The Hashemite Kingdom of Jordan

Deliverable No 7 for FAO/ RFP/ 2010/02

Final report on "Identify and screen adaptation measures to reduce climate change impacts on food productivity"

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Abbreviations

AGDP	Access Grid Documentation Project
AR4	Fourth Assessment Report
BAU	Business As Usual
CBJ	Central Bank Of Jordan
CDM	Clean Development Mechanism
CFCs	ChloroFluoroCarbons
CM	Cubic Meters
DOS	The Department Of Statistics
DNA	Designated National Authority
FAO	Food And Agriculture Organization
FAR	First Assessment Report
G-8	Great Eight summit
GCSE	General Certification of Secondary Education
GDP	Gross Domestic Product
GHGs	Green House Gases
HDR	Human Development Report
IFAD	International Fund for Agricultural Development
INC	Initial National Communication
IPCC	International Panel for Climate Change
JP	Joint Program
JSNC	Jordan Second National Communication
KP	Kyoto Protocol
MDGF	United Nations Development Assistance Framework
MDGS	Millennium Development Goals
MoA	Ministry of Agricultural
MoE	Ministry of Environment
MoEnv	Ministry of Environment
MoL	Ministry of Labor
MoP	Ministry of Planning
OECD	Organization For Economic Co – Operation And Development
PPb	Part Per Billion
SAR	Second Assessment Report
SPM	Summary For Policymakers
SRES	Special Reports On Emission Scenarios
SWOT	Strength, Weakness, Opportunities and Threats
TAR	Third Assessment Report
UN	United Nation
UNDAF	United Nations Development Assistance Framework
UNDP	United Nations Development Programmers
UNESCO	United Nations Educational , Scientific and Cultural Organization
UNFCCC	United Nation Framework Convention On Climate Change
WFP	World Food Program
WGI	Working Group I
WHO	World Health Organization
WMO	World Meteorological Organization

1. INTRODUCTION

1.1 Overview

Climate change is already beginning to transform life on Earth. Around the globe, seasons are shifting, temperatures are climbing and sea levels are rising. If we don't act now by applying adaptation and mitigation measures, climate change will permanently alter the lands and waters we all depend upon for survival. The most significant consequences may include; higher temperatures; changing landscapes; wildlife at risk; rising seas; increased risk of drought, fire and floods; stronger storms and increased storm damage; more heat-related illness and disease; and economic losses.

Climate change and agriculture are interrelated processes, both of which take place on a global scale. Global warming is projected to have significant impacts on conditions affecting agriculture, including temperature, carbon dioxide, precipitation and the interaction of these elements. These conditions determine the carrying capacity of the biosphere to produce enough food for the human population and domesticated animals. The overall effect of climate change on agriculture will depend on the balance of these effects. Assessment of the effects of global climate changes on agriculture might help to properly anticipate and adapt farming to maximize agricultural production.

Agriculture is both a receptor of possible climate changes arising from GHG emissions and a source of GHGs, including CO_2, methane (CH_4), and nitrous oxide (N_2O). Land use changes such as deforestation and desertification, together with use of fossil fuels, are the major anthropogenic sources of carbon dioxide; agriculture itself is the major contributor to increasing methane and nitrous oxide concentrations in earth's atmosphere.

Schneider *et al.* (2007:787) assessed the literature on key vulnerabilities to climate change. They concluded that for about a 1 to 3°C global mean temperature increase by 2100, relative to the 1990-2000 average level, there would be productivity decreases for some cereals in low latitudes. These studies on global agriculture, however, had not incorporated a number of critical factors, including changes in extreme events, or the spread of pests and diseases. Studies had also not considered the development of specific practices or technologies to aid adaptation.

Jordan has limited natural resources such as water and agricultural land. It is classified as an arid and semi arid country (JSNC, 2009), and can be considered as one of the most ten water stressed countries in the world, with less than 150 cubic meters (CM) annual per capita of fresh water resources, which is far below the world water poverty line of 1000 CM. National consumption of water has increased by almost 50% over the twenty-year period 1985-2005 and a rising population has nearly tripled municipal water consumption.

Although a small country, Jordan has many different climatic regions; at least there are three different climatic regions, as sub tropical, Mediterranean, and badia and desert. Temperature and rain differences between these regions are wide, beside fluctuation on climate from year to year. Climate change will add more stress on the natural renewable resources, especially on water and agriculture. This diversity of agro-climatic conditions permits diversification of crops and seasonal distribution of production, and under climate change, benefits from different climatic zones should be maximized.

Livestock production occupies more than 50% of agricultural activities and production in Jordan, the demand for livestock products is expected to increase in the first half of this century, due to the population growth and the rising level of living. Population is about 6 million at present, and is expected to double by the mid of this century. Agriculture is one of the most sensitive and vulnerable sectors to climate change induced impacts. Higher temperatures and lower precipitation are expected as a result of climate change. Furthermore, Climatic changes have a very significant impact on irrigation requirements and irrigation water resources, where climatic factors are most important in the variation of both water resources and water demand (Shnaydman, 1993). In spite that most of agricultural areas in Jordan are rain-fed, this sector utilizes about two-third of the available water resources. Water resources are vulnerable to climate change due mainly to changes in precipitation and its distribution both spatially and temporally. The scarcity of water will be more severe under climatic change; this means that adaptation to climate change is a necessity under these conditions.

Agricultural sector has generally flexibility in crop selection to cover food needs as there are many types and varieties of crops that can adapt to certain climatic conditions. In addition, the vertical crop production is open (no limitation for upper quantities of production), and the selected crops should be accepted by the society. While cropping pattern of Jordan could be described as random, none programmed with any priority for food security, imported man power in agriculture is obvious, and due to these conditions the rate of food security is generally about 30 % of our food needs.

This study was conducted in the context of the UN/FAO activities for helping the developing countries towards the achievement of Millennium Development Goals (MDGs). These goals include reduction of poverty rates (MDG1), achieving adults literacy rates (MDG2), infant mortality rate (MDG4), access to water and to sanitation (MDG7). However, these achievements are undermined by the crippling water scarcity and aggravated by climate change, thus bringing about additional threats to health, food security, productivity and human security. A joint program (JP) is initiated and developed by four UN organizations working in Jordan (FAO, UNESCO, UNDP, WHO).

The program is designed to help Jordan through achieving the following strategic outcomes:

1. Sustained access to improved water supply sources despite increased water scarcity induced by climate change; and

2. Strengthened adaptive capacity for health protection and food security to climate change under water scarcity conditions.

This program includes two overall objectives to achieve the outcomes identified by the program stakeholders:

1. The first objective aims to secure reliable sources of water supply in spite of the potential pressure due to climate change through adopting water resource management plans that ensure more water supplies to protect health and to sustain food production; and

2. The second objective focuses on adopting suitable mechanisms for adaptation to climate change in food production and health.

Food security has four dimensions, and they are all affected by climate change; food availability, food accessibility, food utilization and food systems stability. It will have an impact on human health, livelihood assets, food production and distribution channels, as well as changing purchasing power and market flows. Its impact will be both short term, resulting from more frequent and more intense extreme weather events, and long term, caused by changing temperatures and precipitation patterns. Projected adverse impact of climate change may include reduced crop yields, and a decrease in water availability in already water scarce regions.

The adverse impacts of climate change are more likely to fall disproportionately on poor societies, especially those who live in arid or semi-arid lands. These impacts would add to the many other stresses that are already being faced by these societies. Consistent with their limited resources and human capacity, poorer societies already face greater stress and accordingly have lesser ability to develop and implement adaptation strategies.

FAO's role is to assist member countries, and in particular developing countries which are vulnerable to climate change, to enhance their capacities to cope with the negative impacts of climate variability and change on agriculture. In Jordan, FAO has long-established relationship with the Ministry of Agriculture, Ministry of Water and Irrigation, Greater Amman Municipality, research centers as well as farmers and local organizations. This study entitled "Identify and screen adaptation measure to reduce climate change impacts on food productivity" gives an account of the expected impacts of climate change and presents adaptation measures to be taken by the Ministry of Agriculture, the National Center of the Agricultural Research and Extension, farm operators and other concerned stakeholders to minimize the adverse effects of climate change on food production in Jordan.

1.2 Objectives

The purpose of the study is to Identify and screen adaptation measures to reduce climate change impacts on food Productivity. This specific consultation is designed to carry out the following activities:

1- Develop needed adaptation measures for food productivity in Jordan

- Review all possible adaptation measures for food productivity;
- Evaluate all possible adaptation measures for food productivity in term of suitability and applicability to Jordan main agricultural and rural areas; and
- Review opportunities and barriers to adaptation to climate change risks, there are many known available in the literature. The international experience has suggested many adaptation measures. However, each of these measures has specific needs and requirements that might be site specific or require huge investments.

2- Conduct adaptation measure test

- Develop the reasoning of the intervention and describe both baseline and adaptation scenarios:

  <u>Baseline scenario</u>: The purpose of this scenario is to identify what course of action would be taken in the absence of climate change adaptation, and how climate change is likely to affect agricultural production. Without adaptation, how agricultural production activities would be affected by climate change. This scenario should also include a description of the adaptations to current climate that are already in place. A short discussion on the current baseline effectiveness, gaps and additional needs is also expected;

  <u>Adaptation scenario</u>: the purpose of this scenario is to identify the course of action that will have to be taken to respond to the adverse impacts of climate change on agricultural activities, so as to achieve sustainable results. It seeks to answer the question: "How should the development objective be achieved, taking into account the impacts of climate change, and what immediate and urgent measures are 32 necessary to respond to such impacts?" This scenario must include a description of the activities to be implemented to address the adverse impacts of climate change in the short-term. These activities should include mainstreaming of short-term adaptation strategies into national development frameworks.

3- Select the appropriate measure

- Assessment of opportunities and barriers to adaptation to climate change risks. In this activity the consultant is to evaluate the suitability and potential of each adaptation measure to be implemented in Jordan based on the requirements for each;
- Check for complementarities and synergies with similar existing or planned interventions in the country and the region;
- Suggest and prioritize the best possible adaptation measures for food productivity in Jordan; and
- Lessons learnt from related previous interventions should be incorporated.

1.3 Methodology

Al Shamil team (the consultant) has identified the Climate Change situation in Jordan and its impact on food productivity getting benefits from previous work on adaptation measures to climate change (Worldwide and National) such as; IPCC reports and SNC (Second National Communication) results and developed it further to reduce climate change impact on food productivity.

However, the consultant has highlighted on the national context regarding climate change, agribusiness and agriculture with socioeconomic settings as mentioned the national context chapter.

The methodology have demonstrated to meet the required specifications and provided a detailed description of the essential performance characteristic.

Al Shamil (the consultant) has followed the activities specified in the scope of work of the called RFP. In addition, the related methodologies and the strategic approaches were implemented in a way to meet the assignment's purpose/ objectives according to the goals of the assignment: entitled "**Identify and screen adaptation measures to reduce climate change impacts on food productivity**"

To meet the assignment's objective and related outcomes, the following activities have been conducted:

- Identify alternative adaptation measures;
- Conduct adaptation measure test; and
- Select the appropriate measure.

The study aims to identify adaptation measures that would reduce climate change impacts on agricultural productivity, to test them and to select the best locally appropriate measures, which were revealed in deliverables 2,3,4 and 5 that have been submitted by the consultant.

This deliverable has been conducted based on the following strategy, approach and methodology to fulfill the required objective of this assignment:

- Refereed literature review on impacts of climate change; technological and socio economic adaptation to climate change; and previous relevant research conducted in Jordan, neighboring countries and worldwide with similar agro-climatologically conditions;
- A review was conducted on the state of agriculture in Jordan under rain-fed and irrigation in addition to livestock during the last 20 years based on many previous work (Jordan's Second National to the United Nations Framework Convention on Climate Change (UNFCCC), 2009) Harb 1994 , Jordan's Initial National Communication, UNFCCC,2000, Taimi 1995 Nabulsi Et Al 1993, Katari Et Al 1999 , Committee Of Agriculture 2005), and document the importance of weather conditions on livestock and the arid and rangeland productivity and resource condition;
- The above mentioned reports were used to evaluate current trends in climate change effect on forage and feed production. The evaluation also include the impact of climate change on: feed cycle in Jordan, animal production. The adaption options which could be followed especially in areas which are hard hit like the arid areas in the range;
- A discussion of the suitability and potential of few proposed projects;
- Secondary sources, i.e., previous studies, and publications of the Department of Statistic;
- A number of Jordanian agricultural experts, and researchers were interviewed and referred by name, with the aim of quantifying, as much as possible the impact of climate change on natural resources and potential adaptations and to validate the costs implications of impacts and adaptations. Estimated economic impacts were the best guesses of the selected experts. However, it's noted to say the prospection has been discussed in deliverable number 1 entitled "1 Carry out one meeting with relevant stakeholders to launch the process", in addition to what have been revealed in the

meeting with the agricultural experts held on October.25th.2010 (Annex 1); and

- A focus group interview in the Jordan Valley was organized with nine well experienced farmers. The aim was to discuss issues related to climate change such as increase in temperature, low rainfall, delayed winter rain, short rainy season, and extreme climate conditions, supply and quality of irrigation water in the last two decades and their projections for the coming years and the effects of these variables on agricultural marketing and profitability of production. The estimated impacts that affected various agricultural aspects were the best guesses of farmers who have long experience in the local context, and who added depth and experience to this review. For more information, refer to Focus group meeting report held on October.20th.2010 (Annex 1).

Al Shamil Engineering team (the consultant) approach this deliverable (Final Report) based on the following logical sequenced deliverables (1-8) that were carried out and submitted to FAO previously:

- **Deliverable One:** Carry out one meeting with relevant stakeholders to launch the process;
- **Deliverable Two:** Review and evaluate all possible adaptation measures for agricultural production in term of suitability and applicability to Jordan;
- **Deliverable Three:** Review and assess opportunities and barriers to adaptation to climate change risks;
- **Deliverable Four:** evaluate the suitability and potential of each adaptation measure to be implemented in Jordan;
- **Deliverable Five:** Suggest and prioritize the best possible adaptation measures for food productivity; and
- **Deliverable Six:** Formulate an executive summary on the adaptation measures.
- **Deliverable Seven:** Final draft report.
- **Deliverable Eight:** Report of national dissemination workshop to the involved stakeholders and programme professionals on the findings of the whole assignment findings, results, and recommendations.

This effort was made to prepare for deliverable Nine "Final report taking into consideration workshop outcomes and FAO comments."

1.4 The Structure of the Study

The executive summary synthesizes the salient study findings; draws conclusions and points to policy implications and suggests recommendations. The study deliverable entitled "Final Report" is composed of three main parts of seven chapters including introduction; background; the national context of Jordan; methodology and approach; impacts of climate change; adaptation measures to climate change; implications of climate change and assignment findings, results and recommendations.

Part 1 of the study includes **this introductory chapter** which has set out in broad terms the significance of global climate change including Jordan and the study objectives and methodology. **Chapter 2** presents a summary of the International framework of climate change and the salient issues of the IPCC assessment and Jordan's Second National Communication reports. Chapter 3 provides the national context which includes the socioeconomic setting and agriculture and agribusiness in Jordan Economy.

In **Part 2** (Chapters 4 to 6) **Chapter 4** presents the main features of climate change in Jordan, the state of the agricultural sector and the socio-economic setting of Jordan. **Chapter 5** discusses the impacts of temperature increase, deceasing precipitation and increased frequency of extreme weather events. Socio-economic impacts include impacts on: agriculture and food; water resources; forests; rangeland and animal production; crop production; ecosystem and biodiversity and on the GDP. Chapter 6 discusses the adaptation measures to climate change in rain-fed and irrigated agriculture, for general agronomic and crop adaptations, water resources, forests, rangelands and livestock, biodiversity and socio-economic adaptation and adaptation scenarios and options for the agricultural sector.

Part 3 points to the policy implications of the impacts and adaptation to climate change and suggests recommendations and future areas for research. In addition to; 8 annexes and 2 appendices which are the deliverables and supportive documents are attached to the report.

2. CLIMATE CHANGE WORLDWIDE

2.1 International Framework

The Intergovernmental Panel on Climate Change (IPCC) is a scientific intergovernmental body established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), two organizations of the United Nations. The IPCC does not carry out its own original research, nor does it do the work of monitoring climate or related phenomena itself. A main activity of the IPCC is publishing special reports on topics relevant to the implementation of the United Nation Framework Convention on Climate Change (UNFCCC). The aims of the IPCC are to assess scientific information relevant to human-induced climate change, the impacts of human-induced climate change, and options for adaptation and mitigation. The IPCC bases its assessment mainly on peer reviewed and published scientific literature.

UNFCCC is an international treaty that acknowledges the possibility of harmful climate change. Implementation of the UNFCCC led eventually to the Kyoto Protocol (Wikipedia, 2010). The UNFCCC was adopted on 9 May 1992, in New York, and signed at the 1992 Earth Summit in Rio de Janeiro by more than 150 countries and the European Community. The main objective of the UNFCCC[1] is to: "achieve stabilisation of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". Reaching this objective inevitably entails reducing emissions to the level of uptake by natural sinks, such as oceans and forests - a fraction of current global emissions. As long as emissions are above this level, concentrations will continue to rise. With energy-related CO_2 emissions from fossil fuels accounting for the largest share of anthropogenic GHG emissions. Achieving such drastic emissions reductions will require a shift on a global scale to energy technologies which emit limited GHGs (UNFCCC Website). However, even if this agreement is fully implemented, it still will not achieve stabilization of GHG concentration in the atmosphere, and additional actions will be required to meet the UNFCCC objective. Adaptation, rather than mitigation, is one such action[2].

The UNFCCC and its **Kyoto Protocol (KP) adopted in 1997** provides a framework for climate change mitigation actions for a number of countries in the developed and developing world. Reflecting both the historic emissions levels of industrialised nations, differing capabilities to respond, and the specific national or regional priorities of developing countries, the UNFCCC and its KP are characterised by geographic disparities.

Industrialised countries agreed to take the lead in curbing long-term trends in emissions while developing countries are only encouraged to define programmes to curb emissions trends. Economic and social development, and in particular poverty eradication, remain overriding priorities for developing countries. In light of this, the KP established quantitative emissions objectives for most industrialised countries in its first commitment period to mitigate climate change by reducing their emissions an average 5.2% below 1990 levels during the period 2008-2012. The G-8 Summits in 2008 and 2009 agreed to reduce global greenhouse gas emissions by 50% by 2050 and to limit the rise in worldwide temperatures to no more than 2 °C.

There are two institutional bridges that directly support industrialised countries' efforts undertaken to mitigate climate change in developing countries:

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[1] The IPCC was established in 1988 by the WMO and the UNEP. Since the UNFCCC entered into force in 1992, the parties have been meeting annually in the Conference of the Parties (COP) to assess the progress in dealing with climate change. The first meeting (COP1) was in Berlin in March 1995 and the last one was in Copenhagen (COP 15) in December 2009. Other annual meetings (COP2 in 1996 to COP14 in 2008) were in Geneva-Switzerland, Kyoto-Japan, Buenos Aires- Argentina, Bonn-Germany, Hague-Netherland, Marrakech-Morocco, New Delhi-India, Milan-Italy, Buenos Aires- Argentina, Montreal-Canada, Nairobi-Kenya, Bali-Indonesia, and Poznan-Poland. From 2005, the conferences have met in conjunction with the Meeting of the Parties (MOP), the supreme body of the Kyoto Protocol (KP). The meeting COP 11, MOP 1 was in Montreal-Canada in 2005, and Copenhagen (COP 15/MOP 5) was in 2009. Since the KP entered into force (Feb 2005). Only parties to the KP may participate in deliberations and make decisions. The next conference (COP 16/ MOP 6) will be in Cancun-Mexico in November 29-December 10, 2010.

[2] Mitigation is an action to reduce greenhouse gas emissions and enhance sinks, and adaptation is the initiatives and measures to reduce the vulnerability of natural and human systems to climate change.

1. The first bridge is the Global Environment Facility (GEF) mechanism for the provision of financial resources to developing countries. The OECD members as of 1992 have a number of specific responsibilities regarding developing countries. These include providing financial support, as appropriate through the GEF mechanism, in order to **(a)** define emission reduction programs, and **(b)** promoting the transfer of environmentally-sound technologies to assist them in doing so.
2. The second bridge is the Kyoto Protocol's Clean Development Mechanism (CDM). CDM allows countries that have quantified emissions reductions commitments under the Protocol to meet part of their objectives with reductions achieved through projects undertaken in developing countries. The rational is that as GHGs mix well in the atmosphere, it does not matter where emission reductions take place. The CDM therefore enables emitters to benefit from cheaper reductions without compromising overall environmental integrity. CDM projects, however, have to meet certain criteria. These include the fact that **(a)** emissions reductions should be measurable, and they **(b)** lead to long term benefits to climate change mitigation as well as be additional to any reduction that would occur in the absence of the project. The CDM Executive Board supervises the CDM and ensures that the requirements contained in the Protocol and the subsequent Marrakech Accords are met (UNFCCC Website).

The Kyoto Protocol (KP)[3] is an international agreement linked to the UNFCCC. The major feature of the KP is that it sets binding targets for 37 industrialized countries and the European community for reducing GHG emissions .These amount to an average of five per cent against 1990 levels over the five-year period 2008-2012. The major distinction between the Protocol and the Convention is that while the UNFCCC encouraged industrialized countries to stabilize GHG emissions, the KP commits them to do so.

Recognizing that developed countries are principally responsible for the current high levels of GHG emissions in the atmosphere as a result of more than 150 years of industrial activity, the KP places a heavier burden on developed nations under the principle of "common but differentiated responsibilities" (UNFCCC Website).

2.2 Climate Change Assessment

The 2009 Report of the Arab Forum for Environment and Development (AFED) stated that the Arab countries are in many ways among the most vulnerable in the world to the potential impacts of climate change, the most significant of which are increased average temperatures, less and more erratic precipitation, and sea level rise, in a region which already suffers from aridity, recurrent drought and water scarcity. **By the end of the 21st century, the Arab region is projected to face an increase of 2 to 5.5°C in the surface temperature**. This increase will be coupled with a projected decrease in precipitation up to 20%. Shorter winters, dryer and hotter summers, more frequent heat waves, and more variability and extreme weather events occurrence are projected (AFED, 2009).

The average per capita energy consumption level in the Arab countries (nearly 1.5 tons) lies between some developing countries such as India (0.5 tons), and Brazil (1.1 tons), China (1.3 tons), and some developed economies such as the USA, Canada and Australia (4-5 tons), Japan (4.3 tons), the United Kingdom, Germany, and France 2-2.5 tons (AFED, 2009; Heinzerling, 2010).

There are remarkable disparities in per capita energy consumption amongst different Arab countries depending mainly on income levels, standard of living, degree of urbanization and climatic conditions. The figure ranges from as low as 0.33 tons in Yemen (AFED, 2009) to as high as 11.5 tons in Qatar (Heinzerling, 2010). Industry

3 The Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. The detailed rules for the implementation of the KP were adopted at COP 7 in Marrakesh in 2001, and are called the "Marrakesh Accords".

is the major energy consuming sector in the Arab countries, accounting for about 45% of the total consumption followed by the transport sector (32%).

The agricultural sector can be part of the mitigation strategies by reducing its own emissions, and by offsetting emissions from other sectors by removing CO_2 from the atmosphere (via photosynthesis) and storing the carbon in soils. Through the adoption of agricultural best management practices, emissions of Nitrous oxide (N_2O) (from fertilizer use), methane (from livestock production and manure), and CO_2 (from on-farm energy use) can be reduced (Abdel Gelil, 2009).

Jordan's contribution to global CO_2 emissions is slight, but with major vulnerability to climate change impacts. It contributed 13.8 million tons of CO_2 equivalent in 1994 (GCSE 1997), and 20.14 million tons of CO_2 equivalent in 2000 (MOE, 2009). This represents 0.24% of the total estimated global CO_2 emissions of 8.4 billion tons in 2009. The GHG emissions of the agriculture activities were very small and accounted only for 0.2 and 0.9 percent of Jordan's total GHG emissions in the years 1994 and 2000 (GCSE 1997; MOE, 2009). Emissions of methane from agriculture sector were insignificant, and came from manure decomposition, and field burning of agricultural residues. The emissions from the land-use change and forestry sector accounted for 3.7 percent of Jordan's total GHG emissions in the year 2000. Net CO_2 emissions were estimated to be 17.047 million tons at 84.6 percent of Jordan's total greenhouse emissions in the year 2000. These emissions arise from energy, industrial processes sectors at 86.3 percent, 9.4 percent of the total CO_2 emissions; respectively. Thus, the main source of CO_2 is combustion of fossil fuels (MoE, 2009).

Although a minor contributor to global warming, Jordan is committed to be an active partner in global efforts to promote a low carbon economy, and it is working on formulating national plans that consist of mitigation and adaptation measures. Several studies are ongoing on delineating mitigation options, to prepare for and adapt to climate change and to initiate measures for reducing emissions to control greenhouse gases (MOE, 2009). However, no country can overcome the challenge alone, and negative effects of climate change require concerted efforts and mutual assistance regionally and globally for improving the quality of life for all.

The 2006 Human Development Report classified Jordan as one of the world's most water scarce areas (HDR, 2006). The National Agenda that sets Jordan's development vision till 2015, as well as the United Nations Development Assistance Framework (UNDAF) document (2008-2012), stress that Jordan's remarkable development achievements are under threat due to the water scarcity, which is expected to be worsened by climate change. Jordan made strategic advances towards the achievement of MDG targets. These include MDG 1, 2, 4 and 7: poverty reduction, achieving higher adult literacy rate and lower infant mortality, higher access to water and access to sanitation. But the impacts of climate change are bringing about threats to health, food security, productivity, and human security (MDGF, 2007). The Initial National Communication (INC) to the UNFCCC foresees that over the next decades, Jordan will witness a rise in temperature, drop in rainfall, reduced vegetation cover, reduced water availability, heat-waves, and more frequent dust storms. The Second National Communication (SNC) to the UNFCCC identifies water as a priority area (GCSE 1997; MOE, 2009).

Jordan was actively working in the last five decades in many development activities which were directed to overcome the country's scarcity of natural resources, especially land, water and energy. These include large water development projects in the Jordan Valley and constructing storage dams, largely expanded the irrigated areas. In addition, efforts were made to introduce and disseminate more efficient management of water resources. Drip irrigation is almost a normal practice for irrigation in all irrigated areas. In the highlands, land reclamation, water harvesting, soil and moisture conservation projects were implemented for fruit tree planting and afforestation in cooperation between the Ministry of Agriculture (MOA) and WFP, IFAD, and other international development agencies. Tens of thousands of hectares were planted with olive trees, grapes, almonds and other fruit trees. Similar areas were planted with forest trees. At present, Jordan is self sufficient in olive oil and olive products (MOA, 2004). Besides, many projects for wastewater reuse, and use of green houses in agriculture is widespread. Other development activities include projects for water harvesting and containing desertification; desalination of water and use of renewable energy sources (solar energy) is almost a normal practice in urban areas and for soil solarization. These development efforts serve as mitigation measures to curtail GHG emissions and adaptation measures to lessen the harms of climate change.

2.2.1 IPCC and Jordan's Second National Communication (SNC) Assessment Reports

The IPCC First Assessment Report[4] (FAR) in 1990 reported in the summary for policymakers (SPM) of the WGI, that they are certain that emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases, resulting on average in an additional warming of the Earth's surface, and CO_2 had been responsible for over half the enhanced greenhouse effect. They predicted that under a "business as usual" (BAU) scenario, **global mean temperature will increase by about 0.3 ° C per decade during the 21st century.** They judge that **global mean surface air temperature has increased by 0.3 to 0.6 ° C over the last 100 years,** broadly consistent with prediction of climate models (IPCC, 1990). These results were endorsed at the Earth Summit in Rio de Janeiro in 1992, the United Nations Conference on Environment and Development.

The SPM of the WGI of the IPCC Second Assessment Report (SAR) (IPCC, 1996) reaffirmed the findings of the FAR that climate has changed over the past century and the air temperature has increased by between 0.3 and 0.6 °C since the late 19th century, and the human (anthropogenic) influence on global climate as the GHG concentrations have continued to increase.

The SPM of the WGI of the Third Assessment Report (TAR) (IPCC, 2001) reported that an increasing body of observations gives a collective picture of a warming world and other changes in the climate system. **The global average surface temperature has increased over the 20th century by about 0.6°C.** There is new and stronger evidence that most of the warming observed over the past 50 years is attributable to human activities. Although confidence in the ability of models to project future climate has increased, such models cannot yet simulate all aspects of climate. Sensitivity of climate to GHGs may be overestimated or underestimated because of flaws in the models and because the importance of some external factors may be misestimated.

The TAR estimate for the climate sensitivity[5] is 1.5 to 4.5 °C; and **the average surface temperature is projected to increase by 1.4 to 5.8 °C over the period 1990 to 2100**, and **the sea level is projected to rise by 10 to 90 cm over the same period**. The wide range in predictions is based on scenarios that assume different levels of future CO_2 emissions. Each scenario then has a range of possible outcomes associated with it. The most optimistic outcome assumes an aggressive campaign to reduce CO_2 emissions; the most pessimistic is a "Business as Usual" scenario. Other scenarios fall in between.

The summary for policymakers (SPM) of the WGI of the Fourth Assessment Report (AR4) (IPCC, 2007) stated that the warming of the climate system is unequivocal, and most of the observed increase in global average temperatures since the mid-20th

[4] The IPCC series of reports include (a) the report of the Working Group I (WGI) The Physical Science Basis, (b) the report of the WGII ; Impacts, Adaptation and Vulnerability, (c) the report of the WGIII; Mitigation of Climate Change (final version) and (d) the Summary for Policymakers (SPM).

5 Climate sensitivity is defined as the amount of global average surface warming following a doubling of CO2 concentrations. It is likely to be in the range of 2 to 4.5 °C, with a best estimate of about 3 °C. This range of values is not a projection of the temperature rise we will see in the 21st century, since the future change in CO^2 concentrations is unknown, and factors besides CO^2 concentrations affect temperature (AR4, IPCC, 2007).

century is very likely due to the observed increase in anthropogenic GHG concentrations. The probability that this is caused by natural climatic processes alone is less than 5%. As Table 1 indicates, **the world temperatures could increase between 1.1 and 6.4 °C during the 21st century**, the **sea levels will probably rise by 18 to 59 cm** (this is less than the TAR estimate), there will be frequent heat waves, heavy rainfall at high latitudes or an increase in droughts in the mid latitudes; 30-40° N.

Warming of the climate system has become more evident. Eleven of the twelve years in the period (1995–2006) rank among the top 12 warmest years in the instrumental record since 1850. Warming in the last 100 years has caused about a 0.74 °C increase in global average temperature. This is up from the 0.6 °C increase in the 100 years reported in the TAR (AR4, IPCC, 2007).

