Technology Executive Committee

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Bonn, Germany, 12–15 September 2017

Draft paper on aligning technology needs assessments with the process to formulate and implement national adaptation plans

I. Background

1. The COP-21 in the Decision 3/CP.21 (report of the Adaptation Committee) requested the Technology Executive Committee, in collaboration with the Climate Technology Centre and Network, the Adaptation Committee and the Least Developed Countries Expert Group, to consider how it can help Parties align their technology needs assessments (TNAs) with the process to formulate and implement national adaptation plans.

2. In response to the above COP decision, as per activity 9.1 of its rolling work-plan for 2016–2018, the TEC is to consider, in collaboration with the CTCN, the Adaptation Committee (AC) and the Least Developed Countries Expert Group (LEG), how Parties could be helped to align their TNAs with the process to formulate and implement national adaptation plans (NAPs).

II. Scope of the note

3. This note provides an updated outline and draft of the paper on aligning TNAs with the process to formulate and implement NAPs based on inputs from the various bodies. This paper is introducing necessary background and updates on the TNAs and NAPs, with a focus on technology issues under adaptation and how these can be addressed through the TNAs. Specific options for supporting and helping the countries are viewed in this version of the paper in the context of the mandates and work plans of the TEC, CTCN, AC and the LEG.

III. Expected action by the Technology Executive Committee

4. The TEC will be invited to consider the draft paper and provide guidance for the task force to finalise the paper after TEC 15.

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Annex I

Draft paper on aligning technology needs assessments with the process to formulate and implement national adaptation plans

I. Introduction

1. Decision 3/CP.21, paragraph 5, (report of the Adaptation Committee) requested the Technology Executive Committee, in collaboration with the Climate Technology Centre and Network (CTCN), the Adaptation Committee (AC) and the Least Developed Countries Expert Group (LEG), to consider how it can help Parties align their (work on) technology needs assessments (TNAs) with (that of) the process to formulate and implement national adaptation plans (NAPs).

2. Addressing this request is covered under activity 9.1 of the TEC workplan for 2016–2018, and is in collaboration with the CTCN, the AC and the LEG.

II. Objectives

3. The objectives of the paper should be to:

(a) Explore potential linkages and synergy between the work under the preparation and implementation of TNAs with the work under the process to formulate and implement NAPs;

(b) Identify options for how the TEC, CTCN, AC and the LEG can help countries address their adaptation technology needs under the NAPs through the TNAs.

III. Background

A. Technology as a cross cutting issue under the UNFCCC

Definitions and necessary background

4. The IPCC (2000), in its special report on methodological and technological issues in technology transfer, defined technology as ‘a piece of equipment, technique, practical knowledge or skills for performing a particular activity’. In its fourth assessment report, the IPCC further added that technology is the “practical application of knowledge to achieve particular tasks that employs both technical artefacts (hardware, equipment) and (social) information (‘software’, know-how for production and use of artefacts)”(IPCC, 2007).

5. The term indigenous knowledge generally refer to knowledge systems embedded in the cultural traditions of regional, indigenous, or local communities. Traditional knowledge includes types of knowledge about traditional technologies of subsistence, such as tools and techniques for agriculture, ecological knowledge, the climate knowledge, traditional health care and others. These kinds of knowledge, crucial for subsistence and survival, are generally based on accumulations of empirical observation and on interaction with the environment.

6. Adaptation is a process by which countries, local communities and individuals find and implement ways of adjusting to the consequences of climate change. Adaptation to climate change involves identification and implementation of a diverse and wide range of technological options which can, inter alia comprise “hard” technologies such as seawalls, dykes, irrigation techniques and “soft” ones such as crop rotation patterns as well as information and knowledge.

7. Local communities have been coping with climate variability and change over generations by using accumulated indigenous knowledge and practices. While the concept of adaptation is not new and has nowadays become clearer, the concept of technologies for adaptation has not always received proper attention.

8. Some sources distinguish between technology hard and soft. Hard adaptation technologies are those that involve capital goods, and soft adaptation technologies are those that focus on policy

and strategy development, information, and/or institutional arrangements. In terms of transferring technology, it can be thought of as a process brought about by the exchange of "knowledge, money, and goods" (IPCC, 2007) among stakeholders. This kind of technological cooperation and diffusion can occur inside a country's borders, or it can be transboundary.

9. Definitions of technology and the concept of technologies for adaptation remain broad and provide limited guidance on their application in practice. In this way, the "*UNDP Handbook for Conducting Technology Needs Assessment for Climate Change*" (UNDP 2010), defines the concept of technologies for adaptation very generically as: "All technologies that can be applied in the process of adapting to climatic variability and climate change".[1] A UNFCCC report on the development and transfer of technologies for adaptation to climate change recognizes the difficulty of defining the concept of adaptation technologies and proposes the following definition: "the application of technology in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impacts of climate change" (UNFCCC 2010).

10. Most developing countries have already conducted vulnerability assessments and have identified priority adaptation sectors and activities, for example through TNAs, NAPAs and National Communications. Technologies are embedded in such priority areas and actions. The broad conception and definition of technologies for adaptation facilitates approaching and understanding technologies for adaptation and related technology needs in the wider context of development planning and policy-making.

11. Most methods of adaptation involve one or more forms of technology, including hard forms such as sea walls and irrigation systems and soft forms such as insurance and crop rotation. According to IPCC (2014) engineered and technological adaptation options are still the most common adaptive responses.

12. In the technology transfer debate, historically, the focus has been given more towards mitigation technologies, with limited attention given to adaptation ones. The literature as well as operational experience with adaptation technologies has been quite limited; and there was a lack of clarity even in terms of basic definitions and concepts related to technologies for adaptation. To bring clarity on these issues a number of practitioners, academia and policymakers brought their perspectives on the concept of technologies for adaptation, for example in the TNA guidebook "Technologies for Adaptation: Perspectives and Practical Experiences", in order to further facilitate Technology Needs Assessment (TNA) processes in countries and contribute to a broader international discussion on how to define and operationalize the concept of technologies as it applies to adaptation.

13. The third synthesis report on TNAs from 2013 has shown that more adaptation technology action plans (186) were submitted by 29 developing countries than mitigation technology action plans (142). This shows strong consideration of adaptation related technologies by developing Parties also due to the broader international discussion and exchange of experiences in the last decade.

Categories of Technologies for Adaptation

14. Some sources distinguish between three components of technologies for adaptation: hardware, software and orgware. Hardware refers to so-called "hard" technologies such as capital goods and equipment and includes drought resistant crops and new irrigation systems. Software refers to the capacity and processes involved in the use of the technology and spans knowledge and skills, including aspects of awareness-raising, education, and training.

15. Adaptation methods and practices that may not normally be considered as technologies, such as insurance schemes or crop rotation patterns, may also be characterized as software (UNFCCC 2006). A third distinction which is equally important to the understanding of technologies for adaptation and their implementation is the concept of orgware,[2] which relates to ownership and institutional arrangements of the community/organisation where the technology will be used.

16. Table 1 provides examples of technology types for different sectors according to the above classification.

[1] UNDP Handbook for conducting Technology Needs Assessment for climate change.
[2] Concept introduced by Thorne, Kantor and Hossain (2007).

Table 1
Examples of technology types for different sectors

Sector/Technology type	*Hardware*	*Software*	*Orgware*
Agriculture	Crop switching	Farming practices, research on new crop varieties	Local institutions
Water resources and hydrology	Ponds, wells, reservoirs, rainwater harvesting	Increase water use efficiency and recycling	Water user associations, and water pricing
Coastal zones	Dykes, seawalls, tidal barriers, and breakwaters	Development planning in exposed areas	Building codes, early warning systems, and insurance
Health	Vector control, vaccination, improved water treatment and sanitation	Urban planning, health and hygiene education	Health legislation
Infrastructure	Climate proofing of buildings, roads, and bridges	Knowledge and know-how	Building codes and standards

17. Many adaptation technologies have been utilized for generations to cope with climate variability and improve livelihood resilience to socio-economic stresses. A sector categorization as illustrated in the table above is the most commonly used when addressing technologies for adaptation. Other categorizations may however be more appropriate depending on the specific context.

18. As the table 1 illustrates, hardware may need to be combined with software and orgware to be adequately embedded in vulnerable communities and thereby ensure the acceptance and ownership necessary for their successful implementation. Furthermore, in many cases hard technology may not be central for addressing adaptation needs of the most vulnerable communities. Access to locally available low-cost strategies and knowledge, i.e. software, and an enabling institutional context, i.e. orgware, may be more appropriate for addressing their adaptation needs in the short term and general development actions required for longer term and lasting vulnerability reduction through increased adaptive capacity.

Technologies in the context of adaptation and development

19. In spite of the technologies being available, other potential issues associated with the use of—especially hard—technology for climate adaptation remain, even if access to technologies were greatly improved. It seems clear that a standalone technology, such as physical structures and equipment, in order to be sufficient, should be supported by an enabling framework.

20. The vulnerability of countries to the effects of climate variability and change depends not only on their exposure to climate risks and the magnitude of impacts, but equally on the capacity of affected systems and societies to manage such risks and impacts.

21. Adaptive capacity depends on a wide range of factors that are closely related to development, including income level, education, institutions and governance, health, knowledge, skills and technological development. While technologies can be very important for reducing vulnerability, their effectiveness depends on the economic, institutional, legal, and socio-cultural contexts in which they are deployed.

22. As shown in several results of TNAs and NAPAs, and the preliminary results of TNAs and NAPs, the TNA process for adaptation may complement the adaptation assessments, planning and prioritization processes already ongoing in most developing countries and vice versa.

23. More specifically streamlining the mandates and objectives of the ‘adaptation track’ and the ‘technology track’ in the global process of adaptation would facilitate increasing the effectiveness of the overall adaptation process in developing countries, avoiding duplication of activities, and taking advantage of synergies whenever possible.

24. Specific considerations regarding coherence and coordination could be an integrated part of this exercise. Whether this is best done by formally merging certain deliverables of the two processes, such as implementation planning – thus making the identification and prioritization of technologies for adaptation an integrated part of national adaptation planning processes - or by maintaining two separate processes with clearly defined and mutually reinforcing mandates, is an issue that merits further analysis, although it may have been overtaken in light of the negotiated Adaptation Framework and the Technology Mechanism.

The role of technology in adaptation to climate change

25. Identifying the role of technology in adaptation to climate change may include actions that are directed at improving prevailing social, economic and environmental conditions and management practices in a system or sector. For the purposes of this paper, we identify roles of technology within a four-stage process of adaptation consisting of:

(a) information development and awareness-raising;

(b) planning and design;

(c) implementation, and

(d) monitoring and evaluation.

