CLIMATE SMART AGRICULTURE

TRAINING MODULE

Pakistan Agricultural Research Council
National Agricultural Research Centre
Climate, Energy & Water Research Institute

Prepared by:
Muneeb Ahmed Khan
Muhammad Saqib Sultan
Dr. Haroon Khan

Technical Review by:
Dr. Bashir Ahmed
Zeeshan Tahir Virk

CLIMATE SMART AGRICULTURE

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A Reference Manual for Agriculture Extension Officers, Researchers, Students and Policy Makers

CLIMATE-SMART AGRICULTURE

TRAINING MODULE

Pathways to Strengthening Capabilities for Climate Smart Agriculture in Pakistan

Project Reference Number CBA2019-07SY-Khan

Implemented by **Climate, Energy & Water Research Institute, PARC** in collaboration University of Agriculture, Peshawar and Agriculture Extension Balochistan, Quetta

Disclaimer: *This training module is a non commercial scientific knowledge product made possible by the funding of Asia-Pacific Network for Global Change Research and is aimed at capacity building of agriculture extension officers. Students of agriculture, researchers in agriculture and policy makers can equally benefit from the module. Contents of the training module can be disseminated in any form with proper citation as per principles of "Creative Commons".*

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MESSAGE FROM THE CHAIRMAN
PAKISTAN AGRICULTURAL RESEARCH COUNCIL

Pakistan is one of the most climate vulnerable countries in the world, it ranked 8th in the list of countries most vulnerable to climate change in 2021 . The country is highly exposed to the multidimensional and cross - sectoral threats of changing climate. Over the past few years several factors indicate a deteriorating climate situation with increased average temperatures and increased variability of rainfall across the country . Moreover , the incidence of climate induced disasters such as floods, droughts, heat waves etc. has increased in the past few years. These circumstances demand the country to view its development and governance agenda through the lens of climate change.

Agriculture is the foundation of food security in Pakistan and it not only provides food for human consumption and feed for livestock but also provides raw materials for industry and value added products for both domestic consumption and international markets . Despite its significance to our national food security , economy and development the agriculture sector is seeing a continuous decline the over past few years and its share to the national GDP is shrinking over time due to many reasons . One of the main reasons for these sad affairs for agriculture sector is climate change. Pakistan's agriculture sector is increasingly being impacted by high temperatures , erratic rains, flash floods, salinity, droughts , decertification , wind and hail storms, soil erosion and land degradation.

Agriculture sector is not only impacted by climate change but also a major contributor of greenhouse gas emissions which are causing climate change. Many of our crop and livestock production practices are not sustainable in the context of climate change . There is a need to transform agriculture sector to such a vibrant and resilient scale where it can not only withstand the impacts of climate change and protect the livelihoods of dependent farming communities and agro based industries but it's contributions to the global greenhouse gas emissions are as lower as possible . This sort of transformation of the agriculture sector can be made possible by focusing on Climate Smart Agriculture (CSA). The Climate Smart Agriculture is an ambition to improve the overall integration of agriculture development and climate responsiveness. There is a need to mainstream CSA in our National Development Plans and long term agricultural development and transformation initiatives. There is also a need to strengthen the capabilities of our human resource and agriculture based institutions (universities, research and extension departments) to understand the dynamics of climate change, do research and disseminate the viable options to policy makers and farming communities.

I am hopeful that the current project has successfully completed its core objective of strengthening the capabilities of Agriculture Extension Officers of KPK and Balochistan. I am very pleased with the collaboration between PARC and APN for such a great initiative and wish to have a continuity of such type of collaborations. I am also hopeful that the current publication will be a helpful resource material for our agricultural graduates, agricultural extension officers, agricultural research officers and other stakeholders for understanding the climate change and the Climate Smart Agriculture.

Dr. Ghulam Muhammad Ali
Chairman PARC

MESSAGE FROM THE PROJECT DIRECTOR

Climate Smart Agriculture can substantially reduce the impacts of climate change. CSA practices and technologies like crop and enterprise diversifications, stress tolerant crops and animal breeds, conservation agriculture, organic kitchen gardening, manure management, cultivation of barren lands, sustainable intensification of agriculture, climate information services, use of alternate energy means for water pumping and delivery systems, efficient irrigation systems etc. not only improve farmer's resilience to climate change but also improve adaption and mitigation portfolio of our agriculture.

The CSA practices and technologies cannot be widely adapted into the system without proper government patronage in the form of relevant policies, incentives and capacity building of the agricultural research and extension departments. Agricultural extension departments play the pivotal role in dissemination and upscaling of desired practices and technologies and their importance cannot be nullified. Agricultural extension is the major driving force for improved productivity of crops through transfer of latest knowledge to the farmers. However it is also the fact that agriculture extension departments in Pakistan have limited capacity for CSA advisory and it is one of the major limiting factors in mainstreaming of CSA in Pakistan. Agricultural extension officers usually lack capacities to understand climate change impacts on agriculture, climate change adaptation, climate change mitigation and the climate compatible development (CCD).

Looking at the need for capacity development of our agricultural extension departments, LEAD Pakistan designed a project with coordination and collaboration with PARC and funding from Asia Pacific network (APN). However under some unfortunate circumstances LEAD Pakistan got devolved and the PARC carried on the initiative and project activities with collaboration with the provincial partners (Agricultural University Peshawar from KPK and Department of Agriculture Extension Balochistan). In the project a training module is developed for agriculture extension officers, five knowledge products in the form of brochures are developed for farmers and the recommendations are given for updating the curriculum of Agriculture Training Institutes (ATIs) considering the latest climate change needs. The agriculture extension officers were also trained according to the syllabus of training module. This training module is a brief but comprehensive document that can be utilized alike by agriculture students, agriculture extension officers, agriculture research officers, policy makers, farmers and other stakeholders to understand climate change; impacts of climate change on agriculture, CSA and CSA practices which are relevant to different growing conditions in different agro-ecologies.

I am pleased with the progress made in project and dedicated efforts made by project team to materialize the ideas into realities. I am grateful to the provincial coordinators who supported the project activities and helped in conduct of trainings and other deliverables. I am also thankful to APN for funding this vital and all important project and hope to have future collaborations in such projects which create long lasting impacts for agricultural, social and economic development.

Dr. Bashir Ahmed
Project Director and Director CEWRI

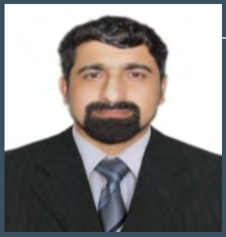
Project Team

DR. BASHIR AHMED (PROJECT DIRECTOR)

Dr. Bashir Ahmad is a professional hydrologist with 25 years of professional experience in research, academia and consultancy services. He holds PhD degree from Department of Civil Engineering, Tokyo University. Currently, he is serving as Director Climate Energy & Water Research Institute (CEWRI) of Pakistan Agriculture Research Council, Islamabad. Dr. Bashir Ahmad has developed and executed 25 projects. He has implemented projects in the fields of Water Resource Assessment & Management, Drip/Sprinkler Irrigation System and, Climate Change Adaptation and Mitigation funded by PSDP, IDRC, DFID, JICA, UNDP, World Bank, ADB etc. He has also organized number of national & international conferences/workshops, professional and farmer's trainings. He has contributed in various policy documents including National Climate Change Policy, National Water Policy, National Food Security Policy and Implementation Framework of these policies. He is leading Pakistan Agriculture & Livestock Working Group of Intended Nationally Determined Contributions (INDC).
(dr.bashir70@gmail.com)

MUHAMMAD SAQIIB SULTAN (PROJECT MANAGER)

Saqib Sultan had the responsibility of Project Manager since the project's inception. He is an alumnus of the Brandeis University, United States, graduated with a Master in Sustainable International Development. He also holds a training certification on agriculture and food security from the NASPAA, Washington DC. Saqib has expertise in policy research, capacity building and project management. Through various projects with LEAD Pakistan, and BRAC, he designed and delivered multi-disciplinary capacity building initiatives for national and international organizations on topics including climate change adaptation and policy response, renewable energy advancement, localization of SDGs and private sector's engagement, and climate smart agriculture. He is founding Director at Pakistan Climate Initiative. As a youth delegate, he joined 'Post-15 development Agenda and Youth Priorities' at the UN General Assembly in 2015.
(saqib@brandeis.edu)



DR. HAROON KHAN (COORDINATOR KPK)

Dr. Haroon Khan is currently working as Deputy Director/ Assistant Professor in Climate Change Centre (CCC), The University of Agriculture Peshawar. He remained a research fellow at The University of Queensland Australia where he worked on operation of CLIMEX software package: Using simulation and modeling techniques, for exploring the relationship between organisms and their climatic environment. Dr. Khan previously worked as Regional Agronomy Manager in Philip Morris International. He has developed a rich expertise (over 15 years) in wide range of issues related to agriculture, weed management and climate change. He has particular focus on climate change adaptation and mitigation. Dr. Haroon played a key role in the establishing of Climate Change Center at the University of Agriculture Peshawar, Pakistan. He also coordinates climate change activities at provincial level and strives to build capacity in students to make them better equipped with essential knowledge to tackle climate change related problems during their professional careers.
(haroonkhan@aup.edu.pk)

DR. ARIF SHAH KAKAR (COORDINATOR BALOCHISTAN)

Dr. Arif Shah Kakar earned his PhD degree in Entomology from Pir Mehr Ali Shah- Arid Agriculture University, Rawalpindi. He is currently the Director Agriculture in Department of Plant Protection Balochistan and supervises the plant protection staff in the province. He also remained Associate Professor and Head of Entomology Department and taught various graduate and undergraduate courses at Balochistan Agriculture College Quetta. Dr. Arif remained member Subject Experts/Program Evaluators at National Agriculture Education Accreditation Council (NAEAC). He also served as Provincial Coordinator of National IPM Program for Balochistan. Dr. Arif also served as Master Facilitator in ACIAR's project "Developing Approaches to Enhance Farmer Water Management Skills in Balochistan, Punjab and Sindh in Pakistan". Dr. Arif was the Principal Investigator of Pakistan Science Foundation's project "Population Dynamics and Life Table of Dubas Bug (Ommatissus Lybicus) on Date Palm in Panjgur, Balochistan". He also organized various trainings on Integrated Pest Management in Balochistan and imparted trainings as Master Trainer.
(arifshahkakar@gmail.com)

MUNEEB AHMED KHAN (CONSULTANT CSA)

Muneeb Ahmed Khan is consultant Horticulturist and Climate Smart Agriculture (CSA) expert with 10 years of experience in farm management, agricultural research and consultancy services. He received his professional education from the Institute of Horticultural Sciences, University of Agriculture, Faisalabad and has a rich farm management experience in diverse agro-ecologies of Sindh, Punjab and KPK provinces of Pakistan. His experience includes designing and execution of CSA pilot sites, managing production of open field and greenhouse vegetables, production of field crops, production of tropical, sub-tropical and temperate zone fruits, organic farming, nursery management, contract farming for export markets and fruit and vegetable supply chain management. He also has the learning experience of the supply chain management of fruits, vegetables and flowers in the UAE market. His noteworthy working experience with Pakistan Agricultural Research Council (PARC) include development of Climate Smart Agriculture (CSA) pilot sites in various agroecologies to impart trainings to farmers, academia and agricultural professionals on Climate Smart Agriculture (CSA). He also served as "Lead Trainer- Food Processing" in UNDP's Youth Empowerment Programme (YEP-2020) to build capacity of graduates of various universities of Pakistan as entrepreneurs in the food business.

(ahmedmuneeb47@gmail.com)

ZEESHAN TAHIR VIRK (CONSULTANT CSA)

Mr. Zeeshan is a sustainable development practitioner and a water management expert. His research and development experience of more than five years expand into multiple avenues including Agricultural Water Management; Climate, Land, Energy and Water Nexus; Food Security and Livelihoods, Climate Change Adaptation, Resilience, Disaster Risk Reduction and Sustainable Systems Dynamics. He holds a master's degree in Water, Energy and Environmental Systems Engineering and currently part of the Hydrosystems research group/lab at the University of Oulu, Finland. Zeeshan has been associated with this project since designing and inception.

(zee.virk1@gmail.com)

PROJECT BACKGROUND

Pakistan is an agro-based economy that significantly depends on the agricultural performance. However, the national GDP is shrinking over time due to many reasons and lower agricultural productivity is a leading cause. Agriculture sector, being an open industry, is the first and foremost witness of climatic variations and climate change that leads to decline and in some cases unpredictable losses.

Our current crop and animal production practices and technologies such as mono-cropping, excessive tillage, intensive cultivation, poor on-farm water management, misuse of fertilizers and pesticides, outdated cropping patterns, poor quality seeds and planting materials and poor crop and animal husbandry practices are vulnerable to climate change. There is a crucial need for attuning the country's agriculture sector under the framework of climate compatible development (CCD).

Transformation to Climate Smart Agriculture (CSA) can substantially reduce climate change impacts. CSA technologies and practices like crop and enterprise diversification, low delta crops, stress tolerant crop varieties and animal breeds, conservation agriculture, organic kitchen gardening, integrated pest management, sustainable intensification of agriculture, solar powered irrigation systems, laser land leveling, climate information services etc. not only help in better utilization of resources but also promote climate resilience in agriculture.

DESCRIPTION

The major inhibiting factors in mainstreaming Climate Smart Agriculture (CSA) in Pakistan are the limited capacities of agriculture extension departments for CSA advisory, resource material for farmers which is either complex or doesn't meet current environmental challenges and lack of proper integration and coordination in academia, research, extension and policy making institutions. To address the challenges in milieu of climate change, a project titled 'Pathways to Strengthening Capabilities for Climate Smart Agriculture in Pakistan – Khyber Pakhtunkhwa and Balochistan' was designed for capacity building of agriculture extension departments of Khyber Pakhtunkhwa and Balochistan.

This project was a collaborative effort, initially designed by LEAD Pakistan and funded by the Asia Pacific Network for Global Change Research. Pakistan Agricultural Research Council (PARC) joined as a national partner alongside Provincial partners - the University of Agriculture, Peshawar from KPK and the Agriculture Extension Department, Quetta from Balochistan. Later, due to internal decision, the LEAD Pakistan stepped back whereas PATCO – PARC took the lead role for the execution of the project with technical and coordination support from its parent organization, PARC, and other provincial partners including Agriculture Extensions Departments of KPK and Balochistan, and The Agriculture University Peshawar, Khyber Pakhtunkhawa.

The project aims at strengthening the capacity of provincial agriculture service delivery organizations (ASDOs) in CSA. The major objective of the project is to develop and provide access to CSA resources for capacity building that must address the challenges of climate change in agriculture, further improve coordination among stakeholders for well-coordinated efforts in scaling up of CSA practices and technologies. For this purpose, provincial extension departments were taken on board and two batches of training were organized. Further, the consultation workshop brought the key stakeholders at one platform to share project experience, provide access to resources and sensitives on the issue, and further extend message to other provinces and organizations working on the agricultural advancement.

KEY OBJECTIVE / DELIVERABLES

The project, Pathways to Strengthening Capabilities for Climate Smart Agriculture in Pakistan, aims on achieving agricultural productivity through capacity building of relevant institutes and field officers. As a part of the project, four major deliverables has been completed:

1. Development of CSA Resource Kit
2. 02 Trainings of District Agriculture Extension Officers
3. Review of Curricula of 2 Provincial Agriculture Training Institute (ATIs)
4. 01 National Consultation Workshop on CSA Capacity Building

ACKNOWLEDGEMENTS

We would like to express our gratitude for our prestigious partners and collaborators for their continuous support, technical assistance, for providing access to knowledge resources, advisory support in person as well as virtually.

In particular, we would like to thank: Dr. Zakir Hussain Dahri (PARC Islamabad), Dr. Iqrar Ahmad Khan (VC, University of Agriculture Faisalabad), Dr. Arif Shah Kakar (Plant Protection Department, Balochistan), Habib Ullah Shah (Agriculture Extension Department, Balochistan), Dr. Muhammad Nadeem Irshad (Agriculture Extension Department, Balochistan), Dr. Abdul Hanan (BARDC- PARC, Balochistan), Dr. M. Naveed Khan (Agriculture Extension Department, Khyber Pakhtunkhwa), Dr Bakhtiar Gul (The University of Agriculture, Peshawar), and Dr. Asif Khan (University of Engineering and Technology, Peshawar) for their contribution and support in various forms throughout the project made it possible the successful delivery.

We would like to mention the staff of LEAD Pakistan, particularly Mr. Zeeshan Tahir Virk, who have major role in planning and designing of this unique initiative; Ms. Fatima Hasan Bajwa, and Mr. Arham Mustafa who have contributed through research and administrative assistance during the inception phase. We are also thankful to Mr. Rohail Khalid and Mr. Arslan Javed from CEWRI, PARC who designed and shaped this document.

We pay our sincere gratitude to all the institutions, individual experts, technical advisors who were readily available whenever we approached for guidance and support during the crucial times of a global pandemic.

LIST OF ABBREVIATIONS USED IN THE MODULE

ADB	Asian Development Bank
APN	Asia-Pacific Network for Global Change Research
AFOLU	Agriculture, Forestry and Other Land Use
CCAC	Climate and Clean Air Coalition
CCD	Climate Compatible Development
CFCs	Chloroflourocarbons
COP	Conference of the Parties
CSA	Climate Smart Agriculture
FAO	Food and Agriculture Organization
GACSA	Global Alliance on Climate Smart Agriculture
GCF	Green Climate Fund
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
GMST	Global Mean Surface Temperature
GWP	Global Warming Potential
HEIS	High Efficiency Irrigation Systems
HFCs	Hydrofluorocarbons
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IRS	Indus River System
KPK	Khyber Pakhtunkhwa
LDCF	Least Developed Countries Fund
LDCs	Least Developed Countries
LEAD	Leadership for Environment and Development
LULUCF	Land Use, Land Use Change and Forestry
MAF	Million Acre Feet
NAMA	Nationally Appropriate Mitigation Action
NAP	National Adaptation Plan
NAPAs	National Adaptation Programmes of Action
NARC	National Agricultural Research Centre
NCCP	National Climate Change Policy
NWP	National Water Policy
PARC	Pakistan Agricultural Research Council
PATCO	PARC Agrotech Company
PCCA	Pakistan Climate Change Act
RCP	Representative Concentration Pathway
SSPs	Shared Socioeconomic Pathways
UNFCCC	United Nations Framework Convention on Climate Change
VOCs	Volatile Organic Compounds
WFP	World Food Programme
WMO	World Meteorological Organization

MODULE 1
UNDERSTANDING CLIMATE CHANGE AND CAUSES OF CLIMATE CHANGE

OVERVIEW OF THE MODULE

In this module some basic knowledge and key concepts of the climate science will be discussed such as atmosphere, weather, climate, climate variability and climate change, global warming, greenhouse gases and natural and anthropogenic drivers of climate change.

OBJECTIVES

After completing this module, reader will be able to:
1. Understand the concepts of biosphere and atmosphere
2. Differentiate between weather and climate
3. Differentiate climate change from climate variability
4. Understand the greenhouse effect and global warming
5. Understand the causes of climate change

KEY QUESTIONS

1. What is difference between weather and climate?
2. What is difference between climate variability and climate change?
3. What are the natural causes of climate change?
4. What are the anthropogenic causes of climate change?
5. How much human activities contribute to climate change?
6. How much is the contribution of agriculture to climate change?

KEY DEFINITIONS

ATMOSPHERE: The gas and aerosol envelope that extends from the ocean, land, and ice-covered surface of the earth outward into space

WEATHER: Weather is the physical condition or state of the atmosphere at any given time and location

CLIMATE: Climate refers to the atmospheric conditions of a particular location over an extended time period from one month to millions of years but usually the values are taken for 30 years

CLIMATE VARIATIONS: These are usually fluctuations in temperature, moisture contents and other weather elements in a location or region from season-to-season, year-to-year and decade-to-decade but do not depict a continuous and long term warming trend of the planet

CLIMATE CHANGE: It can be referred to as the long-term change in global weather patterns, associated especially with increases in temperature, precipitation, and storm activity

GREENHOUSE EFFECT: The greenhouse effect is a process that occurs when gases in Earth's atmosphere trap the Sun's heat. This process makes Earth much warmer than it would be without an atmosphere

GLOBAL WARMING: Global Warming is a term that describes the rise in the average temperature of Earth's atmosphere and oceans since the late 19th century

SECTION A

WHAT IS CLIMATE CHANGE?

In this section we will briefly discuss the concepts of atmosphere, weather, climate, climate variability, climate change, greenhouse effect, greenhouse gasses and global warming to develop understanding on the key concepts related to climate change.

A. 1.1 ATMOSPHERE

The life on earth exists in about 15 km deep thin layer of air, water and soil. This thin layer of the planet earth where life exists is called as biosphere. The biosphere can be further divided into the atmosphere (air component), hydrosphere (water component) and the lithosphere (soil and rock component). The atmosphere extends to about 560 km from the surface of earth but 81 % of the atmospheric contents, mixture of gases and particles, are in 6-17 km range from the surface of earth. Atmosphere provides air to living organisms for breathing, its various gases retain the heat for maintaining the temperature of earth to sustain life and its protective layer ozone, which surrounds the earth, protects earth from the deadly ultraviolet radiation of the sun. The main gases in the Earth's atmosphere are Nitrogen (78.084%) and Oxygen (20.946%) while rests of the gases (carbon dioxide, hydrogen, helium, argon etc.) make less than 1% composition of the atmosphere.

Table 1.1: Composition of atmosphere near the surface of earth

Permanent Gases			Variable Gases (Responsible for global warming and climate change)			
Gas	Symbol	Percent by Volume	Gas	Symbol	Percent (by volume)	Parts per Million (ppm)
Nitrogen	N_2	78.08	Carbon dioxide	CO_2	0.038	385*
Oxygen	O_2	20.95	Methane	CH_4	0.00017	1.7
Argon	Ar	0.93	Nitrous oxide	N_20	0.0003	0.3
Neon	Ne	0.0018	Ozone	O_3	0.000004	0.04
Helium	He	0.0005	Particles (dust etc.)		0.000001	0.01-0.15
Hydrogen	H_2	0.00006	Chlorofluorocarbons (CFCs)		0.000000002	0.0002
Xenon	Xe	0.000009				

**CO2 concentration estimated in 2021 was 415 ppm, which shows a continuous increase over the tabulated concentration. This trend of continuous increase in global CO2 concentration is a major global concern*

Source: Adapted from Ahrens (2009) with slight modification

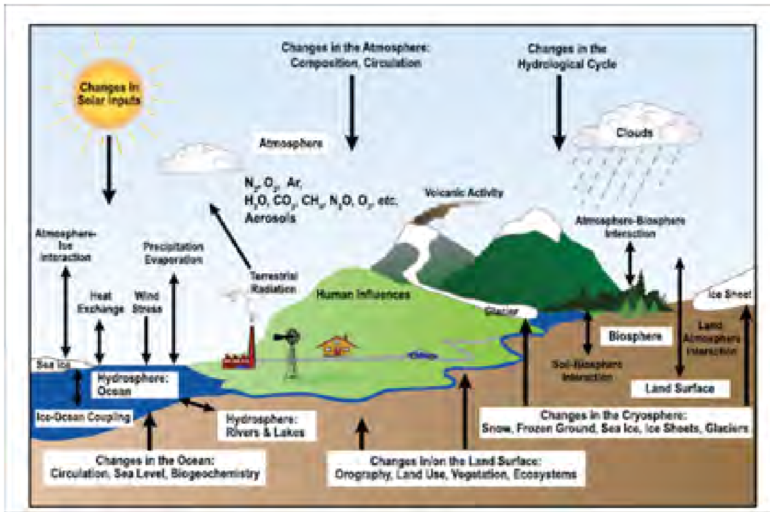
A. 1.2: WEATHER AND CLIMATE

WEATHER: "Weather is the physical condition or state of the atmosphere at any given time and location" (Philander, 2008). It is related to what is happening in the atmosphere at any particular time or over a very brief time period. Temperature, wind, pressure, moisture and precipitation are the main elements of weather. Thus the sum total of these elements (Temperature, wind, pressure, moisture and precipitation) of any place is the weather of that place for a brief time period (a day, part of the day or week). Wind, temperature, sunshine, clouds, thunderstorms, fog, rain, hail and snow are the conditions for expressing weather. Weather can change suddenly and weather of one day is usually different from the weather of next day. If today it is cloudy then the next day it may be sunny. Some terms such as wet or dry, windy or calm, warm or cold, sunny or cloudy etc. are used to describe weather. The science that deals with study of weather is called meteorology. Weather predictions and forecasts are made by meteorologists after measuring temperature, humidity, precipitation, wind, atmospheric pressure, sunshine etc. These forecasts help people make decisions about their routine activities.

Farmers particularly use these forecasts for planning and important decision making regarding various agricultural activities such as field preparation, sowing, harvesting, pesticide application etc.

CLIMATE: Climate refers to the atmospheric conditions of a particular location over an extended time period from one month to millions of years but usually the values are taken for 30 years . Thus climate is the long term summation of various atmospheric components of an area. Sometimes climate is defined as “average weather” which is inadequate because climate not only accounts for average weather conditions but also for extremes of such conditions, their variability and frequencies during a particular time period (Raferty, 2011). When summing up weather conditions to describe climate of an area one year may differ from the other and one century may differ from the other slightly and sometimes significantly. Climate is thus, a time-dependent phenomenon and when climatic values and indexes are quoted the time period or years for which they are quoted should be specified. Climate results from interaction of various factors such as latitude, altitude, proximity to mountains, proximity to oceans, ocean currents, solar radiation, wind, rainfall, continental drift, the greenhouse effect, volcanic activity, tectonic activity, earth’s orbital variations, tilt of the Earth’s axis, photosynthesis and transpiration.

Figure 1.1: The climate system



Source: IPCC (2007)

A.1.3 CLIMATE VARIABILITY AND CLIMATE CHANGE

CLIMATE VARIABILITY: There are usually fluctuations in temperature, moisture contents and other weather elements in a location or region from season-to-season, year-to-year and decade-to-decade but do not depict a continuous and long term warming trend of the planet. The climate of our planet naturally varies on various timescales such as seasonal, interannual, decadal, centennial, millennial and multimillennial timescales and it is referred to as climate variability. Climate variability defined by the World Meteorological Organization is “variations in the mean state and other statistics of the climate on all temporal and spatial scales, beyond individual weather events”. Climate variability may be the internal variability if it is due to internal processes within the climate system or external variability if it is due to external natural or anthropogenic factors (WMO, 2020).

CLIMATE CHANGE: Climate change is commonly used to describe any systematic alteration or statistically significant variation in either the average state of the climate elements such as precipitation, temperature, winds, or pressure; or in its variability, sustained over a finite time period (decades or longer). It can be referred to as the long-term change in global weather patterns, associated especially with increases in temperature, precipitation, and storm activity (Philander, 2008). However, there is a consensus in scientific community that climate change is directly or indirectly the result of human activities that negatively impacted and are still impacting the naturally occurring composition of the global climate elements such as temperature (NASA, 2022). There may be a contribution of the natural factors too such as solar radiation, volcanic activities, Earth’s orbital variables and feedbacks within the Earth’s climate system. Climate change is characterized by changes in ambient temperatures of the biosphere which ultimately leads to heat waves, change in rainfall patterns, hailstorms, flash floods, droughts, increased desertification, habitat loss, biodiversity loss, sea level rise, seawater intrusion and depletion of fresh water resources.