The atmospheric carbon (CO_2), together with other anthropogenically (human-induced) emitted gases (CH_4, N_2O, CFCs, etc.) constitute GHGs that act as the greenhouse glass by preventing the heat to escape to space. Global atmospheric concentrations of GHGs have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values. The amount of CO_2 in the atmosphere in 2005 (379 parts per million (ppm)) exceeds by far the natural range of the last 650,000 years (180 to 300 ppm). The amount of methane in the atmosphere in 2005 (1774 ppb) exceeds by far the natural range of the last 650,000 years (320 to 790 ppb). Methane and N_2O have much higher global warming potential than CO_2. The rate of climate change during the last century seems to be faster than any changes that occurred over the past, strongly implying an anthropogenic effect and in contrast to some scholars who attribute climate change to a weather cycle. The primary source of the increase in CO_2 is fossil fuel use, and for the methane is very likely to be a combination of human agricultural activities and fossil fuel use.

Table 1 summarizes the four Special Reports on Emission Scenarios (SRES) of the AR4 against the projected global average surface warming until 2100. Best estimate for a low scenario (more environmental focus) is 1.8°C with a likely range of 1.1 to 2.9°C. Best estimate for a high scenario (more economic focus) is 4.0 °C with a likely range of 2.4 to 6.4°C. A temperature rise of about 0.1°C per decade would be expected for the next two decades, even if GHG and aerosol concentrations were kept at year 2000 levels. A temperature rise of about 0.2°C per decade is projected for the next two decades for all SRES scenarios. Confidence in these projections is strengthened because of the agreement between past model projections and actual observed temperature increases. Mountain glaciers and snow cover have declined on average in both hemispheres. Sea level rose at an average rate of about 1.8 mm/year during the years 1961-2003. The rise in sea level during 1993-2003 was at an average rate of 3.1 mm/year. It is not clear whether this is a long-term trend or just variability.

Table 1: The four Special Report on Emission Scenarios (SRES) families of the Fourth Assessment Report vs. projected global average surface warming until 2100

	High scenario **More economic focus**	**Low Scenario** **More environmental focus**
Globalization **(homogeneous world)**	A1 rapid economic growth 1.4 - 6.4 °C	B1 global environmental sustainability 1.1 - 2.9 °C
Regionalization **(heterogeneous world)**	A2 regionally oriented economic development 2.0 - 5.4 °C	B2 local environmental sustainability 1.4 - 3.8 °C

The summary for policymakers (SPM) of the WGII of the Fourth Assessment Report (AR4) reported that dry regions are projected to get drier, and wet regions are projected to get wetter. The arid and semi-arid regions are highly vulnerable to climate change. The projected climatic changes will be among the most important challenges for agriculture in the twenty-first century, especially for developing countries and arid regions. By mid-century, annual average river runoff and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical areas, and decrease by 10-30% over some dry regions at mid-latitudes (30-40° N) and in the dry tropics. Drought-affected areas will become larger. Heavy precipitation events are very likely to become more common and will increase flood risk[6]. It is projected that globally, potential food production will increase for temperature rises of 1-3 °C, but decrease for higher temperature ranges. The Summary concludes that stabilization of GHGs is possible at a reasonable cost, with stabilization between 445-535 ppm (380 ppm at present) costing less than 3% of global GDP.

As global climate appears to be changing, we would expect the Mediterranean region climate also to have changed. Yields of rain-fed crops could decrease substantially across the region due to increased frequency of drought. While losses may be partially offset by beneficial effects from CO_2, crop production would be further threatened by increases in competition for water and the prevalence of pests and diseases and land losses through desertification. World prices for many key commodities such as wheat[7], maize, and soybean meal could rise significantly as a result of global climate changes. Not only might Mediterranean countries loose substantially in economic terms, but the combination of higher prices and crop losses would lead to a deterioration in levels of food security[8] in, particularly, southern countries (Near East and North Africa). National economies would be adversely affected not only by the direct impacts of climate change, but also through the cost of adaptive measures and the indirect implications of changes elsewhere. Quantitative estimates of financial costs are unreliable but in general, developing countries are expected to suffer larger relative economic damages than developed countries (Karas, 2000).

Heinzerling (2010) reported that CO_2 emissions in China grew by nearly 9% in 2009. At the same time, emissions in most industrial countries (USA, UK, Germany, France and Japan) dropped by 5-12% from 2007 to 2009 bringing global CO_2 emissions from fossil fuel use down from a high of 8.5 billion tons of carbon in 2008 to 8.4 billion tons in 2009, of which, USA accounted for 17% of the global CO_2 emissions. China and India CO_2 emissions continued to grow rapidly. China's emissions rose to 1.86 billion tons of carbon in 2009, representing 22% of the global CO_2 emissions. China, USA, India and Russia are the largest emitters respectively. Qatar ranks highest in per capita emissions, at 11.5 tons of carbon per person in 2009, followed by several other oil-rich countries. Australia, the United States, and Canada lead the major industrial countries, emitting 4-5 tons of carbon per person in 2009. During the 2000s, global CO_2 emissions rose by an average of 2.5 percent a year—nearly four times as fast as in the 1990s. Other developed countries with comparable standards of living to the USA, but emit only half as much CO_2 per person. While fossil fuel use is responsible for the majority of CO_2 emissions, emissions from changes in land use, such as deforestation (in Indonesia and Brazil and others) were estimated at 1.2 billion tons of carbon in 2008.

More than half of the CO_2 emitted annually is absorbed by oceans, soils, and by the global vegetation. The rapid rate at which CO_2 is emitting into the atmosphere is overwhelming these natural systems, posing a particular threat to ocean ecosystems. The CO_2 that is not absorbed by these natural sinks remains in the atmosphere, where it traps heat. The level of CO_2 in the atmosphere, which stood between 260 and 285

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6 Devastating floods in Pakistan, China and Philippine support this projection. Pakistan experienced unprecedented rainfall, and one third of the agricultural land was flooded with water, and almost destroyed all crops.

7 Russia suffered harvest reductions because of high temperatures and drought in 2010, and an export of wheat is banned.. Russia and Pakistan climate problems contributed to the increased prices of cereals by more than 30%.

8 Lower yields and increased prices are likely to have negative impacts on attempts at alleviating world poverty.

parts per million (ppm) from the beginning of agriculture until the Industrial Revolution, has risen rapidly in the last two-and-a-half centuries, to over than 387 ppm today. The increase in atmospheric CO_2 has driven a rapid rise in global temperature, increased climatic variability and uncertainty, and increased frequency of extreme climatic events (droughts, floods, heat waves, storms etc.), and melting ice sheets and rising sea levels demonstrate the destructive effects of the carbon accumulating in the atmosphere (Heinzerling, 2010).

The IPCC has projected a number of scenarios for possible emissions growth in the coming decades. The likely rise in temperature projected in these scenarios ranges from 1.1 to 6.4 °C by the end of the century (IPCC, 2007a). Carbon Dioxide emissions continue to track some of the worst-case of IPCC scenarios. Increasing numbers of scientists agree that atmospheric CO_2 must be stabilized at 350 ppm or less. In order to achieve this goal, a fundamental shift in course is needed—and quickly to a new energy economy, one that relies on carbon-free sources of energy such as wind, solar, and geothermal instead of climate-threatening fossil fuels, to avoid the worst effects of climate change (Heinzerling, 2010).

3. THE NATIONAL CONTEXT

3.1 Socio-Economic Setting

Jordan is a small country characterized by an expanding population and economic growth in the context of land and water scarcity. Total population was estimated to be 1.81 m in 1975, 2.49 m in 1983 (Rimawi, 1991), 4.14 m in 1994, 4.74 m in 1999 and 5.98 m in 2009, with 37% below the age of 15 years. The population of Jordan was growing at the rate of 3.1% during the 1960s and 3.4% during the 1980s (MOP 1986, and DOS, 2000), 2.5% during the period 1999-2001 and 2.25 during the period 2004-2009 (DOS website). Although, the total area is about 9 m hectares, the populated area is less than 10% of the total area. More than two thirds of the population lives in the main urban areas, of which 39% live in Amman, 18% live in Irbid and 15% live in Zarqa (MoL, 2009).

The GDP at market prices increased from JD 201 million in 1964 to JD 386 m in 1974, JD1787 m in 1984, JD4358 m in 1994, JD8164 m in 2004 and JD16266 m in 2009 (CBJ, 2004, 2005,2009). The rate of growth of the GDP at constant prices was 6.4% during the period 82-1987 (calculated from CBJ 2004), 5.6% during the period 92-1997 (MOP, 1999), 5.8% during the period 01-2005, and 6.3% during the period 06-2009 (CBJ, 2005, 2009).

The relative share of the agricultural sector (AGDP) to the GDP declined from 30% in1954 (Aresvik, 1976), to 12% in 1969, about 6% in1980s, 5% in1996, 3.8% in 2000, and to 3.9% in 2009 (CBJ, 1996 and 2000, 2004, 2009). However, the AGDP at market prices increased from JD 32 m in 1964 to JD57 m in 1974, JD98 m in 1984, JD193 m in 1994, JD195 m in 2004 and JD476 m JD in 2009 (CBJ, 2004, 2005,2009). Jordan has made a steady progress in the field of agriculture in the 1970s and 1980s. Average annual rate of growth in AGDP during 1970s was 4.2% and 6.1% during the 1980s (Randhawa 1990). The rate of growth in AGDP at constant prices during 1996-2000 was negative (CBJ, 2000), but the (geometric) mean of the rate of growth was high and estimated to be 7.8% during 2002-2005 and 3.2% during the period 2006-2009 (CBJ, 2009).

Agriculture provides income to about 10% of the population in 1997 and 2007 (DOS, 1999, 2009). It contributes to improving the balance of trade and food security and food exports has financed about 20-35% of the value of food imports during the 1983-2009 as Table 14 shows. About 6% of the Jordanian labour force was engaged in the sector in 1999, but 2.6% in 2008 as Table 15 shows (MoL 2000, 2009).

Jordan is currently the fourth most water-deprived countries in the world. The available water resources per person are 140 m^3, against 1,000 m^3 per person per year, the common benchmark for water scarcity (Denny, et.al, 2008).

3.2 Agriculture and Agribusiness in Jordan Economy

The main objectives of the agricultural policy in Jordan are; to achieve economic efficiency to improve farm operators income, to conserve the basic natural resources by bringing about sustainable land use and ensuring sustainable development and protecting the environment, and to promote the contribution of the agribusiness sector to GDP through integrating agriculture with other sectors of the economy through backward and forward linkages (MoA, 1997). The sound utilization of scarce natural resources in Jordan is a precondition for agricultural development. With increasing concerns about climate change and its impact on the environment, the scarcity of land and water resources are presenting a long-term constraint on the development of the agricultural sector.

Agriculture contributes to economic development in terms of **(a)** production contribution to GDP, **(b)** resource contribution through supplying raw materials to agricultural industry and exports, and **(c)** market contribution through supplying food products at cheap prices. This improve poverty problems, provides for food, social and national security, and increase demand for non-agricultural products by spending less income on food requirements.

Jordan has made a steady progress in the field of agriculture in the 1970s and 1980s. Average annual rate of growth in AGDP during 1970s was 4.2% and 6.1% during the 1980s (Randhawa 1990). However, the rate of growth in AGDP at constant prices during 1996-2000 was negative (CBJ, 2000), but the rate of growth was high and estimated to be 7.8% during 2002-2005 and 3.2% during the period 2006-2009 (CBJ, 2009). Agriculture provides income to about 10% of the population in 1997 and 2007 (DOS, 1999, 2009). It contributes to improving the balance of trade and food security and food exports has financed about 20-35% of the value of food imports during the 1983-2009 as **Table13** shows.

The relative share of the agricultural sector to the GDP declined from 30% in 1954 (Aresvik, 1976), to 12% in 1969, about 6% in 1980s, 5% in 1996, 3.8% in 2000, and to 3.9% in 2009 (CBJ, 1996, 2000, 2004, and 2009). About 6% of the Jordanian labor force was engaged in the sector, but 2.6% in 2008 as **Table 14 shows** (MoL 2000, 2009).

Although the agricultural sector is small relative to the overall economy[9], and the low share of the agricultural sector in the GDP **(Table 2)** reflects the limited agricultural resource base, this underestimates the real importance of the sector. The farm sector is relatively important in the production of tradable goods. Backward and forward linkages between agriculture and the overall economy are strong. Para agricultural activities, which include inputs and producer services, marketing and processing, are estimated for the period 1987-91 to represent 22.6% of GDP. With the addition of the agricultural sector contribution to GDP (6.4%) in the same period, the overall contribution of the value added by the agribusiness sector to GDP was 29% in the period 1987-91 as Table 2 shows. The components of agribusiness activities and the percentage contribution to GDP are agribusiness services 9%, inputs 8%, agro-industry 5% (Ouedraogo & Hayson, 1993). **Table 2** shows the contribution to national and economic growth of traditional sectors, agribusiness and other sectors based on 1987-91 averages. Looking to traditional sectors approach, the contribution to Jordan's economic growth of the agricultural sector was the lowest of the three sectors, and was estimated to be 11%. However, considering the agribusiness sector as a whole, the contribution of agribusiness to economic growth was the largest, and more than the other two sectors combined.

Table 2: Contribution to National and Economic Growth of Traditional Sectors, Agribusiness and Other Sectors (1987-91 averages)

Measures	**Traditional sectors (%)**			**Agribusiness and other sectors (%)**			**GDP**
	Agriculture	**Industry**	**Services**	**Agribusiness**	**Industry ***	**Services ***	
Share	6.4	30.4	63.2	29.0	17.1	54.0	100.0
Growth	12.5	8.4	6.0	14.3	0.8	5.4	-
Weighted growth	0.8	2.5	3.8	4.1	0.1	2.9	7.1
Contribution to GDP growth	11.2	35.6	53.2	57.8	1.8	40.4	100.0

Source: Adapted from Ouedraogo and Hayson, 1993. * Para agricultural activities in the industry and service sectors are excluded.

The food industries represented 12% of the value added, and 16% of the number of labour in 1995 (DOS, 1996), and 12% of the value added and 14% of compensation of employees in 2007[10]. Food industries is basically flour milling and bakery, dairy products, cooking oil, meat products, chocolate and sugar confectionery, and canning and preserving food products, juices, tomato pastes. The food manufacturing index increased from 43 in 1975 to 104 in 1989 and to 154 in 1999, and to 302 in 2009, and fertilizers manufacturing index increased from 98 in 1989 to 168 in 1999 and to 165 in 2009 (1988 = 100) (calculated from CBJ, 2004, 2010)

Thus, despite significant expansions of the industry and services sectors, agriculture remains an important economic sector in Jordan. The analysis of the contribution of traditional sectors to the growth of GDP does not give a fair credit to the role of agriculture in the economy. Hence, on this broad definition (agribusiness sector), agriculture is a major contributor to the growth of GDP, and to employment, which

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9 The value of the agricultural products is estimated on the basis of farm gate prices which, even without considering the rate of inflation, remained unchanged or decreased especially for vegetables. For example, the price of tomatoes, which occupied 13% of the irrigated area and accounted for 42% of total vegetables production in 2007, decreased from JD 124 in 1979 to JD 90 per ton in 2007 (CBJ, 1984; DOS, 2008), while the cost of living index increased substantially during this period. Thus, the monetary value of the AGDP underestimates the contribution of the agricultural sector to the GDP.

10 The Industry Survey, 2007, Department of Statistics.

makes the development of agriculture under climate change conditions in Jordan of prime importance.

The Department of Statistics (DOS) initiated a project to establish input –output tables in 2009[11]. This aim is to determine the backward and forward linkages of the agricultural sector with the industrial and services sectors, and in turn the para-agricultural activities. This will enable DOS to produce figures which show the contribution of the agribusiness sector in the GDP. This information will provide a comprehensive picture of the role of the agricultural sector in providing employment and generating income by the agribusiness sector.

3.2.1 Land Resources

With increasing concerns over climate change, the scarcity of land and water resources presents a long-term constraint on the development of the agricultural sector. Consequently, it is essential that sound land use patterns and agricultural practices are established and, in many areas, soil and water conservation measures for sustained agricultural development be undertaken. It has been estimated that adoption of improved water conservation technology in the Central Great Plains of the USA made the largest single contribution (45%) to the more than doubling the wheat yield production between 1936-1977, ahead of improved varieties (30%), equipment and fertilizer practice (25%) (FAO, 1995).

Rain starts in October and ends in May, but most of the rain falls in December through to March. The rest of the year is hot and dry with consequent high rates of evaporation. Jordan total land area of about 9 million hectares, only 9% receives more than 200 mm of water (Table 3 and 4), but less than 6% is cultivable, and only 2.5% is cultivated in 2009 (DOS, 2010). The irrigated area represents about one percent of the total land area, but represented 43% of the cultivated area in 2009 as Table 3 shows (DOS, 2010). The irrigated area represented 28% in 1995 (as Table 10 shows). Thus, rain-fed agriculture is decreasing, and one of the main factors for this trend is the erratic availability of water. Thus, under climate change, developing dry farming with improved water harvesting measures as an adaptation is of utmost importance to agricultural development in Jordan.

As **Table 3** shows, more than half of the overall cultivable land is fallow and hilly areas and may be brought into cultivation by land reclamation such as terracing and water harvesting to be used for fruit trees such as olives, grapes, figs, almonds and forage crops. About one fourth of land (2.2 M ha) receives 50-200 mm of rainfall, which offers some potential for livestock development and other crops if water resources are developed (i.e. water harvesting...). Amount of rainfall is not the only factor affecting cultivability of the land. Soil characteristics, topography, distribution of the rainfall, and temperature are among the important factors, which determine the potential of a land for farming.

Table 4 presents the distribution of zones by slope. More than 90 % is classified as arid. Thus, cultivable land is limited, and meeting the demand of the growing population depends on preserving, and improved management of land resources and methods of production to promote land productivity. Expanding land resources depends on developing water resources, but the prospects appear to be quite limited. With the adverse impact of climate change, the growing deficit in water requirements for domestic and industrial uses in the future are more likely to be met by reducing the amount of water available for agriculture. Thus, preserving and reclamation land resources, soil conservation, measures for water harvesting, and improved water management for irrigation, are likely to gain more importance for the future of agricultural development. Table 4 shows that the arid zone represents 91% of the total area, of which 92% has a slope less than 9%, against 42% for the marginal

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[11] A workshop is organized on September 15, 2010 to present the methodology of input –output project, salient results and sectoral applications of the project.

area, 19% for the semi-arid area and less than one percent in the semi-humid zone. Of the total area receiving more than 200 mm (8.7% of the total area), about one third has a slope less than 8%, which represent 2.8% of the total area. This relatively flat area represents the area, which is potentially suitable for cereal production, if other agro-climatic characteristics are fit.

Table 3: Distribution of Land by Agricultural and Non Agricultural Use (%)

Land use	Area (M ha)	Percentage
Land for urban and infrastructure use	0.17	1.9
Land designated as forest land	0.13	1.5
Land covered with natural and artificial forests	0.07	0.8
Land capable of supporting rain-fed agriculture (200 –500mm)	0.7	7.8
Land capable of supporting rain-fed agriculture (> 500mm)	0.1	1.1
Total cultivable land	**0.51**	**5.7**
Total cultivated area (2009)	**0.22**	**2.46**
Cultivated area under dry farming (2009)	**0.13**	**1.46**
Cultivated area under irrigation (2009)	**0.095**	**1.06**
Total range land	8.1	90.6
Range land with less than 50 mm rainfall	5.9	66.0
Range land with 50-100 mm rainfall	1.2	13.4
Range land with 100-200 mm rainfall	1.0	11.2
Water area	0.05	0.5
Total area	8.93	100.0

Source: Calculated from MOA 1996 & 1998, DOS, 2001 and DOS 2009
* M ha: Million Hectares

Table 4: Distribution of Total Land Area (ha) in Jordan by Agro-climatic Zones and Slopes

Zone:	Slope			Total	
Rainfall classes (mm)	**< 9%**	**9 – 25%**	**> 25%**	**Area (ha)**	**%**
Arid (< 200 mm)	7822.3 (92.5%)	414.1 (4.9%)	220.6 (2.6%)	8456.9 (100.0%)	91.3
Marginal (200 – 350 mm)	236.1 (41.9%)	228.3 (40.5%)	98.9 (17.6%)	563.4 (100.0%)	6.1
Semi–arid (350 – 500 mm)	26.2 (19.3%)	64.9 (47.8%)	44.7 (32.9%)	135.9 (100.0%)	1.5
Semi– humid (> 500 mm)	0.6 (0.6%)	61.9 (62.6%)	36.4 (36.8%)	98.9 (100.0%)	1.1
Total	8085.2 (87.4%)	769.2 (8.3%)	400.6 (4.3%)	9255.1 (100.0%)	100.0

Source: Calculated from WFP, 1995, and MOA, 1974.

The farm structure is characterised by the dominance of small farms. As **table 5** shows, several changes can be observed between the 1975 and 2007 Agricultural Censuses:

First: The total area of holdings decreased by about one third, while the number of holdings increased by more than one forth (27%). The average size of holding is almost halved (from 7.8 to 4.0 ha).

Table 5: Distribution of number of holdings by area size groups (%)

Area size	1975 Census (%)		1983 Census		1997 Census*		2007Census	
Group	Number (%)	Area (%)	Number (%)	Area (%)	Number (%)	Area (%)	Numbe r (%)	Area (%)
< 1	24.3	1.1	25.3	1.6	43.3	4.3	37.3	3.5
1 - 2.9	24.2	5.5	28.3	7.7	30.1	12.7	28.1	8.7
3 – 4.9	15.0	7.1	16.2	9.2	9.7	9.1	11.0	7.2
5 –19.9	27.8	32.6	24.2	33.6	13.6	29.8	12.0	17.9
≥20	8.7	53.7	6.0	47.9	3.3	44.1	11.6	62.7
Total	100.0	100.0	100.0	100.0	100.0*	100.0	100.0	100.0
No. / Area (ha)	50791 Holdings	390403 Ha	57438 Holdings	364263 ha	72168* holdings	278589* Ha	64613 holding	258423 ha
Mean holding area	7.8		6.3		3.9		4.0	

*This total number of holdings in 1997 does not include 3806 holdings with an area of 27412 ha in the Jordan Valley.
Sources: Calculated from DOS, 1977, 1985, 1999 and 2009.

Second: the change was more notable in the 1-4.9 ha sizes where the percentage of the number of holdings increased from 63% in 1975 to 76% in 2007, and the percentage of area for these size groups increased from 14% to 19% mainly at the expense of the largest group sizes 5-19.9 ha in which the percentage of the number of holdings decreased from 28% to 12% and the percentages of area decreased from 33% in 1975 to 18% in 2007. Thus, in contrast to the trend in developed countries where the percentage of smaller farms is declining, the percentage in Jordan is increasing. As a general rule, the small farms are located in the high annual rainfall areas and the more fertile lands or under irrigation in the Jordan Valley, whereas the large farms tend to be found in the marginal lands, in the arid areas or where underground water is available.

3.2.2 Water Resources

The limited water resources and potentials are considered the main constraints for increasing production. Only 1.06% of the total area is irrigated. This includes about 36 thousand ha in the Jordan Valley, and the rest in the highlands and in the arid zone (DOS, 2010). The Middle East region is poor in water resources, and Jordan is the poorest among the poor in water resources. This is evidenced in **Table 4**, which shows that less than 10% of Jordan receives more than annual 200 mm of rainfall. Only about 235 thousands hectares receive more than 350 mm which is said to be the minimum annual rainfall that would sustain rain-fed farming. Hence, Jordan has limited surface water with high rates of evaporation and infiltration resulting in relatively small annual stream flow, but good potential for underground water. Thus, developing water resources through constructing dams and implementing irrigation projects was a primary objective for the Government. The total water resources are 900-1000 MCM/ year, of which 20% from non-renewable sources (Denny et al, 2008). As **table 6** shows, more than two thirds of water is allocated for agriculture, and the rest for domestic and industrial consumption. As **Table 3 shows,** 43% of the cultivated land is under irrigation. Water resources is becoming more limiting as few sources remain undeveloped through measures such constructing dams and use of recycled water, while demand is increasing for industrialization and for the growing population.

Table 6: Per Capita Water Demand for Different Uses (MCM, % between brackets)

Uses	1996	2000	2010
Municipal	175 (20.1)	241 (24.5)	350 (29.4)
Industrial	45 (5.2)	55 (5.6)	80 (6.7)
Agriculture	650 (74.7)	686 (69.9)	760 (63.9)
Total	870 (100.0)	984 (100.0)	1190 (100.0)

Source: Adopted from, MWI, 1996.

With the increasing demand of water for the rapidly growing population, industrialization and frequent drought, more water will have to be diverted from irrigated agriculture. The limited potential for promoting agricultural production through horizontal expansion of cultivable land, basically due to limited water resources, calls for adopting a strategy for agricultural development based on the use of improved technologies. These include water harvesting, and rationalizing water use for irrigation on the basis of water requirements for crops. Consequently, increases in production will have to come through increases in productivity that can be facilitated by effective agricultural research and extension services. Constant development or adaptation of new technologies by research, and effective linkages with public and private extension to transfer appropriate technologies are together the corner stone of agricultural development. Hence, research and extension activities have a vital role to play in promoting agricultural development. Policies and reforms are needed to achieve more sustainable and efficient use of the limited natural resources, especially water and land. Institutional reforms are needed in research and extension to increase agricultural productivity and to improve management of resources. Similarly, reforms are needed in factor pricing to achieve more optimal resource allocation.

3.2.3 Agro-Climatic Zones

Geography and topography are important factors in determining the climate of Jordan. As Table 4 shows that 87% of the total area has a slope of less than 9%, and 4.3% has a slope over than 25%. Thus, Jordan is characterized by the diversity of agro-climatic conditions which permits diversification of crops and seasonal distribution of production. Jordan can be divided into almost three distinct zones, namely, the highlands, the Jordan Valley and the arid zone. Therefore, the potentials for adaptations under climate change and the problems associated with agricultural development are different.

3.2.3.1 Highlands

The highland region of the country separates the Jordan Valley from the plains of the eastern desert. The area of this zone, where annual rainfall exceeds 200 mm is about 0.8 million ha **(Table 3)**. The highlands is less than 10% of the country's total area, but, it is the most densely populated as more than 90% of the population lives there. It comprises mountainous and a hilly region with an altitude varies from 600 to 1600 meters above sea level. The highlands has a typical Mediterranean climate, with long, hot, dry summer and mild wet winters, which varies from one area to another and one season to another. It receives Jordan's highest rainfall, and it is the most richly vegetated in the country. The rainy season starts in the middle of October and continues to the end of April. The bulk of the rain falls during November through February. The annual rainfall varies from more than 500 mm in the north with Ajloun as the wettest region, to less than 200 mm in the south. Rain-fed agriculture is dominant in the area. The soil fertility, land topography, and averages of annual rainfall are generally favorable for rain-fed farming. Fruit trees have the largest area of the rain-fed agrarian lands (47%) followed by Field crops and forages (45%), and finally vegetable crops (8%) (DOS, 2008). Crop rotation includes winter and summer field crops and summer vegetables.

Most of the cultivable area (68%) under rain-fed conditions lies in the highlands (DOS, 2008). The production capacity for various cultivated crops is good compared with other zones under rain-fed conditions. The cultivable land (about two thirds) is largely mountainous, with two thirds of it (67%) with slope over than 9% (Table 4). The two basic agricultural farming systems is tree crop production, mainly olives, apples, grapes and almonds in the more humid west or under irrigation, and livestock in conjunction with annual crops in the drier east. Rain-fed fruit trees occupied 53% of the total cropland in the highlands in 2007, of which, olive trees represented 84% of the total fruit tree area (DOS, 2008).

The major constraints facing agricultural development in the highlands are related to:

- Low and erratic annual rainfall, which is worsening with climate change. This necessitates the application of moisture conservation, water harvesting measures, improved soil management and farming practices if sustained agriculture is to be achieved;
- Improper land use which was manifested in the traditional use of hilly areas and the marginal land with low rainfall for growing cereals. Hilly lands are best suited to fruit trees, provided that it is accompanied by soil conservation measures to hold moisture, which are the most limiting factors to agricultural development. With the limited land resource base, protecting soil from erosion is of utmost importance;
- The agrarian structure is dominated by small and fragmented holdings, land distribution is highly skewed with many small farms in the highlands, and man-land ratio is deteriorating over time. The percentage of holdings less than 3 ha increased from 48% in 1975 Agricultural Census to 65% in 2007 Census (Rimawi, 2009).

These conditions in the highlands, have led to low income generating potential and highly precarious living conditions and have prevented the majority of farmers from establishing viable farming. This explain the trend towards part time farming as the percentage of holders who declared that their main occupation is not farming (35% of total holders) increased gradually to 87% in 2007 Agricultural Census. Similarly, the percentage of holders who derive more than 50% of their income from farming decreased from 24% in 1997 Agricultural Census to 18% in 2007 Agricultural Census (Rimawi, 2001, 2009).

Against these problems, the Government adopted a general guideline policy since the early 1960s. The main objectives of this policy were to increase agricultural production through using land according to its capability to foster the safe land use; to protect the soil from erosion by minimum disturbance of the ecological balance of the highlands and to ensure agricultural sustainability through maintenance of the natural resource base.

To put its policy into effect, land development was an integral component of all the development plans since the 1963. With the long term socio-economic and environmental benefits of such projects, significant government support was critical for on-farm construction costs of soil conservation measures to overcome the substantial reluctance of farmers to participate in land development activities. A series of projects were implemented, mainly with the support of the World Food Program. The main objectives of the project were:

- To make more productive use of arable land by establishing fruit trees on the idle land. This requires the application of on-farm soil conservation measures such as contour terracing of stone or earth to arrest the process of soil erosion and to conserve moisture;
- To replace the low yielding field crops which have been grown in some hilly areas by potentially high-yielding and more profitable perennial fruit crops. Since the 1960s, crops in hilly areas were constantly replaced by fruit trees.

The cropped area under field crops is steadily decreasing in the hilly lands. The percentage of the cropped area under cereals decreased from 67% in the period 1971-73 to 41% in 1995 **(Table 10)**. Land under olives alone increased from less than 4 thousand ha in 1982 to 60 thousand ha, which constitutes 84% of the tree crop area in 2007 (DOS 1983, 2008). Significant improvement was introduced to the land use system in the hilly lands which constitutes two thirds of the agricultural land in Jordan. An improved countryside has helped in promoting internal tourism which otherwise would hardly exist. Thousands of job opportunities were created in the rural areas which helped to reduce long term outmigration from the marginal areas and have many multiplier economic and social effects on the rural life and local market economy.