26. <u>Information development and awareness.</u> Technologies for data collection and information development are prerequisites for adaptation, particularly to identify adaptation needs and priorities. The more relevant, accurate and up to date the data and information available to the decision maker, the more targeted and effective adaptation strategies can be. There are several large-scale global and regional data repositories that have been established for a great number of climatic and socio-economic variables relevant to economic sectors and communities.

27. <u>Planning and design.</u> When the available data and information point towards a potential problem that would justify taking action, the next stage is to decide which action could best be taken and where and when this could best be done. The answers to these questions depend on the prevailing criteria that guide local, national or regional policy preparation, as well as on existing development and management plans that form the broader context for any adaptation initiative. Important policy criteria that could influence technology decisions include cost-effectiveness, environmental sustainability, cultural compatibility and social acceptability.

28. <u>Implementation.</u> Once all adaptation options have been considered and the most appropriate strategy has been selected and designed, implementation of the strategy is the next stage. An adaptation strategy can include the application of any of the types of technology described previously. One of the critical components is the presence of appropriate and effective institutions. Institutions vary widely across scales (small to large, local to national), sectors (such as agriculture, water, forestry, transport) and from formal (e.g. ministry or department of environment, NAP focal points, to informal (e.g. a local village community). Whereas formal institutions can respond to adaptation needs and challenges within their regulations, institutional guidelines and allocated resources, informal institutions often respond to specific adaptation challenges, such as drought, flood or cyclones, as self-organized and self-motivated systems.

29. <u>Monitoring and evaluation.</u> It is recommended practice in any field of policy that the performance of technological interventions be periodically or continuously evaluated against the original objectives. Such evaluation can yield new insights and information, which could give rise to adjustments in the technology or strategy as appropriate. This process is illustrated in figure 2 by the feedback loop from evaluation within the shaded box. This evaluation must be distinguished from the evaluation exercise that is done to identify the most appropriate technology, and which is part of the planning and design phase.

Technologies under the UNFCCC negotiations

30. At the COP-16 Parties shared a vision for long-term cooperative action. The vision addressed mitigation, adaptation, finance, technology development and transfer, and capacity-building in a

balanced, integrated and comprehensive manner to enhance and achieve the full, effective and sustained implementation of the Convention.

31. The COP 16 affirmed that all Parties should cooperate, consistent with the principles of the Convention, through effective mechanisms, enhanced means and appropriate enabling environments, and enhance technology development and the transfer of technologies to developing country Parties to enable action on mitigation and adaptation.

32. The COP 16 requested developed country Parties to provide developing country Parties, taking into account the needs of those that are particularly vulnerable, with long-term, scaled-up, predictable, new and additional finance, technology and capacity-building, consistent with relevant provisions, to implement urgent, short-, medium- and long-term adaptation actions, plans, programmes and projects at the local, national, sub-regional and regional levels, in and across different economic and social sectors and ecosystems.

33. The UNFCCC has a comprehensive architecture in which to support the development and transfer of environmentally sound technologies. Its platform continues to evolve with the role of technology enhanced as a cross-cutting issue in the 2015 Paris Agreement. The Technology Mechanism (consisting of a policy and implementing arm) is the main mechanism supporting technology development under the Convention.

34. The Technology Mechanism has embedded in it a Technology Executive Committee (TEC) to advise Parties on policy relevant issues and providing recommendations. A part of the current focus of the TEC is also supporting the UNFCCC endorsed process of Technology Needs Assessments (TNAs). TNAs identify nationally relevant technologies that can help deliver on national strategies, programmes, projects and actions. Examples of deliverance on the national level include:

(a) Technology Action Plans (TAPs);

(b) Nationally Determined Contributions (NDCs);

(c) Low Emissions Development Strategies (LEDS).

35. The Technology Mechanism's implementing arm, the Climate Technology Centre and Network (CTCN) aims to provide technical assistance to developing country project proponents to assist them to overcome implementation challenges.

B. Overview of the process to formulate and implement NAPs

36. COP 16 in 2010 established the process to enable least developed country (LDC) Parties to formulate and implement national adaptation plans (NAPs), building upon their experience in preparing and implementing national adaptation programmes of action (NAPAs), as a means of identifying medium- and long-term adaptation needs and developing and implementing strategies and programmes to address those needs.

37. The objectives of the process to formulate and implement NAPs as defined by the COP (decision 5/CP.17, paragraph 1) are as follows:

(a) To reduce vulnerability to the impacts of climate change, by building adaptive capacity and resilience;

(b) To facilitate 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.

38. The process to formulate and implement NAPs provides a comprehensive country-driven approach for advancing adaptation at the national level. It offers a means for linking climate change adaptation with the Sustainable Development Goals (SDGs).

39. The process to formulate and implement NAPs is framed around four elements, which are (see decision 5/CP.17, annex):

(a) Laying the groundwork and addressing gaps;

(b) Preparatory elements;

(c) Implementation strategies;

(d) Reporting, monitoring and review.

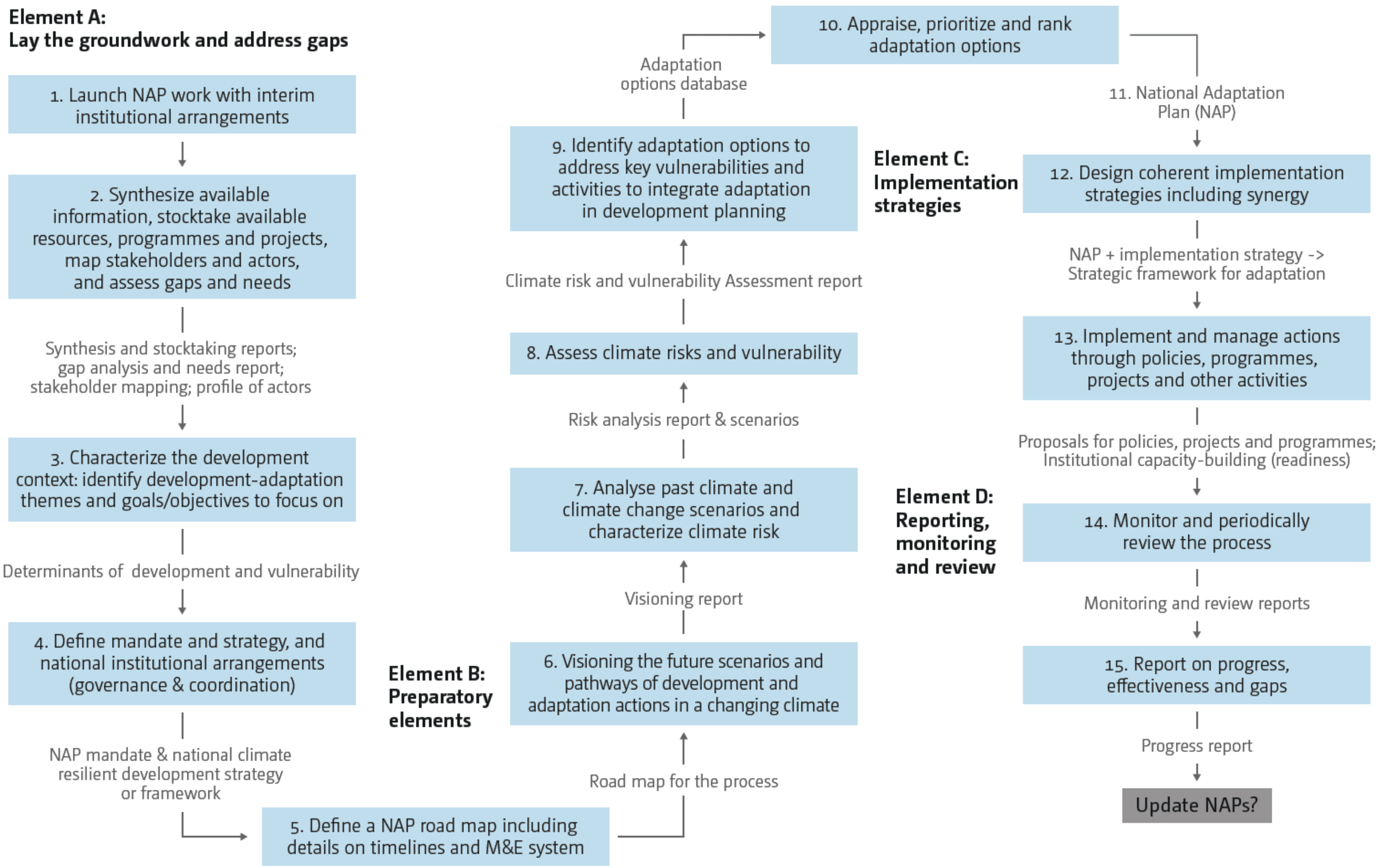
40. Based on these elements, and in response to a mandate from the COP, the LEG developed a technical guidelines for the process to formulate and implement NAPs (available at http://unfccc.int/nap and http://unfccc.int/7279). The technical guidelines offer detailed steps and information on how to formulate and implement NAPs. The LEG also developed a sample process, providing a quick conceptualization on how the process may be rolled out at the national level, as shown in the figure 1 below.

41. In addition, a number of supplementary materials (http://www4.unfccc.int/nap /Guidelines/Pages/Supplements.aspx), tools and methods, and outreach products have been developed by the LEG, the Adaptation Committee and other organizations for the process to formulate and implement NAPs, following the NAP technical guidelines.

42. As at August 2017, a number of developing countries had already embarked on the process to formulate and implement NAPs and had undertaken measures to lay the groundwork for it (place holder for reference to progress report on NAPs). Seven developing countries had submitted their NAPs to the UNFCCC through NAP Central (http://unfccc.int/NAP).

43. There are several places in the process where technology is important – both during the formulation of the NAPs, and more importantly, during the implementation of concrete projects to address adaptation needs identified in the NAPs. These entry points will be explored further by looking at what the TNAs can offer.

Figure 1
Sample flow of the process to formulate and implement NAPs (source: LEG 2017)



C. Overview of the TNA process

44. TNA was introduced under the Convention at COP-7, which encouraged "…developing countries …to undertake assessments of country-specific technology needs, subject to the provision of resources, as appropriate to country-specific circumstances."

45. In 1999, the GEF Council agreed that "some of the immediate capacity building priorities of non-Annex I Countries, identified in the COP decision 2/CP.4, may initially be met through additional funding under expedited procedures for enabling activities. Based on the above COP Decision, the GEF identified a list of eligible activities for the top-up projects, including identification and submission of technology needs, and capacity building to assess the technology needs. Consequently, the GEF funded the development of the first 69 TNAs reports since 1999 until 2008.

46. In 2008, TNA development was included in the Poznan Strategic Programme on Technology Transfer as a key component for "scaling up the level of investment in technology transfer in order to help developing countries address their needs for environmentally sound technologies."

