements of embankments to cope with sea level rise and storm surges, “soft” (non-structural) measures such as improvements in tsunami and storm surge hazard maps and strengthening of measures to prevent outbreaks of infectious diseases such as dengue fever).

(i) Improvements of river and sea embankments, functional improvements of existing facilities, etc. Land use regulations and incentives in affected areas. Construction (nesting) of ecosystem networks. Strengthening of measures to prevent outbreaks of infectious diseases.

(b) Integrated adaptation and basic capacity enhancement: These approaches include integration of measures planned on a sectoral basis to a unified and effective
adaptation plan and enhancement of basic capacities of localities and sectors such as technologies and human resources. These should be implemented with a systematic and long-term perspective.

(i) Acting to clarify issues that require cooperation and cross-sectoral initiatives among multiple departments and sections within an organization, for more efficient implementation of measures. Reviewing the collection and organization of basic data and information relating to impact assessments and adaptation measures, and where found to be inadequate, identifying issues that require priority attention and implementing systematic improvements. Prioritizing climate change adaptation measures within the comprehensive plans of local governments. Establishing organizations that cooperate with local research institutions, non-profit organizations, and various other types of organization.

(c) Awareness raising (improvement of enabling conditions): It is of fundamental importance to raise the awareness and understanding of the people and government agencies responsible for adaptation. It is also important to identify the responsibilities, roles, and collaborations among organizations both at national and local levels. These efforts should be initiated and promoted as quickly as possible.

(i) Improving and promoting the use of basic information about research data and future projections. Developing and providing information about examples of risk assessments and assessment tools. Setting up Internet portal sites for impacts and adaptation information that will be useful for governments. Promoting information exchanges and collaborative research with local research institutes.

(d) Information consolidation (improvement of enabling conditions): Institutional arrangements and methodology development for gathering, managing, and utilizing basic information on the target areas and sectors are the basis for planning and implementation of adaptation measures. These efforts should be initiated and promoted as quickly as possible.

(i) Risk-related information provision, communication about risk, and awareness-raising activities (combined with mitigation efforts) targeting citizens and businesses. Sharing of information among relevant government departments; establishing supportive institutional arrangements; and creating collaborative arrangements among governments, research institutes, and NGOs.

(e) Research and technology development: Research and technology development should be promoted in such areas as monitoring and projections of climate change, measures for the short-term, and the medium- and long-term adaptation effective to improve the resilience of local societies.

Adaptation Planning

The Council on Environmental Quality (CEQ) Task Force during the Obama administration outlined eight guiding principles for adaptation in its 2010 progress report for governments, communities, the private sector, and others in designing and implementing adaptation strategies. These include:

1. Adopt Integrated Approaches: Adaptation should be incorporated into core policies, planning, practices, and programs whenever possible.

2. Prioritize the Most Vulnerable: Adaptation plans should prioritize helping people, places, and infrastructure that are most vulnerable to climate impacts and be designed and implemented with meaningful involvement from all parts of society.
3. Use Best Available Science: Adaptation should be grounded in the best-available scientific understanding of climate change risks, impacts, and vulnerabilities.

4. Build Strong Partnerships: Adaptation requires coordination across multiple sectors and scales and should build on the existing efforts and knowledge of a wide range of public and private stakeholders.

5. Apply Risk Management Methods and Tools: Adaptation planning should incorporate risk management methods and tools to help identify, assess, and prioritize options to reduce vulnerability to potential environmental, social, and economic implications of climate change.

6. Apply Ecosystem-Based Approaches: Adaptation should, where relevant, consider strategies to increase ecosystem resilience and protect critical ecosystem services on which humans depend to reduce vulnerability of human and natural systems to climate change.

7. Maximize Mutual Benefits: Adaptation should, where possible, use strategies that complement or directly support other related climate or environmental initiatives, such as efforts to improve disaster preparedness, promote sustainable resource management, and reduce greenhouse gas emissions including the development of cost-effective technologies.

8. Continuously Evaluate Performance: Adaptation plans should include measurable goals and performance metrics to continuously assess whether adaptive actions are achieving desired outcomes.

On the other hand, the Government of Japan recommends the necessary five steps for adaptation planning and implementation:

Step 1: Share knowledge and approaches to adaptation and examine existing measures.

- Share knowledge and approaches about the need for, the importance of, and concepts relating to adaptation.

- Compile information about adaptation-related aspects of existing policies and measures and identify areas where gaps exist.

Step 2: Assess the risks associated with climate change impacts.

- Collect and analyze existing, readily available monitoring results information, etc.

- Assess risks of climate change impacts using existing information (identify high-risk events and areas).

