Pakistan

TECHNOLOGY NEEDS ASSESSMENT FOR CLIMATE CHANGE ADAPTATION

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Government of Pakistan
Ministry of Climate Change
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Supported by

TECHNOLOGY NEEDS ASSESSMENT FOR CLIMATE CHANGE ADAPTATION

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DISCLAIMER

This document is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP DTU Partnership (UDP) in collaboration with the Regional Centre Asian Institute of Technology, Bangkok. The present report is the output of a fully country-led process and the views and information contained herein is a product of the National TNA team, led by the Federal Ministry of Climate Change, Government of Pakistan.

Forward

Pakistan's high vulnerability to adverse impacts of climate change, in particular extreme climatic events, mean that the country is in dire need of innovative adaptation technologies to lesson damage to life, property, natural eco-systems and economy of the country.

In this backdrop, I am confident that the Technology Needs Assessment (TNA) project initiated by the Ministry of Climate Change in collaboration with the United Nations Environment Program (UNEP), Climate Technology Centre & Network (CTCN) and Technical University of Denmark (DTU) partnership will play an effective role in increasing resilience against climate change vulnerabilities through transfer and diffusion of prioritized technologies in agriculture and water sectors and removing barriers in their adoption.

I am pleased to note that this TNA exercise has been a nationally-driven process involving local expertise and knowledge, supplemented by international experiences. The sectors and technologies that have been prioritized in Pakistan's TNA Adaptation report are the sectors and technologies emphasized in our National Climate Change Policy. I strongly believe that the implementation of adaptation technologies prioritized in this TNA Adaptation Report will help the country in building resilience to the impacts of climate change.

I thank the members of the TNA National Team, TNA National Steering Committee, and my colleagues in the Ministry and experts of the Adaptation Working Group for their invaluable contributions to the preparation of this report.

I also thankfully acknowledge the contributions of Dr. Qamar uz Zaman Chaudhry Lead-Expert and other experts of Global Environment Facility (GEF), United Nations Environment Programme (UNEP), UNEP-DTU Partnership and the Asian Institute for Technology (AIT) for their continuous support for the implementation of the TNA project which has identified specific and prioritized measures for climate change adaptation in Pakistan.

(Zahid Hamid)
Federal Minister
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PREFACE

Climate change is one of the most daunting threats that the world faces today. For Pakistan, it is a colossal challenge to achieve its sustainable development goals without compromising on its socio-economic development needs. Due to its exposure to the recurrent episodes of drought, flooding, heatwaves, and glacial lake outburst floods in the past few decades, the country is consistently ranked as being a highly vulnerable to the impacts of climate change by multiple climate change vulnerability indices.

Building resilience and adaptation to climate change is becoming indispensible for Pakistan. Fortunately, environmentally sound technologies are gaining a high priority in sustainable development policy dialogue and implementing frameworks. Technology Needs Assessment (TNA) is one of the critical steps towards identifying and assessing climate change adaptation challenges for Pakistan in order to align its adaptation needs and opportunities with goals and objectives of its sustainable development. As a climate change adaptation tool this TNA would help the country identify the needs for new equipment, techniques, practical knowledge and skills, which are necessary to successfully pursue climate resilient development.

This report on a technology needs assessment for climate change in Pakistan is the main output of TNA project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP DTU Partnership in collaboration with Asian Institute of Technology (AIT). The TNA process in Pakistan was undertaken between June 2015 to February 2016 with the assistance of the Ministry of Climate Change.

This report identifies and provides a list of prioritized adaptation technologies for climate vulnerable water and agriculture sectors in Pakistan. The report is the result of a fully country driven, participatory process. Views and information in this report are the product of extensive discussions with technology expert team, stakeholders, and National TNA team.

I extend my appreciation to all stakeholders for their constant support and valuable comments through the development of this report. I hope that this assessment will go a long way in mitigating the country's climate change vulnerabilities.

(Syed Abu Ahmad Akif)
Federal Secretary
Ministry of Climate Change
Government of Pakistan

ABBREVIATIONS

AR5	(IPCC) Fifth Assessment Report
COP-13	Conference of the Parties-13
CMIP5	Coupled Model Inter-comparison Project Phase 5
FEG	Framework for Economic Growth
GCISC	Global Change Impact Studies Centre
GDP	Gross Domestic Product
GEF	Global Environment Facility
GLOF	Glacial Lake Outburst Floods
GHG	Green House Gas
GOP	Government of Pakistan
HDI	Human Development Index
HKH	Hindukhush-Karakoram-Himalaya
IBIS	Indus Basin Irrigation System
INDC	Intended Nationally Determined Contribution
IPCC	International Panel on Climate Change
IRS	Indus River System
MCDA	Multi criteria decision analysis
MDG	Millennium Development Goal
MPDR	Ministry of Planning, Development and Reform
MSL	Mean Sea Level Rise
NAP	National Adaptation Plan
NCCP	National Climate Change Policy
NDMA	National Disaster Management Authority
NDMC	National Disaster Management Council
PMD	Pakistan Meteorological Department
PPP	Purchasing Power Parity
RCP	Representative Concentration Pathways
SDG	Sustainable Development Goal
TAP	Technology Action Plan
TNA	Technology Needs Assessment
UNFCCC	UN Framework Convention on Climate Change

WEIGHTS AND MEASURES

^{0}C	Celsius
^{0}F	Fahrenheit
cms	centimeters
ha	hectare
km	kilometer
km^2	square kilometer
m^3/s-1	cubic meters per second
MAF	million acre foot
Mha	million hectare
mm	millimeter

mt	metric ton
$MtCO_2e$	million ton of carbon dioxide equivalent

GLOSSARY

kharif	sowing season of summer crops (autumn)
rabi	sowing season of winter crops (spring)
APHRODITE	Climate model

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EXECUTIVE SUMMARY

Pakistan is consistently ranked as one of the most vulnerable countries of the world due to its recurrent exposure to extreme weather events such as floods, droughts, and heat waves in the past around one and a half decade that have taken a heavy toll on both human lives and its pace of economic growth. The country's past climatic trends indicate a rise in temperature by 0.57^{0}C over the past century, and high precipitation variability embedded with extreme (wet/dry) precipitation episodes. This climatic variability translates into a heightened level of uncertainty about frequency and intensity of extreme weather events with potential to adversely impact the major economic sectors of the country such as agriculture, water, and energy. Within this context, Pakistan needs to build and improve its coping capacity against the climate change risks through adopting a climate resilient development strategy where technological innovation, transfer and successful diffusion sits at heart of effective national response to a low vulnerability pathway in order to effectively address the climate change challenges.

Technology Needs Assessment (TNA) is one of the foremost critical steps towards identifying and assessing climate change adaptation challenges within the United Nations Framework Convention on Climate Change's (UNFCCC) technology mechanism on technology development and transfer. For a climate-vulnerable country such as Pakistan, TNA has an added significance for aligning its adaptation needs and opportunities with goals and objectives of its sustainable development programs.

This report describes the TNA consultative process for Pakistan that was undertaken between June 2015 to February 2016 with the government and non-government stakeholders of the relevant sectors. The process aimed to select and prioritize economically important climate sensitive sectors of the country, and adaptation technologies for these prioritized sectors in this first phase of TNA process, which after the completion, would lead the country to develop an enabling framework for the transfer and diffusion of prioritized technologies in relevant sectors by analyzing technology barriers, and developing Technology Action Plans in order to mobilize resources for implementation of the adaptation technology-centered projects in the country.

Pakistan's TNA process largely remained country driven, participatory in nature for identifying its priority technologies to adapt for sectors economically important and vulnerable to climate change. Pakistan adopted three tiered approach which included to a) identify sustainable development needs and priorities of the country in the face of climate change challenges; b) identify and prioritize climate vulnerable sectors; c) identify, assess and then prioritize adaptation technology needs of the country within these prioritized sectors through multi criteria decision analysis (MCDA) tool.

This whole process was supported by a national and global TNA institutional structures and multi-stakeholders engagement and consultation processes to ensure legitimacy, and earn strong political support for the process. During this entire process, the Director General Environment & Climate Change, Ministry of Climate Change acted as a national TNA focal person, largely facilitating communication and coordination with the National TNA Committee and other

relevant institutions, consultants for adaptation and mitigation technologies, Sectoral Expert Working Groups and other stakeholders. To improve the legitimacy and transparency of the process, the National Climate Change Policy Implementation Committee was designated as the National TNA Steering Committee with the function to provide high-level guidance to the work of national TNA teams. The National TNA Committee, however played the pivotal role in this entire process by acting as a central decision-making body and a core driving group through identifying the priority sectors for the TNA process with help from the sectoral experts; assisted in the constitution of sectoral/technical expert working groups; reviewing and approving technology options for the priority sectors; and the final TNA report.

Pakistan identified agriculture and water as its priority sectors during the inception workshop on TNA in early June 2015. The process of sector selection started with an extensive desk review of relevant documents on country's sustainable development targets, needs and challenges that were identified in various national and sectoral development documents such as Pakistan Vision 2025, Economic Growth Framework, and National Climate Change Policy etc. Next step included identification of climate change impacts on various sectors of the country and their degrees of vulnerability to these adverse impacts in the future along with consultation with key experts. The process of research and deliberation with key experts helped in the selection of a set of six climate sensitive sectors: agriculture and livestock, water, health, urban development, transport and infrastructure. In order to reach to the final selection of the most vulnerable sectors of the country to the impacts of climate change, six climate sensitive sectors were assessed against the set of the following criteria:

1. Contribution to the sustainable development priorities of the country
2. Climate change impacts on Pakistan and its degree of vulnerability
3. Contribution to minimize vulnerability to climate change
4. Sector specific adaptation needs of the country
5. Potential of technology innovation in the sector to improve the resilience of the human and natural systems

Finally, through this process water and agriculture sector were chosen as priority sectors for country adaptation technology needs.

After the sector prioritization process was complete, the TNA process entered in its next step of identifying and prioritizing technologies for each sector through an extensive stakeholder engagement process. For this purpose, the TNA process utilized MCDA tool for comparing adaptation technology options across a number of diverse criteria while taking into account the priorities and values of multiple stakeholders, thereby moving forward the formal decision making process in a transparent and consistent way.

Identifying technology options was a critical initial part of the MCDA process by Expert Sectoral Working Group-Adaptation . Based on desk reviews of technology requirement and status in each sector and expert opinions, initially a list of 19 technologies was prepared for Water Sector, and 21 for Agriculture Sector, which were filtered down to 5 to 6 technologies for each sector through discussion with key experts and stakeholders. 'Technology Fact Sheets' were prepared for the pre-selected lists of technologies that included: brief technology descriptions, total cost of the technology, the application potential, current status and implementation barriers in the

country, the adaptation and other social, economic, and environmental benefits. Using MCDA tool and inputs from Expert Sectoral Working Group-Adaptation, top five technologies for water sector six technologies for agriculture sector were identified, assessed and then prioritized by following several key steps that included:
a) Identification of technology options for water and agriculture sectors. For water sector, the technologies identified were flood early warning system, surface rainwater harvesting, groundwater recharge, wastewater treatment & reuse, and urban stormwater management. While for agriculture sector technologies included: drought resistant crop varieties, high efficiency irrigation systems for rainfed and irrigated areas, salt-tolerant crops, land use planning, livestock breed improvement and Climate monitoring and forecasting- early warning system.
b) Selection of basic criteria and (sub-criteria) for performance evaluation of each technology. The criteria included cost (of technology setup and maintenance), economic benefits (with sub-criteria of creating jobs and improving economic performance), social benefits (with sub-criteria of improving health and reduce poverty and inequality), environmental benefits (with sub-criteria of supporting environmental services, protect biodiversity and environmental resources), and climate related benefit (with sub-criterion of potential to reduce vulnerability and build climate resilience.
c) Weighting and scoring of the criteria by using multi criteria decision analysis (MCDA) tool to get the final top three prioritized technologies for the sectors of water and agriculture.

Based on the final total weighted score, three prioritized technologies identified through TNA process for water sector of Pakistan are:

1. Surface rainwater harvesting
2. Ground water recharge
3. Urban stormwater management

Likewise, priority adaptation technologies identified for agriculture sector of Pakistan are:

1. High efficiency irrigation systems for irrigated and rain-fed areas
2. Drought tolerant crop varieties
3. Climate monitoring and forecasting - early warning system

The results of sector and technologies prioritization in water and agriculture sectors of Pakistan, undertaken through extensive stakeholders consultation process were endorsed initially by the National TNA Committee and subsequently by the TNA Steering Committee during their meetings held in February, 2016.

CHAPTER-1 INTRODUCTION

1.1 About the TNA project

Climate change (CC) is rapidly emerging as a global challenge with capability to erode the gains of sustainable development of countries, specifically of economically vulnerable ones, through amplifying the level of climate change risks to their natural and socio-economic systems and consequently tightening the poverty trap around the most vulnerable communities and nations.

Pakistan is consistently ranked as one of the most vulnerable countries of the world due to its recurrent exposure to extreme weather events such as floods, droughts, and heat waves in the past one decade that have taken a heavy toll on both human lives and its pace of economic growth (Kreft et al., 2015). The country's past climatic trends indicate a rise in temperature by 0.57^{0}C over the past century, and high precipitation variability embedded with extreme (wet/dry) precipitation episodes (Naheed and Rasul, 2011). This climatic variability translates into a heightened level of uncertainty about frequency and intensity of extreme weather events with potential to adversely impact the major economic sectors of the country such as agriculture, water, and energy. Within this context, Pakistan needs to build and improve its coping capacity against the climate change risks through adopting a climate resilient development strategy where technological innovation, transfer and successful diffusion sits at heart of effective national response to a low vulnerability pathway in order to effectively address the climate change challenges.

The country-driven Technology Needs Assessment (TNA) process offers a framework to assist developing-nations that are signatory to the United Nations Framework Convention on Climate Change (UNFCCC) in determining their technology priority needs in order to achieve their goal of climate resilient development. TNA project promises environmentally sound technology development and transfer to developing countries to mitigate its greenhouse gas (GHG) emissions and adapt to the adverse impacts of CC. Developed during COP13, TNA is a key component of the Poznan Strategic Program on Technology Transfer and supported by the Global Environment Facility (GEF). The UNFCCC identifies significance of technology development and transfer under Articles of the Convention (Art. 4.1c, Art. 4.5, and Art. 4.7). The Article 4.5 states:

"*The developed countries and other developed countries in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of or access to environmentally sound technologies and know how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention."*

For meaningful and effective actions to enhance the implementation of Article 4.5 of the Convention, the Marrakech Accord (2001) in its decision 4 of COP7[1] decided to adopt technology transfer framework. The framework consists of five key components:

1. Technology needs assessment
2. Technology information
3. Enabling environment

[1] See section C of the document "Marrakesh Accord & the Marrakesh Declaration". http://unfccc.int/cop7/documents/accords_draft.pdf

4. Capacity building
5. Mechanism for technology transfer

The implementation of the framework was one of the prime focus of the climate negotiations between COP7 to COP13 making GEF oversight authority over all aspects of technology development and transfer, and by making it in charge of providing financial support.. Beyond COP13, the efforts focused on establishing technology transfer mechanisms with a specific call for financial support for preparation and implementation of TNAs (UNFCCC, n.d.).

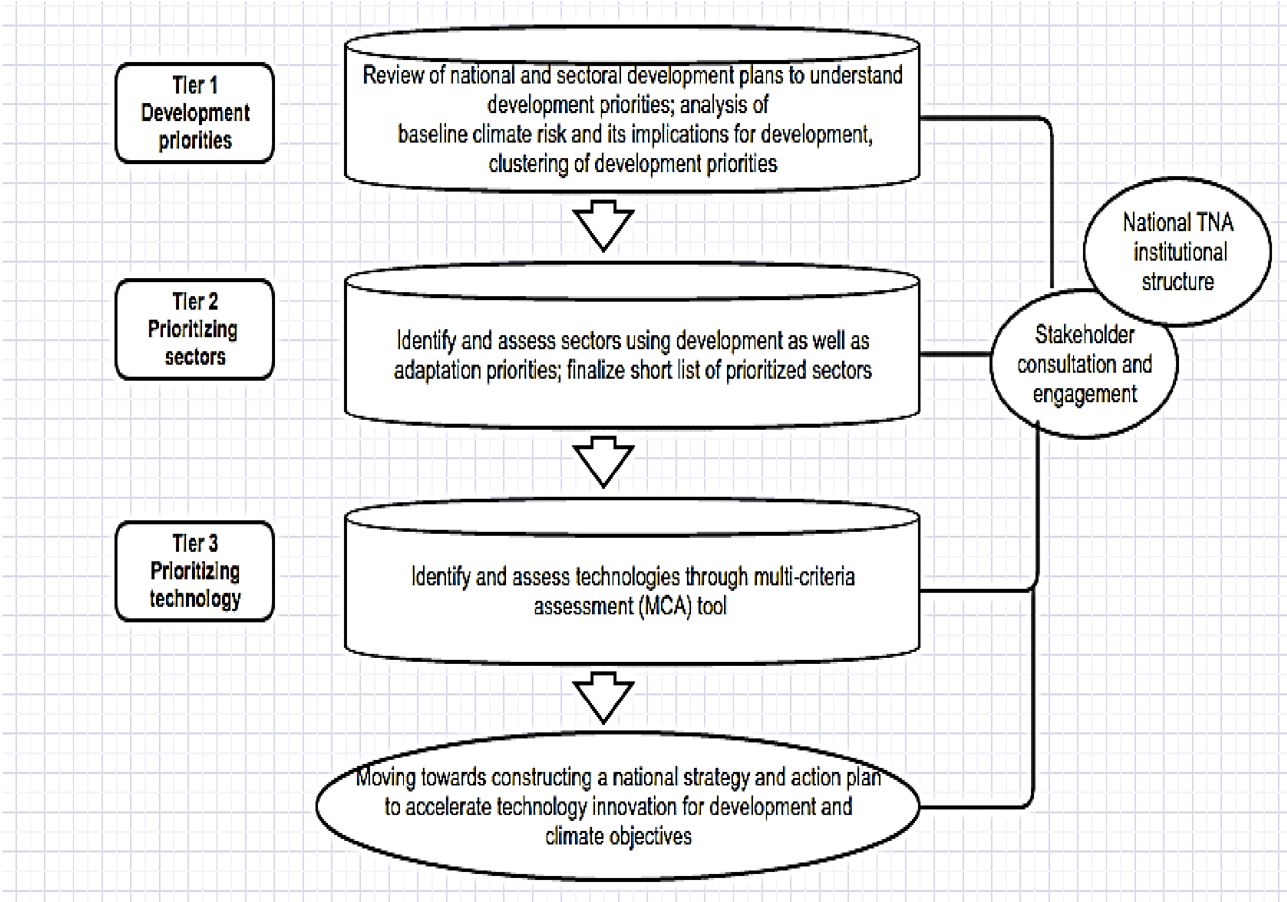
To make this technological deployment successful and sustainable, TNA adopts a policy-led top-down approach to identify and prioritize technologies for critical climate-vulnerable sectors of a country to achieve its sustainable development goals in long run. The entire process is supported by national TNA institutional structure, vigorous assessment processes involving stakeholder engagement and consultation to ensure legitimacy of the process while earning their strong political support to ensure the full perpetuity of the process in the long run.