47. The COP-18 recognized that TNAs and their syntheses "are a key information source for the work of the Technology Executive Committee in prioritizing its activities under the Technology Mechanism, and could be a rich source of information for governments, relevant bodies under the Convention and other stakeholders.

48. The COP-21 identified several technology related elements, in the Paris agreement, which may be considered TNA supportive.

49. In the Decision 1/CP.21, Adoption of the Paris Agreement, the COP-21 requested the SBSTA-44 to initiate the elaboration of the technology framework established under Article 10, paragraph 4, of the Agreement, and to report on its findings to the COP, with a view to the COP making a recommendation on the framework to the COP, serving as the meeting of the Parties to the Paris Agreement, for consideration and adoption at its first session, taking into consideration that the framework should facilitate, inter alia:

(a) The undertaking and updating of TNAs, as well as the enhanced implementation of their results, particularly TAPs and project ideas, through the preparation of bankable projects;

(b) The provision of enhanced financial and technical support for the implementation of the results of the TNAs;

(c) The assessment of technologies that are ready for transfer;

(d) The enhancement of enabling environments for and the addressing of barriers to the development and transfer of socially and environmentally sound technologies

50. Technology adaptation plans (TAPs), as one of four deliverables of the TNA process, are concise plans for the uptake transfer and diffusion of prioritized technologies that will contribute to the country's social, environmental and economic development and to climate change mitigation and adaptation. TAPs are made up of numerous specific actions, employ responsible stakeholders, with timelines and budget. More specifically, TAPs often include sector potentials, targets, existing enabling environment, expected benefits of implementation of actions, budget expenditures in time, sources of funds, associated risks, success criteria and monitoring of implementation.

51. As of February 2017 more than 180 TAPs were conducted and reported by developing countries in adaptation sector. More than 100 adaptation TAPs are expected to be delivered to UNEP and UNFCCC until the end of 2017.

52. Figures 2 shows the conducting steps of the TNA process undertaken by Parties. Figure 3 below highlights the main deliverables of TNA process with TAPs and project ideas being the implementation oriented deliverables.

Figure 2
Steps of the TNA process

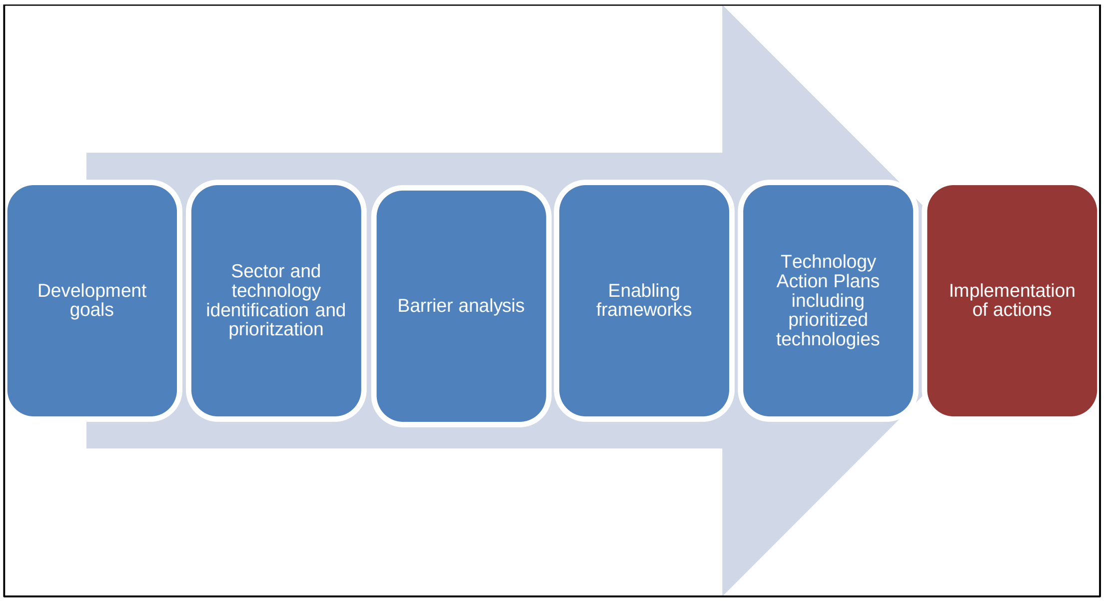
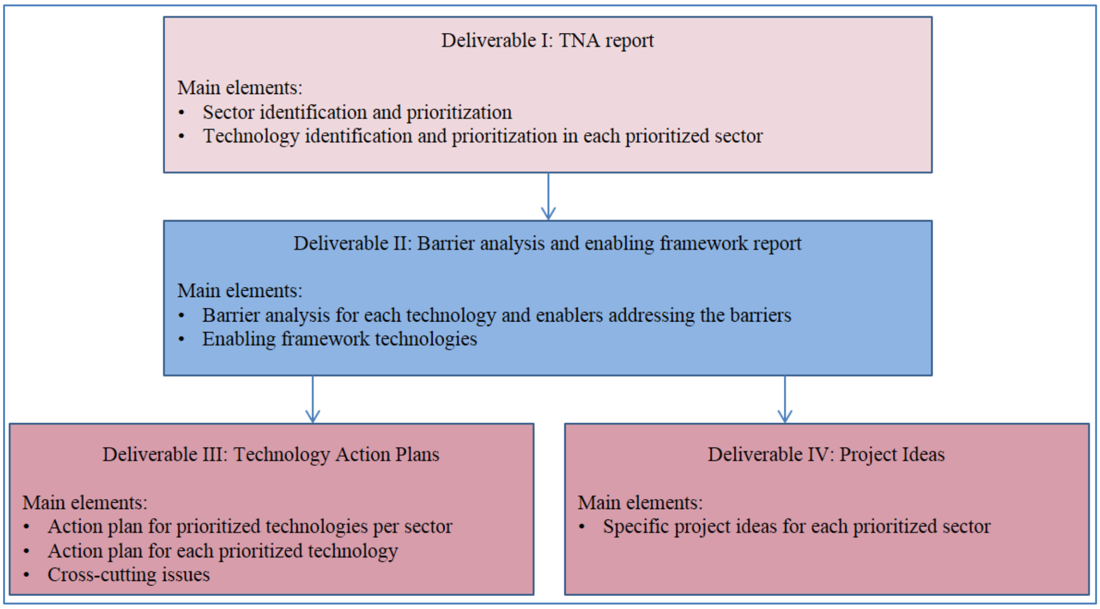


Figure 3
Main deliverables of the TNA process



IV. Use of technologies to advance adaptation

Examples of technologies for adaptation in selected key sectors

53. Multiple technologies are used for adaptation, below are examples from agriculture, water and coastal zones sectors.

Agriculture

54. Examples of technologies that can be employed to develop:

55. Information and awareness rising:

(a) Information on impacts of climate variability and change on agricultural production, available technologies for reducing impacts, assessment of people's needs, and awareness-raising of the different stakeholders, including policy makers, will help in designing adaptation strategies for the agriculture sector. Reducing the uncertainty of impact assessment, and raising the cost effectiveness of agricultural technologies and level of acceptability by different communities will make the adaptation strategies and measures more effective;

(b) Crop simulation models;

(c) Long-term and medium-term weather forecasts;

(d) Breeding of new high-yielding crop varieties;

(e) Information on technologies for water harvesting and soil moisture conservation in watersheds for small-scale irrigation.

56. Planning and design:

(a) Addressing the adverse effects of present climate variability and extreme weather events through the design of projects supported by policy decisions.

(b) Cross-sectoral approach in planning and designing adaptation measures.

(c) Employment of n integrated model comprising a hydrological model, crop simulation model and climate model. A number of decision support models/analyses may also be useful, such as cost-effectiveness, cost-benefit and multi-criteria analyses. It is also necessary to involve multidisciplinary teams in planning and designing adaptation measures for agriculture. Consultation with farmers and agricultural extension agents at the local level is essential.

(d) Planning and design strategy can be comprehensive at a national level, across sectors, regions and vulnerable populations.

57. Implementation:

(a) Many adaptation measures (hard and soft) for protecting agriculture from flood, drought and salinity have been implemented in many parts of the world (e.g. hard technologies - flood control, drainage and irrigation, soft technologies - training on how to use water infrastructure). Learning from existing projects and measures would be helpful. Table 2 below provides a list of currently available adaptation options and technologies that can be applied at the farm or farmer community level;

Table 2

Examples of adaptation opportunities vis-à-vis climate change impacts on agricultural systems

Response strategy	Adaptation options and technologies
• Use of different crops or varieties to match changing water supply and temperature conditions	• Conduct research to develop new crop varieties • Improve distribution networks
• Change of land topography to reduce run-off, improve water uptake and reduce wind erosion	• Subdivision of large fields • Grass waterways • Land levelling • Waterway-levelled pans • Bench terracing • Tied ridges • Deep ploughing • Roughening of land surface • Windbreaks
• Introduction of systems to improve water use and availability and control soil erosion	• Low-cost pumps and water supplies • Dormant season irrigation • Line canals or install pipes • Use brackish water where possible • Concentrate irrigation water during peak growth period • Level fields, recycle tail water, irrigate alternate furrows • Drip irrigation systems • Diversions
• Change in farming practices to conserve soil moisture and nutrients, reduce run-off and control soil erosion	• Conventional bare fallow • Stubble/straw mulching • Minimum tillage • Crop rotation • Contour cropping to slope • Avoid monocropping • Chisel up soil clods • Use of lower planting densities
• Change in timing of farm operations to better fit new climatic conditions	• Advance sowing dates to offset moisture stress during warm period

Source: Smit 1993.

(b) Anticipatory strategies for adaptation to climate change and climate variability aim to increase flexibility so as to allow the type of adjustments shown in table 8. For example, increasing the variety of crops may require the introduction of new knowledge and machinery to a farming community. However, as the climate changes, the technologies listed in table 8 may not be sufficient, and the need may arise for the development of new technologies to allow farmers to cope better with the anticipated impacts of climate change, and to reduce the costs of adaptation (Klein and Tol 1997).

58. Monitoring and evaluation:

(a) Periodic or continuous monitoring and evaluation of the performance of adaptation measures is necessary to allow for modification and readjustment, taking into consideration changing circumstances;

(b) Can be done with the aid of different communities involved in a project's implementation and its beneficiaries at local level;

(c) It is also necessary to identify appropriate indicators, and monitoring must be easy and the cost nominal.