Step 3: Promote communication and decide adaptation plans, programs, and measures.

- Share risk assessment results with the public and stakeholders.

- Determine the necessity of adaptation measures, consider their levels of importance, and prioritize adaptation planning and implementation in the policies.

Step 4: Start with the most feasible initiatives.

- First, initiate urgent response measures to prevent and/or mitigate short-term impacts.

- Next, consider adaptation measures where socioeconomic benefits are clearly higher than costs.

- Track and assess progress and effectiveness of adaptation measures (overall assessment of progress).

Step 5: Consolidate risk assessments and adaptation measures based on monitoring and the latest knowledge.

- Identify areas and items requiring priority monitoring and consider and improve methodologies and arrangements for them.

- Improve future projections using the latest research results and local monitoring data.

- Reassess risks, review, and integrate adaptation measures.
Regardless of which approach the government, or a city applies, it is very crucial to have the following questions answered before implementing any adaptation programs (Palutikof et al. 2013:22). Since climate change impacts are not equally distributed, there will be winners and losers in the process of adaptation. To minimize the risks of inequality, every adaptation plan should address these types of questions specific to the place and risk.

- From whose perspective is the adaptation activity evaluated?
- Whose needs should be paramount?
- Are they those of government or of community?
- If you improve the resilience of a village, will central government care?
- If central government builds a dam to improve water supplies and displaces ten villages, is that a successful adaptation?
- If market forces rule, and water availability is managed through pricing, who looks after the interests of the poor and disadvantaged?
- Who maintains environmental flows?

### Challenges to Adaptation

Limits of adaptation is a condition where despite adaptive action, an actor can no longer secure valued objective from intolerable risk. Some sources for such limits are perception, values, processes, and power structures with the society that impose barriers. Limits can be categorized as ecological and physical, economic, and technological. In the ecological and physical limitation, it is likely human action cannot avoid repeated and severe coral bleaching. Economical limit would be when the costs of adaptation exceed the costs of impacts averted. Finally, technological limitation is when the available technology cannot avoid climate impacts (Barnett and Palutikof 2015). Sometimes, adaptation becomes an alibi for business as usual if it is delinked from climate change mitigation policies (O’Brien 2017). As a result, it can be seen as promoting passive responses to climate change; diverting attention from other possibilities; including responses that minimize risk and vulnerability by changing existing systems, structures, and power relations; or promoting a technical solution to a complex problem such as climate change. The biggest challenges to adaptation are (Palutikof et al. 2013):

1. **Knowledge barriers** – It is one of the biggest barriers when people lack sufficient knowledge about future climate, socioeconomic trends, and technological developments. Even though scholars and decision-makers use scenarios to predict future changes, scenarios are limited and cannot control for the unexpected changes across variables. Related to this is the lack of skills to act upon existing knowledge and the gap between rich and poor nations on knowledge exchange.

2. **Financial barriers** – Money is an impediment at all levels from individuals to national governments to international organizations. The United Nations Framework Convention on Climate Change (UNFCCC) estimates by 2020 100 billion dollars a year for adaptation, and mitigation programs will be needed in least developed countries alone. In response, the international bodies have set up the Green Climate Fund, which will continue to support actions in poor countries. However, many nations have not fulfilled their commitment to the fund, making it a small pool of money. At national, community, and individual levels, perception of the problems makes it hard to allocate funds to address an issue that might happen in the future.

3. **Legislative and regulatory barriers** – Legislations are key to enforce policies and even bring changes in social behavior (fines for food waste) and provide incentive for change. In addition, legislation will play a role in assigning agency responsibilities, establishing and empowering institutions, providing legal authority in decision-making, and identifying process and actors of decision-making. Sometimes, existing legislation and regulation would be in conflict with the proposed adaptation goals and, therefore, need new legislation to support adaptation. Incremental changes to
the legislation process will help in establishing adaptation programs for the long run.

4. Failures of communication – Failure to communicate relevant information on time and in an appropriate manner and ineffective communication can lead to misunderstanding or misinterpretation of the information. Failures of communication to support adaptation have included failure to adequately set communication goals, identify and understand target audiences, appropriately frame messages and use appropriate language, make use of “messengers” most likely to effectively communicate and influence particular audiences, and provide adequate resources (time, funding, expertise) to support communication efforts (p. 14).