3.2.3.2 The Jordan Valley

West of the highlands is the Jordan Valley, which runs along the entire length of Jordan. The Valley is about 400 meters below sea level at the Dead Sea, becoming the lowest spot on earth. The Valley is relatively rich in water resources, and in agricultural land. The annual rainfall varies from more than 300 mm in the north to less than 100 mm in Ghor Safi. The weather is warm throughout the year, and the temperature is normally about 10 C degrees in winter and 38 degrees in summer. Because of these peculiar climate conditions, it is considered to be a natural greenhouse. This permits the growing of vegetables and fruits during the winter season, to be harvested 2-3 months earlier than similar crops grown in the highlands and neighbouring countries. Because of the good agricultural potential of the valley, the Government launched an extensive irrigation project in 1958 to divert water from the Yarmouk River in the north through King Abdulla Canal.

The irrigated area in the valley represents 43% of the total irrigated land in 2007. The percentage of holdings less than 3 ha increased was 44% in 1997 Census (Rimawi, 2001). The main crops produced in the valley in 2007 were tomatoes, potatoes, cucumber, eggplant, melon, squash, lettuce, citrus and banana. The field crops represent 8.5%, of the cultivated area, vegetables crops represent 56%, and fruit trees crops represent 35.5% of the cultivated area. The valley produces 26% of the total production of field crops, 58% of the total production of vegetables, and 38% of the total production of fruit trees (DOS, 2008).

The percentage of area under drip irrigation was 27% in 1983 (DOS 1985). In 2007, 91% of the irrigated area (including the Jordan Valley) was characterised by the use of modern irrigation technologies, which include 5% under sprinklers and 86% under drip irrigation (DOS, 2008). The use of high yielding seed varieties, fertilisers, and pesticides is a common practice throughout the irrigated areas, and 13.3% of the irrigated area under vegetables is planted under plastic tunnels or houses (DOS, 2008). Of the problems which face land resources in this zone are; low water efficiencies, use of poor water quality, degradation of soil properties (for example, salt accumulation...) and general poor farm management practices (Taimah, 1990).

3.2.3.3 The Arid Land Zone

The arid steppe and the desert region (Badia) in the east and south of Jordan are an extension of the Arabian Desert. This region forms more than 90% of the country, and rangeland is largely located in this zone. The altitude varies from 600 to 800 meters above sea level. It is not a true desert, but it is rather an arid area in which small plants survive in winter and spring (Taimah, 1990). The region receives little rain, ranging from about 200mm a year at the margin of the highlands in the east to as little as 50mm in the south in Aqaba. The rainfall in the large part of this area (80%) is less than 100 mm **(Table 3)**.

The size of holdings is generally large and above the national average. About half of the holdings in the size group 10-19.9 ha (48%), and three quarters of the holdings in the more than 20 ha size group (76%) are in the less than 200 mm region (Rimawi, 2009). About one quarter of this area (Table 3) where the annual rainfall ranges between 50-200 mm has a good potential for grazing. Sheep raising is largely practiced in this area for the production of milk products (e.g., white cheese, butter) and wool. Meat production is largely confined to the replacement of old animals and extra males. About half of the irrigated lands are located in this area. Underground water is the main source of irrigation. Melons, tomatoes, cucumber, apples and peaches are the main crops grown in the area under irrigation. Improved farming methods including drip irrigation are almost normal practice. Grains are also produced in this area, but the production under rain-fed conditions is negligible.

The arid zone can be divided into two regions (Taimah, 1990):

- The steppe region which lies in the east and south of the highland zone. It is traditionally called the marginal land, which has been used for grazing. The total of the steppe area represents 11% of the total area with an annual rainfall, which ranges between 100 to 200 mm (Table 3). The area is subject to high rate of desertification due to miss-management of land resources and high variability in the annual rainfall even with no climate change. This in turn increases soil erosion and reduces land productivity and plant cover.
- The Eastern desert which include the rest of the desert region (80% of the total area) in the east of the highland. The annual rainfall is less than 100 mm. The area is subject to higher rate of desertification and soil erosion. Low water holding capacity is evident by the absence of vegetation in most areas except in the waterways. This region is the home to the traditional sheep and goat herders who provide part of the meat for the rest of the country.

Of the problems which face land resources in this zone are overgrazing, improper land use, ineffective legislation to protect natural resources, and soil erosion (Taimah, 1990). These problems are aggravated with climate change and less precipitation. Thus, proper land use according to its productive capability and developing dry farming in Jordan with improved soil conservation and water harvesting measures to maintain the vegetative cover are the corner stones of agricultural development. Classification of land holdings in Jordan by the rainfall lines[12] into agro-climatic zones is a major step in more effective agricultural planning.

3.2.4 Climate Conditions by the Agro- Climaticogical Zones of Jordan

The Jordan Valley is very hot in summer, and the mean daily maximum is 39 OC **(Table 7)**. The highest observed temperature is 51.2 OC near the Dead Sea. During winter the mean minimum temperature is about 9 OC, the temperature is mild and frost is rare. In the highlands, it is cold during winter and the mean daily minimum temperature is about 4 OC.

Table 7: Climate Conditions in the Agro- Climaticogical Zones of Jordan

	Jordan Valley	Highlands	Arid zone
Temperature (mean annual min & max)	9-39° C	4-30° C	9-37° C
Precipitation (mm)	74-394	238-550	12-200
No. of Rainy Days	10-50	21-60	10-45
Snowfall and Hail	Never snow/Rare hail	1-2 times / 12-17 days	Rare snow& hail
Evapotranspiration	2000-2500 mm	2000-2500 mm	3700-3900 mm
Evaporation*	1300-1600 mm	1350-1600 mm	2000-2400 mm
Dew*	Up to 8 mm	10-25 mm	Up to 5 mm

Source: adapted from Al-Shamil, 2000 and MOE, 2009.
* one millimeter of dew is equivalent to 4-5 mm of rain

The lowest recorded temperature at Amman Airport is -7.5 °C at Shoubak it is -12 °C. The annual number of days with air frost is 10-15 days. The mean daily maximum temperature is about 26°C -30°C. The amount of actual evaporation is about 92% of the total annual rainfall. **Table 7** shows a summary of climate conditions in the varied agro- climatic zones of Jordan (Al Shamil, 2000).

3.2.5 Farm Structure by Zone

Table 8 displays farm size groups by rainfall zones in the highlands. The Table shows that the smallest holding category (< 1 ha) represents 43 % of all farms in the highlands, but 32-37% for the less than 300 mm zones, 40-53% for the more than 300 mm zones. The percentage for the < 1 ha holding class is significantly lower (14%) for the Jordan Valley. The 1-2.9 ha group represents 30% of all farms in Jordan, but it can be seen that the percentage is increasing in the higher rainfall zones.

Table 8: Area classes of land holdings by rainfall zones in the highlands (1997 Census)

***Land* Holding Classes (ha)**	**Jordan Valley**	**Rainfall zones**							
		<100 mm	**100–199 mm**	**200–249 mm**	**250–299 mm**	**300–349 mm**	**350-500 mm**	**>500 mm**	**Total**

[12] Rainfall lines are the isohyets which connect the points of the same total precipitation for a given time i.e. a year (Encyclopedia Britannica, WWW.britanica. com).

< 1	622	606	4704	980	2522	3610	11885	6912	31219
	14.4%	37.1%	35.2%	32.7%	36.2%	40.5%	47.2%	52.6%	43.3%
1 – 2.9	1291	350	3174	825	2053	2663	8385	4283	21733
	29.9%	21.4%	23.7%	27.5%	29.5%	29.9%	33.3%	32.6%	30.1%
3 –4.9	1589	115	1458	342	849	958	2253	1020	6995
	36.7%	7.0%	10.9%	11.4%	12.2%	10.8%	9.0%	7.8%	9.7%
5 –9.9	612	238	1856	388	847	899	1675	629	6532
	14.2%	14.6%	13.9%	13.0%	12.2%	10.1%	6.7%	4.8%	9.1%
10 –19.9	168	156	1195	256	427	458	608	191	3291
	3.9%	9.6%	8.9%	8.5%	6.1%	5.1%	2.4%	1.5%	4.6%
20 or more	42	167	983	204	260	318	348	112	2392
	1.0%	10.2%	7.4%	6.8%	3.7%	3.6%	1.4%	.9%	3.3%
Mean	3.57	8.49	5.97	6.64	4.29	3.99	2.90	2.02	3.86
Median	3.00	2.00	2.00	2.00	1.50	1.20	1.00	0.80	1.10
Total	4324	1632	13370	2995	6958	8906	25154	13147	72162
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0

The 3-4.9 ha represents 10 % of all farms in the highlands, and ranges from 7% to 12% within the rainfall zones. In the Jordan Valley, this class appears to be dominant (37%). Similarly, higher percentages of the more than 5 ha farm size classes are found in the lower annual rainfall areas. For example, while 8% of farms in the less than 200-mm zones, less than 1% is found in the more than 500-mm zone. The mean decrease in almost all zones from 85ha in the less than 100 mm zone to 20 ha in the more than 500 mm zone. Similarly, the median decrease in almost all zones from 3ha in the less than 100 mm zone to 8 ha in the more than 500 mm zone. As a general rule, it appears that the small farms are located in the high annual rainfall areas and the more fertile lands or under irrigation in the Jordan Valley, whereas the large farms tend to be found in the marginal lands, in the arid areas or where underground water is available.

Table 9 displays farm size groups by rainfall zones in the highlands in the 2007 Agricultural Census. The Table shows that the smallest holding category (< 1 ha) represents 37 % of all farms in the highlands, but 32% for the less than 350 mm zones, 68% for the more than 350 mm zones. The 1-2.9 ha group represents 28% of all farms in Jordan, but it can be seen that the percentage is increasing in the higher rainfall zones from 5% in the less than 200mm zone to 52% in the more than 500 mm zone. But, for the more than 19.9 ha size group is just the reverse; the percentage is decreasing in the higher rainfall zones from 44% in the less than 200mm zone to 8% in the more than 500 mm zone.

The general rule still applies in the 2007 Agricultural Census; larger percentages of the small farms are located in the high annual rainfall areas, whereas larger percentages of the large farms tend to be found in the marginal lands. With the climate change, these small farms cannot support rural farm households. Thus, the trend towards part time farming will be enhanced, and this will be a form of social adaption to climate change.

Table 9: Area classes of land holdings by rainfall zones in the highlands (2007 Census)

Land Holding Classes (ha)	**Total (% of Number)**	**Rainfall zones**								**Un-defined area**
		< 200 mm		**200 –349 mm**		**350 –500 mm**		**> 500 mm**		
		% of No	% of Area	% of No	% of Area	% of No	% of Area	% of No	% of Area	
< 1	37.3	11.1	10.5	21.2	21.2	20.5	41.1	47.3	24.1	3.1
1 – 2.9	28.1	5.0	11.1	19.2	25.4	21.6	31.6	52.4	15.8	16.1
3 –4.9	11.0	6.0	8.4	19.5	15.0	19.5	12.0	55.3	4.7	59.9
5 –9.9	8.3	9.4	28.0	23.3	32.4	17.6	16.4	49.7	5.3	17.9
10 –19.9	3.7	3.7	19.9	47.6	27.8	32.9	16.9	10.8	35.4	2.9

≥ 20	11.6	44.3	75.7	38.0	16.8	10.0	4.0	7.7	1.3	2.2
Zone %	100.0	9.7	46.9	21.3	20.7	19.9	13.1	49.0	5.8	13.5

3.2.6 Agricultural Production

Recent warming in Jordan is projected to accelerate by climate models, with associated changes in precipitation and frequency of extreme events. Water availability will play a significant limiting role on potential agricultural production due to the combined effects of higher crop water requirements and increasing demand for non-agricultural use of water.
Changes in precipitation will bring about in water availability, irrigation water supply, and in arable land area. However, Jordan would be able to maintain per capita agricultural production, given reasonably optimistic assumptions about policies on land and water management and agricultural technology.

The agricultural sector is characterized by the existence of almost two distinct sub-sectors, a developed irrigated sector and a relatively backward rain-fed system. The modern sector also comprises poultry production and a growing share of fruit production under rain-fed conditions. This dualism also applied to the type of problems associated with agricultural development and to the potential adaptation measures to climate change. While the problems of the modern sector are management oriented, basically those of marketing, soil and water management and disease control, the problems of the rain-fed sector are largely production oriented and related to low productivity due to erratic and variable rainfall, and these problems are getting worse with the adverse impacts of climate change.

3.2.7 Plant Production

The potentially cultivable area in Jordan is 5.7% of the total area (Table 3). An average of 246 thousand ha was cultivated in 2009, of which 39% were irrigated as Table 3 shows (DOS 2010). As **Table 11** shows, the general plant production index increased from 45 in 1968 to 192 in 1996, and as Table 12 shows, the index increased from 126 in 1998 to 160 in 2008. As mentioned earlier, improved methods of production are common practice in the irrigated sub-sector. These developments were largely based on chemical and biological innovations. The application of fertilisers, pesticides and high yielding seed varieties, drip irrigation and greenhouses is common for irrigated farming. 13% of the area under vegetables is under plastic tunnels or houses (DOS, 2008). Imported quantities of nitrogenous fertilisers and pesticides were two to three times the imported quantities between 1986 and 2007 (DOS, 2008).

Table 10: Distribution of Rain-fed and Irrigated Crop Areas (ha) and percentage During the Period 1995-2009

Period	Field crops		Vegetables		Fruit trees		Overall		Total area ha (Total %)
	Rainfed (%)	Irrigated (%)	Rainfed (%)	Irrigated (%)	Rainfed (%)	Irrigated (%)	Rainfed (%)	Irrigated (%)	
1995	138786	11179	3690	39241	47865	22843	190341	73264	263604
	(52.6%)	(4.2%)	(1.3%)	(14.9%)	(18.2%)	(8.7%)	(72.2%)	(27.8%)	(100.0%)
2000	130590	7430	2370	31890	52690	35610	185660	74930	260590
	(50.1%)	(2.8%)	(0.9%)	(12.2%)	(20.2%)	(13.7%)	(71.2%)	(28.7%)	(100.0%)
2005	112628	8534	2112	38054	52601	33457	167341	80045	247386

	(45.5%)	(3.4%)	(0.9%)	(15.4%)	(21.3%)	(13.5%)	(67.6%)	(32.4%)	(100.0%)
2009	80072	11683	2311	38868	37988	44268	129371	94820	224191
	(35.7%)	(5.2%)	(1.0%)	(17.3%)	(16.9%)	(19.7%)	(57.7%)	(42.3%)	(100.0%)

Sources: MOA, 1996 and Annual Agricultural Statistics, 1996-2009, Department of Statistics, Amman, Jordan.

3.2.7.1 Field Crops

Field crops accounted for 39% of the total cultivated area, but only 8% of total production in 2007. In 2007, 85% of the cropped area was under wheat and barley, 4% under fodder crops and 11% under chick peas, lentils and other field crops (DOS, 2008). The cropped area under field crops is steadily decreasing. As Table 10 shows, the area under field crops decreased from 150 thousand ha in 1995 to 92 thousand ha in 2009. As Table 11 shows, the production index for cereals and pulses decreased from 126 in 1968 to 94 in 1996 (1985=100), and all field crops decreased from 88 in 1998 to 46 in 2008 (1997=100). However, the average production of wheat in the period 2005-08 (21.5 mt) is only 13% of the average for the period 1965-68 (160.2 mt), and the average production of barley for the same periods is 40% (CBJ, 2004, 2009). This decrease might be attributed to; first, the continuous division of land, expansion of urban areas, and pooled ownership are commonly cited as deterrent to grain development. The expansion of the urban areas were at the expense of the traditionally field crops lands in Irbid, Madaba and Karak Governorates. Second, the active encouragement by the Government to replace the grains by fruit trees in the hilly areas within a soil conservation scheme for economic as well as ecological considerations. Third, the farm structure is dominated by small holdings where the rainfall exceeds 250 mm (Table 8), and where most of the arable land has a slope more than 9%, and the net return per ha is quite low. Thus, the field crops area is pushed to the marginal areas where the effects of climate change is the highest. Therefore, the prospects for increasing cereal production are very limited.

Table 11: Agricultural Production Index (1985 = 100)

	1968	**1973**	**1978**	**1983**	**1988**	**1993**	**1996**
Overall index	37	33	77	97	141	158	188
General plant production	45	30	94	110	167	144	192
Cereal & pulses	126	66	80	187	142	101	94
Vegetables	36	27	77	86	121	124	143
Fruit trees	22	29	65	111	193	212	241
Olives	64	26	188	113	359	161	450
General animal production	26	37	53	80	106	177	183
Red meat	226	285	132	93	76	174	146
Poultry meat	8	25	43	76	124	152	182
Milk	59	57	61	81	118	295	292
Eggs	5.4	4.8	51	80	73	166	140

Sources: CBJ, 2004.

3.2.7.2 Vegetable Production

Vegetables were produced in about 16% of the total cultivated area in the period 1995 **(Table 10)**. The percentage increased to18% of the cultivated land in 2009. The main vegetables produced were tomatoes, cucumber, potatoes, eggplant and melon. Together, these vegetables accounted for 71% of the total production in 2007. As **Table 11 and 12** show, the production index for vegetables increased from 36 in 1968 to 143 in 1996 (1985=100), and increased from 110 in 1998 to 174 in 2008 (1997=100).

Table 12: Agricultural Production Index (1997 = 100)

	1998	**2000**	**2002**	**2004**	**2006**	**2008**
General plant production	125.9	140.5	182.5	180.3	180.9	159.7
Field crops	88.2	91.4	130.4	81.1	70.1	45.9
Vegetables	110.2	122.1	151.9	173.0	178.8	173.8

Fruit trees	164.1	180.9	240.8	220.4	217.4	174.6

Sources: CBJ, 2004, 2010.

3.2.7.3 Fruit Production

Fruit trees accounted for 40% of the total cultivated area in the period 2005-09. In 2007, 71% of the tree crop area was under olive trees (84% in the rainfed area), 8% under citrus (65% in the Jordan valley), and 4% for grapes, 3% for pome fruits and 6% for almonds (DOS, 2008). Considering the soil, topography and climate conditions, fruit trees have the greatest potential to be developed. Over the past five decades, substantial investments have been made in fruit trees in the highlands. As Table 11 and 12 show, the production index for fruit products increased from 22in 1968 to 241 in 1996 (1985=100), and increased from 164 in 1998 to 217 in 2006 (1997=100). The production index for olives increased from 64 in 1968 to 450 in 1996 (1985=100). The production of olives is highly variable, with a good crop every other year. Thus, the production index for olives was calculated on the basis of the average of two sequence years.

3.2.8 Animal Production

Sheep and goats are raised in Jordan for multiple purposes; milk products, meat, wool, hair and hides, while cows are raised for milk production. The number of sheep and goats was 3.751 million heads in 1991, 2.821 million heads in 2007. The number of cows was 64 thousand heads in 1991, and 81 thousand heads in 2007 (Table 13) (DOS, 2007). Poultry meat production was about 120 thousand tonnes in 1997 and 180 thousand tonnes in 2007. Egg production was 715 million eggs in 1995[13] and 800 million eggs in 2008 (DOS, 2008). More than half of the agricultural holders were found to keep animals (DOS, 1999). Animal production accounted for 55% of the agricultural gross domestic product in 2006 (MOA, 2007). With the sharp increases in the demand for animal products in 1970- and after due to improvement in per capita income and high income elasticity of demand, the production index for poultry meat output increased from 8 in 1968 to 182 in 1996 (Table 11/ 1985=100) Similarly, the production index for milk increased from 59 in 1968 to 292 in 1996, and the production index for eggs increased from 5.4 in 1968 to 140 in 1996 (Table 11/ 1985=100). However, the production index for red meat output declined from 226 in 1968 to 146 in 1996 (Table 11/1985=100). This indicates that raising animals such as sheep and goats is largely for milk and dairy products. The limited rangeland, over grazing and lack of integration between animal and plant production were the main obstacles to the development of livestock production.

Table 13: Distribution of the Number of Sheep, Goats and Cattle, 1991-2007

Year	Sheep	Goats	Cows
1991	2,671,317	1,079,363	64,150
1996	2,671,317	781,976	51,568
2001	1457910	425,920	65,370
2007	2,251,450	569,370	80,990

Source: MOA, DOS

3.2.9 Part Time Farming

In the 1975 Agricultural Census, 35% of total holders declared that their main occupation was not farming. The percentage in 1983 Agricultural Census increased to 43% and to 53% and 87% in 1997 and 2007 Agricultural Censuses. The results of the 1997 Agricultural Census also reveal that only 24% of all holders derive more than 50% of their income from farming. The percentage in 2007 Agricultural Census decreased to 18%. This suggests the number of holdings cultivated by part time farmers were increasing (Rimawi, 2001, 2009).

[13] Ministry of Agriculture, Annual report, 1997.

Part time farming is a worldwide phenomenon and not restricted to Jordan. A growing share of farmers in both the United States and the EU, farming is a part-time occupation. 85% of farm households in Japan are part time farmers [14], 50% in USA and 72% in the European Union[15]. Besides, most of the full time farmers are retired are taking up farming after long careers public or business works.

Factors behind the trend towards part time farming in Jordan include the limited resources base. The cultivable and irrigable area is less than 6%, and 1% respectively of the total area. The farm structure is characterised by the dominance of small farms (Table 5). The mean size of holding decreased from 8 ha in 1975 to 4 ha in 2007 (Rimawi, 2009). Therefore, farming cannot generate enough income to support farm families, and this trend will be enhanced with climate change. Part time farmers have lower expectations for continuing farming both in the short- and long-run compared to full-time farmers. It helps to stabilize the farm household income variability under climate change. But it also would accelerate farm exits under adverse impacts of climate change for those seeking to leave agriculture, and the probability of succession is lower.

The farm population decreased from 22.3% in 1975 to 17.4% in 2009 (DOS, 1977 and website). Depopulation of the rural areas appear to be slowing down or the migration from the rural areas is reversed due to the economic recession, high rate of unemployment, and the high cost of living in urban centres and improvements in the social and physical infrastructure. Most villages are served by paved roads, provided with electricity and water supplies and schools. Good transportation facilities made cities closer to the rural areas, which altered the need to migrate by daily commuting to off farm employment. Thus, taking off farm employment has ceased to be competitive with farm employment, as combining both has become feasible (Rimawi, 1991). With the climate change, the trend towards part time farming will be enhanced. This will decelerate farm exits under adverse impacts of climate change through stabilizing the farm household income variability under climate change. Thus, part time farming can be looked at as a way of adaptation by the rural people under adverse impacts of climate change.

3.2.10 Foreign Trade

The rise in per capita income in constant prices from 1000$ in 1976 to 1523$ in 1999 and to 3370$ in 2009 (CBJ, 1996; MOA, 2000; CBJ, 2010) has led to considerable increases in food consumption particularly animal products, as evidenced in sharp increases in agricultural production index for almost all products (except cereals and red meat), or sharp increases in imports (notably cereals and red meat). Jordan is virtually self sufficient in vegetables, fruits, poultry meat, eggs, but it is a net importer of wheat, red meat, and dairy products. The total consumption of rice, sugar tea and coffee, and cooking oil (apart from olive oil) is imported.

Agricultural products have played an important role in Jordan's foreign trade, even though their proportion is gradually declining. The share of food products in exports (including manufactured food products) was 22% in 1983, 16% in 1998 and 14.4% in 2009 (Table 14). Vegetables, fruits and dairy products were the main exports. The percentage of food imports was 16% in 1983, 20% in 1998 and 14.6% in 2009. The main imports were meat products, rice, coffee, tea, wheat, and fodders (CBJ, 2005 & 2009). The ratio of food exports to imports ranged between 20 to 35% during the period 1983-2009.

Table 14: The Contribution of Agriculture to Total Exports and Imports (MJD)

Year	Exports*			Imports			Imports /Export-s	Import-s /AGDP	Import-s /GDP	Food trade balanc-e deficit
	Food	Total Export-s	Food /Total	Import-s	Total Imports	Import-s /Total				
1983	36	160	22.5	180	1103	144	5	1.6	0.10	144

[14] Facts and details, 2010, Agriculture in Japan (http://factsanddetails.com/japan.php?itemid=941&catid=24&subcatid=159)

[15] U.S.-EU Food and Agriculture Comparisons. Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture, Agriculture and Trade Report. WRS-04-04, 2004

1986	42	226	18.5	166	850	124	3.9	1.5	0.07	124
1989	49	534	9.2	198	1230	149	4.0	1.5	0.07	149
1992	92	633	14.5	416	2214	324	4.5	1.7	0.12	324
1995	100	1004	10.0	419	2590	319	4.2	2.4	0.09	319
1998	165	1046	15.8	532	2714	367	3.2	3.7	0.09	367
2001	136	1352	10.1	524	3454	560	3.8	4.2	0.08	560
2004	2 01	2307	8.7	761	5799	918	3.8	3.9	0.09	918
2007	404	3184	12.7	1322	9722	944	3.3	4.3	0.11	944
2009	513	3573	14.4	1457	9994	560	2.8	3.1	0.09	560

* Exports include food products and live animals. Calculated from CBJ, 1996, 2000, 2004, 2005 and 2009.

The ratio of the value of agricultural imports to the AGDP increased from an average of 57% during the 1960s, 121% during the 1970s, 163% during the 1980s, 283% during the 1990s, and to an average of 375% during the 2000s. As **Table 14** shows, food imports were 2.8 to 5.0 times of food exports and 1.5 – 4.3 times of AGDP, and more than 7-12% of GDP. Jordan is a food deficit country, and the food trade balance was worsening throughout the period 1983 -2008, as the food deficit almost tripled during this period, except for 2009 in the aftermath of global economic crisis and the turn down of world food prices. These figures suggest that there was an upward trend in the reliance on food imports for Jordanian's food supply during the 1960s to 2000s and Jordan is far from being food self-sufficient (CBJ 1996; CBJ 2004; CBJ 2005 and CBJ 2009).

3.2.11 Labour Force

The relative share of the Jordanian labour force engaged in agriculture has steadily declined since the 1960s. The percentage declined from 34% in 1961 to 6% in 1999 and 2.6% in 2008 as Table 15 shows. Taking the broad definition of agriculture, agribusiness contribution to employment is estimated to be 13% in the period 1987-91(Ouedraogo and Hayson, 1993). The decrease in the Jordanian labour force engaged in agriculture was partly compensated by foreign labour, mostly Egyptians. Of the total hired labour in plant production, 67% were foreigners in 1998 out of 71 thousand labours, and 62% were foreigners in 2006 out of 88 thousand labours. Of the total hired labour in animal production, 20% were foreigners in 2006 out of 48 thousand labours; the rest of labour was effectively family labour (95%) (DOS, 2008). There was a drastic change in the composition of hired labour in plant production between 1975 and 2006 in favour of occasional labour as their percentage increased from 40% to 64% in 1998 and to 69% in 2006 In animal production, more than three quarters of the total labour (76%) were family labour in 2007 (DOS 1977, 2000, 2008). The steady increase in the agricultural output as evidenced in the production indexes in **Table 11 and 12**, and the decrease in the size of labour force, suggests that the productivity of labour has notably improved.

Table 15: Distribution of Labor Force by Economic Sector

Sector	1961	1979	1995	1999	2008
Agriculture	33.5	11.5	6.9	6.1	2.6
Industry	20.8	22.2	25.8	22.2	17.7
Service	44.7	63.3	67.3	71.7	79.7
Total	100.0	100.0	100.0	100.0	100

Sources: Rimawi, 1998 and MOL, 2000 and 2009 (Table 21).

The Agricultural Censuses 2007 reveals that 88 % and 94% of labour is provided by the farm households for the holdings of less than one ha under irrigated agriculture and rainfed farming. The percentages were 56% and 89% for the holdings of 1-3 ha. In 84% of all farms most of the labour is provided by the farm households; 58% for irrigated agriculture and 92% for rainfed farming. The percentages were 53% and 84% for all farms for the Jordan valley and the highlands respectively in the Agricultural Censuses 1997 (Rimawi, 2001 and 2009). This explains why it is possible to keep on farming under worsening economic and climate conditions.

A critical policy objective for the development of the agricultural sector is to increase agricultural production to meet the domestic demand of the rapidly growing population, to achieve improved food security, and to minimize the deficit in the agricultural balance of trade (MOA, 1997). As two thirds of the of the total hired labour in plant production in 2006 were foreign labour, in addition to one fifth in animal production according to the latest Agricultural Census in 2007, and the finding that this hired labour was largely occasional_labour (62% in irrigated agriculture), demonstrates the significance of the foreign labour for achieving the policy objectives of Jordan (increasing demand for farm products and food security). Lack of a system of social and health security to cover both farm operators and permanent labour is one of the main cited motives which push farm household members outside the agricultural sector even in situations where labour requirements are high.

Therefore, under threats of climate change and for achieving the policy objectives of the farm sector of Jordan, measures are needed to adopt policies to control and regulate the work of the foreign labour to allow the irrigated farmers to acquire their badly needed farm labour, while taking gradual measures that would make the farm labour more attractive to local labour (e.g. social and health security).

3.2.12 Livestock Feed and Feed Cycle in Jordan

Livestock production occupies more than 50% of agricultural activities and production in Jordan (Harb 2008). The demand for livestock products is expected to increase dramatically in the first half of this century due to the increase in population which is going to reach around 7.0 million and also to the increase in affluence of the society.

Food supply and cost are emerging factors which will affect food security which is of highest priority in Jordan. Animal production plays a key role in this security.

The aim in this section is to analyze and evaluate the effect of climate change on livestock production and what are the changes that could help to mitigate the harmful influence. New adaptation measures are needed to make livestock production systems work efficiently under this global climate worming.

High resolution information concerning the impacts of climate change on productivity of feeds in the range and fields and the effect of this on livestock were used. There are two vulnerabilities which could happen on this relation between feed production and livestock; which are biophysical vulnerability done on the range and land which could harm and reduce the fodder and crop production which could cause great harm to the livestock production and the other vulnerability is the social one which is the sensitivity of the human environment to the exposure (Thornton and Herrero). The people affected in Jordan will be those in the rainfed around the arid and semi arid areas which would be around twenty percent of the population.

The nomadic live primarily in arid and semi arid areas which depend on livestock (sheep, goats and camels) for their livelihood. These people maintain production according to nature vegetation and water availability. These people could adapt well with rainfall decrease of 25-33% and could face climate change efficiently (Adger – et al 2003), what happens in 1998 and 1999 in Jordan caused livestock population to decline, this was due to drought condition which occurred in these years.

The range land tended to become drier and water shortage was worsened. (Angerer et al 2004),in a study initiated and examined the effect of climate change in graze land in Kenya suggested that under all climate change scenarios, areas that were predominantly range lands experienced decreased cattle forge yield up to 25% in some areas.