Water

59. Many of water adaptation technologies already exist and are broadly diffused to the local level, both among developed and lesser developed regions. Others technologies are more familiar to the water planning and management sector in developed nations, and require transfer to less-developed regions. Finally, there are a number of technologies emerging from research and development that have the potential to provide substantial benefits to adaptation efforts in both developed and developing regions, but considerable thought will be required to determine how best, or even whether, these types of technologies can be transferred for use at local level, particularly in developing regions. Technologies which come under the first two categories are discussed below – those broadly known and used and those known but limited in use. These technologies are discussed in the context of the above introduced four-stage process of adaptation.

Examples of technologies that can be employed to develop:

60. Information and awareness rising for adaptation in integrated water resources management:

(a) Building communities of practice (informed, knowledgeable, committed);

(b) Data access (access to information);

(c) Forecasting tools.

61. Planning and design:

(a) Decision support tools;

(b) Demand and supply side of the water equation in fully integrating the biophysical, socio-economic, cultural and political considerations of adaptation issues;

(c) Forecasting water availability;

(d) Scenario analysis;

(e) Use of multi-criteria assessment (MCA) tools.

62. Implementation:

(a) Access to existing technologies;

(b) Technologies involving demand management.

Table 3
Possible implementation technologies (IPCC)

Use category	Supply-side	Demand-side
Municipal/domestic	▪ Increase reservoir capacity *(hard technology)* ▪ Desalinization *(hard)* ▪ Inter-basin transfers *(hard)* ▪ Alter system operating rules (*soft technology*)	▪ Increase use of 'grey' water, e.g. facilitated by use of enhanced filtration (*hard*) ▪ Reduce leakage in distribution system (*hard*) ▪ Non-water-based sanitation (*hard*) ▪ Seasonal forecasting (*soft*) ▪ Legally enforceable water quality standards (*soft*) ▪ Water demand management (*soft*)
Industrial and power station cooling	▪ Use lower grade water (*soft*)	▪ Increase water use efficiency and water recycling (*hard*)
Hydropower	▪ Increase reservoir capacity (*hard*)	▪ Increase turbine efficiency (*hard*) ▪ Encourage energy efficiency (*soft*) ▪ Energy demand management (*soft*)
Navigation	▪ Build weirs and locks (*hard*) ▪ Alternative transport (*hard*)	▪ Alter ship size (*hard*) and frequency (*soft*)
Pollution control	▪ Enhance treatment works (*hard*)	▪ Reduce volume of effluent to treat

		▪ Reuse and reclamation (*hard*)	(*soft*) ▪ Promote alternatives to chemical use (*soft*)
Flood management		▪ Increase flood protection, e.g. levees, reservoirs (*hard*) ▪ Wetland protection and restoration (*soft*)	▪ Improve flood warning and dissemination (*soft*); ▪ Curb floodplain development (*soft*)
Agriculture	Rain-fed	▪ Better soil conservation, e.g. nutrient replacement (*hard*) ▪ Better forecasting (*soft*)	▪ Increase drought tolerant crops (*hard*)
	Irrigated	▪ Alternative tilling practices (*soft*) ▪ Rain harvesting (*hard*)	▪ Increase efficiency of irrigation use, e.g. drip irrigation (*hard*) ▪ Change irrigation water pricing (*soft*) ▪ Increase drought tolerant crops (*hard*) ▪ Change crop patterns (*soft*)

63. Monitoring and evaluation:

(a) Indicators of water stress and poverty.

64. Climate change induced variability in the hydrologic cycle imposes additional challenges on the planning and management of water resources. The development of appropriate adaptation strategies to cope with this uncertainty requires a broad, integrative approach given the multidimensional roles that water plays in sustaining human life, society and the ecosystems on which they depend.

65. Building communities of practice around integrated water resources management can facilitate the mainstreaming of climate adaptation strategies into sustainable development efforts, providing synergy in awareness-raising, capacity-building and in the creation of social, political, and institutional environments receptive to technological innovation. Participatory planning and decision-making approaches have the potential to substantially benefit the climate adaptation process around water.

Coastal zones

66. Examples of technologies that can be employed to develop:

67. Information and raise awareness for adaptation in coastal zones:

(a) Data collection and information development;

(b) Large-scale global and regional data repositories established for a great;

(c) Number of climatic and socio-economic variables relevant to coastal zones;

(d) The Global Earth Observation System of Systems;

(e) Make use of GIS. GIS combines computer mapping and visualization techniques with spatial databases and statistical, modelling and analytical tools.

68. Planning and design of adaptation strategies:

(a) Decide which action could best be taken and where and when this could best be done;

(b) Set of criteria that guide local, national or regional policy preparation, as well as on existing development and management plans that form the broader context for any adaptation initiative. Important policy criteria include cost-effectiveness, environmental sustainability, cultural compatibility and social acceptability;

(c) Coastal planners;

(d) Relevant models to assist planners in identifying appropriate adaptation technologies.

69. Implementation:

(a) Adaptation strategy;

(b) Strategic planning;

(c) Insurance markets to cover climate related risks.

70. Monitoring and evaluation:

(a) Reliable set of data indicators to be collected at regular intervals;

(b) Experience drawn from countries where the coast has been monitored for long periods.

Table 4
Examples of important technologies for coastal adaptation to climate change for collecting data, providing information and increasing awareness.

Application	Technology	Additional information
Coastal system description		
• Coastal topography and bathymetry	- Mapping and surveying	- Birkemeier *et al.* (1985, 1999); Stauble and Grosskopf (1993)
	- Videography	- Debusschere *et al.* (1991); Holman *et al.* (1994); Plant and Holman (1997)
	- Airborne laser scanning (lidar)	- Lillycrop and Estep (1995); Sallenger *et al.* (1999)
	- Satellite remote sensing	- Leu *et al.* (1999)
• Wind and wave regime	- Wave rider buoys	- Morang *et al.* (1997a)
	- Satellite remote sensing	- Martinez-Diaz-de-Leon *et al.* (1999)
• Tidal and surge regime	- Tide gauges	- Pugh (1987); Zhang *et al.* (1997)
• Relative sea level	- Tide gauges	- Emery and Aubrey (1991); Woodworth (1991); Gröger and Plag (1993); Nicholls and Leatherman (1996); NOAA (1998)
	- Historical and geological methods	- Van de Plassche (1986)
• Absolute sea level	- Satellite remote sensing	- Nerem (1995); Fu *et al.* (1996); Nerem *et al.* (1997); Cazenave *et al.* (1998)
	- Tide gauges, satellite altimetry, global positioning systems	- Douglas (1991); Baker (1993); Miller *et al.* (1993); Zerbini *et al.* (1996); Neilan *et al.* (1997)
• Past shoreline positions	- Historical and geological methods	- Crowell *et al.* (1991); Beets *et al.* (1992); Crowell *et al.* (1993); Moore (2000)
• Land use	- Airborne and satellite remote sensing	- Redfern and Williams (1996); Clark *et al.* (1997); Henderson *et al.* (1999)
• Natural values	- Resource surveys	- Lipton and Wellman (1995); Turner and Adger (1996)
• Socio-economic aspects	- Mapping and surveying	- Penning-Rowsell *et al.* (1992)
• Legal and institutional arrangements	- Interviews, questionnaires	- English Nature (1992)
• Socio-cultural factors	- Interviews, questionnaires	- Tunstall and Penning-Rowsell (1998); Tunstall (2000)
Climate impact assessment		
• Index-based methods	- Coastal vulnerability index	- Hughes and Brundrit (1992); Gornitz *et al.* (1994); Shaw *et al.* (1998)
	- Sustainable capacity index	- Kay and Hay (1993); Yamada *et al.* (1995); Nunn *et al.* (1994a,b)
• (Semi-) quantitative methods	- IPCC common methodology	- IPCC CZMS (1992); Bijlsma *et al.* (1996)
	- Aerial-videotape assisted vulnerability assessment	- Leatherman *et al.* (1995); Nicholls and Leatherman (1995)
	- UNEP impact and adaptation assessment	- Klein and Nicholls (1998, 1999)
• Integrated assessment	- Coupled models	- Engelen *et al.* (1993); Ruth and Pieper (1994); West and Dowlatabadi (1999)

Application	Technology	Additional information
Awareness-raising		
• Printed information	- Brochures, leaflets, newsletters	
• Audio-visual media	- Newspapers, radio, television, cinema	
• Interactive tools	- Board-games	
	- Internet	
	- Computerized simulation models	

71. Table 4 above provide information on important technologies for coastal adaptation to climate change for collecting data, providing information, and increasing awareness. The table is not intended to provide an exhaustive list of technologies.

72. Table 5 combines hard technologies, such as dikes, levees and floodwalls, and soft technologies, such as evacuation systems. Note that there are also a range of applications that require only limited technology, such as increasing or establishing set-back zones and creating upland buffers.

Table 5
Examples of important technologies to protect against, retreat from or accommodate sea-level rise

Application	Technology	Additional information
Protect		
• Hard structural options	- Dikes, levees, floodwalls	
	- Seawalls, revetments, bulkheads	- Pilarczyk (1990); Silvester and Hsu (1993)
	- Groynes	
	- Detached breakwaters	
	- Floodgates, tidal barriers	- Gilbert and Horner (1984); Kelly (1991); Penning-Rowsell et al. (1998)
	- Saltwater intrusion barriers	- Sorensen et al. (1984)
• Soft structural options	- Periodic beach nourishment	- Delft Hydraulics and Rijkswaterstaat (1987); Davison et al. (1992); Stauble and Kraus (1993); Hamm et al. (1999)
	- Dune restoration and creation	- Doody (1985); Vellinga (1986); Nordstrom and Arens (1998); Nordstrom et al. (1998)
	- Wetland restoration and creation	- NRC (1992, 1994); Boesch et al. (1994); Tri et al. (1998)
• Indigenous options	- Afforestation	
	- Coconut leaf walls	
	- Coconut fibre stone units	- McLean et al. (1998); Mimura and Nunn (1998)
	- Wooden walls	
	- Stone walls	
(Managed) Retreat		
• Increasing or establishing set-back zones	- Limited technology required	- NRC (1990); Kay (1990); Owens and Cope (1992); Caton and Eliot (1993); OTA (1993)
• Relocating threatened buildings	- Various technologies	- Rogers (1993)
• Phased-out or no development in exposed areas	- Limited technology required	- OTA (1993); DETR (2000)
• Presumed mobility, rolling easements	- Limited technology required	- Titus (1991, 1998)
• Managed realignment	- Various technologies, depending on location	- Burd (1995); English Nature (1997); French (1997, 1999)
• Creating upland buffers	- Limited technology required	- Kaly and Jones (1998)
Accommodate		
• Emergency planning	- Early warning systems	- Penning-Rowsell and Fordham (1994); Haque (1995, 1997); Handmer (1997); Rosenthal and Hart (1998); Elliot and Stewart (2000)
	- Evacuation systems	- Parker and Handmer (1997); Rosenthal and 't Hart (1998)
• Hazard insurance	- Limited technology required	- Davison (1993); OTA (1993); Crichton and Mounsey (1997); Clark (1998); Arnell (2000)
• Modification of land use and agricultural practices	- Various technologies (e.g. aquaculture, salt-resistant crops), depending on location and purpose	
• Modification of building styles and codes	- Various technologies	- FEMA (1986, 1994, 1997)
• Strict regulation of hazard zones	- Limited technology required	- May et al. (1996)
• Improved drainage	- Increased diameter of pipes	- Titus et al. (1987)
	- Increased pump capacity	- Titus et al. (1987)
• Desalination	- Desalination plants	- Ribeiro (1996)

Source: Klein et al. 2000, 2001.
Note: This table is not intended to provide an exhaustive list of applications and technologies.