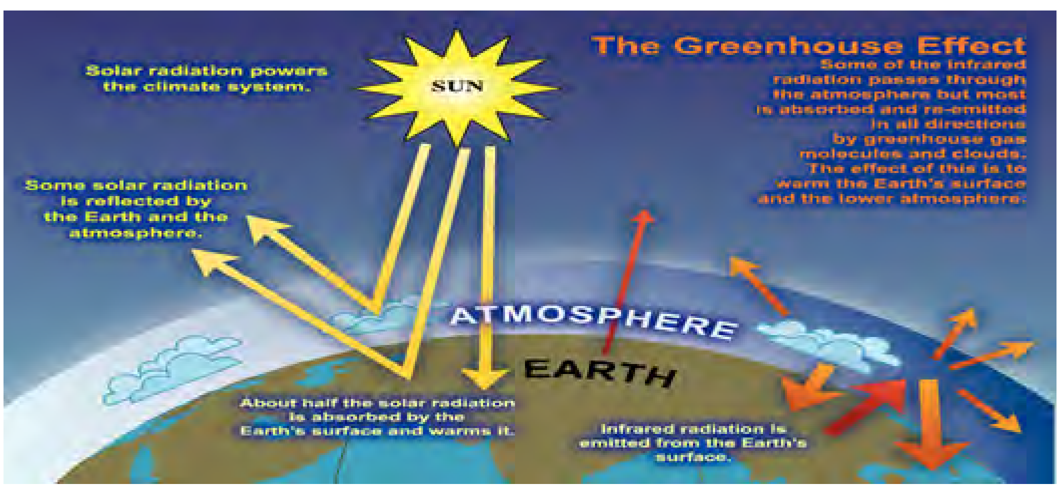
There are many climates on the planet from poles to equator. Human beings have adapted to almost all climates on the planet earth. They live on poles, in deserts, in tropical rainforests, near seashores, in Mediterranean areas, dry arid regions from low altitude to high altitude etc. However, this is not the case with many animals and plants living on the earth. For example a polar bear cannot live in tropical areas while a monkey from equator cannot survive at poles. In contrast, many other animals are adapted to a single climate, and change threatens them. Any change in the earth's climate is detrimental to all those animals and plants which have adapted to only a single climate. Thus various ecosystems and the life they are sustaining face crisis when the climate changes.

A. 1.4 GREENHOUSE EFFECT AND GREENHOUSE GASES

GREENHOUSE EFFECT: When sunlight passes through a greenhouse covering (polythene sheet, fiber glass or glass) and strikes the surface, the wavelength of radiation changes. At the time of entering the greenhouse the wavelength of incident radiation is short while after bouncing from the surface it becomes large. The radiations with large wavelength get trapped in the greenhouse which causes heating of the greenhouse and various warm season crops and plants can be grown in the winter season despite there is cold outside. Similarly when solar radiation strikes the earth surface, its wavelength becomes longer. The radiation with longer wavelength cannot pass easily from atmosphere to space due to various gases and aerosols in the atmosphere. Thus some part of the solar radiation gets trapped in the atmosphere and causes heating of the atmosphere. This phenomenon, similar to phenomenon in an agricultural greenhouse, is called as greenhouse effect.

The normal greenhouse effect is helpful in sustaining the life on earth because it maintains the earth's average temperature around 15°C while if there was no greenhouse effect then the average surface temperature of planet would have been around -18°C which would have made earth a non-livable planet for many organisms (Tomecek, 2012). However, today the planet is warming more than normal and it is due to huge amounts of various greenhouse gases emitted by human activities such as power generation, industry, agriculture, transportation etc. The greenhouse effect caused by anthropogenic activities, in addition to naturally occurring gasses, is usually referred to as "Enhanced Greenhouse Effect".

Figure 1.2: The Greenhouse Effect



Source: IPCC (2007).

GREENHOUSE GASES: The gases which cause greenhouse effect are called as greenhouse gases as they trap infrared radiation in the atmosphere and do not permit it to pass into the space. There are several greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), water vapors (H_2O), ozone (O_3), Chlorofluorocarbons (CFCs) and sulfur hexafluoride (SF_6).

CARBON DIOXIDE is principally produced through burning of fossil fuels for energy generation, industrial processes, transportation means and respiration by living organisms.

METHANE is released by rice paddies (anaerobic conditions), decay of dead organisms, burning of biomass, landfills, manure left on pastures and digestive system of livestock and termites.

NITROUS OXIDE is mainly produced from cultivation of soil, burning of biomass, production of nitrogenous fertilizers, production of nylon and combustion of fossil fuel.

OTHER IMPORTANT GHGs include water vapors, ozone, chlorofluorocarbons, HCFCs and sulfur hexafluoride. Majority of these GHGs are primarily produced by various industrial processes.

Table 1.2: Main greenhouse gases, their pre and latest post-industrial concentrations, atmospheric lifetime, source and global warming potential

Compound	Pre-industrial concentration (ppmv*)	Concentration in 2011 (ppmv)	Atmospheric lifetime (years)	Main human activity source	GWP**
Carbon dioxide (CO_2)	280	390	variable	Fossil fuels, cement production, land use change	1
Methane (CH_4)	0.715	1.803	12	Fossil fuels, rice paddies, waste dumps, livestock	25
Nitrous oxide (N_2O)	0.27	0.324	114	Fertilizers, combustion industrial processes	298
HFC 23 (CHF_3)	0	0.000024	270	Electronics, refrigerants	14,800
HFC 134a (CF_3CH_2F)	0	0.000062	14	Refrigerants	1,430
HFC 152a (CH_3CHF_2)	0	0.0000064	1.4	Industrial processes	124
Perfluoromethane (CF_4)	0.00004	0.000079	50,000	Aluminum production	7,390
Perfluoroethane (C_2F_6)	0	0.0000041	10,000	Aluminum production	12,200
Sulphur hexafluoride (SF_6)	0	0.0000073	3,200	Dielectric fluid	22,800

*ppmv = parts per million by volume, ** GWP = 100-year global warming potential

Source: Center for Sustainable Systems (2019)

The concentration, atmospheric lifetime and warming potential of different GHGs show an interesting trend. Carbon dioxide is the most abundant GHG having 390 parts per million by volume (ppmv) in 2011 (now it has reached 419 ppmv in 2021) against 280 ppmv in pre-idustrial times and is given a global warming potential (GWP) 1 which is a reference value. Methane is the second most important GHG having 1.803 ppmv concentration, 12 years of atmospheric lifetime and GWP value 25. By volume the third most important GHG is nitrous oxide having 0.324 ppmv concentration, 114 years of atmospheric lifetime and 298 times higher GWP than carbon dioxide. Then there are GHGs which have very low concentration but very high GWP and atmospheric lifetimes. For example in the hydrofluorocarbon (HFC) category the HFC 23 has 14,800 times, HFC 134a has 1430 times and the HFC 152a has 124 times higher GWP than carbon dioxide. Similarly the perfluoromethane has 7390 time GWP and 50,000 years of atmospheric lifetime while perfluoroethane has 12,200 times GWP and 10,000 years of atmospheric lifetime. The highest GWP, 22800, is of sulphur hexafluoride which also has about 3200 years of atmospheric lifetime.

Two important terms should be understood by our agriculture students, officers and researchers to better understand greenhouse gases, their behaviour and climate change; Global Warming Potential (GWP) and Carbon Dioxide Equivalents (CO_2-eq). The Global Warming Potential (GWP) allows us to develop comparisons of the global warming impacts of different greenhouse gases. *“GWP is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2). The larger the GWP, the more that a given gas warms the Earth compared to CO_2 over that time period. The time period usually used for GWPs is 100 years* (United States Environmental Protection Agency, n.d.). Global Warming Potential is thus a measurement unit and is used by analysts to estimate emissions of different gases for compiling GHG inventories on the basis of which policymakers can evaluate different options to reduce emissions of different GHGs from various sectors. Carbon dioxide is used as reference by assigning GWP 1 (by definition and without any specification to the time period, although it remains in atmosphere for thousands of years).

On the other hand Carbon Dioxide Equivalent (CO_2-eq or CO_2e or often written as CDE) is a unit used to standardize the climate effects of different GHGs based on their GWPs. The basic idea behind using this standardized unit is that different GHGs remain in atmosphere for different periods of time and have different warming impact on the atmosphere. As CO_2 is most discussed GHG, so sometimes other important GHGs (methane, nitrous oxide, sulfur hexafluoride etc.) get missed in discussion, which creates confusion as all these are also the causing agents of climate change. To avoid this confusion and express all GHGs in one unit, they are expressed in CO_2e. It is calculated by multiplying the tonnes of the gas by the associated GWP and is expressed as million metric tonnes of carbon dioxide equivalents (abbreviated as MMTCDE) (Eurostat, n.d.)

MMTCDE = (million metric tonnes of a gas) x (GWP of the gas).

MMTCDE of Methane = 1 x 25 = 25 million metric tonnes of carbon dioxide (it means 1 million metric tonne of methane has the same global warming impact as 25 million metric tonnes of carbon dioxide)

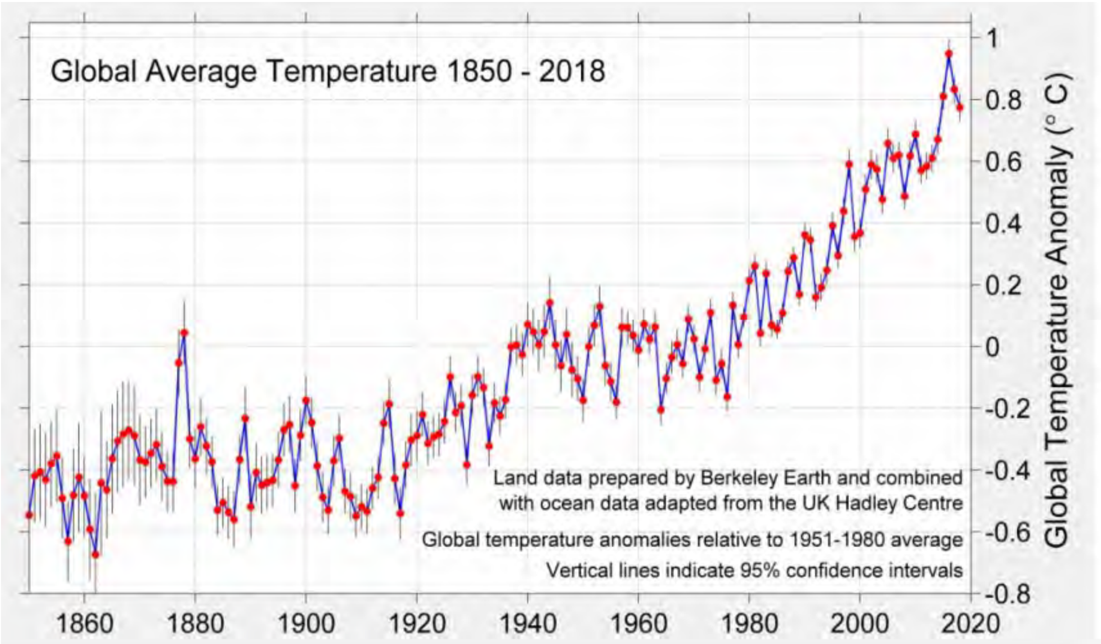
Similarly emissions of 1 million metric tonnes of nitrous oxide is equivalent to 298 million metric tonnes of carbon dioxide as the GWP of N_2O is 298.

A.1.5 GLOBAL WARMING

Increase in earth's average temperature caused by various greenhouse gasses is called global warming (also known as greenhouse effect). These GHGs are produced by human activities such as industrial processes, automobile exhausts and use of nitrogenous fertilizers for crop production and rearing of animals that release large amounts of methane. Various signs indicate that the earth is warming at global scale. For example;

- Increase in global average temperature
- Decreased snow cover at poles
- Increased melting of glaciers worldwide
- Increased intensity of intense rainfall
- ncreased day and night time temperatures
- Increased ocean acidification
- Sea level rise
- Milder and short winter
- Hotter and prolonged summer

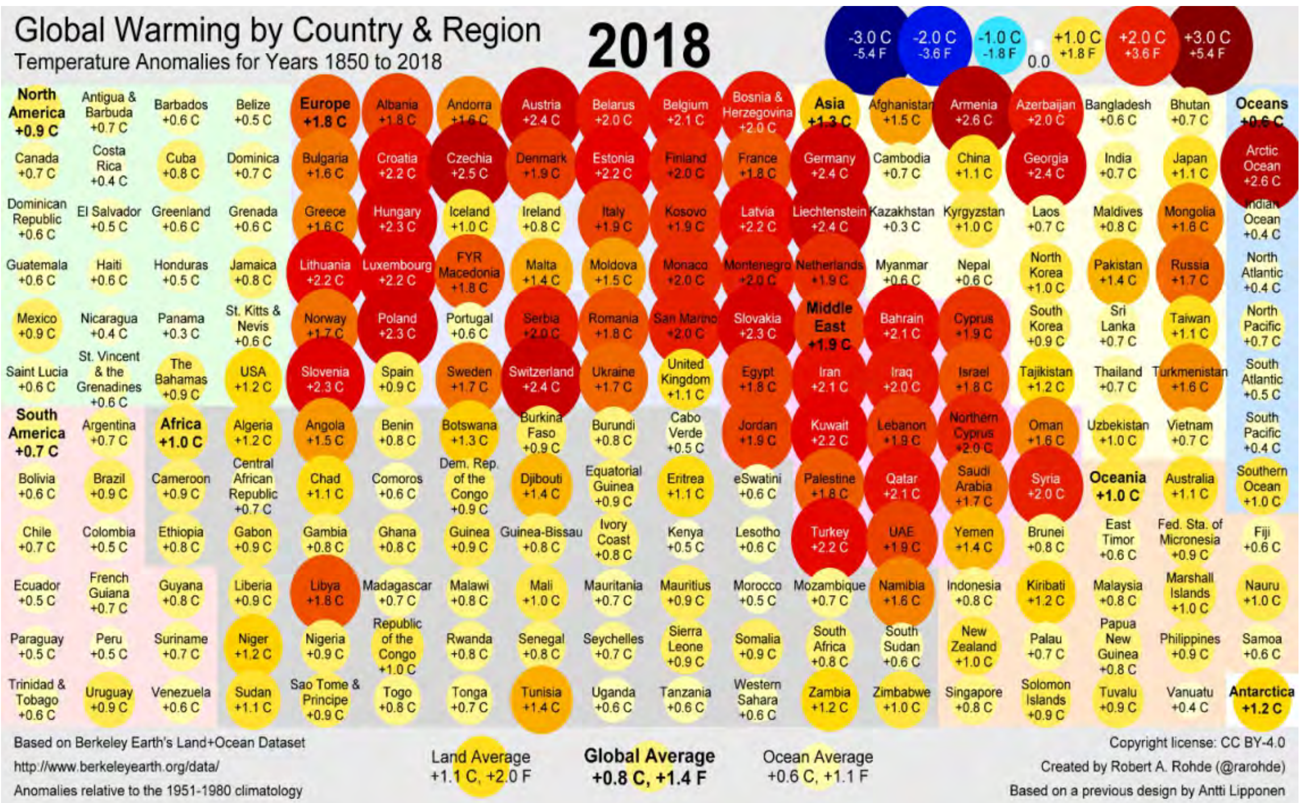
Figure 1.3: Global temperature anomaly since 1850



Source: Berkley Earth (2018)

The global temperature has been continuously increasing since reliable weather records began in 1861. The land surface air temperature has increased almost double (from 1850-1900 to 2006-2015 mean land surface air temperature has increased by 1.53°C) than the global mean surface (land and ocean) temperature (GMST) which increased by 0.87°C (IPCC, 2019). However according to Berkley Earth (2018) the average land temperature has increased by 1.1°C, average ocean temperature has increased by 0.6°C and average global temperature (land and ocean) has increased by 0.8°C. Initially (since 1850) the temperature was rising gradually but after . 1980s there is an abrupt global temperature rise and every decade becomes warmer than the previous one. In the list of 10 warmest years since 1850s, the first two decades of the 21st century have toppled all the previous records. The warmest year ever recorded was 2016, when global mean temperature jumped 1.25°C above the 1880-1910 baseline. The ascending order of warmest years, since 1850, is 2009, 2005, 2013, 2010, 2014, 2018, 2017, 2015, 2019 and 2016 (Climate Central, 2020).

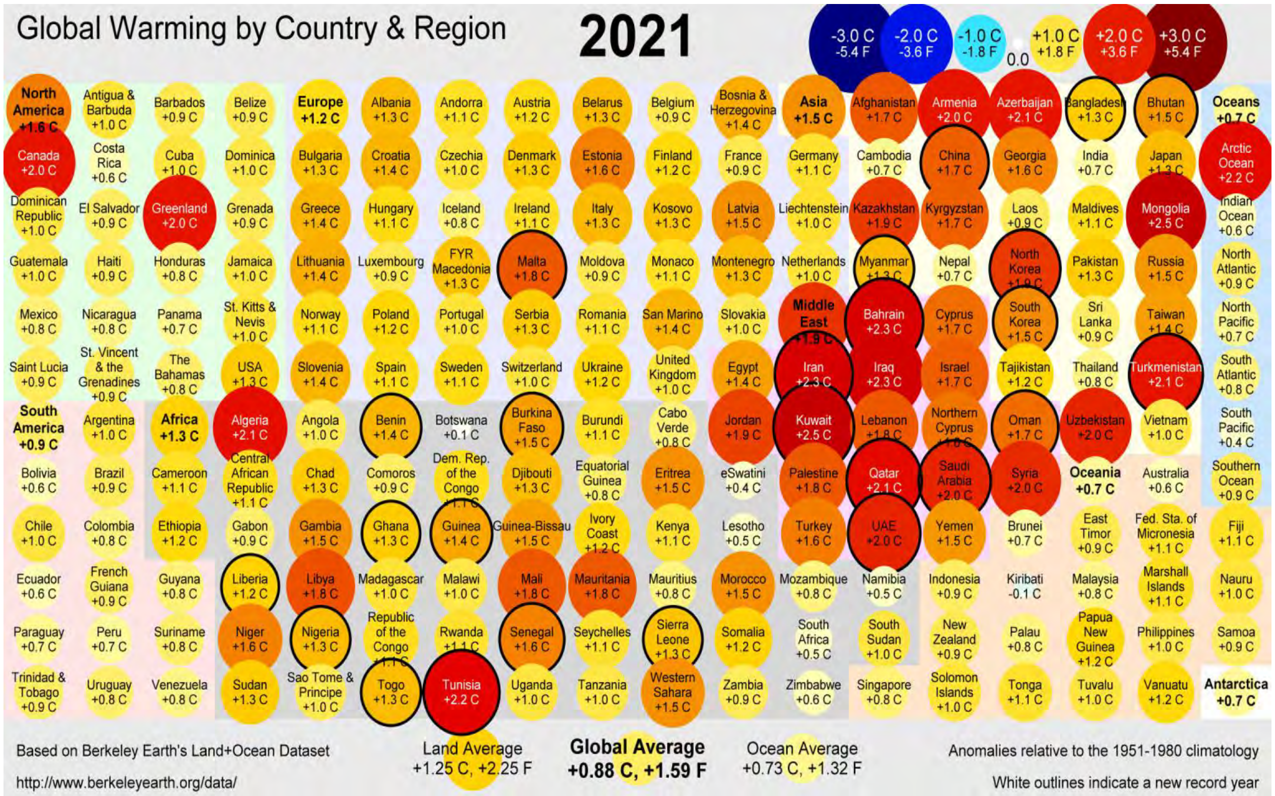
Figure 1.4: Global warming by country and region since 1850



Source: Berkley Earth (2018)

As summarized in the above figure, since 1850, the land surface air temperature has increased by 1.1°C, the average ocean temperature has increased by 0.6°C and the global mean surface (land and ocean) temperature has increased by 0.8°C. However, this increase is the global average and is not uniform in different countries, regions and oceans. For example the average temperature of North America has increased by 0.9 °C, South America by 0.7°C, Africa by 1.0°C, Europe by 1.8°C, Asia 1.3°C, Australia by 1.1°C and Antarctica by 1.2°C. Similarly regarding oceans the temperature of Arctic Ocean has increased by 2.6°C, Indian Ocean by 0.4°C, North Atlantic by 0.4°C, South Atlantic by 0.5°C, North Pacific by 0.7°C, South Pacific by 0.4°C and the Southern Ocean by 1.0 °C. Regarding Countries the trend is also different. Mostly the countries in Europe and Asia have witnessed more temperature increase than other countries of the world. The temperature increase in Pakistan is 1.4°C since the pre-industrial times. This increase is more than other countries in the South Asian region such as Nepal 0.6°C, Bangladesh 0.6°C, Bhutan 0.7°C, Sri Lanka 0.7°C, India 0.7°C and Maldives 0.8°C.

Figure 1.5: Global warming by country and region since 1850



Source: Berkley Earth (2021)

When we compare the data in figure 1.4 and 1.5 we observe the increase in average global temperature and the trend is continuous since 1850. Within these 3 years (2018-2021) the global average temperature increased from 0.8°C to 0.88°C, global average land temperature has increased from 1.1°C to 1.25°C, the average ocean temperature has increased from 0.6°C to 0.73°C. As discussed for figure 1.4 the increase in temperature is not uniform in different countries, regions and oceans. However in figure 1.5 we see some alarming situation where North America, Canada, Greenland, Algeria and Tunisia are facing sharp rise in average temperature.

SECTION B

THE CAUSES OF CLIMATE CHANGE

No other environmental phenomenon got much global attention for the past thirty years than the climate change. Climate change and global warming are the hot topics of the day not only for scientists and policy makers but also for those who are directly or indirectly part of it, either by contributing to climate change or facing its impacts. Climate change is the result of both natural and human factors. However, the natural factors are the part of our planet's evolutionary history and through them it has become a livable place f or living organisms. The major concern today is the human contributions that have disrupted many natural bio-geochemical cycles, burdened the atmosphere with tremendous amount of greenhouse gases and caused the overall warming of the globe. The increased intensity of extreme weather events, many of them unprecedented, is one of the major consequences of climate change. The projections of future global climate are even more horrifying even at modest emission scenarios. Let us briefly discuss the main natural and anthropogenic factors that have resulted in the change of our global climate.

SECTION B1

NATURAL CAUSES

The main natural causes of climate change (may be appropriately called as climate variability) are solar variability, volcanic eruptions, tectonic movements, orbital variations of the earth, naturally present greenhouse gases, including water vapors, in the atmosphere and feedbacks or interactions within various components of the climate system. These are briefly discussed below to have a general overview of them. The discussion about natural causes is mainly derived from Rafferty, (2011).

B. 1A SOLAR VARIABILITY

There is a continuous increase in the brightness of sun since its formation. This continuous increase in its brightness is increasing the temperature on planet earth because earth receives its energy from sun. However, this variability is steadily increasing from the very beginning and has very less direct impact on the global warming and subsequent climate change. It is this gradual increase in temperature on earth due to solar radiation that made earth a livable planet, otherwise there was too cold on earth for sustaining animal and plant life.

B. 1B VOLCANIC ACTIVITY

Volcanic eruptions release large amount of sulfur dioxide, aerosols and other pollutants that reduce the transparency of the atmosphere and thus reduce the solar radiation reaching earth. The sunlight strikes these atmospheric pollutants and bounces back. The repeated bouncing back of solar radiation increases the temperature of the atmosphere and thus causes global warming. However, this should be kept in mind that though the individual volcanic eruption may not substantially pollute the environment and cause its temperature to increase but when these volcanic eruptions are considered on geologic scale (over hundreds and thousands of years) it becomes a major natural cause of heating of the planet.

B. 1C TECTONIC ACTIVITY

The depth of the oceans and position, elevation, size and shape of the continental masses have been affected by the movement of tectonic plates over millions of the years which ultimately have strong effects on atmospheric and oceanic circulations, carbon dioxide concentrations in the atmosphere and general atmospheric chemistry. Continental masses such as Tibetan Plateau are also the result of tectonic activity. The classic example of tectonic activity is the uplift of Tibetan Plateau which impacts climate and circulation patterns of the atmosphere such as creation of the South Asian monsoon.

B. 1D ORBITAL VARIATIONS

Earth has its particular orbital geometry which experiences gravitational influences of other planets of the solar system and results in orbital variations. Many climate variations are caused by these orbital variations through changes in the latitudinal and seasonal distribution of solar radiation. The glacial and monsoonal patterns are also influenced by these orbital variations.

B. 1E GREENHOUSE GASES

The gas molecules which have property of absorbing and reradiating heat energy are called as greenhouse gases. The naturally occurring greenhouse gases are the molecules of carbon dioxide, methane and water vapor. These natural greenhouse gases are the result of different phenomenon taking place on earth such as movement of tectonic plates, at timescales of millions of years, and vegetation, soil, wetlands and oceans (both as sources and sinks), at timescales of hundreds to thousands of years.

B. 1F FEEDBACKS WITHIN THE EARTH SYSTEM

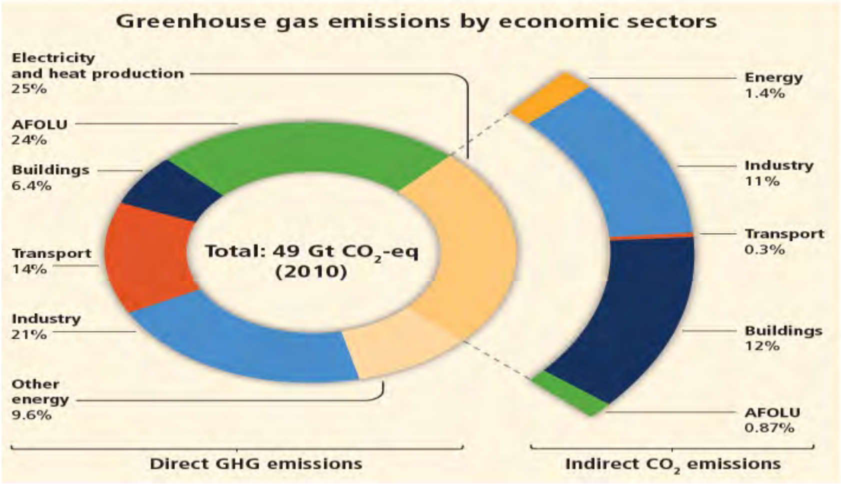
There are different components of the earth system which contribute directly or indirectly to climate change by interacting with atmosphere and each other. For example the atmosphere directly or indirectly effect glacial bodies, sea ice, land vegetation, temperatures of the oceans, rates of weathering, ocean circulation, and concentration of greenhouse gases. The atmosphere is also influenced by these systems in different ways such as land's vegetation cover density influences the reflectivity (albedo) of solar radiation. A more dense vegetation cover absorbs more solar radiation and reflects back little while land areas with scarce vegetation reflect back more solar radiations and add to the warming of the earth from local to global level. The vegetation cover of the earth also influences concentrations of the greenhouse gases in atmosphere because living plants act as sinks of carbon dioxide while dead or burnt plants release carbon dioxide to environment.

SECTION B2

ANTHROPOGENIC ACTIVITIES LEADING TO CLIMATE CHANGE

The natural causes of climate change have a very low and steady effect on our climate. The abrupt and tremendous changes in our weather and atmospheric systems leading to climate change are the result of human activities called as anthropogenic drivers of climate change. Different human activities that increase greenhouse gas emissions in the environment and are thus inducing global warming leading to climate change are summarized as; use of fossil fuel for energy production to meet industrial, domestic, agricultural and transportation needs, industrial processes and lack of proper waste management mechanisms, transportation (road, rail, marine and air), deforestation and conversion of forest land for agriculture and other purposes, increased urbanization and uncontrolled population growth, construction industry and agricultural activities including unsustainable crop and livestock management. The various economic sectors related to human activity that release huge amounts of GHGs and are directly or indirectly causing the climate change are briefly discussed below.