The pastoralists are capable of adaptation to climate change because their lives are shaped to deal with scarce and variable natural resources and uncertain agro – ecological conditions (Macopiya el al 2008).

There will be a decline in agriculture productivity approaching 20-25% of some countries (Cline 2008 Parry et al 2004) found that the decline in agriculture productivity approaching in Mexico may be 20-25%.

The general approach for analyzing agriculture vulnerability and adaptation to climate change is to use a comprehensive evolution of sources of feeds and the feed cycle in Jordan. The feeds which are coming from rangeland, grassland from the area left as fallow and from crop production in rainfed areas are affected directly by weather changes. Thus causing a direct effect on the productivity livestock's available in Jordan. The main livestock affected are sheep because they are produced under extensive conditions. The other livestock sectors are produced and reared are intensive conditions. The whole sectors are shown in appendix 1.

3.2.12.1 Livestock Feeds

The major sources of feed for sheep and goat flocks in Jordan are: native grazing, immature (green) barley, cereal stubble and vegetable crop residues, as shown in **table 16**.

The grazing plains of the steppe and desert ranges are common resources for grazing purposes. This communal grazing prevented conservation of the range and caused also overstocking. These two factors caused low forage production and reduction of palatable perennial plants leaving the unpalatable ones.

The herding is usually done by sheep owner or one of his families. A hired shepherd may herd large herds above 100 heads of sheep.

Water is transported to the herds by pick up and by tanks. Watering is done twice daily in summer and once in winter.

The most critical period in the feeding cycle of ewes and goats is in the autumn / winter feeding because the animals are pregnant or lactating and have high requirement, and when there is on grasses the range and the residues are overgrazed.

The flocks in autumn depend on the remaining stubbles and native pasture. Wheat and barley residues grazing start immediately after harvesting in June until September and provide the basic diet for sheep.

In winter, and during the last decade, the livestock feeding became dependent upon supplementary feeding, principally barley grains, wheat bran and straw. Supplementation may provide about half of the requirements in good years and it may go up to 80% in bad drought years, as shown in **table 17.**

Supplementation starts by the middle of November and it goes on for around three months on average supplementation may be for around 100 days and in drought years supplementation may go up for around 10 months.

A shift to a warmer possibly dried weather would pose a threat to the wheat areas that provide tibbin and stubble gazing to the small ruminants. The straw and stubble are considered the main fodder available to sheep. This will have great repercussions on the herd and would place great pressure on the sheep – owner to obtain supplementary feeding. This has happened in Jordan in the last 10-15 years, particularly for the drought year of 1999.

There has been an increase reliance on the imports of barley grain either by the government, which was subsidized or by private sectors. The barley grain purchase has increased until it constituted more than ½ of the required of small ruminants. This has caused the sheep owners and landowners to decrease the production of forages for animals.

Table 16: Total Feed Production in Jordan (Harb and Karabelliah 1990)

	Area (du)1	**Productivity Kg/du**	**F.U./Kg DM**	**Total tons DM**	**Production ton F.U./ used**
1. Range steppe rangeland	10,000,000	10	0.4	100,000	40,000
(used)				(50,000)	(20,000)M

desert rangeland	71,000,000	4	0.3	384,000	115,200
(used)				(192,000)	(75,000)
2. Crops barly – grain	500,000	39.7	1.0	19,850	19,850
Vetch – grain	20,235	91.8	1.0	1,866	1,866
Corn – grain	2,927	607.4	1.0	1,978	1,778
Wheat straw	1,000,000	60.0	0.3	60,000	18,000
Barley straw yetch	500,000	60.0	0.3	30,000	9,000
straw	20,325	91.8	0.3	1,200	366
3. Natural vegetative Fallow grasses land	501,000	15	0.5	7,517	3,758
Unuses land – grasses & forests	791,000	20	0.45	15,820	7,119
4. Irrigated legumes feeds Alfalfa	1,123	17.8	0.5	1,960	882
Berseem	50	1.2	0.45	60	27
5. Agricultural by – products Wheat bran			0.65	110,000	71,500
Industrial by-products			0.50	65,000	32,500
Vegetables by- products			0.20	40,000	8,000
Total				597,071	252,246

*1 dunum = 1000m^2, F.U.: feed unit= 1 kg barley , DM = Dry Matter

Table 17: Supplementation feeding in the Hamad in Jordan basin and in Syria steppe region.

	Jordan		Syria	
	Dry year	Good year	Dry year	Good year
Duration of feeding (days)	175	99	196	154
Amount of feed offered in the winter (kg)	175	50	225	136

Amount given daily (kg/day)	1.0	0.5	1.3	0.9
Energy given daily (mj/day)	-	-	10.5	8.1
Crude protein required(g/day)	-	-	116	90

Source Thomson et al (1989)

3.2.12.2 Feed Cycle in Jordan:

A typical calendar for sheep production is given in table 18. Total feed production in Jordan was about 597 thousand tons of dry matter. The major sources of feed for sheep and goats flocks in Jordan are: native grazing, immature (green) barley, cereal stubble, and vegetable crop residual as mentioned earlier.

The most critical period in the feeding cycle of ewes and goats are autumn and winter when the animals are pregnant or lactating and have high requirement, and when there is no grasses in the ranges and the range and residues are overgrazed.

The flocks in autumn depend on the remaining stubbles and native pasture. Wheat and barley residue grazing start, immediately after harvesting in June until September, provide the basic diet feed for sheep.

The estimated number of days of grazing is around 90 days – 120 days followed by 2 months in cereal stubble.

In winter and during the last decade, the livestock feeding became dependent upon supplementary feeding, principally barley grains wheat bran and straw. Supplementation may provide about half of the requirements in good years and it may go up to 80% in bad drought years.

Supplementation starts by the middle of November and continues for around three months. On average, supplementation may be for around 100 days and in bad years it may go up to 175 days. However in drought year's supplementation may go up for around 10 months.

The amount of feed needed for supplementation could be considered at a minimum of around 0.5 – kg per head daily and at a maximum of around 1.0 – kg.

The amount of barley grains used in supplementation in autumn and winter feeding is around 377.000 tons in normal years. Most of the barley grains are imported. In drought years, the amounts imported could be doubled and could reach725 thousand tons of barley grains, as in year 1999. After winter which finishes usually in March, supplementation ended.

The spring feeding for most of the flocks takes place in the pasture especially in the steppe area after winter.

The total amount of dry matter (DM) available for grazing from the pasture is estimated of around 700 thousand tons.

The summer feeding depends on the agricultural land. The animals graze the remains of the whole crop of barley in addition to the cereal stubble. The body condition of the ewes improved at this time according to FAO, 1988, the animals meet their requirements as follow:

- Grazing on marginal land for 3.0 months
- Grazing on cereal stubble for 4.0 months.
- Grazing on natural pasture in rain fed areas for 1.5 months.
- Feeding supplement for 3.5 months.

However, these requirements may differ completely in drought years.

In the drought season of 1999/2000, around 59000 livestock holdings has been affected. There was a loss in meat production of around 7000 tons.

Table 18: Feed calendar under extensive conditions in the area

Period	Physiological	Area	Main feed	Subsidiary
June – Sept.	Mating Early Pregnancy	Agricultural land	Cereal stubble	Vegetable crop residue
Oct. – Nov.	Pregnancy	• Agricultural land • Steppe	Crop residues , straw	
Dec. – Feb.	Late pregnancy Early location	Steppe	Straw , barley grain	Barley wheat bran straw
March- May	Location	Steppe	• natural pasture • barley & straw in dry years	standing barley

4. CLIMATE CHANGE IN JORDAN

4.1Overview–Identification (Conceptualizing Vulnerability, Impact and Adaptation)

A climate adaptation plan call for a summary of the climate change impacts and provides recommendations on how to manage and adapt against those threats. The following sections will discuss global warming and conceptualize vulnerability, impact, adaptation and mitigation, and climate change in Jordan, impact of climate change on agriculture and the potential means of adaptation to adjust to the impact of climate change in Jordan.

Global warming is resulted from the so called "greenhouse effect". Gases that make up our atmosphere are analogous to a greenhouse in that they allow sunlight to pass through, and then trap most of the heat from escaping. This naturally keeps earth's surface warmer than it would be otherwise. The problem arises when human produced compounds such as carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs) and ozone are regularly released into the atmosphere and accumulated beyond the natural levels. This makes the virtual greenhouse wall thicker than it would be otherwise, thus allowing less heat to escape, and causing temperature to rise. This is called Global warming, the driving force to climate change.

The burning of fossil fuels creates more ozone. Although it is a natural gas in the lower atmosphere that helps trap heat, its accumulation beyond the natural levels traps more heat, thus contributing to global warming or to the greenhouse effect. Ozone plays an extra role in upper atmosphere that shields the earth from harmful ultraviolet (UV) radiation. CFCs in normal levels help to trap heat from escaping, but as CFCs builds beyond the natural level, it makes holes in the upper ozone layer in the atmosphere, thus exposing the earth to the risks of UV radiation (Global Warming; Wikipedia, 2010)[16].

The global warming is largely due to the increase in the emission of carbon dioxide CO_2. The average land and ocean's surface temperature had risen by about 0.3 C - 0.6 C in the last century. The rate of warming varies from one region to another on the earth surface, but, urban areas are warming more rapidly than rural areas, due to high emission of gases in highly populated areas (IPCC, 1995).

Adaptation is the adjustment of an organism or population to a new or altered environment. Adaptation also refers to decisions people make to adjust to the change. Adaptation largely depends on the capacity to adapt the relevant systems to their exposure to the change. Exposure refers to the climatic parameters that serve as stimuli to these systems. A system's adaptability to exposure depends on its

[16] Global Warming, Wikipedia , 2010, http://en.wikipedia.org/wiki/Global_Warming.

sensitivity— the degree to which a system is affected by its exposure and is determined by the system's properties. The system's exposure, sensitivity and adaptability jointly combine to determine its vulnerability, that is, the degree to which it is susceptible to adverse effects of climate change. Thus, the impact on a system depends on its vulnerability. If, for example, the sensitivity to the exposure is great and adaptability is low, then the impact of the change will be high. If, on the other hand, sensitivity to the exposure is great but adaptability is also great, and the means for adaptation are available, then vulnerability is low, and hence, the impact will be small (IPCC, 2001)[17].

The following **Figure (1)** conceptualizes vulnerability of the agricultural systems to climate change, potential impact and adaptation to climate change effects. Exposure is the nature and degree to which a system is exposed to significant climatic variations. Adaptation to climate change consists of initiatives and measures to reduce the vulnerability of natural, agricultural and human systems against actual or expected climate change effects (IPCC, 2007a). The sensitivity of agricultural systems to the climate change is very high because all the components of the systems (soil, water, weeds, crops, pest/ diseases, livestock) are strongly affected.

<table>
<tr><td>Exposure</td><td></td><td>Sensitivity</td></tr>
<tr><td>Exposure is the nature and degree to which a system is exposed to significant climatic variations.</td><td></td><td>Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate--related stimuli.</td></tr>
<tr><td colspan="3">⇩ Potential impact ⇩</td></tr>
<tr><td>Potential impact</td><td colspan="2">Adaptive capacity</td></tr>
<tr><td>Any effect caused by a proposed activity on the environment</td><td colspan="2">Adaptive is the ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.</td></tr>
<tr><td colspan="3">⇩ Vulnerability ⇩

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. It is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.</td></tr>
</table>

Adapted from (IPCC, 2001), Annex B. Glossary of Terms

The potential Impact is any effect caused by a proposed activity on the environment including flora, fauna, soil, air, water, climate, landscape and human health and safety, or the interaction among these factors. It includes effects on socio-economic conditions resulting from alterations to those factors. The adaptive capacity is the capacity and potential for human systems to adapt, is closely linked to social and economic development (IPCC, 2007a).

Adaptive capacity is unevenly distributed across different regions and populations. Climate changes impact includes direct impact through stimulating crop photosynthesis and water use, and indirect Impact through affecting the length of the growth season, the plant water availability, etc. The economic costs of

[17] IPCC, 2001, Annex B. *Glossary of Terms*, http://www.ipcc.ch/pdf/glossary/tar-ipcc-terms-en.pdf

adaptation are potentially large, but also largely unknown (IPCC, AR4, WG II, 2007). There is wide agreement that adaptation will be more difficult for larger magnitudes and higher rates of climate change (IPCC: Wikipedia, 2010).

Adaptation strategies to a changing climate include:

- Agronomic and crop strategies that are intended to offset either partially or completely the loss of productivity caused by climate change through the application of defense tools with different temporal scales, e.g. short term adjustments and long term adaptations, and - spatial scales, e.g. farm, regional or national level adaptation; and
- Socio economic strategies are intended to meet the agricultural costs of climate change.

Main climate change and global warming elements affecting agricultural systems include:

- Changes in mean temperature (general warming);
- Precipitation (total precipitation, rainfall intensity); and
- Climatic extremes and season length increases in atmospheric CO_2 and other GHGs concentrations.

Climate change scenarios of the above mentioned elements can be used to project impacts on various climate-sensitive systems. These impacts depend on the vulnerability of the systems, an attribute that depends both on the sensitivity and the adaptability of the systems.

The following section will discuss the impact of climate change on Jordan, addressing Jordan's vulnerability to climate change and its available means of adaptation.

4.2 Climate Change features in Jordan

Jordan is located at 29° 10' and 33° 22' N latitude. The climate of Jordan is predominately of the Mediterranean type, which is characterized by a hot dry summer and rather cool wet winter. Rain starts on October and extends to May, but about 75 percent of precipitation falls during winter season, which extends from December to March (MoEnv, 2009).

Global Circulation Models (GCMs)[18] predict increased precipitation in latitudes above 35°N and decreased precipitation in mid latitudes below 35°N (Wigley 1992). However, in a review of literature, Karas (2000) reported that a common feature of many projections is the declining of annual precipitation over much of the Mediterranean region south of 40° N, with increases to the north of this. With global warming, even areas receiving more precipitation may get drier than today due to increased evaporation and changes in the seasonal distribution of rainfall and its intensity.

[18] General circulation models (GCMs) are sets of sophisticated computer programs that simulate the circulation patterns of the earth's atmosphere. The purpose of these climate models is to describe how major changes in the earth's atmosphere, such as changes in the concentrations of GHGs, affect climatic patterns including temperature, precipitation, cloud cover, snow cover, winds, and atmospheric currents. The models are not intended to predict weather events, and they are too simple to account for the effects of local geographic features such as mountains that may influence regional climate, with typically several hundred kilometers between grid points. There is often significant weather variation between grid points that is not captured by the GCMs. They are, however, useful tools for examining long-term climatic trends, patterns, and responses to significant changes. These models continue to evolve as better information on and understanding of physical relationships are developed, and as improvements in computing power are realized. Climate models differ with respect to their assumptions, detailed structure, spatial and temporal resolution, and complexity, and as a result there is significant variation in the projected results of different models. This variation illustrates the degree of uncertainty associated with climate projections but can also provide a sense of reliability to the extent that consistent patterns emerge across different models (Adams, Hurd & Reilly, 1999).

The IPCC, AR4 WG1 (2007a) reported that there was an increase in temperature in the last 100 years by about a 0.74 °C in global average temperature. The IPCC AR4 (SPM, WGII 2007) reported that globally, dry regions are projected to get drier, and the arid and semi-arid regions are highly vulnerable to climate change. The projected climatic changes will be among the most important challenges for agriculture in the twenty-first century, especially for developing countries and arid regions. By mid-century, annual average river runoff and water availability are projected to decrease by 10-30% over some dry regions at mid-latitudes. Drought-affected areas will become larger. It is projected that globally, potential food production will decrease beyond 3 °C (IPCC, 2007). As global climate appears to be changing, we would expect the Mediterranean climate also to have changed. Yields of rain-fed crops could decrease substantially across the Mediterranean region due to increased frequency of drought (Karas, 2000). By the mid-21st century, it is projected that crop yields could decrease up to 30% in Central and South Asia (IPCC (2007).

The Arab countries are in many ways among the most vulnerable in the world to the potential impacts of climate change, the most significant of which are increased average temperatures, less and more erratic precipitation in a region which already suffers from aridity, recurrent drought and water scarcity. By the end of the 21st century, the Arab region will face an increase of 2 to 5.5°C in the surface temperature. This increase will be coupled with a projected decrease in precipitation up to 20%. These projected changes will lead to shorter winters and dryer and hotter summers, more frequent heat wave occurrence, more variability and extreme weather events occurrence (AFED, 2009).

The scale of future climate change in Jordan is analyzed on the bases of past trends in weather variables. Six stations were selected to represent the varied agro-climate conditions to analyze the surface temperature, precipitation and evaporation. In general, all stations show an increase in temperature beyond 1970, and slight decrease in precipitation beyond the rainy season 1970/1971. Ten-years moving average during the period from 1960-1998 were examined, and found that the temperature increased by 0.3-0.9 ° C (Al Shamil, 2000).

In the following, a summary review of information on such changes (Al Shamil, 2000), and the findings of the MoEnv (2009) in the 2nd report presented to the UNFCCC:

4.2.1 Temperature

- An increase by about 0.9° C beyond the year 1965 for Amman Airport Station, and in the mean annual temperature by about 1.5°C during the period 1972-1998;
- An increase by 0.3°C during the period 1968-1980, and 0.8 0C beyond the year1982 for Mafraq Station;
- A clear increase in temperature (undefined) during the period 1968-1998 for Dhulail Station;
- An increase in temperature (undefined) beyond the year 1981 for Irbid Station; and
- A general increase in the temperature (undefined) beyond the year 1983 for Azraq Station.

Annual maximum air temperature records do not show clear trends, but annual minimum temperatures have increased. Minimum air temperature has increased since the seventies of the last century. This increase indicates a slight change in regional climate (Hamdi, et. al. 2009).

The MOE (2009) reported that both maximum and minimum temperature time series in a selected 19 meteorological stations had shown significant increasing trends during the period 1961-2005. Increasing trends in the annual maximum temperature range between 0.3 and 1.8°C. The increasing trends in the annual minimum temperature range between 0.4°C and 2.8°C, which are obviously greater than maximum temperature trends.

4.2.2 Precipitation

The IPCC, WG1 (2007) projected that the annual average precipitation decreases in most of the Mediterranean during winter. In Jordan, and based on ten-years moving average during the period from 1960-1998, Al Shamil (2000) found that the following:

- A gradual decrease of precipitation from 1938-1999 (with the exception of the period 1960-1968) recorded in Amman Airport Station. The decrease in precipitation was found to be associated with an increase in temperature and verse versa;
- A sharp decrease beyond the season 81-1982 for Mafraq, Wadi Dhulail and Irbid stations;
- A stable precipitation during the period 1980-1988 for Azraq Station; and
- A sharp decrease beyond the season 1985/1986 for Aqaba Station.

In a study covering records ranging between 30-83 years during the period 1922-2003 at six different stations, rainfall records indicated that precipitation has been fluctuating, and no statistical trends of increase or decrease in the annual precipitations indicating climatic change were detected (Hamdi, et, al. 2009).

Based on a selected 19 meteorological stations during the period 1961-2005, a trend analysis of climatic variables was carried out and presented in the Jordan's Second National Communication to the UNFCCC (MOE, 2009). The main conclusions of the report can be summarized as follows:

- A decreasing trend in the annual precipitation by 5-20% in the majority of the stations was apparent, which provide evidence to a climate change in Jordan during the last 45 years;
- The relative humidity exhibited significant decreasing trends, leading to significant increasing trends in evaporation;
- The number of rainy days reveals decreasing trends of about 3 -10% in most of the stations; and
- Shortened rainy season.

Decreasing humidity and a delay in winter rains, with no extension of the rainy period, may explain the decrease in Jordan's total annual rainfall.

Changes in annual rainfall varied among regions in Jordan. This suggests that specific regional factors might play an important role in the local climatic trend (Freiwan and Kadioglub 2008; MOE, 2009). The temporal and spatial distribution of rains in the Mediterranean basin is highly changeable, with rainfall varying greatly both from year to year and within the year (Karas, 2000). Even greater variability due to climate change will likely be as important as or more important than changes in mean climate conditions for determining climate change impacts and vulnerability (IPCC 1996).

4.2.3 Temperature and Precipitation beyond the Season 1991/1992

The temperature and precipitation time-series beyond the winter season 1991/1992 (which was exceptional rainy season) showed the following (Al-Shamel, 2000):

- A general increase in temperature that amounted to 0.9° C, and a general decrease in precipitation for Amman Airport Station;
- A general increase in temperature that amounted to 0.8° C and a slight decrease in precipitation for Mafraq Station;
- A general increase in temperature that amounted to 1.2° C and a slight decrease in precipitation for Wadi Dhulail Station;
- A general increase in temperature that amounted to 1.0° C and a general increase in precipitation for Irbid station;

- A general increase in temperature that amounted to 1.0°C for Azraq Station, and a general decrease in precipitation (for Safawi Station located northeast of Azraq); and
- A general increase in temperature that amounted to 0.6° C, but, no trend in precipitation for Aqaba station.

In conclusion it was found that all station in the study area show an increase in temperature ranges 0.5° C and 1.2° C in the period 1992-2000 (Al-Shamil, 2000).

5. CLIMATE CHANGE IMPACTS

5.1 Climate Change Projections for Jordan

MoEnv. (2009) projected a general increase in temperature in Jordan of approximately 1.0 to 1.3 °C (less than 2°C) by the year 2050 and that summer warming is more substantial than winter warming[19]. Warming was projected to be stronger during the warm months of the year while less warming is projected to occur in the cold months of the year. Although, the climate change scenarios for precipitation were highly variable, the German model predicts a decrease in precipitation in the cold and rainy months (MoEnv. 2009).

5.1.1 Impact of Temperature Increase on Potential Evaporation

Moisture availability is determined both by water gains from precipitation and water losses through runoff and evapotranspiration. As temperature increases, evapotranspiration will also increase (all other things being equal). This means that even where precipitation is projected to increase, actual moisture availability could go down if the gains are outweighed by losses. This is because extra precipitation in winter may not be stored in the soil, but lost as runoff. The occurrence of precipitation in intense episodes has a similar effect (Karas, 2000).

For the calculation of potential evaporation and potential evapotranspiration, meteorological data from Irbid station was considered (Al Shamil, 2000). For the summer (July) period, the mean potential evaporation (E) and potential evapotranspiration (ET) for the selected period were 5.65 and 6.99 mm/day, respectively.

Should the temperature increased by 3°C, the amount of increases in potential E and ET for the summer (July) period per 1° C were estimated to be 0.17 and 0.19 mm/day respectively. This is equivalent to an annual increase of 64-70 mm (mean annual rainfall 431 mm) of evaporation. The amount of increase in potential E and ET for the winter (January) period per 1°C was 0.043 and 0.05 mm/day. The average annual increases in potential E & ET for an increase in temperature 1°C were estimated to be 3.4% and 2.73% respectively.

With the anticipated increase in overall temperature, and, the increase of 1°C in the Jordan is expected to increase evaporation rates up to 15% in summer. These results suggest an overall trend towards a greater water deficit.

5.1.2 Impact of precipitation

Warming will be accompanied by changes in precipitation, moisture availability and the frequency and severity of extreme events. Significant uncertainties remain over future precipitation patterns in the region, but the balance of current evidence suggests annual precipitation may decline over much of the Mediterranean region. Moisture availability may go down even in areas where precipitation goes up due to higher evaporation and changes in the seasonal distribution of rainfall and its intensity. As a consequence, the frequency and severity of droughts could increase (Karas, 2000). The reduction of moisture availability would inevitably add to the

19 In a personal communication, the Director of the Meteorology Department supports this conclusion.

problem of water scarcity. The changes in precipitation combined with increased evaporation would directly reduce runoff and ground water levels.

5.1.3 Increased Frequency of Extreme Weather Events

Recent years have witnessed an increase in the frequency of extreme weather events. This includes years which are either exceedingly wet or exceedingly dry, with predictions pointing to further increases in the number and frequency of such events (e.g., drought years, heat waves).

The incidence of extreme weather events during the 1990s and 2000s in Jordan is evident. The annual mean precipitation in 1991/1992 was exceptionally high (200% of the annual average) ; heavy, long and frequent snowfalls in 92-1993; the period 1998/2000 witnessed extreme drought conditions in two successive years (50-63% of the annual average; the summers of 1998, 2000 and 2010 were exceptionally hot with mean temperatures 3-4°C higher than average, with the highest recorded temperature (43.5° C) in Amman since 1970 and that the temperature in August 2010 was higher than the average by 1-11°C[20]; November was exceptionally cold in 07-2008 with 2.3 degrees below average; January temperature in the winter season 2008/2009 was exceptionally low, with more than a week of heavy frost and January temperature in the winter season 2009/2010 was exceptionally warm with 2-3 degrees above average[21].

Based on the literature review, with higher atmospheric CO_2 concentration (560 ppm) in the following decades, temperature is expected increase 0.3-0.8° C by 2050, and this increase will double in the second half of the century (from 1.6° to1.8°C) (IPCC, 2007). This increase in temperature will lead to more climatic variations and uncertainty, more frequent extreme events, reduction in precipitation in latitudes below 35°N, delayed winter rains and thus shortened rainy season, more seasonal variability in temperature, as observed worldwide (IPCC 1996), and increases in evapotranspiration by 10%.

5.2 Socio-Economic Impacts of Climate Change on Food /Agriculture Productivity

Despite technological advances, such as improved varieties, fertilizers and irrigation systems, weather is still a key factor in agricultural productivity. Agriculture depends upon temperature and precipitation. Rise in temperature of about 0.1-0.2 °C per decade up to 2050 (AR4, WGI, IPCC, 2007) due to increases in CO2 concentration. At present, CO_2 level is approximately 390 ppm as of 2010 and rising by about 1.9 ppm/yr (Carbon dioxide in Earth's atmosphere: Wikipedia, 2010). It is projected that globally, potential food production will increase for temperature rises of 1-3 °C, but decrease for higher temperature ranges beyond 3 °C.

Precipitation changes can have significant changes on crop growth in the marginal areas. A warmer climate will change rainfall, lead to increased droughts and floods, and result in accelerated sea-level rise. Rising temperature will lead to an increase in the level of evaporation of surface water; the air will also expand and this will increase its capacity to hold moisture. This, in turn, will affect water resources, agriculture, forests, and other natural ecological systems. However, in the higher

[20] Director of the Meteorology Department, Al-Rai Newspaper, August 25, 2010.
[21] Director of the Meteorology Department, personal communication, October 28,

latitudes (> 35°C), agriculture will benefit with the rise in temperature as the winter season will be shorter and the growing seasons longer. This will also mean that pests will move towards the higher latitudes as the temperatures rise.

Duration of crop growth cycles are related to temperature. An increase in temperature will accelerate crop development. In the case of an annual crop, the duration between sowing and harvesting will shorten by a number of weeks. The shortened growth period have an adverse effect on productivity and potential yield. Farmers in the Jordan Valley were used to harvest their cucumbers up to June, but at present, they stop harvest by the end of April, with more than 30% reduction in yield[22]. Many crops are already subjected to heat stress in the Jordan Valley. But, with further temperatures increases above the threshold for heat stress, crop failure is becoming more commonplace. This would happen if farmers continue early planting in October in the Jordan Valley. With higher temperature, they would face the risk of crop failure due to heat stress at the critical time of flowering[23]. Farmers would adapt to such loss of production potential if new technologies and genetic resources be practically and economically accessible by farmers. Thus, further research is required for more adapted cultivars or crop species.

Higher temperatures lead to higher respiration rates, shorter periods of seed formation, and consequently lower biomass production. For example, higher temperatures result in a shorter grain filling period, smaller and lighter grains, and therefore lower crop yields and perhaps lower grain quality, i.e., lower protein levels (Adams, Hurd & Reilly 1999). Plants can partly cope with heat stress where there is sufficient soil moisture. Plant developmental rate will be accelerated with increasing temperature, and this may benefit leafy vegetables such as lettuce. But, increase in temperature leads to reduced fruit set, and thus reduce production of fruity crops[24]. Higher temperatures will also result in an upward shift in zones appropriate to each crop. High temperatures also contribute to increased evaporation and lower soil moisture; when coupled with reduced precipitation in much of the country, the incidence of drought is very likely to increase. More frequent droughts and lower levels of soil moisture coincide with a reduced supply of irrigation water.

Vulnerability to climate change depends mainly on the level of economic development and adaptive capacity of nations. Progressive farmers in the Jordan Valley express confidence that they can cope with many of the adverse effects of the climate change (i.e. shortage of water, occasional frost and pest infections due to higher temperature and humidity in the irrigated areas…), thus, their adaptive capacity to climate change is higher. The ability of progressive farmers to escape the harmful effects of the infection of the *Tuta absoluta* which attacked tomatoes plants in late summer 2010 demonstrates the capacity of knowledgeable farmers to adapt to climate change and the importance of training and extension services **(A Focus Group Interview, October 20, 2010)**. Climate change effects impose significant additional stress on ecological and socioeconomic systems. Agriculture, water resources, forestry and ecosystem, are key elements of human development and well being that are all sensitive to climate change. The impact of climate change on these aspects is not uniform. Some of these elements will experience beneficial consequences due to the CO2 fertilization effect, while others may suffer irreversible detrimental change. If the climate change has adverse impacts, measures are needed for mitigation or adaptation.

22 Hassan Rouka in a focus group interview with nine progressive farmers in the Jordan Valley on October 20, 2010.
23 Mustafa Khadam, a farmer in the Jordan Valley, personal interview, October 25, 2010.
24 Professor Fahmi Shatat, Faculty of agriculture, University of Jordan.

Jordan faces formidable environmental and socio-economic challenges in its effort to protect its quite limited natural resources. The impact of climate change when added to existing stresses is difficult, and in some cases impossible to evaluate. Land and ecosystems are being degraded, threatening to undermine food security. Climate change will affect many sectors, including water resources, agriculture and food security, ecosystems and biodiversity, and human health.

The climatic change could affect agriculture:

- In productivity, in terms of quantity and quality of crops;
- In agricultural practices through changes of irrigation and use of agricultural chemical inputs such as pesticides and fertilizers; and
- Environmental effects such as soil erosion, and reduction of crop diversity.

The socioeconomic impacts of climate change in Jordan on agriculture include:

5.2.1 Impacts on Agriculture and Food

Food production in Jordan is a fundamental component of Jordan's economy and national policies on agriculture. Sustaining and increasing output to meet growing demand faces significant challenges including, climate change, changing patterns of food consumption, increasing population, agricultural land conversion, and competing demands for water.