73. Coastal technologies for adaptation are most effective as part of a broader, integrated coastal zone management framework that recognizes immediate as well as longer-term sectoral needs. A successful adaptation strategy will comprise a mix of various adaptation approaches, tailored to the particular needs of area at risk and aimed at reducing implementation constrains.

74. Adaptation technologies case studies in various regions.

Table 6

Summary of nine case studies reviewed in the Annex I

Sector	Case study name	Type of technology	Technology classification
Coastal zones	• Storm-surge early warning • Factoring future climate change in today's decisions: The case of Boston harbour • Biorock	• Soft • Soft • Hard	• Traditional/modern • Modern • Future
Water resources	• Water harvesting in North Darfur state, Sudan • The SWMnet regional network, Eastern and Central Africa • Seasonal forecasting in adaptation to long-term climate change, Burkina Faso	• Hard • Soft • Soft	• Traditional • Traditional/modern • Traditional/modern
Agriculture	• Floating agriculture in the flood-prone areas of Bangladesh • Mexican farmers learn new irrigation methods • New rice for Africa (NERICA)	• Hard • Soft • Hard	• Traditional • Modern • Modern

Summary of sectoral adaptation technology related findings

Agriculture

75. For agriculture, because there are a number of uncertainties regarding the range of impacts associated with climate variability and climate change, it is important to consider a diverse portfolio of potential technologies for adaptation. This is essential to retain the flexibility to transfer and adopt needed technology. Barriers, such as lack of information, lack of financial and human capital and unreliable equipment and supplies can rarely be surmounted unless the transferred technology has high probability of directly addressing climate related impacts in a cost-effective manner.

76. The effectiveness of technology transfer in the agricultural sector in the context of climate change response strategies also depends to a great extent on the suitability of transferred technologies to the socio-economic and cultural context of the recipients, considering development, equity and sustainability issues. Constraints on the supply of new technologies, a shortage of technological information and a shortage of capital are also important aspects of technology transfer. It is evident that integration of both hard and soft technologies and building working partnerships between government and non-governmental organizations is necessary to increase the effectiveness of different technologies for adaptation to adverse climatic effects. Governments can facilitate the flows of technologies within countries with incentives, regulation and by institutional strengthening.

Water

77. For water resources, climate change induced variability in the hydrologic cycle superimposes additional challenges on planning and management of water resources. The development of appropriate adaptation strategies to cope with this added uncertainty requires a broad, integrative approach given the multidimensional roles that water plays in sustaining human life, society and the ecosystems on which they depend. The intrinsic characteristics of integrated water resource management make it an ideal overarching framework in which to evaluate, design, implement and monitor adaptation strategies for climate impacts to water resources.

78. Building communities of practice around IWRM can facilitate the mainstreaming of climate adaptation strategies into sustainable development efforts, providing synergy in awareness-raising, capacity-building, and in the creation of social, political and institutional environments receptive to technological innovation. These communities of practice aid in the transfer of technologies for adaptation that meet key needs, such as information technologies (remote sensing, forecasting) that enhance understanding of natural (e.g. hydrologic) and

engineered (e.g. demand) system components and tools that support decision-making (e.g. scenario-driven processes and multi-criteria assessment technologies).

Coastal zones

79. In many coastal locations technology has been instrumental in reducing society's vulnerability to ever-present weather related hazards. Many existing technologies that have proven to be effective in reducing vulnerability to weather related hazards will also be important as technologies for adaptation to climate change. Technologies may have to be adjusted to meet local needs, and technological development and innovation will continue to increase the effectiveness and efficiency of existing technologies, but given current projections of climate change, successful adaptation is possible without having to rely on the development of new technologies specifically for adaptation.

80. Climate change is but one of many interacting stresses in coastal zones. The importance of controlling non-climatic stresses in the quest to reduce vulnerability to climate change must not be underestimated. Vulnerability to climate change is not only determined by the degree of climate change but also by prevailing social, economic and environmental conditions and by the existing management practices in a system or sector. Therefore, successful adaptation to climate change (i.e. actions that reduce vulnerability to the impacts of climate change) may well include actions that are directed at improving such conditions and management practices. Finally, technology by itself is not a panacea for coastal areas, but it can make an important contribution towards the sustainable development of coastal zones, provided it is implemented within an enabling economic, institutional, legal and socio-cultural environment.

81. Technologies for adaptation are therefore most effective as part of a broader, integrated coastal zone management framework that recognizes immediate as well as longer-term sectorial needs. A successful adaptation strategy will comprise a mix of various adaptation approaches, tailored to the particular needs of the area at risk and aimed at reducing implementation constraints.

V. Role of TNAs in addressing technology considerations in adaptation process and actions

82. One of the objective of the TNA process is to identify priority adaptation technology needs of developing countries in various sectors, to facilitate adaptation to the adverse impacts of climate change. The TNA process also draws attention to specific barriers to transfer of adaptation technologies, and suggests enabling measures to address them, including through capacity building.

83. In the TNA reports developing countries identify their adaptation technologies to respond to the adverse impacts of climate change and to enhance resilience. They also highlight various ways used to involve stakeholders in a consultative process, to assist with such identification, including the methodologies and criteria used.

84. Within the TNA process countries identify their technology action plans (TAPs), which are concise plans for the uptake and transfer of prioritized technologies with a potential to contribute to country's social. Environmental and economic development and to climate change adaptation and mitigation.

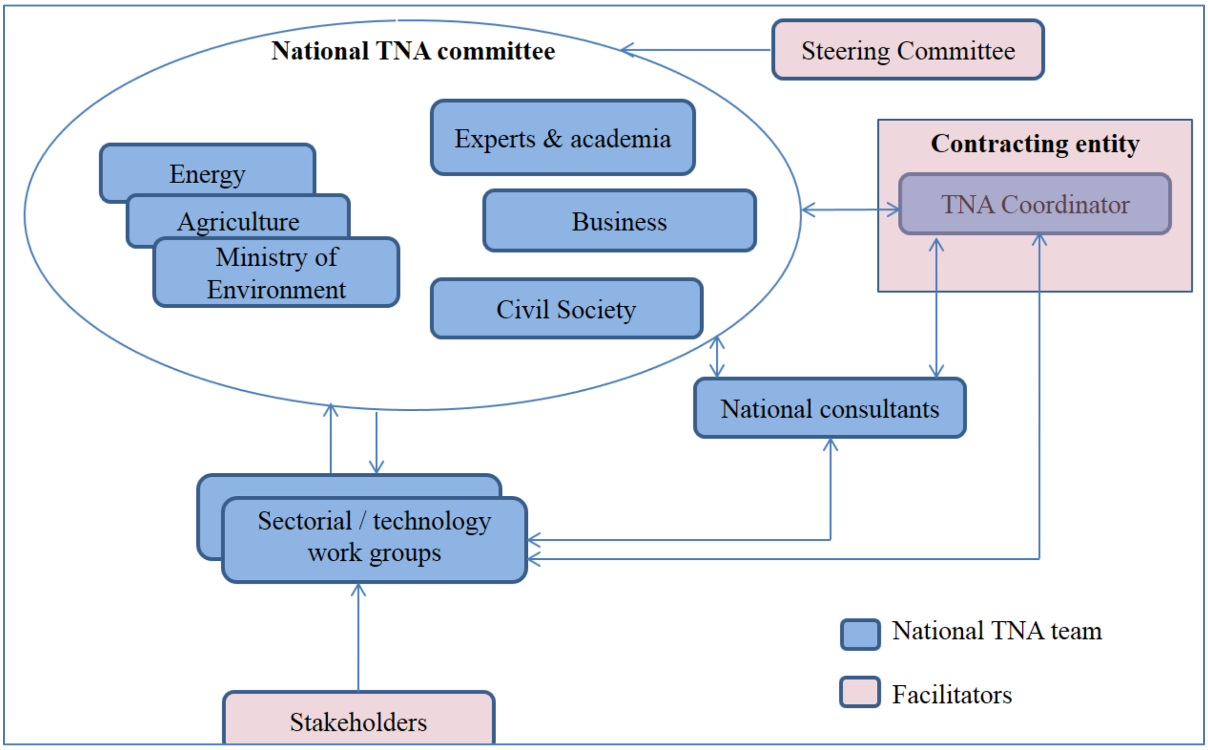
85. In the TNA reports adaptation played a major role for countries with large coastal zones and high vulnerability to climate change vis-à-vis water resources, agriculture, health, natural disasters and hydro-meteorological events.

86. More specifically, the most commonly identified technology needs for adaptation were related to crop management, efficient water use, improving irrigation systems, early warning systems for forest fires, technologies for afforestation and reforestation, and technologies to protect against and accommodate rises in sea level.

87. The latest, third TNA synthesis report, released in 2013, has shown that many developing countries reported more adaptation needs than mitigation. Such dense adaptation technology needs focused reporting provided enhanced clarity on methods and criteria used

by countries for prioritization of adaptation sectors and technologies, for identification of adaptation related barriers and enablers, and for conducting their TAPs. The work on the fourth TNA synthesis report is expected to be initiated once the Phase II TNA reports are available, possibly in early 2018 with a view to be delivered before COP-24. The fourth synthesis report may encompass both Phase I and Phase II TNA countries, giving opportunity to synthesize a representative sample of information delivered by some almost 60 developing countries on their recent technology needs in adaptation and mitigation.

Figure 4
Institutional arrangements of the TNA process



VI. Opportunities for addressing technology needs for adaptation in the NAPs through the TNAs

88. The following are potential areas for supporting technology needs during the implementation of adaptation actions identified in the NAPs, including technology needs during the formulation of the NAPs:

(a) During the formulation of NAPs:

(i) Using technological solutions to improve observations, data analysis and exploration of high-tech solutions that are more efficient;

(b) During the implementation of NAPs:

(c) In addition, the consideration of technology in NAPs can be facilitated by the following:

(i) Institutional arrangements: Collaboration between national TNA and NAP teams to enrich the work;

(ii) Knowledge support: Provision of “both ways” knowledge support;

(d) Institutional level (TNA stakeholders in collaboration with NAP stakeholders).