Figure 1.6: Anthropogenic greenhouse gas emissions (Gt CO_2-eq/year) by economic sector



Source: IPCC (2014)
AFOLU = agriculture, forestry and other land use

B. 2A ELECTRICITY AND HEAT PRODUCTION

While electricity generation and heat production are key elements of sustaining modern day's life, the largest source of atmospheric pollution is the use of fossil fuels to generate electricity and heat. Electricity and heat generation accounted for nearly 25% GHG emissions in 2010 (IPCC, 2014). Carbon dioxide is the major greenhouse gas produced from generation of energy and it accounts for about 80% portion of the greenhouse gases emitted from energy sector.

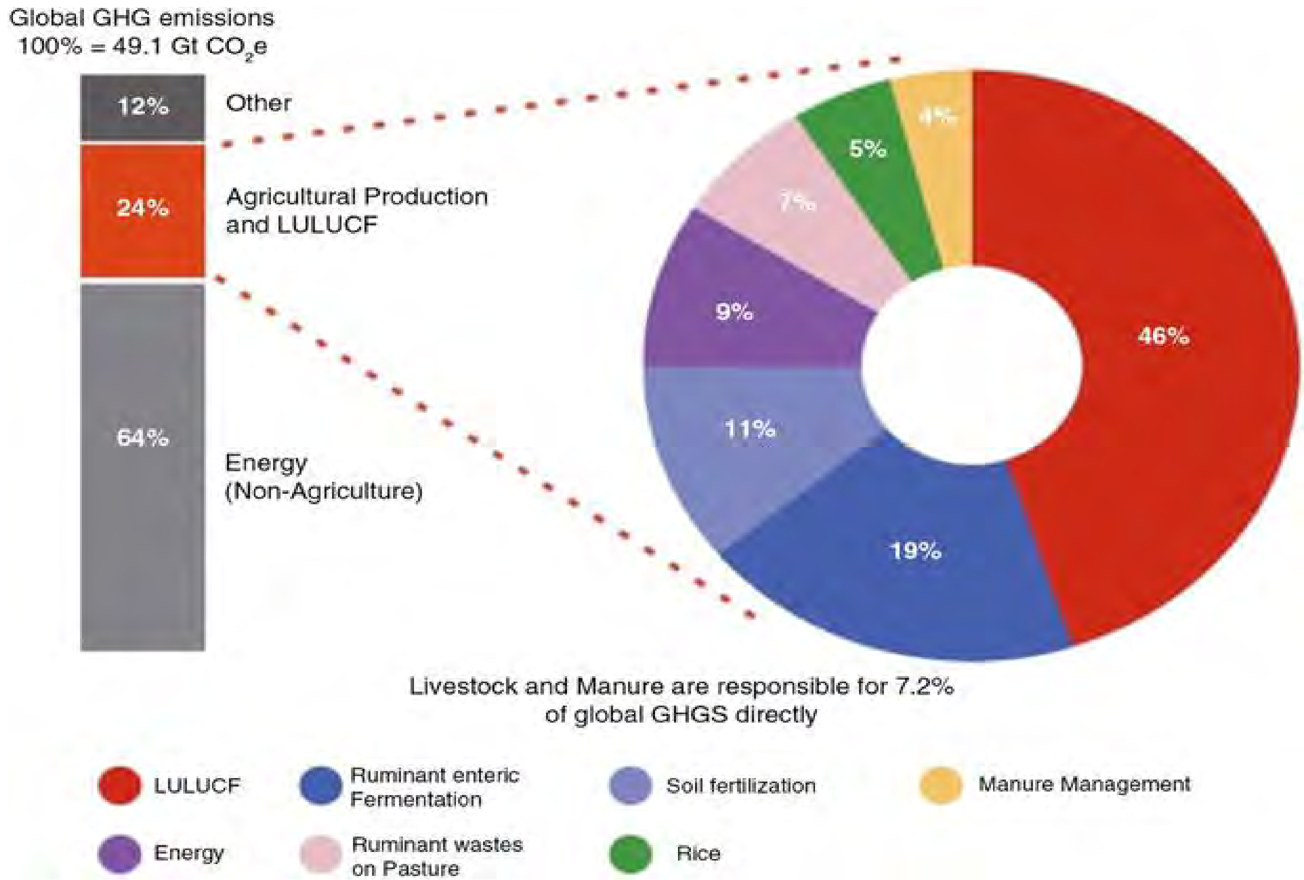
B. 2B INDUSTRY

Industrial sector impacts environment both positively and negatively. The positive impacts may be its help in adaptation of modern technologies that play role in preservation of the environment and development of equipment and instruments that help in monitoring our environment. On the other hand industrial development plays prominent and major role in the climate change. Industrial development ruthlessly exploited our natural resources and burdened our environment with greenhouse gases such as carbon dioxide, carbon monoxide, methane, nitrous oxide, volatile organic compounds (VOCs), chloroflourocarbons (CFC), hydroflourocarbons (HFCs) etc. Moreover industrial wastes degrade soil, water and other natural resources. According to the 5th assessment report of IPCC (2014) the contribution of industrial sector towards the global greenhouse gas emissions was 21% in 2010.

B. 2C AGRICULTURE, FORESTRY, AND OTHER LAND USE (AFOLU)

Agriculture accounted for 24% of the total GHG emissions in 2010 (IPCC, 2014). However, over period from 2007-2016 agriculture contributed to 23% of total net anthropogenic GHG emissions which is equivalent to 12.0 ± 2.9 Gt CO_2 eq yr^{-1}. During this period, 2007-2016, AFOLU (Agriculture, Forestry and Other Land Use) activities contributed to about 81% of global nitrous oxide (N_2O) emissions, 44% of methane (CH_4) emissions and 13% of global CO_2 emissions (IPCC-2019). In agriculture both crop and livestock sub-sectors contribute to the GHG emissions. The major contributor in agriculture sector is LULUCF (46%), enteric fermentation in livestock (19%), soil fertilization (11%), fossil fuel usage to produce energy and run machinery (9%), ruminant wastes on pastures (7%), methane emissions from rice paddies (5%) and manure management (4%). Deforestation is one of the major causes of climate change as it degrades land, releases sequestered carbon and reduces or eliminates capacity of forested lands to act as potential sinks of the atmospheric CO_2. The major causes of deforestation are the transformation of forested lands to agricultural purposes and logging of trees to meet the ever increasing demands of growing population for timber, fodder and fuel wood. It has been estimated that about 5.2 ± 2.6 Gt CO_2 yr^{-1} of net CO_2 emissions occurred during 2007-2016 from land use and land-use change of which mostly were due to deforestation(IPCC, 2019).

Figure 1.7: Agriculture, forestry and other land use (AFOLU) emissions by component in 2010



Source: World Resources Institute (2014)
(LULUCF stands for land use, land use change and forestry)

B. 2D TRANSPORTATION

Transportation sector involves burning of fossil fuels for road, air, rail and marine transportation. The contribution of transportation sector to global GHG emissions is estimated to be 14% of global greenhouse gas emissions.

B. 2E BUILDINGS

The burning of fossil fuels for cooking and heat generation in buildings accounted for about 6% of 2010 global GHGs. However, the emissions from usage of electricity in buildings are excluded from it and are estimated in the electricity and heat production sector.

B. 2F OTHER ENERGY

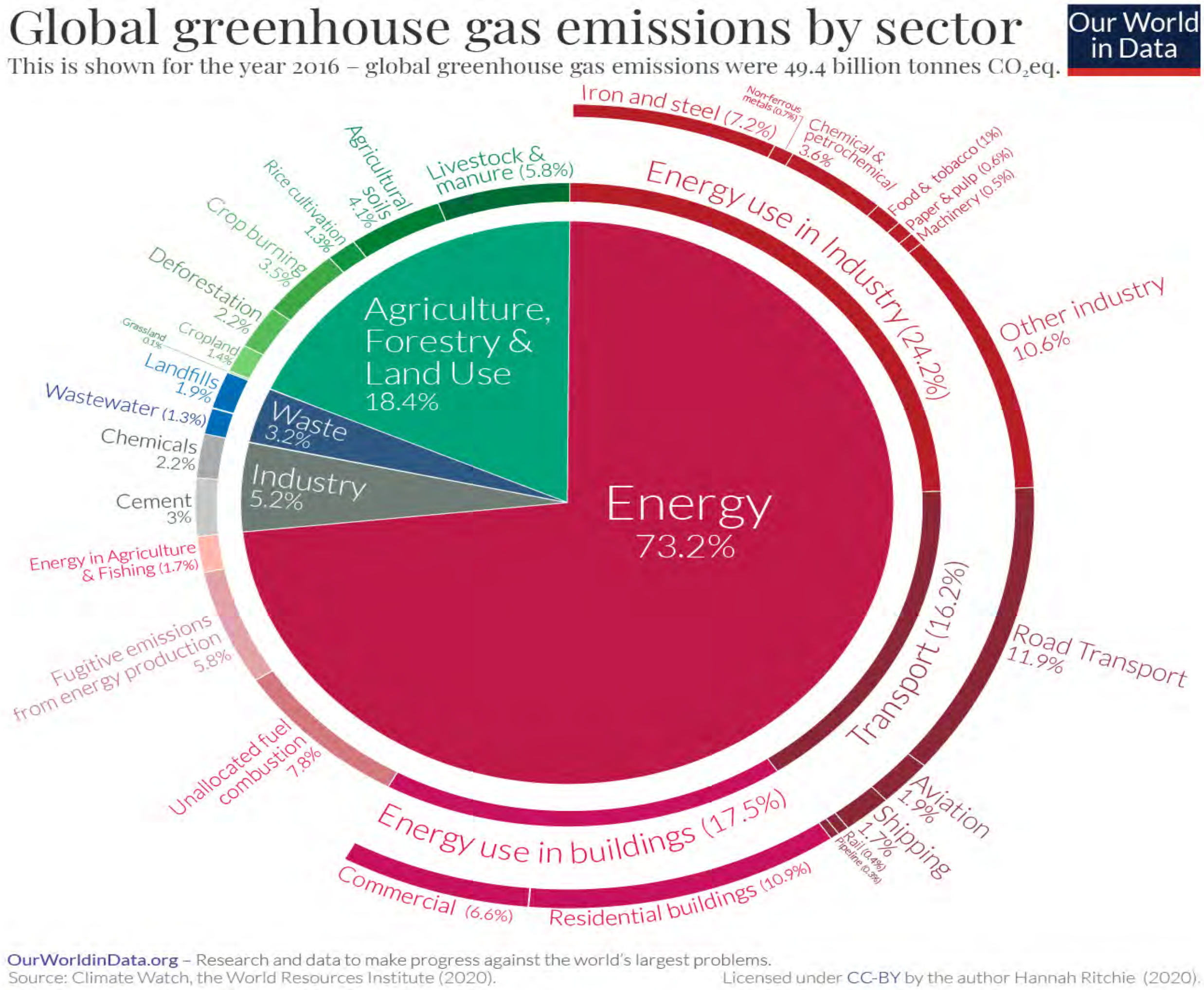
There are certain sub-sectors in the energy sector which are not directly related with the energy and heat production but they generated about 10% of global greenhouse gas emissions in 2010. For example the extraction of fossil fuels, their refining, processing and transportation generate lot of GHGs.

NOTE: There may be variations in estimation of GHGs from various sectors reported in literature. It might be due to various obvious reasons such as;

a. the data is recorded for different years
b. the development, expansion and evolution of some technologies or practices in a sector over the time may either reduce or increase its GHG emissions. For example a new industrial process may be more efficient resulting in lower GHG emissions or a new or modified practice in agriculture sector may reduce its emissions. Similarly expansion in wetland rice production or clearance of more forest land for agriculture may increase the sectors emissions.
c. with the advent of science and technology, new analytical approaches may come to use for estimation of GHGs from a sector which are more sophisticated and reliable.

This variation of GHGs estimation can be more evident when we compare the following figure (Figure 1.8) with the previous figures (1.6 and 1.7). In figure 1.8 we notice that AFOLU (Agriculture, Forestry and Other Land Use) emissions are 18.4% of the total GHG emissions while in figures 1.6 and 1.7 the contributions of Agriculture sector were reported to be 24% of the total GHG emissions. Figure 1.8 is more detailed breakdown of sectoral emissions and has more recent data (2016) against the previous figures which show less detailed picture and have data from 2010.

Figure 1.8: Detailed breakdown of the GHG emissions from various sectors



Source: Ritchie (2020), *World Resources Institute*

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MODULE 2
CLIMATE CHANGE IMPACTS ON AGRICULTURE AND NATURAL RESOURCES

MODULE OVERVIEW

This module elaborates the overall impacts of climate change on agriculture and food security with special focus on impacts on agronomic crops, horticultural crops, livestock, fisheries, forestry, soil and water resources.

OBJECTIVES

To have a basic understanding of the climate change impacts on agriculture and food security with special reference to impacts on;

1. Agronomic crops
2. Horticultural Crops
3. Livestock
4. Fisheries
5. Forestry
6. Soil
7. Water Resources

KEY QUESTIONS

1. How climate change is impacting agriculture sector in the world?
2. How climate change is impacting agriculture sector in Pakistan?
3. Which agriculture sub sectors are impacted by climate change and how?
4. What are the impacts of agriculture on water and soil?

KEY DEFINITIONS

CLIMATE CHANGE: A change in the state of the climate that can be identified by changes in the mean and /or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

ENVIRONMENTAL DEGRADATION: The reduction of the capacity of the environment to meet social and ecological objectives and needs.
RESILIENCE: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

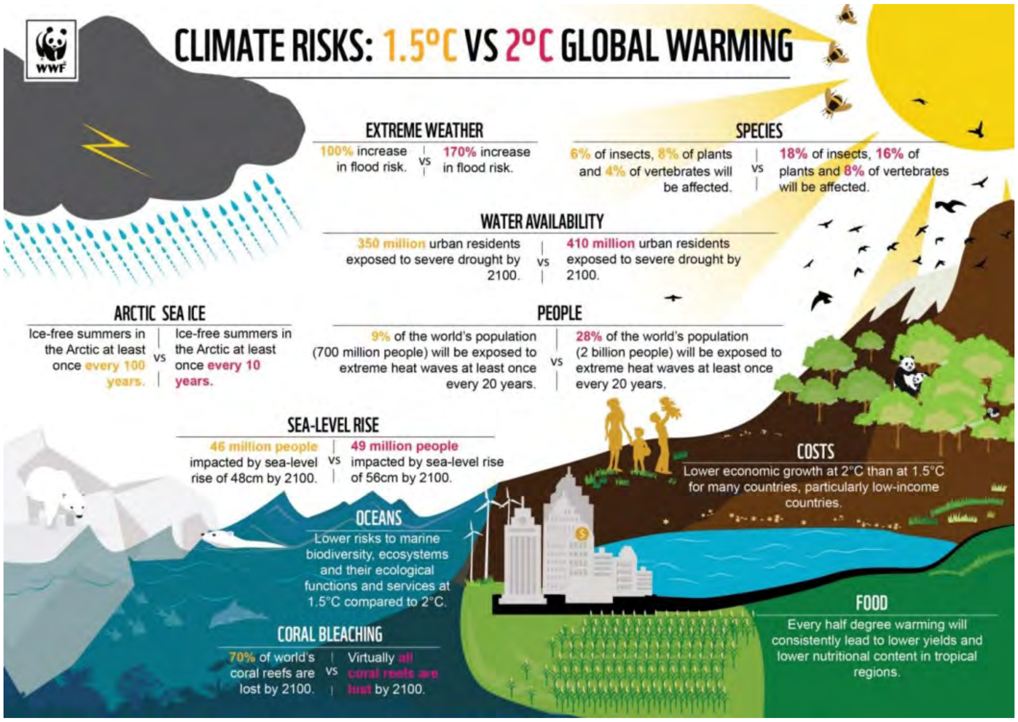
VULNERABILITY: The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community or society to the impact of hazards.

SECTION A

GLOBAL CLIMATE CHANGE TRENDS AND VULNERABILITIES OF THE AGRICULTURE SECTOR; A GENERAL OVERVIEW

The global temperature has increased to about 1°C over the preindustrial era. At present the global temperature is rising about 0.2°C (±0.1°C) per decade and is expected to further increase to 1.5°C in 2040 and may increase to 2°C before the end of century. The increase of 2°C is inevitable and a very optimistic estimate at our current emission regimes, otherwise some studies suggest an increase of up to 6°C in global mean temperature, if we do not practice appropriate adaptation and mitigation measures now. Although an increase of 1.5°C or 2°C may seem quite a small figure to an ordinary person, it has huge implications for our ecosystems and the very existence of many species living on the planet.

Figure 2.1: An estimation of climate risks at 1.5°C vs 2°C

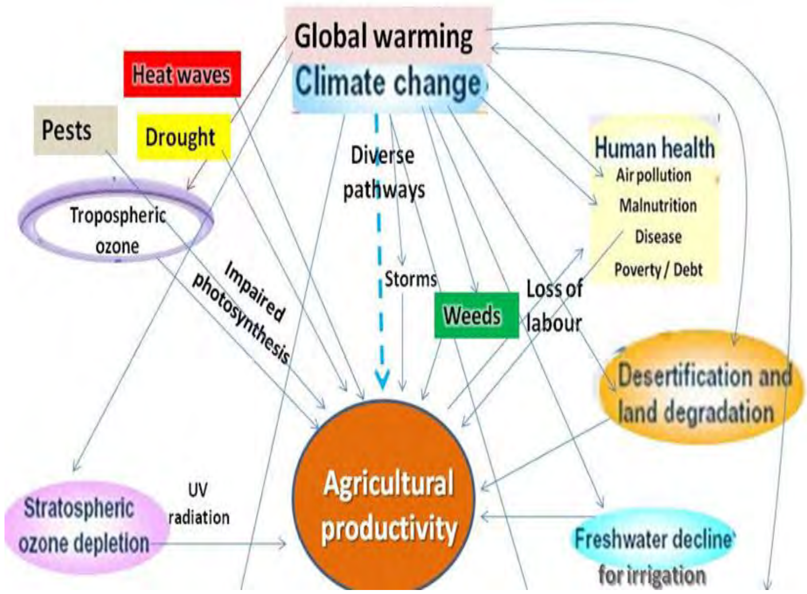


Source: WWF (2018)

Climate change is impacting many important sectors and resources on which human lives depend such as human health, agriculture, food security, water supply, transportation, energy and ecosystems. Agriculture is one of the most vulnerable sectors to the anticipated impacts of climate change throughout the world. Mostly the crops and livestock need specific growing and living conditions for optimum productivity. These specific conditions are determined by climate and soil types in addition to many other factors in a location or region. The growth of most of the agricultural crops is determined by specific climatic conditions. Changes in the climate may have deleterious impacts on crop growth, development and yield impacting the livelihoods of the dependent community and humanity as a whole.

Climate change is impacting the climatic conditions for growing crops differently in different regions across the world. Some regions are experiencing positive effects regarding crop growth (Polar region is becoming more ice free thus expanding land area for agricultural production) and some regions are facing negative effects like rising surface temperature, unequal rainfall, droughts etc. The negative impacts of climate change may be in form of stunted growth, reduced yields, reduced quality, poor colour development, decrease in nutritional contents, reduced storage stability in fruits and vegetables, reduced soil fertility, increased soil erosion and land degradation, increase in incidence of weeds, insect pests and diseases, decreased amount of irrigation water and many climate extreme events that directly or indirectly impact crop growth and livestock production.

Figure 2.2: Impacts of global warming and climate change on agriculture



Source: https://static.secure.website/wscfus/1897311/uploads/Mutiple_impacts_agriculture_image.png

The worst hit areas by climate change in the world are poor countries of Asia and Africa. It will be very difficult to steer an appropriate response to climate change as many countries in these continents face social, political and economic problems and vast portion of their population lives under poverty. Our current world population is 7 billion and it is expected to be around 9 billion in 2050, while out of our current population more than 800 million do not have enough food to eat. This poses additional challenges for the agricultural sector which is already overstretched by diminishing natural resources and increasing threats by climate change. The climate change is making the situation difficult with impacts on agricultural production and food security around the globe. The situation demands sincere efforts by all countries to work hard on climate and food security fronts, go extra mile to feed the additional 2 billion people with lesser impacts on already vulnerable natural resources.

Table 2.1: Potential impacts of climate change on different sectors of agriculture

Sector	Impact
Crop	Increase in ambient CO_2 concentration is beneficial since it leads to increased photosynthesis in several crops, especially those with C3 mechanism of photosynthesis such as wheat and rice, and decreased evaporative losses. Despite this, yields of major cereals crops, especially wheat, are likely to be reduced due to decrease in grain-filling duration, increased respiration, and/or reduction in rainfall/irrigation supplies
	Increase in extreme weather events such as floods, droughts, cyclones, and heat waves will adversely affect agricultural productivity
	Reduction in yields in the rainfed areas due to changes in rainfall pattern during monsoon season and increased crop-water demand
	Incidence of cold waves and frost events may decrease in future due to global warming, and it would lead to a decreased probability of yield loss associated with frost damage in northern India in crops such as mustard and vegetables
	Quality of fruits, vegetables, tea, coffee, aromatic, and medicinal plants may be affected
	Incidence of pest and diseases of crops to be altered because of more enhanced pathogen and vector development, rapid pathogen transmission, and increased host susceptibility
	Agricultural biodiversity is also threatened due to the decrease in rainfall and increase in temperature, sea-level rise, and increased frequency and severity of droughts, cyclones and floods
Water	Demand for irrigation water would increase with rise in temperature and evapo-transpiration rate. It may result in lowering of groundwater table at some places
	The melting of glaciers in the Himalayas will increase water availability in the Ganges, Brahmaputra, and their tributaries in the short run, but in the long run, the availability of water will decrease considerably
	A significant increase in runoff is projected in the wet season that, however, may not be very beneficial unless storage infrastructure is vastly expanded. This additional water in the wet season, on the other hand, may lead to increase in frequency and duration of floods
	The water balance in different parts of the world will be disturbed, and the quality of groundwater along the coastal track will be affected more due to intrusion of sea waters
Soil	Organic matter content, which is already quite low in soils, would become still lower. Quality of soil organic matter may be affected
	The residues of crops under the elevated CO_2 concentrations will have higher C:N ratio, and this may reduce their rate of decomposition and nutrient supply
	Rise in soil temperature will increase N mineralization, but its availability may decrease due to increased gaseous losses through processes such as volatilization and de-nitrification
	There may be a change in rainfall volume and frequency, and wind may alter the severity, frequency, and extent of soil erosion
	Rise in sea level may lead to saltwater ingression in the coastal lands, turning them less suitable for conventional agriculture
Livestock	Climate change will affect fodder production and nutritional security of livestock. Increased temperature would enhance lignification of plant tissues, reducing the digestibility. Increased water scarcity would also decrease production of feed and fodder
	Major impacts on vector-borne diseases will be through expansion of vector populations in the cooler areas. Changes in rainfall pattern may also influence expansion of vectors during wetter years, leading to large outbreaks of diseases
	Climate change is likely to aggravate the heat stress in dairy animals, adversely affecting their reproductive performance
	Global warming would increase water, shelter, and energy requirement of livestock for meeting the projected milk demands
Fishery	Increasing temperature of sea/river water is likely to affect breeding, migration and harvests of fishes
	Impacts of increased temperature and tropical cyclonic activity would affect the capture, production and marketing costs of the marine fish
	Coral bleaching is likely to increase due to higher sea surface temperature

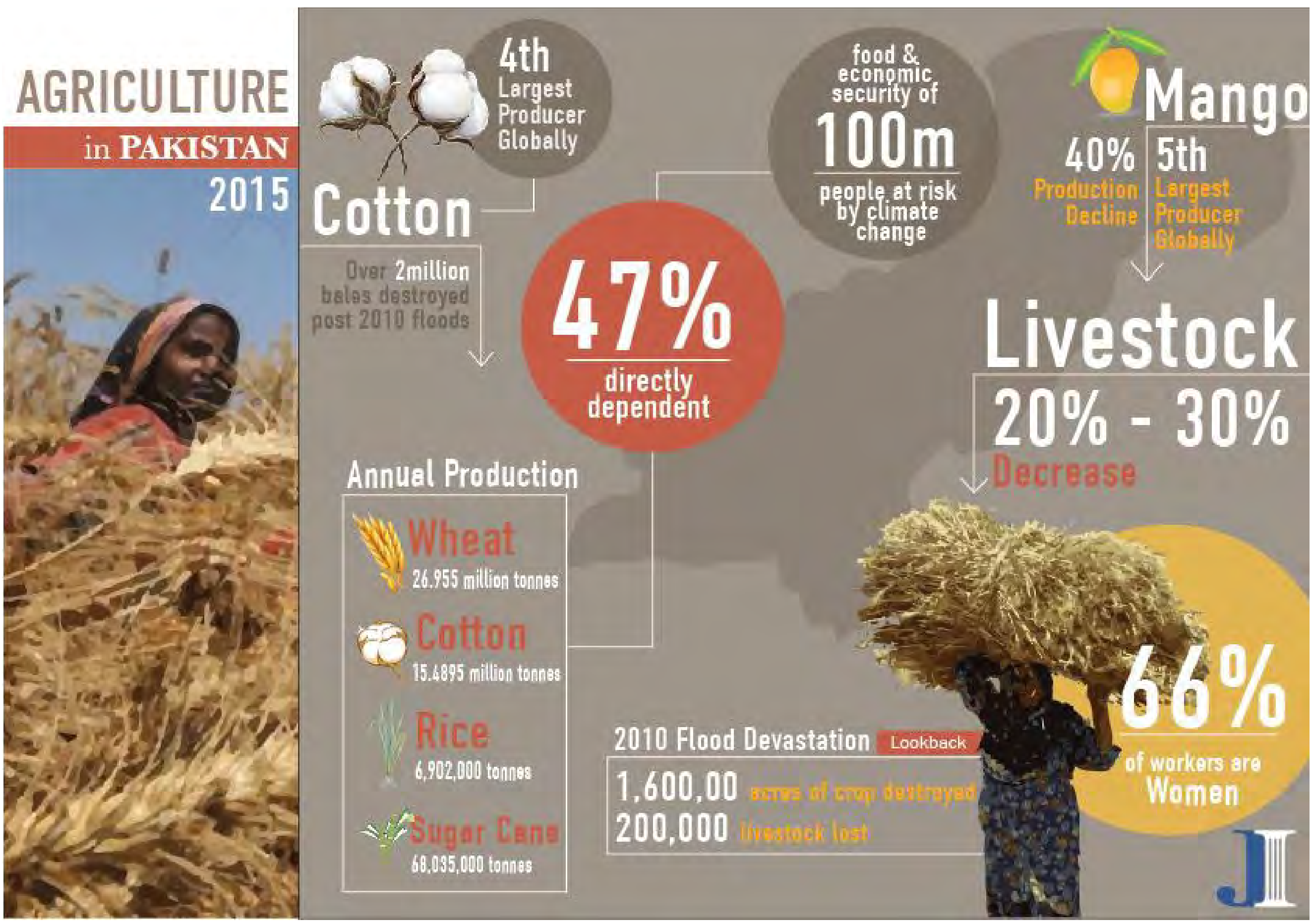
Source: Aggarwal et al., (2009)

SECTION B

CLIMATE CHANGE TRENDS IN PAKISTAN AND VULNERABILITIES OF THE AGRICULTURE SECTOR: A GENERAL OVERVIEW

Agriculture is an important sector of Pakistan's economy contributing 18.5% to the GDP, 60% of exports and employing 38.5% of the total workforce (Pakistan Economic Survey, 2019). Agriculture is the foundation of food security in Pakistan, provides food for population, feed for livestock, raw materials for industry and value added products for both domestic consumption and international markets. However, the growth rate of the agricultural sector is seeing a decline over past few years and its share to the national GDP is shrinking over time due to too many reasons of which one is the climatic variations and climate change. Agriculture sector, being an open industry, is the first and foremost witness of climatic variations and climate change. Pakistan's agriculture sector is often impacted by high temperatures, erratic rains and change in rainfall patterns, salinity, droughts, desertification, low water availability, storms, flash floods, soil erosion and land degradation.