Climate change is expected to harm agriculture. But it can produce some gains where increases in temperature will lengthen the effective growing season in areas where agricultural potential is currently limited by cold temperature stress. The negative climate change impact on food production system can be **direct or indirect:**

The **direct impacts** are through rise in temperature, low water balance, changes in atmospheric composition and extreme weather events. Climate change will affect agricultural yield directly because of alterations in temperature and rainfall. The yield of rain-fed crops is expected to decline in the Middle East (AFED, 2009). Therefore, climate change is projected to reduce agricultural production in Jordan, but, it would be able to maintain per capita agricultural production, given reasonably optimistic assumptions about policies on land and water management and agricultural technology. Adaptation based on sustained improvements in agricultural technology results in significant increases in agricultural productivity.

The Ministry of Environmental Protection (MOEP) iexpected damage to crops due to decrease in water availability, 20% increase in water demand, and 20% increase to pests better suited to warmer climate. The water scarcity problem may cost the economy about $120 M per year up to 2020. Floods is expected to damage human structures and crops during peak water flows and to cost $90 M a year, while damages to agriculture may reach some $800 M a year. Total cost to the economy is about $1000 M per year MOEP, 2009). Thus, the cost would be 0.0048 of the GDP in

2009 (World GDP, World Bank Website). Considering that the GDP of Jordan in 2009 was JD16 billion, the estimated cost to agriculture would be about JD 77 M per year.

However, reductions in agriculture production could also impact on Jordan's Para agricultural activities, and thereby have a wider-reaching effect on the economy. The components of agribusiness sector activities and their contribution to GDP are agribusiness services 9%, inputs 8%, agro-industry 5% and 6% for the agricultural sector contribution (Ouedraogo and Hayson, 1993). On this broad definition, there are important indirect agricultural losses which include inputs and producer services, marketing and processing. If para agricultural activities losses are considered, losses in the future for the agribusiness sector would add to the estimated cost to agriculture.

Extreme events are more likely to have an adverse effect on agricultural production than climatic trends. Gradual changes in temperature and the timing and levels of rainfall will reduce yields in some areas and enhance yields in others, depending on initial conditions. With climate change, weather patterns are expected to become more erratic (very low or high temperature in winter, floods, winds, etc....). Changing weather patterns may cause damage to crops and agricultural lands in ways that cannot be predicted by mean temperature increases or changes in annual precipitation levels. In the most affected countries, cropping patterns may have to change to respond to changing climatic conditions. For example, a temperature increase and decrease in rainfall would reduce the total area available for growing pome and stone fruit trees, and restrict it to higher altitude areas.

Extreme weather conditions such as high or low temperature, heavy rainfall, floods, droughts, etc. will also affect crop production. Greater rain intensities and resulting floods may damage crops in the low and plain areas, such as the case of Pakistan, China and Thailand in 2010. Increases in seasonal temperature variability, and frequency of temperature extremes, e.g., frost and heat waves in Jordan in the last three years may endanger cold- and heat-sensitive crops. Heat waves affect tomatoes flowers and prevent fruit set, tomatoes production declined in Jordan and neighboring countries, Palestinian authority, Lebanon, Syria, Egypt and Turkey[25]. Ministry of Agriculture sources[26] estimated a 40% decline in tomatoes, due to the extreme rise in temperature (43.5 C° in Amman and 49 C° in the Jordan Valley) in August 2010 which increased the prices by more than 300%.

The **indirect impacts** are through changes in frequency distribution and severity of pest and disease outbreaks, incidence of fires, changes in soil quality and failure to meet chilling requirements. Damage to crops would be due to decrease in water availability and due to pests better suited to warmer climate. Short life of wild flowers results in shortage of feed for bees, and consequently, honey production would be reduced. Honey production decreased drastically in the last decade. The 2005 report on the state of agriculture by the Ministry of Agriculture reported a 40% decrease of honey production. Heat waves in Jordan drastically reduced honey production in 2010[27]. As the temperature rises, organic matter will dry out, the soil characteristics will change and with the shortages of water, or low quality of water, yield will decline[28]. As the temperature rises, conditions will become more favorable for pests. More pests and pathogens will not only increase crop diseases but also their sensitivity to drought and loss of biodiversity may reduce the natural control of agricultural pests. Drought damages are also expected to increase with the anticipated decrease in water availability, hotter temperatures and shorter winters. Failure to meet low chilling requirements of pome and stone fruits in the Jordan Valley due to high temperature

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[25] Hassan Abu Sedo, a progressive farmer in the Jordan Valley.
[26] Dr Yosef Qat, Manager of Marketing Department, Ministry of Agriculture, Amman.
27 Professor Ibrahim Al-Nather, Faculty of agriculture, University of Jordan.
[28] Hassan Abu Seedo, a progressive farmer in the Jordan Valley (October 20, 2010).

in the last decade force farmers to discontinue growing these crops[29]. Trees can grow quite well, but they produce little fruits or none.

Climate change is expected to benefit agriculture in some areas. These include:

- Climate change is likely to increase crop yields due to extended growing seasons in colder regions where plant growth is limited by frost;
- As climate change occurs, the higher atmospheric concentrations of CO_2 may increase photosynthesis. Carbon fertilization effects and farm-level adaptations would have substantial cancelling out effects on the adverse impact on climate change. Laboratory experiments have shown that the anticipated doubling of CO_2 atmospheric concentrations could increase crops such as wheat, rice, soybeans by 34%. These same experiments also suggest that climate change may induce a 40% increase in maize and sorghum crop yields. Another study suggests that crop yields of citrus fruits and tomatoes may also increase as a result of climate change (Fankhauser, 1995).

Abu Irmaileh (2010) reported that weeds benefit far more than crop plants from higher levels of CO2 and that the implications of this for agriculture and public health are grave. Weeds are able to respond rapidly to disturbances giving them a competitive advantage over the less aggressive species. Enhancing CO2 levels, not only increases growth rates of many weeds, but may lead to changes in their chemical composition. When ragweed (Ambrosia sp.) was grown in an atmosphere with 600 ppm of CO2 (the level projected for the end of this century) they produced twice as much pollen as plants grown in an atmosphere with 370 ppm. The pollen harvested from the CO2-enriched atmosphere proved far richer in the protein that causes allergic reaction. Perennial weeds may become more difficult to control, if increased photosynthesis stimulates greater production of rhizomes and other storage organs. Overall, there are strong empirical reasons for expecting climate and/or rising CO2 to alter weed management. Adaptation strategies are available, but the cost of implementing such strategies (e.g. new herbicides, higher chemical concentrations, new biocontrol agents) is unclear. If an increase in CO2 and temperatures allow invasive weed species to expand their geographical locations new herbicides may be needed to combat them (Abu Irmaileh, 2010).

Thus, there are disagreements concerning the effects of climate change on crop production estimates of damages are equally conflicting (e.g. Allen, Baker and Boote, 1995). The effects of higher atmospheric concentrations of CO_2 on crop production in open field conditions may be limited by the availability of water and nutrients (Adams, Hurd & Reilly 1999)). However, although CO_2 is expected to somewhat mitigate the effect of heat and drought, the overall effect of CO_2 enrichment is still poorly understood. Thus, further research is required for designing cultivars with improved photo-assimilation utilization.

The Jordan Valley continue to enjoy the comparative advantage to produce vegetable crops earlier at no cost for heating, thus less cost as compared to neighboring countries, in addition to the opening market of Europe. Thus, higher temperature due to climate change may help to promote exports during a critical period of exports for some crops. The number of green houses planted for export contracts to Europe increased from 250 in 2005 to 10000 in 2010[30].

29 Hassan Abu Seedo, a progressive farmer in the Jordan Valley (October 20, 2010).
[30] Fuad Salameh and Saleh Al-Yaseen, progressive farmers in the Jordan Valley (October 20, 2010).

5.2.2 Impacts on Water Resources

Anticipated changes in precipitation due to climate change may place considerable stress on water supplies in some areas and changes in arable land area. Water availability plays a significant limiting role on potential agricultural production due to the combined effects of higher crop water requirements (due to rise in temperature) and increasing demand for non-agricultural use of water (due to population growth and expanding service and industrial sectors). Changes in the rates, timing, and intensity of precipitation combined with changes in evapotranspiration rates will ultimately decrease soil moisture. If precipitation in some area actually decreases or does not increase enough to account for increase evaporation rates induced by increasing temperatures, this gap between precipitation and evaporation rates will lead to decreases in soil moisture.

The impact of climate change on water resources will affect human well-being to various levels, depending on how country-specific water management methods can accommodate such change. Countries that are more dependent on seasonal rain fall will be more vulnerable. In general, the irrigated agriculture is the first activity to be significantly affected in many countries due to the water shortage.

Climate change impact estimation of water resources is complex because of the interaction of various climate as well as non-climate factors. Factors promoting demand for water include population growth, rise in per capita income, urbanization, industrial development, and levels of agricultural development. The GDP of Jordan at current prices increased from 4982 m JD in 1996 (per capita income 1121 JD), to 16266 m JD in 2009 (per capita income 2720 JD). The GDP of the industrial sector increased from 1083 m JD in 1996, to 4728 m JD in 2009. The contribution of the industrial sector increased from 26% in 1996, to 30% at const price in 2009 (CBJ, 2000, 2009). The agricultural GDP at market prices increased from 193 m JD in 1994 to 476 m JD in 2009. The relative share of the agricultural sector to the GDP declined from 5% in1996 to 3.9% in 2009 (CBJ, 2005 and 2009).

Thus, it is difficult to project whether human water supply system will advance sufficiently to counteract the anticipated negative impact of climate change and increased demand. Some of the factors such as vegetation, use of technology and development, projected water demand and population growth make the assessment of the impact of climate change on water resources more complicated.

Taking into consideration the widening of the gap between supply and demand due to climate change and socioeconomic factors, which will aggravate water scarcity, the National Water Strategy 2008-22 envisage putting a limit, control system and charging higher prices on water available for irrigation. Ground and surface water available for irrigation in the highlands are expected to decrease from 272 mm^3 in 2007 to 114 mm^3 in 2022. Besides, measures will be adopted to increase the use of treated water in the Jordan Valley and the highlands (from 91 mm^3 in 2007 to 220 mm^3 in 2022), and brackish water for irrigation (MWI, 2009).

The combination of higher temperatures and lower precipitation, across most of Jordan, would result in productivity losses as the demand for irrigation was already unmet in 2007. Demand for water for irrigation exceeds supply, as 70% of demand for irrigation was met in 2007, and this percentage will decrease to 60% in 2022 (MOWI, 2009).

Water is vulnerable to climate change of both quantity and quality. The benchmark minimum water availability is 1,000 cubic meters of water per year per person; nations having less than this amount are considered to have a water scarcity (Karas, 2000). Jordan falls much below this benchmark. Increased uncertainty in future supply and demand for water raises the urgency of developing sound water management strategies even in regions now not experiencing water resource difficulties. The National Water Strategy 2008-22 is a step in this direction (MOWI, 2009).

In 1966, 66% of the population lived in the main urban areas (33% in Amman, 18% in Irbid and 15% in Zarqa) (Al-Shamel 2000). In 2008, the percentage increased to 72% (39% in Amman, 18% in Irbid and 15% in Zarqa (MOL, 2009). Population increased from 4.14 m in 1994 to 5.98 m in 2009 (DOS website).

With decreased precipitation and increased evaporation from higher temperatures, average spring flow in Jordan and underground aquifers decreased. Increased rain intensity combined with a reduction in overall precipitation will diminish vegetation cover and increase surface runoff and evapotranspiration, leading to desertification, especially in the low rainfall, marginal and arid areas. The resulting soil erosion, salinization, and loss of vegetation will further increase surface runoff. Underground water recharge will be reduced, and many springs throughout the country will dry up. This reduces the availability of water, especially for agriculture. MoEP (2009) expects a reduction of at least 25% in water availability by the end of the 21st century. Reduction in water availability in Jordan up to 2100 would be 25% or more. Reductions in water supply will coincide with an increase in demand as households require more drinking water because of high temperatures and farms require more irrigation water because of hotter, drier conditions.

The agriculture sector, is highly dependent on irrigation water, many of its sources will suffer large-scale reductions in flow as climate change progresses. The irrigated area was 95 thousand ha out of the total cultivated are 224 thousand ha in 2009 (DOS, 2010). Thus, 42% of the land under production requires irrigation; with climate change more land will fall under this category but less water will be available. However, increase in irrigated area does not mean a proportional increase of water allocated for irrigation. Farmers in the Jordan Valley[31] said; the number of green houses increased three times in the valley, yet the quantity of allocated is the same. Generally, the allocated water to the farmers is reduced by 50%. Besides, the quality of water is lower[32].

The actual impact on agricultural production will depend on policy decisions regarding the allocation of irrigation water among farms, and the allocation of all water resources among all uses. The National Water Strategy 2008-22 has limited the water available for irrigation. This also call for important policy decisions choices regarding the introduction of farming practices that require less water and less crops which are more vulnerable to drought and far more likely to require irrigation. Total water available for irrigation from all sources will decrease from 597 M m^3 in 2007 to 568 M m^3 in 2022. But, the percentage of supply to demand in 2007 (55%) will slightly increase in 2022 to 57%. However, the percentage of treated water to total water available for irrigation will increase from 14.6% to 38.7% (MOWI, 2009).

Water supply may severely decrease, falling to around 25% of current levels by 2100 (MOEP, 2009), due to sedimentation in reservoirs and the lack of reservoir recharge. Increased surface runoff will reduce aquifer recharge, and sea level rise. The quality of stored water will degrade due to salinization, and the increased surface runoff will transport dissolved pollutants and soil sediments to waters reservoirs. This will gradually reduce the water storage capacity of the dams, which reduce the economic age of these reservoirs, which add to the costs to agriculture.

5.2.3 Impacts on Forests

[31] Nabil Al-Tagi, and Khalil abu Ghannam, progressive farmers in the Jordan Valley.
[32] Hasan Abu Seedo, progressive farmer in the Jordan Valley.

Climate is an important determinant of the geographical distribution, composition and productivity of forests. Climate change impacts over forestry depend on various factors such as species, age of trees, possibilities for forests to migrate, and quality of forest management. Specific impacts include forest decline due to high tree mortality in planted forests, invasive pathogens, drought, and high frequency of fires. Impacts have profound implications for traditional livelihood, biodiversity, soil and water resources and these leads to changes in agricultural productivity.

Forests play a particularly distinctive role because of their long time scale for change, their role as repository of large part of all above-ground vegetative carbon and of below ground carbon, and their role as hosts to two thirds of the planet's biodiversity. More than half of the CO^2 emitted annually (8.4 billion tons in 2009) is absorbed by oceans, soils, and trees (Heinzerling, 2010). A preliminary assessment of changes in the water balance over the eastern Mediterranean from Turkey through to Egypt also found a tendency for a northwards shift of the desert line (Karas, 2000).

Global warming at a rate of 1.8 to 4.0 degrees over the next 100 years (IPCC, 2007) will shift to higher zones. Species that live in the higher zones are forced to move higher up to find a suitable environment thus reducing the area in which they can live. If the rate of climate change continues to accelerate, then the extinction of some mountain plants and animals is quite likely. Some forests are likely to disappear due to higher temperature and an increase in the number of pests and pathogens.

With alterations in temperature and rainfall, Jordan's forests would shrink in size and deteriorate in biodiversity with climate change. Higher temperatures will cause an upward shift in the zones appropriate to each species; trees species may have trouble migrating quickly enough to remain in a zone in which they can thrive. Reduced precipitation and increased evaporation will cause an encroachment of drought-tolerant species into existing forests. Where drought-tolerant species do not migrate quickly enough, dead zones or areas of extremely limited vegetation may develop.

These dead zones will reduce the recharge of underground aquifers and promote run-off, which can result in soil erosion. Arid conditions also make forests more vulnerable to fires and pests infections. Delayed winter rains will increase the risk of forest fires, as most fires occur in autumn when dry vegetative matter peaks. The frequency, intensity and extent of fires will increase due to lower soil moisture, increased evaporation and increased frequency and intensity of heat waves. About 50 fire cases were reported annually in Jordan with more than 4000 damaged trees[33].

Potential losses in forest area from climate change include damages from changing climatic zones, pest infestation, and forest fires, and use of forest wood as a fuel for some of the Jordanian households, although, as winter temperatures are expected to increase, this may reduce demand for wood for heating. High costs of fuel would increase demand for fire wood. A consistent supply of heating fuel, especially at higher elevations, is essential to maintaining the forest areas.

Soil erosion is caused by deforestation and arid soils, which reduce the ability of the land to absorb water into underground aquifers. Instead, rainfall and snowmelt run off the surface causing erosion and picking up dirt and stones as it flows. Soil erosion occur primarily on areas with steep grades – mountain slopes and hillsides. Much of Jordan's land area is prone to soil erosion. The value for the ecological losses of large-scale deforestation needs to be taken into considerations.

[33] Annual Reports of the state of agriculture for 2005 and 2007, Ministry of Agriculture.

5.2.4 Impacts on Livestock

Livestock products are impact of human diet. The Jordanian citizen consumes 39.4 kg of red and white meat 91.5 liters of milk and 8.2 kg eggs annually.

The climate has direct and indirect effect on livestock. The direct effects include:

- Animal metabolism;
- Feed intake;
- Growth;
- Reproduction;
- Health; and
- General performance.

The indirect effects would be on:

- Feed production;
- The increase parasitic and animal, diseases.

5.2.4.1 Impacts of Climate Change on Rangeland

Rangelands are sometimes defined as grasslands, shrub lands, savannas and deserts. They cover about half of the earth's land surface and contain about 36% of the total living and dead plant carbon. Small changes in extreme temperatures and precipitation have disproportionately large effects in these regions because of the vulnerability to water availability and water balance (Rangelands; Wikipedia Website)[34].

Dry lands (< 200 mm annual rainfall) cover more than 90 per cent of Jordan's land area (Table 3). Desert is a landscape or region that receives an extremely low amount of precipitation, less than enough to support growth of most plants. Deserts are defined as areas with an average annual precipitation of less than 250 millimeters per year (Rangelands; Wikipedia Website). While rangeland in Jordan is not as arid as deserts, dry lands are characterized by their limited water supply, low and highly variable rainfall, and recurrent drought. Even where surface waters accumulate, these are not easily retained, as high temperatures and intense precipitation will result in that much of the water is lost to evaporation and run off, respectively. Dry lands in Jordan consist primarily of rangelands, which support domestic livestock production, and rainfed and irrigated agricultural lands, which produce major food crops wherever water is sufficient enough to support rainfed or irrigated farming.

Rangeland is expected to deteriorate with climate change and many rangeland areas would disappear altogether. With a 0.3°C warming per decade during the 21st century according to the FAR, WGI (IPCC, 1990), the reduction in moisture availability projected under climate change would both increase the aridity of existing dry lands

[34] http://www.cnr.uidaho.edu/what-is-range/Rangelands_Defined.htm.

and progressively *shift* the boundaries of areas susceptible to desertification northwards in the Mediterranean region to encompass areas currently not at risk (Karas, 2000). Thus, the (arid) desert ecosystems may be expected to replace semi-arid Mediterranean ecosystems in Jordan. Desertification is defined as land degradation in naturally dry areas resulting from various factors including climate variations and human activities. Desertification is more likely to be irreversible if the environment becomes drier.

Total rangelands in Jordan are expected to decline and a reduction of the productivity of range lands or grazing capacity is expected. Normally, rangelands allow animal breeders to cover 50% of the feed requirements for 6 to 8 months, but under drought conditions, it provides 20-25% of the feed requirements for 3 to 4 months[35]. Because of the importance of livestock (which rely for part of the year on grazing) in the Jordan diet and agricultural economy, and the likely vulnerability of pastures to climate change, this is a high priority area for new research.

5.2.4.2 Impact of Climate Change on Animal Production

i. Impact of climate change on milk production

Heat stress is a major source of loss in dairy industry .In the year 2006, the heat wave in California caused a loss of 1 billion dollar in milk and meat production and in 1990 heat wave in Nebraska caused a death loss in cattle of 20 million dollars.

The milk production of cows and ewes will be reduced due to the heat wave. The reduction will be higher for the high producing animals. This is due to the fact that high producing cow produce more heat than low producing cows. A dairy cow producing 60kg/ day milk and with a body weight of 700 kg produce 44171 kcal/day while the same cow producing 20kg milk/ day at the end of lactation will produce 25782 kcal/day . It could be summarized that in mid lactation the dairy cows are more heat sensitive and the decline in milk may be up to 38%.

ii. Impact of climate change on meat and egg production

Heat stress will reduce the productive performance of laying hens. It will be of a major concern on broiler industry because the broiler chicken grown under heat waves will have lower body weight gain and lower carcass yield.

Research showed that the same effect could be also on sheep and goat. The body size could be reduced in heat waves for lambs which could risk in average carcass weight.

iii. Impact of climate change on animal health

The increased temperature will have an effect on temperature related illness like laminitis. It may cause cows to produce less saliva and may also cause production of milk with less fat. The heat may cause also higher mortality rate and morbidity of disease especially in summer. In addition to that there will be also a higher mortality rate of new born lambs during the hot months. This is due to that fact of the influence of heat on cholesterol immune globulin. The alterations of productive traits of animals under hot waves were due to:

- Reduction in feed intake;
- Increase in respiration rate;
- Change in hormonal stimuli that affect environmental stimuli;
- High incidences of mastitis; and
- Increase of mycotoxins in feeds.

[35] The 2007 Annual Report of the state of agriculture, Ministry of Agriculture.

iv. Impact of climate change on reproduction

High environmental temperature will compromise oocyte growth due to the reduction of secretion of LH and FSH hormones .the hormone dynamics during estrus cycle may be altered and may cause impairment of growth. The experiments showed that there will be a drop in conception of 20-27% in summer and that the first successful service to cow will be longer. In bulls the semen concentration and the number of spermatozoa and motile cell per ejaculate are lower in summer than that in spring and winter.

v. Indicators effect of climate change on animal production

- The effect of climate on the feed of animals and on the supply of grains and the price of both the feed and the concentrated grains;
- The climate affects the feed availability and production of range in Jordan in addition to that it will affect the forage production in rain fed areas and the Jordan valley. Climate will also affect the quality of forge in all these areas;
- The climate will also increase livestock diseases and parasites: the internal and the external parasites; and
- Climate change will affect reproduction of animals and the growth rate of adult animal in feedlot center.

5.2.4.3 Climate change and crop production

The area which has a rainfall of 200 mm and above is around 9.0 million dunums (0.9 million hectares) which occupied around 8.9% of the area of Jordan. Around 5.542 million dunums of that area are good for cultivation. 3.5 million Is cultivated by wheat, barley, lentil, chick peas, summer vegetables and trees. The trees are mainly olives, grapes. Around 1.6 million dunums are cultivated with wheat and barley. The trees occupy around 678,000 dunums especially olives trees. Around 1.18 millions of land is left without cultivation and left as fallow.

The data showed that the crop cultivation area deteriorated. There is a trend of decrease in cereal production.

This is clear when 1.2 – 1.5 million of land is left fallow or uncultivable. The data showed that the area cultivated with wheat decrease by 66% and with lentils and others by 77%the barley increased by 83% in arid and semi arid areas by the year 2000.

5.2.5 Impacts on Ecosystem and Biodiversity

Human societies are mainly dependents upon commodities (goods and services) provided by the ecosystem. But, the global climate change will lead to a reduction in the commodities that ecosystem provides, as well as decline in genetic and species diversity. Fluctuations of temperature and precipitation caused by climate change affect the geographical distribution of biological habitats. Some of the species will be able to migrate or adapt, those who cannot adapt quickly enough may become extinct.

Ecosystems sustain the earth's entire storehouse of species and genetic diversity. Plants and animals in the natural environment are very sensitive to changes in climate. Global climate change can alter environmental conditions. Species and populations may be lost if they are unable to adapt to new conditions or relocate (ESA, 2009). With the high rate of climate change, whole populations or even species may be lost if the propagules[36] cannot shift northward through urban areas and other infrastructures. There is medium confidence that approximately 20-30% of species assessed so far are likely to be at increased risk of extinction if increases in global average warming exceed 1.5-2.5°C (relative to 1980-1999). Short lives of wild flowers due to high temperature results in a shortage of feed for bees, and consequently, fewer bees for flower pollination, and in turn lower seed set and lower yield and regeneration of wild plants. As global average temperature increase exceeds about 3.5°C, model projections suggest significant extinctions (40-70% of species assessed) around the globe (SPM, IPCC, 2007).

Interspecies variation in response to environmental stress usually exists in populations subjected to year-to-year climate change, and some genotypes in such populations are expected to be more resistant to climate change than others. Such genotypes are more common in peripheral populations than in core populations of species. Although the core population may become extinct because of global warming, resistant types in peripheral populations will survive and can be used to rehabilitate and restore affected ecosystems. The geographic locations of the peripheral species population usually coincide with climatic transition zones, such as at the edges of dry lands or along the transition between different types of dry lands. Many countries in Asia have more than one dry land type and hence should have peripheral populations—especially in desert and non-desert transitions, which often occur within semi-arid dry lands. Identifying regions with concentrations of peripheral populations of species of interest and protecting their habitats from being lost to development therefore can play a role in enhancing planned adaptation for natural and semi-natural ecosystems (IPCC, 2001, WGII).

The Arab countries will be further damaged by intensifying climate change. A 2°C rise in temperature will make extinct up to 40% of all the species. Many plant and animal species in the Arab world already face threats to their survival, and their vulnerability will be exacerbated by the projected impacts of climate change. The general harshness of the arid climate makes the region especially vulnerable to significant species loss. Unique species that are restricted in their habitat range, and/or are at the margin of their ecological tolerances, are most vulnerable to climate change. Many unique formations are especially vulnerable to climate change risk, such as the cedar forests in Lebanon and Syria, the high mountain ranges of Yemen and Oman, and the coastal mountain ranges of the Red Sea, the large rivers of the Nile (Egypt and Sudan), the Euphrates and Tigris (Iraq and Syria), and Yarmuk (Syria and Jordan). Arab countries are located on important bird migration routes. Ornithological diversity is a major asset to the Arab world and is very threatened by climate change. Many Species range shifts and impacts of extreme events often occur on regional scales so an effective climate change strategy must include mechanisms for coordinating conservation actions at the regional level across political boundaries and agency jurisdiction (Talhouk and Abboud, 2009).

[36] Propagules are any plant part, such as a bud, that becomes detached from the rest of the plant and grows into a new plant.

Estimation of species loss in terms of monetary would vary, because of large amount of subjectivity involved. The monetary estimates of biodiversity loss are generally based on willingness to pay (WTP). Fankhauser (1995) estimate the total costs of species and habitat loss from climate change to be about US $40 billion per annum for the whole world. One third of this loss is expected from the developing countries. Because of the inherent difficulties of assessing the value of a species and uncertainties about which species shall be affected by climate change, estimates of these damages are necessarily tentative and will certainly require further research. However, the vulnerability of the different species is difficult to evaluate, and the role of the different species in the provision of ecosystem services is not known. Therefore it is impossible to assess neither which species will be lost nor the impact of their loss.

5.2.6 Impacts of GDP reduction from climate change

The scale of climate change damages will depend almost entirely on what allocative and adaptive policies are put in place, whether sufficient funding can be found to support adaptive policy measures, and how quickly these policies can be implemented. In this section (Table 19), social and economic impacts from climate change in Jordan – high temperatures and heat waves, water shortages, reduced agricultural production, and price increases, damage to rangelands and forests are discussed. Each impact is described and subjected to socio-economic analysis as well as the need for further research. In the next section, potential adaptation measures to address each type of damage are discussed.

Table 19: Summary of Socio-economic Impacts of Climate Change in Jordan

Climate Impact Category	Social Impacts	Economic Impacts	Research Needs
High temperatures and heat waves	Has implications for employment in agriculture, forest fires, increases demand for certain food and drink	Reduce plant and animal production due to pest infestation and failure of the plants	How farming practices may be adapted according to heat waves. Examples include change in planting time, or adopting new heat tolerant crop varieties to avoid heat stress during flowering (tomatoes, cucumber…)
Water shortages: loss of precipitation, less water is stored in dams and in spring flow			
▪Less water available for irrigation Lower water quality available for irrigation ▪ More areas may need to have	Reduced agricultural productivity; income insecurity for the full time farmers	Decline of AGDP by 2 -5% in agriculture production, and similar decline in food processing	▪ Reduced contribution to GDP37 in food production and input industry and services. ▪ Study of water requirements starting with major crops ▪ How farming

[37] The Department of Statistics has a project to estimate the agribusiness sector contribution to GDP.

irrigation systems			practices may be adapted such as adopting new crop varieties more tolerant to water stress
Decreasing water level stored in the dams	Ecosystem damages and a loss of species	Reduction in irrigated areas or agricultural production	▪ Project the impacts of climate change on water stored in dams ▪ Reconsider the plans for building new dams or expanding the old dams
Decreasing groundwater reserves	Insufficient water for drinking and irrigation	Insufficient water for irrigation	Project the impacts of climate change on groundwater reserves
Declining water quality	Low quality of food	Lower production, and possible effects on export	More cost effective ways to water treatment and desalinization
Reduced agricultural production			
Climatic zones move upward in elevation changing the appropriate mix of crops in each area	▪ Income insecurity for the full time farmers or herders ▪ Some full time farmers or herders resort to part time farming	Reduced agricultural Productivity	▪ Studying shifts in crops production areas. ▪ Assessment of the need for off farm employment and job retraining. ▪ Studying the effect of increasing level of carbon loads to increase forests.
Less water available for irrigation and more areas may need to have irrigation systems		▪ Agribusiness contribution to GDP might shrink (the production, input and food industry subsectors	
Changing weather patterns and extreme storms cause crop damage			
Loss of pastures and pasture-land		Need for off farm employment for farmers or herders	Project impact of climate change on pasture productivity
Damage to forests: loss of Jordan's forest-land			
Climatic zones move upward in elevation; precipitation decreases and evaporation	Ecosystem damages; losses to biodiversity; Forest fires	Additional costs to control fires Use of wood as fuel	▪ Growing new forest trees or varieties more tolerant to water stress ▪ Impact of increasing prices of fuel on increased use of forests

increases making forest environments more arid			wood.

6. ADAPTATION MEASURES to CLIMATE CHANGE

This chapter is considered as the core of this assignment "Identify and screen adaptation measures to reduce climate change impacts on food productivity" as it's the main goal/objective. The adaptation measures were the subject of the five deliverables already submitted to FAO as mentioned in the introduction of this deliverable; in which more details of the adaptation measures are presented that one can refer to "Annexes from 3-6" . This section presents identification and summarizes the adaptation measures suggested by the above said assignment.

Climate change is already beginning to transform life on Earth. Around the globe, seasons are shifting, temperatures are climbing and sea levels are rising. If we don't act now by applying adaptation measures, climate change will permanently alter the lands and waters we all depend upon for survival. The most dangerous consequences may include; Higher temperatures; Changing landscapes; Wildlife at risk; Rising seas; Increased risk of drought, fire and floods, Stronger storms and increased storm damage, More heat-related illness and disease, Economic losses.