Pakistan is amongst 26 countries of the world conducting TNA process in the second phase of this program under the auspice of UNEP—the implementation entity of TNA on behalf of GEF. The Ministry of Climate Change is leading the TNA process in the country covering both areas of adaptation and mitigation technologies.

1.1.1. Technology Needs Assessment Process and Objectives

By recognizing its high vulnerability to climate change impacts, Pakistan adopts TNA process to identify and prioritize adaptation technologies for its climate sensitive sectors. TNA process takes a three-tiered approach for finalizing its technology needs (Figure 1.1). The first level of analysis caters to the country's developmental priorities in context of its socio-economic demographic and geographic conditions, and the level of climate change risk it is exposed to. It reviews various national and sector-specific development plans, policies and strategies, for example, National Climate Change Policy (2012), water and agriculture draft policies, annual development plans, Vision 2025 etc. It also identifies sector specific vulnerability to impacts of climate change, and important technologies that would help in leading to low-vulnerability pathways in the long run in the face of climate change. The second level of analysis identifies and assess sectors that are most vulnerable to climate change impacts. Informed by first level of analyses, it finalizes a short list of prioritized sectors with a stakeholder engagement and consultation in the process. The third level of analysis focuses on identifying technologies that would help the government meets its low vulnerability pathway ambitions.

Figure 1.1: Three tiered approach to TNA process in Pakistan



The TNA adaptation process is aimed at eventually leading to the formulation of a national strategy and action plan for technology innovation for developmental and climate change objectives in its next phase after the completion of this phase I activity. The plan would also take an in-depth look at barriers in transfer and diffusion of these prioritized technologies to create an enabling environment for the technology transfer and diffusion process. Once completed, it is expected that TNA project would benefit the country by creating an enabling environment for technology deployment and diffusion through addressing policy and legal gaps, and institutional capacity issues.

Some important specific objectives of TNA are outlined here:

1. Define priority sectors for which technologies are needed to sustain national development projects and programs in light of the UNFCCC strategy and potential impacts of climate change
2. Identify and prioritize suitable technologies that contribute to climate change adaptation in the relevant sectors
3. Develop an enabling framework for the development and diffusion of prioritized technologies in relevant sectors by analyzing technology barriers

4. Develop project proposals for priority technologies in relevant sectors to mobilize resources for implementation of the program
5. Identify key social, economic and environmental development priorities of a country mentioned in various policy and development plans, such as vision 2025, strategy papers on poverty reduction, policy papers such as climate change policy etc.

This TNA report focuses on various aspects of adaptation technology identification and prioritization for the two most climate change vulnerable sectors of the country. The report quickly reviews the required institutional structure for TNA in Pakistan, discusses briefly the past trends and future projections for changing climate, links it up with identification of climate vulnerable sectors of the country in the light of national development goals and type of climate risks and finishes off the report with identification and prioritization of sector-specific technologies by using multi criteria decision analysis tool.

1.2. Existing national policies related to technological innovation, adaptation to climate change and development priorities

1.2.1 National circumstances

Pakistan covers an area of 880,000 km^2 with a prevailing arid to semi-arid climatic conditions and a small portion of north showing humid sub-tropical climate. The precipitation ranges from 200 millimeters (mm) per month in the north to 20-30 mm per month for western areas of the southern half of the country. The Southwest monsoon system accounts for 60percent of its total annual precipitation (from June to September) and the Western weather disturbances (from December to March) account for the remaining proportion of precipitation. Temperature ranges from -50°C to 23°C during winter season and from 15°C to 50°C during summers. This high variation in climate is largely a function of elevation. Pakistan has mountain ranges of Himalaya, Karakoram, and Hindukush in the north including K2, the second highest mountain in the world (8,611meters), as well as low-lying areas along the coast of Arabian Sea in the Indus River delta and Balochistan Plateau in the southern and western part of the country. The Indus river basin plain supports extensive agricultural practices backed up by the world’s largest contiguous Indus Basin irrigation system accounting for 95 percent of the total irrigation system in the country. On the other hand, the Balochistan Plateau is a vast wilderness of mountain ranges with some seasonal rivers flowing through it. Flooding is frequent in summer season, while drought is prevalent in southwestern and some central parts of the country.

The demographic features of the country further adds a level of fragility to the climate change vulnerability profile of Pakistan. With a current population growth rate of 2 percent and population size of 184.5 million, Pakistan is the sixth most-populous country of the world. The recent Human Development Report ranks Pakistan 147 out of 188 countries (UNDP, 2014). At $2 a day purchasing power parity (PPP), the poverty rate is 60 percent with southern parts of all the provinces showing higher poverty incidences in comparison to the northern parts. An estimated 38 percent of the population lives in the urban areas, of which around 47 percent lives in slums. The current total fertility rate of 3.8 percent is one of the highest in the world.

The economy of country is heavily dependent on natural resources, which in turn is sensitive to changing climate. Although service sector makes up more than two-thirds of the economy’s growth, and industry and agriculture jointly contribute about one-third only, yet agriculture is the backbone of the economy employing 47 percent of the national employed labor force and contributing towards development goal of food security. The economy is currently facing many challenges including continuing energy constraints and recurrent floods making it stand at the bottom of eight economies in South Asia—the second lowest after Afghanistan (WB, 2015).

Pakistan ranks 135th globally based on its per capita greenhouse gases (GHG) emission. According to the national GHG inventory of Pakistan for the year 2011-2012, energy (45.9 percent), agriculture and livestock sectors (44.8 percent), and industrial processes (3.9 percent) contributed largely to the total national GHG emissions pool that stood at 369 million tons of carbon dioxide equivalent ($MtCO_2e$). According to a preliminary projection, the GHG emissions levels for Pakistan are expected to increase manifold in the coming decades. Thus, the projected total GHG emissions of Pakistan—in line with government economic growth strategy—will more than double by 2020 (compared to the emissions in 2008) and increase around 14-fold by 2050.

This high GHG emission profile of Pakistan calls for attention to climate induced damages in the future and the associated high cost of adaptation that is estimated in the range of US $6 billion to US $14 billion per year range for Pakistan over the next 40 years horizon (Khan et al., 2011). While ensuring low carbon trajectory, it is equally important to create space for rapid economic growth by integrating climate resilient measures in its development plans and strengthen it by adequate finance and appropriate technology options.

1.2.2 National strategies, policies and actions related to climate change

Climate change (CC) is both developmental and environmental challenge for Pakistan as it poses a serious risk to achieving its Millennium Development Goals (MDGs). Recurring events of climate related disasters such as floods, heat waves, cyclones and droughts in the country have proved to be the major stimulus for the growing awareness among policy makers about nature and extent of impacts of climate change. There is clearly a shift in policy documents from envisaging CC as a stand-alone environmental issue to CC as a risk to economic growth. It is important to stress that the dominant development paradigm in country has thus far mainly focused on human and sustainable development as attempts to address respective economic growth, inequality, poverty, and environmental degradation. Poverty alleviation remains the primary objective of many socio-economic development plans but there is a lack of explicit attention to CC, which is mainly addressed in the context of natural disasters as a key risk to the economy. For instance, Framework of Economic Growth (FEG), released by the Ministry of Planning, Development and Reforms (MPDR) in 2011, recognizes climate change as a risk to sustained economic growth and social wellbeing. The section on environment and CC within the FEG proposes to:

1. Protect economic growth from the risk and associated economic cost of climate induced natural disasters by mainstreaming risk reduction and management concerns within the Government’s planning processes
2. ‘Climate proof’ economic growth from the impacts of CC, paying attention to the agriculture, water and energy sectors
3. Promote ‘green growth’ by attracting investment in low-carbon technologies

a. Pakistan Vision 2025: A roadmap to sustainable development

The Pakistan Vision 2025 document, approved in 2011 by the National Economic Council (NEC) of the country, provides an effective strategy and roadmap to achieve long-term national development goals. Meeting both the elements of MDGs and Sustainable Development Goals (SDGs), the vision document stands on the following seven pillars:

1. People first- Developing human and social capitals and empowering women
2. Growth- Sustained, indigenous, and inclusive economic growth
3. Governance- democratic governance, reform and modernization of public sector
4. Security- Energy, water and food security
5. Entrepreneurship- Private sector and entrepreneur-led growth
6. Knowledge economy- Developing a competitive knowledge economy through value addition
7. Connectivity- Modernizing transparent infrastructure and regional connectivity

For translating the vision into an effective action plan, the document identifies CC as one of the major threats to sustained growth. The Roadmap recognizes the risks that CC is posing in the form of extreme events and to the importance of addressing them through integration and mainstreaming of CC in long term planning processes. The Roadmap also strongly acknowledges the inter-linkages of CC with development through acknowledging developing human and social capital, gearing towards inclusive economic growth and assuring energy, water and food securities for the vulnerable segments of population.

To reduce the risk of CC for development gains, the Vision document proposes to:

1. Design ‘water, food and energy security’ policies and plans of the country with specific reference to the profound challenges posed by climate change
2. Explicitly recognize relevant risks, associated economic and social costs, and implementation of well-defined mitigation and adaptation strategies / measures
3. Promote long term sustainability, conservation and protection of natural resources
4. Access international resources for mitigating the impacts of CC and adapting to it, specifically tapping into funding resources available for clean development mechanism (CDM), Nationally Appropriate Mitigation Actions (NAMA) and the Green Climate Fund
5. Leverage capacity building opportunities offered by UNFCCC and the Kyoto Protocol secretariats for strengthening the institutional arrangements for addressing the climate change issues.

b. National Climate Change Policy: moving towards climate resilient development

The National Climate Change Policy (NCCP) provides an overarching framework for addressing the challenges that Pakistan faces or will face in the future due to climate change. The document identifies major climate related threats to the country, which are summarized below:

1. Considerable increase in the frequency and intensity of extreme weather events, coupled with erratic monsoon rains causing frequent and intense floods and droughts

Box 1: National Climate Change Policy Goal and Objectives

Goal

To ensure that climate change is mainstreamed in the economically and socially vulnerable sectors of the economy and to steer Pakistan towards climate resilient development.

Policy Objectives

1. To pursue sustained economic growth by appropriately addressing the challenges of climate change;
2. To integrate climate change policy with other inter-related national policies;
3. To focus on pro-poor gender sensitive adaptation while also promoting mitigation to the extent possible in a cost-effective manner;
4. To ensure water security, food security and energy security of the country in the face of the challenges posed by climate change;
5. To minimize the risks arising from the expected increase in frequency and intensity of extreme weather events such as floods, droughts and tropical storms;
6. To strengthen inter-ministerial decision making and coordination mechanisms on climate change;
7. To facilitate effective use of the opportunities, particularly financial, available both nationally and internationally;
8. To foster the development of appropriate economic incentives to encourage public and private sector investment in adaptation measures;
9. To enhance the awareness, skill and institutional capacity of relevant stakeholders;
10. To promote conservation of natural resources and long term sustainability.

2. Projected recession of the HinduKush-Karakoram-Himalayan (HKH) glaciers due to global warming and carbon soot deposits from transboundary pollution sources, threatening water inflows into the Indus River System (IRS)
3. Increased siltation of major dams caused by more frequent and intense flood.
4. Rising temperatures resulting in enhanced heat and water-stressed conditions, particularly in arid and semi-arid regions, leading to reduced agricultural productivity
5. Further decrease in the already scanty forest cover, from too rapid change in climatic conditions to allow natural migration of adversely affected plant species
6. Increased intrusion of saline water in the Indus Delta, adversely affecting coastal agriculture, mangroves and breeding grounds of fish
7. Threat to coastal areas due to projected sea level rise and increased cyclonic activity due to higher sea surface temperatures
8. Increased stress between upper riparian and lower riparian regions in relation to sharing of water resources
9. Increased health risks and climate change induced migration

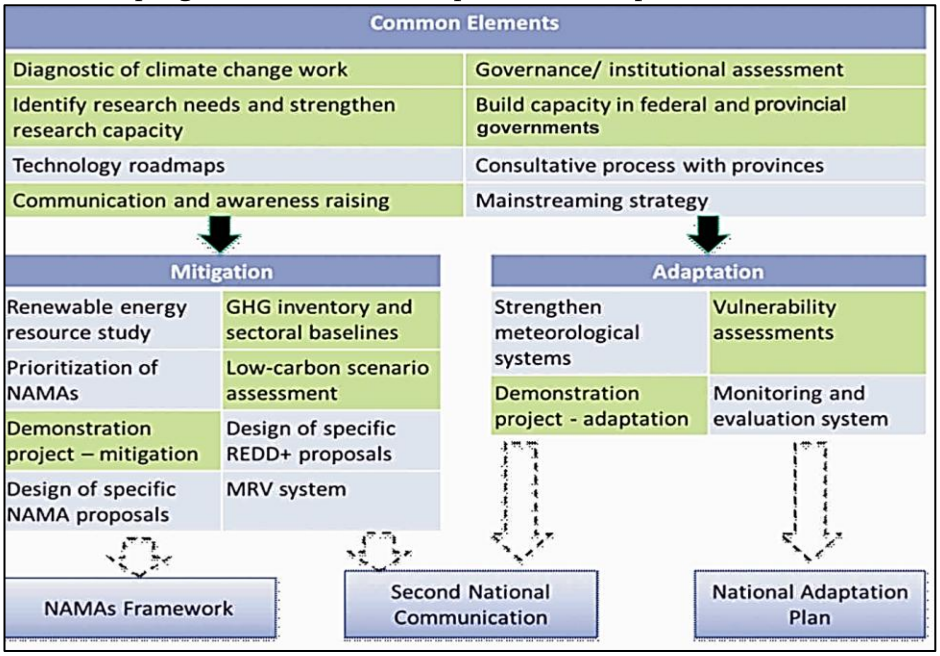
NCCP introduces ‘climate resilient development’ as a future development paradigm for the country that would see better links and synergies between climate change adaptation, mitigation and with sustainable development. The Policy acknowledges that vulnerabilities are symptomatic of deep socio-economic inequalities already existing in the society. Therefore, it stresses on efforts to build adaptive capacity while simultaneously addressing climate threats and long-standing development needs. In doing so, it pays specific attention to the following issues:

1. Climate risks to eco-regions and sectors and importance of risk management adaptation and mitigation needs and opportunities
2. Institutional, and social issues that would impede socio-economic development such as poverty, gender mainstreaming, and cc related institutions with low capacity and promoting status quo
3. Interactions between the natural climate system, ecosystems, and human beings

The Policy document rests the important task of the policy implementation contingent upon devising an "action plan" at the federal, provincial and local government level. For this purpose, the Ministry of Climate Change in 2013 formulated the '**Framework for Implementation of Climate Change Policy for 2014-2030'.** This framework provides guidelines for the implementation of the NCCP by considering both the current and future anticipated climate change threats to the country. Keeping in line with the NCCP policy measures, it spells out a comprehensive list of both adaptation and mitigation strategies, and actions for each key sector primarily identified in the NCCP while prioritizing the adaptation efforts at the sectoral level. The framework document aims to provide a basis and form the building block that will lead to the development of a National Adaptation Plan (NAP), National Appropriate Mitigation Actions (NAMA), and the preparation of the Second National Communication to the UNFCCC. The framework enlists important enabling factors for the success of this framework, which include building high-level political support, enhancing donor community interest, attracting international climate financing among others. It pinpoints the lack of interest by donor community in climate change related initiatives as a major implementation challenge for the mainstreaming of the NCCP. Similarly, it identifies the importance of private sector participation in the successful implementation of climate change adaptation and mitigation programs in the country.

The **'Work Program on Climate Change Adaptation and Mitigation in Pakistan'** has set some important short-term objectives for the country and has identifies priority actions for climate change to steer cumulative actions towards achieving climate resilience at the national and sub-national levels. These objectives include development of the NAP, NAMA framework and preparation of the second national communication to the UNFCCC; while the priority actions for mitigating GHG and adapting to the impacts of CC are: need for climate information, research and building research capacity; devising technology roadmap, governance and institutional assessment; mainstreaming in planning processes with consultation with provinces. In the context of CC adaptation specifically, the priority actions acknowledges vulnerability assessments, monitoring and evaluation, and strengthening of meteorological systems in the country (Figure 1.2).

Figure 1.2: Work program for climate compatible development in Pakistan



GHG = greenhouse gas, MRV = monitoring, reporting and verification, NAMA =national appropriate mitigation actions, REDD = Reducing Emissions from Deforestation and Forest Degradation

Note: Priority actions in green.

Source: Government of Pakistan, Ministry of Climate Change. 2014.

c. National Disaster Risk Reduction Policy (NDRRP) (2013)

The National Disaster Risk Reduction Policy aims to build resilience of the nation by reducing level of risks faced by the country in the form of torrential rains, floods, drought, Glacial Lake Outburst Floods (GLOFs) among the few, and its degree of exposure to these risk. The policy objectives recognize climate change challenges in the context of national capacity building and development planning.

The Policy aims to achieve this objective by adopting principle of strengthening community resilience that include improving vulnerability and risk assessment through multi-hazard approach, assigning a clear division of roles and responsibilities, improving inter-organizational partnership, and accountability and transparency of the responsible institutions.

The institutional setup for disaster risk reduction in the country is a prime representative of the cross-sectoral mainstreaming of climate change. The National Disaster Management Commission (NDMC), established under the Chairmanship of the Prime Minister is the apex policy making body in the field of Disaster. The National Disaster Management Authority (NDMA), executive arm of the NDMC, is the lead agency at the Federal and provincial levels to deal with whole spectrum of disaster management activities supported by The National Disaster Risk Management Framework which focuses on nine priority areas:

1. Institutional and legal arrangements for DRM
2. Hazard and vulnerability assessment
3. Training, education and awareness.

4. Disaster risk management planning
5. Community and local level programming.
6. Multi-hazard early warning system
7. Mainstreaming disaster risk reduction into development.
8. Emergency response system, and
9. Capacity development for post disaster recovery

d. National Environmental Policy 2005

The National Environment Policy (NEP) 2005 was formulated at the time when understanding among policymakers about country's climate change challenges was low. Therefore, the NEP recognizes climate change mainly in the context of ozone depletion and some other natural resource challenges such as dwindling water resources, desertification etc. without acknowledging climate change as major agent of change.