Figure 2.3: Contributions of agriculture sector in Pakistan's economy and challenges to agriculture sector by climate change



Source: Jinnah Institute (2015)

Geographically Pakistan lies in a region where temperature increase is expected to be higher than global average. This makes Pakistan's agriculture sector particularly vulnerable to climate change. According to ADB (2017), during the period 1960-2007 Pakistan has witnessed a decrease of 10-15% in summer and winter rainfall in arid plains and coastal areas, a decrease of 5% in relative humidity over Balochistan province, an increase of 0.5%-0.7% in solar radiation over the southern half of the country, an increase of 0.6°C to 1.0°C in the mean temperature in several parts of the country. Future projections are even worse than current trends. Temperature rise is expected to be higher than global average temperature rise, frequency of hot days and hot nights is expected to increase, the yields of major crops such as wheat, rice, cotton, sugarcane etc. may decrease significantly and per capita water availability will further decrease. It is projected that mean temperature will rise by 1.4°C - 3.7°C by 2060 (Collins et al., 2013) which is higher than expected global average during this period. Our northern belt will experience more warming than our southern areas. This warming trend of the north is alarming as it comprises of snow covered mountains and glaciers that contribute to river flows and forms the base of our irrigation system and power generation. The increased snow and glacial melt will increase trend of floods for certain period in near future followed by permanent water scarcity. Both scenarions (increased floods in near future and permanent water shortage in long term) will have drastic impacts on our agriculture.

Temperature increase is expected to speed up the crop growth cycles of various crops which will ultimately reduce yields by decreasing time between sowing and harvesting. It is estimated that with rise of temperature (+0.500C–2.00C), agricultural productivity will decrease around 8-10% by 2040 (Dehlavi, Groom, & Gorst, 2015). More frequent and intense floods, salinization of farmland, increased soil erosion and melting of glaciers in northern areas will force portions of the population to resettle along rivers.

Model based studies also show that under climate change scenario our agricultural production will greatly reduce. It has been estimated byRobinson et al (2015), using IMPACT (International Model for Policy Analysis of Agricultural Commodities and Trade) model, that Pakistan’s agricultural production will be hit hard by climate change. They used SSP 2 and RCP 4.5 pathways for estimation of their results and calculated substantial reduction in yield of our major crops by 2050; wheat 5.9%, cotton 6.1%, rice 5.7%, maize 11.7%, sugarcane 6.2%, chickpea 12.6%, tropical fruits 5.2% and vegetables 6.0%. The reduction in yields of most of the crops estimated by them is despite the fact that area of production for most of the crops (except wheat, chickpea and vegetables) under their study will increase.

The low agro-technological development base of our agriculture is also making farming communities more vulnerable to climate change. Farmers in Pakistan are still practicing traditional forms of agriculture and employ crop production practices and technologies which are vulnerable to climate change such as mono-cropping, excessive tillage and intensive cultivation, poor on-farm water management, misuse of fertilizers and pesticides, outdated cropping patterns, poor quality seeds and planting materials, poor crop and animal husbandry practices, climate vulnerable value chains etc. The poor agro-technological base of agricultural systems cannot meet the challenges of ensuring food security in climate change scenarios. Therefore there is a need to attune our agricultural production under the framework of climate compatible development (CCD).

SECTION C

IMPACTS OF CLIMATE CHANGE ON DIFFERENT SECTORS OF AGRICULTURE AND NATURAL RESOURCES

C 2.1 CLIMATE CHANGE IMPACTS ON CROPS

C 2.1A IMPACTS ON AGRONOMIC CROPS

Agronomic crops comprise of a diverse group of crops which is further classified into several sub groups such as cereal crops (Wheat, Maize, Rice, Barley, Oats etc.), legume crops (pulses- Chickpea, Beans, Lentil, Mashbean, Mungbean etc.), sugar crops (Sugarcane, Sugarbeet etc.), oilseed crops (Canola, Soybean, Groundnut, Sun flower, Sesame etc.), fiber crops (Cotton, Jute, Sunn hemp, Deccan hemp etc.) and fodder crops (Lucerne, Berseem, Sorghum, Pearl millet, Rhodes grass etc.). These crops constitute the largest cropped area in Pakistan. Majority of the agronomic crops grown in both irrigated areas as well as under spate farming systems are highly sensitive to the temperature variability and amount of water. The increase in temperature has complex impacts on crop growth and yield. For example 1°C increase in temperature during the growing period may reduce wheat yield by 3-10%, winter wheat yields by 5-35% and maize yield by 2.4-45.6%.

Iqbal, Goheer, & Khan (2009) using the crop–growth simulation model estimated a decrease in the yield of major crops, specifically wheat and rice in four agro-climatic zones of Pakistan. They estimated 6% reduction in wheat yield and 15-18% decrease for fine-grain aromatic basmati rice yield in all agro- climatic zones by 2080. Barlow, Christy, O'leary, Riffkin, & Nuttall (2015) analyzed the effect of temperature extremes, frost and heat on wheat production. They reported that excessive heat caused reduction in grain number and grain filling period while frost caused sterility and abortion of formed grains. Ahmed et al., (2018) estimated 27% yield reduction in maize crop due to climate change in a simulation study. Rahman et al., (2018) estimated about 8% yield reduction in cotton crop due to climate change in a multi-model projection study. It is anticipated that rising CO_2 level may favour certain crop pests and diseases. It has been reported that aphids (Newman, 2003) and weevils (Staley & Johnson, 2008) respond positively to higher CO_2 levels. The changing rainfall patterns impact migration of desert locusts in which can become major devastating pests for agronomic and other crops in Pakistan.

Table 2.2: Impact of climate change on cotton and sugarcane production

Crop	Country/contin	Yield	Reference
Cotton	China	−5.5	(Chen, Pang, Pan & Zhang, 2015)
	USA	−17	(Adhikari et al., 2016)
	Africa	−7	(Amouzou et al., 2018)
	USA	−9	(Reddy et al., 2002)
	Pakistan	−8	(Rahman et al., 2018)
	Australia	−17	(Williams et al., 2015)
Sugarcane	Swaziland	-9	(Knox, Rodríguez Díaz, Nixon, & Mkhwanazi, 2010)
	USA	-40	(Zhao & Li, 2015)
	Brazil	-27	(Carvalho et al., 2015)
	India	-30	(Kumar, 2014)

Source: Ahmed et al., (2019)

Table 2.3 : Impact of climate change on wheat, rice and maize crop production

Crops	Country/Continent	Yield reduction (%)	Reference
Wheat	Australia	−32	(Luo, Bellotti, Williams & Bryan, 2005)
	Iran	−37	(Valizadeh, Ziaei, & Mazloumzadeh, 2014)
	Worldwide	−5.5	(Lobell, Schlenker & Costa-Roberts, 2011)
	Mexico	+25	(Lobell et al., 2005)
	Asia	−7.7	(Asseng et al., 2016)
	India	−5.2	(Gupta, Somanathan, & Dey, 2017)
	Pakistan	−50	(Hussain, Khaliq, Ahmad, Akhter & Asseng, 2018)
	Turkey	−20	(Özdoğan, 2011)
	Indonesia	−11	(Naylor, Battisti, Vimont, Falcon & Burke, 2007)
Rice	India	−8	(Saseendran, Singh, Rathore, Singh & Sinha, 2000)
	Asia	−6.3	(Masutomi, Takahashi, Harasawa & Matsuoka, 2009)
	Italy	−12	(Bregaglio et al., 2017)
	Japan	−11.3	(Iizumi, Yokozawa & Nishimori 2011)
	Nepal	−24	(Khanal, Wilson, Hoang, & Lee 2018)
Maize	Portugal	−17	(Yang, Fraga, Ieperen & Santos 2017)
	Africa	−20	(Rurindra et al., 2015)
	Pakistan	−27	(Ahmed et al., 2018)
	China	−30	(Xiao and Tao, 2015)
	USA	−50	(Xu, Twine & Girvetz, 2015)

Source: Ahmed et al., (2019)

C 2.1B IMPACTS ON HORTICULTURAL CROPS

Horticulture may be defined as the intensive cultivation and harvesting of plants for financial, environmental and social profit. Horticulture encompasses the study and production of fruits, vegetables, flowers and ornamental plants, spices, beverage plants, herbs and medicinal plants. Changing climate is anticipated to have considerable impacts on horticultural crop production and supply chain across the globe. Water and other vital resources may become scarce in some regions reducing opportunities to grow horticultural crops. Damaging winds, hailstorms, unpredicted frosts, heat waves and other climate extremes may seriously impact horticultural production in many regions. The pest and pathogen dynamics may also change with climate change. Many new pests will threaten the production of horticultural crops in areas where the climate previously excluded their activity.

In horticultural crops the increased temperature will effect photosynthetic activity causing changes in sugar contents, organic acids, flavonoids and antioxidant levels. In strawberries, the increased atmospheric ozone can lead to reduced photosynthetic activity, growth and biomass accumulation while increased vitamin C contents (Mattos et al., 2014). According to Dixon (2012) climate change will result in alteration in growth patterns and capabilities of flowering and fruit setting in many annual and perennial horticultural plants. The perennial fruit crop production may suffer problems in dormancy, acclimation, flowering and fruit production from altered seasonal conditions. However, in some cold regions fruit production may benefit from increased temperature that will result in reduced cold damage and increased length of growing season. Fruit production in tropical and sub-tropical regions is also impacted by variations in climatic factors. For example, mango becomes more vegetative at higher temperatures and shows less reproductive growth leading to decline in fruit production. On the other hand sharp reduction in temperature causes cold stress that also leads to decline in mango production. At the same time insect pests and diseases of fruit crops increase with increasing temperatures. Rainfall during fruit maturation and ripening damages many fruits such as mango, datepalm, grapes etc. Reduced light intensity during fruit maturation causes reduction in ascorbic acid and sugar contents in mango. Similarly in grapes, the rising temperatures delay fruit maturation and reduce fruit quality.

Table 2.4: Effects of climate change on fruit crops

Affected Fruits	Incident	Cause	Adverse Effect	Reference
Apple and other fruit crops	Lack of chilling	Lack of cold temperatures during the winter	Delayed flowering and increase in risk of frost	(Kauffman & Blanke, 2017)
Cherry, apple, apricot and others	Frost	Slight increase in the risk of frost	Damage to flowers and fruitlets, yield loss	(Blanke & Kunz, 2009)
Peach, Cherry, Apricot, Plum	Flower bud differentiation problems in subtropical conditions	High temperatures and water stress during flower bud differentiation period (June-August)	Double fruit formation, lower yields, lower fruit quality	Kuden, 2020
Apple and other fruit crops	Rise of fruit temperature >50 °C	Sunny and hot periods	Sunburn	(Blanke & Kunz, 2009)
Apple and other fruit crops	Insufficient water supply to the fruit	Warm and dry periods	Smaller and softer fruit, less fruit color	(Blanke & Kunz, 2009)

Source: Adapted from Bisbis, Gruda & Blanke (2019)

Vegetable crops also suffer from climate change. As these crops are mostly succulents and usually have shallow root systems, they are more vulnerable to climate extremes than fruit crops. Fluctuations in temperature may cause bolting (pre-mature flowering) in many vegetable crops such as carrots, radish, cabbage, cauliflower, coriander, spinach etc. Rise in night time temperatures may increase rate of respiration leading to less distribution of assimilates to reproductive sinks (fruits). This will ultimately lead to smaller sized fruits (cucurbits, tomatoes, peppers etc.) with low market value. This may result in extensive breeding and biotechnological approaches to develop vegetable varieties that have optimum sizes to meet the market demand.

Different vegetables respond differently to climatic variations and change. For example, potato has a shallow root system and water shortage or drought results in less partitioning of assimilates to the root, shoots and leaves during developmental stages. This results in poor growth and lower yields. Excessive rains before planting season delay planting, while rains and flooding near harvesting delay harvesting time. Excessive rains favour late blight of potato during growing period and tuber rotting near harvest. The rising temperature also favour increase in aphid populations. The aphids are viral vectors for many viral diseases and the seed potato production becomes difficult in high aphid populations.

The temperature increase also impacts germination process of many vegetables, particularly those vegetables which require vernalization for seed germination. It is assumed that indeterminate vegetables may be less impacted by heat stress than determinate types as their flowering time is extended. The rise in temperature severely affects flowering, fruit setting, fruit maturation, fruit size and ripening resulting in lower yields. It has been reported by Mattos et al. (2014) that increased atmospheric carbon dioxide may affect post-harvest quality of potatoes due to reduction in sugar contents, tuber malformation and increased incidence of potato scab. On the other hand transient increase in β-carotene, lycopene and lutein contents was found in tomatoes when they were exposed to ozone concentrations ranging from 0.005 to 1.0 µmol/mol.

Table 2.5: Effects of climate change on vegetable crops

Affected Vegetables	Incident	Cause	Adverse Effect	Reference
Cauliflower	Lack of Vernalization	Lack of cold temperature during vegetative growth	Delay of head formation	(Wurr, Fellows & Phelps, 1996).
Lettuce	Pressure to complete life cycle	Warm and dry Periods	Bolting	(Eriksen, Knepper, Cahn & Mou, 2016)
Lettuce, Tomato	Lack of Ca transport	Warm and dry Periods	Tip burn, blossom end rot	(Eriksen, Knepper, Cahn & Mou, 2016)

Source: Adapted from Bisbis, Gruda & Blanke, (2019)

Medicinal plants are used in traditional and modern medicines and generate a considerable amount of revenue for indigenous communities across the world. Climate change will also affect quality and production of medicinal plants. It is anticipated that, under climate change, protein quality of these plants will be lower and antioxidant levels higher. The lower quality plants and reduced yields will impact the revenue generation for local communities.

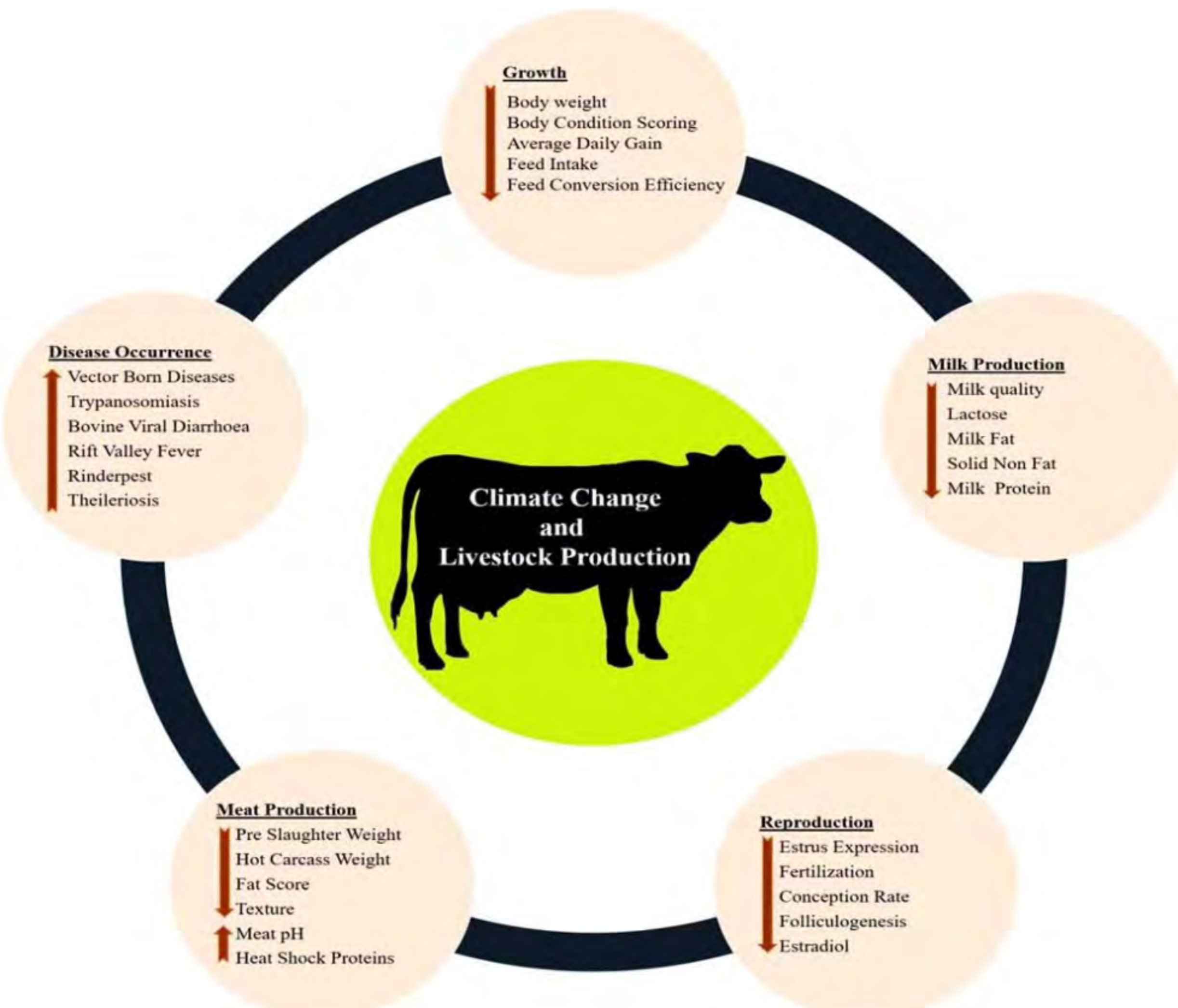
C 2.2 CLIMATE CHANGE IMPACTS ON LIVESTOCK

Livestock is an important source of food and income in Pakistan which contributes 56.3% of agriculture sector output and 11.8% to the national GDP (Pakistan Economic Survey, 2014–15). In mountainous areas and arid regions of Southern Punjab, Sindh and Balochistan, where agricultural production is more complex, many people rely primarily on livestock to meet their food and other needs. Eight million households in the country are involved in livestock management, which accounts for 35% of their income. Pakistan is the 4th leading producer of milk in the world. Given the scale of livestock production, Pakistan earns significant foreign exchange by exporting livestock and their by-products (World Food Programme, 2018)

Climate change poses serious threats to livestock production in Pakistan. Increased temperatures, change in rainfall patterns and increased frequency of extreme weather events adversely affect livestock productivity. All livestock operations require good quality drinking water and without it livestock will suffer. The negative effects of high temperature on feed intake, reproduction and performance of livestock are well documented. Increase in temperatures also causes decreased forage quality and availability, reduced water availability, increased heat stress and emergence of diseases. Negative impacts are anticipated to be most severe in arid and semiarid grazing systems (Potohar plateau, Thal and Thar Deserts, Baluchistan and dry regions of KPK) where high temperatures coupled with low rainfall are expected to increase land degradation and reduce rangeland yields. All these negative impacts lead to decline in livestock productivity. Highly productive livestock breeds are more sensitive to heat stress than low producing breeds. Young animals are less tolerant to wide fluctuations in the temperature than adults. Milk and meat production in cattle, buffalo, sheep and goats greatly reduces in temperature extremes.

Poultry production will also suffer due to increase in temperatures. Heat stress causes reduction in the protein and muscle calorie contents, feed intake and body weight and egg production in poultry. The quality of eggs also lowers at high temperatures. Poultry diseases also increase at higher temperatures. High temperature even can lead to mortality of birds.

Figure 2.4: Climate Change and Livestock Production



Source: Sejian, Bhatta, Gaughan, Dunshea, & Lacetera (2018)

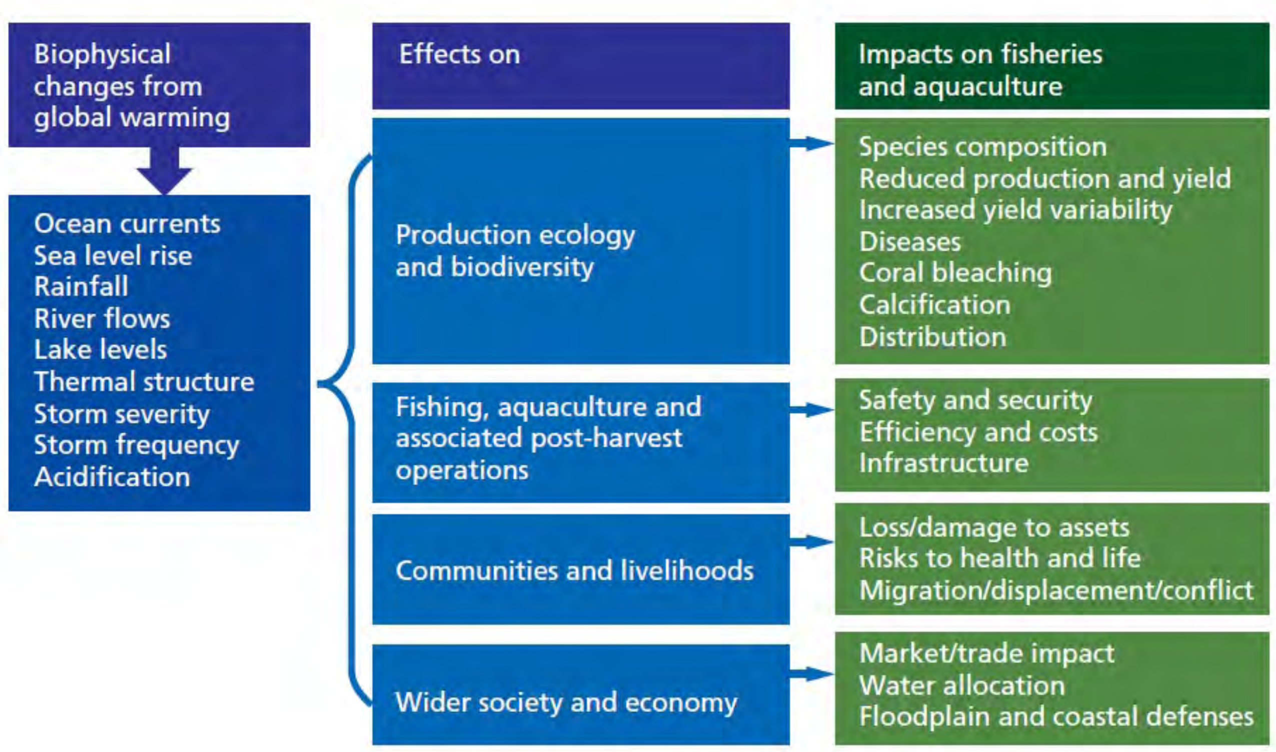
C 2.3 CLIMATE CHANGE AND FISHERIES / AQUACULTURE

Over 500 million people in the world depend, directly or indirectly on fisheries and aquaculture to earn their livelihoods. Around 3 billion people in the world get their essential nutrition from fish. In the poorest countries of world, around 400 million people get 50% of the animal protein and essential minerals from fish. However this important source of human nutrition and livelihoods is facing some major challenges including the climate change. Climate change (frequency and intensity of storms increase and extreme weather events become more frequent) is exerting great pressure on the fisheries sector which is already in crises due to over fishing and poor production management. Due to frequent extreme weather events the fishers are also at risk of losing means to catch fish such as boats, nets and other infrastructure. Climate change is impacting current and future production levels and employment in the fisheries industry. The anticipated physical and chemical changes in the oceans and fresh water bodies are having profound impact on yield and biodiversity of the fisheries and associated living organisms. Warmer seawater holds less oxygen leading to hypoxia (inadequate oxygen). Under higher CO_2 concentrations the seawater will absorb higher amounts of carbon dioxide and become more acidic which will impact aquatic biodiversity.

Physiological and behavioral processes of fish and the organisms they feed on will also be affected. There is increasing evidence that global warming is already modifying the distribution of marine species. Warm water species are being displaced towards the poles and experiencing changes in their size and the productivity of their habitats. Rising sea levels will also impact fisheries and aquaculture. The increased variability in rainfall patterns as well as changes in air and water temperatures will also severely

impact freshwater fisheries and aquaculture with decline in the productivity of rivers, lakes and other fresh water sources.

Figure 2.5: Climate variability and change impact pathways in fisheries and aquaculture



Source: Badjeck et al., (2010)

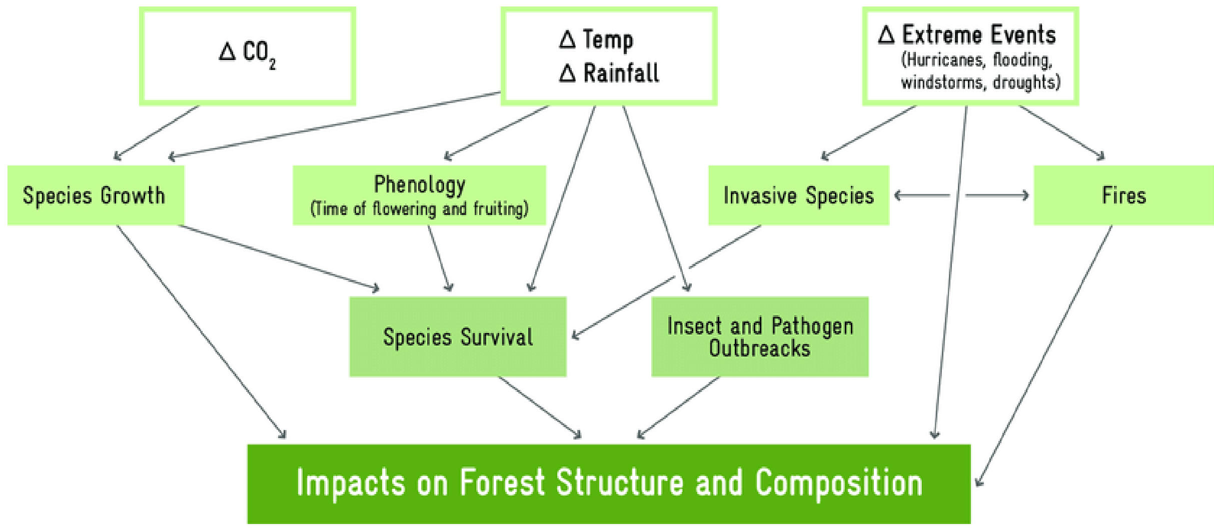
Climate change does not only impact the production of ocean and fresh water fisheries but also impacts the postharvest activities and supply chain by affecting supply and distribution channels and key inputs such as energy and water for processing. Fishing strategies in climate change scenarios may require transformation to more technologically productive means which may not be commercially viable for a vast majority of poor fishermen across the globe. This will further make them vulnerable to climate change as they will not be able to compete with corporate giants in fishing industry.

