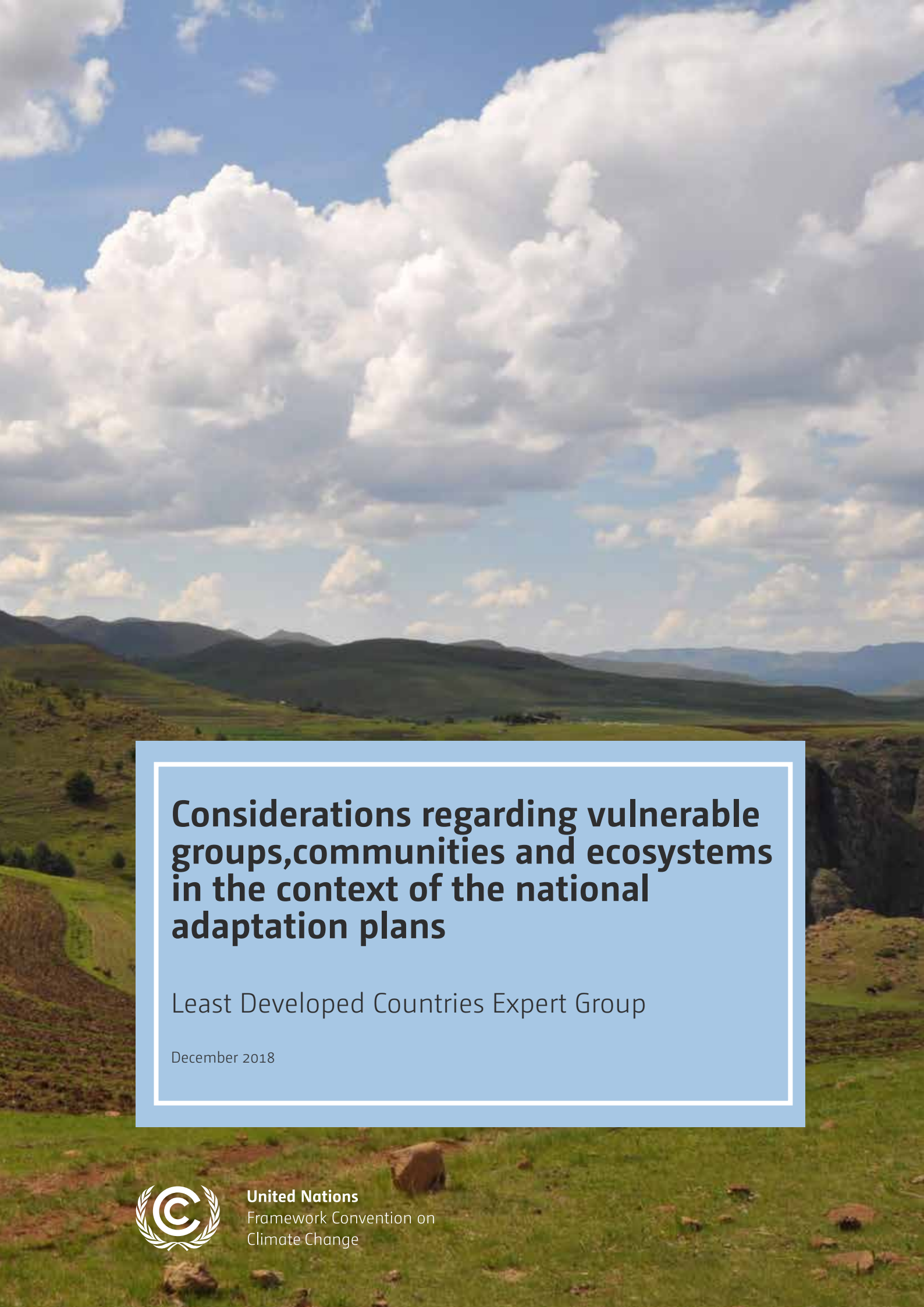

# Considerations regarding vulnerable groups,communities and ecosystems in the context of the national adaptation plans

Least Developed Countries Expert Group

December 2018

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Climate Change

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# PREFACE

Climate change poses disproportionate risks to human and natural systems due to differences in vulnerability and exposure. According to the IPCC (2014), vulnerability is the propensity or predisposition to be adversely affected. It is the result of a complex set of drivers and interacting conditions of a system that derive from the historical and prevailing cultural, social, environmental, political, and economic contexts (Cardona et al., 2012).

People who are socially, economically, culturally, politically, institutionally, or otherwise marginalized are especially vulnerable to climate change (IPCC, 2014). The rural and urban poor, and remote groups and communities have limited adaptive capacity due to their economic status, thereby making them more vulnerable than other members of the society. The young and the old are in most cases more exposed to climate change risks than other members of the population.

Similarly, ecosystems are constantly exposed to natural and human-induced hazards that often diminish their capability to maintain the provisioning of ecosystem services, and the species and ecosystems that are particularly vulnerable to climate change or have limited adaptive capacity are subject to very high risks with the additional warming of 2°C (IPCC, 2014). Depending on the scale and magnitude of the hazards, some ecosystems may be able to adapt (e.g. by evolutionary change or plasticity), some may migrate, while some would undergo collapse or extinction (Nogués-Bravo et al., 2018).

Furthermore, people and ecosystems are inseparable. Ecosystems provide critical services to people and their livelihoods. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth (MEA, 2003). Therefore, as adaptation moves from reactively addressing immediate risks of climate change to medium-and long-term strategies, it will be important to take stock and learn from earlier adaptation experiences. Adaptation strategies targeted at vulnerable socio-ecological systems that consider people and ecosystems together can enhance resilience and serve as effective pathways to sustainable development.

This paper is part of the activities of the Least Developed Countries Expert Group to provide technical guidance and advice to the least developed countries on how to strengthen considerations regarding vulnerable groups, communities and ecosystems in climate change adaptation. It has received wide inputs from the partner organizations to the Nairobi work programme on impacts, vulnerability and climate change. The paper also incorporates feedback solicited from Parties during its development.

Aderito Santana
Chair of the Least Developed Countries Expert Group,
December 2018

*The Least Developed Countries Expert Group (LEG) is mandated to provide technical guidance and advice on considerations regarding vulnerable communities within LDC Parties*

- Decision 6/CP.16, paragraph 2c

This paper is prepared with wide inputs from the partner organizations to the Nairobi work programme on impacts, vulnerability and climate change

# 1. INTRODUCTION

# A. MANDATE OF THE PAPER

The Least Developed Countries Expert Group (LEG) is mandated to provide technical guidance and advice on considerations regarding vulnerable communities within LDC Parties (see decision 6/CP.16, paragraph 2c). The LEG decided to initiate work on this mandate by developing practical guides on both gender considerations and on vulnerable communities. The gender guide was published in 2016 and is available on NAP Central[1] as part of the supplements to the guidelines for the formulation and implementation of NAPs.

This paper develops technical guidance on the consideration of vulnerable groups, communities and ecosystems in the formulation an implementation of NAPs. It builds on work that has focused on vulnerability in broader terms than climate change alone, especially given the fact that vulnerability and exposure arise from non-climatic factors and from multidimensional inequalities often produced by uneven development processes (IPCC, 2014).

It draws upon case studies from the Nairobi work programme of impacts, vulnerability and adaptation to climate change (NWP), covering a set of diverse actions and efforts for strengthening the consideration of vulnerable groups, communities and ecosystems in adaptation planning and implementation. The case studies cover a variety of societies, regions and biomes, diversity of adaptation actions, project implementation stage, quality of documentation about the case study, and potential scalability to the national level in the context of NAPs.

# B. CONSIDERATIONS OF VULNERABLE GROUPS, COMMUNITIES AND ECOSYSTEMS UNDER THE UNFCCC PROCESS

The differential vulnerability and exposure of vulnerable groups, communities and ecosystems to climate hazards is well recognized under the Convention (e.g. through the different decisions of the Conference of the Parties such as decisions 1/CP.16, paragraph 12; 6/CP.16, paragraph 2c; and 5/CP.17, paragraph 3) and the Paris Agreement (e.g. the preamble and Article 7, paragraphs 5 and 9c). Consequently, guidance on adaptation action requires special consideration of such vulnerable groups, communities and ecosystems.

**Box 1: References to vulnerable groups, communities and ecosystems under the UNFCCC**

**In the Paris Agreement**

*Article 7.5:* Parties acknowledge that adaptation action should follow a country-driven, gender-responsive, participatory and fully transparent approach, taking into consideration *vulnerable groups, communities and ecosystems,* and should be based on and guided by the best available science and, as appropriate, traditional knowledge, knowledge of indigenous peoples and local knowledge systems, with a view to integrating adaptation into relevant socioeconomic and environmental policies and actions, where appropriate.

*Article 7.9c:* Each Party shall, as appropriate, engage in adaptation planning processes and the implementation of actions, including the development or enhancement of relevant plans, policies and/or contributions, which may include the assessment of climate change impacts and vulnerability, with a view to formulating nationally determined prioritized actions, taking into account *vulnerable people, places and ecosystems.*

**In the decisions of the Conference of the Parties**

*Decision 1/CP.16, paragraph 12 (guiding principles for adaptation action):* The Conference of the Parties affirms that enhanced action on adaptation should be undertaken in accordance with the Convention, should follow a country-driven, gender-sensitive, participatory and fully transparent approach, taking into consideration *vulnerable groups, communities and ecosystems,* and should be based on and guided by the best available science and, as appropriate, traditional and indigenous knowledge, with a view to integrating adaptation into relevant social, economic and environmental policies and actions, where appropriate.

*Decision 5/CP.17, paragraph 3 (guiding principles for national adaptation plans):* The Conference of the Parties agrees that enhanced action on adaptation should be undertaken in accordance with the Convention, should follow a country-driven, gender-sensitive, participatory and fully transparent approach, taking into consideration *vulnerable groups, communities and ecosystems,* and should be based on and guided by the best available science and, as appropriate, traditional and indigenous knowledge, and by gender-

1 Available at: <http://www4.unfccc.int/nap>

sensitive approaches, with a view to integrating adaptation into relevant social, economic and environmental policies and actions, where appropriate.

*Decision 6/CP.16, paragraph 2c (mandate to the Least Developed Countries Expert Group):* The Conference of the Parties *decides* that the Least Developed Countries Expert Group should be mandated to provide technical guidance and advice on strengthening gender-related considerations and considerations regarding *vulnerable communities* within least developed country Parties.

# C. CONSIDERATIONS OF VULNERABLE GROUPS, COMMUNITIES AND ECOSYSTEMS UNDER THE WIDER UNITED NATIONS SYSTEM AND OTHER ORGANIZATIONS

At the heart of the 2030 Agenda for sustainable development is the pledge to leave no one behind, by paying particular focus on, among others, the poorest, most vulnerable and those furthest behind (UN General Assembly, 2015). Many targets of the Sustainable Development Goals (SDGs) respond to the needs of the vulnerable groups, communities and ecosystems. Box 2 below provides relevant references to the vulnerable groups, communities and ecosystems in the SDGs.

Several UN system organizations have specific programmes, activities or resources targeting vulnerable groups, communities and ecosystems. Examples include: the United Nations Educational, Scientific and Cultural Organization world heritage centre which maintains information on world heritages sites; the United Nations Convention on Biological Diversity Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets; the United Nations Environment Programme work on mountain areas and other vulnerable ecosystems; the United Nations Convention to Combat Desertification 10-year strategic plan and framework to enhance the implementation of the Convention (2008–2018); the Food and Agricultural Organization of the United Nations global food and agriculture data, database of vulnerable marine ecosystems, and various programmes to support vulnerable groups, communities and ecosystems across the globe; and the United Nations High Commissioner for Refugees support for people affected by forced displacement.