Agricultural systems have evolved to cope with modest variations in drought severity (within the coping range), but they are vulnerable to the extremes. With climate change, a one in five to seven years drought year drought may now become a one in two to three years drought year. While these droughts cannot be attributed only to climate change, an increased frequency and severity is exactly what can be expected with climate change. The serious economic and social costs of these recurring climatic changes demonstrate the vulnerability of the sector and the need for adaptation strategies.

Adaptation can be defined as: ‘adjustments in human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities. Another definition used here is taken also from IPCC 2001, wherein adaptation refers to, “adjustments in ecological, social or economic systems in response to actual or expected stimuli and their effects or impacts. This term refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change”.

In Jordan, agriculture is the most sensitive and vulnerable sector to climate change induced impacts. This is because the limitation of water and land resources where most of the country's land is arid (JSNC, 2009). In spite of most of agricultural areas in Jordan are rain-fed, this sector utilizes about two-third of the available water resources. Water resources are vulnerable to climate change due mainly to changes in precipitation and its distribution both spatially and temporarily.

Livestock production occupies more than 50% of agricultural activities and production in Jordan ,the demand for livestock products is expected to increase dramatically in the first half of this century, due to the increase in population which going to the expected of around 7.0 million and to the increase in affluence of the society .

Food supply and cost are emerging factors that will affect food security, which is of highest priority in Jordan. Animal production plays a key role in food security.

The goal of agricultural adaptation to climate change is to maintain agricultural production in Jordan. The Third Assessment Report (TAR; IPCC, 2001) defines climate change, impacts and adaptation as following:

- **Climate change** refers to "any change in climate over time, whether due to natural variability or as a result of human activities";
- **Impacts** are the "consequences of climate change on natural and human systems"; and
- **Adaptation** is the adjustment to a new or altered environment such as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects. It refers to decisions people make to moderate harms or exploit beneficial opportunities of the change, i.e., climate change.

Thus, along with impacts of climate change, there are practical actions that can be taken to anticipate, prevent, reduce or mitigate undesired impacts or to take advantage of desirable ones.

The IPCC (2001) lists two reasons for adaptation to be important in the climate change issue:

First, an understanding of expected adaptation is fundamental in evaluating the risks of climate change;

Second, adaptation is a key response option or strategy, along with mitigation. However, even with reductions in greenhouse gas emissions, some climate change is regarded as inevitable, and it will be necessary to develop planned adaptation strategies to deal with the associated risks as a complement to mitigation actions.

Adaptation largely depends on adaptability, that is, the capacity to adapt the relevant systems to their exposure to the change. For example, progressive farmers stated that they can adapt to shortages of water if better quality water are made available to them. They can cope with lower quality of water if provided with enough quantity of water, and to be allowed to organize themselves in an independent cooperative to treat or modify the quality of water[38]. In a literature assessment, Smit et al. (2001) concluded that enhanced adaptive capacity would reduce vulnerability to climate change. In their view, activities that enhance adaptive capacity are essentially equivalent to activities that promote sustainable development.

Adaptation to climate change has the potential to substantially reduce many of the adverse impacts of climate change and enhance beneficial impacts. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and farm level (autonomous adaptation) and at decision-maker level (planned adaptation). The following adaptation options are examples of adaptations that will have to be evaluated if adaptation measures are to be taken. **Table 20 presents** a summary of climate change impacts and possible adaptations to be evaluated.

However, to fulfill the required scope of work, Al Shamil Engineering carried out the activities below as mentioned in the scope of work of the RFP. Adaptation measures tests are shown in appendix (2).

[38] Focus Group Interview with progressive farmers in the United Farms Society at the Jordan Valley on October 20, 2010. Participants were the agricultural engineers; Hasan Abu Seedo, Saleh Al-Yaseen, Hasan Barghoti, Hasan Rouka, Dr. Fuad Salame, Khalil Abu Ghannan, Hasan Zahran, Omar Abdul Aziz, and Nabeel Al-Tagi,

6.1 Needed Adaptation Measures for Food Productivity in Jordan

6.1.1 Needed Agricultural Adaptation Measures in Jordan

Future changes in agricultural production will not only depend on the magnitude of changes in climatic variables, but also on how well agriculture can adapt to these changes. Adaptation will play a key role in determining the economic and social costs of climate change. The IPCC AR4 (IPCC, 2007) reviews how adaptation can reduce the adverse impacts of climate change.
A large number of studies have examined the consequences of agronomic adaptation. Research is needed to assess the effectiveness of different adaptation strategies. Differing scenarios of population growth and economic development will affect the level of future climate change as well as the responses of agriculture to changing climate conditions.

The following sections will discuss the possible means of adaptation to adjust to the impact of climate change in Jordan. It must be stressed that these adaptations measures present a win-win situation, and thus they are appropriate even under no climate change impact considering that Jordan is characterized by low rainfall amounts (50 mm to 600 mm annually) and has limited renewable water resources.

A significant effect of global climate change is the increases in temperature and altering of global rainfall patterns, with certain effects on agriculture. High temperature, particularly during critical crop growth periods, can speed plant development and reduce yields. Extended drought can cause the failure of small and marginal farms with resultant economic, political and social disruption. Along with impacts of climate change, there are adaptation measures at farm level that can be taken to adapt to the harmful impacts or to benefit from of positive ones. These adaptation measures include improved farming practices, agro-technological advances, improvement of water use efficiency, implementation of water harvesting techniques, supplemental irrigation with treated wastewater, community-based conservation agriculture and management of rangeland resources.

6.1.1.1 Adaptation of Rain-fed Agriculture

Rain-fed agriculture is strongly influenced by the availability of water. Climate change will modify rainfall, evaporation, runoff, and soil moisture storage. Changes in total seasonal precipitation or in its pattern of variability are both important. The occurrence of moisture stress during flowering, pollination, and grain-filling is harmful to most crops. Increased evaporation from the soil and accelerated transpiration in the plants themselves will cause moisture stress. The First Assessment Report of the UNFCCC showed that all rainfed crops were adversely affected by projected temperature increase and rainfall decrease. Results, however, would not be necessarily accurate, as crop yield prediction was carried out by applying simple production functions that consider one factor at a time.

In Jordan, wheat is the main rainfed field crop in areas that receive more than 350 mm, while barley is cultivated in areas where rainfall is between 100 and 350 mm. Both of wheat and barley are important for many local farmers for direct consumption and as a feed for their livestock.

Any increase in temperature was expected to reduce the length of the growing season as a whole, as well as the grain filling period. Shortening the growing season would reduce the crop water requirements and that should reduce the water stress under rainfed conditions.

Higher temperatures could decrease yields by decreasing the duration of the grain-filling period or shorten the vegetative stage of annual crops. However, the reduction of grain filling period had a negative impact on grain yield because it would result in smaller grains resulting in reduction of total yield. Decreases in cover by vegetation or annual or perennial crops, caused by declines in rainfall could lead to soil structure degradation, as well as increased runoff and erosion on sloping sites and by the concomitant more extensive and rapid sedimentation.

As a result, there will be a need to develop general and specific measures to adapt to the impacts of drought prone situation. Adaptation of agricultural techniques will be central to limit potential damages under climate change. These include the following:

- **Land-use management**: aiming to conserve fertile and high precipitation lands for rainfed agriculture.
- **Effective water use**: adopting supplementary irrigation in dry seasons or during heat waves.
    - **Reducing need for water**: by choosing drought tolerant species and varieties especially in fruit trees.
    - **Water conservation measures**: developing easy, low cost and practical mulch methods for rainfed fruit trees .
    - **Development of a national drought management strategy**. and
    - Use of drought tolerant crop varieties, the NCARE has ongoing research activities to find out drought tolerant barley and wheat varieties, using the participatory approach[39]. A farmer in Madaba[40], Jordan stated that his yield of barley in 2010 was more than 400 kg per dunum, although the rainy season stopped too early in March. This demonstrates that by good farming practices and drought resistant varieties, adverse effects of climate change may be overcome or mitigated;
    - Use of heat tolerant crop varieties, the NCARE has an ongoing research project to find out heat resistant wheat varieties in Maru, Irbid and Ghor Al-Safi[41];
- **Modification of sowing dates:** Delaying seeding time in response to delayed winter rains.
    - Change of crop cultivars;
    - Shifts in crops production areas; and
    - Adopting the "Conservation Agriculture (CA)" approach.

According to the FAO, key elements in this approach are the following: minimum mechanical soil disturbance which is essential to maintaining minerals within the soil, stopping erosion, and preventing water loss from occurring within the soil; managing the top soil to create a permanent organic soil cover can allow for growth of organisms within the soil structure; and the practice of crop rotation with more than two crop species (Wikipedia, CA, 2010). The NCARE carried a research project to apply the CA principles among wheat growers in Irbid, Madaba and Karak[42]. The case of the farmer in Madaba presented above has adopted this approach.

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[39] Researcher Nawal Hagag of the NCARE.

[40] Shawqi Qaradshi, personal interview, October 25, 2010.

[41] Research coordinator Fadel Ismil of the NCARE in cooperation with the University of Jordan and the Royal Scientific Society.

[42] Dr. Yahia Shakhatreh, NCARE.

6.1.1.1.1 Water Harvesting

Rainfall in arid and semi-arid areas constitutes a major resource, but it is partly or completely lost through direct evaporation or through uncontrolled runoff. Only a small fraction of the rainfall falling in arid areas percolates into deeper soil or rock layers to recharge an aquifer. Another small fraction is used for transpiration of vegetation or of agricultural crops. The majority of the precipitation evaporates from the often bare soil or from surface depressions.

With climate change, the water situation is more "precarious". Rainfall without intervention is of little use in these areas. Adaptive measures include water harvesting, innovative land-use practices, adoption of new technologies, and economic diversification. If agricultural production and livelihoods are to be sustained, even at current levels, increasing the productivity of water in agriculture in dry areas becomes a crucial issue that is to produce more with less water and lower quality. Economic agricultural production can be achieved by concentrating the water into smaller areas through water harvesting techniques. Hence, water harvesting supports agriculture in many water-stressed areas, where rainfall is low and erratic in distribution. Water harvesting systems make water available to supplement rainfall for winter crops and as a sole source of water for summer crops, especially when supplemental irrigation is important.

Water harvesting is the process of diverting, collecting, and storing rainwater from surface runoff and effectively using the water for beneficial purposes. Rainfall, although low in annual average, when multiplied by the vast areas amounts to a large volume of water. Thus, water harvesting aims at concentrating rainfall as runoff from a larger area for use in a smaller target area to be used for the irrigation of crops, pastures, trees, for livestock consumption and for household purposes.

Different indigenous techniques and systems were developed in different parts of the world. These techniques comprise water and soil moisture control at a very simple level, often involving the placement of a rigid row of rocks or stone terraces along the contours of slopes for capturing the surface runoff and trapping the silt.

Water harvesting is generally feasible in areas with an average annual rainfall of at least 100 mm in winter rains. It is practiced in arid and semiarid regions and requires a runoff producing area, runoff collection scheme and a runoff receiving area. Water may be stored directly in the soil profile or in small reservoirs or dams, excavated cisterns, tanks, and aquifers. The higher the aridity of an area, the larger is the required catchment area in relation to the cropping area for the same water yield.

For agricultural purposes, two major types of water harvesting may be distinguished, rainwater and floodwater harvesting:

① Rainwater harvesting is defined as a method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions. There are two major groups of techniques of rainwater harvesting:

- Micro-catchment water harvesting (micro basins or contour strips) is a method of collecting surface runoff from a small catchment area and storing it in the root zone of an adjacent infiltration basin by applying flood water spreading systems. The basin is planted with a tree, or with annual crops or rangeland improvement. Crops grown under micro catchment water would be more viable and than any of the traditional methods; and
- Macro-catchment water harvesting for utilizing the runoff from a nearby slope to convey water for agricultural purposes (with or without interim storage).

② Flood water harvesting (large catchment water harvesting) may be classified into the following two forms:

- Floodwater harvesting within stream bed: the water flow is dammed, and as a result, saturates the valley bottom of the flood plain. The water is forced to infiltrate and the wetted area can be used for agriculture or pasture improvement. The Marab belongs to this group; and
- Floodwater diversion by forcing the stream water to leave its natural course and conveyed it to nearby cropping fields.

Water harvesting systems have been successfully utilized in Jordan and in some parts of the world where water shortage exists. However, the application of water harvesting techniques has some requirement:

- They need different geographic settings to be implemented. Besides the topography, the runoff conditions of the surface, the infiltration rates, and the soil types of the run-on areas, the depth of the soil layer in the cropping areas and plant location and watering requirements are among the most important natural parameters for the implementation of any water harvesting system;
- Select plants based on rainwater capture/storage potentials and on the amount of water they require throughout the year;
- Local approaches and indigenous experiences have to be encouraged as they may be applied easily at both village and household levels. Successful water harvesting projects are often based on farmers' experience and trial and error rather than on scientifically well established techniques, and can therefore not be reproduced easily. Agricultural extension services have often limited experience with it and have to be trained;
- Socio-economic factors have to be taken into due consideration. Traditional rules on the water and land rights influence the development of the water-harvesting activities strongly. Use of additional rainwater from rainwater harvesting techniques will affect water users downstream that may rely on the same water supply for their crop production; and
- As most farmers or herders practicing water harvesting are resource-poor, some intervention of state authorities is needed, e.g. financing the construction of small reservoirs.

The above mentioned water harvesting techniques have the advantage to increase the amount of water available for agricultural and other purposes, and to ease water scarcity in arid and semi-arid areas. They have the potential to increase the productivity of field crops and fruit tree planting and grazing land by increasing the yields and by reducing the risk of crop failure. They require relatively low input and, if planned and managed properly, can contribute to the sustainable use of the precious resource water. They are relatively cheap to implement and can therefore be a viable alternative where irrigation water from other sources is lacking.

A well trained state supported extension service is a must, if new tools shall be successfully applied. Training is essential to strengthen the technical capacity of field staff on basic principles and practical aspects of different types of water harvesting projects. Only, well established methods of water harvesting have to be used. Further research and experimentation is still required before a certain method can be recommended. Scientific research should then be carried out in collaboration with farmers.

6.1.1.1.2 Land Resources

Although the agricultural land resources and forests are already limited in Jordan they are not entirely used, especially in rain fed agricultural areas. To increase the production, it is necessary to increase planted land resources. More efforts are required in this sector; this is a socioeconomic and environmental issue. The most required adaptation measures regarding land resources, which are very important input for the agricultural productivity includes the followings:

6.1.1.1.2.1 Land Development Projects

The Impact of Agricultural Land Resources Projects in Conserving Soil Using GIS of semi arid and sub-humid regions of Jordan where the agricultural resources projects are working on forming about 0.87 million ha of farmland, grazing, and forest areas. Water erosion is a serious problem on these lands mainly due to land mismanagement. Particularly On the projects area, conventional farming practices increases water erosion. To assess the damage caused by water erosion in the area, the Universal Soil Loss Equation (USLE) was used to predict the annual soil loss of a representative area of about 108 ha in Balqa district before and after the projects activities talk place. From soil survey reports, site information, land capability, erosion hazard, existing and future land use were then compiled in a soil base map for the area. The map consists of six themes; four of it characterizes the soil loss before and after constructing soil conservation structures (SCS), ten and twenty years later using universal soil loss equation. Before constructing SCS about 32%, 7%, 61% of total area has slight, moderate and high water erosion respectively. Twenty years later (after constructing SCS and 25% tree coverage) about 58%, 34%, 8% of the total land area becomes slight, moderate and high water erosion respectively.

The Highlands zone constitutes an almost a distinct ecosystem. Although it represents only 10% of the country's total area, it is the most populated as more than 90% of the population lives there. By the same token, most of the cultivable area (90%) lies in this area. However, only 50% of this cultivable area (0.25 million ha) is cropped each year and agricultural activities are basically under rain-fed farming. Most of the cultivable land (about two thirds) is largely mountainous, with more than two thirds of it with slope over than 9% (World Bank 1990).

The amount of rainfall in the highland increases with altitude from east to west, and decreases from north to south. Thus, eastern and southern regions are largely marginal and arid. Given the overall semi-aridity of Jordan, about 92% of the highly fluctuating rainfall is lost to evaporation. Water scarcity is considered to be the most threatening constraint to sustainable development. Natural water shortages are further aggravated by the successive years of severe drought in the last two decades, and lack of sufficient resources to optimize water harvest efficiency.

Moderately mountainous lands are best suited to fruit trees, and normally are accompanied by a soil conservation measures. This makes tilling along the contour lines a must. The roots hold the soil and the green foliage of the permanent vegetation cover reduces the intensity of rain. Thus soil movement will be effectively restrained, and soil capacity to hold moisture will be enhanced. With the limited land resource base, protecting soil from erosion is of utmost importance.

Soil erosion occurs primarily on areas with steep grades, mountain slopes and hillsides. Much of Jordan's land area is prone to soil erosion. Thus, soil conservation and moisture conservation and water harvesting measures are important adaptation measures. A number of measures were introduced to promote water harvesting. These include construction of cisterns as a source of supplementary irrigation in the frequent dry periods and low rainfall areas (including a runoff collection system), contour earth banks (gradoni lines), bench terraces with a ridge to conserve water, stone and earth crescents to promote the early establishment of trees by conserving water in the root zone and more recently absorption contour earth terraces (banks).

The government of Jordan has long viewed highland development as an effective adaptation strategy for stabilizing rain-fed farming systems through implementing land development projects. These projects were basically designed to achieve more proper management of the limited natural resources, soil, water, forests and rangeland. Thus, the general objectives were to conserve soil and moisture, planting fruit trees in the private land (with slopes between 9-25), to plant forest trees in the public land and to develop rangeland to promote meat and dairy production. The Highland Development Project (HDP) experiences have influenced the way resources at the national level are allocated and spent on these efforts.

Under the HDP, in cooperation with the UN World Food Program (WFP), land developments activities for fruit trees production have been conducted in more than 50000 ha. The positive outcomes of the HDP are self-evident throughout the mountainous areas in Jordan. The local environment has started to recover and stabilize. Improved soil conditions and moisture conservation have led to observable changes in the landscape. Previously barren hills are now covered with vegetation. Rehabilitated watershed ecosystems have boosted and diversified agricultural production, thereby securing food supplies and livelihoods and communities have an increased resilience to drought. In 2009, more than one third of the cultivated area is under fruit trees, and olives constitute about three fourth of the fruit area, and this is largely under rain-fed farming (> 75%) (DOS, 2010). The largest area under fruit trees (olives, grapes, stone fruits) were developed under the HDP of the Ministry of Agriculture and WFP support and similar projects.

Rain-fed agriculture will maintain an important role in the growth of food production in the future. Water harvesting expands the productive asset base of the poor, and has the potential to improve rain-fed crop yields, increase the degree of crop–livestock integration, and can buffer risks related to rainfall variability due to climate change and frequent crop failure. This helps to reduce poverty, increase household food and income security and improve nutrition for the poor. The conservation of soil moisture (reduce drought stress and irrigation requirements) and introduction of moisture conserving tillage methods (minimum tillage, conservation tillage, stubble mulching etc.). The experiences in Jordan have demonstrated that the resilience of dry land communities can be successfully built through a wide range of ecosystem management and restoration activities, enabling them to better cope with climate-induced stresses such as drought.

6.1.1.1.2.2 Improving and extending dry land farming

Jordan government encourages farmers in this field but this should be enforced. Farmers need some specific machinery to help in stone collection and help building steeps without soil compaction.

6.1.1.1.2.3 Lease government lands

Jordan has a potential government land, where there are land that could be used for leasing the indigenous farmers to cultivate such lands that benefit both the government and the unemployment man power.

6.1.1.1.2.4 Enhance new land reclamation and productivity

To increase the agricultural productivity as the land , is an important input for improving in such regard, which is applicable in the lands of south of karama and Suwimeh in the Jordan valley where as well as the brackish water and saline soil, reclamation and good management practices for improving or increase the food productivity. However, Use of the land according to its productivity, Jordan has four climatic zones and many types of soil where it should be considered for crop selection to maximize benefits e.g. stone fruits required calcareous soil and moderate rain.

However, the adaptation measures related to rainfed agriculture could be divided to short term and long term measures as follows:

☒ **Short term**

- Use alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies;
- Delaying seeding time in response to delayed winter rain;
- Modification of sowing dates;
- Shifts in crops production areas;
- Use of crop varieties with greater drought tolerance and change of crop cultivars; and
- Greater opportunism in planting rules and planting decisions (e.g. time of sowing, seeding rates, row spacing, tactical applications of nitrogenous fertilizers)

☒ **Long term**

- Developing varieties with greater drought tolerance, heat shock tolerance, resistance to flower abortion in hot/windy conditions and resistance to new or more virulent pests and diseases; and
- Support dry land farming for winter and low water requirement crops.

6.1.1.2 Adaptation of Irrigated Agriculture

Irrigated agriculture depends on the availability of water, temperature and extreme weather conditions. These adaptations are appropriate even with no climate change, but, their implementations are more imminent to cope with climate change impacts. Higher temperature may result in substantial yield decreases because of the sensitivity of flowering and seed set to high temperatures in addition to short fruit growth stage which results in smaller fruits and the possibility of water stress that may result from increased evapotranspiration.

☒ **The short-term adjustments** to climate change as a first defense tools to optimize production with minor system changes are through the management of cropping systems to reduce yield variability. Short-term adjustments include the following:

- **Developing early warning systems:** that provide daily weather predictions and seasonal forecasts
- **Introducing varieties with greater stress tolerance:** drought tolerance, heat shock tolerance, resistance to flower abortion in hot/windy conditions, resistance to new or more virulent pests and diseases

Emergency planning and awareness-raising;

- Diversify crop types and varieties, e.g., different thermal requirements and crop substitution, to address the environmental variations and economic risks associated with climate change;
- Change the intensification of production to address the environmental variations and economic risks associated with climate change;
- Changes in agronomic practices e.g., sowing and planting dates;
- Changes in fertilizer and pesticide: Use Optimal and responsible use management of inputs.

- Adopting practices which conserve heat in green or plastic houses in case of frost conditions. The NCARE has a project to evaluate and compare the productivity of green pepper with and without using heating units in the green houses[43]. Farmers in the Jordan Valley used thermal plastic to protect their crops under green houses. With this cover, temperature was 6 degrees higher inside the house[44];
- Adoption of new tools for crop selection such as climate seasonal forecasts
- Soil management such no or proper tillage, or use of alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies. Mixing plant residues with the top soil with continuous moisturizing generates enough heat to eliminate or inhibit the growth of weeds, sterilizes the soil and improves the soil characteristics. Organic materials give far more lasting improvements in soil structure[45].

☒ **<u>The long-term adaptation</u>** to climate change would include the following:

- Revised water and investment policies. More spending on irrigation will be needed with projected increases in the demand for water for irrigation in a warmer climate, bringing increased competition between agriculture (already the largest consumer of water resources in semi-arid regions) and urban as well as industrial users. Falling water tables and the resulting increase in the energy needed to pump water will make the practice of irrigation more expensive, particularly when with drier conditions more water will be required per ha;
- Improved management of irrigation with respect to amount and efficiency. There are agronomic and crop adaptations that are complementary defense tools to optimize production via larger structural system changes;
- Develop farm-level resource management innovations to address the risk associated with changing temperature, moisture and other relevant climatic conditions. **These include:**
    - Develop new crop varieties, including hybrids, to increase the tolerance and suitability of plants to temperature, moisture and other relevant climatic conditions. These include development of "designer-cultivars" to rapidly adapt to climate change stresses (heat, water, pest and disease, etc.)[46]. Promising results are emerging from genetic experiments in the University of Jordan (supported by Hamdi Mango Center for Scientific Research) to generate drought, selected strains of viruses and salinity resistant varieties of two important crops;

[43] Dr Mueen Qaruti and Saad Al-Awamleh of the NCARE
[44] Hassan Abu Seedo, a farmer in the Jordan Valley.
45 Dr. Ayman Sulieman, Faculty of Agriclture, University of Jordan.
[46] Hassan Abu Seedo, a progressive farmer in the Jordan Valley.

tomatoes and barely[47]. Other activities include partial budgeting for growing salinity resistant varieties of fodder crops in Zarqa governorate[48]. Varieties resistant to pest and diseases are available to most crops in the market[49]. Soil Solarization controls a wide range of soil- borne fungi, weed seeds, and nematodes in fields. Thus it can contribute to the control of pest infections due to climate change[50]. Soil that has been solarized allows plants to draw on the nutrients, especially nitrogen, calcium, and magnesium more readily. In solarized soils, crop seeds germinate quickly and grow faster, with substantial increased yields. Thus, with proper research and development and extension services, adaptive capacity of the farmers to climate change to the risk of pest infections can be enhanced.

- Testing the growth and productivity of selected crops (peppers) in a saline soil with varied levels of water requirements in the Jordan Valley (Karameh Station)[51]
    - Changes in land allocation to optimize or stabilize production.
    - Crop substitution to conserve soil moisture (e.g. barley is more tolerant of hot and dry conditions than wheat).
    - Microclimate modification to improve water use efficiency in agriculture (e.g. windbreaks, intercropping, multi-cropping techniques).
    - Changes in nutrient management to reflect the modified growth and yield of crops.
- Prioritization of water use; restricted water abstraction for appointed uses
- Introduction or strengthening of a sustainable groundwater management strategy;
- Identification and evaluation of alternative strategic water resources (surface and groundwater);
- Identification and evaluation of alternative technological solutions (cost effective ways for desalinization; reuse of wastewater);
- Restrictions for water abstraction for appointed uses;
- Increase of storage capacity (for surface and ground waters) both natural and artificial;
- Enlarging the availability of water whenever it is feasible (e.g. increase of reservoir capacity);
- Considering additional water supply infrastructure, i.e., installation of irrigation;
- Water saving (e.g. permit systems for water users, education and awareness-raising);
- Fostering water efficient technologies and practices (e.g. irrigation);
- Agro-technological advances;
- Introducing new crops with lower water requirements;

47 Dr. Ayed Abdeallat, Faculty of Agriclture, University of Jordan.
48 Dr. Misanat Hiari of the NCARE
49 Hassan Abu Seedo, a farmer in the Jordan Valley.
50 Dr. Fuad Salmeh, , a farmer in the Jordan Valley.
51 Dr. Seren Naoum, Dr. Mueen Qaruti and others of the NCARE.

- Testing productivity of crops with less than the water requirements. NCARE is experimenting the productivity of one cubic meter of water for tomatoes and peppers that are grown under green houses technology in Maraq and Ghore Al-Safi (using 80% and 90% of water requirements)[52]. Similar experiments were carried out to promote water efficiency to identify the minimum quantity of water to be used for irrigating Superior Seedless Grapes;
- Joint operation of water supply and water management networks or building of new networks;
- Shifts in the planting date;
- Modification of fertilizer application;
- Optimization of water and nitrogen management;
- Search for germplasms that are adapted to higher day and night temperatures, and incorporate those traits into desirable crop production cultivars to improve flowering and seed set;
- Change planting dates and other crop management procedures to optimize yields under climatic changes, and select cultivars that are adapted to these changed conditions; and
- Shift to species that have more stable production under high temperatures or drought.

Since the 1980s Jordan's government has supported research in agricultural technology, including the development of new wheat crop varieties with better harvest indices, and insect and pathogen resistant crops. Efforts have also been made to preserve genetic diversity.

More focus on research should be directed to the extension of the grain-filling period and shortening the duration of vegetative growth; ability to flower and set seed at higher temperatures; and capability of utilizing photo-assimilates more effectively.

6.1.1.3 General Agronomic and Crop Adaptations

- Altering the timing or location of cropping activities; can be applied widely on rain fed field crops;
- Improving the effectiveness of pest, disease and weed management practices through wider use of integrated pest and pathogen management;
- Use alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies;
- Adopt crop rotation systems in both rain fed and irrigated farming; adoption of crop rotation is very important to Jordan agriculture mainly under rain fed conditions for sustainable production;
- Soil management such no or minimum tillage, or use of alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies. Mixing plant residues with the top soil of continuous moisturizing generates enough heat to eliminate or inhibit the growth of weeds, sterilizes the soil and improves the soil characteristics. Organic material gives far more lasting improvements in soil structure[53];
- Implement irrigation practices to address the moisture deficiencies associated with climate change and reduce the risk of income loss due to recurring drought;

[52] Dr. Seren Naoum, in cooperation with Dr. Mueen Qaruti and others of the NCARE.
53 Dr. Ayman Sulieman, Faculty of Agriclture, University of Jordan.

- Supplementary irrigation for rain fed fruit trees orchards, which is very important in dry seasons to assure maintenance and yield for rain fed fruit trees orchards;
- Change timing of farm operations to address the changing duration of growing seasons and associated changes in temperature and moisture;
- Greater opportunities for planting rules and planting decisions (e.g. time of sowing, seeding rates, row spacing, tactical applications of nitrogenous fertilizers); optimal use of inputs will increase crop production efficiency;
- Better strategies on crop selection and planting will buffer adverse effects; crop type and variety is directly related to climatic conditions;
- Diversifying income by integrating other farming activities such as livestock raising, this measure is the most applicable and suitable for small holdings of family farming especially in villages;
- Crops are planted late or harvested early, and are partially stored for use during exceptionally severe periods of drought or cold;
- Heat tolerant varieties of crops are obtained through technology transfer or genetic selection and applied research[54];
- Farm operators plant a mixture of crops to protect against climate extremes and thereby avoid the possible loss of a single weather-sensitive crop;
- Use of thermal plastic to protect against climate extremes and thereby avoid the possible loss of a single weather-sensitive crop;
- Adaptation of farming practices (planting and harvesting timing);
- Improved water management i.e., water requirement starting with major water consuming crops in terms of area or type of crops; and
- Better strategies on crop selection and planting will buffer adverse effects.

6.1.1.3.1 Cropping Pattern

In spite of poor natural resources, cropping pattern in Jordan requires maximizing and benefiting more from these resources. The actual cropping pattern is rich in vegetables and fruits production while it is poor in field crops production, especially through irrigated lands, vegetables cover about half of irrigated lands. There is a shortage in field crops. This leads to low prices in vegetables. (MoA Yearly report 2007).

Agriculture sector is flexible, there is a wide range of plants to be used in different climatic conditions, and this leads to many alternatives related to climatic conditions.

Programmed cropping pattern, considering the food security in a certain grade (e.g. 70%) and covering this value is necessary to reduce the gap between production and demand at least each 4-5 years concerning drought conditions.

Programmed cropping pattern requires the following:

- Select drought resistance crops, as wheat, olives and barley;
- Concentrate on winter crops for vegetables specially in the Jordan valley and minimize summer season to reduce crop water requirement;

[54] A private company is experimenting heat tolerant tomatoes in the Jordan Valley (A personal interview with Mr. Saleh Al-Yaseen in October 20, 2010). Similarly, Dr. Muhannad Al-Akash of the University of Jordan supervised an MSc research work to develop genetically heat resistant tomatoes.