C 2.4 CLIMATE CHANGE AND FORESTRY

About 1.6 billion people in the world directly or indirectly depend on forests for various goods (wood and non-wood) and ecosystem services (Brack, 2018). Forests are an important natural resource for these people, particularly for those who live in rural areas. Forests help to stabilize the climate, produce oxygen and mitigate CO_2, ensure clean and sustainable water supply, regulate ecosystems and protect biodiversity, protect land from degradation and soil erosion, provide timber, fuel wood, food and habitat for wildlife. To maximize the climate benefits of forests, we must keep more forest landscapes intact, manage them more sustainably and restore more of those landscapes which we have lost. Restoring 350 million ha of degraded land in line with the Bonn Challenge could sequester up to 1.7 giga tons of CO_2 equivalents annually. According to scientists if forest degradation is stopped and forest ecosystems are restored then forestry sector has the potential of 1/3rd of the total climate change mitigation that is required by 2030 to meet the objectives of the Paris Agreement.

It is evident that climate change, in many places of the world, is contributing to a decline in the productivity of trees, dieback of trees from drought and temperature stress, increased frequency of forest fires, landslides and avalanches, increased storm damage, increased wind and water erosion, inundation and flood damage, saltwater intrusion and sea-level rise, pest and disease outbreaks and changes in the composition of plants and animals which are dependent on forest ecosystems (Braatz, 2012). About 1 billion, out of the 1.6 billion people relying on forests for their livelihoods, live under extreme poverty. Changing climates and subsequent forest degradation will severely impact the livelihoods of these people. They will be hit the hardest by climate change and will be more vulnerable. As forests play a very crucial role in maintaining the biological diversity of the various ecosystems (forests are home to about 80% of the world's terrestrial biodiversity), it is very difficult and often impossible to recover the biodiversity once it is eroded. It means that a threat to forests is an ultimate threat to the very existence of many living organisms dependent on forest for there survival.

Figure 2.6: Climate change impacts on forests



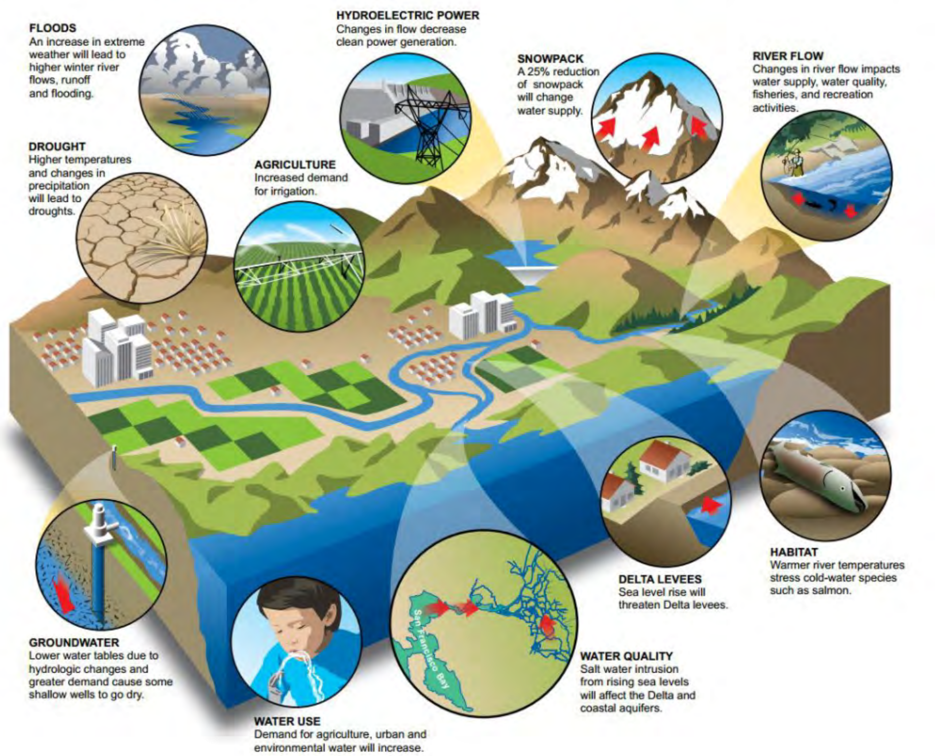
Source: Hergarten, Liagre, & Froede-Thierfelder (2013)

Forest area in Pakistan is 4.19 million ha, representing 5% of the total land area. Coastal mangrove forests in the Indus Delta extend over 132,000 ha, representing about 3% of the forest area of Pakistan. About 135,000 people in the Indus Delta depend on these mangrove forests to earn their livelihoods. Climate change is likely to have adverse effects on the already vulnerable forestry sector in Pakistan. The most likely impacts will be reduced forest area, decreased productivity, changes in species composition, loss of biodiversity, higher flood risks, increased silting in dams etc.

C 2.5 CLIMATE CHANGE AND WATER

Climate change will greatly impact the water sector which will then cause problems for many other sectors such as agriculture, health, industries and urban development. However, the worst impacts of disturbance in water sector will be on the agriculture sector. One of the concerns of climate change is that the global warming will lead to an increase in melting of the snow and ice from glaciers increasing the amount of water in the rivers. However this increase in river flows will be only short term followed by a long term permanent decline in the river flows due to less snow available on glaciers. This is a major concern for scientists and policy makers in Pakistan because our Indus basin derivers major chunk of its flow from these glaciers. In the sub-tropical regions climate change will likely lead to reduced rainfall, further stressing water availability in these already dry areas. Thus the overall effect of climate change on water resources is an intensification of the water cycle that will cause more extreme floods and droughts regionally and globally.

Figure 2.7: Climate change impacts on water



Source: https://unfccc.int/sites/default/files/demuth.pdf

Pakistan has the world's largest canal system (Indus Basin Irrigation System) which depends on precipitation, glaciers, snow melt and ground water pumping. Agriculture sector has lions share in the total water consumption (92%) followed by domestic and infrastructure (5%) and industrial sector (2%) (Chaudhry, 2017). The growing population demands more food but with our traditional crop production practices we need more water to produce the extra amount of food for growing population. This will be jeopardized by increasing competition among the sectors (agriculture, industries, domestic and infrastructure) for water and the diminishing water resources due to climate change. The situation in future will become more complex because Pakistan is among the most water stressed countries of the world. The annual per capita water availability has decreased from 5140 cubic meters in 1950 to 850 cubic meters in 2016 (Young et al., 2019). Pakistan is rapidly approaching to the status of water scarce country according to water scarcity indicators (Table 2.6). The situation demands immediate attention by government and subsequent rapid development and management of water resources on a war footing.

Table 2.6: Water scarcity indicators

S. No.	Water availability (m3/capita/year)	Status
1	<1700	Water stress
2	<1000	Water scarcity
3	<500	Water famine

Source: Falkenmark, Lundqvist, & Widstrand (1989)

The rising temperatures, rapid melting of glaciers, more intense rainfall, changes in monsoon and winter rainfall patterns, an increased threat of glacier lake outburst floods, flash floods, decreasing river flows and increasing saltwater intrusion in coastal areas are few of the ways in which climate change is expected to affect Pakistan's water resources. As discussed above the Indus River System (IRS) of Pakistan gives rise to the largest canal irrigation system in the world. The IRS derives its major chunk of water primarily from snow and ice melt in the Hindu Kush-Karakoram Himalaya Mountains. The rapid melting of glaciers, causing long term reduction in water flow in the Indus basin, will have significant implications for food security in Pakistan because 90 % of the total agricultural production in Pakistan occurs on arable land supported by the Indus Basin irrigation system. In Pakistan the present shortfall of water is about 20 MAF which is estimated to rise to 31 MAF by the 2025. This will greatly stress the agricultural production in the country.

C 2.6 CLIMATE CHANGE AND SOIL

Climate change can have a tremendous impact on soils and their functions. Due to climate change their will be more soil erosion, salinization and desertification. All these processes lead to land degradation which will ultimately impact the capability of soils to support agricultural production. Bullock (2005) summarized some of the impacts of climate change on soils as discussed below.

In climate change scenarios the soil water contents (soil moisture) will be influenced by precipitation (rainfall, snowfall), evaporation and transpiration (due to higher temperatures and enhanced CO_2 levels), different plant growth rates, climate change induced changes in vegetation and different rates of soil-water extraction.

Air and soil temperatures have close correlation. An increase in air temperature leads to increased soil temperature and vice versa. Warmer soil temperatures will lead to increased microbiological activity, rapid decomposition of organic matter, quicker release of nutrients and increased rates of nitrification.

Soil organic matter is a major pool of carbon in the biosphere, estimated at about 1500 Gt of carbon (dou ble than that is in the atmosphere at present). So increased organic matter decomposition will result in release of tremendous amounts of CO_2 to environment causing global temperatures to rise considerably.

The structure of the soil (the way in which the soil particles combine together) affects the movement of gases, water, nutrients, soil fauna, and the germination of seeds and emergence of crops. Soil structure is greatly influenced by soil organic matter and under climate change scenarios a decline in soil organic matter level will lead to a decrease in soil aggregate stability, increased compaction, lower water infiltration rates, increased surface runoff and an increased susceptibility to erosion.

Soil flora and fauna play a vital role in organic matter decomposition, nutrient retention and soil porosity. As soil flora and fauna have a wide optimum range for various temperature regimes, so they may not directly be impacted by climate change. However the change in ecosystems and migration of vegetation zones may affect them considerably.

With significant increase in rainfall there will be an increase in soil acidification (depending on the buffering pools available in soil), leaching and nutrient loss. With decrease in rainfall under warmer and more evaporative regimes soil salinization will become a major risk.

Increasing urbanization, clearing of forests for agricultural production, climatic variations and extreme weather events all are responsible for increased land degradation. Soil erosion and desertification are two important land degradation phenomena. The erratic rains, flash floods, intense storms and droughts are some of the major factors causing soil erosion. Desertification is caused by human and natural factors such as rapid urbanization, water scarcity, overstocking, over cultivation and deforestation.

The accumulation of salts in soil negatively affects soil properties and plant growth. Soil salinization leads to degradation of soil structure, reduction in porosity and impacts negatively nutrient dynamics and nutrient-holding capacity. Soil salinity ultimately leads to a decline in crop productivity and even can cause land to become unsuitable for agricultural production. The higher temperatures due to climate change will result in more evaporation of water from soil surface, leaving behind the salts. The sea level rise will also increase soil salinity in the coastal areas due to salt water intrusion.

Soils provide water, nutrients and growing medium to plants. One of the most important functions of soils is their use for agricultural production and food security. The physical, chemical and biological properties of soils in addition to the climatic factors govern the type of crops grown in an area and their productivity. Changes in air and soil temperatures and rainfall will impact days to maturity and harvesting of crops. The increased land degradation (soil erosion, salinization and desertification) will hamper crop productivity as the soils cannot sufficiently provide essential nutrients, moisture and other conditions for proper crop growth. The changes in soil functions due to climate change are likely to be reflected in the form of change in entire ecosystems. However, the degree of change will depend on the level of warming and change in precipitation.

Figure 2.8: Impacts of climate change and other factors on soils; consequences and the sustainable soil management solution

Source: FAO (2015)

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MODULE 3

CLIMATE SMART AGRICULTURE (CSA)

OVERVIEW OF THE MODULE

In this module some basic knowledge of the climate smart agriculture (CSA) concept and its relation to adaptation, mitigation and ensuring food security will be discussed. The concept of landscape approach will also be presented and how the landscape approach is important for global agriculture transformation. In the final section of the module, some salient practices of climate smart agriculture that are relevant to our local agricultural conditions will be presented.

OBJECTIVES

1. Understand the concept of Climate Smart Agriculture (CSA)
2. Explain why CSA is necessary to meet sustainable development goals
3. Understand the basics of landscape approach
4. Understand why the landscape approach is needed to transform agro-ecosystems in changing climates
5. Identify the salient CSA practices
6. Select CSA practices relevant to their agro-ecologies
7. Identify CSA practices from unsustainable agricultural practices on the basis of integration of adaptation, mitigation and food security objectives

KEY QUESTIONS

1. What is Climate Smart Agriculture (CSA)?
2. What are the three pillars of CSA?
3. How will CSA ensure food security?
4. How CSA addresses key problems of agriculture in a changing world?
5. What is Landscape Approach?
6. How CSA integrates to Landscape Approach?
7. Which salient CSA practices and technologies are relevant to Pakistan?

KEY DEFINITIONS: (IPCC 2018)

ADAPTATION: In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.

ADAPTIVE CAPACITY: The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

CARBON SEQUESTRATION: The process of storing carbon in a carbon pool.

FOOD SECURITY: A situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life

MITIGATION (OF CLIMATE CHANGE): A human intervention to reduce emissions or enhance the sinks of greenhouse gases.

RESILIENCE: The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation.

SINK: A reservoir (natural or human, in soil, ocean, and plants) where a greenhouse gas, an aerosol or a precursor of a greenhouse gas is stored.

SECTION A

CLIMATE SMART AGRICULTURE-AN INTRODUCTION

A 3.1 MEETING THE INTERTWINED CHALLENGES OF FOOD SECURITY AND CLIMATE CHANGE

Climate Change, coupled with ever increasing population and demand for food, is among the top and most urgent issues of the 21st century. Maintaining agricultural production in changing climates at a level that can meet the food demand remains a constant challenge particularly when food security is increasingly being disrupted by extreme weather events over the past few decades. Pakistan, being an agro-based economy that largely depends on domestic food production to sustain is hugely impacted by these abruptly changing climates. Agriculture is not only suffering by climate change but also a major cause to it due to GHG emissions from crop and livestock sub-sectors. To adapt agriculture to changing climates at a level that ensures food security while reducing emissions from its sub-sectors (crops and Livestock) is one of the major challenges. To meet the growing challenges of food security in changing climates, developing countries like Pakistan must adapt to these environmental challenges.

A 3.2 CLIMATE SMART AGRICULTURE CONCEPT

To come up with these intertwined challenges, the Food and Agriculture Organization (FAO) introduced the concept of “Climate Smart Agriculture” (FAO 2010a). Climate Smart Agriculture is a holistic agriculture production and management system that adapts to a changing climate, mitigates environmental impacts and ensures food security for an ever growing world population. It focuses on reorientation and transformation of agricultural systems to sustainably ensure food security in changing climates. CSA is not a technology or practice that is universally applied for agricultural production, rather it is an approach that requires locality or region specific assessments and proposes sustainable actions considering economic, social and environmental dimensions.

A CSA model for any specific location is the integrated landscape approach that is based on rational management and utilization of natural resources in an ecosystem. The recommended CSA approach for any region aims to improve livelihood options especially for smallholders through enhanced capabilities to rationally utilize the available resources such as quality seeds, fertilizers, pastures and livestock feed, land, water and energy; and manage tactfully the production, post-harvest and marketing practices. It also aims to enhance the adaptive capacity of farmers to climate change, decrease pressure on scarce resources and reduce GHG emissions.

A 3.3 THREE PILLARS OF CSA

According to the FAO (2010a) CSA has three pillars;

1. Adaptation; adapting agriculture to climate change and building resilience in it
2. Mitigation; reducing greenhouse gas emissions to possible levels from agriculture sector
3. Food security; increasing agricultural productivity and income sustainably

These are not only the three pillars but are also the core objectives of climate-smart agriculture.

A 3.4 HISTORIC OVERVIEW OF CSA

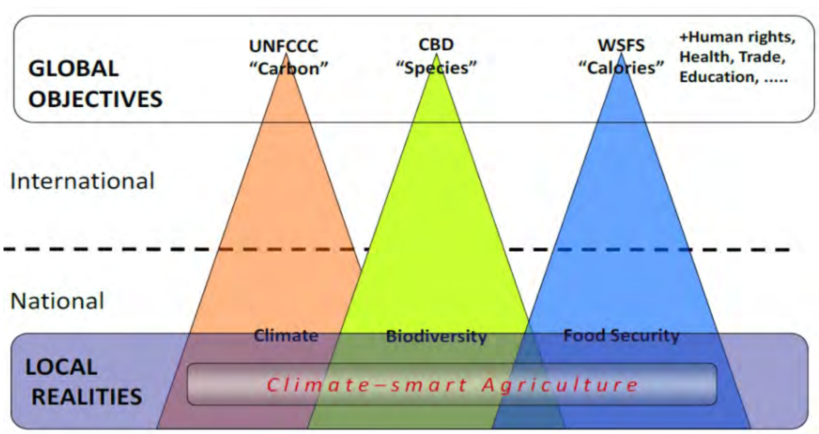
- The initial concept of the agricultural adaptation, mitigation and food security (CSA) was presented by FAO in a report "Food Security and Agricultural Mitigation in Developing Countries: Options for Capturing Synergies" at the Barcelona Climate Change Conference in November 2009.
- In October 2010, FAO presented a paper "Climate-Smart" Agriculture, Policies, Practices and Financing for Food Security, Adaptation and Mitigation at the Hague Conference on Agriculture, Food Security and Climate Change.
- To strengthen the CSA concept backed by science a series of "CSA Science Conferences" was held. The first global CSA Science Conference was held at Wageningen, Netherland in 2011, the second at University of California at Davis (USA) in 2013 and the third at CIRAD Montpelier (France) in 2015.
- Global Alliance on Climate Smart Agriculture (GACSA) was launched in September, 2014 (as outcome proposal of the CSA Science Conference) to bridge the science and policy gap by focusing on three key areas;
    - knowledge
    - enabling environment
    - investments

Memberships in GACSA may include intergovernmental organizations (including UN entities), governments, non-government organizations, organizations of farmers, fishers and foresters, private sector organizations, research/ extension/ education organizations and financing institutions (Lipper & Zilberman, 2018). As of March 2020 the GACSA has 345 members.

A 3.5 WHY CSA PRACTICED LOCALLY IS IMPORTANT GLOBALLY?

Some people may question why there is too much focus on CSA in the world and why global bodies are pushing for CSA adoption. Even farmers may question about the impacts of CSA practices they are being advised by experts. The localization of CSA practices from crops, livestock, fisheries and forestry sectors contribute to meet the global objectives. Reduction in GHGs helps meeting the objectives of UNFCCC (United Nations Framework on Climate Change) and adaptation to climate change meets the objectives of CBD (the Convention on Biological Diversity). Similarly, ensuring food security helps meeting the objectives of WSFS (World Summit on Food Security). However, meeting all these global objectives requires that we attain a sustainable local landscape as the first step.

Figure 3.1: How CSA practice locally meets the global objectives of sustainable development



Source: Holmgren (2012)

A 3.6 LANDSCAPE APPROACH IS NEEDED FOR CSA

With increasing population and food insecurity massive ecosystem destruction is becoming inevitable. For example the clearance of forests for food production is creating a collision between agriculture and the environment. There is no sustainable solution to meet the human needs and conserve nature and biodiversity together. The sustainability of agriculture, forestry and fisheries depend upon the healthy ecosystems which depend upon people centered participatory approaches. One such approach is the 'Landscape Approach'. Landscape approach is a set of tools, methods and strategies that aim to optimize and protect the shared social, economic and environmental interests of all the stakeholders in a given environment. The approach puts human wellbeing and needs, particularly of the concerned farmers and their socio-cultural values, at the center of any land use decision making. All the objectives of collective wellbeing are met through multidisciplinary integration and coordination of stakeholders.

A 3.7 HOW LANDSCAPE APPROACH SUPPORTS CSA?

The base of landscape approach is a good natural resource management system that accepts the value of ecosystem services to stakeholders. Climate smart agriculture has multiple objectives that can be met through adopting a proper landscape approach. There are various examples of landscape approach that not only enhance food production but also protect the environment and also support the objectives of the climate smart agriculture. Examples may include organic agriculture (Sandhu, Wratten, & Cullen, 2010), agroforestry (José, 2009), conservation agriculture (Kassam, Friedrich, Shaxson, & Pretty, 2009), sustainable crop production intensification (FAO, 2010b) and integrated crop-livestock management (Russelle, Entz, & Franzluebbers, 2007).

Figure 3.2: Sustainable vs unsustainable practices/phenomenon related to agriculture

Source: The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2018)

SECTION B

PRACTICES AND TECHNOLOGIES THAT CAN BE PROMOTED UNDER CLIMATE SMART AGRICULTURE

As discussed previously, there are no universal or uniform model of CSA practices that could be applied to all locations and ecologies all over the world. Instead CSA approach lays stress on identification and assessment of local agricultural problems and their solutions through an integrated landscape approach. Thus it is imperative to find solutions of agricultural problems related to climate change and natural resource management in local context. Here are the salient agricultural practices and technologies that are relevant to Pakistan's context and may have potential adaptation, mitigation and food security features.

Table 3.1: Salient CSA Practices/Approaches/Technologies Relevant to Agriculture Sectors in Pakistan

S. No.	Practices/Approaches/Techno logies
Relevant to Crop Production	
1	Crop Diversification
2	Crop Rotations
3	Stress Tolerant Crops
4	Low Delta Crops
5	Residue Management and Conservation Tillage
6	Organic Kitchen Gardening
7	Integrated Pest Management
Relevant to Animal Production	
1	Stress Tolerant Animal Breeds
2	Manure Management
Relevant to Mixed Farming	
1	Enterprise Diversification
Relevant to Sustainable Resource Management	
1	Sustainable Intensification
2	Agricultural Production on Sloppy and Barren Lands
3	High Efficiency Irrigation Systems
4	Alternate Energy
Relevant to Farmer's Timely Action (Enabling Environment)	
1	Climate Information Services

B 3.1: CROP DIVERSIFICATION

Two major challenges faced by a farm enterprise are climate variability and market uncertainties. Crop diversification helps meeting both challenges. It is a cost effective methodology that even smallholder farmers can easily manage. Increasing genetic diversity on the farm through different varieties of the same crop and multiple species reduce certain risks such as adverse weather conditions, diseases and insects, market uncertainties and risks related to mono-cropping. It is because the genetic diversity of crops allows that some varieties may be suited to shifts in temperature, precipitation and other climatic regimes or phenomenon related to climate change (Scherr, Shames, & Friedman, 2012).

Diversity of crops promotes natural enemies of many pests. Similarly, there are many mechanisms through which many disease cycles, that are common in monocultures, break in a diversified cropping pattern. This leads to a reduction in the incidence of various diseases. Crop diversification also leads to sustainable production in extremely variable climate because each variety and species respond differently to climatic extremes (Lin 2011; Roesch-McNally, Arbuckle, & Tyndall, 2018). The decreased level of pests and diseases indicate healthy and quality crops, higher yields while leading to reduced use of pesticides which significantly decreases the cost of production.

Figure 3.3: Crop diversification

Source: Living Field (2018), *reproduced with permission*

B 3.2: CROP ROTATION

Crop rotation is an important adaptation tool to tackle climate change at farm level that have positive impacts on the whole ecosystem. Crop rotation helps in soil carbon sequestration, increasing soil organic matter content, nutrient cycling, improving soil microbial activity and thus soil fertility, improving water holding capacity of soils and suppressing weeds, insects and diseases. This not only leads to healthy soils and ecosystem but also yields are increased. This way crop rotations help in fulfilling the objectives of CSA through a well-planned and adapted pathway which makes agricultural systems more resilient. It has been reported that through a proper long term crop rotation a farmer can earn higher net returns while the practice might significantly lower the GHG emissions (Meyer-Aurich, Weersink, Janovicek, & Deen, 2006). Thus crop rotation is an important adaptation and mitigation tool that not only improves yields but also reduces GHG emissions from the crop production. However, the mentioned benefits of crop rotation can only be reaped when it is practiced properly and on the basis of some scientific principles such as;

- shallow rooted crops should be followed be deep rooted crops
- tap root crops should be followed by fibrous root crops
- exhaustive crops (wheat, maize, sugarcane etc.) should be followed by replenishing crops (legumes; nitrogen fixing crops)
- location of same family annual crops (particularly solanaceous vegetables-tomato, chillies, brinjal, potato) should be changed/rotated each year
- break weed, disease and insect cycles by planting different crops in different locations
- always plan some green manure and other crops in the rotation that produce large amount of biomass to be incorporated in the soil to increase soil organic matter content.

Figure 3.4: Example of poor vs. good rotations

Source: Pittman and Flessner (n.d.)

B 3.3: STRESS TOLERANT CROPS

If varieties with multiple objectives of adaptation, mitigation and ensuring food security are developed, then farmers will have a window of opportunity to select varieties which best suit their prevailing conditions or any unseen variability. Thus potential varieties to meet CSA objectives should have combination of some of the following traits;

- tolerant to high temperatures
- tolerant to high salinity levels
- resist water logging/flooding conditions
- tolerate high CO_2 levels coupled with higher temperatures
- can tolerate rain fed and water deficit conditions
- can mature faster when considered for rainfed areas to avoid sensitive growth stages (pollination, fruit setting and growth) being impacted by high temperatures and water stress
- adjustable to different cropping calendars
- can withstand higher insect pest populations
- can resist existing and emerging new diseases

However, it should be kept in mind that fast maturing varieties are possible adaptation measures for rainfed areas which face higher temperatures and water scarcity conditions at critical growth stages. For areas having ample water and no such stress the reverse strategy, the longer maturing varieties, will work better because warmer weather may speed up the growth and development and thus early maturity which will result in lower yields (Burke & Lobell, 2010). The development of water efficient cultivars with ample heat tolerance will be a great hope in combating climate change (Trethowan, Turner, & Chattha, 2010)

Table 3.2: Some potential crop varieties with stress tolerant traits in Pakistan

Variety	Trait	Agro-ecology	Approximate Area Under Cultivation (Acres)
Wheat			
Chakwal-50	Drought tolerance	Rainfed areas of Punjab	850,000
NARC-2009	Drought tolerance		170,000
BARS-2009	Drought tolerance		34,000
Uqab-2000	Drought tolerance		85,000
FSD-08	Drought tolerance		5,080,000
Dharabi-11	Drought tolerance		340,000
Pakistan-13	Drought tolerance		340,000
Borlaug-16	Drought tolerance		New Release
Fatehjang-16	Drought tolerance		New Release
Shahkar-CCRI	Drought tolerance	Rainfed areas of Khyber Pakhtunkhwa	183,000
NIFA-Lalma	Drought tolerance		915,000
Pakhtunkhwa-15	Drought tolerance		36,600
Pirsabak-15	Drought tolerance		36,600
Shafaq	Heat tolerance	Southern Punjab	36,000
Farid-06	Heat tolerance		340,000
Seher-06	Heat tolerance	Central & Southern Punjab	2,540,000
SKD-1	Heat tolerance	Sindh	4,132,000
TD-1	Heat tolerance		1,240,000
Chickpea			
Thal-2006	Drought tolerance	Thal ecology	200,000
Bhakkar-2011	Drought tolerance	Thal ecology	
Lentil			
Markaz-09	Drought tolerance	Pothowar region of Punjab	10,000
Oilseeds			
PARC Canola Hybrid	Frost tolerance	Pothowar region of Punjab	10,000
Khanpur Raya	Drought tolerance	Southern Punjab area	10,000
Maize			
Fakhar-e-NARC Hybrid	Drought tolerance	ICT, KP, AJ&K, GB	1,500
Haq Nawaz Gold	Drought tolerance	Rainfed areas of Punjab	1,500
Islamabad White	Drought tolerance		New Release

Courtesy Dr. Bashir Ahmed, Climate, Energy and Water Research Institute, National Agricultural Research Center, Islamabad

B 3.4: LOW DELTA CROPS

Rainfed areas of Pakistan face the major problem of water insecurity like other rainfed areas across the globe. The crops that need comparatively less amount of water from sowing to harvesting are called low delta crops. The promotion of low delta crops is a much needed cropping strategy for rainfed agro- ecologies to combat climate change. There is need to effectively communicate and demonstrate potential low delta crops to local farming communities so that they can be envisioned to effectively adapt them. Thus the adoption of low delta crops is an important adaptation measure in rainfed ecosystems that secures food production and also has good mitigation potential as most of these crops have low input requirements. Some potential drought tolerant crops that have comparatively less water requirements are sorghum, millet, sesame, pulses, quinoa, sweet potato, okra, eggplant, watermelon, tamarind, date-palm, fig, grapes, pomegranates, pistachio, olives etc.