Other international and regional organizations also have activities related to the needs of vulnerable groups, communities and ecosystems in their work. These include, among others, CARE International, Conservation International (CI),

### Box 2: References to vulnerable groups, communities and ecosystems in the Sustainable Development Goals

**Goal 1: End poverty in all its forms everywhere**

1.3 Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of **the poor and the vulnerable**;
1.4 By 2030, ensure that all **men and women, in particular the poor and the vulnerable**, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance

1.5 By 2030, build the resilience of the poor and **those in vulnerable situations** and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters

**Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture**

2.1 By 2030, end hunger and ensure access by all people, in particular **the poor and people in vulnerable situations**, including infants, to safe, nutritious and sufficient food all year round

Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

4.5 By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including **persons with disabilities, indigenous peoples and children in vulnerable situations**.

**Goal 6: Ensure availability and sustainable management of water and sanitation for all**

6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and **those in vulnerable situations.**

**Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable**

11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of **those in vulnerable situations**, women, children, persons with disabilities and older persons.

11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and **people in vulnerable situations.**

International Union for Conservation of Nature (IUCN), International Federation of Red Cross and Red Crescent Societies (IFRC), and World Wildlife Fund (WWF).

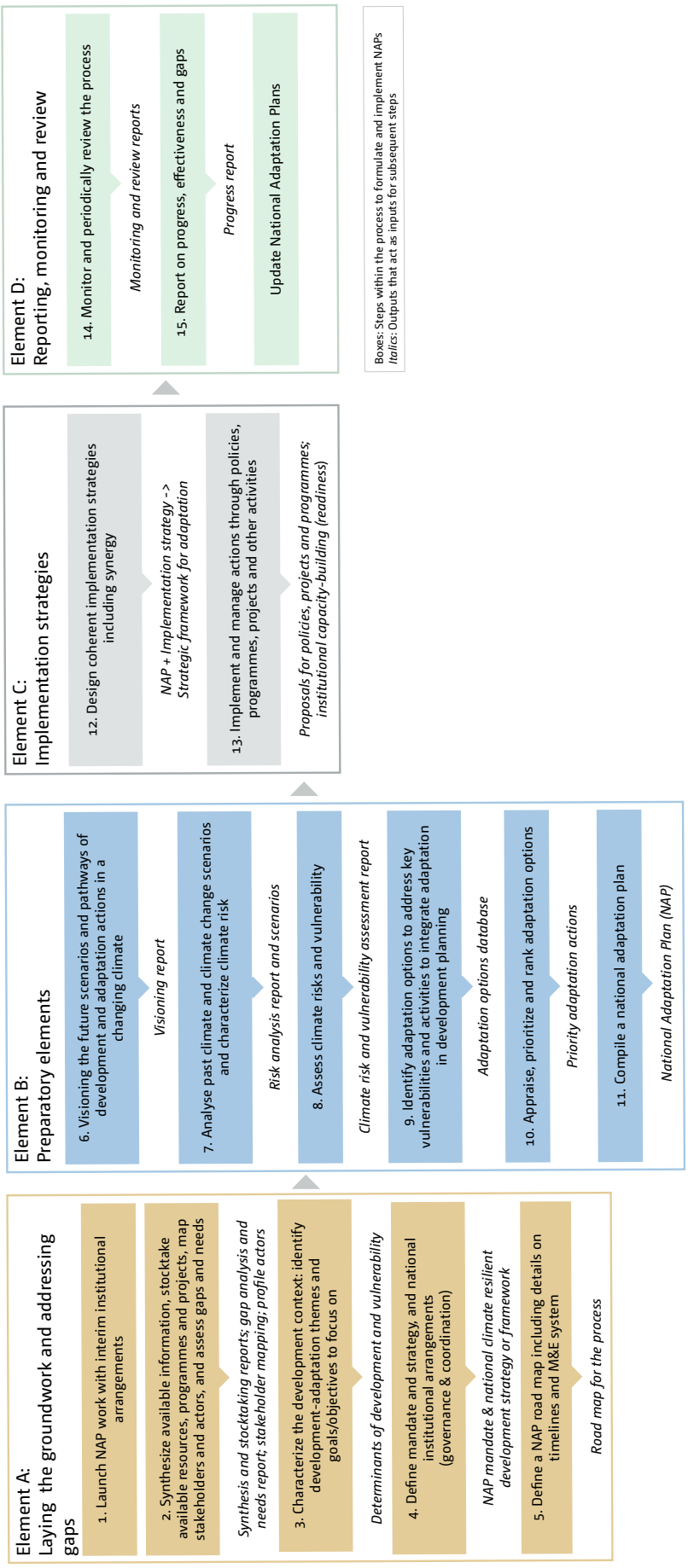
# D. OVERVIEW OF THE PROCESS TO FORMULATE AND IMPLEMENT NATIONAL ADAPTATION PLANS AND ENTRY POINTS FOR VULNERABLE COMMUNITIES, GROUPS AND ECOSYSTEMS

The process to formulate and implement NAPs enables countries to identify medium- to long-term adaptation needs, and to develop and implement strategies and programmes to address those needs. It carries the two objectives of: (i) reducing vulnerability to the impacts of climate change by building adaptive capacity and resilience; and (ii) facilitating the integration of climate change adaptation, in a coherent manner, into relevant new and existing policies, programmes and activities, in particular, development planning processes and strategies, within all relevant sectors and at different levels, as appropriate.

The process is based upon guidelines, guiding principles and relevant support provisions from the Conference of the Parties. One of the core guiding principles of the process is taking into consideration vulnerable groups, communities and ecosystems. While such would be crucial throughout the process to formulate and implement NAPs, specific areas where explicit attention would be required include the following:

- *Institutional arrangements:* establishing explicit institutional arrangements or incorporating specific provisions within existing arrangements to address the needs of vulnerable groups, communities and ecosystems;
- *Mandate:* ensure that the NAP mandate explicitly identifies the vulnerable groups, communities and ecosystems and how their consideration would be strengthened;
- *Assessment framework:* to include the vulnerable groups, communities and ecosystems in the assessment criteria;
- *Prioritization of adaptation actions:* assigning appropriate criteria that takes into account the specific needs of the vulnerable groups, communities and ecosystems;
- *Implementation of policies, projects and programmes:* where necessary and effective, to implement specific policies, projects and programmes for addressing the vulnerable groups, communities and ecosystems;
- *Monitoring and review:* to capture the progress made in adaptation of the vulnerable groups, communities and ecosystems.

Figure 1: Sample process to formulate and implement a national adaptation plan, showing steps where explicit consideration of vulnerable groups and communities may be applied



# 2. VULNERABLE GROUPS AND COMMUNITIES: RECOMMENDED GUIDANCE

# A. RECOMMENDATIONS ON IDENTIFYING VULNERABLE GROUPS AND COMMUNITIES

While adaptation assessments focus on vulnerable systems exposed to climate hazards, the approaches applied may not provide the right level of information or fully encompass the identification of particular vulnerable groups and communities for a specific country. Additional considerations are therefore required to ensure the identification of key vulnerable groups and communities, and hence prioritize them in adaptation planning and implementation.

Once vulnerable groups and communities have been identified, it will be easier to include their specific considerations and needs in the national adaptation mandates, frameworks and institutional arrangements. This would also help when assessing how the NAP has addressed all the guiding principles of the process to formulate and implement NAPs.

Two general approaches may be applied to identify the vulnerable groups and communities: one applying existing definitions; or one involving new/additional assessments to identify the vulnerable groups and communities.

*Identify vulnerable groups and communities using existing definitions.*

There are established examples of groups and communities that are particularly vulnerable and disproportionately affected by the impacts of climate change. The young and the old are in most cases more exposed to climate hazards than other members of the population. Equally so are the poor, remote and at times indigenous groups and communities. Furthermore, in many societies men and women have different rights and responsibilities and consequently, those with more restricted rights and more responsibilities suffer disproportionate impacts of climate change. It is important to note that the specific groups and communities would differ from country to country. This would also depend on the factors of vulnerability for the specific communities or groups being considered. For example, indigenous pastoralist communities living in arid and semi-arid areas may be considered particularly vulnerable to climate change, whereas in other places they may be less so.

For most countries, it is likely that such vulnerable groups and communities are known from existing administrative data and policies. Countries may therefore consider such known vulnerable groups and communities and integrate their specific considerations in the process to formulate and implement NAPs.

*Identify vulnerable groups and communities through new assessments*

The following approaches or methods can be applied to identify vulnerable groups and communities:

- *Targeting based on climate change impacts.* This considers groups and communities that have adversely been affected by climate hazards, and having limited ability to recover by themselves. This would include vulnerable groups and communities that have severely been affected by droughts, floods, coastal inundation, and extreme temperatures;
- *Categorical targeting* such as by gender, age, income, education, ability, ethnicity and social caste. For example, the State of California developed a resource guide for public agencies and the public to define vulnerable communities in an adaptation context. The guide includes a set of indicators for analysing and defining vulnerable communities: These are demographics, housing security, mobility, health services, environmental hazards, business/jobs, available public and private utilities, social services, governance, community, fiscal health and culture.
- *Geographical targeting.* Under this method, the government or responsible authority identifies priority regions or boundaries whose groups and communities should be prioritized, based on specific criteria. Such criteria may include arid or semi-arid lands, mountain regions, or remote areas;
- Using locally derived assessment tools such as community-based targeting or community participatory methods. Community-based targeting is administered by local governing authorities, recognized community groups, non-governmental organizations or religious to decide on which groups and communities are most

vulnerable to climate risks and hence deserve special consideration. Community-based targeting may also apply participatory approaches, which representative members of the authority or society are involved in deciding on the vulnerable groups and communities.

It is worth noting that the approaches and methods above would not individually cover all vulnerable groups and communities in a given country. For example, targeting based on climate change impacts will only cover those that have been adversely been affected by climate hazards, and may leave groups and communities that are extremely exposed to future hazards. It might therefore be helpful to apply a combination of the methods in situations where that is possible.

Below are the steps that could be followed to assess vulnerable groups and communities:

- Decide on the approach(es) or method(s) to be applied;
- Define specific factors of vulnerability;
- Identify the key vulnerable groups and communities;
- Validate results through established administrative processes.

Box 3 provides an example on vulnerability mapping in Lesotho, to identify the most vulnerable households to the effects of climate change.t therefore be helpful to apply a combination of the methods in situations where that is possible.