5. Cognitive and psychological barriers – It is true even if all the above barriers are addressed, adaptation is likely to fail if perception of vulnerability, risk, and urgency is missing. “Human cognition is the basis for all other barriers to adaptation, and it presents arguably one of the most vexatious challenges to address in adapting to climate change” (p.14). In the political process, the lack of ability or willingness to combat the complexity of climate change reduces the ability of decision-makers to enact effective adaptation policies. For individuals, the long time lags between prediction of future change and the occurrence of those changes affects their perception of risks in the future. One of the ways to address cognitive barriers is to build adaptive capacity by dealing with current adaptation deficits such as preparation for extreme events and management of water resources.

6. Barriers to adaptation and lack of adaptive capacity – The presence of all these barriers creates a deficit of adaptive capacity. Because of this deficit, communities may fail to adapt to current climate conditions and engage in misdirected adaptation or maladaptation. Some of the sources for the deficit would be lack of resource (financial constraints), poor understanding (knowledge constraints), or a rapidly changing set of social, economic, and demographic variables (instability constraints).

On the other hand, climate change presents its own challenges to building an effective adaptation system (Schneider 2013). These include:

1. Uncertainty – The biggest uncertainty with climate change is the uncertainty about how much future emissions will decrease globally. In addition, there are other non-climatic sources of uncertainties such as demographic change, technological change, markets and economic change, and social and political change that will affect adaptation.

2. Rates of change and feedbacks – The rates of change in both climate system and other drivers of change (population growth) can affect the rates of temperature change. Furthermore, most feedbacks in the climate system will be positive (increase of plant productivity in colder regions), creating special challenges for adaptation.

3. Equity in adaptation – Impacts of climate are unevenly distributed; the poor in every society are the most vulnerable. Developing nations that contribute little to the problem are most affected. Therefore, adaptation assistance to the most vulnerable population is critical. There are also concerns that the current practice of inserting adaptation in the broader development agenda might increase the risk of reducing resilience and adaptative and lead to maladaptation.

Addressing the above challenges requires adaptation to become more inclusive of different groups of people and increase cooperation and coordination among different stakeholders. Community based adaptation (CBA) is one of the ways to overcome the barriers. Involving local people in the decision-making process means those decisions will better reflect citizens’ needs and result in more widely accepted interventions. If adaptation is to address social vulnerability, then the best source of information is vulnerable people themselves, who can say why they are vulnerable, how they experience vulnerability, and what can help them adapt to stresses. In this framework, adaptation can become an intervention done to the community, to protect the community, and be
determined by the types and scales of climate impacts (Ayers and Forsyth 2009). Importantly, local governments are close to constituencies and can influence behaviors of people in their choice of energy consumption and transportation options and can influence the daily use of energy, transportation, and other sources of greenhouse emissions (Zimmerman and Faris 2011). At higher levels, there are two ways to tackle the challenges to adaptation (Palutikof et al. 2013):

1. Market-based and regulatory instruments – Economists believe climate is the greatest market failure; therefore, a strong and flexible economy can help successful adaptation. They see an active role of markets to deliver successfully adapted societies where industry, business, communities, and individuals are incentivized to adapt. Here, the role of governments is to create frameworks for these markets to operate. One example of this idea is carbon pricing, which would be available in the markets for maintenance of healthy ecosystems and biodiversity and for disadvantaged groups. However, this will happen only in an ideal world, and in many cases, market will be unable to drive successful adaptation. In these cases, governments still can play a role to build adaptive capacity and to ensure that the right actions are taken at the right time, that the necessary regulatory frameworks are in place, that ecosystem services are properly recognized, and that vulnerable communities are protected (p. 16).

2. Role of engagement and communication – Engagement and communication can play a role in ensuring that robust and informed adaptation decisions and actions by audiences who have access to and the ability to consider and use the information to achieve adaptation goals. There is a need to make the communication of information about climate change adaptation to be participatory, integrated, iterative, outcomes focused, and accounts the scale at which such adaptation measures need to be undertaken (individual, local, regional, or global). This is crucial for local communities where adaptation action is happening on the ground and the success of the program depends on the inclusion of local knowledge and expertise.

**Adaptation in the Agriculture Sector**

Agriculture sector is one of the biggest contributors to climate change, and it is also the most vulnerable sector that could affect billions of people. This will have severe consequences to the biodiversity (new areas exploited for farming) and society (displacement, social unrest, and conflict). Therefore, adaptation and mitigation strategies can be used to limit the damage and to develop a sustainable agriculture sector. This can be done through specific cultural, technical, system, and policy options that are embedded within, but also informing, socioeconomic development strategies (e.g., diversification of income, rural energy planning) (Tubiello 2012:9). Some ways adaptation and mitigation can enhance resilience of vulnerable people is by implementing win-win strategies such as developing more diverse crop strains tolerant of a variety of different conditions (heat, drought, salt, etc.), bolstering social capital and resilience, creating early warning systems and preparedness plans, improving public health infrastructure, and bolstering disease surveillance (El-Ashry 2009:60).