Figure 3.5: Pearl millet: a potential low delta crop for rain fed agro-ecologies

Source: Pixabay (n.d.)

Figure 3.6 : Quinoa is potential climate smart crop

Source; International Center for Biosaline Agriculture (n.d.)

Figure 3.7 : Sweet potato, a potential low delta vegetable crop

Source: istockphoto (n.d.)

Figure 3.8 : Date palm, a potential low delta fruit crop

Source; International Center for Biosaline Agriculture (n.d.)

Figure 3.9: Olive growing very well in low water conditions of Balochistan

Courtesy Dr. Bashir Ahmed, Climate, Energy and Water Research Institute, National Agricultural Research Center, Islamabad

Figure 3.10: Pomegranate adapts very well to Agro-ecological conditions of Balochistan and grows very well under low irrigation regimes

Courtesy Mr. Ahmed Aziz Kurd, Senior Scientific Officer, Balochistan Agricultural Research and Development Center, Pakistan Agricultural Research Council, Quetta

Figure 3.11: Pistachio is a potential low delta crop and is becoming increasingly popular among fruit growers of Balochistan particularly in Mastung District

Courtesy Mr. Ahmed Aziz Kurd, Senior Scientific Officer, Balochistan Agricultural Research and Development Center, Pakistan Agricultural Research Council, Quetta

B 3.5: RESIDUE MANAGEMENT AND CONSERVATION TILLAGE

The major greenhouse gasses from the agriculture sector are CO_2, CH_4 and N_2O. Tillage exposes the organic matter to oxygen which is broken down to release carbon dioxide. The consumption of fossil fuels in tillage operations, planting and harvesting the produce and transportation of inputs and outputs also release CO_2. Intensive tillage has proved to be detrimental to soils and the environment because soils are more exposed to climatic factors such as intense rainfall and wind storms which cause soil erosion and environment degradation. To remedy the effects of intensive tillage on soils and environment conservation tillage is considered an alternate option. In conservation tillage there is minimal soil disturbance and seed is directly planted through some sort of seed drill in the residue of previous crop. Thus minimal tillage and incorporating crop residues to soils enhance their organic matter content, improves water holding capacity, support microbial activities and nutrient cycling.

Some potential benefits of conservation tillage mentioned by Coreil and Padgett (2012) are summarized below;

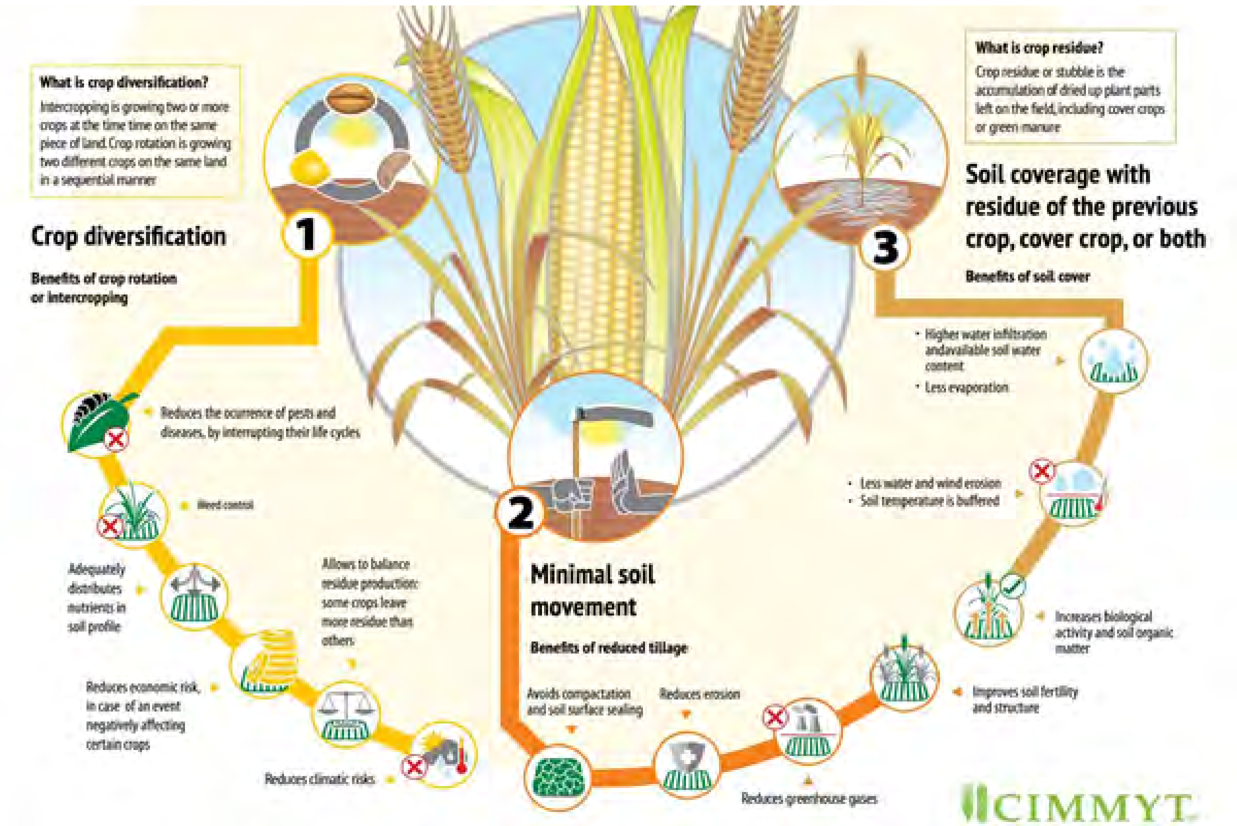
1. Significant reduction in overall energy usage
2. Yields are comparable with those from conventional tillage systems
3. Water holding capacity of the soils is increased thus less water stress to plants than conventional tillage systems
4. Harvesting conditions are better
5. Organic matter increases
6. Nutrient loss by run off decreases
7. Reduction in pesticide wastage because their off-site movement decreases
8. Creates a healthy environment for macro- and microorganisms
9. Maintains soil fertility and reduces soil erosion

Figure 3.12: Soybean cultivated on zero tillage fields

Source; Padgett, (2012)

The conservation tillage and residue management lays foundation of conservation agriculture which is a climate smart approach. Conservation agriculture has three basic principles; crop diversification, minimal soil disturbance and maximum soil cover.

Figure: 3.13 Conservation tillage and residue management forms the foundations of conservation agriculture



Source: Donovan, (2020)

B 3.6: ORGANIC KITCHEN GARDENING

Improving livelihoods of climate vulnerable communities is a challenging task. Organic kitchen gardening is a wonderful practice that not only improves livelihoods by provision of safe and fresh kitchen commodities to growers but also improves their economic resilience to market related supply chain problems and climate change. Moreover, the dependence of farming households and urban kitchen garden growers is reduced on markets for many of the fresh fruits, vegetables and herbs. The growers can utilize their own grown commodities at any time. Switching to organic farming and using non- synthetic inputs reduces farmer's cost on the inputs and increases soil carbon and nitrogen by 15-28% and 8-15% (Milder, Majanen, & Scherr, 2011). This will ensure food security and increase their resilience to climate change and market fluctuations. Some potential benefits of organic kitchen gardening are;

- It is a sort of physical exercise that improves mental and physical health
- It gives aesthetic satisfaction.
- It provides fresh, healthy, safe and nutritious vegetables, fruits and herbs
- It ensures accessibility and easy availability of grown commodities
- It reduces expenses on external buying of many fresh fruits, vegetables and herbs
- It improves chances to get balanced diets
- It reduces GHG emissions related to production and transportation of a considerable quantity of fresh commodities.

Thus kitchen gardening can be a potential adaptation to climate change that improves food security situation and reduces dependency of farmers and urban kitchen gardeners on markets to meet their fruit and vegetable demands to some extent.

Figure 3.14: A well planned demonstration kitchen garden at National Agricultural Research Center, Islamabad.

Source: Kitchen Gardening NARC, (2019).

Figure 3.15: Rooftop kitchen gardens in containers (grow bags in this image) can be an option for many urban residents who do not have enough space for kitchen gardens in their homes

Source: Rosete, (April 9, 2020)

B 3.7: INTEGRATED PEST MANAGEMENT

With the advent of modern agriculture farmers heavily relied on synthetic pesticides to control various pests. However, the indiscriminate use of pesticides further aggravated the problem and the solutions were only short term with no long term good. This is because the indiscriminate use of pesticides disrupt the life cycles and hence populations of beneficial insects and microorganisms (predators, parasitoids and pathogens) that feed on the harmful insects and cause diseases in them. The disruption of lifecycles of beneficial insects results in the heavy infestations of deadly crop pests. The infestations also become worse in case of mono-crop agricultural systems because specific crop pests increase their populations without major disruption by the diverse range of beneficial insects which are raised on different crops.

So instead of relying on single measure such as indiscriminate use of pesticides or growing same one crop year after year, some holistic and multifaceted approach is required that not only effectively controls insect pests but also reduces use of pesticides and associated environmental pollution. The reduction inpesticide usage will not only reduce the GHG emissions related to pesticide production, transportation and application but will also improve the biodiversity especially of many insect pollinators and bio-control agents. The increased population of pollinators will ultimately improve pollination mechanisms and bio-control agents will suppress the populations of pests leading to increased food productivity and food security.

This holistic approach that helps in fulfilling objectives of sustainable agricultural production is referred to as the "Integrated Pest Management (IPM)". IPM is defined as "a sustainable approach to managing pests that combines biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks". It is thus a systems approach that finds sustainable solutions to pest problems (Cuperus, Mulder, & Royer, 2000). The aim of IPM programs is to strive for keeping pest problems below the level of economic damages while maintaining profits and reducing environmental damages. Some of the key practices, technologies or approaches that may become part of a successful IPM system are briefly discussed below.

B 3.7A CULTURAL CONTROL

It is basically a preventive pest management and may disrupt life cycles of pests by cultural measures. It is the most economical measure that farmers can take. Practices may involve field sanitation, crop rotations, crop diversification, fertility management, adjustment of sowing/planting dates.

B 3.7B BIOLOGICAL CONTROL

It involves using biological agents (pathogens, predators, parasitoids, antagonists and competitors) to control pests. Bacillus thuringiensis (Bt), Saccharopolyspora spinosa (spinosad- a mixture of spinosyns A and D), lacewings, ladybird beetles and predatory wasps are examples of biocontrol agents.

B 3.7C CHEMICAL CONTROL

It involves chemicals (pesticides) to control pests. However in IPM systems pesticides are judiciously used. Chemical control may mostly involve synthetic pesticides (insecticides, fungicides, herbicides etc.) and sometimes the natural pesticides which may be naturally occurring minerals, plant extracts and microorganisms (e.g., neem oil and spinosad are insecticides while raw copper and sulfur are fungicides).

B 3.7D PHYSICAL AND MECHANICAL CONTROL

This control involves some physical and mechanical means such as tillage to bury or injure pests and destroy their colonies, screening and cleaning produce (particularly relevant to weed seeds), regulating temperatures (such as hot water and cold treatments for fruit fly control, ventilation for controlling stored grain pests and reducing humidity in greenhouses that may otherwise lead to higher insect pest and disease problems.

B 3.7E HOST PLANT RESISTANCE

It is heritable characteristic of plants (and animals) to resist the level of damage by pests (insects, weeds, pathogens etc.). Breeders always try to develop crop varieties that have higher level of resistance to specific insects and diseases.

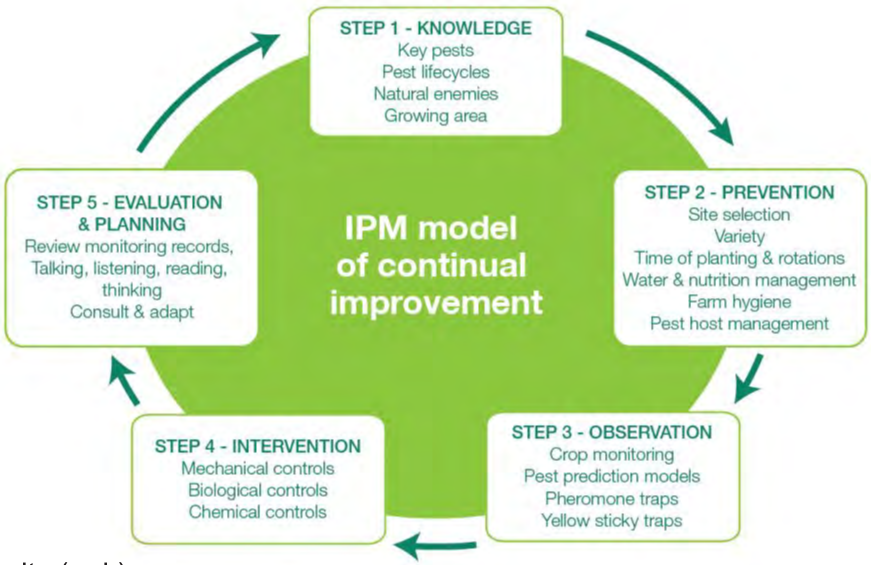
B 3.7F REPRODUCTIVE MANIPULATION

It involves sterilizing the males (Sterilized Insect Technique) and then releasing them in the pest populations and releasing lethal genes and mating disruption by pheromone traps.

B 3.7G REGULATORY CONTROL

It involves government level interventions such as plant quarantines and inspections. It is particularly important to restrict entry of new pests (insects, weeds, diseases) from entering the country through imports.

Figure 3.16: A schematic diagram of IPM model and how it works



Source: Farm Biosecurity (n.d.)

B 3.8: STRESS TOLERANT ANIMAL BREEDS

The animal breeds with good adaptive capacity to changing climates, low enteric fermentation emissions and retaining sustainable production will be instrumental for implementing successful climate smart agriculture in a region. The local livestock breeds in many regions of the world, although their productivity may be low, are adaptive to climate change regarding heat tolerance, disease resistance and nutritional requirements (Thornton et al., 2018). The adaptation to changing climates is one aspect of the potential livestock breeds. The other aspect that needs consideration is that the breeds should play important mitigation role i.e., the methane emissions from enteric fermentation should be low. Mainitainig higher productivity in animal breeds to meet food security is a constant challenge while adapting to climate change and reducing emissions. The challenge can be met by cross breeding the highly productive but sensitive breeds with local breeds that are tolerant to high temperatures, poor nutrition and resistant to parasites and diseases.

Figure 3.17: Our traditional animal breeds are adaptive to existing local conditions such as high temperatures, scarcity of water and fodders.

Source: Jailani (2015)

MODULE 3: CLIMATE SMART AGRICULTURE (CSA)

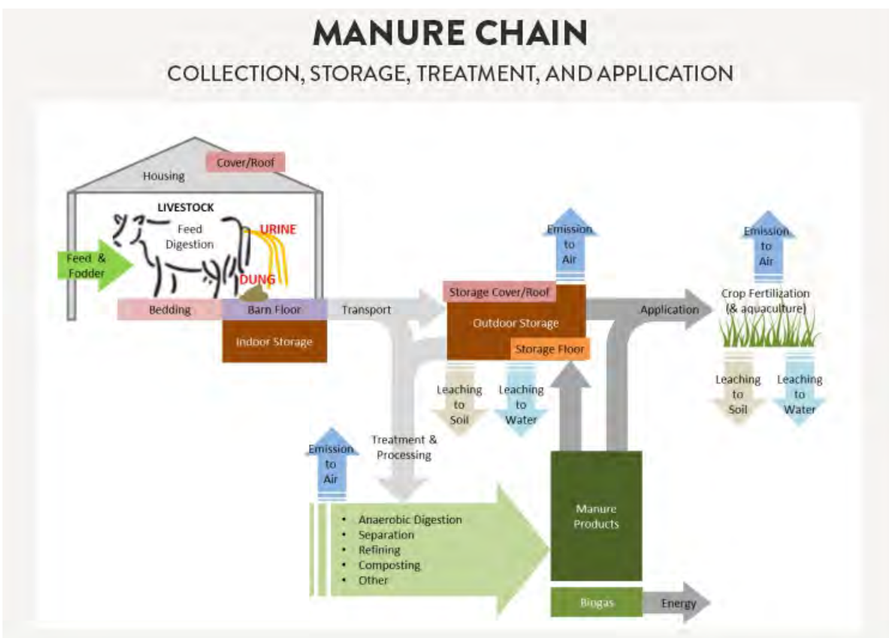
B 3.9: MANURE MANAGEMENT

Conventional manure has high GHG emissions because they release significant amounts of nitrous oxide and methane. The emissions from enteric fermentation and storage, can be reduced to a considerable amount if the manures are collected, stored, processed and applied in proper ways. Even if the diets of ruminants/livestock are improved or certain additives are added to the feed, the emissions can be reduced (FAO 2013). Methane emissions can also be reduced when;

(a) More concentrates are fed to the animal
(b) Oils added to the diet
(c) Protein intake is optimized
(d) Pasture quality is improved

If manure is properly composted or the heaps of stored manure are properly covered the emissions related to storage are reduced. Manure can even be used as a source of energy when anaerobically digested to release methane (Smith et al. 2008). It has been suggested that fossil fuels in local agro-processing industries may be replaced with methane from livestock wastes (Scherr et al., 2012). The rapid application and incorporation of manures in soil after transportation to field can also significantly reduce the emissions (FAO, 2013).

Figure 3.18: A schematic diagram of Manure Chain



Source: Climate and Clean Air Coalition (n.d.)

B 3.10: ENTERPRISE DIVERSIFICATION

Diversification is an important adaptation measure that develops resilience at farm, landscape and national levels to the climate change. Enterprise diversification includes the mixed farming practices where crops and livestock, crops and fisheries, crops and forests (agroforestry) or any other combination of these are practiced. Integration of crops, trees, fish and livestock make the base of agricultural enterprise diversification that not only reduces risks of market related failures but also increases the resilience of farming systems to climate change (FAO, 2013). With a diverse food and income sources such as crops, livestock and agroforestry the resilience to climatic and other shocks increases (Bernazzani, Bradley, & Opperman, 2012; Ureta, Martínez-Meyer, Perales, & Álvarez-Buylla 2012)
.

The crop and livestock farming is a well-integrated approach that ensures food security, increases farm resource utilization efficiency, reduces risks of failure associated with single enterprise and is more environmentally resilient. It also increases farmer's income which makes them economically sound to adjust to climate change shocks and reallocate their capital resources in case of any extreme events. The application of manures as fertilizers reduces the farmer's expenses on purchase of external synthetic or organic fertilizers while the use of crops, their byproducts and residues reduces farmer's investment on purchase of these feeding stuffs for their livestock. The consumption of cereals, fruits, vegetables, eggs, milk and meat from a well-integrated and model crop-livestock farming system helps in maintaining balanced diet for the farming households which improves their physical and mental health. This also ensures their food security while reducing their expenditure on buying many of the food commodities (Thornton et al., 2018).

Agroforestry involves cultivation of annual and perennial crops with trees on the same land. The crops are grown as main enterprise while trees are secondary source of income which not only provide wood (for fuel, furniture and timber) but also shade, fruits, medicines, honey and many other products. The trees not only generate oxygen but also become sinks for carbon dioxide and sequester carbon in tree biomass and soil. Agroforestry is a low input enterprise which uses less inputs (energy, fertilizer, pesticides etc.) but generates sustainable income. The trees of an agroforestry system also become strong wind barriers to storms that may potentially damage standing crops and cause premature fruit drop in orchards (Lin 2011). Agroforestry is thus a major climate-smart agriculture enterprise that has huge adaptation and mitigation potential along with sustainable production and maintaining healthy biodiversity.

Figure 3.19: Cattle, sheep and goat farming can become part of a successful enterprise diversification strategy for farmers in addition to agronomic and horticultural crops.

Source: Punjab Livestock & Dairy Development Board, (n.d.)

It's well said "don't put all your eggs in one basket". Crop diversifications can suppress pest out breaks as many crops become biotic barriers against new pests. So, enterprise diversification sequence focuses on a mix of possible enterprises such as crops (fruits, vegetables, cereals, legumes and fiber crops among others) livestock, fisheries and agroforestry etc.

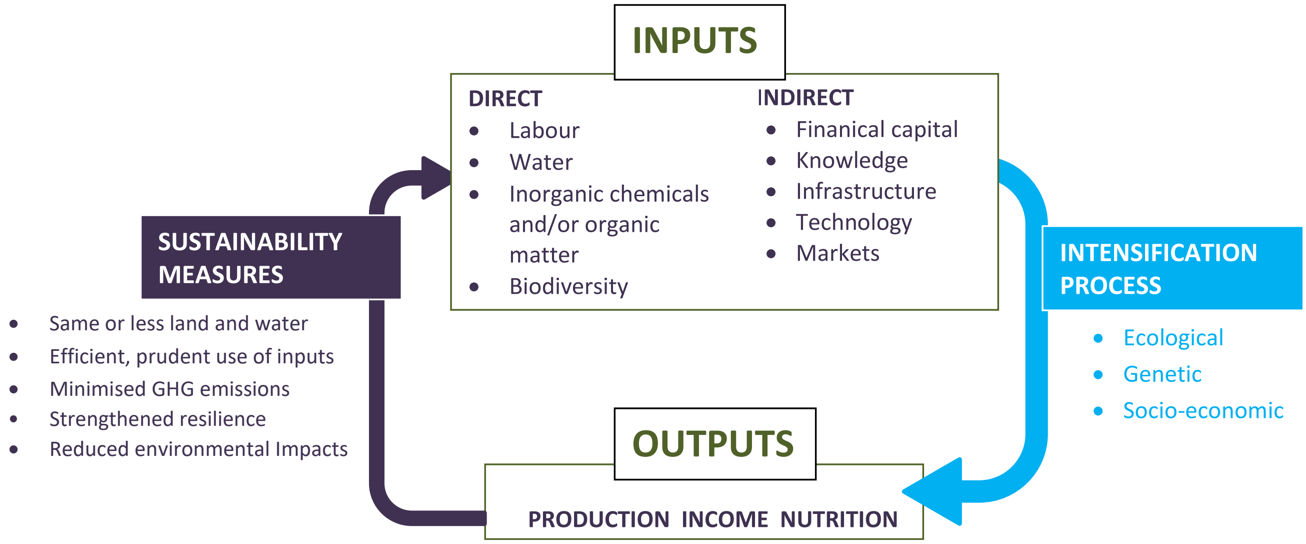
Figure 3.20: Horticultural crops can also be added to the diversification of enterprises

Source: Photo credits- Muneeb Ahmed Khan

B 3.11: SUSTAINABLE INTENSIFICATION

Sustainable intensification aims to increase the production from existing land resources without depleting natural resources and compromising the stability of agricultural landscapes. FAO considers it a save and grow approach (FAO, 2013). Sustainable intensification has 3 pillars including social intensification, ecological intensification and genetic intensification (The Montpellier Panel, 2013). The sustainable intensification works on the basis of ecosystem approach which focuses on conservation of natural resources and their contribution to agricultural production. For example sustainable intensification is achieved when a high yielding stress tolerant variety is given optimum external inputs and is grown under suitable natural conditions such as enough soil organic matter content, sufficient soil microbial activity, water balance, pollination and biological control. This not only produces sufficient high quality agricultural produce but also helps in preserving natural resources and biodiversity.

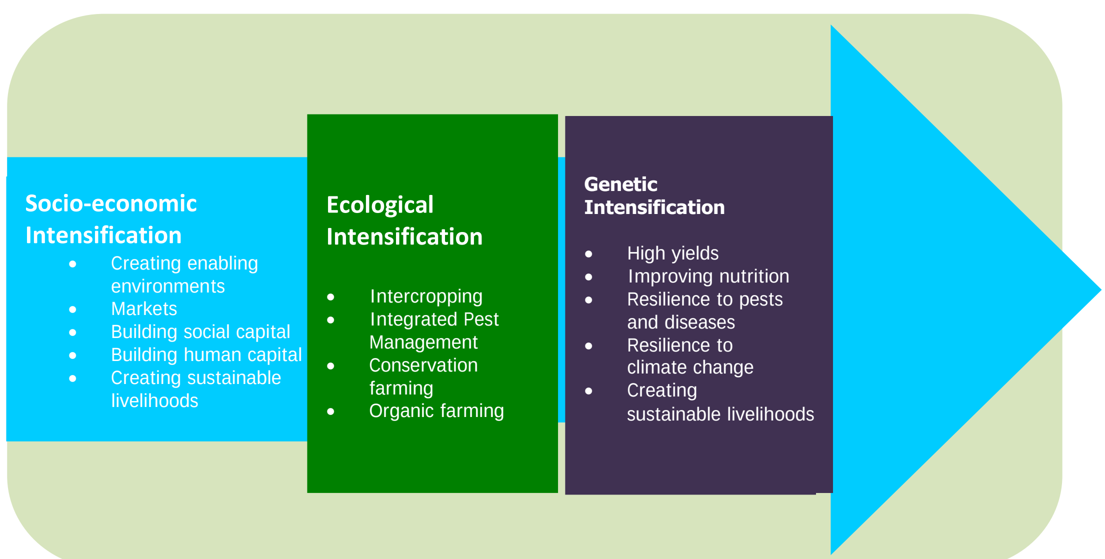
Figure 3.21: A schematic model of sustainable intensification



Source: The Montpellier Panel (2013)

When sufficient quantity, of high quality produce can be obtained sustainably from existing land resources then the need for further deforestation and conversion of forested lands for agricultural production reduces. Thus more sustainable intensification results in potential mitigation efforts. When resources are used efficiently the economy of farmers improves as their money is saved from being wasted on misuse of various inputs. The efficient use of resources also leads to minimum use of some particular inputs such as fertilizers, insecticides and herbicides. Thus through more sustainable intensification, ideally, the rational use of inputs and ecosystem services is attained which ultimately results in sustainable production with conservation of natural resources and biodiversity and reduction in GHG emissions from agriculture sector.

Figure 3.22: The practical approaches for achieving sustainable intensification.