The issue of climate change is explicitly mentioned only in Section 4.7 of the environment policy reproduced below:

4.7. "Climate Change and Ozone Depletion". In order to effectively address challenges posed by climate change and to protect the ozone layer, the government shall: Develop and implement the national climate change action plan; establish National Clean Development Mechanism (CDM) Authority; develop and implement policy and operational framework for effective management of CDM process; promote the use of ozone friendly technologies; and phase out the use of ozone depleting substances in line with the provisions of the Montreal Protocol.

1.3. Sector selection for the TNA process

1.3.1 An overview of expected climate change and its impacts in sectors vulnerable to climate change

1.3.1.1 Past observed trends in climate variables

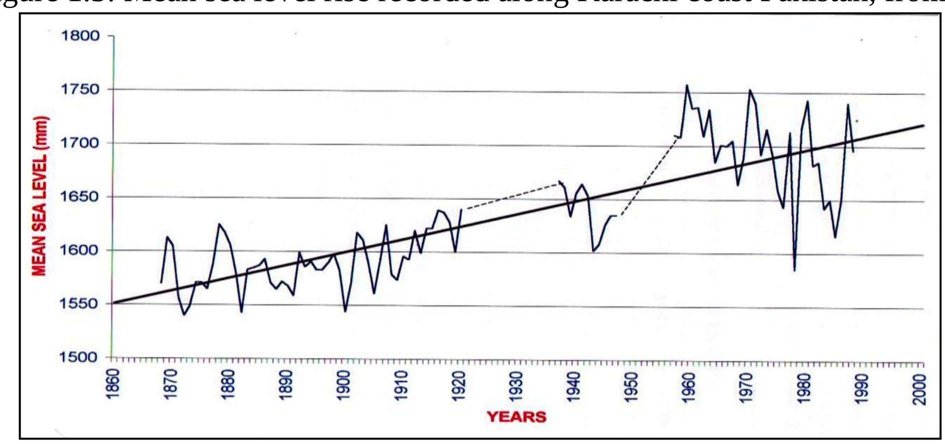
Pakistan is seeing impacts of climate change as an increase in its mean annual temperature, decrease in precipitation and a rise in sea level. This changing climate obviously has bearing on the productivity and efficiency of climate sensitive sectors of agriculture, water and energy.

In the past century from 1901 to 2000, mean annual temperature has increased by 0.57°C which is however lower than mean annual temperature increase of 0.75°C noted for the South Asia region in the past century (Ahmed and Suphachalasa, 2014). The temperature increase is observed for most parts of the country except the Sub-Mountain and Western Highlands and Lower Indus Plains (Global Change Impact Studies Centre, 2005). Winters are getting more warmer and shorter compared to summers with a temperature change ranges from 0.52 to 1.12°C. Central parts of the country shows considerable 3-5percent reduction in cloud cover, southern part shows 0.5-0.7 percent increase in solar radiation and monsoon whereas the northern parts of the country outside monsoon region have suffered from expanding aridity (Farooqi et al., 2005). The trend over Indus delta is mixed, but there is no alarming warming or cooling change found so far (Rasul et al., 2012a).

Precipitation across the country shows a variable trend for the duration of 1951-2000. For arid plains and coastal areas, precipitation amount is decreased by 10-15 percent in summers whereas the monsoon rain system shows a rise of 18-32 percent rainfall. Balochistan province displays a decrease of 5percent in its relative humidity. Similarly, a decrease of 17-64 percent in rainfall has been observed during the seven strong El Nino events in the last 100 years. The frequency of depressions, storms and cyclones that form in the Arabian Sea and Bay of Bengal has increased during the last decades of the 20th century and has been affecting Pakistan along with other countries in the region (Farooqi et al., 2005).

A significant increase in the number of heat wave days with the rate of 11 days per decade is observed over the period 1980-2007 for Pakistan. A positive linear trend was observed in the frequency of heat waves at 5, 7 and 10 consecutive days for moderate heat waves (≥ 40 °C) in the Sindh province of Pakistan. A rise of 30-60 days in cold wave is observed in the north western parts of the country while a decrease in the number of cold wave days in Punjab, Azad Jammu and Kashmir (AJK) and southern parts of Sind province. No significant trend, however, was observed in the averaged cold wave days over the country. Sea level rise for Pakistan is estimated at 1.1mm per year (mm/year) from 1856-2000 along Karachi coast (Rabbani et al., 2008) (Figure 1.3).

Figure 1.3: Mean sea level rise recorded along Karachi coast Pakistan, from 1850-2000



mm = millimeter.

Source: M.M. Rabbani et al. 2008.

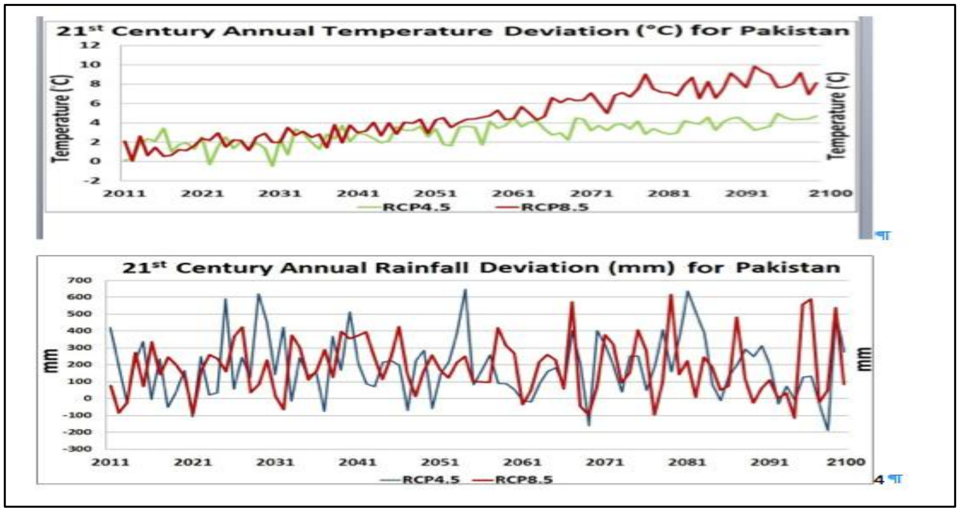
1.3.1.2. Projections of future climate trends in Pakistan

The observed climate trend in Pakistan is expected to continue in future. The climate model (CMIP5) using different emission scenarios given in IPCC Fifth Assessment Report (AR5) for the period of 2010-2100 proposes 3°C–6°C rise in mean temperature with a sharp increase noted after 2050 under RCP 8.5[2] (Pakistan Meteorological Department (PMD), 2015). According to the model, the rainfall is highly variable in both spatial and temporal domains. Area-averaged rainfall over Pakistan shows a large inter-annual variability. Sharp rising peaks give some

[2] The IPCC Fifth Assessment Report defined a set of four new scenarios, denoted Representative Concentration Pathways (RCPs) RCP2.6, RCP4.5 and RCP 6,and RCP8.5. RCP 4.5 is a stabilization scenario where GHG emissions stabilize by 2100. RCP 8.5 is another scenario with very high greenhouse gas emissions where radiative forcing does not peak by year 2100.

indication of extreme precipitation events while negative peaks indicate droughts (Figure 1.4). CMIP5 multi-model mean projections of annual average temperature and precipitation changes for 2046–2065 and 2081–2100 under RCP 4.5 and 8.5 relative to 1986–2005 are given in Figure 1.4.

Figure 1.4: Pakistan's mean annual temperature and precipitation deviation projections during 21st century using two different emission scenarios

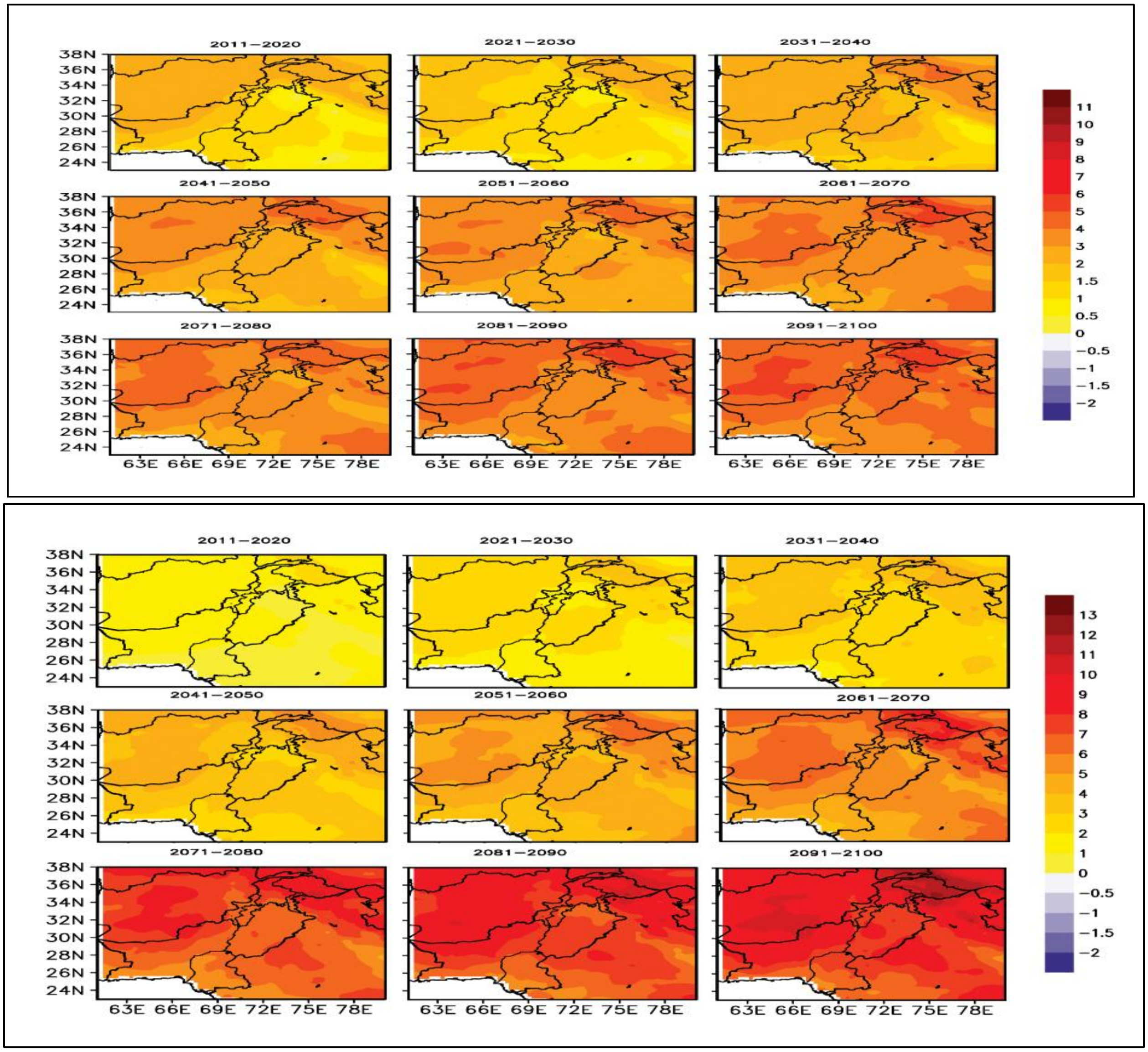


RCP 4.5 is a stabilization scenario where GHG emissions stabilize by 2100. In RCP 8.5 radiative forcing does not peak by year 2100.

Source: Pakistan Meteorological Department, 2015.

According the model, spatial patterns of temperature and precipitation have similar behavior. Snow covered areas of Pakistan in the north are showing larger increase in mean temperature as compared to central and southern regions under both RCP scenarios. However, RCP 8.5 shows more abrupt increase in temperature in the region after 2060 and up to 10°C -12°C especially in the northern Pakistan whereas RCP 4.5 shows similar increasing trend but with less intensity i.e., 5°C-6°C (Figure 1.5).

Figure 1.5: CMIP5 projections of annual average temperature (°C) for 2011-2100 under RCP4.5 (top) and RCP8.5 (bottom), relative to 1975-2005 APHRODITE baseline.

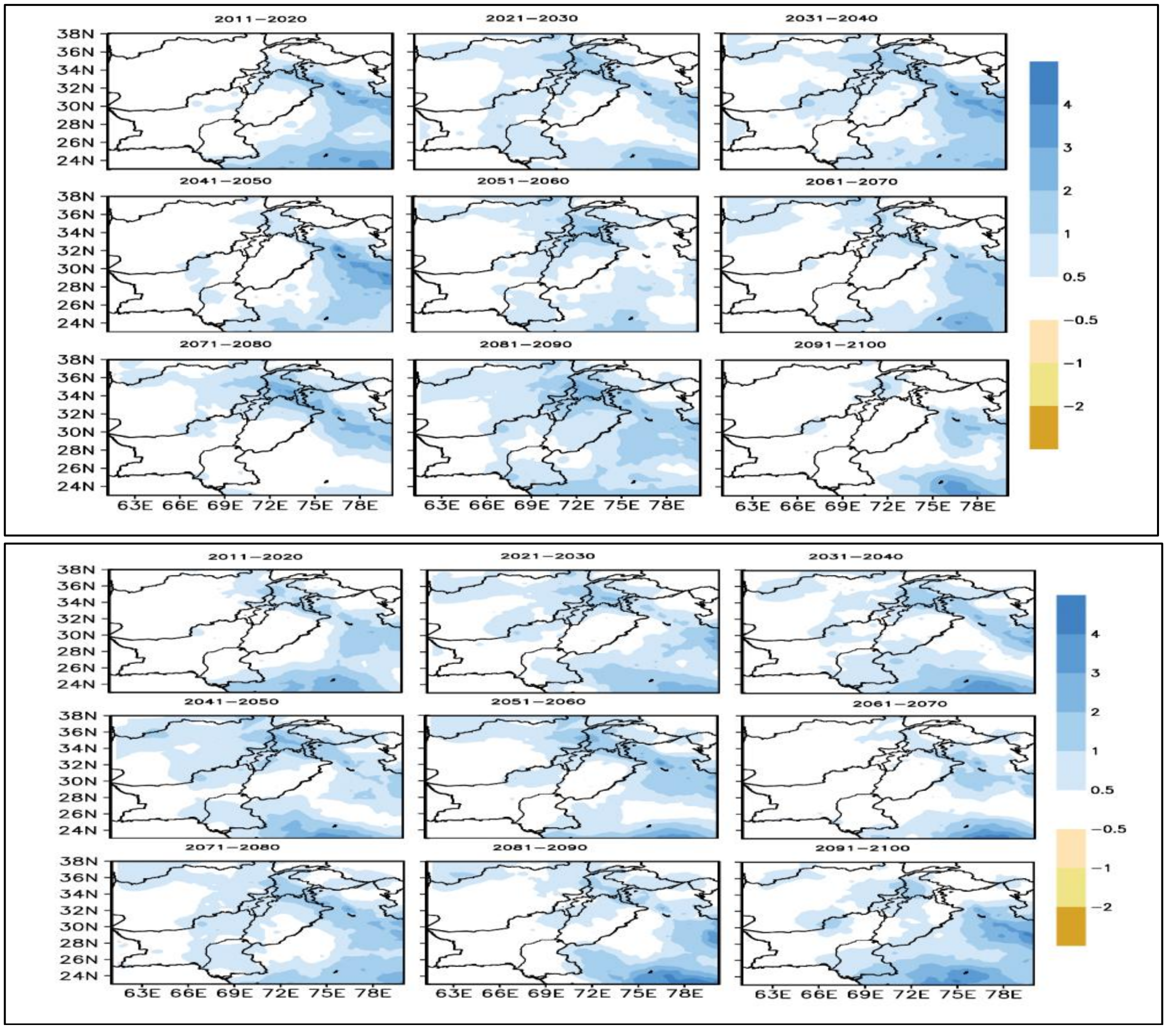


CMIP5 = Coupled Model Intercomparison Project Phase-5, RCP = Representative Concentration Pathways. APHRODITE= Climate model

RCP 4.5 is a stabilization scenario where GHG emissions stabilize by 2100. In RCP 8.5 radiative forcing does not peak by year 2100. Source: Pakistan Meteorological Department, 2015

For area-averaged rainfall over Pakistan, the model shows a large inter-annual variability with sharp spatial and temporal variation. According to CIMP5 model, mid–century summer rainfall peaks will shift towards August while those of winter season will shift towards March. The shifts in the rainfall peaks continue even up to the end of the century. RCP4.5 shows an increase of 4 mm/day in annual mean precipitation, with a shift in maxima towards the northeastern part of the country until 2050. After 2050, the precipitation pattern shifts towards northwest until the end of the 21st century with the same magnitude and wet situation in the southern region. RCP8.5 scenario shows similar but with lesser magnitude of up to 2-3 mm/day and with more spatial spread (Figure 1.6).

Figure 1.6: CMIP5 projections of annual mean precipitation changes (mm/day) for 2011-2100 under RCP4.5 (top) and RCP8.5 (bottom), relative to 1975-2005 APHRODITE baseline



CMIP5 = Coupled Model Intercomparison Project Phase-5, mm = millimeter, RCP = Representative Concentration Pathways. RCP4.5 = Stabilization pathway where radiative forcing stabilized by the year 2100. RCP8.5= High GHG emission pathway scenario where radiative forcing does not peak by year 2100APHRODITE = Climate model

Source: Pakistan Meteorological Department, 2015

1.3.2 Overview of climate change vulnerability and its impacts in sectors vulnerable to climate change

1.3.2.1 Agriculture and Livestock Sector

Agriculture sector is the key economic sector of the country that contributes 21 percent to the gross domestic product (GDP), employs 45 percent of the total labor workforce and contributes about 60 percent to national exports (GOP, 2015). The sector is, however, one of the most sensitive one to changing climate. Some of the expected major impacts are:

1. Shift in spatial boundaries of crop potential areas due to change in growing season length of crops because of higher temperature, reduced soil moisture, crops pests and diseases.