The Food and Agriculture Organization (FAO), United Nations, contends, the sooner the mitigation activities begin, the lesser the impacts and less adaptation. On the other hand, adaptation measures should protect livelihoods and food security in many developing countries, which are more vulnerable. These measures can be implemented locally to safeguard food availability and minimize impact on access, stability, and utilization of food resources. Some of the available adaptation strategies for the agriculture sector include (Howden et al. 2007):

- Altering inputs, varieties, and species for increased resistance to heat shock and drought, flooding, and salinization; altering fertilizer rates to maintain grain or fruit quality; altering amounts and timing of irrigation and other
water management; and altering the timing or location of cropping activities.

- Managing river basins for more efficient delivery of irrigation services and prevent water logging, erosion, and nutrient leaching; making wider use of technologies to “harvest” water and conserve soil moisture; and using and transporting water more effectively.
- Diversifying income through the integration of activities such as livestock raising, fish production in rice paddies, etc.
- Making wider use of integrated pest and pathogen management, developing and using varieties and species resistant to pests and diseases; improving quarantine capabilities and monitoring programs.
- Matching livestock stocking rates with pasture production, altered pasture rotation, modification of grazing times, alteration of forage and animal species/breeds, integration within livestock/crop systems including the use of adapted forage crops, reassessing fertilizer applications, and the use of supplementary feeds and concentrates.
- Undertaking changes in forest management, including hardwood/softwood species mix, timber growth and harvesting patterns, rotation periods; shifting to species or areas more productive under new climatic conditions, planning landscapes to minimize fire and insect damage, and adjusting fire management systems; initiating prescribed burning that reduces forest vulnerability to increased insect outbreaks as a nonchemical insect control; and adjusting harvesting schedules.
- Introducing forest conservation, agroforestry, and forest-based enterprises for diversification of rural incomes.

Other long-term adaptation programs that nations can include in their policies are long-term investments in plant and animal breeding programs (including of underutilized crops), building capacity in the science and user communities, developing quarantine systems, establishing perennial crops and forest plantations, making land purchases or sales, and building (or decommissioning) major infrastructure such as dams and water distribution systems, flood mitigation works, and storage and transport facilities, as well as shorter-term investments, to ensure access to food and safety nets (Howden et al. 2007:12).

**Conclusion**

It is believed that for effective implementation of adaptation programs, it requires an understanding of current and future climate risks. This information can be used to develop new measures, policies, programs, and projects to minimize the risks. This process is known as “climate proofing” – the development of actions to protect infrastructure, systems, and processes against climate impacts. This integration of adaptation in policies is key to providing protection from climate change (Parry et al. 2005). Adaptation against climate change requires rethinking the current model of development that is harmful to the natural and social systems. To balance development and adapt to climate change nations must adopt a development paradigm that is based on a low-carbon economy and re-examine the role of global public policy and institutions to deal with crises in the financial, food, water, and energy sectors (El-Ashry 2009:60). In addition, where possible adaptation programs should apply win-win strategies that can bring multiple benefits to the people and the ecosystem. Some of the priorities national and local governments can use to make adaptation successful are (Parry et al. 2005):

a. Integrate adaptation across local, sectoral, national, and international levels; it is crucial to engage diverse stakeholders and include non-climate experts to develop anticipatory strategies.

b. Disseminate and implement the knowledge, tools, and technologies to assist communities reduce vulnerability to climate change.

c. Finance vulnerability reduction activities in poor countries that are inclusive and accessible to these nations.
d. International financial institutions and the private sector must be effectively engaged as well to support adaptation efforts, particularly in poor countries.

Furthermore, adaptation strategies can be designed for short-term coping to longer-term, deeper transformations, aiming to meet more than climate change goals. Three approaches can be conceptualized that can assist nations reach their goals (Roy et al. 2016:23):

1. First, adaptation should not be just about climate change alone and should include non-climate factors.
2. Second, adaptation programs should prepare for mixed outcomes. The chances of success of such programs in moderating harm and exploiting beneficial opportunities depend on many factors, not just on the adaptive action itself.
3. Third, local adaptations of a community and its members can be supported, constrained, or undermined by external interventions. Therefore, examining who acts is critical to understand effective adaptation.

Cross-References

▶ Adaptation
▶ Climate Change Impacts
▶ Climate Change Impacts and Resilience
▶ Climate Change Planning
▶ Climate Change Policy
▶ Climate Resilient Communities
▶ Maladaptation

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