### Box 3 : Vulnerability mapping in three pilot community councils in Lesotho

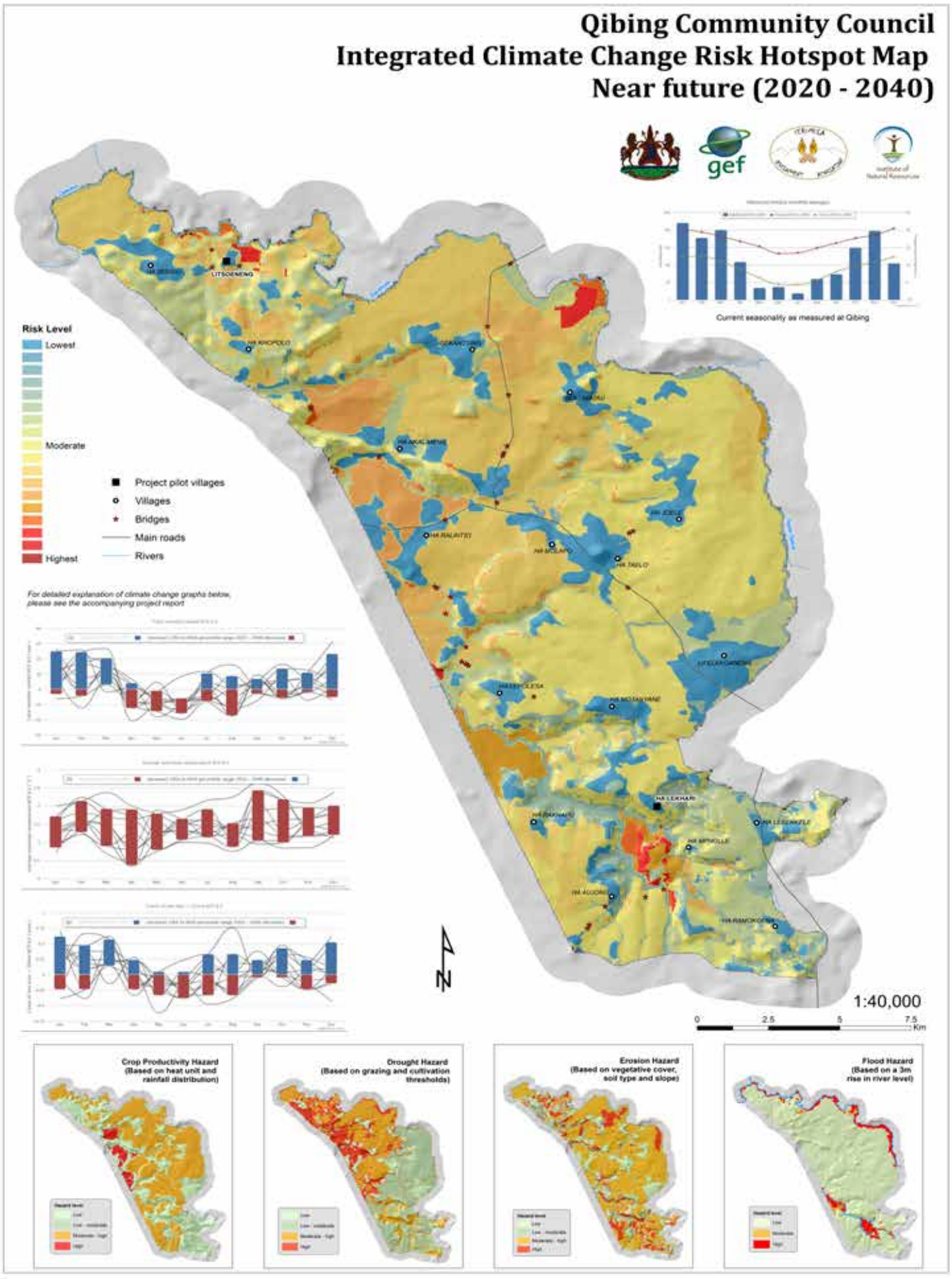
In recognizing that different communities including households would are disproportionately vulnerable to climate change impacts, Lesotho conducted a detailed vulnerability mapping exercise in three pilot community councils (Linakeng, Qibing and Tosing) known to possess particular vulnerability to climate change, and having different characterises (climate, socio economic profiles, topography, resources, etc.).

The methodology for the assessment had three components: the first part to develop detailed climate change projections for the site; the second to do a vulnerability mapping for key sectors; and the third to facilitate stakeholder engagement and capacity building of the local communities. The key sectors considered were: agriculture (crops and livestock); water supply (water and hydro politics); natural resources (soil, biodiversity and vegetation); forestry; and socio-economics (health, culture).

To understand the vulnerability of these sectors, detailed spatial hazard and vulnerability maps were developed on soil erosion hazard, flood hazard, drought hazard, heat units and loss of agricultural productivity. The maps were developed using various models and techniques and the engagement of the local communities to validate the outputs. The individual maps were overlaid to produce an integrated vulnerability hotspot map for each of the regions, using graduated colours where high risk areas are demarcated in red and low risk areas in blue.

Figure 2 shows an integrated climate change risk map for one of the community councils (Qibing). The map provides fine details on particularly vulnerable communities or areas within the community council, which would help in prioritizing and targeting adaptation actions.

Figure 2: Qibing Community Council projected climate change hotspot vulnerability map for the 2020-2040 Period, showing particularly vulnerable communities and areas (red).




*Source: Government of Lesotho (2015). Vulnerability mapping: Qibing Community Council. Maseru*

# B. RECOMMENDATIONS FOR STRENGTHENING CONSIDERATIONS REGARDING VULNERABLE GROUPS AND COMMUNITIES

This section provides examples of actions implemented by countries to strengthen the consideration of vulnerable groups and communities, that can be applied in the formulation and implementation of NAPs.

*Policies and institutional arrangements to guide, coordinate and manage support for vulnerable groups and communities*

This entails the enactment or enhancement of policies and regulations aimed at ensuring and facilitating climate change adaptation actions for the vulnerable groups and communities. It also entails establishment or dedication of specific institutions to handle issues of all or a part of the vulnerable groups and communities. In the case of Nepal, the climate change policy adopted in 2011 helped operationalize the Local Adaptation Plan of Action (LAPA) framework. The framework is aimed at ensuring that climate change adaptation actions benefit vulnerable local communities.

Such policies and institutional arrangements can be integrated into the mandate and institutional arrangements for the process to formulate and implement NAPs.

Box 4 provides an example of how explicit provisions for vulnerable communities in the national climate change policy of Nepal enabled the design and implementation of adaptation actions targeting vulnerable people.

*Include vulnerable groups and communities or related systems in the assessment*

The criteria for assessing vulnerability draws on five key elements that are characteristic of vulnerable groups and communities: exposure to climate stressors, importance of the vulnerable systems, limited ability to cope or respond

**Box 4: Promoting local adaptation actions in Nepal**

Nepal put in place a climate change policy in 2011. The policy carries a strategic objective to ensure the participation of poor people, marginalized people, indigenous communities, women, children and youth in the implementation of climate adaptation and climate change-related programmes. It also includes a goal of allocating at least 80 percent of the total budget from the National Climate Change Fund directly to programme implementation at the community levels.

Drawing from the country's national adaptation programme of action, the policy initiated community led adaptation actions through the preparation and implementation of local adaptation plans of action (LAPAs). The LAPAs were designed to identify the most vulnerable villages, wards, and people, and their adaptation needs, and to implement local adaptation actions to address those needs.

Through the LAPAs, the government implemented over 2,303 adaptation actions benefiting over 600,000 climate vulnerable people during the period 2013–2016. Below is a list of examples of the measures delivered to the grass roots community levels:

- Sixty households were supported to shift to river bank farming, as a response to frequent flooding that left sandy soil deposits on their farmlands that turned them infertile;
- Gabion walls were constructed in: Dhungachalna, in Accham district, to protect communities from Monsoon flooding; and in eight Village Development Committees (VDCs) in Bajura district to protect local communities from floods and landslides; Liku VDC in Dolpa district to protect infrastructure from landslides and soil erosion; Khalanga VDC in Jajarkot district to protect school infrastructure;
- Rehabilitation and improvement of irrigation canals and facilities in: Bela VDC in Dang district; Gola VDC in Bardiya district to restore farming; Raku VDC if Kalikot district;
- Introduction of alternative livelihood practices through training and mentoring: production of materials from bamboo in Duli VDC in Rukum district; mushroom farming in Patmara VDC, Jumla district;
- Construction of water tanks to store clean drinking water in Chhipra VDC of Humla district, and Nepa VDC of Dailekh district;
- Construction of community pond in Rowa VDC in Mugu district to support irrigation.

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to climate related hazards, persistence of vulnerable conditions, and presence of other conditions that make societies susceptible to the hazards (IPCC, 2014). The assessment framework for the NAP therefore needs to include the vulnerable groups and communities in order to accurately assess the risks that they are liable to, and hence develop appropriate measures to help alleviate or minimize the risks.

Flexible and inclusive definitions and approaches will need to be applied on a regular basis to reflect potentially shifting trends in vulnerabilities, and changing climate or socio-economic contexts regardless of the method applied for identifying vulnerable groups and communities. For example, building dams or digging wells to address climate-induced water shortages in a community provides relief on a local and short-term scale, but may result in negative effects downstream, such as lowering of the water table with impacts felt by all at the basin level, thereby creating new vulnerabilities.

*Creating or dedicating funding towards the most vulnerable*

Several countries have created or put in place specific provisions to channel climate change funds to the most vulnerable groups and communities. Kenya has created a climate change fund under its Climate Change Act 2016. The country also launched the Isiolo County Climate Change Fund in 2013 (see mode details in box 5 below). The Nepal Climate Change Policy 2011 contains a goal of allocating at least 80 percent of the total budget from the National Climate Change Fund directly to programme implementation at vulnerable community levels. Such provisions can also be included in the mandate for the process to formulate and implement NAPs.

*Engaging vulnerable groups and communities and integrating their knowledge and experience in adaptation planning and implementation*

Engaging vulnerable groups and communities in the planning stages would not only ensure implementation of actions that effectively address the needs of the vulnerable groups and communities, but would also allow the groups and communities to directly inform the identification and implementation of options that will be best suited to their particular circumstances.

Local communities for example possess rich dynamic knowledge of the local environment and have extensive experience and expertise in dealing with environmental change that can provide an important basis for effective climate change adaptation actions, complementing science. They can play significant roles in providing fine-grained information and experiences on climatic change risks and impending natural hazards, and in proposing ways to address the associated impacts (UNESCO, 2017).

Integrating the knowledge of the indigenous peoples and local communities would also help acknowledge their role as knowledge holders and rights holders. For example, pastoralist communities around the world have well established knowledge systems to study weather and climatic conditions, and apply adaptation practices that include seasonal livestock migration, grazing patterns and livestock rationing. These knowledge and practices can be used in the process to formulate and implement NAPs to provide validation of scientific information findings and options.

Box 6 provides a detailed example on how indigenous peoples and local communities were engaged in the design and implementation actions in Chad, and highlights some of the lessons learned and best practices.

## Box 6: Participatory mapping with M'bororo Indigenous People in Baïbokoum, Chad

This mapping project focused on training M'bororo nomadic and semi-nomadic indigenous pastoralists living between Niger, Nigeria, Cameroun, Central African Republic and Chad, on the basics of cartography through Participatory 3D Modeling (P3DM), which enabled the documentation of traditional knowledge, mapping of landforms and identification of risks posed by climate change and natural hazards. Through multi-stakeholder dialogue and knowledge exchange, the mapping exercise also aimed to alleviate conflict between pastoralists and sedentary farmers. The project was implemented by the Association des Femmes Peules Autochtones du Tchad (AFPAT), in cooperation with the Secretariat of the Indigenous Peoples of Africa Coordinating Committee (IPACC).

### Key vulnerabilities

In Chad, pastoralist populations are increasing, with a steady southward migration of communities, increasing pressure on land and resources. At the same time grazing lands are progressively decreasing and degrading. Baïbokoum's rural population in particular is faced with competing resource challenges. These include land encroachment by sedentary farmers resulting in blockage of transhumance routes that allow cattle access to water, loss of biodiversity as a result of land use change, the impact of extractive industries including oil wells being dug in the adjacent territory. All of these impacts are exacerbated by sudden shifts of weather and climate, including both droughts and floods. These combined factors contribute to increasing local communities' vulnerability, soil and biodiversity degradation, food insecurity and risks of armed conflict in the region.