Crop –growth simulation models point to shortening of length of growing season for wheat crop by 14 days for every 1^0C rise in temperature in northern regions by 2040

2. Changes in productivity potential of crops either through direct effect from changes in temperature, water balance, CO2 concentration, and extreme events or/and indirect effects through changes in distribution frequency, disease outbreak or changes in soil properties. Six percent reduction in wheat and 15-18 percent for fine-grain aromatic basmati rice yields will occur in all agro-climatic zones of the country except in northern areas
3. Changes in water availability through increase in plant evapotranspiration rate and soil moisture
4. Changes in cropping pattern due to increase in net irrigation water requirement of crops
5. Changes in land use systems: The climatic changes in arid climates would result in increased salinity and/or water logging; which would certainly demand for integration of forestry and aquaculture with the crop based farming systems

To increase the resilience of agricultural system against climate risks, the sector has to overcome some of the challenges that it is grappling with. Some of them are identified in The Vision 2025 document which are given below:

1. Slow rate of technological innovation
2. Limited adoption of progressive farming techniques
3. Poor input supply
4. Pest and livestock disease problems
5. Limited access to agricultural credit
6. Marketing and trade restriction

Water Sector

Pakistan has the world's largest integrated Indus Basin irrigation system with a command area of around 14.3 million hectare representing about 70 percent of the total cultivated area in the country. The irrigation system is fed by the glaciers in Hindukush-Karakoram range in the northern part of the country and seasonal rainfalls. Water is a precious commodity used in agriculture, industry, energy sectors, and to meet various domestic demands.

The Task Force on Climate Change (2010) has identified some climate change related threats to water security to the country (GOP, 2010):

1. Increased variability of river flows due to increase in the variability of monsoon and winter rains and loss of natural reservoirs in the form of glaciers
2. Increased demand of irrigation water because of higher evaporation rates at elevated temperatures in the wake of reducing per capita availability of water resources and increasing overall water demand
3. Increase in sediment flow due to increased incidences of high intensity rains resulting in more rapid loss of reservoir capacity
4. Increased incidences of high altitude snow avalanches and GLOFs generated by surging tributary glaciers blocking main un-glaciated valleys
5. Increased degradation of surface water quality due to increase in extreme climate events like floods and droughts; and

6. Lack of current knowledge and monitoring effort on climate change impacts in the HKH region; also lack of understanding and modeling capability about the patterns of glacier melt and rainfall feeding the Indus River Systems (IRS) and the corresponding impact on IRS flows

To cope with climate change threat and ensure water security, Pakistan vision 2025 document as a focal development roadmap lays out five goals to achieve water security:

1. Increase water storage capacity from currently 30 days to 45 days by 2018, and 90 days by 2025
2. Invest in proven methods and technologies to minimize wastage, promote conservation
3. Enable more effective allocation with direct reference to national and provincial priorities and related social and economic consideration
4. Establish institutional mechanism to effectively manage water resources
5. Provision of access to a minimum baseline of suitable water to every person in Pakistan

1.3.3 Process and result of sector selection

In TNA process, sector selection is an important step towards priority technology identification and ranking which would finally lead to the construction of technology action plan for diffusion and adoption of prioritized technologies in its respective sectors with available sources of financing.

The process of sector selection started with an extensive desk review of relevant documents on climate change impacts on various sectors of the country and their degrees of vulnerability to these adverse impacts in the future along with consultation with different key experts. The process of research and deliberation helped in the selection of a super set of six climate sensitive sectors: agriculture and livestock, water, health, urban development, transport and infrastructure. In order to reach to the final selection of the most vulnerable sectors of the country to the impacts of climate change, six climate sensitive sectors were assessed against the set of the following criteria:

1. Contribution to the sustainable development priorities of the country
2. Climate change impacts on Pakistan and its degree of vulnerability
3. Contribution to minimize vulnerability to climate change
4. Sector specific adaptation needs of the country
5. Potential of technology innovation in the sector to improve the resilience of the human and natural systems

Based on this set of criteria, the most vulnerable sectors of agriculture and water were selected and prioritized (Table 1.1).

Table 1.1: Steps for priority sectors selection and prioritization for adaptation technology needs assessment in Pakistan

Steps for priority sector selection	**The outcome of the process**
Step 1: Development priorities identification **Methodology:** Desk review of existing national policy documents and reports, complemented with expert consultations	The most important development priorities identified include: 1. Human and social development 2. Gender empowerment 3. Inclusive economic growth 4. Food, water, energy security 5. Entrepreneurship 6. Building knowledge economy 7. Improving regional connectivity through developed road network and transport system
Step 2 Identify impacts and vulnerabilities of climate change on the country **Methodology:** Desk review of existing documents and reports on sector specific vulnerability and risk assessment studies	A super set of possible sectors under consideration: 1. Agriculture and livestock 2. Water 3. Energy 4. Health 5. Urban development 6. Transport and infrastructure 7. Industry
Step 3 Identify the most vulnerable sectors based on the degree of impact on meeting development priorities, contribution to minimize vulnerability to climate change, sector specific adaptation needs of the country, and potential of technology innovation in sectors to improve resilience of human and natural systems	The most vulnerable sectors identified were agriculture and water
Step 4: Validation of the results in Stakeholder (TNA Inception) Workshop	Final selection and validation of sector prioritization for TNA process were: water and agriculture.

The results were validated in the first TNA Inception workshop and further endorsed by the members of the National TNA Committee (Appendix I provides the list of member who attended the TNA Inception Workshop).

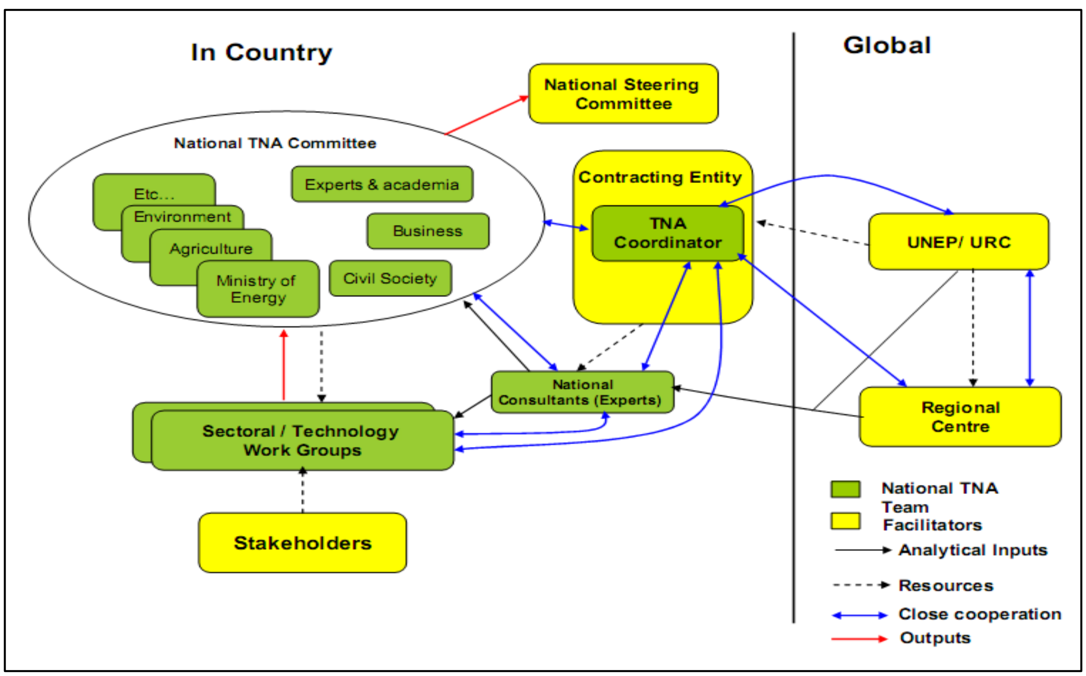
The climate change profiles of these two sectors supported the fact that due to adverse impacts of climate change, these two sectors will be highly vulnerable in terms of losses in human, social and economic development gains in the long run than those of other sectors. Therefore it is necessary to adapt to climate change by selecting suitable environmentally sound adaptation technologies that will help country achieve its goal of sustainable development in the face of climate change.

CHAPTER-2 INSTITUTIONAL ARRANGEMENT FOR THE TNA PROCESS AND STAKEHOLDERS INVOLVEMENT

To set up an organization structure, Pakistan has followed the guidelines of UNFCCC/ UNDP for developing a national TNA team for coordination of the work, and organization of stakeholders' involvement. The initial steps taken to form an organizational structure for TNA are as follows:

1. Identify and establish a lead agency for TNA project implementation;
2. Explore objectives and scope of the Project through a consultation meeting;
3. Identify relevant stakeholder agencies and personnel for the TNA Committee;
4. Identify a core team involving the lead technical institutions and representing participants, and other technical experts from all the sectors;
5. Appoint TNA coordinator and national consultants;
6. Define a process for stakeholders consultation by establishing the 'National TNA Committee' and 'Expert Sectoral Working Group' for the priority sectors (Figure 2.1)

Figure 2.1: A generalized institutional arrangement for the TNA project

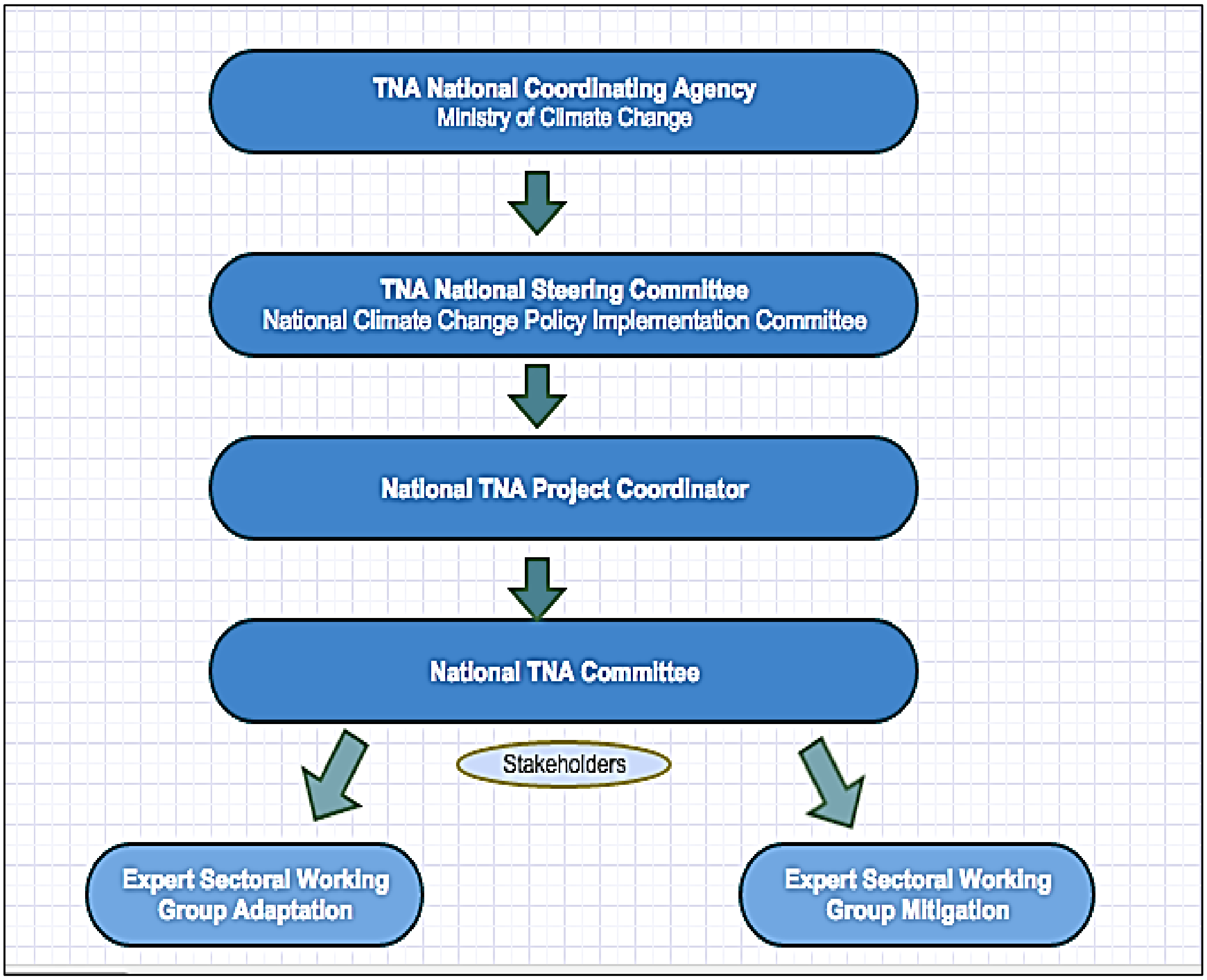


Source: UNFCCC/UNDP guidebook on the TNA process

To ensure that the TNA process is country driven and a sustainable initiative, Pakistan has used the existing national climate change institutional structures, wherever possible, to complement the TNA project implementation. Thus, Federal Ministry of Climate Change is designated as the lead Ministry and coordinating entity responsible for TNA. The National Committee for Climate Change Policy Implementation is assigned to serve as the TNA National Steering Committee;

and the Director General (Environment & Climate Change) of the Ministry of Climate Change is nominated to act as the National TNA Project Coordinator. After this umbrella organizational setup, the TNA process is led by a team of national consultants and technical expert working group members identified during the process for sector and technology prioritization. The structure of Pakistan's National TNA team is shown in Figure 2.2.

Figure 2.2: National TNA organizational structure in Pakistan



2.1. TNA organizational structure in Pakistan

i. National Project Steering Committee (NPSC): The Committee oversees the TNA process in the country and provides high-level guidance to the work of national TNA team. The National Committee for the Implementation of Climate Change Policy –a policy level multi-stakeholder decision-making body tasked to oversee the implementation and mainstreaming of the National Climate Change Policy– is designated to act as the NPSC for the TNA project. The Federal Minister of climate change chairs this committee and other members include secretaries of ministries of climate change, planning and development, foreign affair, science and technology, industries and production, finance, water and power, food and agriculture, health, defense and members of provincial ministries, research institutions, and civil society organizations. The role of this committee is to provide high-level guidance to the work of national TNA team and later to help secure political acceptance for the Technology Action Plan (TAP).

ii. **National TNA Committee**: This is the central decision-making body acting as a core driving group. The committee is composed of 19 members from to the Ministries of climate change, planning & development, agriculture, water & power among others. (Appendix I provides the member list of the National TNA Committee).

The Committee performs specific responsibilities such as:

1. Identify national development priorities and priority sectors for the Technology Need Assessment;
2. Assist in the constitution of sectoral/technical expert working groups;
3. Define stakeholder consultation processes;
4. Review and approve technologies and strategies for mitigation and adaptation as recommended by expert sectoral working groups;
5. Review and approve the TNA report, report on barrier analysis and technology enabling environment.

iii. **The TNA Coordinator**: The Ministry of Climate Change has designated its Director General (Environment & Climate Change) as the national TNA Coordinator who is a lead focal point and a manager of entire TNA process. The Coordinator's role requires a good amount of experience with country's mitigation and adaptation challenges in the context of national development objectives and sector policies.

The responsibilities of TNA Coordinator largely cover facilitation of communication with the National TNA Committee and consultants; coordination and communication with sectoral expert working groups and other stakeholders; formation of networks with across sectors and ministries for information acquisition; preparation of work plans and monitoring of the progress of the project etc.

iv. **Project Implementation Unit (PIU):** The Ministry of Climate Change has established a Project Implementation Unit under its assistant director (Climate Change) for providing necessary support in project execution, especially in organizing the expert working group discussion, stakeholder consultation at national and local level, and provision of administrative and logistic support to TNA team members.

v. **National Consultant:** National consultant for adaptation technology is responsible for the research, analysis, and synthesis of the entire TNA process. Under the guidance of the TNA Committee and Coordinator, the consultant is required to provide the required technical expertise for adaptation, help identify, and prioritize adaptation technologies with the help of adaptation sector expert working group.

vi. **Sectoral Expert Working Group-Adaptation**: This expert working group on adaptation is composed of a wide range of stakeholders with different backgrounds and expertise particularly in the area of agriculture, water resources, climate change technologies and adaptation. The group includes relevant officials from federal ministries and line departments, provincial governments & their associated departments, civil society organizations, and international donor organizations (Appendix I shows the composition of Adaptation Working Group).

2.2. Stakeholders engagement process- overall assessment

A wide range of stakeholders have been engaged and consulted at each step of the TNA process through providing them an inclusive environment and space to share their insights, expertise, and knowledge to detect and manage external risks early on in the process. This inclusive process, induces legitimacy and enhances the chances of successful ownership of this whole process.

The participants engaged and consulted belonged to both federal and provincial government ministries such as federal ministries of Climate Change, Water & Power, Food Security, Planning & Development and their associated wings/departments including National Disaster Management Authority (NDMA), Federal Flood Commission, Global Change Impact Study Centre (GCISC), Pakistan Meteorological Department; representatives of international donor organizations, civil society, academia and research institutes, and private sector. They however, differed from each other on the basis of their interest in the TNA process, availability, and influence.

The stakeholders holding higher tiers of management and leadership in TNA organizational structure such as those members of National Project steering Committee and the National TNA Committee also hold higher level of authority and influence, though the numbers of their members are limited. On the other hand, sectoral technical expert working group's composition is more varied and flexible so more members can be added as per requirements.

The stakeholder engagement plan for the TNA carried the following building blocks.

1. Identification of the TNA national team including Steering Committee, National TNA Committee, Consultants and Sectoral Expert Working Groups;
2. Information disclosure about the role of the group, objectives to achieve, and communication method etc. This has taken place early in the process.
3. Stakeholder consultation and involvement in devising communication strategy, sector prioritization, resource selection and mobilization, and technology prioritization;
4. Establishment of a process for a continuous stakeholder engagement that would ensure that all stakeholders are kept updated on the level and type of activities going on through a continuous flow of information and sharing of materials such as the final TNA report.

CHAPTER-3 TECHNOLOGY PRIORITIZATION FOR WATER SECTOR

The TNA process entered in its next step of identifying and prioritizing technologies for the most vulnerable sectors of the country once the sector prioritization process was complete. The process involved various sector specific key experts and practitioners for the sake of identifying the current status of adaptation technologies at local and regional levels and specifically those with a successful replication potential in order to meet the crucial yet diverse demands of the technology users in the water sector of Pakistan. This process of extensive consultation with experts and stakeholders ended up in short listing of seven technologies out of a long list of 19 technologies initially identified through literature review.

The 'Technology Fact Sheets' were prepared for these short-listed technologies that covered: brief technology introduction, descriptions, adaptation benefits to the country, social, economic, and environmental benefits, the total cost of the technology implementation and recurring maintenance, current status in the country and implementation barriers (Appendix II). The Fact Sheets were presented in and discussed with the Sectoral Expert Working Group-Adaptation. After detailed discussions, the Experts Group with slight modification endorsed five technologies options in water sector for further analysis through MCDA, and also agreed on the analysis criteria and their weights.