Source: The Montpellier Panel (2013)

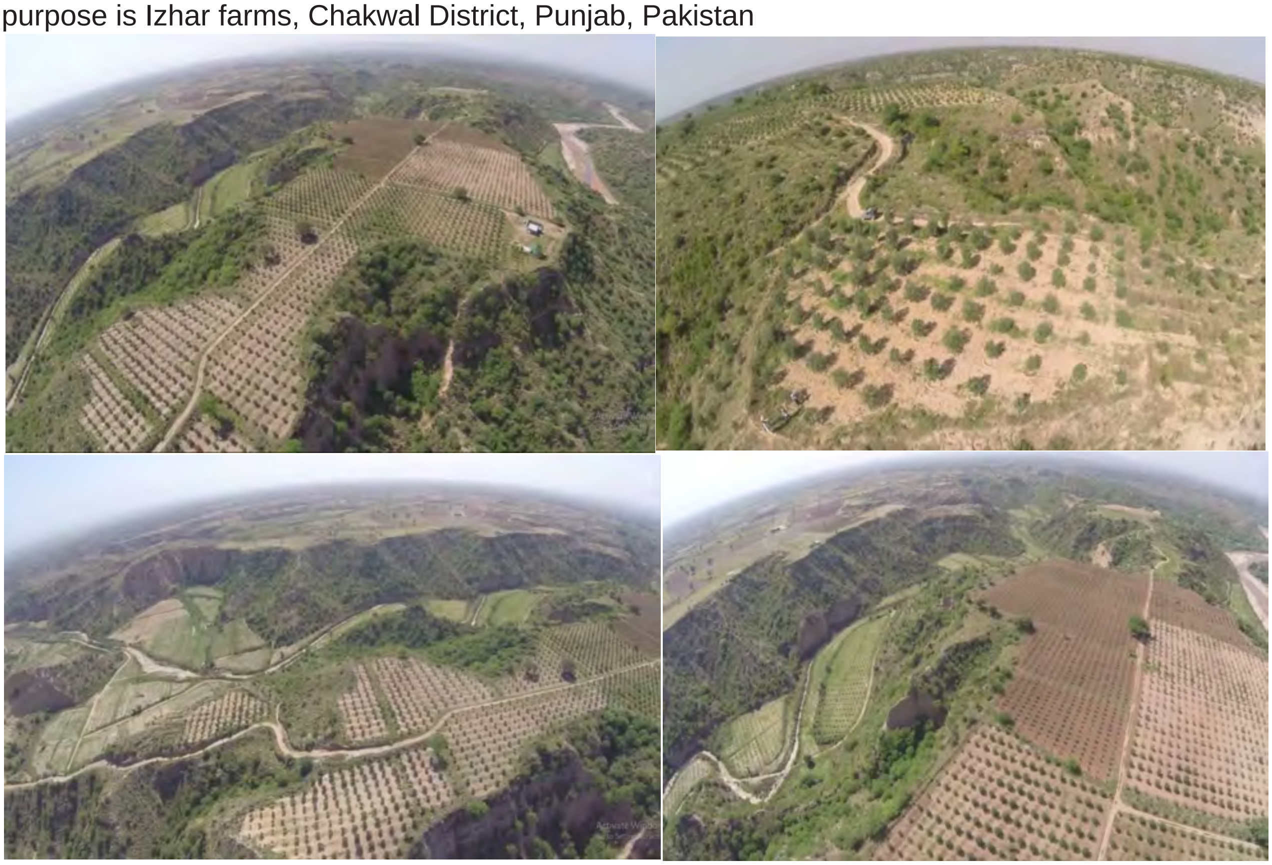
B 3.12: AGRICULTURAL PRODUCTION ON SLOPPY AND BARREN LANDS

Huge land area in the world is barren and uncultivated due to either lack of resources or mismanagement of natural resources. A major portion is sloppy or undulated. If there is no proper vegetation cover then these soils gradually become degraded due to wind and water erosion. According to FAO (2013) the degraded lands have the highest carbon sequestration potential. These can be managed effectively if due consideration is paid and resources are allocated for bringing them to production. The perennial plants such as fruit trees and forestry plants are more suitable for these lands because once planted they need no or little soil disturbance (as soil disturbance also releases the stored carbon in soil to atmosphere) and their roots go deep where they can sequester carbon. There will be need of proper land management practices to protect sloppy and degraded lands from further erosion. These practices may include;

- Contour farming (cultivating across the slope and not along the slope)
- Bunds to save water and erosion control
- Terrace farming
- Reducing degree and length of the slope

If a proper irrigation source is available nearby then some type of high efficiency irrigation system can be laid out to cultivate such lands for fruit production. For example a drip irrigation system can support with good results the fruit production on such lands. One of the best example of commercial olive production through drip irrigation system on sloppy areas and hills is Izhar Farm Chakwal. A model high efficiency irrigation system for levelled and sloppy areas is also present at PARC demonstration site in Fateh Jang. If fruit production is made possible on commercial lines on barren lands and sloppy areas then it will not only help in sustainable fruit production that will improve food security situation and farmers income but will also help in carbon sequestration which is a potential mitigation practice. Instead of opting for fruit plants that require more water and are sensitive to deficit irrigation regimes such fruit plants can be planted which are tolerant of low water conditions such as figs, grapes, date palm, loquat, olive, almond and pomegranate.

Figure 3.23: A good example of utilization of barren and sloppy land for agriculture purpose is Izhar farms, Chakwal District, Punjab, Pakistan



Source: https://youtu.be/KNsolbbZw-I

B 3.13: HIGH EFFICIENCY IRRIGATION SYSTEMS (HEIS)

One of the important climate smart measures that makes farmers climate resilient is improving water use efficiency and water management. It has been emphasized to consider it a priority investment for improving the livelihoods of climate vulnerable communities (Burney, Naylor, & Postel, 2013; Rockström & Falkenmark 2015). Flood irrigation systems have less efficiency and capability of effectively and uniformly irrigating diverse range of soils and topographies. Flood irrigation causes soil compaction and water logging in heavy soils which creates anaerobic conditions under which methane is produced, a potential GHG. Efficient irrigation technologies can transform barren lands and deserts to productive agricultural areas as we are witnessing an agricultural revolution in Cholistan desert of Pakistan with the establishment of fruit orchards on drip irrigation system.

High GHG emissions associated with conventional irrigation systems can be reduced by improving design and water delivery mechanisms. One potential opportunity lies in switching to the high efficiency irrigation systems such as sprinkler irrigation, drip or trickle irrigation (surface and sub-surface), bubbler irrigation etc. These systems not only save considerable amount of precious water but also are suited for almost all soil types and non-leveled surfaces. Some of the advantages of the HEIS are summarized below (Ayars, Bucks, Lamm, & Nakayama, 2007);

1. Saves water and reduce losses
2. Saving in fertilizers
3. Labor saving
4. Improved application of fertilizer and other chemicals
5. Increased water use efficiency
6. Improved uniformity in application
7. Improved crop yields
8. Improved crop quality
9. Reduced runoff and deep percolation
10. Weed problem is particularly reduced in drip irrigation because only the root zone is wetted around the plant base while the remaining surface is dry which does not support weed growth
11. Can be designed according to the needs and requirements of crops, diverse soil types and topographies.

Mostly the HEIS are pressurized systems and require energy for operation. The solar operated HEIS are getting common which are completely climate smart as they reduce GHGs (mitigation), are water saving (adaptation) and also increase yields (productivity and food security).

Figure 3.24: Different grapes varieties showing excellent growth and development on drip irrigation system in Balochistan

Courtesy Mr. Ahmed Aziz Kurd, Senior Scientific Officer, Balochistan Agricultural Research and Development Center, Pakistan Agricultural Research Council, Quetta

Figure 3.25: Fruit orchards on drip irrigation system in Cholistan desert

Courtesy Dr. Bashir Ahmed, National Agricultural Research Center, Islamabad.

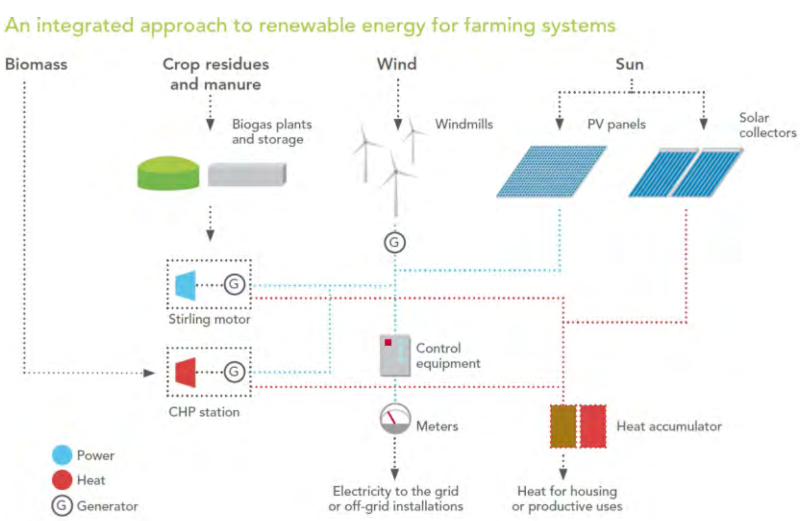
B 3.14: ALTERNATE ENERGY

To reduce the impacts of fossil fuel intensive farming systems switching to alternate energy sources is a valuable adaptation measure which promotes Energy Smart Foods. The adoption of energy smart food production systems has great adaptation and mitigation potential in changing climates. While switching to alternate energy may be costlier at the beginning it pays off in the long term both economically and environmentally.

A mix of alternate energy means can be used in the smart food systems. These may be planned and designed according to natural conditions of a location, skills available in the labor and prevailing infrastructure. Many alternate energy means can become part of the smart food systems such as wind mills, solar systems and biogas production units. These energy means can be utilized in operating water pumping and irrigation systems (such as drip, sprinkler etc.), farm heating and lighting systems, cooking systems, renewable energy-powered vehicles, bio-oil extraction, distillation and filtration systems, monitoring systems and equipment for water supply, distribution and purification (FAO 2013).

The alternate energy improves the resilience of farming communities to climate change. Their one time investment will take their burden, of buying expensive energy means to meet domestic and farm needs, for many years. The spared resources can then be used on some alternatives that can improve their livelihoods. Similarly a farmer using bio-gas for cooking and other domestic and farm purposes not only saves his financial resources to otherwise meet his domestic and farm requirements but also improves production of crops by adding slurry or compost (which is byproduct of the biogas production process). Biogas production is also a way of reducing methane emissions from manures. Thus alternate energy means are not only helping farmers to adapt to climate change and improve their livelihoods but are also a potential mitigation area in agriculture.

Figure 3.26: Alternate Energy Sources



Source: Holmgren (2012)

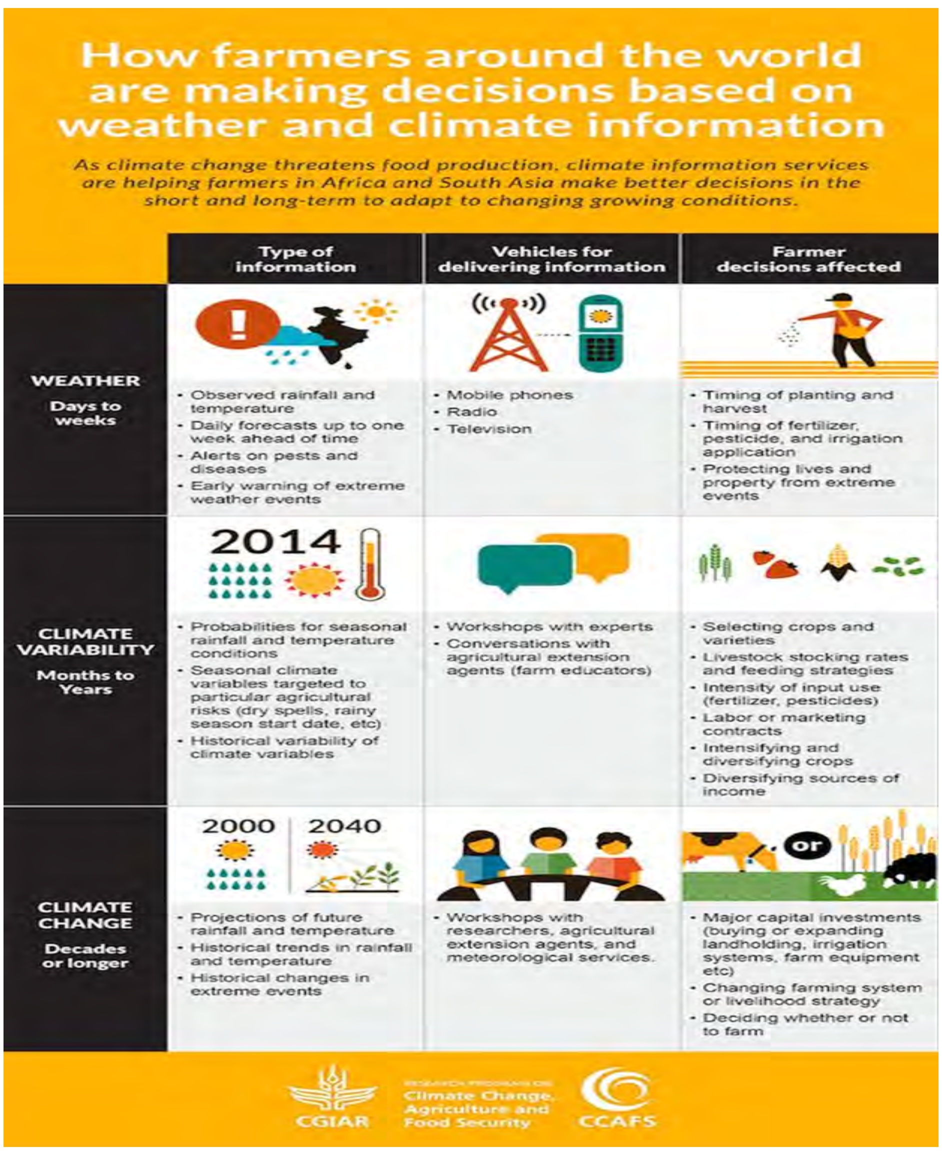
B 3.15: CLIMATE INFORMATION SERVICES

The farmers need climate information to take key decisions such sowing, irrigation, application of fertilizers and plant protection chemicals, harvesting, storing and transportation of produce etc. At farmer field level the resilience of farmers to climate change and extreme weather events increases if they have good climate information.

Climate information at different timescales may help farmers in the following ways as mentioned by Selvaraju (2012);

- Daily weather forecasts help them in taking day to day decisions such as irrigation, fertilizer application etc.
- Intra-seasonal information helps them to take key decisions like scheduling irrigation, procuring and storing fertilizers etc.
- Seasonal information helps them in taking strategic decisions such as selection of crops and varieties, marketing plans for different commodities etc.
- Climate change scenario helps them to understand the climate change trend of their area and helps them to take system level decisions such as whether they should go for crops or livestock or a mix of these enterprises that suits them well in the existing conditions and in any possible changed scenario.

Fig 3.27 : How Climate Information Services help farmers in decision making around the world



Source: Consultative Group on International Agricultural Research. (n.d.)

SECTION C

LEARNING FROM GLOBAL EXPERIENCE; CLIMATE SMART AGRICULTURAL PRACTICES/TECHNOLOGIES ADOPTED IN THE WORLD

As mentioned in the beginning of the module CSA is not “one fit for all” approach and rather it focuses on practices that are relevant to existing conditions of a location. For example a flood tolerant crop variety may not be the option for farmers of arid region while a drought tolerant variety cannot be part of a CSA package for farmers of areas that have plenty of water throughout the year. Similarly a high tech efficient irrigation system that has high cost, complex electronic control and sensitive to rough handling cannot be a viable CSA option for very poor communities that do not have financial capacity, awareness and technological skills to handle such systems. So, success of a Climate Smart Agriculture system depends on the assessment of local conditions and fitting relevant practices and technologies that suit the existing conditions.

There is a growing literature on existing and developing practices and technologies in agriculture sector that are considered to be climate smart. However, here we primarily mention the practices and technologies that have been reported to be climate smart by the Food and Agriculture Organization (FAO) of the United Nations.

Table 3.3: practices/technologies that are part of CSA in the world

S. No.	Practice/Technology/Approach	Reference
	CSA Practices Relevant to Crop Production	
1	Improved crop varieties	FAO 2013
2	Precision farming	FAO 2013
3	Conservation Agriculture	FAO 2010a, FAO 2013, FAO 2016
4	Crop diversification	FAO 2013
5	Crop rotations	FAO 2010a, FAO 2013
6	Cover crops	FAO 2010 a, FAO 2013
7	Crop residue management	FAO 2013
8	Intercropping with leguminous plants	FAO 2013
9	Use of mulches for crop production	FAO 2013
10	Soil and water conservation	FAO 2013
11	Efficient water and irrigation management	FAO 2010a, FAO 2013
12	Integrated soil-crop-water management	FAO 2013
13	Integrated nutrient and soil management	FAO 2010a, FAO 2013
14	Integrated Weed Management (IWM)	FAO 2013
15	Integrated Pest Management (IPM)	FAO 2013
16	Disease surveillance	FAO 2013
17	Sustainable Crop Production Intensification (SCPI)	FAO 2013
18	System of Rice Intensification (SRI)	FAO 2013
19	Alternate-Wetting and Drying (AWD) in Rice	(Bouman *et al*. 2007) in FAO 2013
20	Urea Deep Placement (UDP)	FAO 2013
21	Urban and peri-urban agriculture (Micro-Gardens and Rooftop Gardens)	FAO 2010a
22	Tree nursery	FAO 2016
	CSA Practices Related to Livestock Production	
1	Animal breeding (to develop resilient breeds)	FAO 2013
2	Animal and herd management	FAO 2013
3	Animal disease and health management	FAO 2013
4	Improved fodder production and conservation	FAO 2016
5	Improved pasture management (bush clearing, paddocking and spot and strip sowing with legumes)	FAO 2016

6	Rotational grazing	FAO 2013
7	Supplementary feeding	FAO 2010a, FAO 2013, FAO 2016
8	Improved feeding practices (e.g. precision feeding)	FAO 2013
9	Livestock feed and manure management	FAO 2010a, FAO 2013, FAO 2016
10	Anaerobic digesters for biogas and fertilizer	FAO 2013, FAO 2016
11	Adjust stocking densities to feed availability	FAO 2013
CSA Practices Related to Inter-sectoral Integration		
1	Agroforestry	FAO 2010 a, FAO 2013, FAO 2016
2	Integrated crop and livestock systems	FAO 2010a, FAO 2013
3	Integrated crop-fishery system in rice	FAO 2010a
4	Integrated Food Energy Systems (IFES)	FAO 2010a
Miscellaneous		
1	Improved cooking stoves (energy efficiency, reduces fuel wood consumption and associate deforestation)	FAO 2016

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MODULE 4
ENABLING ENVIRONMENTS AND POLICY INTERVENTIONS FOR CSA

MODULE OVERVIEW

In this module concept of climate and gender inclusion, institutional capacity building, policies relevant with CSA and barriers and opportunities for CSA in Pakistan are discussed

OBJECTIVES

1. To understand why gender and climate mainstreaming are important for development
2. To know how different social groups are impacted by climate change differently
3. To understand why it is important to integrate climate change into planning process
4. To get know how of institutional engagements and policy making in Pakistan for CSA
5. To get awareness about required capacity development for successful CSA implementation

KEY QUESTIONS

1. What is gender mainstreaming?
2. What is climate mainstreaming?
3. What is capacity building?
4. Which capacities are required for a comprehensive CSA adoption?
5. What are opportunities for CSA in Pakistan?
6. What are barriers for CSA in Pakistan?

KEY DEFINITIONS

MAINSTREAMING: Mainstreaming is defined as a process that brings what can be seen as marginal into the core business and main decision-making process

CAPACITY: It is defined as “the ability of people, organizations and society as a whole to manage their affairs successfully

CAPACITY DEVELOPMENT (CD): It is defined as “the process whereby individuals, organizations and society as a whole unleash, strengthen, create, adapt and maintain capacity to set and achieve their own development objectives over time

ADAPTIVE CAPACITY: Refers to individual and or collective strength and resources that can be accessed to allow individuals and communities to reduce their vulnerability to the impact of hazards.
CLIMATE CHANGE ADAPTATION: It is considered as adjustment in natural or human systems in response to actual or expected effects of climate change.

DISASTER: A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

DISASTER RISK REDUCTION: Disaster Risk Reduction is the concept and practice of reducing disaster risks through systematic efforts to analyze and reduce the causal factors of disasters.

SECTION A

INSTITUTIONAL ENGAGEMENT AND POLICY MAKING

A 4.1 ENABLING ENVIRONMENT FOR CSA

Enabling environments for climate-smart agriculture (CSA) means that there is support and facilitation to adopt CSA practices and technologies. The enabling environments include relevant policies, institutional arrangements, involvement of stakeholders, supportive infrastructure, access to weather information and farm services. The enabling environments may also support agricultural transformation to Climate Smart Agriculture by providing appropriate incentives, laws and regulations. It may also involve the capacity building at individual and institutional levels.

A 4.2 ENABLING POLICY ENVIRONMENT FOR CSA

To transform agriculture and promote climate smart agriculture we need to have an enabling policy environment. This requires greater coherence, coordination and integration of policies between climate change, agricultural development and food security. The integration of policies in these three areas ultimately impact agricultural production systems and GHG emissions in a more likely way. Lack of coherence, coordination and integration can negatively impact the desired objectives. Every country has its own strategy and plan of action to combat climate change at national level while contributing to regional and global agendas.

A 4.3 NATIONAL INSTITUTIONAL ARRANGEMENT

The Government of Pakistan has framed out its overall objectives towards climate change adaptation and mitigation through a number of policies and actions. Our efforts date back to 1974 with the establishment of a dedicated “Environment and Urban Affairs Division” at federal level, in follow up to 1972’s Stockholm Declaration. With the passage of time Government of Pakistan took every possible step to deal with environmental degradation and climate change problem. In 2012 Government of Pakistan established a fully dedicated ministry (Ministry of Climate Change) to deal with the climate change problem.

Table 4.1: History of institutionalization of climate change in Pakistan

Year	Accomplishment	Purpose and/or Function
1974	• Environment and Urban Affairs Division established at the Federal level	Follow up to Stockholm Declaration June 1972
1983	• Pakistan Environment Protection Ordinance enacted	First comprehensive environment-specific legislation
1989	• Environment and Urban Affairs Division upgraded to Federal Ministry of Environment, Forestry, and Wildlife	
1991–1993	• National Conservation Strategy prepared • National Environmental Quality Standards adopted in1993	It provided the broad framework for addressing environmental challenges
1995	• Cabinet Committee on Climate Change established	Acted as policy coordination forum for CC
1997	• Pakistan Environmental Protection Act enacted	First environmental act of the country
2002	• Global Centre for Impact Studies on Climate Change established	This research center on climate change functioned for 10 years as a development project
2004 – 2005	• Prime Minister Committee on Climate Change convenes National Environment Policy	Includes Prime Minister, Ministers of Water and Power, Food and Agriculture, Science and Technology, Environment, Planning Commission, Special Advisor to the Prime Minister
2006	• National Energy Conservation Policy • National Renewable Energy Policy • Clean Development Mechanism • National Operational Strategy	
2010	• 18th Amendment to the 1973 Constitution	Devolution of power to the provinces
2011	• Ministry of Environment ceases to exist • New Federal Ministry of Disaster Management established	Functions transferred to the Planning Commission
2012	• Ministry of Disaster Management renamed to the Ministry of Climate Change • National Climate Change Policy approved by Federal Cabinet • Punjab and Balochistan Environmental Protection Act prepared and enacted • "Green Benches" established in all High Courts and Supreme Court of Pakistan by the Chief Justice of Pakistan • National Disaster Management Plan approved • National Sustainable Development Strategy	Elevate climate change issue to a cabinet level portfolio A dedicated policy on climate change Deals with environmental cases; 2013 prioritizes environmental cases in the High Courts
2013	• Ministry of Climate Change downgraded to Division of Climate Change • Global Climate Change Impact Studies granted autonomous status • National Disaster Risk Reduction Policy approved	Becomes part of Cabinet Secretariat Serves as the secretariat for the Prime Minister Committee through "GCISC Act 2013"
2014	• Framework for Implementation of Climate Change Policy adopted	
2015	• Division of Climate Change upgraded to the Ministry of Climate Change	Federal focal ministry on all climate change-related issues
2017	• Pakistan Climate Change Act approved • National Forest Policy approved	
2018	• National Water Policy approved	

Source: Chaudhry (2017)

A 4.4 POLICIES & FRAMEWORKS RELEVANT TO ADOPTION OF CSA IN PAKISTAN

The government of Pakistan has approved some policies which support directly or indirectly some key practices and technologies that are part of the climate smart agriculture. A brief description of some of these policies is discussed below.

A 4.4A ALTERNATIVE AND RENEWABLE ENERGY POLICY (ARE-2011)

The Alternative and Renewable Energy policy provides national strategy and plans for the utilization of alternative and renewable energy (ARE) in Pakistan. Alternative and Renewable Energy (ARE) policy focuses on all ARE sources including solar, wind, small-scale hydropower, biogas, biofuel, and energy from waste.

A 4.4B NATIONAL CLIMATE CHANGE POLICY (NCCP-2012)

The National Climate Change Policy (NCCP) was developed in 2012 with the collaboration of UNDP. The NCCP is a guiding policy document for the country on climate change risks and appropriate adaptation and mitigation measures. The NCCP lays out pathways for achieving climate resilient development through mainstreaming climate change in the economically and socially vulnerable sectors.

A 4.4C FRAMEWORK FOR IMPLEMENTATION OF CLIMATE CHANGE POLICY (2013)

This framework is a guiding document for the implementation of the NCCP keeping in view the current and future anticipated climate change threats. The framework is a comprehensive list of both adaptation and mitigation strategies, and actions for each key sector (agriculture, water, energy etc.).

A 4.4D NATIONAL DISASTER RISK REDUCTION POLICY (2013)

The National Disaster Risk Reduction Policy (2013) aims to build resilience by reducing exposure to various types of hazards, both human and naturally induced (such as extreme weather events - floods, droughts etc.). It also lays stress on multi-sectoral integration, coordination and inter-organizational partnerships for combating climate change and reducing risks associated with climate change.

A 4.4E NATIONAL WATER POLICY (NWP-2018)

National Water Policy is focused on integrated water resource management and outlines a framework of interventions to address declining supply and deteriorating quality of water. The NWP stresses the need for adaptation and sustainable water resources development and management to minimize the impacts of climate change on water resources

SECTION B

MAINSTREAMING GENDER AND CLIMATE CHANGE IN NATIONAL DEVELOPMENT PLANS

Climate change has complex and interrelated impacts on every aspect of our life. It directly and indirectly impacts ecosystems, biodiversity, land, water and energy resources, infrastructure, social and cultural values and behavior and psychology. Addressing climate change requires attention to structural and social dimensions. The structural dimensions of climate change are related to land use, infrastructure, transportation, water and energy etc. while the social dimensions of climate change are related to cultural and psychological values, lifestyle and consumption behavior etc. However, it should be understood that the policy level interventions (mainstreaming climate and gender into NAP, NAPA etc.) are to be made effective (designed and implemented) by policy makers. These interventions cannot be assumed to be the task of agriculture extension departments.

B 4.1 UNDERSTANDING NAP, NAPA AND NAMA

Without mainstreaming climate into our decision making at national level, we cannot address the structural dimensions of climate change and that requires understanding of the NAP, NAPA, NAMA etc. As discussed above that these are the interventions at policy level, so understanding them is the responsibility of our policy makers as they have the responsibility to design and develop the structural and financial frameworks for the mainstreaming of effective policies to tackle climate change at social, economic and environmental dimension. In this manual we are just briefly discussing the basic terms for general understanding of our agriculture officers.