### Adaptation activities

- Nomadic and semi-nomadic community members from the villages in the district were trained on ephemeral mapping, GPS skills training, and orientation on the basics of cartography, scaling and geo-referencing.
- Participants constructed a scaled, geo-referenced 3D model (Participatory 3D Model (P3DM)) of Baïbokoum and environs (24km x 20 km; 1:10 000 scale). They used indigenous traditional knowledge to map land use, ecosystem features and biodiversity information. They also documented their historic cattle migratory routes, which once linked pastoral tenure systems with water rights in the area.
- Participants and government discussed the impacts of climate change including surges in extreme weather events (both flooding and drought) and changes in seasonal patterns and predictability. Babokoum, even though in a relatively humid part of Chad, suffers from water stress in the dry season.

### Experiences and lessons learned

- Pastoralists found the model was a valuable platform for expressing their concerns about land use changes and marginalisation. Participants in the mapping exercise acknowledged how the mapping allowed issues of climate change and land use competition, including administrative decisions to become more transparent, with the opportunity to do conflict prevention work between farmers and herders.
- Participants noted that sedentary and nomadic communities could have symbiotic and supportive relationships. Resolving conflicts and having a preventative approach to resolving resource competition is a fundamental aspect of climate adaptation and development of rural areas.
- The mapping exercise showed that indigenous peoples could play an effective role in decision-making, and enabled participation by all members of the community, particularly women.
- Traditional knowledge and climate science are both critically important for adaptation policy and supporting resilience-building of rural communities necessary to cope with climate change.

### Best practices

- Documentation of traditional knowledge is essential to ensure safeguarding the rich source of information. Pastoralists have a substantial body of traditional knowledge that needs to be taken into consideration in the process of developing adaptation policies;
- Participatory tools should be an essential element in developing national adaptation plans and other development plans and policies;
- An essential element of climate adaptation is ensuring good governance, human rights and social equity to maintain local, national and regional harmony during times of stress;
- Both traditional knowledge and climate science need to inform national adaptation processes, and this can be facilitated by translating both knowledge systems into media that is understood by the public and usable for national adaptation platforms.

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N'Djamena Declaration on Adaptation to Climate Change, indigenous Pastoralism, Traditional Knowledge and Meteorology in Africa (2011)

Results of High Level Round Table on Pastoralism, Traditional Knowledge, Meteorology and Implementation of Policies of Climate Adaptation (2011) http://participatorygis.blogspot.it/2011/11/results-of-high-level-round-table-on.html

Local communities for example possess rich dynamic knowledge of the local environment and have extensive experience and expertise in dealing with environmental change that can provide an important basis for effective climate change adaptation actions, complementing science. They can play significant roles in providing fine-grained information and experiences on climatic change risks and impending natural hazards, and in proposing ways to address the associated impacts (UNESCO, 2017).

Integrating the knowledge of the indigenous peoples and local communities would also help acknowledge their role as knowledge holders and rights holders. For example, pastoralist communities around the world have well established knowledge systems to study weather and climatic conditions, and apply adaptation practices that include seasonal livestock migration, grazing patterns and livestock rationing. These knowledge and practices can be used in the process to formulate and implement NAPs to provide validation of scientific information findings and options.

*Building the resilience of vulnerable groups and communities through social protection systems*

According to the World Bank, "social protection systems help individuals and families, especially the poor and vulnerable, to cope with crises and shocks, find jobs, improve productivity, invest in the health and education of their children, and protect the aging population". Social protection systems include welfare, care or benefits that are often provided in the form of cash or in-kind transfers.

Some social protection systems are targeted at or include components to reduce vulnerability to climate change for the most vulnerable groups and communities. Mostly, they help build the social capital of vulnerable groups and communities, and hence consequently help them to reduce their vulnerability to climate change. Furthermore, social protection systems can provide invaluable lessons for the design and implementation of adaptation actions. Social protection systems are also an integral part of the Sustainable Development Goals whereby goal 1.3 calls for the "implementation of nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable".

Box 7 below provides an example on Ethiopia's productive safety net programme.

**Box 7: Building climate resilient communities through Productive Safety Net Programme in Ethiopia**

Ethiopia started a Productive Safety Net Programme (PSNP) in 2005, building on its National Food Security Strategy. The PSNP was designed to complement the existing humanitarian appeal system and assist millions of chronically food insecure people in rural Ethiopia. The programme is aimed at providing both short-term relief and long-term solutions to food-insecure households, by addressing the causes of food insecurity, including environmental degradation.

The programme provides predictable and timely resources in the form of payments to able-bodied members for participation in labor-intensive public works and through direct support to labor-poor, elderly or otherwise incapacitated households under three general pillars:

- Public works programme: under which eligible households with able-bodied adults participate towards enhancing infrastructure and enriching community-based resources, such as schools in return for cash or in-kind transfers;
- Direct support programme: under which those who are unable to work due to disability, illness or age are provided with cash or in-kind transfers every month;

Temporary programme: focusing on temporary clients such as pregnant or lactating mothers or caregivers for malnourished children, who are enrolled in the public works component and temporarily shifted into direct support.

The PSNP is currently in its fourth phase covering the period 2015-2020 and has mobilized multi-annual resources from development partners to support adequate planning, capacity building, and monitoring and evaluation systems. It has received support from the Canadian International Development Agency, the European Commission, the International Development Association, the Irish Aid, the Netherlands Development Association, the Swedish International Development Cooperation Agency, the United Kingdom Department for International Development, the United States Agency for International Development, the World Bank, and the World Food Programme.

The programme beneficiaries have grown from nearly 5 million at the start of the programme in 2005 to nearly 8 million beneficiaries in 2018. Performance results demonstrate that the direct effect of the programme has helped to significantly reduce poverty levels, helped to put in place major building blocks of the government's disaster prevention and relief efforts, and has helped build essential infrastructure to address root causes of vulnerability and poverty.

The programme has at the centre of its strategy a Climate Smart Initiative which facilitated the integration of environment and climate change considerations into its interventions. The PSNP is regarded as one of the success stories of social protection programmes as it has helped build climate resilient communities among the vulnerable poor, facilitated efforts to eradicate poverty and contributed towards sustainable development.

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# C. MEASURING PROGRESS OF ADAPTATION OF VULNERABLE GROUPS AND COMMUNITIES TO THE IMPACTS OF CLIMATE CHANGE

*Setting the baseline scenario of the vulnerable groups communities*

Vulnerability varies over space and time due to the multiple factors involved. New climate extremes, demographic dynamics, changes in disease patterns or emergence of new diseases, changes in differentiated responsibilities and rights of men and women, etc., will alter the vulnerability of a community or group. Furthermore, as adaptation measures are implemented, groups and communities may increase their resilience to the impacts of climate change. It is therefore important to understand how vulnerability and the resilience of the groups and communities continues to evolve over time. This will ensure that appropriate adaptation measures are implemented on time to prevent catastrophic damages, failures and loss of life further on.

The first step towards measuring progress is developing the baseline scenario of the vulnerable groups and communities.

*Indicators for measuring progress*

Specific indicators and metrics can be developed to measure progress in adaptation of vulnerable groups and communities. This would need to be aligned with the overall national framework while ensuring that they are appropriate to the context and incorporate the perspectives of the vulnerable groups and communities. It is important to note that such indicators and metrics would differ from one country to the other, and by individual groups and communities. Box 8 below provides an example on measuring progress on adaptation and climate resilience for particularly vulnerable regions in Canada.

**Box 8: Measuring progress on adaptation and climate resilience for particularly vulnerable regions in Canada**

The Government of Canada established an external Expert Panel on Climate Change Adaptation and Resilience Results to recommend indicators to measure progress on adaptation and climate resilience in Canada. The indicators were to align with the five key areas of action identified under the adaptation and climate resilience pillar of the Pan-Canadian Framework on Clean Growth and Climate Change. These five key areas are: translating scientific information and traditional knowledge into action; building climate resilience through infrastructure; protecting and improving human health and well-being; supporting particularly vulnerable regions; and reducing climate-related hazards and disaster risks.

The development of the indicators followed a four steps process: setting the context; defining key objectives; describing pathways; and reviewing and selecting indicators.

The northern, coastal, and remote regions of Canada are identified as the most vulnerable regions owing to a variety of factors, including:

- Disproportionate impacts of climate change;
- Historical and ongoing burden of colonialism, geographic remoteness, and disproportionate fiscal pressures;
- Sub-standard infrastructure, limited access to services, and a heavy reliance on climate-sensitive economic activities;
- Highly sensitive landscape to slight changes in temperature and precipitation;
- Shortened winter road season that can prevent critical shipments of food, necessary infrastructure, medical supplies, equipment, and fuel, while also raising costs;
- Economic, health, and cultural, and livelihood impacts, resulting from the shift from localized subsistence economies to centralized cash economies and a decline in access to traditional food and medicine.

On the basis of the abovementioned factors and other additional considerations, the panel developed the indicators for measuring progress on adaptation and climate resilience for particularly vulnerable regions. The indicators were designed to evaluate the understanding of exposure, reducing sensitivity, increasing adaptive capacity, and improving regional collaboration. These are presented in table 2 below.

Table: Objectives and indicators to measure progress on adaptation and climate resilience for particularly vulnerable regions in Canada.

| ***Objectives*** | ***Indicators*** |
|---|---|
| *Objective 1*: Increase northern remote, and coastal regions' understanding of slow-onset events | *Indicator #10:* Percentage of communities in northern, remote, and coastal areas with community-based, specialized (e.g., coastal erosion, permafrost thaw, etc.) environmental monitoring programs that incorporate climate/weather observations |
| | *Indicator #11:* Percentage of population with access to local information on climate change, weather patterns, and associated impacts to regions and sectors in northern, remote, and coastal regions |
| | *Indicator #12*: Percentage of communities and regions in northern, remote, and coastal areas with planning mechanisms that incorporate or consider climate risk and opportunities |
| *Objective 2:* Reduce the sensitivity of northern, remote, and coastal regions to slow-onset events | Indicator #13: Number of key members of community (e.g., police, firefighters, water technicians, harvesters) with safety training and equipment to adapt to changing conditions |
| | *Indicator #14:* Maximum response times in northern, remote, and coastal regions related to search & rescue and emergency response programming |
| | *Indicator #15:* Percentage of people in northern, remote, and coastal communities whose access to the land, including country foods and traditional ways of life, is impacted by slow-onset events |
| | *Indicator #16:* Number of funded initiatives directed at protecting cultural assets (e.g., archaeological/historical sites, spiritual sites, traditional foods/ plants/ medicines) located in vulnerable regions from climate risks |
| *Objective 3:* Increase the adaptive capacity of northern, remote, and coastal regions by providing the human, technical and financial resources to self-determine their response to slow-onset events | *Indicator #17:* Percentage of northern, remote, and coastal communities with experienced and/or trained locals (including Elders with Indigenous Knowledge Systems) that are designing and implementing adaptation actions in their regions and/or communities |
| *Objective 4:* Improve regional collaboration between governments, communities, Indigenous Peoples, the private sector, and other relevant stakeholders (including agreements like Memoranda of Understanding (MOUs) and Data Sharing, which facilitate data access) | Indicator #18: Number of adaptation initiatives and/or formal agreements (MOUs, etc.) that include a multi-stakeholder approach (governments, communities, Indigenous Peoples, private sector, and others) for regional planning |

*References*

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# 3. VULNERABLE ECOSYSTEMS: RECOMMENDED GUIDANCE

# A. RECOMMENDATIONS ON IDENTIFYING VULNERABLE ECOSYSTEMS AT DIFFERENT SCALES

The determination of ecosystems that are particularly vulnerable to climate change is largely attributable to their characteristics. The examples below consider examples of vulnerable ecosystems under four broad characteristics: unique or rare species, global biodiversity value or significance, significant ecosystem function and service, and fragility. These characteristics could be considered at the national level when identifying vulnerable ecosystems under the process to formulate and implement NAPs.