- Limit the production of high water requirement crops for local consumption only;
- Select efficient water use crops, e.g. potato is highly efficient crop, its production and nutrition value is high and water requirement is low, Jordan still imports about 50000 tons of potato/yr (MoA2007);
- Use the different climate regions in Jordan properly;
- Increase fruit crops on dry farming system and stop this activity on irrigated lands;
- Increase field crops in irrigated lands to cover the required self sufficiency integrated with marginal water as Brackish water; and
- Proper use of water in agriculture in the most important crops.

However, cropping pattern is affected by water quality. Marginal water reveals different cropping patterns. It may be used in forestry and forages and to grow tolerant crops as sugar beet, dates and guava. This is suitable in Swaimeh area south of Shuneh, near the Dead Sea, where there is brackish ground water that could irrigate about 20 thousand donums.

6.1.1.3.2 Improving on farm management

The improving of the on farm management includes:

- Long growing season will increase total yield for many crops and changing the timing of cropping activities will help in introducing new crops and improves directly crop yield and productivity;
- Modification seeding or sowing time in response to delayed winter rains;
- Change of crop cultivars. Shifts in crops production areas, Crop rotation will improve soil fertility and control of soil born diseases, as a consequence increase crop yield;
- Adopt crop rotation systems in both rain fed and irrigated farming, is very important because this will maintain soil fertility and reduce the harmful impact of soil born pests, beside the efficient use of available water;
- Adoption of crop rotation is very important to Jordan agriculture mainly This measure is the most applicable and suitable for small holdings of family farming especially in villages under rain fed conditions for sustainable production;
- Adaptation of farming practices of rain fed and irrigated Agriculture;
- Development of a drought management plan;
- Delaying planting date of field crops until the amount of soil moisture will be enough for seed emergence and development in early stages. While irrigated vegetables depend on the availability of irrigation water which is the most limiting factor, therefore this kind of farming will be established in the location of water availability;
- Improving the effectiveness of pest, disease and weed management practices through wider use of integrated pest and pathogen management, which is very important to

improve production efficiency, and it is a dynamic process that depends on active research and reliable extension services, this could have great positive effect on production efficiency;

- Altering the timing or location of cropping activities will be applicable in case of rain fed field crops and irrigated vegetables;
- Delaying planting date of field crops until the amount of soil moisture will be enough for seed emergence and development in early stages. While irrigated vegetables depend on the availability of irrigation water which is the most limiting factor, this can be applied widely on rain fed field crops;
- Use alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies, conservation agriculture is started to be applied in many regions of rainfed farming of field crops in Jordan which is the most suitable for wheat and barley and some legumes, conservation agriculture system with the same amount of rain;
- Diversifying income by integrating other farming activities such as livestock raising is the most applicable and suitable for small holdings of family farming especially in villages. Family farming is the most efficient measure to cure poverty, internal emigration and unemployment;
- Use plastic houses and tunnels, decrease water requirements for unit of production , (via water use associations and local communities); and
- Develop water management innovations, including irrigation, to address the risk of moisture deficiencies and increasing frequency of drought. This measure will maximize the productivity of each cubic meter of irrigation water in either returns or crop production which will improve the efficiency of irrigation water .The potential of such measure depends on research and extension institutions, this is a time consuming.

6.1.1.3.3 Crop Adaptation measures to be adopted by the government

- Maintaining or improving quarantine capabilities, and sentinel monitoring programs;
- Modify subsidy, support and incentive programs to influence farm-level production practices and financial management;
- Development of water use efficiency strategies to manage potentially lower irrigation water availabilities;
- Policy and legislation for climate change with concentration on irrigated agriculture; and
- Develop and implement bylaws for Agricultural Risks Fund to influence farm-level risk management strategies with respect to climate-related loss of crop yield.

6.1.1.4 Adaptation Measures Related to Water Resources

Water in Jordan is critically scarce, rural people traditionally use water harvesting techniques. For thousands of years, farmers have literally harvested rainwater by collecting runoff from roofs and ground surfaces and by spreading or diverting floods, Jordan is a master on water harvesting all through centuries.

Many actions taken to adapt to water shortage, these actions could be considered as climate change adaptation actions, but more efforts required in this field.

Since the sixties Jordan started to govern water resources mainly for agriculture development, but in the eighties, it was necessary to transfer irrigation water to municipal water as a result of sudden over population due to the fluxes of migration. However, the following are actions taken as a result of water shortage. However, Jordan had been practiced using previous adaptation measures including the following previous adaptation measures:

6.1.1.4.1 Previous Adaptation Measures

Concerning the infrastructure, Jordan had implemented the following:

6.1.1.4.1.1 King Abdulla Canal (KAC)

This canal irrigates about 360 thousand donums north of the Dead sea in the Jordan Valley. KAC is the main water conveyer for irrigation and drinking water. To transfer and distribute the water of this canal , the following systems were construct:

- **Transfer and distribute irrigation water**
  Most conveyance systems are closed and most farmers use drip irrigation.
- **Automatic Control of KAC**
  It allows the automatic control of 28 out of the 38 check gates across KAC from the control center.

6.1.1.4.1.2 Dams

Jordan established several dams along main wadies all through Jordan, especially Jordan Valley. Total water storages impoundments of the water harvesting facilities in Jordan have reached 327 million cubic meter (MCM) as Dams.

6.1.1.4.1.3 Water harvesting in the soil

Dry land conservation and water harvesting as wadi Zarqa and Yarmouk basins development projects, and develop high lands projects in general and increasing rain fed agriculture specially tree crops as olives.

6.1.1.4.1.4 Treated Wastewater (TWW)

TWW is accounted for in the Kingdom's Water Budget. In 2003, a 76 MCM was produced from 19 domestic wastewater treatment plants distributed all over the country.

6.1.1.4.1.5 Farmers participation

Formal Water Users Communities (WUCs) could facilitate the relation between JVA and farmers. This could facilitate the relation between government and farmers.

6.1.1.4.2 Suggested Adaption Measures for Water Sector

The following required adaptation measures could be approached to cope with the risk of climate change impacts:

- Water demand management;
- Finding additional water sources (desalination and wastewater reuse). NCARE is experimenting the treatment and use of grey water for home gardens in a number of villages in Madaba[55]. Similar experiments were undertaken in Balqa, Ramtha, Karak, Tafila and Maan[56] and the Jordan Valley[57];
- Saving water by changing gardens plants to use plants which require less water;
- Water conservation and generation of additional water sources (treating and recycling wastewater and desalination using more cost effective methods). These measures are already adopted to counter the mounting water scarcity in Jordan. A number of research works are carried out to test the effects of varied levels of treated water on the growth and productivity of sunflower plants in Ramtha Station, and on the chemical characteristics of the soil[58]. Similar ongoing research activities are undertaken in Ramtha to test different filtration methods and use of treated water for feed crops[59] ; and to test varied fertilizers levels on Lilium flowers[60];
- Water harvesting in rain-fed areas. NCARE is experimenting water harvesting activities for rangeland development and for supporting forest trees;
- Preventing deep percolation of irrigated water, by increasing the number of times and reducing the quantity of water to strike a balance between the plant requirements and the field capacity of irrigated water[61];
- More cost effective use of water for irrigation. Abu Seedo, a progressive farmer in the Jordan Valley stated that: we can cope of shortage of water if we are provided with good quality of water. Abu Ghannam[62], another farmer in the Jordan Valley, said we have to find out cost effective way to clean water. A fully independent farmer society was suggested to help in solving the quality of water cooperatively;
- Improving management such as maintenance and use of close system for distribution of water for irrigation;
- Discouraging the growing of high water demanding crops through imposing higher prices for water (MOWI, 2009); and
- Rainwater storage in appropriate areas, given that, with the expected reduction of at least 25% in water availability by the end of the 21st century (MOEP, 2009), construction of additional dams and reservoirs might not serve as effective adaptive measures against increased uncertainties and frequency of extreme climatic events.

6.1.1.5 Adaptation measures related to livestock

6.1.1.5.1 Adaptation measures for Livestock production

Livestock is affected directly by the changes in temperature and indirectly by the productivity of the rangeland and cereals fields. The major sources of feed for sheep

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55 Dr. Esmat Karadsheh and others of the NCARE. Thirteen units for water treatment were installed, and these sites were used for training researchers in the West Bank and Lebanon.

56 Researcher Abeer Balawneh and others of the NCARE.

57 Dr. Yaseen Al-Zouby, Balqa University and others in the NCARE.

58 Researcher Hamza Rawashdeh and others of the NCARE.

59 Researcher Luna Hadidi and others of the NCARE.

60 Researcher Saeed Zuraki and others of the NCARE.

61 Dr. Ayman Sulieman, Faculty of Agriclture, University of Jordan.

62 Hassn Abu Seedo and Khalil abu Ghannam are progressive farmers in the Jordan Valley.

and goat flocks in Jordan are: native grazing, immature (green) barley, cereal and vegetable crop resident.

The grazing of the steppe and desert ranges are a common resource for grazing purpose. This communal grazing prevented conservation of the range and caused low forge production and reduction of palatable perennial vegetable leaving the unpalatable ones.

The most critical period in the feeding cycle of ewes and goats is in the autumn/ winter feeding because the animals are pregnant or lactating and has high requirement and when there is no grasses in the ranges and the range and the residues are overgrazed.

Adaptation measures related to Livestock production as Production Adjustment, Breeding, New management system and Support Extension and research centers.

6.1.1.5.1.1 Production Adjustment

- Diversification and integration of fodder production;
- Incentive and subsidy programs to prevent the collapse of animal production in drought condition;
- Conservation and protecting the range;
- Change the management of grazing, destocking and routing movement; and
- Introducing the forage-livestock system especially for dairy farm.

6.1.1.5.1.2 Breeding

- Tolerance of animals to heat stress; and
- Cross breeding of local breeds to other breeds that are tolerant to heat stress and to certain disease

6.1.1.5.1.3 Increasing forage production and preservation

As Jordan has used its fresh water primarily for domestic uses, Use of treated water for production of forage is important e.g. Wadi Dulail land rural areas encouraging using of small treated wastewater plants in small communities.

6.1.1.5.1.4 Institutional and policy change

- Subsidies for livestock production; and
- Early warning system.

6.1.1.5.1.5 Science and technology development

- Water harvesting;
- Conservation of agricultural land;
- Veterinary services; and
- Using of complete rations using agricultural byproducts.

6.1.1.5.1.6 New management system

- Fits the dairy and poultry production, but not sheep;
- Provide shelters, use of drip and sprinkles for heat rising adaptation;
- Feed production development;
- Plantation of adaptive species like a triplex;
- Biotechnology and genetic sciences for livestock; and
- Genetic improvement of range plants resistant to heat stress.

6.1.1.5.1.7 Support Extension and research centers

Support extension and research centers regarding sustainable development for livestock production since climate change is happening faster than science predicted ultimately includes the following:

- Stopping of deterioration on herd and the range;
- living in the range, Help in giving grazing permissions and prevent grazing on deteriorated range;
- Organizing the community, Formation of community cooperatives responsible about the use of range land and the grazing right; and
- Controlled grazing.

6.1.1.5.2 Adaptation measures for Rangelands

The rangelands consist of marginal land, which became increasingly degraded under combined anthropogenic and climatic pressures. With a population highly dependent on the productive capacity of grazing lands, land degradation often leads to food insecurity. Average rainfall in the areas is quite low, (less than 200 mm per year), and the region experiences significant seasonal and inter-annual rainfall variability. The cumulative impact of recurring droughts, cultivation of marginal lands, fuel wood gathering and overstocking of livestock have drastically depleted the vegetation. As a result, soil erosion, desertification and atmospheric dust have emerged as significant environmental challenges. The local resource base has been degraded, undermining livelihoods and leaving communities more vulnerable to the adverse effects of future droughts.

Inhabitants of dry lands have learned to cope with unreliable rainfall and threats of recurrent drought through practices such as surplus accumulation of produce, shifting cultivation to utilize soil moisture, and nomadism. However, amid widespread poverty and increased human pressure on the fragile resource base, these coping strategies are becoming insufficient in reducing people vulnerability.

Unsustainable farming, grazing and wood fuel gathering have led to dry land degradation and desert encroachment. Fuelled by lack of appropriate policies and ineffective governance structures, desertification already affects the larger part of the Jordan's dry lands. Climate change will likely exacerbate this trend, as increasing temperatures will bring drier conditions and shorter and more intense rainfall events. Water harvesting activities contribute to adaption of such activities. NCARE is experimenting water harvesting activities in the Middle Badia for rangeland development [63] and in Maan for growing fodder plants in established contour lines[64]. Other research activities include studying the effects of land tenure on adopting water harvesting activities[65], and to assess the limiting factors for adopting water harvesting activities in Badia areas[66].

Reducing the vulnerability of dry land communities to climate change will require measures that diversify livelihood options, reduce pressure on natural resources, and restore and protect dry land ecosystems through sustainable management practices. Examples of such measures are already used in communities in Jordan. This valuable

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63 Dr. Esmat Karadsheh and others of the NCARE.

64 Researcher Mohammad Mudeer and others of the NCARE.

65 Researcher Raed Badwan and others of the NCARE.

66 Dr, samia Akroush and others of the NCARE.

community experience, can offer guidance for future adaptation processes of dry land.

- Community-based rangeland rehabilitation measures to restore overexploited lands and enhance local livelihoods were implemented with the support of UN WFP. Rangeland rehabilitation covered land management, livestock improvement and agro forestry to prevent overexploitation and restore productivity of rangelands;
- Natural resource management, including establishing protected areas, with the aims to prevent overexploitation of marginal lands and rehabilitate rangelands for the purpose of biodiversity preservation, and the reduction of atmospheric dust. Success and sustainability of this approach depends on diversifying local production systems and improving socio-economic conditions. Development activities address immediate needs of communities by diversifying local production systems and income-generating opportunities, thereby reducing pressure on rangeland resources. Training in a wide range of activities to build local capacity for project implementation and ensure project sustainability.

Following is a summary of the adaptation measures for rangeland:

6.1.1.5.2.1 Stopping the deterioration of herd and the range

- Incentive and subsidy programs to prevent the collapse of animal production in drought condition;
- Provision of feed that is subsidized under the range condition;
- Applying clear policy and applying the law in the range.

6.1.1.5.2.2 Organizing the community

- Formation of community cooperatives responsible about the use of range land and the grazing right

6.1.1.5.2.3 Living in the range

- Information center responsible about mapping the range land and their productivity

6.1.1.5.2.4 Development of the range

- Genetic improvement of range plants resistant to heat stress;
- Protection of seed bank for the plant in the range;
- Study the quality and composition of range plants;
- Water harvest in the range;
- Production of fodder in irrigation area with treated water; and
- Improvement of veterinary service in the range.

6.1.1.5.3 Adaptation Measures for Agricultural Crops as Feed

6.1.1.5.3.1 Use of the land according to its productivity

- Conservation

6.1.1.5.3.2 Feed production development

- Protection of the range;
- Plantation of adaptive species like triplex;
- Controlled grazing; and

- Water harvesting.

6.1.1.5.3.3 Biotechnology and genetic sciences

- Development of varieties from barley and wheat that is resistant to drought

6.1.1.5.3.4 Extension and research centers

- Advising the farmers for applying the best methods of using his land for the production of crops either as feed or food

6.1.1.6 Adaptation Measures Related to Forests

- The main aim of this action is to prohibit the use of Jordan's remaining forest lands for any other use and to declare forests, like the nature reserves, protected areas;
- Controlled livestock grazing may serve as adaptive measures to reduce woodland dry matter and reduce the risk of fire;
- Afforestation with species that survived dry conditions to prevent further deterioration;
- Measures for combating desertification, such as afforestation, and methods for rehabilitating and regenerating natural vegetation are also mitigations for climate change as they serve as natural sinks for CO_2;
- Some forest trees (crops) may benefit from increased CO_2 levels;
- High costs of fuel would increase demand for fire wood. A consistent supply of heating fuel, especially at higher elevations, is essential to maintaining the forest areas;
- Developing a forest fighting emergency unit at the Civil Defense Department (CDD), and a volunteer fire fighters program to support the CDD efforts; and
- NCARE is experimenting water harvesting activities in the Royal Botanic Garden in the Rumman area and Amra Castle for supporting forest trees[67].

6.1.1.7 Adaptation Measures Related to Biodiversity

Adaptations include conservation of ecotones as well as conservation of corridors between biomes, especially along the north-south axis of the country, enabling propagules to migrate and colonizers to move northward with the desert.

6.1.1.8 Adaptation Measures Related to Socioeconomic

The viability of socioeconomic adaptation to climate change is determined by the strength of the economy, the quality and coverage of health services, and the integrity of the environment.

Vulnerability to climate change depends mainly on the level of economic development and adaptive capacity of nations, the impact of climate change on

[67] Researcher Mohammad Mudeer and others of the NCARE.

these aspects is not uniform. Some of these elements will experience beneficial consequences due to the CO^2 fertilization effect, while others may suffer irreversible detrimental change. If the climate change has adverse impacts, measures are needed for adaptation.

The adaptation challenge is not only a technical challenge but a social process with strong requirements to open stakeholder engagement. Adaptation options have to be developed in a highly localized context and with significant uncertainty concerning the future state of the local resource. The 'best mix' and sequence of adaptation measures should be established as part of a risk assessment process.

However, the adaptation measures related to socioeconomic impacts of climate change, as Public awareness, local community participation, Enhance community stabilization, stop inertial immigration, Modify subsidy, support and incentive programs to influence farm-level production practices and financial management and Subsidy of food.

6.1.1.8.1 Public Awareness

Conduct awareness campaign for farmers to understand what climate-related risks exist and their adaptation response through effective communication from scientists, experts and others; to improve life level in effective use of renewable natural resources is available.

6.1.1.8.2 Local Community Participation

Especially females / women in decision and practices, to improve life level in effective use of renewable natural resources, and try to share in solving related problems in healthy and economic way. E.g. food production on family level as gardens especially for fresh edible plants as mint, and parsley.

6.1.1.8.3 The Subsidy of Food

Jordan has adverse effect on food security , food security was 100% when there were no subsidy while now it is 30% only , Test the subsidy effect on the development of the agricultural sector is important .The picture in Jordan now having imported agricultural inputs, imported man power, imported products, so if subsidy is moved, prices rises this leads to equity of agriculture and other sectors, and decrease governmental expenses, if there is any subsidy, this should support field crop producers and not consumers. Raise the lower limit of farmer's income to enhance local man power in this field is important to support agriculture in Jordan. Agriculture sector is highly absorbance of man power and solve the problem of unemployment.

The real subsidy required from government is to govern imported food without farmers' negative effect, especially when they are so close to harvest their products. The traditional farming activity were lost, Jordan was the master in water harvesting even in badia and desert as Petra and um Al-Jemal .proper subsidy for producers will help field crop production and increase employment.

6.1.1.8.4 Enhance Community Stabilization and Stop Inertial Immigration

Better and cheap life cost, efficient use of natural resources, opportunity to have food self sufficiency, benefits from by products are available.

6.1.1.8.5 Strengthen Farmers Association

Strengthen farmers association will improve the agricultural sector and help in cooperation between farmers, and arrange the agriculture sector. Relations between farmers should be strong and good relation with government is essential

Table 20: Climate Change Impacts and Possible Adaptations

Climate Change Impact	Possible Adaptations

Agriculture	
▪ Increases in seasonal temperature variability and frequency of temperatures may endanger cold- and heat-sensitive crops. ▪High temperatures shorten the growing season resulting in reduced yield. ▪ A delayed or irregular growing season ▪ Drought damages would increase with the decrease in water availability, hotter temperatures and shorter winters. ▪ More pests and pathogens will increase crop diseases, and their sensitivity to drought, ▪ Reduced irrigation water available for agriculture ▪ Loss of biodiversity may reduce the natural control of agricultural pests.	× New crops and heat tolerant and drought resistant varieties, × Agro-technological advances × Revised water policies × Modify subsidy, support and incentive programs × Revised investment policies × Delaying seeding time × Tolerant crops for different pests × Adopt Conservation agriculture system for rainfed field crops × Water harvesting projects. × Altering the timing or location of cropping activities.
Water Resources	
▪ Reduction in overall precipitation, plus increased rain intensity result in diminishing vegetation cover, increase surface runoff, thus, leading to desertification.	× Measures for combating desertification, such as afforestation × Methods for rehabilitating and regenerating natural vegetation
▪ Soil erosion and loss of vegetation will further increase surface runoff. ▪ Increased surface runoff will increase flash floods during peak water flows, damaging infrastructures and crops.	× Conservation and rehabilitation of natural vegetation in rural areas × Promote water infiltration into the soil, × Water-sensitive urban planning to reduce surface runoff
▪ Water supply may be severely decreased due to sedimentation in reservoirs, and the lack of reservoir recharge. ▪ Increased surface runoff will reduce aquifer recharge and groundwater. ▪ Degradation of the quality of stored water due to salinization and increased surface runoff will transport dissolved pollutants to reservoirs, often causing algal blooms.	Water conservation reduce sedimentation × More efficient water harvesting measures × Generation of additional water sources such as treating and recycling wastewater and desalination.
▪ Increased demand for water due to climate change leads to less balanced supply and demand, and adds more problems to the already water scarcity dilemma. ▪ With the uncertainties and frequency of extreme climatic events, the problem may not be due to the low water storage capacity, but because the stored water is below the storing capacity of dams.	× Construction of additional dams and reservoirs when technically feasible × Better management of water harvesting to direct more water to the existing dams × Improving urban planning and promoting groundwater recharge in urban planning.
Forests	
▪ A prolonged dry season increases the risk of forest fires. This critically damages the ecosystems, reduces the already very limited green area, and represents a high financial loss due to the high cost level associated with afforestation activities	× Better management of forest areas including: - Controlled livestock grazing to reduce woodland dry matter, - Establishing fire lines, - Removing less fire-tolerant trees - Growing more fire-tolerant trees

▪ Increasing use of firewood as a fuel for heating ▪ A more frequent occurrence of extreme climatic events and greater seasonal temperature variability, in addition to population growth and rising standards of living, will increase energy requirements for winter heating and summer cooling of buildings.	× Use of treated water for fast growing wood trees to be used for fuels × Designing buildings and urban areas in ways that buffer temperature changes will serve as an adaptation for overall warming and the increased frequency of temperature extremes.
Natural Ecosystems	
▪ Fast rate of climate change and the tendency of urbanization at the expense of the agricultural land. Whole plant populations or species may be lost. It may be impossible to assess which species will be lost, or what is the impact of their loss.	× Conservation of ecotones and corridors between urbanized and non-urbanized areas to conserve biodiversity.

6.2 Evaluate the suitability and potential of each Adaptation measure to be implemented in Jordan

This section focuses on the suitability and potential of the identified adaptation measures to be implemented in Jordan based on the requirements for each. The suitability and potential of these adaptation measures should consider the dimension of food security that will be affected by climate change, which includes: Food availability, Food accessibility, Food utilization and Food system stability. The adverse impacts of climate change that may include crop yield reducing and water availability decreasing; particularly in already water scarce regions shall be considered. For this reason, suitability and potential of the adaptation measures will also consider these parameters.

This section covers the overall objectives to achieve the outcomes that were identified by the program stakeholders. The objective is to adopt suitable mechanisms for adaptation to climate change in food production. This task includes the important related aspects in ample detail by evaluating all possible adaptation measures for food productivity in terms of suitability and applicability to Jordan. This can be done by developing needed adaptation measures for food productivity in

Jordan by reviewing and evaluating all possible adaptation measures for food productivity in term of suitability and applicability to Jordan's main agricultural and rural areas. This study identified factors that influence adaptation and hence reduce vulnerability. The importance of these factors may change however when thresholds are approached.

- Ease of implementation including barriers to implementation and the need to adjust other policies to accommodate the adaptation option. Insufficient infrastructure dictates climate change policy to focus on mitigation instead of adaptation. Despite the crucial need to incorporate adaptation (McKibbin & Wilcoxen, 2004);
- Acceptability to local stakeholders as well as technical feasibility, (not all will be equally attractive to all stakeholders for political, economic, social, or cultural reasons);
- Endorsement by experts taking into consideration the consistency of proposed adaptation options with international best practices;
- How much knowledge transfer and capacity building is required for the adaptation option to be implemented;
- Institutional capacity;
- Adequacy for current climate, are there negative current climate. Some adaptations may be targeted at the future climate, the adaptation option might have consequences under current climate;
- Cost to implement adaptation options or cost of not modifying the project;
- Size of beneficiaries group; adaptations that provide small benefits to large numbers of people will often be favored over those that provide larger benefits, but to fewer people;
- Timeframe (speed) for implementing the adaptation;
- Effectiveness of adaptation options as a solution to problems arising from climate change (benefits, damages mitigated, costs avoided, etc.).

However, the suitability and potentiality of the assessed adaptation measures shall be addressed in this section for agronomy and horticulture, water resources, land resources and forests, livestock production and socioeconomic.

6.2.1 Agronomy and Horticulture

The adoption of the adaptation measures which are supposed to alleviate the negative impact of climate change on productivity of agronomic and horticultural sector depends mainly on suitability and potential of each measure to Jordan circumstances. Threats or barriers beside the opportunities are the main factors that should be taken in consideration when deciding suitability and potential for adaptation measures.

Table (21): Adaptation measures related to the agronomic and horticultural sector with their suitability and potential

ADAPTATION MEASURES	SUITABILITY	POTENTIAL
General Agronomic and Crop Adaptations		
I- <u>Adaptation of farming practices</u> Altering the timing or location of cropping activities	This will be applicable in case of rain fed field crops and irrigated vegetables. Delaying planting date of field crops until the amount of soil moisture will be enough for seed emergence and development in early stages. While irrigated vegetables depend on the availability of irrigation water which is the most limiting factor, therefore this kind of farming will be established in the location of water availability.	Can be applied widely on rain fed field crops.
Improving the effectiveness of pest, disease and weed management practices through wider use of integrated pest and pathogen management	This measure is very important to improve production efficiency and it is a dynamic process that depends on active research and reliable extension services.	Application of this measure could have great positive effect on production efficiency.
Use alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies	Conservation agriculture is started to be applied in many regions of rainfed farming of field crops in Jordan which is the most suitable for wheat and barley and some legumes.	Higher yield will be obtained by conservation agriculture system with the same amount of rain.
Adopt crop rotation systems in both rain fed and irrigated farming	It's very important because this will maintain soil fertility and reduce the harmful impact of soil born pests, beside the efficient use of available water.	Adoption of crop rotation is very important to Jordan agriculture mainly under rain fed conditions for sustainable production.
ADAPTATION MEASURE	**SUITABILITY**	**POTENTIAL**
Implement irrigation practices to address the moisture deficiencies associated with climate change and reduce the risk of income loss due to recurring drought	Some irrigation practices are already implemented like adoption of drip irrigation systems by most farmers and wise management of irrigation timing and duration.	Some other practices are needed to be adopted like irrigating according to tensiometers readings, which will increase water use efficiency.

Change timing of farm operations to address the changing duration of growing seasons and associated changes in temperature and moisture.	This measure is theoretical and such change in farm operations will occur slowly, while it is difficult to notice this change in few years.	Potential of this measure cannot be evaluated due to very slow adoption.
Greater opportunism in planting rules and planting decisions (e.g. time of sowing, seeding rates, row spacing, tactical applications of nitrogenous fertilizers)	Accuracy of planting decisions and optimal use of inputs will maximize productivity .While this measure depends mainly on improvement of research programs and extension services.	Optimal use of inputs will increase crop productivity.
Diversifying income by integrating other farming activities such as livestock raising	This measure is the most applicable and suitable for small holdings of family farming especially in villages	Family farming is the most efficient measure to cure poverty and unemployment
Supplementary irrigation for rain fed fruit trees orchards	This measure is very important in dry seasons.	High improvement of production for rain fed fruit trees orchards
Better strategies on crop selection and planting will buffer adverse effects	The most important decision is the crop selection	Crop type and variety directly affect productivity.
Crops are planted late or harvested early	Changing planting dates to escape adverse conditions	Highly beneficial
ADAPTATION MEASURE	**SUITABILITY**	**POTENTIAL**
II-<u>Adaptation of rain fed Agriculture</u> **Development of a drought management plan**		
Land-use management	A project for application of this system has been started.	High potential of benefits.
Conservation agriculture and water conservation measures		
Effective water use	Practical and helpful for field crops.	High potential for stable production.
Improved practices and technologies		
Use of crop varieties with greater drought tolerance and change of crop cultivars		
Delaying seeding time in response to delayed winter rains		
Reducing need for water		

Modification of sowing dates Shifts in crops production areas		

ADAPTATION MEASURE	SUITABILITY	POTENTIAL
III-<u>Irrigated agriculture</u>		
Develop early warning systems that provide daily weather predictions and seasonal forecasts	This should be practical and easy to achieve because these technologies are available in many countries and qualified personal are easy to employ and train	Direct positive effect in reducing production risks.
Developing varieties with greater drought tolerance, heat shock tolerance, resistance to flower abortion in hot/windy conditions, resistance to new or more virulent pests and diseases	Developing these varieties is a slow and continuous process which needs special research programs to be carried out by NCARE and Universities, this measure is very important on the long run	Introduction of such varieties might be more practical for the short run
Revised water and investment policies	Important for ground water management.	Pumping according to recharge records of water basins is a must.
Develop water management innovations, including irrigation, to address the risk of moisture deficiencies and increasing frequency of droughts	This measure will maximize the productivity of each cubic meter of irrigation water in either returns or crop production which will improve the efficiency of irrigation water	The potential of such measure depends on research and extension institutions.
Improved management of irrigation (amount and efficiency)	By developing water use extension	Highly needed for Jordan circumstances
Changes in land allocation to optimize or stabilize production	This change depends on water availability	
ADAPTATION MEASURE	**SUITABILITY**	**POTENTIAL**
Microclimate modification to improve water	Suitable to apply on large scale.	Alleviate impact of adverse conditions.

use efficiency in agriculture (e.g. windbreaks, intercropping, multi-cropping techniques)		
Changes in nutrient management to reflect the modified growth and yield of crops	Efficient use of fertilizers depends on crop growth conditions.	Such management highly improves yield.
Identification and evaluation of alternative technological solutions (Unconventional water resources for irrigation, desalinization, reuse of wastewater)	Suitable for many water resources	Potential depends on cost and users awareness.
Developing irrigation water users associations	Important in irrigated agriculture Farmers involvement in water supply management Understanding the water budget available Support to Water users association	Transparency and information flow Lack of sustainable income of those associations
Increase of storage capacity (for surface and ground waters) both natural and artificial	Harvesting water by recharge techniques to certain water basins.	Potential of this measure depends on technical studies and application
Enlarging the availability of water (e.g. increase of reservoir capacity)	Increasing dams capacity and building new dams is needed for Jordan	Enlarging dams and is beneficial to harvest water in extreme rain
ADAPTATION MEASURE	**SUITABILITY**	**POTENTIAL**
Considering additional water supply infrastructure	Water harvest projects	
Water saving (e.g. permit systems for water users, education and awareness-raising)	This measure should be applied on all water consuming sectors.	Huge direct benefits.
Fostering water efficient technologies and practices (e.g. irrigation)	Introducing such technologies is applicable.	High potential of water saving.
V- <u>Improve and strengthen agriculture related laws</u>		
Laws of exporting and importing of agricultural products	Competitive and comparative advantages should be considered	Productivity and revenues will be improved.
Laws to support the forestry sector	Amending laws is a dynamic process	Direct benefit on conservation and development of forests
Laws to support irrigated agriculture	Needed to support food production	Legislation is very important for sustainable agricultural

Develop and implement bylaws for Agricultural Risks Fund to influence farm-level risk management strategies with respect to climate-related loss of crop yields	This fund is very important to support sustainable agricultural production and will alleviate the risks and danger that might threat farmers and their production without direct financial support from the government	This fund will provide sustainable and stable agricultural sector
Policy and legislation for climate change with concentration on irrigated agriculture	Such measure can be accomplished easily	Policy and legislation is crucial for sustainable use of resources
ADAPTATION MEASURE	**SUITABILITY**	**POTENTIAL**
VI-Governmental responsibility		
Maintaining or improving quarantine capabilities, and sentinel monitoring programs	Improvement of institution which is responsible for quarantine and monitoring is possible and can be achieved in short period of time with a reasonable investment cost	High potential for pest and disease management and control
Modify subsidy, support and incentive programs to influence farm-level production practices and financial management	Such programs of subsidy and support are vital for agriculture and food production to decrease and mitigate the danger of risks and insure sustainable food production but the only constraint of such measure is the financial recourses	These programs should be directed to support sustainable production to maximize their potential
Development of water use efficiency strategies to manage potentially lower irrigation water availabilities	Development and implementation of such strategies by public and private sectors are strongly needed in Jordan even without future threats of climate change because of water scarcity	Maximizing water use efficiency will increase crop yield and productivity

6.2.2 Water Resources

The number of adaptation opportunities for the water sector is vast. For each of the many ways in which water is important, there exists a range of approaches that have been used to adapt to existing climate variability, along with numerous options for adapting to anticipated climate changes. A logical frame for classifying adaptation measures might be used in this study. The basis of such frame is the study of extreme events floods and droughts (Kates, 1985). This frame places adjustments to extreme events in three categories: changing uses and/or locations, preventing events and accepting losses. These categories reflect on all types of stakeholders. The stakeholders could be individual farmers, irrigation district, or government.