3.1 Climate change vulnerability and existing technologies in water sector

According to the World Bank Report (2006), Pakistan is rapidly moving from water stressed country to a water scarce country mainly due to growing population size, and deterioration of water quality and quantity. The world's largest integrated Indus Basin Irrigation System is largely dependent on precipitation, snow and glacier melt that are highly sensitive to the growing impacts of climate change in the future. Despite overuse of water in some sectors such as agriculture (92 percent)—water use in industries is roughly 3percent, domestic and infrastructure roughly 5percent—the consumptive demand for water is increasing without any major improvement in the supply side of this precious commodity. The seasonal and annual river flows in the Indus Basin Irrigation System are highly variable, where the highest flows are almost double of the lowest flows and total flows during kharif season is five-fold of the rabi season flows. The Seepage losses in the Indus River Irrigation System alone reaches to 65 million acre feet (MAF) per year, whereas the storage capacity of major water reservoirs are at 9 percent compared to 40 percent world average.

Climate change is expected to enhance the vulnerability of the water sector by adversely impacting the future water availability as the glaciers are projected to retreat due to rising temperatures. It is projected that due to retreating mass of the Western Himalayan glaciers over the next 50 years, the Indus river flows will see a substantial amount of increase during the initial period of water melt, but subsequently will experience a decrease of 30 to 40 percent in the river flows. Other studies, however, show conflicting findings and projections that leave the fate of river flows and water availability subject to high uncertainty.

Rainfall data for the period 1951-2000, nonetheless, shows a decrease of 10-15 percent in winter and summer rainfall in arid plains and coastal areas of Pakistan, while a rise of 18-32 percent in the summer rainfall over the major monsoon regions of Pakistan (GCISC, 2005). This study findings point to an increasing degree of aridity and dry lands in existing arid and semi-arid areas of the country that not only will demand for more water but also need to conserve the scarce freshwater resources in the future.

Similarly, the monsoon rainfall system—which brings above 60 percent of the total rains in the country just in four months of summer—is projected to become more variable and unreliable with possible consequences including an increase in the intensity of rainfall and a reduction in the duration of the monsoon. Climate change is also predicted to increase the likelihood of both coastal and inland flooding initiating a demand for stormwater management in both rural and urban centers of the country.

The analysis of climate change risk profile of the water sector of Pakistan clearly portrays two major threats faced by this sector in the wake of climate change a) reduced availability of water for irrigation and other consumptive uses; b) increased flooding due to melting of glaciers and intense short-duration rainfalls that could affect both urban centers and rural agricultural lands along with other livelihood assets.

Existing technologies in water sector

Following are the current adaptation technologies in water sector:

1. Harvesting rainwater from ground surfaces for irrigation and drinking purposes
2. Water purification systems;
3. Water storage structures that serve dual purposes of storing water and recharging groundwater, such as delay action dams, check dams;
4. Boreholes and tube wells;
5. Flood early warning system with flood protection structures such as levies.

As both the climate hazards come with a high potential to compromise food, water and energy security of the country, therefore TNA adaptation technologies mainly focus on these two subsectors of water i.e. flood protection and resource availability.

3.2. Decision context

The National Water Policy (draft), formulated in 2003, highlights some of the important needs of this sectors including doubling the value of agricultural output, tripling the hydropower generation, reducing by half the areas affected by floods, and treating all wastewater and establishing a national water information bureau to address provincial concerns over developing new water reservoirs and canals among other important initiatives. The draft policy is clearly aligned with the development priorities of the country outlined in the Vision 2025 document to meet water and food security of the country. To cope with climate change threats and ensure water security, Pakistan Vision 2025 document serves as a focal development roadmap and lays out five goals to achieve water security:

1. Increase water storage capacity from currently 30 days to 45 days by 2018, and 90 days by 2025
2. Invest in proven methods and technologies to minimize wastage, and promote conservation

3. Enable more effective allocation with direct reference to national and provincial priorities and related social and economic consideration
4. Establish institutional mechanism to effectively manage water resources
5. Provision of and access to a minimum baseline of suitable water to every person in Pakistan

In 2014-15, Rupees 43.5 billion were allocated for the water sector's programs/strategies which were planned by keeping in view Vision 2025 and 11th Five Year Plan. Major strategy adopted to overcome the water sector's issues and investments in the sector were: a) augmentation measures by construction of water storage such as small/medium dams and rainwater harvesting, hill torrents management; b) conservation measures (lining of irrigation channels, modernization/rehabilitation of existing irrigation system) and efficiency enhancement by rehabilitation & better operation of existing system; c) protection of agriculture land and infrastructure from onslaught of floods and waterlogging & salinity; d) formulation of an effective implementation monitoring system and comprehensive set of measures for the development and efficient management of water resources.

3.3 Adaptation technology options for water sector and their main adaptation benefits

Water sector experts, practitioners, and stakeholders members of Sectoral Expert Working Group agreed on the following five adaptation technologies options for water sector (Table 3.1)

Table 3.1: Adaptation benefits of water sector technologies

Technology	The main climate change adaptation benefits
Surface rainwater harvesting	1. Reduce pressure on the surface and groundwater resources by decreasing household water demand 2. Mitigate or reducing the instances of flooding by capturing rooftop runoff during intense rainstorms 3. Provide a short-term security to households against periods of low rainfall or water scarcity
Groundwater recharge	1. Allow for an increased abstraction of water during water stressed seasons 2. Water use for water supply or environment protection
Urban Stormwater management	1. Reduced stress on surface and groundwater resources 2. Mitigate flood by capturing stormwater runoff during rainstorms
Wastewater treatment and reuse	1. Diversify use of water resources 2. Low instances of crop failures due to more recurrent droughts 3. Used for groundwater and aquifer recharge 4. Prevent saline water intrusion in coastal areas

Flood early warning system	1. Minimize risk level to property and life 2. Early evacuation of the vulnerable population 3. Allow for installation of flood resilience measures such as sand bags 4. Help in pre-flood maintenance operations to ensure safety of flood control structure

3.4. Criteria and process of technology prioritization for water sector

3.4.1. Identifying adaptation technology options for water sector

Identifying technology options was a critical initial part of the MCDA process. After the endorsement of five short listed technology options in water sector by the 'Sectoral Expert Working Group-Adaptation' after detailed deliberations, the TNA process entered in its next step of identifying and prioritizing technologies for water sector through an extensive stakeholder engagement process by utilizing the multi criteria decision analysis (MCDA) tool. This tool help in comparing adaptation technology options across a number of diverse criteria while taking into account the priorities and values of multiple stakeholders, thereby moving forward the formal decision making process in a transparent and consistent way.

The 'Sectoral Expert Working Group's short listed technologies included:

1. Flood early warning system
2. Surface rainwater harvesting
3. Groundwater recharge
4. Wastewater treatment and reuse
5. Urban stormwater management

3.4.1.1 Characterization of short-listed adaptation technologies

All the short listed technologies were categorized on the basis of its availability in time and applicability in scale. The categorization criteria were: short term, medium term, long term, small scale and large scale.

1. The short term implies that the technology is reliable, and commercially viable in a standard market mechanism and thus is available in the market in a shorter time period.
2. The medium term technologies will approximately take 5 years to full market availability in the standard market context
3. A long term technology would still be in an R&D phase or a prototype
4. Small scale technologies are applied at the household and/ or community level with potential to be scaled up into a program, and
5. Large scale technologies are applied on a scale larger than household or community level (Table 3.2).

Table 3.2: Characterization of short-listed technologies for the water sector

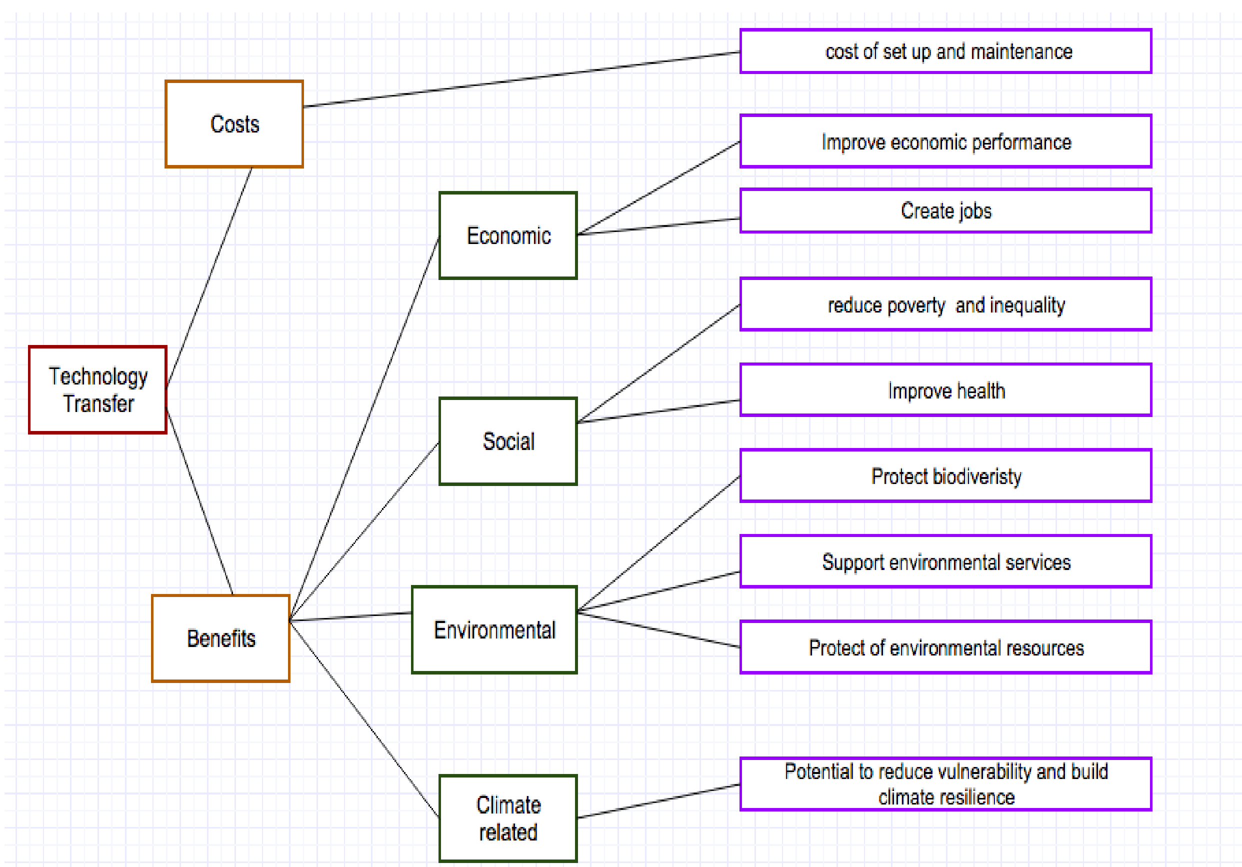
Technology	Scale of technology application	Availability of technology in time
1- Surface rainwater harvesting	Large scale	Short and medium term
2- Urban stormwater management	Medium scale	Medium term
3- Flood early warning system	Large scale	Medium term
4- Treatment and reuse of wastewater	Small to large scale	Short and medium term
5- Groundwater recharge	Medium to Large scale	Short and medium term

3.4.2. Multi criteria decision analysis process:

3.4.2.1. Determination of criteria and weightings

The criteria applied for evaluation of technologies were: cost of technologies, economic, social and environmental, and climate related benefits. Each of these benefit categories were judged against sets of sub-criteria selected by the Sectoral Expert Working Group-Adaptation technology that helped in scoring and weighting of the technology options (Figure 3.1)

Figure 3.1: Multi criteria decision analysis criteria tree for adaptation technology needs assessment for water sector of Pakistan



Source: MCA4Climate UNEP, 2011

As a central element of the MCDA analysis, scores were assigned to each criterion through stakeholder consultation using technology option scoring justification table provided in the guidebook of MCDA process by UNEP DTU (Table 3.3). The scoring scale of 0-100 was used where a score of '0' was given to the technology option which was least preferred under that criteria and 100 was given to the most preferred option under the same criteria . The technology scores are provided in the Technology Performance Matrix (Appendix III).

Table 3.3: Technology option scoring justification table

Score	General Description
0	Used when information on a technology does not apply to the particular criteria
1-20	Extremely weak performance; strongly unfavorable
21-40	Poor performance, major improvement needed
41-60	At an acceptable or above level
61-80	Very favorable performance, but still needing improvement
81-100	Clearly outstanding performance which is way above the norm

Source: UNEP DTU Partnership. 2015.

Once the scoring process was complete, weights were assigned to the selected set of criteria including economic, environmental, social and climate related benefits while the sub-set of criteria, provided in the criteria tree (Figure 3.1), were only used to fully comprehend the aspects of the selected criteria under consideration, so no disaggregated weights were assigned to the sub-set of the criteria. The purpose of this step was to determine the relative preference of a criterion over the others by giving a weight that represents relative strength of a criterion. The weight assignment was done in two steps of assigning first a basic weight through consultation with stakeholders and then finding out swing weights for each criterion for an option. The swing weight technique was utilized in this MCDA process to fully account for the difference in scoring value range (or swing of the indicator value) assigned to each criterion by the stakeholders. The basic weights were normalized for swing variation and swing adjusted weights were calculated (Table 3.4).

Table 3.4: Weighting of criteria showing assigned base weight and swing weight values

Criteria	Assigned base weight (%)	Swing weight (%)
Cost	20	25
Economic benefit	25	20
Social benefit	15	12
Environmental benefit	15	19
Potential of reducing vulnerability	25	24

Finally, to get the total aggregated score for each technology option, the scores for each criterion were normalized and then multiplied with its respective swing weight calculated earlier. The new weighted scores for all the criteria for an option were added up to get an overall weighted sum of scores for each adaptation technology (Table 3.5).

Table 3.5 : Swing weighted scores for the selected adaptation technologies in water sector

Technology Options	Criteria					Total weighted scores
	Cost	Economic benefit	Social benefit	Environmental benefit	Potential of reducing vulnerability	
Swings	70.00	47.37	50.00	77.78	57.14	
Base weight ratio	1.33	1.67	1.00	1.00	1.67	
Swing weights	0.24	0.20	0.13	0.20	0.24	
Surface rainwater harvesting	77.8	88.9	66.7	100.0	100.0	88.28
Wastewater treatment and reuse	0.0	0.0	0.0	71.4	0.0	13.91
Groundwater recharge	77.8	88.9	100.0	42.9	100.0	81.11
Urban stormwater management	55.6	66.7	100.0	100.0	95.0	81.09
Flood early warning system	100.0	100.0	66.7	0.0	100.0	76.57

3.4.2.2. Result of technology prioritization

On the basis of total weighted scores, the technology options were prioritized and ranked by the 'Sectoral Expert Working Group' from high priority to low priority order. According to the result, thus surface rainwater harvesting got the highest weighted score of 88.28 and thus the most preferred option.

According to MCDA result, the top three adaptation technologies with the highest priority ranking in the water sector of Pakistan are (Table 3.6):

1- Surface rainwater harvesting
2- Groundwater recharge
3- Urban stormwater management

Table 3.6: Priority adaptation technologies in water sector of Pakistan

Name of the technology	Technology score (Output from the MCDA)	Technology priority order
Surface rainwater harvesting	88.28	1
Groundwater recharge	81.11	2
Urban stormwater management	81.09	3

The prioritized technologies approved in consensus by the 'Sectoral Expert Working Group ' were later on endorsed by the National TNA Committee and the TNA Steering Committee in their meeting held in February, 2016.

Here is a brief account of the priority adaptation technologies in the water sector of Pakistan:

1. Surface rainwater harvesting

Pakistan is water stressed country with current per capita water availability reaching to around 1066 cubic meters per year and is expected to reduce to 858 cubic meters by 2025 with a growing demand for water at an annual rate of 10 percent. Rainwater as a source of fresh water ensures water security, which is not only fit for human consumption but also for other multi-purpose uses such as irrigation, household utilization, and groundwater recharge.

Rainwater harvesting from ground surfaces and flash floods have a long history in Pakistan in the form of one of the world's largest indigenous water harvesting system for irrigation known as spate irrigation. Pakistan has 0.343 mha under this system in arid and semi-arid areas of Balochistan, Sindh, Khyber Pakhtunkhuwa and Punjab. In the past, there have been many efforts to modernize this system with a considerable amount of investment by different international donor agencies and the system has a tremendous potential to bring more land under cultivation and ensure food security in the country.

Rainwater harvesting offers many adaptation benefits in the form of increase in supply of water, reduced pressure on the ground and surface water resources, reduced inflow of flood to rivers and watercourse channels, control on soil erosion and stabilization of groundwater table.

2- Groundwater recharge (Managed aquifer recharge)

Groundwater resource provides adequate security against cyclic drought or poor surface water quality. It makes important source for agriculture, domestic and industrial use in Pakistan. However, excessive depletion of groundwater all over the country is widening the gap between demand and supply due to insufficient natural recharge. Excessive depletion is observed in the Lower and Central parts of the Bari Doab, non-perennial areas in Punjab canal command, the Barani (rainfed areas) outside command of Indus Basin Irrigation (Potohar in Punjab, Thar Desert in Sindh. Balochistan province presents the worst-case scenario of depleting groundwater where groundwater depth has reached 120m hitting the alluvial aquifer bottom. The groundwater use in Balochistan exceeds recharge by 22 percent and aquifer is drying up in many parts of the province.

Groundwater recharge takes many forms, through boreholes, delay action dams, etc. depending on the geo-physical conditions, amongst others. The recharge is an important adaptation technology with many benefits to user communities through protecting groundwater quality, ensuring water security during dry spells of climate, sustained supply of water for agriculture and thus ensuring food security.

3- **Urban stormwater management**

Managing stormwater poses a huge challenge for urban centers in the form of loss of property, livelihood, polluting environment and deteriorating living quality. The management choices are tough because it is inextricably linked to other public services; for example, good storm drain is essential for basic sanitation and decent transportation. Whereas good drain system needs proper solid waste management, so ultimately it requires solid land use planning and management.

An important aspect to consider in design element is climate change induced change in rainfall, which could compromise the resilience of existing stormwater infrastructure. The system can be adapted by increasing the infiltrating capacity of the landscape through low impact development approaches such as source control that is the main cause of urban flooding, on-site stormwater treatment and reuse, use of bio-ecological drainage systems for private and public buildings, e.g. the use of swales, dry ponds, rain gardens, or constructed wetlands etc.

The adaptation benefits offered by stormwater management system include increased resilience of stormwater infrastructure, incorporation of green design in urban planning, improved community health, protection and improvement of livelihood sources especially in poor neighborhoods.