*Unique or rare species*

Ecosystems that are characterized by unique or rare species are at z risk of extinction due to climate change. These include centres of endemism, areas with rare, declining, threatened or endangered species, and areas with slow-maturing or long-lived species. For instance, despite their tolerance to climate extremes (such as temperature variability), mountain gorillas have limited ability to adapt to the changing climate due to their small population sizes, low reproductive rate, low regeneration time, limited genetic variation, susceptibility to disease and highly restricted habitats (Advani, 2014). The Tsingy de Bemaraha Strict Nature Reserve, Royal Hill of Ambohimanga and Rainforests of the Atsinanana of Madagascar are listed in the UNESCO World Heritage List for hosting many of the endemic species of Madagascar's 'megadiversity', including lemurs. The biggest threat to the lemurs is their habitat destruction and degradation. Climate change is also projected to increase the richness, abundance and distribution of lemur parasite (Barrett et. al., 2013). The Cape Floral Region in South Africa is considered as one of the most special places for plants in the world due to its diversity, density and number of endemic species, in particular the fynbos biome. Climate change is projected to exterminate or significantly shrink the suitable habitat for fynbos by mid-century (Midgley et al. 2003). The Caribbean Sea is home to several species of coral that are considered to be critically endangered – these include acropora cervicornis, acropora palmata, cicindela albissima, hexalectris revolute, micrurus ruatanus, rhizopsammia wellingtoni, and tubastraea floreana (IUCN, 2018). Climate change risks including increased severity of El-Nino Southern Oscillation events and storms, temperature extremes and ocean acidification are particularly threatening the survival of these endangered species of the coral.

*Global biodiversity value or significanc*

Ecosystems with global biodiversity value or significance are also at risk of losing their functional significance due to climate change. These include ecosystems that are necessary for the life history stages of species (such as breeding, spawning, feeding, resting, wintering, and moulting) and the ecosystems with high concentrations of biological diversity. The Lake Malawi National Park located in the southern end of Lake Malawi is of global importance for biodiversity conservation due to its evolutionary fish diversity (UNESCO, 2018a). The park is home to the endemic cichlid fish species. The cichlids have gone through unique evolutionary processes that are considered a significant example of biological evolution and "adaptive radiation" in the world (Ivory et al., 2016). While the cichlid fish exemplify unique evolutionary processes over time, the timescale of such processes is in the order of centuries and changes in the climate (which are happening at much shorter timescales) will undermine their adaptive radiation. Moreover, their habitat (i.e. Lake Malawi) is particularly vulnerable to climate change, especially rainfall variability and increasing temperatures.

*Significant ecosystem function and service*

Areas with significant ecosystem function and service warrant special attention for their preservation for maintaining national, regional and global diversity. This includes ecosystems that serve as the natural habitats and support the life-cycle history (breeding, spawning, feeding, migration corridors, resting, wintering, moulting, etc.) of biological diversity, and the areas with high concentrations of biological diversity.

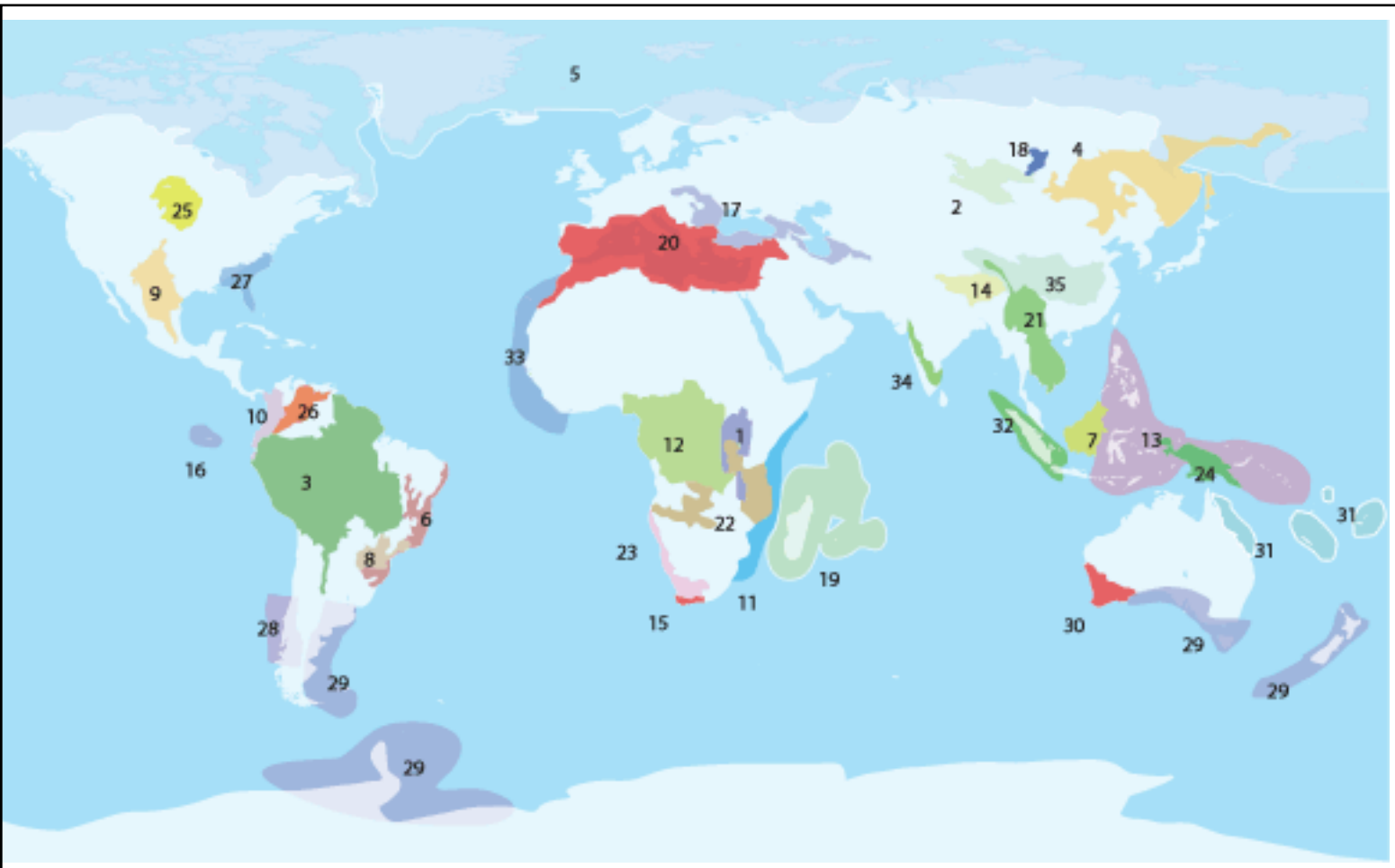
The Greater Mekong Subregion stretching across Cambodia, China, Lao People's Democratic Republic, Myanmar, Thailand and Vietnam is one of the most biologically diverse places on earth (WWF, 2013). It is among the places with the highest ecosystem value in monetary terms per hectare (Turner et al., 2012), and over 300 million people directly depend on its ecosystems services. The subregion is home to many endangered species, including the Asian elephant, the Indochinese tiger, the Irrawaddy dolphin, Javan rhino, and the Mekong giant catfish, and many endemic species, including the saola, the kouprey and the giant and white-shouldered ibises (WWF, 2013). The rate and nature of development in the subregion and climate change risks are posing extreme risks to the subregion's rich biodiversity.

The Serengeti ecosystem in Africa is home to the largest remaining unaltered terrestrial mammal migration in the world. It is home to the largest number of terrestrial mammals and the highest concentration of large predators in the world. The combination of conductive climatic factors (rainfall, temperature), plain topography, wilderness savanna ecosystem, drainage systems, rich volcanic soils and its ecology have made the Serengeti one of the most productive ecosystems in the world. As with all natural ecosystems, continued existence of the ecosystems is dependent on its protection and preservation.

Climate change is projected to significantly alter the conditions of migratory birds throughout their annual cycle. It is widely recognized that climate change threatens natural ecosystems (IPCC, 2014) and thereby the habit for breeding and non-breeding ranges of the birds (Stevens et al., 2017). In addition, climate change is projected to significantly increase the distances between suitable breeding and non-breeding habitats (Howard et al., 2017). These two factors are also anticipated to result in changes in migratory journeys of the birds.

Figur 1 provides a list of regions that are home to irreplaceable and threatened biodiversity; or representing an opportunity to conserve the largest and most intact representative of their ecosystem.

**Figure 1: WWF places that are particularly rich in biodiversity. These are irreplaceable and threatened biodiversity, and/or those that present an opportunity to conserve the largest and most intact representation of their ecosystem. Source: WWF (2018). Where we work. Available at http://wwf.panda.org/knowledge_hub/where_we_work (accessed 2 August 2018).**



*Fragile ecosystems*

*Fragile ecosystems* such as mountain ecosystems, low-lying coastal areas and delta areas are susceptible to increased degradation from climate change impacts and human activities. The degradation of these ecosystems can diminish their provisioning of ecosystem services, or worse, turn them into natural hazard risks.

*Mountains* for instance are home to diverse ecosystems that play important roles in climatic conditions, ecosystem service provision (water, energy, food security, etc.), tourism and raw materials. On the other hand, they can also present natural hazard risks such as floods, landslides, avalanches, etc., that can defy even the most robust risk-management strategies (Kohler et al., 2014). Warming is projected to alter mountain ecosystems through migration of species to find new suitable habitats (e.g. to higher altitudes), or extinction for those species than cannot easily migrate fast enough (especially plants). At higher latitudes, higher temperatures elevate runoff in winter and cause an earlier melting of snow in spring, resulting in reduced runoff in the summer, and thereby affecting all downstream ecosystems. On the other hand, rivers originating from the mountains cut through highly varying terrain, and increased flow due to high precipitation or elevated snow melting can significantly amplify their flow, undermining hillslopes and eventually inducing the collapse of mountain peaks (Kohler et al., 2014). The consequences of these hazards severely threaten the livelihoods of the communities living in the mountains or relying on their ecosystem services.

*Low-lying* coastal areas are at heightened risk of submergence, coastal flooding, and coastal erosion due to climate change throughout the century and beyond (IPCC, 2014). Due to its geological and physical features, a significant part of Kiribati is severely faced with coastal erosion, salt-water inundation, posing significant impacts on mangroves and coral reefs, fresh water resources, agriculture, and public health (GoK, 2014).

The *Ganges-Brahmaputra-Meghna Delta* covering most of Bangladesh and part of the Indian state of West Bengal is identified as the most vulnerable delta in the world from natural and human-induced stressors (UNEP-DHI and UNEP, 2016). Sea level rise and declining aggradation are the greatest threats and are putting the delta at a high risk of coastal erosion and salt-water intrusion (UNEP-DHI and UNEP, 2016; World Bank, 2013). The delta is also located in the track of tropical cyclones from the Indian ocean and regularly experiences floods that claim large number of lives and cause substantial damage to agriculture and infrastructure. Other particularly vulnerable deltas include the Niger and Volta deltas in West Africa and the Orange and Limpopo basins in Southern Africa.

Climate change is expected to exacerbate existing stresses to water availability and agricultural systems and cause the disruption of biological cycles in arid or semi-arid areas (IPCC, 2014).