VII. Other possibly related issues

A. Linkages and co-benefits with TNA mitigation actions

89. The main difference between adaptation and mitigation lies in the objective that each option pursues. While mitigation focuses on the causes of climate change by decreasing greenhouse gases in the atmosphere or enhancing the sinks of greenhouse gases, adaptation addresses the impacts of climate change through an 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC 2001).

90. The sectors that offer the most obvious co-benefits between adaptation and mitigation are forestry and agriculture. The linkages between adaptation and development are much broader, covering most of the sectors reviewed. It should be noted that there are a number of adaptation sectors that provide neither development nor mitigation benefits. These are primarily related to longer term risk mitigation activities related to disaster risk reduction and infrastructure protection. It is important that co-benefits do not prejudice against such interventions.

91. Co-benefits can play a useful role in prioritising adaptation interventions. There are a number of potential methods, for example through inclusion in multi-criteria analysis or cost-benefit analysis.

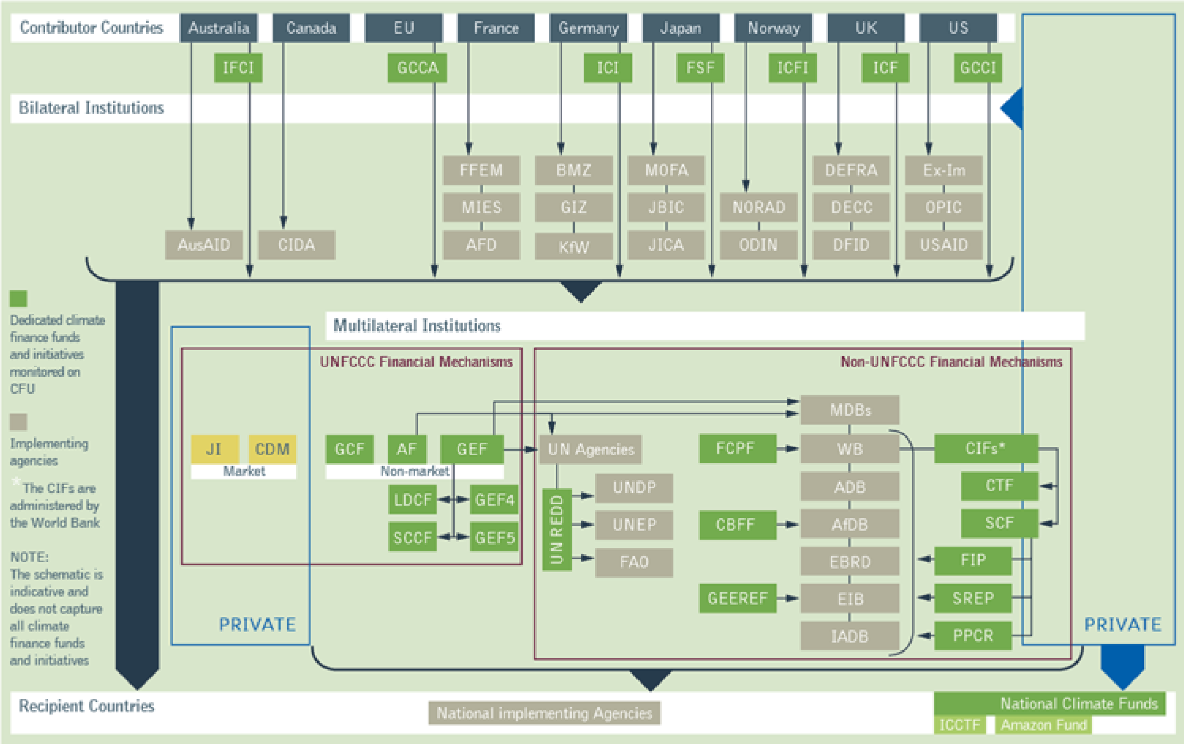
92. Initial selection of priorities should be done on the basis of adaptation outcomes. A secondary exercise may then be used to determine prioritisation of those initial interventions chosen on the basis of mitigation or development co-benefits.

93. Adaptation options in certain sectors are more likely to be aligned with potential mitigation and/or development outcomes. For example, adaptation activities related to forestry and agriculture will have direct influence upon levels of GHG emissions.

B. Possibilities to access funding

94. The global climate funding architecture is comprehensive, as it is channelled through multilateral funds, such as the GEF and Climate Investment Funds, as well as increasingly through bilateral channels. In addition, a growing number of recipient countries have set up national climate change funds that receive funding from multiple developed countries in an effort to coordinate and align donor interest with national priorities. There is generally much more knowledge about the status of implementation of multilateral climate finance initiatives than of bilateral initiatives, also due to the different levels of transparency. A solution could be employment of certain climate change mechanisms also to increase the challenges of coordinating and accessing finance.

Figure 5
The architecture of funds



1. TNAs

95. There are several technology related elements in the Paris agreement which may be considered TNA supportive. They include the following:

(a) Shared long-term vision, on the importance of fully realizing technology development and transfer in order to improve resilience to climate change and to reduce greenhouse gas emissions;

(b) Importance of technology, noted for the implementation of mitigation and adaptation actions under the Paris Agreement, and recognized existing technology deployment and dissemination efforts which shall strengthen cooperative action on technology development and transfer;

(c) Technology Mechanism, serving the Paris Agreement;

(d) Established Technology Framework, to provide overarching guidance to the work of the Technology Mechanism in promoting and facilitating enhanced action on technology development and transfer in order to support the implementation of this Agreement, in pursuit of the shared long-term vision;

(e) Support, including financial support, which shall be provided to developing country Parties for the implementation of this Article, including for strengthening cooperative action on technology development and transfer at different stages of the technology cycle, with a view to achieving a balance between support for mitigation and adaptation;

(f) The global stock take, referred in the Article 14 of the Paris Agreement, which shall take into account available information on efforts related to support on technology development and transfer for developing country Parties.

96. In the Decision 1/CP.21, Adoption of the Paris Agreement, the COP-21 requested the SBSTA-44 to initiate the elaboration of the technology framework established under Article 10, paragraph 4, of the Agreement, and to report on its findings to the COP, with a view to the COP making a recommendation on the framework to the COP, serving as the meeting of

the Parties to the Paris Agreement, for consideration and adoption at its first session, taking into consideration that the framework should facilitate, inter alia:

(a) The undertaking and updating of TNAs, as well as the enhanced implementation of their results, particularly technology action plans and project ideas, through the preparation of bankable projects;

(b) The provision of enhanced financial and technical support for the implementation of the results of the TNAs;

(c) The assessment of technologies that are ready for transfer;

(d) The enhancement of enabling environments for and the addressing of barriers to the development and transfer of socially and environmentally sound technologies.

2. NAP

97. There are several technology related elements in the Paris agreement which may be considered NAP supportive. They include the following:

(a) The global goal, established by Parties, on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the temperature goal referred to in Article 2 of the Paris Agreement;

(b) Engagement in adaptation planning processes, and the implementation of actions, by each Party, as appropriate, including the development or enhancement of relevant plans, policies and/or contributions, which may include:

(i) The implementation of adaptation actions, undertakings and/or efforts;

(ii) The process to formulate and implement NAPs;

(iii) 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;

(iv) Monitoring and evaluating and learning from adaptation plans, policies, programmes and actions.

(c) Submit and update periodically an adaptation communication, by each Party, as appropriate, which may include its priorities, implementation and support needs, plans and actions, without creating any additional burden for developing country Parties;

(d) The adaptation communication, referred to above, which shall be, as appropriate, submitted and updated periodically, as a component of or in conjunction with other communications or documents, including a NAP, a nationally determined contribution as referred to in Article 4, paragraph 2, and/or a national communication.

98. In the Decision 1/CP.21, Adoption of the Paris Agreement, the COP-21 requested:

(a) the Green Climate Fund to expedite support for the least developed countries and other developing country Parties for the formulation of NAPs, consistent with decisions 1/CP.16 and 5/CP.17, and for the subsequent implementation of policies, projects and programmes identified by them;

(b) the Ad Hoc Working Group on the Paris Agreement, in developing the modalities, procedures and guidelines referred to in paragraph 91 of the Paris Agreement, to consider:

(i) That Parties report information on adaptation action and planning including, if appropriate, their NAPs, with a view to collectively exchanging information and sharing lessons learned.

99. Funding good practices

VIII. Recommendations

100. How can the TEC, CTCN AC, LEG, help countries in aligning TNAs and NAPs?

101. How can the other bodies also help countries using the coherent approach elaborated in this paper for the consideration of technology for adaptation?

Annex II

Adaptation technology inclusive case studies

I. Coastal zones

Coastal zone early warning systems in Bangladesh

1. Need. Every year millions of people in Bangladesh are exposed to catastrophic flooding in coastal areas. These floods can result in thousands of deaths and can lead to epidemics, as well as seriously damage habitats, agricultural production, fisheries, and pastoral systems. In rural areas of Bangladesh, disaster preparedness and early warning systems are very limited. Moreover, millions of people living in coastal communities have little possibility for evacuation from flood prone areas and are highly vulnerable to flood related diseases.

2. Transfer mechanism. The technology was transferred as part of a project called Vulnerability and Risk Reduction through a community-based system for flood monitoring and forecasting - Community Flood Information System (CFIS) designed to enhance the capacity of Bangladeshi communities to adapt to the risks of floods and cyclones. Experience throughout the world has shown that local people are best placed to prepare for and respond to disasters, including floods. The CFIS project worked in several coastal districts in partnership with local organizations and communities. Its goal was to build an interactive process of collecting and disseminating information on monsoon floods to community stakeholders to increase the capacity of local communities to adapt to adverse climate phenomena.

3. Barriers to further implementation. Prior to the project, most people in the project region obtained flood forecast information from a combination of sources: word-of-mouth (neighbours, relatives, friends), traditional knowledge (wind, cloud, rain patterns), and local media (radio, television, newspapers). The first two are notoriously “hit-or-miss” and prone to inefficiencies. And information from local media is ineffective as most people are unable to understand media reports easily and as a result cannot take full advantage of warnings provided.

4. Stakeholder engagement. Individuals in coastal communities were consulted during the planning stages of the project, as well as once the project was completed to assess its value in improving the preparedness of local communities to flood surges.

5. Results and lessons learned. The CFIS project generated useful information during the devastating floods of 2004. The timely and widespread delivery of flood warnings in the project region was widely acknowledged to be helpful in prompting communities to take steps to protect crops, habitats, livestock and other support systems. Initial findings of the project were shared in a national workshop just after the flood in September 2004. The Honourable Prime Minister of Bangladesh appreciated the experience of the CFIS project and recommended that the concerned agencies, including the Disaster Management Bureau, replicate the model in other flood prone areas of the country.