CHAPTER-4 TECHNOLOGY PRIORITIZATION FOR AGRICULTURE SECTOR

After the prioritization of agriculture sector as one of the two priority sectors selected for TNA process in Pakistan was complete the next step of the process was to identify and prioritize adaptation technologies in this sector.. In the first stage of this process an extensive literature review of the relevant material helped in identifying 21 adaptation technologies. Next the process involved various sector specific key experts and stakeholders for the sake of identifying the current status of these adaptation technologies at local and regional levels and specifically of those ones with a successful replication potential in order to meet the crucial yet diverse demands of the technology users in the agriculture sector of Pakistan. This stage finished with shortlisting of seven technologies for the agriculture sector.

Technology Fact Sheets were prepared for each of the seven technologies, which were presented in and discussed with the Sectoral Expert Working Group-Adaptation. The Fact Sheets covered different aspects of technology including brief technology descriptions, the total cost of the technology, implementation and recurring maintenance, current status and implementation barriers in the country, and the adaptation and other social, economic, and environmental benefits (Appendix II). After detailed discussions, the Sectoral Expert Working Group with a slight modification in technology titles endorsed six technology options in agriculture sector for further analysis through MCDA, and also agreed on the analysis criteria and their weights.

4.1. Climate change vulnerability and existing technologies and practices in agriculture sector

Agriculture sector is one of the largest sectors of the country that employs 45 percent of the total labor workforce and contributes about 60 percent to national exports (GOP, 2015). The past climate trends for Pakistan show a more warmer and shorter duration winter than summer season with large increase in nighttime temperature than day time. Similarly, summer season has also experienced a non-uniform rather a mixed trend of maximum temperature all over the country. The minimum temperature is increasing over Central parts of Pakistan, while extreme north and south have shown slightly cooling trend in some climatic zones (Rasul, 2012a). This change in temperature with difference in day length has serious implications for crop growth and productivity in future.

It is estimated that with rise of temperature (+0.5-2°C), agricultural productivity will decrease by around 8-10% by 2040 (Dehlavi et al. 2015). Different simulation studies, using crop–growth simulation model estimated a decrease in yield of major crops specifically for wheat and rice, and the length of growing season in four agro-climatic zones of Pakistan. The model predicted the largest decrease of around 14 days for 1°C rise in temperature in growing season length of wheat in northern mountainous region compared to southern Pakistan (Iqbal et al. 2009).

Climate change will severely affect two major crops of wheat and fine-grain basmati rice in Pakistan. It is estimated that, under IPCC A2 Scenario, wheat yield will reduce by 6% and fine-grain aromatic basmati rice will experience 15-18% decrease in yield in all agro-climatic zones by 2080 except in some areas of the north (ibid).

Existing adaptation technologies/ practices in agriculture sector

1. Adaptation strategies/technologies in use in rain-fed areas of Pakistan

1. Using drought-resistant varieties such as mustard, and wheat.
2. Shifting to delayed sowing of wheat and mustard crops by 15-30 days.
3. Using deep tillage to preserve the available soil moisture.
4. Diverting river/stream/spring water through private water channels.
5. Building small check dams to recharge groundwater.
6. Using rain harvesting techniques and dug wells.

2. Adaptation technologies in use in irrigated areas of Pakistan

1. Preferring low-delta and low input canola/mustard oil seed crops, as an alternate to wheat crop especially in water stressed areas of Sindh.
2. Delaying wheat sowing by 15-20 days to compensate higher temperatures in mid-October to mid-November particularly in Sindh, and earlier sowing of cotton crop shifted from May/June to March.
3. Direct seeding of rice crop to save water and input cost.
4. Combating frost impact, the farmers in Punjab and upper Sindh, use water and in some cases smokes in the frost vulnerable areas.
5. Increasing rate of tube-well installation and usage.
6. Switching to hybrid maize cultivation in February/March to compensate the higher temperatures in certain areas of Punjab particularly in Sahiwal, Pakpattan and Okara District
7. Adopting a heat resistant rice variety (i.e., Superi) which is non-recommended, but high-yielding short duration rice variety, while super basmati is planted three weeks late in third week of July.
8. Early sowing of cotton in March before temperature shoots up and on ridges of farms to manage water scarcity.
9. Shifting from sugarcane and rice to cotton in Khairpur and Nawabshah Districts.
10. Replacing long duration (i.e., 110 days) rice varieties such as IRRI-6 and DR-83 with short duration hybrid rice varieties (90-days).
11. Increasing preference of fish farming in water logged areas.
12. Delayed sowing of wheat, rice and gram by 15-30 days to compensate changing weather patterns in Khyber Pakhtunkhawa province.
13. Increasing trend of rainwater harvesting in desert areas for animals and human drinking.
14. Intercropping of wheat in sugarcane and mustard in cotton by farmers in Sindh to save water resources.
15. Increasing popularity of tunnel farming for growing off-season vegetables.

4.2. Decision context

The food security in Pakistan is inextricably linked with agriculture and water sectors and as such the need to adapt to climate change is duly acknowledged as an intrinsic element of Pakistan future development. The ‘Vision 2025’ document provides guidelines to improve the productivity of the agriculture sector in order to attain food security.

During 2013-14, an allocation of Rs. 750 million was made to 13 development projects of Ministry of National Food Security and Research. Against this allocation, 90% of the allocation was utilized. Some new initiatives had been proposed and approved that include application of satellite remote sensing and geological information system (GIS) technology for crop forecasting and estimation, value addition in agriculture – cluster development approach, and capacity building of agriculture extension services among the few.

4.3 Adaptation technology options for agriculture sector and their main adaptation benefits

Adaptation benefits of selected technologies were identified with the help of key sector experts and desk review of research material on agricultural technologies (Table 4.1).

Table 4.1. Adaptation benefits of agriculture sector technologies

Technology	The main climate change adaptation benefits
High efficiency irrigation systems	1. Efficient use of water supply especially in drought prone areas or those with seasonal rainfall 2. Reduced demand for water by decreasing water evaporation losses 3. Improved crop health by easy fertilization in case of drip irrigation system, less leaching of nutrients from the root zone, and thus with lower probability of onset of diseases such as fungus 4. High adaptability to a wide range of topographies, and soil characteristics (including saline and sandy soils) except heavy clay soils
Development of drought-tolerant crop varieties	1. Efficient use of available crop water in drought prone areas or those with seasonal rainfall 2. Reduced demand of water by minimized evaporation losses from the crop surfaces. 3. Improved food security
Climate monitoring and forecasting - early warning system	1. Early identification of type and extent of climatic hazards and population at-risk 2. Effective prevention or mitigation of risk with quick recovery of hazard-hit population in disaster prone areas 3. Enhanced effectiveness of vulnerability monitoring, allowing individuals (farmers) and community systems to prepare for hazards 4. Improved adaptation planning and monitoring at high policy level
Salt-tolerant crop varieties	1. Provide strong defense against twin problem of salinity and water logging in the soil and thus ensures good crop productivity 2. Help to achieve food security target in changing climate by bringing more area under cultivation

Land use planning	1. Protect fertile agricultural lands from encroaching by land mafia 2. Improve chances of availability of more land for increasing acreage of farming 3. Improve disaster management approaches and risk reduction

The pre-selected technologies were characterized further on the basis on their scale of application (small to large) and range of availability (short, medium and long terms) (Table 4.2)

Table 4.2: Characterization of short-listed technologies for the agriculture sector of Pakistan

Characterization of technologies in agriculture sector		
Technology options	**Scale of technology application**	**Technology availability in time**
1- High efficiency irrigation systems for irrigated and rain-fed areas	Small to large scale	Short and medium term
2- Drought tolerant crop varieties	Large scale	Medium to long-term
3- Climate monitoring and forecasting – early warning system	Large scale	Medium to long-term
4- Land use planning	Small to large scale	Short and medium term
5- Livestock breed improvement	Small to large scale	Medium term
6-Salt tolerant crop varieties	Large scale	Medium to long-term

4.4 Criteria and process of technology prioritization for agriculture

In order to prioritize the adaptation technologies in agriculture sector of Pakistan, a set of locally-validated criteria were selected based on the framework proposed in the guidebook on MCDA process from UNEP DTU (See Figure 3.1 for the MCDA criteria tree showing different criteria adopted in this TNA process). Based on the 'Technology Fact Sheets' and Sectoral Expert Working Group members' preference and expertise, the technologies were quantified on the scale of 0-100 based on the technology scoring justification table (Table 3.3). A score of '0' was given to a least preferred technology option under that criterion, and 100 was given to the most preferred option under the same criteria. The remaining criteria were then given scores on a scale between these two values (See Appendix III for technology performance matrix).

After scores were assigned each criterion was assigned a base weight which represented the relative preference of a criterion over the other. A swing weight method was employed to calculate the total weighted score for each technology option at the end of the MCDA process. The swing weight technique accounted for the difference in the range (or swing) of the scores assigned to a criterion for a technology option. Table 4.3 shows the base weight and swing weight values of a criterion.

Table 4.3: Weighting of criteria showing assigned base weight and swing weight values

Criteria	Assigned base weight (%)	Swing weight (%)
Cost	20	22
Economic benefit	25	19
Social benefit	15	12
Environmental benefit	15	21
Potential of reducing vulnerability	25	26

The scores were normalized and the total weighted score was calculated for each technology option by multiplying the swing weight of each criterion with its respective score and getting an aggregate weight for each technology option by adding up all the weighted scores (Table 4.4)

Table 4.4: Swing weighted scores for the selected adaptation technologies in agriculture sector

Technology Options	Criteria					Total weighted scores
	Cost	Economic benefit	Social benefit	Environmental benefit	Potential of reducing vulnerability	
Swings	62.50	44.44	44.44	81.25	61.11	
Base weight ratio	1.33	1.67	1.00	1.00	1.67	
Swing weights	0.22	0.19	0.12	0.21	0.26	
Climate monitoring and forecasting- Early warning system	0.0	100.0	25.0	46.2	100.0	58.33
High efficiency irrigation systems for irrigated and rain-fed areas	50.0	75.0	100.0	84.6	81.8	76.31
Drought tolerant crop varieties	40.0	100.0	87.5	30.8	63.6	61.33
Land use planning	100.0	12.5	0.0	100.0	45.5	57.19
Livestock breed improvement	80.0	75.0	50.0	0.0	0.0	37.52
Salt tolerant crop varieties	40.0	0.0	62.5	30.8	18.2	27.18

The technology with highest weighted score was ranked as a priority technology. According to the order of priority, three technologies received the highest degree of priority:

(a) High efficiency irrigation systems for irrigated and rain-fed areas; (b) Drought tolerant crop varieties; (c) Climate monitoring and forecasting - early warning system (Table 4.5).

Table 4.5: Priority order of adaptation technologies for agriculture sector in Pakistan

Name of the technology	Technology score (Output from the MCDA)	Technology priority order
High efficiency (drip & sprinkler) irrigation systems for irrigated and rain-fed areas	76.31	1
Drought tolerant crop varieties	61.33	2
Climate monitoring and forecasting - early warning system	58.33	3

Here is the brief account of priority adaptation technologies in the agriculture sector of Pakistan:

1. High efficiency (drip & sprinkler) irrigation systems for irrigated and rainfed areas

Pakistan has the world's largest contiguous Indus Basin Irrigation System (IBIS), which is the lifeline of irrigated agriculture in the country. The irrigation efficiency of the system, however, is highly comprised due to high amount of water losses at the different stages of water conveyance system including canals, water courses and field where water losses at the field level is the highest in the system. Outside IBIS in rain-fed agricultural system, sustainable supply of water is a major issue due to increasingly uncertain rainfall patterns and dwindling groundwater resources. To improve productivity of the agricultural system, high efficiency irrigation systems such as drips and sprinklers etc. offer sustainable solutions in changing climate.

The technology has adaptation benefits: (1) provides efficient use of water supply especially in drought prone areas or those with seasonal rainfall; (2) reduced demand for water by reducing water evaporation losses; (3) ensures healthy crop by easy fertilization in case of drip irrigation system, less leaching of nutrients from the root zone, and thus with lower probability of onset of disease such as fungus; (4) provides high adaptability to various topographies, and soil characteristics (including saline and sandy soils) except heavy clay soils.

2. Drought tolerant crop varieties

Drought tolerance is an important management strategy for efficient water use and better crop yield in the areas with limited or uncertain water supply. The technology employs both conventional breeding and genetic engineering techniques and tools to create stress-tolerant crop varieties such as wheat, and rice.

The technology provides efficient use of available crop water especially in drought prone areas or those with seasonal rainfall; reduces high demand of water by minimized evaporation losses from the crop surfaces; exhibit generally multi-stressor tolerance such as resistance against pests and salinity

3. **Climate monitoring and forecasting - early warning system**

The accurate and reliable predictions of day to day weather, and particularly future impacts of climate change are largely handicapped by high level of uncertainty associated with non-availability of accurate and reliable data. Due to the complexity of global climate and weather systems, regular measurement of specific variables provided by climate monitoring and early warning systems are indispensable that would facilitate disaster preparedness and adaptation planning in the country. With effective early warning communication channels in place, this technology increases the effectiveness of vulnerability monitoring, allowing individuals (farmers) and community to prepare for hazards. It also enables early identification of at-risk population in disaster prone areas and provides decision makers with the information for effective adaptation planning and its mainstreaming in national development goals.

Pakistan Meteorological department is the national institution responsible for early warning systems for floods, drought, heat wave, and diseases of which flood-warning system is the most mature and sophisticated one. After the floods of 2010, the Department has installed a flood alert and management information system (PIFMIS)- a comprehensive system that serves multipurpose ranging from flood alert, flood control and management.

CHAPTER 5 SUMMARY & CONCLUSIONS

For this TNA exercise, two key economic sectors of **water** and **agriculture** are identified, as those sectors most vulnerable to the adverse impacts of climate change, therefore technological interventions in these sectors are deemed necessary to adapt to climate changes for achieving sustainable socio-economic development in the country.

This TNA report, which is prepared with support from GEF, UNEP and AIT, is the outcome of extensive consultation process which led to the identification prioritized sectors and technologies through the use of MCDA tool. The adaptation technologies were prioritized based on a set of the following criteria group with varying weights;

1. Benefits –Contribution to economic & social and environmental goals.
2. Relevance to climate change –Potential to reduce vulnerability and built climate resilience.
3. Cost of technology –Implementation and maintenance

The prioritized technologies in water and agriculture sectors are given below:

Prioritized Sectors	Prioritized Technologies
Water Sector	1. Surface rainwater harvesting 2. Groundwater recharge 3. Urban stormwater management
Agriculture Sector	1. High efficiency (drip & sprinkler) irrigation systems for irrigated and rainfed areas 2. Drought tolerant crop varieties 3. Climate monitoring and forecasting- early warning system

After the TNA sector and technology prioritization processes for water and agriculture sectors were complete, it was presented to the National TNA Committee for the final approval. After approval by the Committee, the results were subsequently presented to and endorsed by the TNA Steering Committee during their meetings held during the month of February, 2016.

This TNA report will lead the way to the next phase of the TNA, which is - Barrier Analysis Report, followed by the development of Technology Action Plans and Project Ideas.

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APPENDIX I

A. National Technology Needs Assessment (TNA) Committee composition

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2. Syed Naseer Gillani, Chief Environment, Ministry of Planning, Development and Reforms, Islamabad.
3. Director General, Pak. EPA, Islamabad
4. Dr. Muhammad Rehan Anis, Senior Scientific Officer, GCISC, Islamabad.
5. Mr. Irfan Yousaf, Director (CDM), Alternative Energy Development Board (AEDB), Islamabad
6. Deputy Secretary (IF), Ministry of Industries & Production, Islamabad
7. Mr. Ashfaque Ahmed Memon, Dy. Technological Adviser, Ministry of Science and Technology, Islamabad
8. Mr. Asad Mehmood, Manager (Tech), ENERCON, Islamabad
9. Dr. Muhammad Aslam, Food Security Commissioner, Ministry of National Food Security and Research, Islamabad.
10. Dr. Shahida Waheed, Chief Scientist/ Director Coordination, Pakistan Institute of Nuclear Science & Technology Directorate of Coordination, Islamabad
11. Dr. Afzal Hussain Kamboh, Deputy Director, PCRET.
12. Dr. Aurangzeb Khan, Director, AJK-Environmental Protection Agency, Government of Azad Jammu & Kashmir.
13. Managing Director, Punjab Small Industries Corporation, Industries, Commerce & Investment Department, Government of Pakistan
14. Ms. Saira Atta. Director General, Industries Department, Government of Balochistan.
15. Mst. Tanzeel Nazir, Deputy Director (Environment), Sindh Coal Authority, Energy Department, Government of Sindh.
16. Mr. Zia-ur-Rehman, Assistant Director (Environment), Directorate of Power Development Sindh, Energy Department, Government of Sindh
17. Mr. Shariq Raza, Technical Officer, Energy Department, Government of Sindh
18. Dr.Javaid Iqbal, Director General, Environmental Protection Department, Government of Punjab.
19. Mr. Nusrat Baloch, Director Electricity (North), Energy Department, Government of Balochistan.
20. Mr. Ali Bakhsh Bezinjo,(Director Technical) Environmental Protection Agency, Quetta, Government of Balochistan
21. Mr. Ahmed Kamal, Member, NDMA, Government of Pakistan
22. Mr. Sajjad Yaldram, Dy. Secretary, Ministry of Climate Change, Government of Pakistan

B. Adaptation expert working group composition

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APPENDIX II

A. List of adaptation technologies presented to the Adaptation Expert Working Group for prioritization in agriculture and water sectors of Pakistan

i. Agriculture sector

Technology 1: High efficiency irrigation systems-drips and sprinklers
Technology 2: Conservation tillage
Technology 3: Development of drought-tolerant wheat varieties
Technology 4: Climate change monitoring system
Technology 5: Farmer field schools (FFS)
Technology 6: Integrated nutrient management (INM)
Technology 7: Laser land leveling
Technology 8: Salt tolerant rice and wheat varieties
Technology 9: Heat and pest tolerant cotton varieties
Technology 10: Community extension agent
Technology 11: Index based climate insurance
Technology 12: Crop rotation and diversification
Technology 13: Land use planning
Technology 14: Ecological pest management
Technology 15: Seed and grain storage
Technology 16: Livestock disease management
Technology 17: Selective breeding via controlled mating
Technology 18: Mixed farming
Technology 19: Agro-forestry
Technology 20: Forest user groups
Technology 21: R & D research center

ii. Water Sector

Technology 1: Rooftop rainwater harvesting
Technology 2: Rainwater harvesting from ground surfaces
Technology 3: Water efficient fixtures and appliances
Technology 4: Water reclamation and reuse
Technology 5: Constructing new water storages (small dams)
Technology 6: Early warning systems
Technology 7: Enhancing aquifer recharge through boreholes
Technology 8: Water user association
Technology 9: Constructed wetlands/wetland restoration
Technology 10: Water safety plans
Technology 11: Flood proofing of buildings