Further examples can be found from national, regional and global assessments. These include, among others:

- National Biodiversity Strategies and Action Plans (NBSAPs) developed by Parties under the Convention on Biological Diversity (CBD); [1]
- National adaptation plans; [2]
- Ecological and Biologically Significant Marine Areas by the CBD;[3]
- Important Bird and Biodiversity Areas by Birdlife International; [4]
- Important Plant Areas by Plantlife International; [5]
- Particularly Sensitive Sea Areas by the International Maritime Organization; [6]
- Thirty-five (35) priority areas for conservation by World Wildlife Fund (WWF); [7]
- Red List of Threatened Species [8] and the Red List of Ecosystems [9] by IUCN;
- Wetlands of International Importance by the Ramsar Convention of Wetlands; [10]
- World Heritage Sites by the UNESCO; [11]
- Vulnerable Marine Ecosystems by the FAO. [12]

1 https://www.cbd.int/nbsap.
2 http://www4.unfccc.int/nap/Pages/national-adaptation-plans.aspx.
3 https://www.cbd.int/ebsa.
4 https://www.birdlife.org/worldwide/programme-additional-info/important-bird-and-biodiversity-areas-ibas.
5 http://www.plantlifeipa.org/home.
6 http://www.imo.org/en/OurWork/Environment/PSSAs/Pages/Default.aspx.
7 https://www.worldwildlife.org/places.
8 http://www.iucnredlist.org.
9 https://iucnrle.org.
10 https://www.ramsar.org/about/wetlands-of-international-importance-ramsar-sites.
11 https://whc.unesco.org.
12 http://www.fao.org/in-action/vulnerable-marine-ecosystems/en.

# B. STRENGTHENING CONSIDERATION OF VULNERABLE ECOSYSTEMS IN ADAPTATION PLANNING AND IMPLEMENTATION

This section provides examples of actions on strengthening the consideration of vulnerable ecosystems that can be applied in the formulation and implementation of NAPs. The actions are clustered into the following broad areas: policies and frameworks for the conservation and management of vulnerable ecosystems; transboundary cooperation; and creation and protection of migration corridors.

*Policies and frameworks for the conservation and management of vulnerable ecosystems*

These put in place by governments to ensure conservation and protection of ecosystems individually within the jurisdiction of one country, or regionally involving two or more countries. At the national level, such policies and frameworks include legislation or acts establishing protected areas (such as natural parks), institutional management and coordination of the parks, funding, restrictions on access to protected areas, and other provisions. In other countries, these are further complemented by a variety of community based natural resources management approaches that help transfer user rights

**Box 10: Wildlife management areas in Tanzania**

Tanzania is well known for its wildlife and conservation. Nearly 40% of the country's land area is set aside for conservation. The country has 16 national parks and five other game reserves and protected areas, including marine parks. Conservation of natural ecosystems in Tanzania is governed by the Wildlife Conservation Act of 1974 which allows the Government to establish protected areas and outline how they should be organized and managed. It is coordinated by the Tanzania National Parks (TANAPA) established under the Tanganyika National Parks Ordinance CAP 412 of 1959, and now operating under the new National Parks Act enacted in 2002.

Apart from the central legislation, Tanzania has a strong community based national resources management approach dating back to the 1980s. Formalized as Wildlife Management Areas (WMAs) in 2003, the approach allows communities to allocate their land (or part of) for wildlife conservation, and in return earn income from associated eco-tourism activities. The approach helps expand conservation beyond the national protected areas. In 2012 the government issued WMA regulations, setting provisions for: establishment of community based organizations, declaration of WMAs, administration and management of the WMAs, utilization of resources in the WMAs, investment and development, and other provisions.

To establish a WMA, a community needs to work through appropriate administrative procedure to identify the land for the WMA, register a community based organization to manage the WMA, and gazette the WMA and obtain legal rights to wildlife, after which the operation of the WMA including investments can be pursued. To support communities in the process, the Wildlife Division of Tanzania's Ministry of Natural Resources and Tourism has developed a Reference Manual for Implementing Guidelines for the Designation and Management of WMAs in Tanzania.

WMAs present opportunities for achieving both ecosystem conservation and improved livelihoods of the communities. Preliminary benefits from the Tanzania WMAs include the following:

- Improved ecosystem health;
- Increased wildlife populations;
- New investments to scale up conservation efforts and increase revenue;
- Income generation for local communities from eco-tourism activities;
- Reduced poaching as the communities take more ownership and protection of the wildlife.

References:

Tanganyika National Parks Ordinance CAP 412 of 1959, Tanzania Wildlife Conservation Act of 1974

Tanzania National Parks Act 2002, Tanzania Wildlife Conservation (Wildlife Management Areas) Regulations, 2012

Government of Tanzania (2003). Reference Manual for Implementing Guidelines for the Designation and Management of Wildlife Management Areas (WMAs) in Tanzania.

USAID (2013). Tanzania Wildlife Management Areas Evaluation Final Evaluation Report. Available at https://pdf.usaid.gov/pdf_docs/pdacy083.pdf (Accessed 19 September 2019)

and responsibilities for the ecosystems from the central government to the local communities. These frameworks can be included in the mandate and framework for the process to formulate and implement NAPs.

Box 10 provides an example from wildlife management areas approach in Tanzania, which help in achieving both ecosystem conservation and improved livelihoods of the communities.

Regional policies and frameworks are often aimed at promoting cooperation for the conservation or protection of the shared ecosystems of interest. They provide opportunities for joint assessment, planning, implementation, monitoring and evaluation of preservation and conservation activities by the countries involved, and relevant stakeholders. Such cooperation often yield better results that would have otherwise been difficult to achieve by the countries individually, due to the effort required in terms of resources and scale. It enables the sharing of costs and benefits of adaptation measures and prevents potentially negative impacts of unilateral adaptation measures. It can also trigger opportunities for socioeconomic development and management of issues at appropriate ecosystem scales.

Box 11 below provides an example of a regional programme launched by the Micronesian Islands to collectively protect their territorial terrestrial and marine ecosystems.

### Box 11: Protecting marine and terrestrial environments in the Micronesian Islands

In recognition of the need to preserve the marine and terrestrial environments of the Micronesian Islands and safeguard future economic, cultural and political health, the Governments of the Republic of Palau, the Federated States of Micronesia, the Republic of the Marshall Islands, the U.S. Territory of Guam and the U.S. Commonwealth of the Northern Mariana Islands, signed a commitment (Micronesian Challenge) to conserve at least 30% of the near-shore marine resources and 20% of the terrestrial resources across Micronesia by 2020.

A success story in the region, the challenge embodies a number of activities that include: the strengthening and establishment of over 150 protected areas throughout the Micronesia region; enactment of laws for the closure on key spawning sites for fish and the management of marine areas by the local communities such as in Palau; community-based watershed conservation programmes including local conservation groups in the Federated States of Micronesia; awareness raising and capacity-building of policy makers on conservation of terrestrial and marine ecosystems across Micronesia; and the creation of the Pacific Islands Managed and Protected Areas Community (http://www.pimpac.org). The challenge has also inspired similar regional initiatives in the Central Pacific, the Caribbean and the Western Indian Ocean.

The challenge is supported by the United States Department of Interior, the National Oceanographic and Atmospheric Administration (NOAA), the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of Germany, David and Lucile Packard Foundation, the Nature Conservancy and Conservation International. The challenges also has a strong community of global stakeholders, island communities and leaders who work with international governments and organizations, corporations, schools, and educators.

The figure in the next page shows the areas covered by the challenge.

Figure: 3: Conservation areas of the Micronesia Challenge.
Source: Coral Reef Initiative. http://cnmicoralreef.com/our-work/education-outreach-2/micronesia-challenge.htm


*References*

*United Nations (2018). Micronesia Challenge. Available at https://sustainabledevelopment.un.org/partnership/?p=2502 (Accessed 18 September 2018)*

*Capturing knowledge home (2018). The Micronesia Challenge. Available at https://www.capturingknowledge.org/micronesia-challenge (Accessed 18 September 2018).*

*Projects and programmes for the protection and conservation of vulnerable ecosystems*

There exist a wide range of activities for the protection and restoration of vulnerable ecosystems from the natural and human-induced hazards that can be applied in the formulation and implementation of NAPs. They include measures such as watershed and reservoir conservation, afforestation, maintaining wetlands and urban green spaces, reduction of other stressors on ecosystems and of habitat fragmentation, maintenance of genetic diversity, manipulation of disturbance regimes, and community-based natural resource management.

These activities can be implemented either at the national level within one jurisdiction or as transboundary programmes. Transboundary adaptation can provide multiple benefits, enabling more efficient and effective adaptation by pooling available data, models and resources and enlarging the planning space for locating adaptation measures.

The Great Green Wall for the Sahara and Sahel initiative in Africa (see box 12) is a classic example for the restoration of the degraded and barren land across North Africa, the Sahel and the Horn of Africa to create productive landscapes.

**Box 12: The Great Green Wall for the Sahara and Sahel initiative**

The Great Green Wall for the Sahara and Sahel Initiative (GGWSSI) brings together more than 20 countries from the Sahara, the Sahel and the horn of Africa, including Algeria, Burkina Faso, Benin, Chad, Cabo Verde, Djibouti, Egypt, Ethiopia, Libya, Mali, Mauritania, Niger, Nigeria, Senegal, Somalia, Sudan, the Gambia and Tunisia, to restore the degraded landscape and transform the livelihoods of the communities along the southern edge of the Sahara Desert.

The need for the creation of the GGWSSI dates back to the 1970s when vast swathes of fertile land once rich with biodiversity and vegetation in the southern part of the Sahara Desert started to become severely degraded due to climate change impacts, population pressure and unsustainable land-use practices. The loss of fertile land resulted in a combination of calamities that included severe food and water shortages, unemployment, conflicts, forced migration, etc., leaving the communities to spiralling exposure to vulnerability from climate change and other shocks. In recognition of the scale of the problem, leaders from the region continued to develop the idea to turn it into reality.

In 2007, African Heads of State and Government under the auspices of the African Union endorsed the GGWSSI with the objective of tackling the detrimental social, economic and environmental impacts of land degradation and desertification in the region. Eleven countries from the region (Burkina Faso, Chad, Djibouti, Eritrea, Ethiopia, Mali, Mauritania, Niger, Nigeria, Senegal and Sudan) signed the initiative and created the Panafrican Agency of the Great Green Wall to follow up on the realization of the GGWSSI. The GGWSSI has now expanded to include more countries from north and west Africa.

The GGWSSI is designed to cultivate an 8,000 km long and 15 km wide belt of green vegetation along the southern edge of the Sahara Desert, to fight the impacts of climate change and desertification. It is built around three major pillars of expanding investments in sustainable land water management technologies, improving land-use planning and improving, and applying information base for decision making.

Major achievements under the GGWSSI include the plantation of 12 million drought resistant trees in Senegal, and the restoration of degraded land in Burkina Faso (3 million hectares), Nigeria (5 million hectares), Niger (5 million hectares) and Ethiopia (15 million hectares). In Niger, the rehabilitated land is now delivering additional 50,000 tonnes of grain per year, significantly contributing towards national food security.

By 2030, the GGWSSI aims to restore 100 million hectares of currently degraded land, sequester 250 million tonnes of carbon and create 10 million jobs in rural areas. This will greatly help fight poverty and hunger, contribute towards mitigation of greenhouse gases, boost economic activities and improve health and wellbeing of the communities.

In addition to the 20 countries, the GGWSSI is supported by the Africa Union, the European Union, the Food and Agricultural Organization of the United Nations, the Government of France, the Global Environment Facility, the International Union for Conservation of Nature, the Permanent Inter-State Committee for Drought Control in the Sahel, the Royal Botanical Gardens, the Sahara and Sahel Observatory, the United Nations Convention to Combat Desertification and the World Bank.