Factoring future climate change in today’s decisions: The case of Boston harbour

6. Need. Even before the arrival of English and European settlers, Boston harbour was an important natural resource for local Native Americans who fished and planted crops along the coasts of the 30 or so islands that dot the harbour. In the early 1600s the Massachusetts Bay Company landed and began settling the area, clearing land for livestock and firewood. Boston harbour quickly became a busy trading port and by 1660 almost all English imports to New England came through these waters. However, as Boston grew and flourished over the next 300 years, the city's waste began to exert a heavy pollution toll on the harbour. Those treatment plants that were installed only performed primary sewage treatment, and the facilities were often overloaded. By the early 1980s the media were calling Boston harbour the filthiest harbour in the United States. The Massachusetts Water Resource Authority (MWRA) realized that a sewage treatment plant was needed for the greater Boston

metropolitan area, but one that could withstand climate change – and in particular accelerated sea-level rise.

7. Transfer mechanism. This case study is a good example of technology flows that need to happen within countries. The technology was readily available but it was implemented as a result of litigation initiated by a private citizen that led to the courts ordering the city of Boston to build a new secondary treatment plant, and carry out a subsequent clean-up of the harbour. Deer Island, located within the harbour, was selected as the site for the sewage treatment plant. The design called for raw sewage collected from communities on shore to be pumped under Boston harbour and then up to the Deer Island treatment plant. After waste treatment, the effluent would be discharged into the harbour through a downhill pipe. In order to reduce the costs of pumping untreated sewage from the shore up to the Deer Island treatment plant, the MWRA originally planned to lower the level of the Deer Island plant about half a metre to be closer to sea level. However, design engineers were concerned that sea-level rise would necessitate construction of a wall around the treatment plant to keep the sea out. The effluent would then need to be pumped up over the wall and into the harbour. Such a pump would cost several hundred million dollars. To avoid such a cost, even though it might be decades before it would need to be installed, the designers decided to leave the island at its higher elevation. In 1998 the Deer Island treatment plant was completed.

8. Three points deserve special mention concerning the proactive adaptation planning by the MWRA. First, the decision by the MWRA to account for climate change will also enhance the resilience of the harbour treatment system under current climate variability from storm surges (Weiner (1993) found the 10-year surge elevation in Boston harbour to be 2.8 metres, the 100-year surge elevation to be 3.16 metres and the 500-year surge elevation to be 3.41 metres). Second, while the planning involved was proactive and innovative, the pump technology involved was conventional and readily accessible. Finally, Boston harbour has become progressively cleaner. Native fish species, such as smelt, herring, striped bass and bluefish have returned to the harbour, as have porpoises and seals.

9. Barriers to further implementation. The potential for more widespread planning to address the effects of climate change exists through municipal and state governments, but there is currently a lack of government commitment at the federal level to address climate change effectively.

10. Stakeholder engagement. The process of implementing the design change was a public process that was open to citizen participation. Indeed, the process was initiated due to the intervention of an individual citizen.

11. Results and lessons learned. The planning for climate change exemplified by this case study has rendered the coastal infrastructure more resilient to future sea-level rise.

Biorock: Coral reef restoration technology

12. This case study is different from the coastal case studies previously discussed in the sense that it is a high technology that is still in the testing stage. As such, the issues relating to transfer mechanisms, barriers to further implementation, stakeholder engagement and lessons learned do not apply. The discussion is limited to a description of the technology and its potential to reduce some of the adverse impacts associated with a rise in sea-water temperature.

13. Biorock is a technology for adaptation that shows high potential for reducing the harmful effects of seawater temperature rise and other global-warming-related impacts on coral reefs.

14. The technology works by applying a low-voltage electrical current through seawater, causing dissolved minerals to precipitate on to surfaces that eventually grow into white limestone structures similar to those materials that make up coral reefs and nourish tropical white sand beaches. Various field tests show evidence that these methods have been successful in the acceleration of coral growth in areas subjected to environmental stresses (e.g. temperature rise, pollution, sedimentation) and have produced structures that have been populated by a range of coral reef organisms, such as fish, crabs, clams, octopus, lobster, sea urchins and barnacles.

II. Water resources

15. The three case studies below provide examples of a traditional technology that could be more widely harnessed (water harvesting), a soft technology that focuses on building a knowledge network around small-scale, effective solutions, and a high technology that provides weather forecasting support to small farmers.

Water harvesting in North Darfur state, Sudan

16. Need. With most people dependent on rain-fed agriculture, livelihoods in North Darfur are often threatened by drought. Declining rainfall and soil degradation over recent years have led to lower crop yields, making households vulnerable to food crises. Traditionally, farmers have practiced rain-fed cultivation in sandy soils called qoz, but, more recently, have begun to shift to water harvesting cultivation in the alluvial soils along Wadi El Ku as a means to mitigate some of the risks inherent in rain-fed cultivation.

17. The water harvesting technique being adopted, trus (terrace), captures and conveys rainwater to the arable land. With this technique, cultivated land is bounded on three sides, and a rainwater collection area is positioned at the open side upslope of the cultivated land. This collection area impounds rainwater, allowing it to infiltrate into the soil. An outer collection arm is constructed at a right angle to the base to direct surface run-off to the cultivated land. The dimensions vary with slope and amount of run-off expected in the area. Base bund lengths are between 50 and 300 metres, with arms usually 20–100 metres.

18. Transfer mechanism. The trus is a locally developed, endogenous technology that has been further developed by the Intermediate Technology Development Group (ITDG). Since 1998, as part of its food security programme in North Darfur, ITDG has helped local communities to improve water harvesting techniques and has provided training in trus building. The construction methods are simple and easy to master, with only hand tools required. The cost is low, as labour and the renewal of worn-out hand tools are the main expense for the farmers. The work is carried out in the dry season, when it does not conflict with food production.

19. Barriers to further implementation. Potential for more widespread dissemination exists through the Ministry of Agriculture, which is responsible for providing agricultural extension services to rural farmers. Ten pilot projects were established as demonstration plots to diffuse technical know-how concerning the different aspects of water technologies. In these project areas, land was distributed to the poor and landless farmers according to a list provided by the tribal leaders. Unfortunately, the pilot projects suffered from under-funding and limited infrastructure; the result being that the pilot projects did not demonstrate substantially improved productivity and reduced costs. Moreover, the ministry has not been able to develop the scientific and the institutional capacity to design location-specific agricultural technologies concerning water harvesting, with the result that perceptions of the technology have suffered, and even where positive results have been obtained, there are insufficient channels through which to spread the innovation.

20. There is also a lack of government commitment to provide assistance in years of exceptional torrents and floods that destroy the trus. The lack of commitment leads to bureaucratic delays in approving funding, poor coordination and poor logistics. There is also a lack of regional planning and policy initiatives to support the farmers in maximizing the use of their limited resources and farming investment. For example, even where water harvesting cultivation has been shown to increase agricultural production and income, there is still limited accessibility to credit and delays in delivering loans to farmers, due to restrictive lending conditions formulated by the Agricultural Bank authorities.

21. Political and social instability in this region is also a severe challenge to the effective implementation of this technology. Civil war has caused displacement of civilian populations from rural areas, leading to disrupted and unsystematic farming practices.

22. Stakeholder engagement. In Sudan, farmers are organized into unions at the village level, through which farmers voice their opinions and elect representatives at the state level. Tribal leadership is also involved in management of the natural resources. However, the Sudanese government often frames policies and programmes without consulting these local

constituencies; and this top-down approach fosters reluctance to support even programmes that may provide benefits to local farmers.

23. Results and lessons learned. Water harvesting cultivation in alluvial soils has diversified the crop varieties and extended the agricultural season for another four months. Farmers have reported substantial productivity growth for vegetables and cash crops, leading to increased employment opportunities, secured family food supplies, and increased affordability for children's education. Moreover, higher agricultural production has opened new opportunities for trading in agricultural products.

24. Lessons learned from the case study include the recognition that (1) developmental interventions that are flexible and agile are needed to respond to the changing environmental, social and demographic conditions of the study area, (2) pastoral and farming production systems are dynamically interrelated; these links must be considered in any future interventions to reduce resource-based conflicts, (3) women play an important role in cultivation activities and need to be a key target of interventions, (4) climate change technologies for adaptation require policy reform and incorporation into national development plans, and (5) the implementation of adaptation measures and national strategies needs to involve the rural communities impacted by these measures and strategies. Effective community development should be built on grass-roots participation and involvement.

The SWMnet regional network, Eastern and Central Africa

25. Need. In Eastern and Central Africa (ECA), smallholders produce more than 95 per cent of crops using low-input systems, which have degraded soil quality (capacity of soil to maintain productivity in terms of plant growth and environmental health). Although farmers' skills, local knowledge and ingenuity had helped to improve and maintain soil quality over long periods, changing demands have made endogenous techniques inadequate. In addition, ECA experiences alternating floods and droughts, both leading to severe land degradation and frequent famines.

26. To address these constraints, the Soil and Water Research Network (SWMnet) (www.asareca.org/swmnet/home.htm) was created to enhance investments in, and the role of the management of, soil and water to improve productivity, and to add value and increase the competitiveness of, agricultural enterprises in the ECA subregion. A particular focus is the development of effective strategies to enable farmers, communities and countries to adapt and cope with climate variability.

27. Transfer mechanism. SWMnet provides demand-driven knowledge and technologies for integrated management of soil and water for agriculture and the environment, and promotes improved strategies for adaptation and coping with climate-induced crises and shocks. SWMnet promotes effective participation of stakeholders, who take part in implementing the technologies. One of the main problems for soil and water management technologies is the inadequate understanding of their performance in locations other than where they were originally developed. Consequently, many proven technologies and practices have not been widely spread, and only small islands of success have been achieved. Limited understanding of best-bet options for different eco-regions, and opportunities and circumstances facing the local people increase the risk to investments and highly reduce overall productivity and profitability of soil and water management interventions. SWMnet facilitates and supports research to establish the spatial and temporal applicability of proven options and verify their suitability under different conditions.

28. Barriers to further implementation. There are critical constraints and barriers to collaboration in ECA, which hinder networking at the subregional level. These constraints include financial, political, social and cultural constraints. Currently, the agro-meteorological capacity within this region is weak; therefore, climate variability is normally not fully considered in decision-making at the farm and policymaking levels.

29. There is also low implementation of proven strategies that reduce vulnerability to climate variability and provide options for stakeholders to predict climate situations. Moreover, possibilities for positive exploitation of the temporal and spatial variability of

climate, through trade and commodity exchange across zones and countries, have not been realized in national and regional planning.