Technology 12: Post construction support for community managed water system
Technology 13: Flood protected wells
Technology 14: Flood hazard maps
Technology 15: Green landscaping with impervious surfaces
Technology 16: Reducing water leakages in water management facilities
Technology 17: Low impact development designs
Technology 18: Desalination
Technology 19: Storm surge barriers and closure dams

B. Technology fact sheets for agriculture sector

Technology 1: High efficiency irrigation system

Sector	Agriculture/Water
Category	Water conservation and efficiency
1. Technology name	High efficiency irrigation system
Introduction	Efficient irrigation systems ensure meeting crop water demand in a changing climate. Pakistan has the world's largest contiguous Indus Basin irrigation system (IBIS), which is the lifeline of irrigated agriculture in the country. The irrigation efficiency of the system, however, is highly comprised due to high amount of water losses at the different levels of water conveyance system including canals, water courses and field where water losses at the field level is the highest in the system. The yearly water losses for instance, according to water balance sheet 2014 for Punjab province, reaches up to 45 million acre foot (MAF) out of 90 MAF of total available water to crops. Out of 45MAF water losses, 13MAF is lost at canal levels, 11MAF at watercourses, and 21 MAF at the field levels[3]. Outside IBIS in rainfed agricultural system, a sustainable supply of water is a major issue due to increasingly uncertain rainfall patterns and dwindling groundwater resources. The future projections on climate change impacts depict a situation of increasing water scarcity with high demand. This scenario calls for an effective and efficient irrigation water management systems in the country. High efficiency irrigation systems (HEIS) including sprinklers and drip systems offer a high water-use efficiency of around 75-90 percent respectively compared to 60 percent for surface irrigation systems.
Technology characteristics	Drip system assures a specific and focused quantity of water directly applied to the root zone of the plants through a pipe

[3] Directory General Agriculture, Water management Wing. 2015. *Briefing to the Secretary Agriculture on Water Management Wing Projects and Performance*. Punjab Agriculture Department. Lahore.

	distribution network at a low flow rates (0.22 to 0.45 GPH). Drip irrigation zones are identified based on various factors such as topography, field length, soil texture and filter capacity. Drip is used best for a wide range of orchards, vegetables, and cotton crop. Sprinkler system uses various mechanical and hydraulic devices that simulate natural rainfall. Water is sprinkled, sprayed or misted through emitters by throwing through the air. In this way each plant get the right amount of water it needs. The system caters for both small and large scale applications and comes in hand-move systems and mechanically operated ones. The system is suited to most row, field, and tree crops that are grown closely such as cereals, wheat, pulses, cotton, vegetables, and fruits. Both systems require: 1- Pumps or pressurized water systems which take water from the source and provide pressure for delivery into pipe systems. Pressure vary from 2-3 bars to more than 10 bars 2- Filtration system 3- Nutrients application system 4- Pipes (including main pipe line and tubes) 5- Control valves and safety valves 6- Drip emitters or mini-sprinklers and their variances 7- Monitoring plant water need through tensiometer or through programs addressing irrigation quantity and frequency provided by technicians.
Climate change adaptation benefits	The technology 1) provides efficient use of water supply especially in drought prone areas or those with seasonal rainfall. 2) Reduces demand for water by reducing water evaporation losses. 3) Ensures healthy crop by easy fertilization in case of drip irrigation system, less leaching of nutrients from the root zone, and thus with lower probability of onset of disease such as fungus. 4) Provides high adaptability to various topographies, and soil characteristics (including saline and sandy soils) except heavy clay soils.
Benefits to Economic, Social and Environmental Development	
Economic development	High value agriculture development, job creation and expansion of market for skilled labor, high returns on drip investment cost generally though it partially depends on market prices.
Social development	Food security through healthy crops as disease prevalence is reduced; alternative livelihood strategy for rural populace; Positive impact on family and nutritional intake by reducing farmer especially women workload and put with increased participation in high value crops farming such as vegetables
Environmental	Reduced runoff through deep percolation of water; low soil

development	disturbances and erosion due to site specific irrigation; high adaptable to terrains where other irrigation system can not function properly due to steep topography, soil or climatic conditions
Costs, Current Status and Implementation Barriers	
Costs	Drip system average per acre cost= Rs. 116790 Sprinkler average per acre cost = Rs. 110970. The estimated costs ignores 9 percent service charges on the installation of the system and training of the farmers.
Current status and application potential in the country	It has been a decade that this technology is introduced in the country and adopted by farmers. The most commonly used types are micro-sprinkler, bubbler, micro jets, and spin nets. In the Province of Punjab, out of 29 million acres of irrigated land, 22,000 acres are using HEIS. Sindh, by 2013 had 5,911 acres total area of which 1025 acres were installed with drip irrigation system alone. The government is offering this technology at the subsidized rates of 60 to 80 percent on total system installation cost on up to 15 acres in Punjab and Sindh/Balochistan respectively. The adoption and success of the technology in the country is mixed despite high subsidies offered by the government. For instance, according to Ashraf (2012) [4], 71percent of drip irrigation system is non-functional in Balochistan.
Implementation barriers	High initial cost of system installation and lack of access to finance to bear this cost, maintenance/operation and capacity building of farmers; lack of knowledge about irrigation scheduling; difference in quality and price of the irrigation system component offered in the market; high damage incidence by flood, rodent and animals; difficulty in combining the system with other farm machinery such as tractor, or seed driller etc; higher possibility of water right or land conflicts on water resource in water constrained areas.

Technology 2: Development of drought-tolerant crop varieties

Sector	Agriculture
Category	Improved crop varieties
Technology name	Development of drought-tolerant crop varieties
Introduction	Drought is the principal constraint on crop production in dry land areas specifically impacting the lives of poor. Drought tolerance is an important management strategy for efficient water use and better crop yield in the areas with limited or unpredicted water

[4] Ashraf, M. 2012. *Overview of Drip Irrigation System: Potential, Issues and Constraints*. International Centre for Agricultural Research in the Dry Areas (ICARDA). NARC, Islamabad. http://www.pec.org.pk/sCourse_files/DDIS/Lectures/Drippercent20overview.pdf

	supply.
Technology characteristics	The technology employs both conventional breeding and genetic engineering techniques and tools to create stress-tolerant wheat varieties. The participatory plant breeding offers a more active role to farmer by offering them observer plant performance in the field while attempting to select the plant traits for better drought tolerance. Genetic engineering involves the use of molecular markers to better understand the genetic basis of drought tolerance and to select more efficiently for this trait. Both techniques though take considerable time in development of a new crop variety and its field-testing procedures.
Climate change adaptation benefits	The technology provides efficient use of available crop water especially in drought prone areas or those with seasonal rainfall; reduces high demand of water by minimized evaporation losses from the crop surfaces; exhibit generally multi-stressor tolerance such as resistance against pests and salinity.
Benefits to Economic, Social and Environmental Development	
Economic development	High grain yields in less productive agro-climatic zones or areas and as such contributes in achieving food security goal of the country; opening market for new jobs, research and service provision in climate smart agriculture.
Social development	Aid in improving livelihood and strengthening the resilience of rural farmers to climate change
Environmental development	Enhancing the productivity of the drought prone areas of the country and ensuring conservation of biological resources in these areas.
Costs, Current Status and Implementation Barriers	
Costs	It is difficult to calculation exact expense due to many reasons including: investment is needed to build well equipped laboratories of molecular biology and reliable mutagens resources, maintenance of laboratories and permanent operations require stable and permanent funding and a pool of technology experts and trainers.
Current status and application potential in the country	The technology has been developed for both irrigated and rainfed areas of the country and is adopted by the farmers. In case of wheat, for example, Chakwal-50, GA-2002, Inqilab-91, Dharabi-11, NRL-2017 are some examples of drought tolerant varieties that have been developed in the past and currently in use by the farmers. Most of the drought tolerant wheat varieties have displayed pest resistant with good grain yield and high bread-making (chapatti) quality in field trials. Monitoring and evaluation of the performance of technology, however, at the farm level is limited.
Implementation barriers	1) Long time period for the detection, transfer, and diffusion of new improved crop varieties; (2). High skilled technical staff

	required with on-farm trial equipment; (3). Uncertainty about market demand for new wheat varieties; (4). Poor seed supply chain due to shortage of good grain storage houses in the country; (5). Lack of monitoring and evaluation of performance of new varieties under farmer's field conditions.

Technology 3: Climate change monitoring system- early warning system

Sector	Agriculture
Category	Hazard/disaster management
Technology name	Climate change monitoring system
Introduction	The accurate and reliable predictions of future impacts of climate change is largely handicapped by high level of uncertainty associated with availability of accurate and reliable data. Due to the complexity of global climate and weather systems, regular measurement of specific variables provided by climate monitoring systems are indispensable that would facilitate disaster preparedness and adaptation planning in the country.
Technology characteristics	This technology integrates satellite observation, ground based data and forecast models to monitor and forecast changes in climate and weather. Meteorological centers serve as the main operating institutions at the national level to monitor various weather variables and timely communicate with individuals and communities about potential changes in the climate system such as drought, flood, cyclones, or heat waves on monthly or seasonal basis.
Climate change adaptation benefits	1) With effective communication channels in place, this technology increases the effectiveness of vulnerability monitoring, allowing individuals (farmers) and community systems to prepare for hazards. 2) Enables early identification of at-risk population in disaster prone areas. 3) Provides decision makers with the information for effective adaptation planning and its mainstreaming in national development goals.
Benefits to Economic, Social and Environmental Development	
Economic, social, and environmental development benefits	1. Potential saving in disaster avoidance and livelihood saving 2. Reduction in agriculture losses, and thus increase in agricultural productivity 3. Strong monitoring and evaluation of projects related to agriculture sector due to reliable and easily available data 4. Help reduce the number of displaced and distressed peoples
Costs, Current Status, And Implementation Barriers	
Costs	Pak Rs. 8 million. The cost include up gradation of the pre-existing climate monitoring stations, and dissemination of early warning information at a district level.

Current status and application potential in the country	In Pakistan, weather system monitoring and information dissemination is the responsibility of Pakistan Meteorological Department (PMD). Pakistan's hydro-meteorological warning systems are reasonably satisfactory due to installation of powerful weather surveillance radars (WSR) at Lahore, Sialkot, Karachi, Islamabad, Rahim Yar Khan, and Dera Ismail Khan. PMD is presently setting-up a specialized medium range weather forecasting center (SMRC) at Islamabad which is expected to be operational by 2017. The SMRC will add to the technical capacity of PMD in the field of multi hazard warning systems including flood, and epidemic outbreak.
Implementation barriers	The principal barriers to implementation of this technology are: 1) Financial and human resources required to set-up or improve the existing weather systems; (2) limited or inappropriate modes of communication and knowledge exchange particularly with end users (such as farmers or decision makers).

Technology 4: Land-use planning

Sector	Agriculture
Category	Planning and monitoring
1. Technology name	Land use planning
Introduction	In the wake of climate change, communities have to adopt an anticipatory response to climate generated risk factors rather than taking a reactive planning measures such as enforcing building codes, offering compensations or subsidies. Successful adaptation measures require localized planning and policies that can be achieved by sound land use planning. Land use planning (LUP) is the systematic assessment of land and water potential, alternatives for land use and economic and social conditions in order to select and adopt the best land-use options" Without proper land use policy, fertile agricultural lands are rapidly encroached for residential development that are causing agricultural lands to unavailable to productive crop cultivation and resultantly decreasing land size and reducing its potential for viable farming.
Technology characteristics	To guide land use planning for successful adaptation, the planning procedures are required to assess climate change vulnerability and risk associated with likely impacts of and the level of vulnerability to those risks: This assessment contributes to decision making and policy development by providing a basis for establishing priorities. The acquired information needs to be embedded into all steps of the planning process:
Climate change adaptation benefits	The technology will aid in successful adaptation by: 1) Protecting fertile agriculture lands from encroaching by land mafia; (2) improving chances of availability of more land for increasing acreage of farming; (3) improving disaster management approaches and risk reduction
Benefits to Economic, Social and Environmental Development	
Economic development	There are benefits availed from this technology through: protecting land quality and agricultural productivity; ensuring land availability for food and timber production; benefits reaped from mitigating or minimizing climate induced risks such as flooding, crop damages etc.
Social development	LUP ensures proper utilization of land resources in an efficient and ethical way among different user groups and communities; it thus reduces social and political conflict over land control and resource distribution. On a larger scale, it affects the ways in which community is organized, a rapid rate of land use changes can intensify income segregation and economic disparities among communities.

Environmental development	Unplanned and un-checked and-use changes comes with its environmental degradation and deterioration that includes: Rise in GHG emission due to deforestation and clearing of agricultural lands, destruction of habitats that support biodiversity; air, water pollution due to urban development, runoff and flooding; threatening marine environment in coastal areas due to development and intensive agriculture. A sound LUP has the ability to address this multitude of issues so the vulnerabilities of the risk-exposed communities could be reduced.
Costs, Current Status, and Implementation Barriers	
Costs	The cost depends on level of planning, number of involved stakeholders and their engagement levels, available tools and expertise in the required planning field
Current status and application potential in the country	Land use planning in Pakistan is not a-strictly-followed planning procedure thus far due to conflicting and sometimes ambiguous land and property rights. A systematic and digital land record keeping system is totally lacking in most parts of the country except in the Province of Punjab that is currently digitizing its land record data. Consequently, many fertile agricultural lands and biodiversity hotspots in the recent years are lost to the booming housing market.
Implementation barriers	Political acceptance and institutional support

Technology 5: Salt-tolerant crop varieties

Sector	Agriculture
Category	Improved crop varieties
Technology name	Salt-tolerant crop varieties
Introduction	Salinity poses a major threat to agriculture; salt-tolerance is an ability of plants to survive under excess salts in the rooting medium without any adverse affects on the growth of plants. Pakistan has about 22.6 million hectare (mha) land under cultivation, of which nearly 6.8 mha are salt-affected, with only 3.9 mha land under cultivation while the rest exist as wasteland. Salt-tolerant crops offer a good promising future for these wastelands to bring more land under cultivation.
Technology characteristics	The technology helps to identify specific characteristics related to salt tolerance. The process involves screening and selection of highly salt tolerant plant species/varieties from the naturally existing germplasm or from these developed through breeding, hybridization and other techniques and then introducing the selected plants for increased plant establishment and productivity in saline area.

Climate change adaptation benefits	The salt tolerant crops provide strong defense against twin problem of salinity and water logging in the soil and thus ensures good crop productivity. By bringing more area under cultivation, it helps to achieve target of food security in changing climate.
Benefits to Economic, Social, and Environmental Development	
Potential economic/social and environmental development benefits and impacts	The technology gives good economic return on salt affected lands; provide vegetative cover to soil which in turn improves soil quality and makes handling of salinity issues manageable. Brining in more salt-encrusted wasteland under cultivation not only ensures food security but also help farmers to diversify their livelihood and reduce poverty.
Costs, Current Status, and Implementation Barriers	
Costs	It is difficult to calculation exact expense due to many reasons including: 1) investment is needed to build well equipped laboratories of molecular biology and reliable mutagens resources, maintenance of laboratories and permanent operations require stable and permanent funding and a pool of technology experts and trainers.
Current status and application potential in the country	Pakistan has major advantage in the development of saline agriculture systems started as early as in 70s. Over the last three decades, there has been crucial work on the selection of salt tolerant trees, shrubs, grasses and crops that enable increased production from salt affected land. International funding agencies and research institutions have supported much of this work. However, despite these achievements there have been very few varieties tested in field condition and available in market for farmers.
Implementation barriers	The technology needs longer time period for salt-tolerant gene detection, its transfer in to desirable plant species, and ultimately maturity of technology as of it could be marketable. This requires high skilled technical staff and equipment. Moreover, uncertainty about market demand, poor seed supply are some of the other barriers this technology face.

Technology 6: Livestock breed improvement

Sector	Agriculture
Category	Food security
Technology name	Livestock breed improvement
Introduction	Livestock is a key asset to poor families fulfilling multiple economic, social, and risk management functions. The possible impact of climate change on food production is not limited to crops and agriculture sector only but it is expected to manifest its severe effects on livestock through loss of cultural and genetic diversity of local and rare breeds, reduced animal productivity,

	increased spread of vector-borne diseases and macroparasites with a possibility of new transmission models, and low quality feed[5]. To cope with these harsh consequences of impacts of climate change, livestock owners need to improve tolerance and resistance levels of livestock to shocks such as temperature, drought, flooding, pests and diseases through selective breed improvement technology.
Technology characteristics	Selective breed improvement is the systematic breeding of animals inorder to improve their productivity and other key characteristics. There are various methods in use to manage and improve the livestock breed. These include artificial insemination, transplanting fetuses and transferring egg-cell etc. However, the technology requires livestock producers to incorporate various important measures in their long-term production management strategies such as (i) identifying and strengthening local breeds that have adapted to local climatic stress and feed sources and (ii) improving local genetics through cross-breeding with heat and disease tolerant breeds.
Climate Change adaptation benefits	Livestock producers and managers would own resilient animal breeds with tolerance against thermal shocks, prolonged droughts or appearances of new diseases. The low mortality rates among livestock would provide herders with increased production that would contribute towards economic uplift of the poor families.
Benefits to Economic, Social, and Environmental Development	
Potential economic/social and environmental development benefits and impacts	The potential benefits include: 1. Creation of jobs and increase in income 2. Improved pasture management due to reduced but high quality animal breeds 3. Decrease in GHG emissions
Costs, Current Status, and Implementation Barriers	
Cost s	The cost and other financial requirements depend on the livestock species and location, and type of technique used for the breed improvement.
Current status and application potential in the country	Livestock is one of the major sub-sectors of agriculture in Pakistan. According to 2014-15 estimates, livestock population in the country stood at 181.2 million and contributed 11.8 percent to the national GDP[6]. More than 8 million rural population in Pakistan is engaged with this sub-sector making up 40% of their total income, however, small dairy holders dominate the sector by possessing more than 90% of livestock. Livestock genetic

[5] International Fund for Agricultural Development (IFAD). Livestock and climate change. https://www.ifad.org/documents/10180/48b0cd7b-f70d-4f55-b0c0-5a19fa3e5f38
[6] Government of Pakistan, Ministry of Finance. 2015. Economic Survey of Pakistan 2014-15. http://www.finance.gov.pk/survey/chapters_15/02_Agricultre.pdf

	improvement programs are very limited in number and mainly focused on supply of high breed bulls, provision of artificial insemination (AI) services from 189 AI centers and 7 semen production units in the country, progeny testing program and import of exotic germplasm.
Implementation barriers	1) Lack of institutional support in the form of a concrete livestock (breeding) policy, lack of information on high quality breeds, and technical expertise 2) Lack of R & D and knowledge gaps about how breeds react to conditions brought about by climate change.