*References*

More information about the GGWSSI is available at http://www.greatgreenwall.org and https://www.thegef.org/news/great-green-wall.

*Protection and creation of biodiversity corridors*

Climate change induced migration involve shifting of species to cooler places (either at higher latitudes or altitudes) as the climate warms, or recolonization of new habitats as present habitats lose fertility or specie populations change. Actions for strengthening consideration of vulnerable ecosystems in this context are focused on protecting existing corridors, or creating new corridors to enable species to move connect to more suitable habitats. The actions help preserve and increase populations of threatened species, and by extension the continued provisioning of ecosystems services.

*Biodiversity corridors* are stretches of land that connect core ecological areas. They help maintain or promote cohesion of biodiversity in otherwise fragmented ecosystems. By connecting the core ecological areas, the corridors help expand the habitats and thereby enabling gene flow and movement of biota. They also support the regular migration of animal species to follow the seasonal changes in availability of good pasture and water resources. They also enable the migration of plant and animal species to new habitats that are more suitable for their survival when the climatic conditions of their present habitats change (Bennet et al., 2016).

The protection and creation of biodiversity corridors provided medium- to long-term preservation of species and entire ecosystems, and can be used as one of the adaptation measures in the NAPs in cases where applicable.

Box 13 provides an example on the improvement of ecosystems through biodiversity corridors in the Terai Arc Landscape between Nepal and India.

### Box 13: Biodiversity corridors improving ecosystems in the Terai Arc Landscape - Nepal and India

The Terai Arc Landscape (TAL) is a transboundary conservation area between India and Nepal with biodiversity corridors connecting 16 protected areas (Thapa, K. et al., 2018), over a land area of 50,911 km2 and 700 km long (Thapa, K. et al., 2017). The programme was initiated in 2001 with the purpose of protecting the Bengal tiger, rhino and Asian elephant by creating links between the protected areas (Thapa, G. et al., 2015). All three species have extensive spatial habitat requirements (ecological, behavioral and demographic) that could not be fulfilled by the small secluded protected areas (Thapa, G., 2015). The added pressure of climate change negatively impacts protected areas and surrounding communities due to ecosystem shifts and forest fragmentation (ibid.).

Since 2001, the TAL's goal has been to restore and create habitat linkages that increase the well-being of the protected areas, while identifying climate change impacts and societal trends on specific species to integrate informed adaptation strategies within conservation planning (Thapa, G., 2015). The TAL applies various approaches to maintain overall connectivity to enable the dispersal of key species, particularly megafauna, to manage them as resilient, robust metapopulations. These include: community reforestation projects, monitoring via camera trapping, creating climate microrefugia through preserving cold air drainage areas (such as valley bottoms and local depressions) and slopes to maintain cooler temperatures and water balance, and contesting development activities that negatively impact the protected lands and corridors (WWF India, (n.d.), Thapa, G., 2015).

TAL is linked to positive trends of species and resource restoration. Research on the overall population trends of tigers within TAL evidences that the corridors increase the movement and dispersal of tiger sub-population throughout the conservation area (Thapa, K., 2017). Findings show a 15-21% minimum increase in tiger population in one of TAL's conservation areas from 2009 to 2014 (ibid). Through corridor usage, the tiger meta-population is experiencing an upward trend due to increased genetic diversity, creating population persistence. This finding is significant because the utilization of the corridors prevents inbreeding depression within isolated tiger populations (Thapa, K., 2017).

Regarding resource restoration, researchers have concluded that forest area in the Lamahi bottleneck area of TAL expanded by ~20 km2 over the last 16 years (Thapa, K., 2018). In turn, the increase in closed canopy cover of forested areas not only provides a safer landscape for endangered species to roam but contributes to societal benefits through resource generation, such as water (ibid). Waterspouts in the form of conservation ponds are utilized by the communities living downstream for farming. In turn, downstream communities have experienced an increase in agricultural outputs and higher income generation (ibid). Therefore, the Terai Arc Landscape is improving the well-being of endangered species and the livelihoods of neighboring human settlements.

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*Applying traditional and indigenous knowledge in protecting ecosystems*

Indigenous groups have valuable practices and experience in managing ecosystems that can prove more effective than scientifically sought measures. In the village of Hin Lad Nai in Thailand, local communities applied indigenous farming practices to safeguard the natural biome while continuing to farm on the same ecosystem (see box 14).

### Box 14: Supporting the regeneration of flora and fauna through indigenous farming practices in Hin Lad Nai, Thailand

In the Hin Lad Nai village of Chiang Rai in Northern Thailand, the indigenous Karen community practices rotational farming as a means of sustainable forestry management and food cultivation. Through their self-made Northern Farmer's Network, established in 1994 to protect land rights of hill tribes and local farmers within the village, the Karen community and other indigenous communities continue to promote community approaches to natural resource management and conservation, carry out advocacy work for community land rights recognition, and support a model of sustainable agriculture by using the community's traditional knowledge and rotational farming (International Land Coalition, n.d.).

After decades of facing threats of land eviction and natural resource degradation from the logging industry, the Karen community's rotational farming method is now protected under the Thai Ministry of Culture (Government of Thailand, 2017). The Network achieved political success in 2010 by being identified as a Special Cultural Zone under the state, allowing the villagers to legally practice rotational farming within their current 3688 hectares of land (Mellegård, 2018, International Land Coalition, n.d.).

The recognition of the Karen community's natural resource management under law allowed for further research on their indigenous knowledge as an example of a sustainable adaptation approach. Karen natural resource management methods are proved successful through increases in flora and fauna regeneration as well as a reduction in carbon footprints. 30 years after decades of intensive logging, 80% of the forest regenerated through Karen reforestation practice (Trakansuphakon, 2016). The rotational farming not only allowed for plant species to become abundant, but the method increased biodiversity in the area, as fallows serve as a place for animals to hide from predators, dwell and reproduce (Malmer, 2018). Indicative of the scale of biodiversity within the community, is the production of more than 100 different varieties of vegetables, out of which, 90 varieties are from shifting cultivation (study).

Without fallows, plant seed varieties will decrease and in turn, animals will become extinct (Malmer, 2018). Therefore, rotational farming provides food security, as evidenced by 92% of food within the Hin Lad Nai village comes from household production, while 8% comes from markets outside the community (NDF, 2011). Research also finds that the practice contributes toward less energy consumption, 1.70 hectares per head is the average carbon footprint of Thailand, compared to approximately .5 hectares per head in Hin Lad Nai (ibid).

The success of the natural resource management methods practiced by the Karen community is an international inspiration used in workshops with the aim to continue a multi-stakeholder dialogue to promote more indigenous/local knowledge exchange between governments and other development actors (Malmer, 2017). The Hin Lad Nai community is one out of five indigenous communities within a working group composed of international development organizations and indigenous knowledge network created to inspire, understand gaps and analyze best practices of knowledge cogeneration and local/indigenous practice integration (ibid).

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# C. METHODS FOR MAPPING VULNERABLE ECOSYSTEMS AND MONITORING AND ASSESSING THEIR CHANGE OVER TIME

Mapping of vulnerable ecosystem

A mapping of vulnerable ecosystems and their ecosystems services should be one of the first steps in the planning and implementation of adaptation measures for vulnerable ecosystems. It would help examine key features of the ecosystem, ecosystem goods and services that are essential for communities and development initiatives, the supply and demand for the ecosystems services, natural and human induced risks to the ecosystem, stakeholders, and institutional setup for the management of the ecosystem. It would form the basis for deciding on and implementing actions to strengthen the consideration of vulnerable ecosystems in adaptation planning and implementation. Box 15 below provides an example of the benefits of comnining participatory and scientific appraoches in mapping vulnerable ecosystems.

Box 15 below provides an example of the benefits of combining participatory and scientific approaches in mapping vulnerable ecosystems.

**Box 15: Participatory digital mapping of pastoral ecosystem dynamics in Kenya and Tanzania**

Pastoralists in Kenya and Tanzania understand the nuances within the ecosystems of arid and semi-arid lands (ASALs), of which are distinguished by varying rain patterns, soil types and topographical features that allow multiple grass species to grow at different times during the year (Krätli and Schareika, 2010). Pastoralism is accustomed to the ecosystem's fluctuating nature by using livestock mobility in open spaces as the primary method of maximizing productivity (ibid). Despite familiarization in coping with unpredictable weather, pastoral communities will face increases in drought-related shocks and more unpredictable, rainfall events due to climate change, potentially affecting their grazing land, livestock and livelihoods (Kirkbride, 2008). Whether climate change will be extremely detrimental to ASAL communities or whether pastoralists will be able to continuously adapt to even more climate unpredictability, adaptive measures depend on improving access to pastoral knowledge within local communities and government in order to accurately monitor the ecosystem and take informed action.

From 2011 to 2016, local pastoral community members in Isiolo Country, Kenya and Longido District, Tanzania articulated local knowledge on ASAL ecosystem dynamics, resources and infrastructure onto geo-referenced maps to improve universal data accessibility and fill knowledge gaps about impacts on ASALs from both climatic and societal trends (Rowley, 2013). The mapping projects, Mainstreaming Climate Change Adaptation in Drylands Development Planning in Tanzania and Supporting Local Climate Resilience through Innovative District Funding and Social Protection Mechanisms in the Drylands of Kenya (http://pubs.iied.org/pdfs/G03659.pdf), were funded by DFID (UK's Department for International Development) with technical support from the GeoData Institute at Southampton University, UK and IIED (International Institute for Environment and Development), and governmental support from the National Drought Management Authority and Isiolo County government (Kenya) and the district of Longido (Tanzania) (Hesse, 2013).

The project supported a series of mapping processes: data-collecting through drafting paper perception maps of the ecosystem, cross-referencing perception maps with Google Earth and creating GIS (global information system) maps to geo-reference natural resources, process/mobilization pathways, species type, among other elements (Rowley, 2013). Local community members were drivers of translating their qualitative and quantitative data into GIS to provide an interactive database that not only visualizes dynamics of pastoralism in a way that is geographically accurate but also enhances the availability of valuable, local data (ibid).

The project was successful in advancing local adaptive capacity to climate variability and change through geo-referencing and digital map-making training. It increased the local sense of ownership over natural resources, as the use of geographically-coordinated maps triggered extensive discussions about community natural resource management approaches (ibid). The power of local knowledge served as an impetus for the development of bylaws and investments to support pastoral livelihoods and further climate resilience initiatives in ASALs (Hesse, 2013). Because of the success in transferring the value of local data on complex, vulnerable ecosystems to a single, accessible platform, plans were made to replicate the project in neighboring counties/districts in Kenya and Tanzania (ibid).

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*Monitoring change over time*

Ecosystems and ecosystem services are subjected to continuous change from natural and human risks. Land use and land use change for example often lead to the degradation and fragmentation of the terrestrial and aquatic ecosystems. Continuous monitoring and assessment of changes in ecosystems is therefore helpful to understand the evolution of the ecosystem and underlying risk factors, and hence be able to put in place appropriate measures to maintain the ecosystem health and protect them from degradation and possible extinction (MEA, 2003).

*Monitoring the effectiveness of adaptation measures*

Monitoring and evaluation of adaptation actions is critical step in the adaptation process, to enabling learning from implementation and evaluation of effectiveness. Monitoring and evaluation are also key to informing future policy and practice. As in the planning stages, participatory approaches to monitoring and the use of local knowledge help to ensure that adaptation strategies effectively respond to the needs of the most vulnerable, using locally-relevant criteria.