30. Stakeholder engagement. There is extensive endogenous knowledge in the region; therefore, in every strategic theme, SWMnet directs efforts towards an intensive, systematic and detailed stock-taking of knowledge and experience at local, national and international levels.

Seasonal forecasting in adaptation to long-term climate change, Burkina Faso

31. Need. Rural households in the Sudan–Sahel region that depend largely on rain-fed agriculture for food and income could substantially benefit from climate forecast information to improve agricultural productivity. In 1997 the Climate Forecasting for Agricultural Resources (CFAR) Project, funded by the United States National Oceanic and Atmospheric Administration, was initiated to assess how farmers (both agriculturists and pastoralists) in Burkina Faso could use climate forecasts to enhance agricultural sustainability and food security. This two-phase initiative included a study of local forecasting knowledge, adaptive strategies to climate variability, and farmers’ information networks through fieldwork, surveys, interviews and participatory exercises (1997–2001). The second phase (2001–2004) involved the experimental dissemination of seasonal rainfall forecasts based on sea surface temperature in selected communities, monitoring of farmers' and pastoralists' responses, and the circulation of information among and beyond the communities. The forecasts were presented as the probability of rainfall being in the higher, middle, or lower percentile of total historic seasonal rainfall for the region.

32. Transfer mechanism. Radio broadcasts and workshops were used to disseminate forecasts to farmers and herders. These workshops were held at the village level at three project sites at the Sahel, Central Plateau, and southwest. Participants were selected jointly by facilitators with village chiefs, administrative leaders (délégué), and key farmers whom CFAR had been working with for some time, and included women and immigrants. The workshops included presentation of the forecast, discussion of response strategies, the plan for dissemination at the village level, clarification by the project teams and discussion of issues with the farmers, and distribution of a leaflet summarizing the forecast in local languages. Key farmers explained to everyone what they learned when they got back to their villages.

33. Barriers to further implementation. The forecasts were often late, were for three months and three zones only, and were not specific to individual farm locations. They provided only total seasonal rainfall, not rainfall distribution. Institutional barriers, such as village politics, ethnic identity and gender roles, contributed to exclusion of certain groups. Social norms for appropriate social interaction occasionally hindered outreach. There were also obstacles in village dissemination as some participants downplayed the probability aspect of the forecast to reinforce their own credibility. Farmers’ perceptions and priorities affected how they understood and what they remembered of the information received from the forecast dissemination team or from radio broadcasts. Finally, there were resource barriers as forecast dissemination ceased after completion of the CFAR project because the Burkina Faso government lacked the financial resources to continue or extend the project and feared the potential political liabilities stemming from the risk of forecast failure and subsequent economic losses and popular discontent.

34. Stakeholder engagement. The project engaged farmers, including agriculturists and pastoralists, in collaboration with major institutional stakeholders, including the Direction de la Météorologie Nationale (forecast development and presentation), the National Agricultural Research Service (to determine the farming implications of the forecasts through crop modelling components), and Plan International, one of the largest development NGOs operating in Burkina Faso (to provide logistics and communication support). Provincial level representatives of technical services (ministries of agriculture, livestock, environment) and other local level stakeholders (representatives of NGOs, farmers’ organizations, agribusiness, etc.) participated in the forecast dissemination workshops as well.

35. Results and lessons learned. Most rural producers, even those with limited resources, can use and benefit from climate forecasts by making small adjustments in their livelihood and production strategies. However, seasonal forecasts require enhancements and supporting

resources, such as risk-based decision-making tools, before they can be implemented widely in support of adaptation to long-term climate change.

III. Agriculture

36. The three agriculture case studies below provide examples of a traditional technology that could be more widely harnessed (floating agriculture), and two modern technologies (high efficiency irrigation schemes and new rice varieties).

Floating agriculture in the flood-prone areas of Bangladesh

37. Need. The southern, south-western and coastal areas of Bangladesh remain inundated for long periods every year, especially during the monsoon season. People dependent on agriculture have been using a method of cultivation locally referred to as vasoman chash, meaning floating agriculture, since the time of their forefathers. This system is similar to hydroponics, which is a method whereby plants are grown in the water and derive their nutrients from the water instead of from soil. A bio-land or floating bed, is prepared with biomass using water-hyacinth, aquatic algae, waterwort and the other water-borne creepers, straws and herbs or plant residues. The people have adopted and modified the method for different locations according to their needs. The modifications include adjustments in the size, shape and materials used for preparing the floating beds, and are made to enhance the system's ability to cope with monsoon and tidal flood. After harvesting the Aman paddy (cultivated in the monsoon season), people collect and preserve the stubble in the winter for the preparation of floating beds, together with the water hyacinth, collected in May and July from the rivers, channels and other water bodies.

38. Beds can be of any shape or size (perhaps 50 metres long by 15 metres wide and about three quarters of a metre high), and can easily be floated into location. The size depends on the body of water available and farmer's needs, preferences and resources. Though the bed has no definite size, small size beds are easier to manage and better for crop production. The most durable and stable beds are made of base layer and water hyacinth. The upper layer, which is laid about a week after the first layer, is comprised of small and quick-rotting waterworts (or small duck weed type of plant), which make good manure. It takes 15–20 days from the collection of the materials to the start of cultivation.

39. There are two main systems of floating beds: floating island type and stabilized floating island type. The first system is used widely in the Pirojpur and Barisal districts. The second system was introduced about two and the half years ago in Atghar-Kurian union in Shawrupkathi in the Pirojpur district. Now the latter system is used widely throughout the district. The floating beds, which are used mostly to cultivate vegetables, are more fertile and productive than traditional garden beds on land.

40. Transfer mechanism. A number of projects have promoted this technology in recent years. The noteworthy are the Sustainable Environment Management Programme (SEMP) and Reducing Vulnerability to Climate Change (RVCC). The RVCC project has provided technical training and motivational activities to promote the technology as a way to diversify livelihoods at the community level, while the SEMP project has provided financial support along with technical training and motivational activities.

41. Barriers to further implementation. This technology faces few barriers. However, small amounts of financial capital for marginalized farmers can help a lot in promoting this type of technology. In some cases, lack of water hyacinth and other aquatic vegetation has been a barrier.

42. Stakeholder engagement. Communities are involved in floating agriculture. Community members themselves decide on the size of the beds and type of vegetables that will be grown. They are involved fully from preparation of the bed to sale of the product in the market.

43. Results and lessons learned. An assessment of vulnerability to climate change and sea-level rise for Bangladesh revealed that the southwestern and coastal areas of Bangladesh will become more vulnerable to inundation and more areas will suffer water logging. To

adapt with coastal inundation and water logging problems, floating agriculture will help diversify livelihoods and help coastal communities to adapt to these effects of climate change.

Mexican farmers learn new irrigation methods

44. Need. Groundwater became depleted in Sosa Oaxaca Valley, Mexico, due to over-extraction, drought and inefficient water-use. Farmers wanted to build new wells and expand their fields and took their request to Mexico's National Water Commission, but they were turned down. So the farmers turned for help to a bilateral donor agency, which helped to facilitate the creation of a local Groundwater Technical Committee (GTC).

45. Transfer mechanism. Through the group, farmers learned new methods of irrigation. They also learned how to produce organic vegetables and other crops, and how to use water and energy resources efficiently. Farmers were also taught about the causes and effects of watershed problems and how to adopt new technologies. The National Water Commission contributed half the cost of constructing new irrigation systems, while local governments picked up 25 per cent and the farmers pitched in the rest. The key is the new irrigation system housed inside a 1.5-hectare greenhouse. Its automated system has sprinklers and drip lines to supply water and nutrients to the soil inside and outside the complex. Producers are planning to increase the size of the greenhouse so they can expand the irrigation system. Meanwhile, the National Water Commission reports that the groundwater level in Oaxaca Valley is returning to healthy levels.

46. Barriers to further implementation. Unknown.

47. Stakeholder engagement. Farmers, the National Water Commission and the bilateral agency were involved. Farmers received training and were involved in the creation of the GTC. Eighty of the 88 families in Sosa now use the new systems, complete with walking sprayers, sprinklers, and drip lines.

48. Results and lessons learned. Since drought intensity and scale are expected to increase, the promotion of improved irrigation technology will help to address drought problems in many areas.

New rice for Africa (NERICA)

49. Need. After much effort, breeders at the Africa Rice Center in Côte d'Ivoire were able to cross varieties of African rice (Oryza glaberrima, adapted to African conditions but prone to lodging and grain shattering) with varieties of Asian rice (Oryza sativa, high yielding, but susceptible to stresses) to produce early maturing, higher yielding, drought tolerant, pest resistant varieties able to thrive in saline soils. Known by the acronym NERICA, which stands for New Rice for Africa, these varieties could revolutionize rice farming in Sub-Saharan Africa because they produce a crop with minimal inputs even under stress, yet respond well, with bountiful crops, when farmers are able to apply additional inputs. Varieties of NERICA are being planted on 100,000 hectares (including 60,000 hectares in Guinea and about 10,000 hectares in Uganda) and are helping countries cut crippling rice import bills.

50. Transfer mechanism. The West African Rice Development Association (the former name of the Africa Rice Center, which retains WARDA as its acronym) used participatory varietal selection (PVS), an impact-oriented and demand-driven technology generation and dissemination approach. In the first year of the typical three-year programme, WARDA and extension agents established a 'rice garden' in a target village, often in the field of a leading or innovative farmer. The rice garden contained NERICA varieties; modern, improved Asian rice; popular local and regional varieties; and a few glaberrimas (African Rice). Farmers from the host community and surrounding villages were encouraged to visit the garden as often as they liked to monitor progress. WARDA also spread the news among its other 17 member countries, and workshops were held in 1998 and 1999 at which two-person teams from each country were trained in the PVS methodology. The PVS approach has since been applied in all 17 countries, and a regional network was established whose participants meet annually to discuss progress.

51. Barriers to further implementation. Once the new varieties gained a level of acceptance among farmers, seed supply was identified as a bottleneck to wider distribution. To overcome this problem, WARDA imported and adapted a community-based seed system

(CBSS) developed in Senegal. The system builds on farmers' own seed-saving practices, with some training input on selecting panicles for seed harvest and methods of preparation, storage and maintenance. With the adoption of CBSS, new varieties can be made available to farmers in four years, as opposed to the seven normally required with formal seed systems. With initial success in Côte d'Ivoire, the system was adapted further and adopted in Guinea, and it is expected to spread elsewhere soon.

52. Results and lessons learned. New varieties able to cope with stresses relating to climate change are necessary to meet the food demands of growing populations. Cross-breeding of varieties with different stress tolerances would be helpful, and therefore further research into development and dissemination is necessary.