Technology Fact Sheets for Water Sector

Technology 1: Surface rainwater harvesting

Sector	Water
Category	Water conservation and productivity
Technology name	Rainwater harvesting
Introduction	Pakistan is a water scarce country with a growing demand at an annual rate of 10 percent. The current total available water at 191 million-acre foot (MAF) is projected to rise to 274 MAF by 2025 and this gap of about 81 MAF is almost two-thirds of the entire Indus River system's current annual average flow (UNESCO, 2012). To narrow down this gap, there is a dire need for alternative water resources. Rainwater harvesting technique is emerging as a new promising low cost technology in developing countries with the potential to enhance water productivity particularly in areas receiving annual rainfall from 1800 mm to 400 mm.
Technology characteristics	The technology harvests either rainfall water collected directly from the ground surfaces by utilizing micro-catchments or floodwater from river, stream or other natural watercourse by utilizing small reservoirs. The water collected in storage structures is generally utilized for non-potable purposes including irrigation, livestock and other domestic use except drinking.
Climate change adaptation benefits	This technology contributes to climate change adaptation by: 1. Reducing pressure on surface and groundwater resources by decreasing household water demand. 2. Mitigating flood by capturing rooftop runoff during rainstorms. 3. Providing a short-term security to households against periods of low rainfall or water scarcity.
Benefits to Economic, Social, and Environmental Development	
Potential economic/social and	1) Diversification of household water supply; (2) Increased level of resilience to water quality degradation; (3) Mitigation of flooding by capturing stormwater runoff; (4) Utilization for

environmental development benefits and impacts	managed aquifer recharge and reduced overexploitation of ground and service water with consequent environmental benefits; (5) Cost saving in obtaining piped water for agricultural purposes; (6) Increase in agricultural productivity and hence food security; (7) Decrease in travel time for household members particularly women to remote water resources that would result in better health and time for social activities.
Costs, Current Status, and Implementation Barriers	
Costs	Pak Rs. 2 million. The cost includes construction of 1 large storage pond (with capacity of 1 million litres of water) and 7 small storage ponds (each with a storage capacity of 8,000 litres) for a village of 160 households.
Current status and application potential in the country	Rainwater harvesting is one of the priority programs for rural socio-economic development in the country. Rainwater harvesting from ground surfaces and flash floods have a long history in Pakistan in the form of one of the world's largest indigenous water harvesting system for irrigation known as spate irrigation. Pakistan has 0.343 mha [7]under this system in arid and semi-arid areas of Balochistan, Sindh, Khyber Pakhtunkhawa and Punjab. Local farmers and their associations in coordination with local governments predominantly manage the system for growing sorghum, bean, wheat and cotton crops. The system's productivity however suffers from lack of concerted management strategy, investment, and high level policy support
Implementation barriers	1) High capital cost for reservoir construction and maintenance; (2) Potential for adverse hydrological impacts downstream in case of large storage infrastructures; (3) Conflict over land and water rights among communities; (4) Poor aesthetic and microbial quality of water

Technology 2: Wastewater treatment and re-use

Sector	Water
Category	Diversification of water supply
Technology name	Wastewater treatment and reuse
Introduction	Water reclamation and reuse involves the treatment of domestic and industrial wastewater to make it reusable for other purposes such as agriculture, and aquifer recharge with improved water quality. With climate change projected to adversely impact the fresh water resources in future, finding and utilizing a supplemental source of water is a must requirement for the country to meet the increasing demand of water particularly for food security. This has added benefits of reducing pollution, and

[7] NESPAK 1998; Agriculture Census of Pakistan, Census Organization of Pakistan, 2000

	protecting the environment. Total quantity of wastewater produced in the country is 962,335 million gallons and around 392,511 million gallons of sewage is discharged to main water bodies. [8] Although treatment facilities exist in about a dozen major cities, in some cases these have been built without the completion of associated sewerage networks, and the plants are often either under-loaded or abandoned (Pak-SCEA, 2006[9]).
Technology characteristics	Wastewater treatment schemes incorporate different steps like physical, biological and chemical treatment to ensure that discharged water doesn't pose risk to the environment or health. The degree to which reclaimed wastewater could be reused depends upon the treatment level that has been conducted. Primary, secondary and tertiary treatment doesn't always remove 100 percent of the waste from the water due to which many organisms still remain in the wastewater. Sterilization/disinfection could be needed in order to destroy pathogens depending on the intent reuse.
Climate change adaptation benefits	1. Water reclamation and reuse contributes to climate change adaptation by allowing water resources to be diversified and conserved. 2. Reclaimed water could be applied to permeable land surfaces or directly injected to the ground for the purpose of recharging groundwater aquifers and preventing saline water intrusion in coastal areas.
Benefits to Economic, Social, and Environmental Development	
Potential economic/social and environmental development benefits and impacts	1. Creation of jobs as the technology will require trained staff to operate and maintain the system 2. Acting as a supplemental source to fresh water irrigation system, and thus the potential to promote development 3. Supportive in diversification and intensification of crops particularly in rainfed areas 4. Reduction in environmental pollution and enteric disease burden

[8] Murtaza, G. and Zia, M.H. n.d. Wastewater Production, Treatment and Use in Pakistan. http://www.ais.unwater.org/ais/pluginfile.php/232/mod_page/content/134/pakistan_murtaza_finalcountryreport2012.pdf

[9] Pak-SCEA. 2006. Pakistan Strategic Country Environmental Assessment Report: Rising to the Challenges.

Costs, Current Status, and Implementation Barriers	
Costs	The financial requirements for implementing water reclamation and reuse system is related to installation and maintenance of system, expanding works to include tertiary stage, which does not exist at this time in the country, and distribution system to the required areas. Estimates for facility serving 500 houses is Pak PKR 40 million.
Current status and application potential in the country	Of total wastewater produced in the country, only 8 percent of is treated before disposal that doesn't involve any biological treatment. 26 percent of the total domestic vegetable comes from wastewater agricultural farms while 32,500 hectares of land are directly irrigated with untreated wastewater (Ensink et al., 2004)[10]. There is no prevailing concept of treatment at secondary and tertiary level in the country. The farmers value the wastewater for irrigation purposes in Pakistan due to its nutrient content and reliability of supply despite of the ill effects caused by untreated wastewater on soil chemical and physical properties in addition to the contamination of food chain.
Implementation barriers	High cost associated with treatment of wastewater; public opposition to its use; lack of communication and collaboration between stakeholders

Technology 3: Flood early warning system

Sector	Water/Agriculture
Category	Disaster preparedness
Technology name	Flood early warning system
Introduction	Early warning system is a key element for disaster reduction and comprises of coordinated procedures through which information on foreseeable hazards is collected and analyzed for predicting a possible future hazard. This would benefit communities and government by preventing or reducing loss of life and assets. Pakistan has been adversely affected by recurrent spell of floods in the past one decade. A series of recurrent floods hitting the country in 2010, 2011 and 2012, have affected 18, 5.4, and 4.8 millions of people each time respectively including a larger proportion of victim population's lives and livelihood sources that were

[10] Ensink, J.H.J. , Mahmood, W.van. der. Hoek, Raschid-Sally, L. and Amerasinghe, F.P.. 2004. A Nationwide Assessment of Wastewater Use in Pakistan: An Obscure Activity or a Vitally Important One? *Water Policy*. 6 (3): 197-206.

	affected repeatedly without providing a window for full recovery. The super flood of 2010 alone caused around $10 billion in damages to infrastructure, irrigation systems, bridges, houses and roads[11]. The country has consistently been ranked as a highly vulnerable one to the impacts of climate change at the global level by multiple climate change impact indices, for example, German Watch-Global Climate Risk Index 2016[12] has kept Pakistan among the 10 climate change most vulnerable countries globally. The future cost of climate impacts is estimated somewhere between $6 billion to $14 billion per year over the next 40 years.
Technology characteristics	To ensure effective warning system, four elements are have to be present: (1) monitoring, detection and forecasting of hydro-meteorological hazards providing lead-times for action; combined with, (2) Risk analysis; (3) dissemination of timely and authoritative warnings; and, (4) activation of emergency plans to prepare to respond. These four components must be supported by appropriate policies, legislations and legal frameworks, with coordination across many agencies at national to local levels.
Climate change adaptation benefits	Improving the resilience of communities by disaster risk reduction;
Benefits to Economic, Social, and Environmental Development	
Potential economic/ social and environmental development benefits and impacts	The technology will increase sense of security among communities; help in reducing the magnitude of disasters by lessening the number of human casualties and loss of properties and livestock.
Costs, Current Status, and Implementation Barriers	
Costs	Pakistan already has a well managed flood early warning system but one with a limited coverage. To upgrade the system, the estimated cost for a single district level area will be around PKR 6 million.
Current status and	Pakistan Meteorological Department is the national institution responsible for early warning systems for

[11] Thomson Reuters Foundation. *Pakistan Floods*. http://www.trust.org/spotlight/Pakistan-floods-2010

[12] S. Kreft, D. Eckstein, L. Dorsch, L. Fischer. 2015. *GLOBAL CLIMATE RISK INDEX 2016: Who Suffers Most From Extreme Weather Events? Weather-related Loss Events in 2014 and 1995 to 2014*. Briefing Paper. GermanWatch. http://germanwatch.org/en/download/13503.pdf

application potential in the country	floods, drought, heat wave, and diseases of which flood warning system is the most mature and sophisticated one. After the floods of 2010, the Department has installed a flood alert and management information system (PIFMIS)- a complementary system that serves multipurpose ranging from flood alert, flood control and management, knowledge base for policy and decision making.
Barriers to implementation	High investment costs in human and technical resources; low risk knowledge, lack of policy and legal frameworks to ascertain authority and accountability of disaster dealing agencies; weak warning services in terms of its reach to the communities.

Technology 4: Groundwater recharge

Sector	Water
Category	Water conservation
Technology name	Groundwater recharge
Introduction	Groundwater occurs in Pakistan under varying conditions. As such it is affected largely by changes in prevailing climatic conditions. Groundwater investigations started in the Indus basin during 1957 and extended to mountainous areas of NWFP, Balochistan and desert areas of Cholistan. Altogether, 33.4 million ha were covered by groundwater investigations. In areas outside the Indus basin, development of tubewells and irrigated horticulture is now leading towards a stage of groundwater depletion, or 'water mining', which is a major problem associated with the growth of human settlements in arid areas. The groundwater table in the Northern Basin of the Quetta valley is lowering by almost 2 m per annum, while a fall of 0.6 m is reported for its southern basin”[13].
Technology characteristics	The artificial recharge is augmentation of underground aquifers by some methods of construction of artificially changing the natural conditions. The technology is varied depending majorly on the geological characteristics of the site. It could be through rainwater harvesting, percolation tanks, boreholes, dune filtration, underground dam, action-delay dams, sand dams, recharge release etc.

[13] S. Ahmad, S.U. Malik, A. Muhammad.n.d. *Groundwater Management in Pakistan*. http://waterinfo.net.pk/sites/default/files/knowledge/Groundwaterpercent20Managementpercent20inpercent20Pakistan.pdf

Climate Change adaptation benefits	Groundwater plays a critical role in adaptation to hydrological variability and climate change. The potential benefits include: 1. Reliability and easy access to this resource during drought periods in arid and semi-arid areas 2. Stabilizing or recovering groundwater level in over-exploited aquifers; 3. Storing water for future use; 4. Managing saline intrusion or land subsidence in coastal areas 5. Enabling reuse of waste or waste water 6. Ensures viability of irrigated agriculture
Benefits to Economic, Social, and Environmental Development	
Economic development	Economic benefits are immense because of elevating water tables, there will be increased flows in the Karez systems, which will make it possible to start intense agricultural activity with high value orchards and other value crops. While pumping costs would reduce, easy access of women to drinking and domestic water would bring about an increase in their productive hours.
Social development	The adaptation recharge technology would provide immense benefits to both urban and rural population, as land subsidence due excessive withdrawal of water from underlying aquifers will reduce. The population will have greater and improved access to water for domestic and agricultural uses.
Environmental development	Better water and sanitation facilities and hygiene practices. Local environment will improve due to easier access to good quality water.
Costs, Current Status, and Implementation Barriers	
Cost to implement adaptation options	The costs vary from case to case in the range 1.0 to 2.5 million rupees (in case of use of boreholes for aquifer recharge). However, the cost can go up as the depth of the boreholes increases and distance of the boreholes network from the dam body.
Cost of operation and maintenance	The estimated cost of operation and maintenance is as under: • Operation: Annually PKR 180,000 (Engaging a full time person as watch man and to operate the siphon pipes and see that the system is not damaged and remains in working order.

	Maintenance: PKR 300,000 (Changing filter material, replacing damaged pipes, and addressing clogging issues)
Current status and application potential in the country	Leaky/recharge or action delay dams are the most popular form of groundwater recharge in areas outside the Indus Basin irrigation system in Pakistan such as Balochistan. In this technique, dams are constructed across stream to store floodwater for recharging groundwater. A number of such dams are constructed in Balochistan and Sindh over the past two decades but initially more of it came out with technical Issues specifically rapid siltation, which reduced the storage capacity of the dams and thus failed to serve the real purpose. The improved design include watershed management to control the silt deposition in the dams and preventing to clog the natural downward movement of water to recharge aquifer.
Implementation barriers	No major barriers are anticipated in the implementation of the technology in Pakistan. There are no policy restrictions on the technology.

Technology 5: Stormwater management

Sector	Water/Agriculture
Category	Planning/ water conservation and productivity
Technology name	Stormwater management
Introduction	Precipitation from rain or snow melt cause stormwater runoff, which cause flooding of inhabited rural or urban areas, erosion of agricultural lands and resultantly affecting human lives and environment. The amount of stormwater depends on the intensity and length of rainfall, and the characteristics of the surface upon which the rainfall falls. The country has been hit hard by recurrent spells of floods in the past few years and flash floods have caused major damage in both rural and urban centers. Pakistan receives 76percent of its rains during monsoon season (July-September) that normally sub-merge low-lying areas because stormwater drainage system either doesn't exist or have been converted into sewers that consequently cause heavy damage to property and human lives each year.
Technology characteristics	The management approaches aims to mitigate the changes to both the quantity and quality of stormwater runoff that are caused by urbanization, in such case, t could be engineered or constructed facilities, such as stormwater

	wetland or infiltration basin, rain gardens or bioswales, green roofs etc. In case of rural setup and agricultural land, there are some other specific tools such as spate irrigation, or small-scale precipitation techniques such as dams, micro-basin, trenches and rooftop harvesting.
Climate change adaptation benefits	Harvesting stormwater serves as an alternate source of surface water for agriculture, industrial or domestic purposes and thus help in reducing stress on groundwater us; mitigate flood by capturing stormwater runoff during rainstorms
Benefits to Economic, Social, and Environmental Development	
Potential economic/ social and environmental development benefits and impacts	A solid stormwater management technology would protect health, prevent water pollution, (re)-use precipitation water and prevent damages to infrastructure. Environmental impacts are substantial: solids in stormwater can form sediment and clog drains, streams and rivers. It carry pollutants such as heavy metals, fertilizers etc. which deteriorate the water quality by causing eutrophication of water bodies.
Costs, Current Status, and Implementation Barriers	
Costs	It is difficult to estimate the exact cost of technology due to scale, and location of the technology among some important factors.
Current status and application potential in the country	Stormwater management system have never been a high priority in big cities of Pakistan and newly developed large housing schemes around country lack proper storm drains or the existing ones are clogged with solid waste. In this situation, inundation of property and infrastructure is becoming a common scene around the big cities. In the past two decades, Pakistan has experiences two hundred years return period flooding that inundated more than half part of the country including both rural and urban areas. Furthermore, flash floods are becoming common phenomenon after heavy rains in many urban centers of the country that calls for an immediate attention to proper stormwater management technologies and strategies.
Implementation barriers	Lack of institutional and political support and funding.

APPENDIX III

A. Criteria and measurement scales used in MCDA process during technology prioritization

Criteria	Weight (%)	Indicators	Measurements scale
Cost	20	Cost of setup and maintenance	Likert scale 0 (high cost of setup and maintenance) - 100 (low cost of setup and maintenance)"
Economic benefit	25	Improve economic performance	Likert scale: 0 (lowest improve/creation) – 100 (highest improve/creation)
		Create jobs	
Social benefit	15	Reduce poverty and inequality	Likert scale: 0 (lowest benefit) - 100 (highest benefit)
		Improve health	
Environmental benefit	15	Protect biodiversity	Likert scale: 0 (lowest benefit) - 100 (highest benefit)
		Protect environmental services	
		Protect of environmental resources	
Climate related benefit	25	Potential to reduce vulnerability and build climate resilience	Likert scale: 0 (lowest resilience) – 100 (highest resilience)

B. Performance Matrix of MCDA for the Water Sector of Pakistan

Criteria	Cost (PKR)	Cost	Economic benefit	Social benefit	Environmental benefit	Potential of reducing vulnerability	Total weighted score
Base weight		20	25	15	15	25	
Preferred value		High	High	High	High	High	
Technology options							
Surface rainwater harvesting	2 million/ 160 households	50	90	80	90	70	87.8
Wastewater	40 million/	15	50	50	70	30	10.7

treatment and reuse	500 households						
Groundwater recharge	480,000/250 households	50	90	95	50	70	84.2
Urban stormwater management	-	40	80	95	90	68	81.5
Flood early warning system	6 million/district	60	95	80	20	70	80.0

C. Performance matrix of MCDA for the agriculture sector

Criteria	Cost (PKR)	Cost	Economic benefit	Social benefit	Environmental benefit	Potential of reducing vulnerability	Total weighted score
Base weight		20	25	15	15	25	
Preferred value		High	High	High	High	High	
Climate monitoring and forecasting - Early warning system	8 million/district	30	90	60	45	90	60.67
High efficiency irrigation systems for irrigated and rain-fed areas	116790/acre (drip) 110970/acre (sprinkler)	55	80	90	70	80	76.90
Drought tolerant crop varieties	-	50	90	85	35	70	66.65
Land use planning	-	80	55	50	80	60	49.49
Salt tolerant crop varieties	-	70	80	70	15	35	42.25
Livestock breed improvement	-	50	50	75	35	45	26.54