In Fiji, indigenous rural communities were involved in reviewing and adjustment of the Community Adaptation Plan, i nvolving a workshop on community-based monitoring and field visits with the aim of checking on the implementation of adaptation activities and to review and update the CAP to keep it relevant to the existing needs and concerns of the c ommunity (Dumaru, 2010).

In Colombia, strategies for adaptation in high mountain ecosystems included the participatory action-research approach, which allows the generation of relevant, timely and efficient information to be interpreted and handled by different people, communities and institutions that are involved. The success of this methodological approach enables it to be replicated and allows for monitoring at different scales (national, regional and local) with a high level of accuracy. It also recognizes local knowledge and experiences in climate change adaptation.

# 4. VULNERABLE GROUPS AND COMMUNITIES THAT DEPEND ON FRAGILE ECOSYSTEMS

In many cases, vulnerable groups and communities rely on vulnerable ecosystems. As a result, they are faced with heightened risks from both natural and climate-inducted hazards. Adaptation strategies in this context are also bound to be faced with important trade-offs and policy choices. To be effective, strategies and interventions that will help meet societies' goals for the conservation and sustainable use of ecosystems would need to incorporate the value of ecosystems in their design (MEA, 2003). They will need to be supported by effective communication of the ecosystem benefits and local interests to the decision makers. They will also need to invest in sustaining and improving the ecosystems and the services they provide. Figure 4 below shows ecosystem services and their links to human well-being.

An assessment of the vulnerability of ecosystems and their services, and their relation to the well-being of the vulnerable groups and communities requires an integrated approach (MEA, 2003). This would help to identify which ecosystem services are most important, and how to develop measures that would best adapt the ecosystems and retain the ecosystem services from the adverse effects of climate change. The Integrative Framework for NAPs and SDGs (NAP-SDG iFrame) developed by the LEG would particularly be useful in this context, to pursue an integrated systems approach while ensuring achievement of the development goals and targets of the systems at hand.

Prioritizing adaptation actions for vulnerable ecosystems provides multiple benefits, including enhancing resilience of critical ecosystems that provide ecosystem services such as livelihood opportunities to vulnerable groups and communities. In addition, integrating ecosystems into adaptation responses enables general applicability and implications for poverty and food security within the framework of sustainable development.

Adaptation of vulnerable groups, communities and ecosystems would also enhance synergies in implementation of the Rio Conventions and other multilateral environmental agreements. It can help meet the global goal on adaptation under the Paris Agreement, meet the objectives of biodiversity conservation under the Aichi Targets of the UNCBD, and the land degradation neutrality targets under the UNCCD. Most importantly it can help to contribute towards the achievement of the SDGs.

Box 16 provides a case of smallholder coffee farmers in Costa Rica, Honduras and Guatemala with limited land area and lack of access to credit and technical support, thereby leaving them particularly exposed to unpredictable rainfall variation. The coffee growing area is also facing the risk of substantial reduction due to warming climate. Various actions have been implemented to improve the resilience of the farmers from climate and other risks.

**Box 16: Vulnerability to climate risks of smallholder coffee farmers in Costa Rica, Honduras and Guatemala**

Smallholder coffee farmers in Costa Rica, Honduras and Guatemala, are vulnerable to the effects of climate change-induced rainfall variability on two fronts: ecologically and economically. Unpredictable rainfall creates conditions on coffee plantations that are inhospitable to coffee yields. The overall effect is a decline in coffee production from which the livelihoods of the farmers are dependent. Additionally, the climate-induced vulnerability of smallholder coffee farmers is increased by obstacles such as limited areas of land with a lack of access to credit or technical support. Areas suitable for coffee production expect estimated losses of 73-88% in size by 2050 due to climate change (Conservation International, 2018). Ecosystem vulnerability perpetuates an increased livelihood vulnerability of coffee farmers, creating a "double-exposure" effect. Throughout the region, ecosystem-based adaptation (EbA), information-exchange programs and financial support mechanisms address this dilemma.

Coffee farming EbA mostly takes shape through agro-forestry, serving as a combined carbon sequestration and climate adaptation approach. Costa Rica's Nationally Appropriate Mitigation Action (NAMA), "Café de Costa Rica," which aims to produce the world's first low-carbon coffee as a part the national carbon neutral goal, uses agro-forestry as a centerpiece for adaptive coffee production (Namacafe, 2018). The NAMA is still in the midst of completion, however, the NAMA attends expos, trains farmers on EbA and sustainable production, and has over 50 permanent participating mills (ibid). Coffee quality has increased due to agro-forestry, which reduces soil erosion, increases fertility and safeguards biodiversity, on top of providing income diversification through additional fruit and firewood production (ibid).

Agroforestry techniques are already significant within the region, as evidenced by estimating 3.8 EbA practice per farm within a sample population of all three countries (Harvey, 2017). However, information exchange among farmers is necessary to further progress agro-forestry. Compañia Hondureña del Café, a foundation established by Honduran coffee farmers enhances the capacity of farms to adapt to market and climate changes via farmer-to-farmer information exchange (CoHonduCafe, 2017). Supporting 20,000 farmers since 2013, Compañia Hondureña del Café has dispersed EbA practice throughout Honduras (Global Coffee Report, 2017). Within the realm of the project's influence, overall coffee productivity has increased by 25% (ibid).

Climate impacts can negatively impact farms with or without EbA. Therefore, securing financial support to sustain smallholder farmer livelihoods is vital to mitigate loss. Guatemala's Guate Invierte instrument supports the agriculture sector by guaranteeing lines of credit and insurance coverage to the small and medium-sized agricultural producers (MAGA, 2018). From 2005 to 2015, the financial instrument subsidized up to 70% of insurance premiums according to the crop and location of the farmer (MAGA, 2018). In only two years, 6300 animals and 5082 hectares were insured (Velasco, 2009). With 70 million dollars in agricultural support, Guate Invierte now has a policy that loans are a necessity for minimizing increasingly expensive climate risks to sustain economic growth (Ayala, 2018).

Costa Rica, Honduras and Guatemala's smallholder farmer populations are subject to the double vulnerability of ecosystem decline, and therefore, coffee production decline. However, the research, capacity building techniques and policy planning initiatives within the region allow for opportunities to increase and secure EbA practices, farmer-to-farmer exchange and national support systems which can hopefully further the progress of stabilizing smallholder coffee farmer's ecosystems and income.

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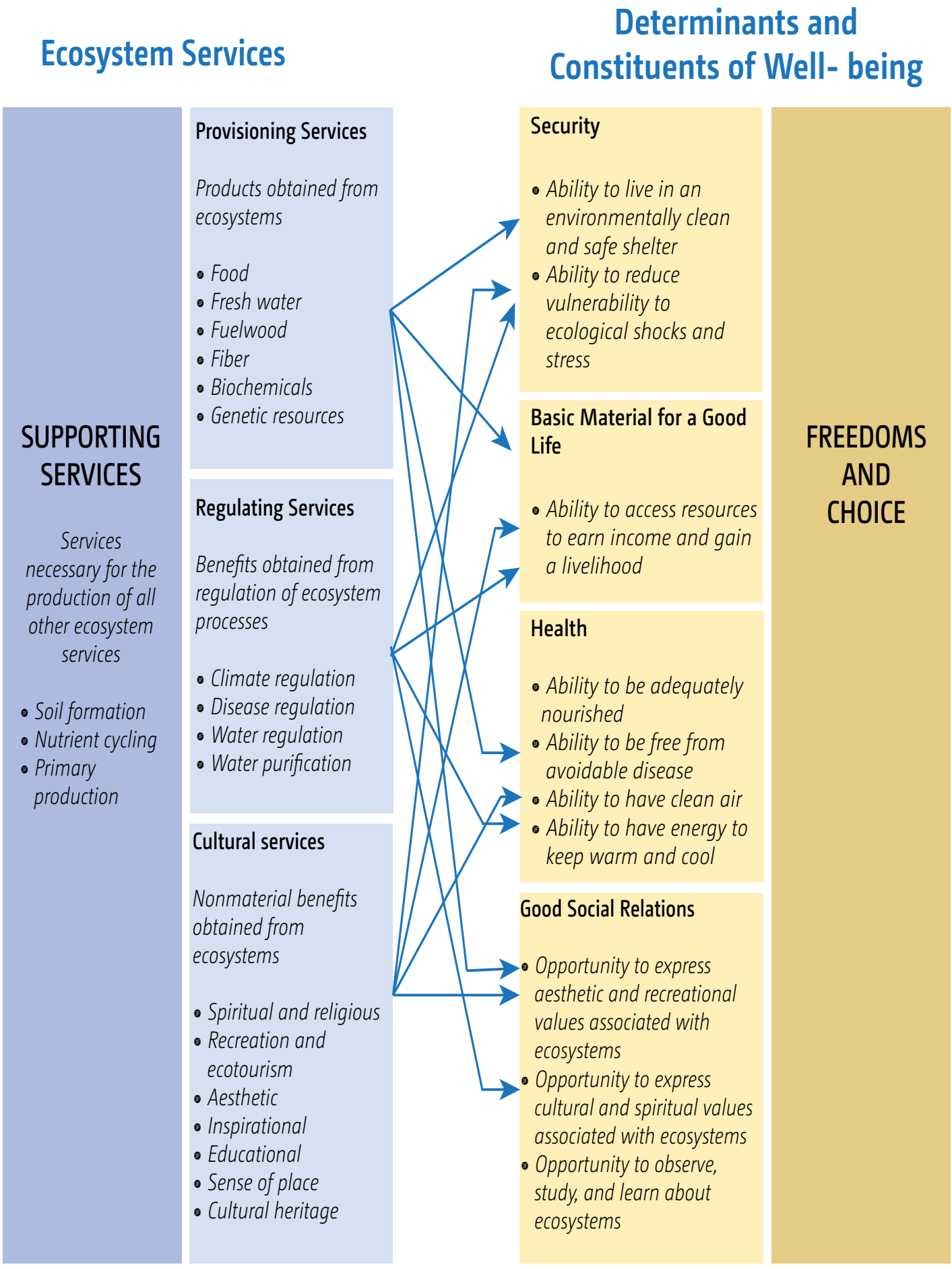
Figure 4: Ecosystem services and their links to human well-being.
Source: Millennium Ecosystem Assessment (Programme) (2003). Ecosystems and human well-being: A framework for assessment. Washington, DC: Island Press.



# 5. SUMMARY

Special considerations on venerable groups, communities and ecosystems is crucial in adaptation planning and implementation. Without doing so, there is a risk of their exclusion from national adaptation processes, further exacerbating existing vulnerability. There are established approaches for identifying vulnerable groups, communities and ecosystems that can be applied by countries under during the formulation and implementation of NAPs. These include adopting established groups, communities and ecosystems that are characterized as vulnerable within existing national frameworks, or the application of assessment methodologies to arrive at which groups, communities and ecosystems are most vulnerable to climate change.

Special regulatory frameworks, institutional arrangements, programmes and resources can facilitate the strengthening the consideration of the vulnerable groups, communities and ecosystems. In some countries, dedicated funding allocation has been effective in addressing the needs of the most vulnerable communities. The protection and creation of biodiversity corridors presents further opportunities to connect ecological areas, help to maintain the cohesion of biodiversity in otherwise fragmented areas, and hence preserve and expand vulnerable species.

A combination of vulnerable groups and ecosystems depending on vulnerable ecosystems can present challenges on how to manage trade-offs between biodiversity preservation efforts and the immediate livelihood needs of the groups and communities. However, this can also present opportunities for exploring measures that response to both the needs of the vulnerable groups and ecosystems, while maintaining ecosystem health and services.

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