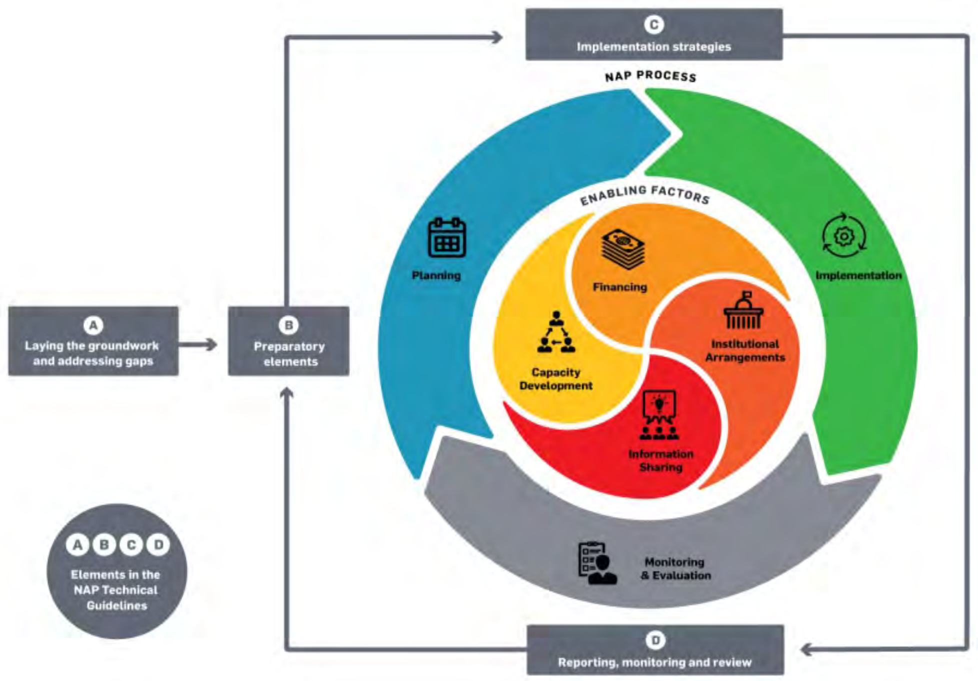
Climate change policies and actions at the national level of countries are expressed in the National Adaptation Plan (NAP), National Adaptation Programmes of Action (NAPA) and the Nationally Appropriate Mitigation Action (NAMA). Now let us briefly discuss these terms;

NAPs: The National Adaptation Plan (NAPs) process helps countries in conducting comprehensive medium and long-term planning for climate adaptation. It is not a tailored product; instead it focuses on each country's existing adaptation needs and helps in integration of climate change into national decision making. There is support by UNFCCC (United Nations Framework Convention on Climate Change) in conducting NAP process to every willing member country.

NAPAs: NAPAs are focused to meet adaptation needs of the Least Developed Countries (LDCs) which are vulnerable to climate change. There is also a Least Developed Countries Fund (LDCF) under the COP (Conference of the Parties- the supreme decision-making body of the UNFCCC) to financially support the preparation and implementation of NAPAs in LDCs. There is also an LDC Expert Group (LEG) to provide technical assistance and advice to the LDCs.

NAMAs: NAMAs refer to any action (policies or activities) that aim to reduce emissions in developing countries. NAMAs are outcome of COP 18 and under NAMAs the developing countries are asked to lead emission reduction strategies at national level and communicate these with the UNFCCC.

Figure 4.1: The NAP Process



Source: Hammill, Dazé, & Dekens (2019)

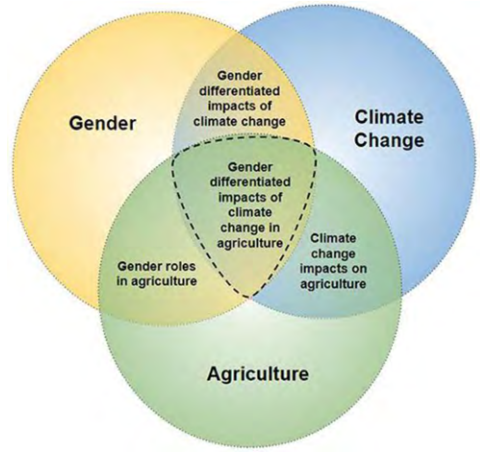
B 4.2 MAINSTREAMING GENDER INTO CLIMATE CHANGE DECISION MAKING

Mainstreaming is defined as a process that consists in bringing what can be seen as marginal into the core business and main decision-making process. Gender equality means fair and impartial treatment of men and women regarding their rights, benefits, obligations and opportunities. A society is strengthened to its core when inequalities and injustices are overcome and effective participation of all stakeholders is ensured in policy making and development. Moreover the development of the society becomes faster when equal opportunities are provided to all sexes and stakeholders without any discrimination. Gender mainstreaming is the process of assessing the implications of any policy and planned action in all areas and at all levels for men and women. Gender mainstreaming ensures that men and women get equal benefits from the development processes.

The development of adaptive capacity of all members of the society is needed when we are addressing a particular problem. It is a fact that climate smart agriculture needs development of the adaptive capacity in farming community as a whole. Women suffer more from climate change than men because of their limited access to different resources. Women also use and manage natural resources differently from men so their inclusion in any decision making process and policies is essential that are directed for climate change adaptation and mitigation. We cannot neglect almost half of the population of a community to address climate change problem. Therefore men and women should be fully informed and have the capacity to practice climate smart agriculture.

As we discussed in Section A of Module 3 (Climate Smart Agriculture-An Introduction) the Climate Smart Agriculture works on the basis of landscape approach and the landscape approach has three dimensions; social, economic and environmental. When we do not address the social dimensions it means our policies for CSA mainstreaming are not comprehensive. Meanwhile it should also be in our mind that every society and civilization has its core values and norms and they should be respected in all circumstances. The mainstreaming should consider those values and norms of the society otherwise there will be more of hindrance and fraction for CSA than acceptance in the farming community

Figure 4.2: Gender, climate change and agriculture



Source: Paudyal et al., (2019)

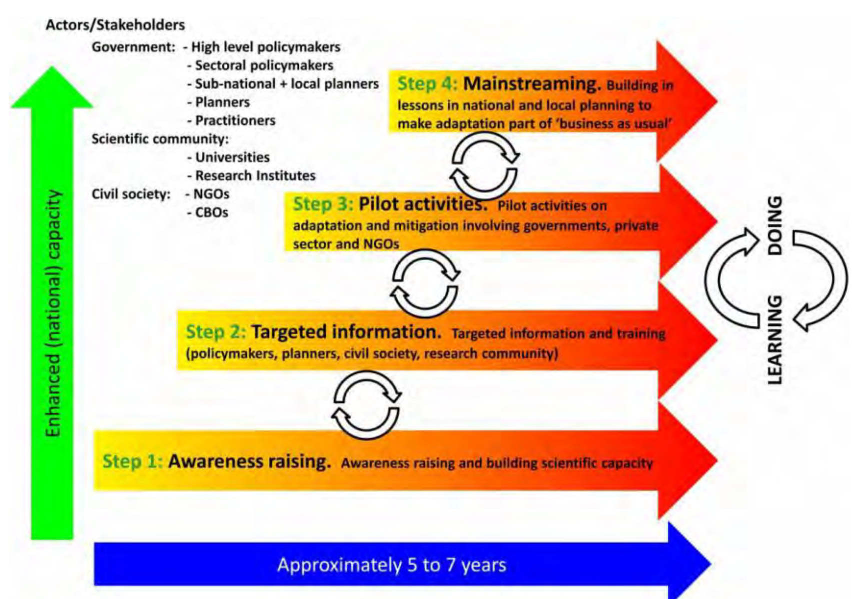
B 4.3 MAINSTREAMING CLIMATE CHANGE INTO DEVELOPMENT DECISIONS

Impacts of climate change are multi-sectoral (environmental, economic, political etc.) and the needed adaptation measures also demand cross sectoral integration. Therefore there is need of participatory approach to include impacts of climate change and the necessary adaptation plans in national development planning. The integration of climate change into development policy planning and budgeting is a complex process involving many sectors and hence it requires a carefully thought-out process which is termed as climate change mainstreaming.

Climate vulnerabilities have never been comprehensively integrated in the development planning of Pakistan. As Pakistan is among the most climate change vulnerable countries in the world, there is a need to mainstream climate change into national development plans and processes. This will help in Pakistan's informed decision making on development and will positively contribute to global development goals.

Climate mainstreaming helps in poverty reduction, more employment, food, health and energy security, benefits from ecosystem services and benefits from improved infrastructure. Government of Pakistan (GoP) is aware of the climate change related issues and has prioritized climate change agenda in developmental plans to deal with the issue.

Figure 4.3: Mainstreaming Climate Change in Planning and Development



Source: Ayers, Huq, Wright, Faisal, & Hussain, (2014)

SECTION C

INSTITUTIONAL CAPACITY BUILDING FOR CSA

Ensuring sustainable food security and development in changing climates, without further depletion of natural resources and land degradation, is a complex process. With more food production, to feed the ever increasing population, there will be more water requirements, more deforestation, more land degradation and more GHG emissions. A major transformation of the agriculture sector is necessary to ensure sustainable food production with efficient utilization of natural resources and low GHG emissions. This transformation requires greater cooperation among academia (agricultural colleges, universities and training institutions), agricultural establishments (agricultural research, agricultural extension, water management, plant protection, soil conservation etc.), environmental departments, policy makers and financial institutions of the country.

C 4.1 PRIORITIZATION OF INSTITUTIONS FOR CAPACITY BUILDING

The capacity development of those institutions is needed to be built first which are directly involved in knowledge generation, experimentation, agricultural training, projects financing and information dissemination. When capacity building for CSA is planned, following institutions should be prioritized for capacity building.

1. **Agricultural Research** – technical knowledge generation on CSA in local contexts because appropriate CSA technologies are needed to be designed according to existing local conditions
2. **Agricultural Extension-** delivering the technologies to farmers through extension services (FFS, demonstration plots etc.), information dissemination on CSA
3. **Agricultural Education Institutions** - (Universities, colleges, training institutes)- capability enhancement in agricultural graduates to tackle climate related complex issues in research, developmental planning and execution of resilient practices in field
4. **Agricultural Meteorology-** (weather and climate information services) to develop capable system that can communicate effectively with all stakeholders and develop efficient response measures for forecasted and sudden extreme weather events in advance.
5. **Policy Making Institutions-** for making relevant policies, incentivizing agricultural subsidies for CSA
6. **Policy Implementation**- administration- for enforcement of developed CSA policies into action
7. **Financial Institutions-** in designing financial mechanisms and assistance for adoption of CSA and other agricultural transformation practices and technologies

C 4.2 TARGETING FUNCTIONAL CAPACITIES FOR SUCCESSFUL ADOPTION OF CSA

The capacity development has three dimension; individual, organizational and enabling environments. For successful adoption of CSA all these three dimensions of capacity development should be addressed at all levels. Moreover, for successful adoption of CSA in national planning and development requires that all functional capacities should be utilized in addition to the technical capacities (such as intensifying the production systems or increasing efficiency of natural resource utilization etc.). FAO (2013) mentioned some characteristics of the various functional capacities (copied as such from FAO-2013);

- **Implementation capacity:** implement and deliver programmes and projects, from planning to monitoring and evaluation
- **Partnering capacity:** engage in networks, alliance and partnerships
- **Knowledge capacity:** access, generate, manage and exchange information and knowledge
- **Policy and normative capacity**: formulate and implement policies and lead policy reform

Table 4.2: Examples of the required technical and functional capacities at different levels for CSA

	Individual level	Organizational level	Policy level
Technical capacity (technical)	Regularly updated knowledge and skills. Understanding of broader technical context of CSA.	Appropriate knowledge and skills mix, such as agronomic, environmental, engineering, economic, social, legal, financial, institutional knowledge; knowledge on investment procedures	Policy for critical review of knowledge and information; allocation of adequate resources for CSA related capacity development requirements
Implementation capacity (functional)	Skills for CSA project and finance management; personnel/team management/mentoring skills, ability to deliver, leadership, mediation skills.	Ability to set goals/strategies. Financial and people management; staff rotation; incentive systems, project management including proper planning and M&E, ability to deliver in a timely manner.	Sound task assignments and clear mandate of sector agencies; cross-sectoral collaboration mechanisms; sound finance and budgeting systems, facilitating proper organisational management.
Partnering capacity (functional)	Ability to engage stakeholders, apply inclusiveness; capacity for collective action	Transparent decision-making processes (including budgets and plans); accountable procedures for stakeholder consultation and empowerment.	Policy to ensure inclusiveness, transparency and accountability; conducive regulations.
Knowledge capacity (functional)	Desire to keep learning and attend trainings, self reflection of performance; skills for knowledge sharing and management.	Procedures for continuous performance review; mechanisms and rewards to support information/ knowledge exchange and learning; support for communities of practice.	Policy to promote an open work atmosphere and inclusiveness; openness to continuous sector performance review and implementation of adjustments.
Policy and normative capacity (functional)	Ability to meaningfully engage in CSA-related policy and planning processes	Ability to formulate and implement policies and lead policy reform, including climate change mainstreaming in policies.	Capacity to administer legal and institutional frameworks, including those related to UNFCCC.

Source: FAO (2013)

As it is evident from Table 4.2, the capacity building in CSA needs to be addressed at all levels including individual, organizational and policy levels. This should be understood very clearly that addressing capacity building needs at only individual or organizational level will not serve the purpose. We are generally good at various technical capacities but usually lack some of the above mentioned functional capacities at all levels. For example our agriculture officers generally lack the "partnering capacity" which means that they lack the ability to engage with stakeholders, do not plan to execute something with inclusiveness and involvement of other stakeholders. Similarly our organizations and policy makers are usually weak in the implementation capacity owing to too many reasons which root from bad governance, administrative and financial problems. The weakness of the implementation capacity then translates to the unnecessary delay of projects. That is why when we talk about CSA mainstreaming in Pakistan, we should give emphasis on the development of required technical and functional capacities at all levels, from individual to organizational.

C 4.3 ROLE OF DISTRICT AGRICULTURE OFFICERS (DAOs) IN CSA DISSEMINATION AND IMPLEMENTATION

District Agriculture Officers (DAOs) are the leaders at the district level who plan and execute agricultural development programs. They are responsible for effective dissemination of potential agricultural practices and technologies to the farming community. They have a team of agriculture extension officers and field assistants who continuously remain in contact with the farming community. They have expertise in convincing farmers to adapt new technologies which are crucial to sustain their livelihoods.
Agriculture extension officers under the leadership of their district officers can take leading role for the dissemination of potential CSA practices and technologies to the farming communities. They can use tested approaches like "Demonstration Plots" to show the competitive edge of CSA prctices and technologies to the farming community. They can practically show the effectiveness of different smart practices and approaches like low delta crops, stress tolerant crop varieties, crop diversification, crop rotations, efficient irrigation systems, integrated pest management etc. in these CSA demonstration plots.

District Agriculture Officers can also arrange capacity building programs and trainings in CSA for potential farmers from all categories (small, medium and large farm land holders) in their districts with collaboration with both public and private sector organizations. They can convince progressive farmers who are practicing climate smart farming methods to allow trainee farmers to visit their farms and learn from their experiences. They can also mobilize the available resources to support these trainee and trainer farmers for effective utilization of the opportunities. They can also arrange visit of aspiring farmers to government facilities for first hand learning.

District Agriculture Officers (DAOs) can also use whatsapp and other social media platforms to effectively disseminate CSA practices and technologies. They can also form crop specific and general farming groups on social media for willing farmers. Although many of such groups are already formed by extension departments there is need for making regular updates by concerned staff. As DAOs have access to authentic government data regarding weather events, emerging pests and diseases (pest warning), fertilizer situation, seed status, government subsidies etc. they should regularly update on these social media platforms for awareness of the farmers and keeping them up-to-date on the actual situation for timely decision making.

While DAOs can help in mainstreaming and implementation of CSA they can also become the bridge between research, academia and policymaking by giving them the feedback about the latest climate challenges for agriculture sector at the farmer field level and throughout their agro-ecologies. The feedback from extension departments to academia can help academia to prepare future leaders of agriculture according to the prevailing and expected climate challenges. The feedback to research institutes can help them to plan, design and carry effective research programs that can help in better crop production and resource utilization in changing climates in respective agro-ecologies. The feedback from extension departments to the policymakers can help them to make relevant policies, based on ground situation that can help in shared social, economic and environmental benefit of all stakeholders.

This way the role of DAOs and agriculture extension departments is very crucial in mainstreaming of effective CSA practices and technologies. They are the pivot of CSA implementation and effective policy translation and agricultural transformation. The need is to develop their capacities on CSA, take them into confidence and solve their problems (administrative, structural and financial problems) and give them go ahead with goal of agricultural transformation in wake of climate change and increased competition for natural resources by other sectors.

SECTION D

BARRIERS AND OPPORTUNITIES FOR CLIMATE SMART AGRICULTURE (CSA)

D 4.1: BARRIERS FOR CSA IN PAKISTAN

To the best of our knowledge and what has been studied from literature, a number of barriers exist for the implementation of climate smart agriculture across the country such as;

- Poor financial conditions of the farming households for some of the technologies such as HEIS.
- Lack of proper education and skills in the farming community to adapt to climate change and practice climate smart agriculture.
- Poor agro-technological development base of the country for the implementation of many climate smart technologies such as precision agriculture.
- Limited research on locality specific climate smart solutions (adaptive varieties, breeds, production technologies) and their translation and technology transfer in local languages.
- Lack of proper capacity in the agricultural extension departments to understand climate related challenges and training and dissemination of CSA to address the challenges.
- Lack of functional capacities (functional capacities are soft skills such as communication, coordination, articulation and managerial skills) in our human resource and institutions, from individual to organizational levels, to tap available global resources for CSA adaptation.
- Lack of coherent policies on Climate Smart Agriculture. There needs to be a coherent policy on CSA involving participation and feedback of all stakeholders
- Lack of implementation of existing policies.
- Lack of coordination between federal and provincial governments, particularly after the 18th amendment.
- Lack of proper financial support to incentivize climate smart practices and technologies in the agriculture sector at massive scales.

D 4.2: OPPORTUNITIES FOR CSA IN PAKISTAN

CSA has been featured in Pakistan's INDC and the government is focusing on implementation of a comprehensive CSA policy through medium and long-term action plans. The government has laid out following action plans for CSA implementation in the INDC.

- Training of national, sub-national and local authorities on climate change and CSA by national and international experts.

- Farmer field schools focused on locality specific CSA activities (e.g. soil conservation).
- Exposure visits of farmer groups to different CSA pilot sites to learn CSA activities.
- The development and enhancement of curriculum of agricultural universities, colleges and technical institutes to capacitate agricultural graduates and extension workers on climate change and CSA practices.

Moreover the development and integration of following climate and water related policies and frameworks is a positive step for the transformation of agriculture sector to a more vibrant and resilient agriculture;

- National Climate Change Policy (NCCP)
- Framework for Implementation of the Climate Change Policy
- Intended Nationally Determined Contribution (INDC)
- Pakistan Climate Change Act (PCCA)
- National Adaptation Plan (NAP) (in developmental stages)

D 4.3 INTERNATIONAL FINANCING OPPORTUNITIES THAT CAN SUPPORT CSA RELATED PROJECTS IN PAKISTAN

Previously there was less emphasis on climate change adaptation and most of the funds promised by international donor agencies were targeted for climate change mitigation. Even then the lion's share of the mitigation funding was taken by industrial and energy sectors with minimum share spared for agriculture sector mitigation projects. However, due to continuous efforts and negotiations at international level and with the establishment of Green Climate Fund (GCF), now agriculture sector financing is getting more momentum. Climate finance can help meeting the sustainable agricultural development and transformation by promoting CSA. It is expected that under Green Climate Fund developing countries will be supported through a 100 billion annual fund by the year 2020 (FAO, 2013). Green Climate Fund is the largest climate fund in the world and it is mandated to support developing countries in their ambitions to low emission and climate resilient pathway.

There is need to understand the international climate financing architecture by our agricultural scientists, extension officers, academicians and policy makers to successfully tap available financing opportunities for CSA projects. Furthermore, there is also need to highlight the mitigation potential of the CSA practices and technologies when a CSA related project is submitted to any international climate financing body. For this purpose there should be realistic assessment of the mitigation potential of the desired adaptation practice and technology. As CSA practices and technologies focus on both climate change adaptation and mitigation, there is bright future for CSA in Pakistan.

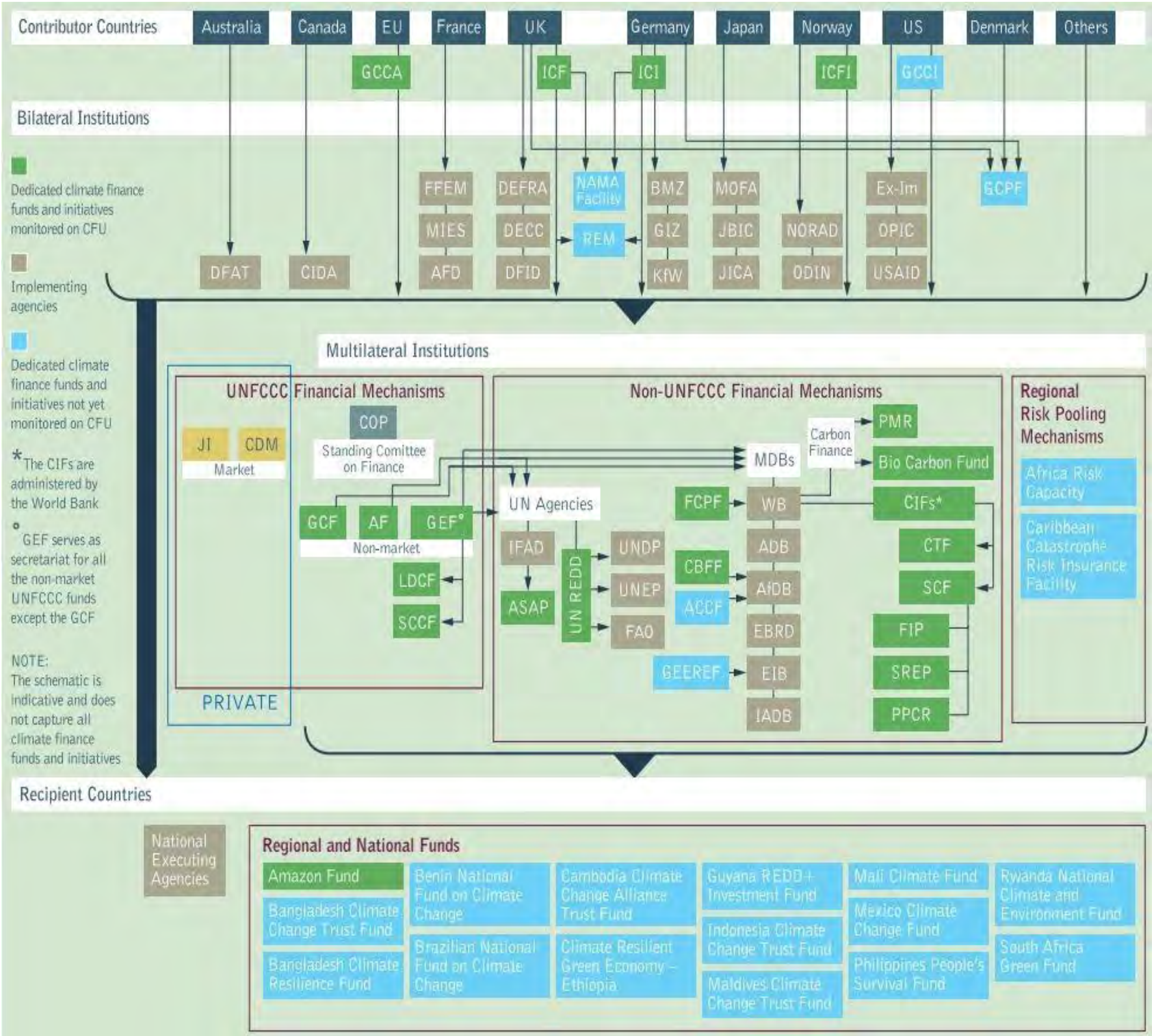
However, there needs to be capacity building of our agricultural stakeholders to;

- Understand the architecture of international climate financing institutions.
- Understand the prerequisites to meet the criteria to get financial support from these institutions.
- Build the evidence base of potential CSA interventions.
- Assess the mitigation potential of CSA practices/technologies.

Following figure describes the international climate financing architecture; institutions and global bodies that can be considered for climate financing. Many of these institutions can be contacted for CSA financing.

Figure 4.4: Institutions at international level that can directly or indirectly support CSA or climate change related project

Figure 4.4: Institutions at international level that can directly or indirectly support CSA or climate change related projects



Implementing Agencies and Institutions	
AfDB	African Development Bank
AFD	Agence Française de Développement (French development agency)
ADB	Asian Development Bank
BEIS	Department for Business, Energy & Industrial Strategy (UK)
BMZ	Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung (federal ministry of economic cooperation and development, Germany)
CIDA	Canadian International Development Agency
DEFRA	Department for Environment, Food and Rural Affairs (UK)
DFAT	Department of Foreign Affairs and Trade (Australia)
DFC	United States International Development Finance Corporation
DFID	Department for International Development (UK)
EBRD	European Bank for Reconstruction and Development
EIB	European Investment Bank
Ex-Im	Export-Import Bank of the United States
FAO	Food and Agriculture Organization of the United Nations
FFEM	Fonds Français pour l'Environnement Mondial (French global environment facility)
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (German technical cooperation)
IDB	Inter-American Development Bank
IFAD	International Fund for Agricultural Development
JBIC	Japan Bank of International Cooperation
JICA	Japan International Cooperation Agency
KfW	Kreditanstalt für Wiederaufbau (German development bank)
MIES	Mission Interministérielle de l'Effet de Serre (inter-ministerial taskforce on climate change, France)
MOFA	Ministry of Foreign Affairs (Japan)
NMFA	Norwegian Ministry of Foreign Affairs
NORAD	Norwegian Agency for Development Cooperation
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
WB	World Bank

Multilateral Funds and Initiatives	
AF	Adaptation Fund (GEF acts as secretariat and WB as trustee)
ACCF	Africa Climate Change Fund
AREI	African Renewable Energy Initiative
ASAP	Adaptation for Smallholder Agriculture Programme
CAFI	Central African Forest Initiative
CBFF	Congo Basin Forest Fund (hosted by AfDB)
CDM	Clean Development Mechanism (implemented under the Kyoto Protocol)
CIF	Climate Investment Funds (implemented through WB, ADB, AfDB, EBRD and IDB)
CTF	Clean Technology Fund (implemented through WB, ADB, AfDB, EBRD and IDB)
FCPF	Forest Carbon Partnership Facility
FIP	Forest Investment Program (implemented through WB, ADB, AfDB, EBRD and IDB)
GCCA	Global Climate Change Alliance
GCF	Green Climate Fund
GEF	Global Environment Facility
GEEREF	Global Energy Efficiency and Renewable Energy Fund (hosted by EIB)
JI	Joint Implementation (implemented under the Kyoto Protocol)
LDCF	Least Developed Countries Fund (hosted by the GEF)
PMR	Partnership for Market Readiness
PPCR	Pilot Program on Climate Resilience (implemented through WB, ADB, AfDB, EBRD and IDB)
SCCF	Special Climate Change Fund (hosted by the GEF)
SCF	Strategic Climate Fund (implemented through WB, ADB, AfDB, EBRD and IDB)
SREP	Scaling Up Renewable Energy Program for Low Income Countries (implemented through WB, ADB, AfDB, EBRD and IDB)
UN-REDD Programme	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation

Bilateral Funds and Initiatives	
GCCI	Global Climate Change Initiative (US)
GCPF	Global Climate Partnership Fund (Germany, UK and Denmark)
ICF	International Climate Finance (UK)
IKI	Internationale Klimaschutzinitiative (international climate initiative, Germany)
MDG-F	MDG Achievement Fund (implemented by UNDP)
NAMA Facility	Nationally Appropriate Mitigation Action facility (UK, Germany, Denmark and the EC)
NICFI	Norway's International Climate Forest Initiative
REM	REDD+ Early Movers (Germany and UK)

Source: Watson & Schalatek, 2021

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