As water resources are one of the most vulnerable natural resources to climate change risks and the main input in agriculture, the suitability and potential of the adaptation measures on climate change related to these resources are shown in table (22) that represents the suitability and potential of the adaptation measures to climate change risks on food productivity related to water resources.

Table (22): Adaptation measures related to water resources with their suitability and potential

ADAPTATION MEASURE	SUITABILITY	POTENTIAL
<u>I- Improve and Strengthen agriculture related legislations</u>	Important for sustainable agriculture in Jordan Water demand management shall achieve the highest efficiency in the conveyance, distribution Systems, application and use. Too much suitable due to enforcement of the adaptation measures Facilitate the application of the adaptation measures	Clear water allocation and management in agricultural sector Bridge the gap between supply and demand
Planning, policies and strategies, , Standards Guidelines, Procedures ,laws and by-laws, and coding		
Adopt the water strategy for 2008-2022 and action plans meeting its objectives focusing on adopting and implementing guidelines for water used in irrigation,		
Identify responsibilities of the involved regulatories to avoid duplication ,develop and implement		
Implement agriculture Policy along with action plan as response to climate change impacts		
Develop water harvesting strategies to maximize irrigation water availability		
Development of water use efficiency strategies to manage potentially low irrigation water availabilities		
ADAPTATION MEASURE	**SUITABILITY**	**POTENTIAL**
Restore trans-boundary water rights	Support water rights	Affected by politics
water Planning, allocation and pricing	operation and maintenance cost recovery	Questionable
Develop ~~integrated water management~~ practices into specific institutional settings for all water regularities	~~Clear water allocation for different sectors~~	~~Adaptable~~

Sustain irrigation water in the highlands and Badia areas through, technical, Managerial and legislative actions	Monitoring the situation and give recommendations for irrigated high lands	The main Source of irrigation water in the high land is the groundwater.
Develop and implement policies and programs to influence farm-level, land, water resource use and management practices in light of changing climate conditions	Water demand management	obtain sustainable fresh water in Jordan
II- Improve water conveyance system efficiency	It is a continues process	High potential
Minimize irrigation water losses , e.g., switch open canal systems to a pressurized pipe system		
ADAPTATION MEASURE	**SUITABILITY**	**POTENTIAL**
III- Water harvesting		
Developing both micro and macro integrated watershed management plan. This includes developing integrated farming systems in response to climatic change	The most suitable solution for decrease water shortage in Jordan	Water harvesting and conservation in Jordan is a Historical and traditional activity Plan to harvest certain percentage of rainfall yearly.
Development of sustainable management plans and systems for surface water in Jordan Valley		
ground water recharge		
flood management and artificial recharge of groundwater	Increase water availability	Low potential
Water harvesting in the rangeland		

Conserve water and usage within its production capacity to ensure sustainable and long term agricultural production		
Promote rain-fed farming and the efficient use/conservation to get of water through	Conservation practices for water such as: conservation terraces, contour tillage, mulching, adopting efficient irrigation systems and efficient irrigation schedules, planting in controlled environment	Moderate potential through incentives for the farmers to do so
Increase and improve water projects infrastructure and management	Ongoing activity in Jordan	Highly potential
ADAPTATION MEASURE	**SUITABILITY**	**POTENTIAL**
<u>IV- On farm irrigation water management</u>		
Introduce, invest and use efficient water saving technologies in irrigation systems, as drip or sprinklers, tensiometers and watermarks	Drip and sprinklers technology are widely used, others need promotion	Maximize the net production from the water unit
Improve the efficiency of irrigation systems And irrigation scheduling	as using plastic houses and tunnels This is used in Jordan but needs improvement	It needs more resources
Provide adequate drainage systems to mitigate soil Salinization	Badly needed in some areas	Costly but efficient
Rehabilitate and protect irrigation water ponds, springs and networks and reducing seepage from agricultural and aquaculture ponds	Need awareness	Easy to adapt
Use suitable windbreaks within the orchard	This is suitable for Jordan	Using low water requirement trees
<u>V- Technology transfer and knowledge</u>		
Establish an integrated irrigation advisory services unit	simplify the results of researches to be adaptable by farmers	For Farmers benefits high
Monitoring program on water use efficiency	To improve water use efficiency by farmers	Good potential

Collect analyze distribute technical and scientific data suitable for Jordan conditions	Using qualified people and media	High Potential
Research and development	Continues activity	Need financial support
VI- Irrigation with marginal and treated wastewater (TWW)		
Use of all non-conventional water resources along with introducing and enforcing national standards to evaluate irrigation water quality	Jordan has experience in this field but this need more continues research and precautions	Introduce more tolerant crops
Ensure a sound monitoring system when using treated wastewater in irrigation	Jordan has experience in this field on governmental and water distribution the results should transfer to farmers in simple way.	With Qualified team
Activate standards for wastewater discharges to sewers, treated effluent and water for irrigation uses		
Introduce water Quality improvement e.g., desalinize brackish water, use solid water, magnetizing water, grey water, cloud seeding, fog harvesting, etc.) improvement technology such as softening	This is started in Jordan on the farm levels	Potential for cash crops.
VII- Water use association		
Farmer's involvement in water supply management and understand the water budget available	Encourage these associations to distribute all along irrigated areas Increase the number of WUA	Highly potential
Assisting and training water users for proper operation and maintenance of the system and for efficient use of water and	supporting farmers both financially and technically to encourage using water saving techniques and approaches	Highly potential
VIII- Establish a climate change unit		

Conducting climate change research including evapotranspiration reduction techniques and generating local crop coefficients	Research for some crops in Jordan is ongoing using protected and open agriculture in the Jordan valley	More efforts are required
Drought forecasting, and drought management and desertification control	Farmers' awareness	Low to moderate
Establish/extend climate information systems for irrigation water management	Water control saving	Easy to implement
Actions to prevent sudden impact on crops as frost and high temperature impacts related to Climate Change	Establish early warning system	Moderate potential through cooperation and coordination of metrological department
Capacity building and Training	Continuous process	Moderate to High potential

6.2.3 Land Resources

Although the agricultural land resources and forests are already limited in Jordan they are not entirely used, especially in rainfed agricultural areas. To increase the production, it is necessary to increase planted land resources. Table (23) shows the suitability and potential of the adaptation measures to climate change risks on food productivity related to land resources.

Table (23): Adaptation measures related to land resources with their suitability and potential

ADAPTATION MEASURE	SUITABILITY	POTENTIAL
I- Improve and strengthen agriculture related laws mainly Land use laws	support agricultural sector, and help Jordan to benefits from available natural resources, should given priority,	Technical experts and financial inputs are required,
II- Land Development Projects as Soil conservation projects	Soil conservation,(anti erosion techniques proper methods as zero tillage, stone walls, organic matter application. Sustainable dry land farming Vertical production of soil increased. Desertification prevention are promising in Jordan	High potential Technical training is required
III- Improve and extent dry land farming	Benefit from land classification data in Jordan is adaptable. Most required data for soil reclamation and conservation are there	Especially for fruit trees and field crops
IV- Lease government lands	Decrease poverty and unemployment Government and society benefits	The Government can benefit with transparency
ADAPTATION MEASURE	**SUITABILITY**	**POTENTIAL**
V- Enhance new land reclamation	Decrease poverty	Technical and financial requirements
VI- Shifts in crops production areas	Conserve biodiversity	Technical supports required
VII- Improve and strengthen agriculture related laws mainly Land use laws	support agricultural sector, and help Jordan to benefits from available natural resources, should given priority	Technical experts and financial inputs are required

6.2.4 Livestock Production

Table 24 summarizes the suitability and potential of the adaptation measures to climate change risks related to the Livestock production

Table (24): Adaptation measures related to Livestock production with their suitability and potential

ADAPTATION MEASURE	SUITABILITY	POTENTIAL
I- Production Adjustment		
Diversification and integration of fodder production	Very suitable to intensive sheep production	May increase lambs fattening and cheese producing from eves
Conservation and protecting the range	The amount produced from range could be tripped	The potential is high but the programs at the beginning may be costly
Change the management of grazing, destocking and routing movement	May be not suitable to sheep owners and they may not like the new system but it is needed to prevent deterioration	This system need and organized institution and participation of community is needed for success
Introducing the forage-livestock system especially for dairy farm	This suitable for intensive and dairy production	Could be economical of performed by family members but this system needs a lot of investment and needs land and water
II-Breeding		
Tolerance of animals to heat stress	Suitable for development of the animals resistant to diseases and parasites	Good potential suggestion but should be done in research centers
Cross breeding of local breeds to other breeds with are tolerant to heat stress and to certain disease	Suitable suggestion if the local breed is going to survive	It is a time consuming suggestion and it needs 10-15 years of research
III- Institutional and policy change		
Subsides for livestock production	This will came increased production and protect the live hood of people in arid and semi arid area	Government subsidies are already removed

Early warning system	This is very beneficial to framers	This needs grants and disaster preparedness investment
<u>IV-Science and technology development</u> Water harvesting	This is needed to be done in all areas in future	Could be done in area with high rainfall
Conservation of agricultural land	This is needed for preservation of agricultural land	
Veterinary services	This is suitable to sheep owners	Government should tale core of this service because it is costly
Use of complete rations using agricultural by products	This suggestion is suitable because all by – products could be used in feeds	High amounts could be added to the feed from byproducts but labs are needed to observe the quality
<u>V- Increasing forage production and preservation</u>		
Use of treated water for production of forage	Silage and hay making is suitable for promoting dairy production and very suitable for Jordan	A lot of extension is needed to promote this technology
<u>VI- New management system</u>		
Fits the dairy and poultry production but not sheep Provide shelters, use of drip and sprinkles	Very suitable suggestion to remove heat stress	Could increase milk production in dairy cows
<u>VII- Stopping of deterioration on herd and the range</u>		
Incentive and subsidy programs to prevent the collapse of animal production in drought condition	Suitable for keeping the livelihood of people in arid and semi arid areas	Policy makers do not like subsidy policies
Provision of feed that is subsidized under the range conditions	Suitable to keep livestock healthy and productive	The number of sheep increase above range capacity
Applying clear policy and applying the law in the range	This suggestion is important in protecting and improvement he range	Community and tribes participation is necessary to apply the laws
<u>VIII- Organizing the community living in the range</u>		
Formation of community cooperatives responsible about the use of range land and grazing right	This suggestion is very suitable if the range development is applied	It needs the governmental assistant and cooperative and community participation

Information center responsible about mapping the range land and their productivity	This suggestion is of technical importance only	Scientific center and university staffs has to participate in it
<u>**IX- Conservation and protecting the range**</u>	The amount of feed from range could be 3-5 times increased by protection	The potential is high but the application of the programs at the begging is costly
Genetic improvement of range plants resistant to heat stress	This suggestion is suitable for development resistant plants to heat stress	This suggestion is needed to preserve the plants in the range but it needs scientific and technical support
Protection of seed bank for the plant in the range	This suggestion is needed to protect the favorable species in range	Research centers are needed for the application
Plantation of adaptive species like a triplex	A very suitable suggestion – feed production could be tripled in 2-3 years	It has very good potential but it is costly
Production of fodder in irrigated area with treated water	Very good suggestion and it is important for dairy production	It has a good potential for silage production which is important in feeding dairy cows
Improvement of veterinary service in the range	Suitable to keep sheep and cows healthy	Has good potential but it is costly
Controlled grazing	It is a good suggestion to prevent deterioration of range	It has good potential but needs community participation

6.2.5 Socioeconomic

Table 25 summarizes the suitability and potential of the adaptation measures to climate change risks related to the Livestock production

ADAPTATION MEASURE	SUITABILITY	POTENTIAL
I-Develop and implement bylaws for agricultural Risks Fund to influence farm-level risk management strategies with respect to climate-related loss of crop yields	This fund is very important to support sustainable agricultural production and will alleviate the risks and danger that might threat farmers and their production without direct financial support from the government	This fund will provide sustainable and stable agricultural sector
II-Public awareness	farmers understand what climate -related risks exist and their adaptation response through effective communication from scientists and others can be raised	This is a long term issue and requires different ways of awareness
III-Share local community	improve life level in effective use of renewable natural resources	Understand the mentality of the society, the local culture consideration
IV-Enhance community stabilization and stop inertial immigration	Suitable	Better infra structure in rural areas
IIV-Water harvesting subsidy on the level of dry land farming	Jordan have the potential to increase the productivity of field crops and fruit tree planting and grazing land by increasing the yields and by reducing the risk of crop failure Increase the amount of water available for agricultural Improve dry land farming	This is continuous process in Jordan
ADAPTATION MEASURE	**SUITABILITY**	**POTENTIAL**
V-Modify subsidy, support and incentive programs to influence farm-level production practices and financial management	Such programs of subsidy and support are vital for agriculture and food production to decrease and mitigate the danger of risks and insure sustainable food production but the only constraint of such measure is the financial recourses	These programs should be directed to support sustainable production to maximize their potential

VI-Subsidy of food	proper subsidy for producers will help field crop production in Jordan	Food subsidy in Jordan help food producers, and help in employment

6.3 Suggest and Prioritize the Best Possible Adaptation Measures For Food Productivity In Jordan

Most of the identified adaptation measures that were mentioned in the previous sections can be implemented in Jordan. Many of them are more suitable than the others under Jordanian conditions. Local conditions and circumstances are expected to influence the specific adaptations that are, or can be, used for each sector, and by each stakeholder. Consultations with stakeholders and decision-makers were useful in selecting the final set of factors and assigning "weight" or level of importance to each of them. This reinforces the need to develop criteria that can be used by stakeholders to select one or more of the finalized measures that are suitable for their local situations. Assessment of priorities of different adaptation measures to meet Jordan needs should consider all essential factors such as socio-economic impact, institutional, financial, technical, environmental, and time frame of each measure.

To obtain reasonable results, each one of the mentioned factors should take certain weight for assessment process. The study team developed criteria for ranking the suggested best possible Adaption measures for food productivity in Jordan. These criteria consider the following:

1. **Socioeconomic consideration (8 scores):** the socio–economic effect of the adaption measures is of high importance to prioritize the suggest adaption measures, what is important here is to assess the total benefits that come from adaptation measures application for individuals, community and the country;
2. **Institutional (5 scores):** The institutional importance is community from that institutional strongly the house hold decision about adaption;
3. **Technical (5 scores);**
4. **Financial (5 scores)**;
5. **Environmental (4 scores);** and
6. **Time frame (3 scores). Making (30) scores in total.**

Once an adaptation strategy has been evaluated, the measures that yield the greatest benefits will be chosen.

Regarding the agronomy and horticulture in rainfed and irrigated agriculture, **Table 26** and **table 27** summarize the adaptation measures to climate change risks with their weights and rankings respectively.

When prioritize the water sector according to the local capability, it seems that the on farm management then water harvesting, Improve and strengthen agriculture related legislations issues are the main priorities , but also all of these adaptation measures are important to Jordan. **Tables 28 and 29** represent the adaptation measures to climate change risks with their weights and rankings related to water resources.

According to the proposed criteria for prioritization of the adaptation measures related to land resources, **table 30 and table 31** represent the priorities of these adaptation measures.

The most important point in this classification is to increase the quantity of feed available to livestock because without this venue no improvement in animal production will happen. This is why increasing feed productivity take the most important priority in the facing of changing the climatic conditions. Water harvesting is important from the side animal drinking and in planting barely and other cereal crops. Encouraging the government and institution to water harvesting could remove the expenses and difficulties facing the communities in the range to make water available to their animals. Livestock health is important for keeping the herds healthy and decrease the mortality of the new born lambs.

Improving the breeding of Awasi ewes by genetic methods in a long term project and government should have breeding centers in Jordan University or the University of Science and Technology in Irbid taking care of that.

This improvement is of a long term project. The final point is the policy of government which should be strictly applied after the participation of the community for improving the range and after convincing them that the improvement is for their sake. The adaptations measures related to livestock production prioritization and ranking are presented in **tables 32 and 33** respectively.

The prioritized and ranked adaptations measures to climate change risks on food productivity related to socioeconomic sector are presented in **tables 34 and 35**.

6.3.1 Agronomy and Horticulture

The following Table 26 and table 27 summarize the adaptation measures to climate change risks on food productivity related to agronomy and horticulture in rainfed and irrigated agriculture with their weights and rankings respectively

Adaptation measure	Socio-economic	Institutio-nal	Financ-ial	Tech-nical	Environ-mental	Time frame	Total
	8	**5**	**5**	**5**	**4**	**3**	**30**
A. Technology dependant adaptations 1. Developing varieties with greater drought tolerance, heat shock tolerance, resistance to flower abortion in hot/windy conditions, resistance to new or more virulent pests and diseases	6	5	3	3	3	2	**22**
2. Develop early warning systems that provide daily weather predictions and seasonal forecasts	5	5	5	4	3	3	**25**
3. Wider use of technologies to 'harvest' water; conserve soil (e.g., crop residue retention) and to use water more effectively (e.g., soil less cultures)	6	4	4	4	3	2	**23**
4. Develop farm-level resource management innovations to address the risk associated with changing temperature, moisture and other relevant climatic	5	4	3	4	3	2	**21**
5. Develop water management innovations, including irrigation, to address the risk of moisture deficiencies and increasing frequency of droughts	6	5	4	5	3	2	**25**
B. Farm practices adaptations 1. Altering the timing or location of cropping activities.	5	4	2	3	3	3	**20**

Adaptation measure	Socio-economic	Institutio-nal	Financ-ial	Tech-nical	Environ-mental	Time frame	Total
	8	**5**	**5**	**5**	**4**	**3**	**30**
2. Improving the effectiveness of pest, disease and weed management practices through wider use of integrated pest and pathogen management	7	5	4	4	3	2	**25**
3. Use alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies	5	5	3	4	3	2	**22**
4. Adopt crop rotation systems in both rain fed and irrigated farming	5	5	3	4	3	2	**22**
5. Implement irrigation practices to address the moisture deficiencies associated with climate change and reduce the risk of income loss due to recurring drought	6	5	4	5	3	2	**25**
6. Change timing of farm operations to address the changing duration of growing seasons and associated changes in temperature and moisture	5	4	2	3	3	3	**20**
7. Greater opportunism in planting rules and planting decisions (e.g. time of sowing, seeding rates, row spacing, tactical applications of nitrogenous fertilizers)	6	4	2	3	3	3	**21**
8. Diversifying income by integrating other farming activities such as livestock raising	8	5	4	4	3	3	**27**
9. Supplementary irrigation for rain fed fruit trees orchards	7	4	4	3	3	3	**24**

C. Governmental responsible adaptations 1. Maintaining or improving quarantine capabilities, and sentinel monitoring programs	6	5	5	5	3	2	**26**
2. Modify subsidy, support and incentive programs to influence farm-level production practices and financial management	7	5	5	4	3	2	**26**
3. Develop and implement bylaws for Agricultural Risks Fund to influence farm-level risk management strategies with respect to climate-related loss of crop yields.	7	5	4	4	3	2	**25**
4. Develop and implement policies and programs to influence farm-level land and water resource use and management practices in light of changing climate conditions	6	4	4	4	3	2	**23**
5. Development of water use efficiency strategies to manage potentially lower irrigation water availabilities.	6	5	5	5	3	2	**26**
6. Develop water harvest strategies to maximize irrigation water availability	7	5	5	5	4	2	**28**
7. Improve research and extension services for agricultural sector to alleviate the adverse impacts of climate change	7	5	5	5	3	2	**27**
8. Investment in water projects infrastructure and management (e.g., dams, desalination plants)	7	5	3	4	4	2	**25**

Adaptation Measure	Priority
Technology dependant adaptations	1
Develop early warning systems that provide daily weather predictions and seasonal forecasts	2
Develop water management innovations, including irrigation, to address the risk of moisture deficiencies and increasing frequency of droughts	3
Wider use of technologies to 'harvest' water; conserve soil (e.g., crop residue retention) and to use water more effectively (e.g., soil less cultures)	4
Develop farm-level resource management innovations to address the risk associated with changing temperature, moisture and other relevant climatic	5
Developing varieties with greater drought tolerance, heat shock tolerance, resistance to flower abortion in hot/windy conditions, resistance to new or more virulent pests and diseases	6
Farm practices adaptations	
Diversifying income by integrating other farming activities such as livestock raising	1
Improving the effectiveness of pest, disease and weed management practices through wider use of integrated pest and pathogen management	2
Change timing of farm operations to address the changing duration of growing seasons and associated changes in temperature and moisture	3
Implement irrigation practices to address the moisture deficiencies associated with climate change and reduce the risk of income loss due to recurring drought	4
Supplementary irrigation for rain fed fruit trees orchards	5

Adaptation Measure	Priority
Use alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies	6
Adopt crop rotation systems in both rain fed and irrigated farming	7
Greater opportunism in planting rules and planting decisions (e.g. time of sowing, seeding rates, row spacing, tactical applications of nitrogenous fertilizers)	8
Altering the timing or location of cropping activities	9
Governmental responsible adaptations	
Develop water harvest strategies to maximize irrigation water availability	1
Improve research and extension services for agricultural sector to alleviate the adverse impacts of climate change	2
Maintaining or improving quarantine capabilities, and sentinel monitoring programs	3
Modify subsidy, support and incentive programs to influence farm-level production practices and financial management	4
Development of water use efficiency strategies to manage potentially lower irrigation water availabilities.	5
Develop and implement bylaws for Agricultural Risks Fund to influence farm-level risk management strategies with respect to climate-related loss of crop yields	6
Investment in water projects infrastructure and management (e.g., dams, desalination plants)	7

6.3.2 WATER RESOURCES

The following Tables (28) and (29) represent the adaptation measures to climate change risks on food productivity related to water resources in terms of priorities and ranking.

Adaptation measure	Socio-economic	Institutio-nal	Financ-ial	Tech-nical	Environ-mental	Time frame	Total
	8	5	5	5	4	3	30
A- Improve and strengthen agriculture related legislations							
1- Planning, policies and strategies, , Standards Guidelines, Procedures ,laws and by-laws, and coding	7	5	5	4	4	1	26
2- Adopt the water strategy for 2008-2022 and action plans meeting its objectives focusing on adopting and implementing guidelines for water used in irrigation	7	5	5	4	3	3	27
3- Identify responsibilities of the involved regulatories to avoid duplication ,develop and implement	7	5	5	4	4	1	26
4- Implement agriculture Policy along with action plan as response to climate change impacts	7	5	4	4	4	2	26
5- Develop water harvesting strategies to maximize irrigation water availability	8	4	4	4	4	3	27
6- Development of water use efficiency strategies to manage potentially low irrigation water availabilities	7	5	4	4	4	3	27
7- Restore trans-boundary water rights	8	2	2	4	4	1	21

Adaptation measure	Socio-economic	Institutio-nal	Financ-ial	Technical	Environ-mental	Time frame	Total
	8	**5**	**5**	**5**	**4**	**3**	**30**
8- water Planning, allocation and pricing	2	4	3	5	4	1	19
9- Develop integrated water management practices into specific institutional settings for all water regularities	7	5	4	5	4	2	27
10- Sustain irrigation water in the highlands and Badia areas through, technical, Managerial and legislative actions,	4	4	4	4	4	2	**22**
11- Develop and implement policies and programs to influence farm-level, land, water resource use and management practices in light of changing climate conditions	8	5	3	4	4	1	**25**
B- Water harvesting							
1- Developing both micro and macro integrated watershed management plan. This includes developing integrated farming systems in response to climatic change	8	5	3	4	4	3	**27**
2- Development of sustainable management plans and systems for surface water in Jordan Valley	8	4	4	4	4	3	**27**
3- Ground water recharge	8	4	4	3	4	2	**25**

Adaptation measure	Socio-economic	Institutio-nal	Financ-ial	Tech-nical	Environ-mental	Time frame	Total
	8	**5**	**5**	**5**	**4**	**3**	**30**
4- Flood management and artificial recharge of groundwater	8	4	3	4	4	2	**25**
5- Water harvesting in the rangeland	8	4	4	4	4	3	**27**
6- Conserve water and use it within its production capacity to ensure sustainable and long term agricultural production	6	4	4	4	4	3	**25**
7- Promote rain-fed farming and the efficient use/conservation to increase soil water holding capacity	8	4	4	4	4	3	**27**
8- Increase and improve water projects infrastructure and management (e.g., dams, desalination plants)	8	5	2	5	4	2	**26**
C- On farm irrigation water management							
1- Introduce, invest and use efficient water saving technologies in irrigation systems as drip or sprinklers, tensiometers and watermarks	7	5	4	4	4	3	**28**
2- Provide adequate drainage systems to mitigate soil Salinization	8	4	2	3	4	2	**23**
3- Rehabilitate and protect irrigation water ponds, springs and networks and reducing seepage from agricultural and aquaculture ponds	7	4	4	5	4	3	**27**
4- Use suitable windbreaks within the orchard	6	5	4	5	4	3	**27**

Adaptation measure	Socio-economic	Institutio-nal	Financ-ial	Tech-nical	Environ-mental	Time frame	Total
	8	**5**	**5**	**5**	**4**	**3**	**30**
D- Technology transfer and knowledge							
1- Establish an integrated irrigation advisory services unit	8	4	3	4	4	2	**25**
2- Monitoring program on water use efficiency	7	4	2	4	4	2	**23**
3- collect analyze distribute technical and scientific data suitable for Jordan conditions	8	4	4	4	4	2	**26**
4- Research and development	8	4	3	4	4	2	**25**
E- Irrigation with marginal and treated wastewater (TWW)							
1- Use of all non-conventional water resources along with introducing and enforcing national standards to evaluate irrigation water quality	6	4	4	4	3	3	**24**
2- Ensure a sound monitoring system when using treated wastewater in irrigation	8	4	3	4	4	3	**26**
3- Activate standards for wastewater discharges to sewers, treated effluent and water for irrigation uses	8	4	3	4	4	2	**25**
4- Introduce water Quality improvement e.g., desalinize brackish water, use solid water, magnetizing water, greywater, cloud seeding, fog harvesting, etc.)improvement technology such as softening	6	4	2	3	2	3	**20**

Adaptation measure	Socio-economic	Institutio-nal	Financ-ial	Tech-nical	Environ-mental	Time frame	Total
	8	**5**	**5**	**5**	**4**	**3**	**30**
F- Water use association							
1- Farmers' involvement in water supply management and understand the water budget available.	8	4	3	4	4	3	**26**
2- Assisting and training water users for proper operation and maintenance of the system and for efficient use of water	8	4	3	4	4	3	**26**
G- Establish a climate change unit							
1- Conducting climate change research including evapotranspiration reduction techniques and generating local crop coefficients	8	4	2	3	4	2	**23**
2- Drought forecasting, and drought management and desertification control	8	4	3	4	4	2	**25**
3- Establish/extend climate information systems for irrigation water management	8	4	3	4	4	2	**25**
4- Actions to prevent sudden impact on crops as frost and high temperature impacts related to Climate Change	8	4	4	4	4	3	**27**
5- Capacity building and Training	8	4	2	4	4	2	**24**

Adaptation measure	Priority
On farm irrigation water management	
Introduce, invest and use efficient water saving technologies in irrigation systems as drip or sprinklers, tensiometers and watermarks	1
Rehabilitate and protect irrigation water ponds, springs and networks and reducing seepage from agricultural and aquaculture ponds	2
Use suitable windbreaks within the orchard	3
Provide adequate drainage systems to mitigate soil Salinization	4
Water harvesting	
Developing both micro and macro integrated watershed management plan. This includes developing integrated farming systems in response to climatic change	1
Development of sustainable management plans and systems for surface water in Jordan Valley,	2
Water harvesting in the rangeland	3
Promote rain-fed farming and the efficient use/conservation to increase soil water holding capacity	4
Increase and improve water projects infrastructure and management (e.g., dams, desalination plants)	5
Ground water recharge	6
Flood management and artificial recharge of groundwater	7
Conserve water and usage within its production capacity to ensure sustainable and long term agricultural production	8
Improve and strengthen agriculture related legislations	
Adopt the water strategy for 2008-2022 and action plans meeting its objectives focusing on adopting and implementing guidelines for water used in irrigation	1
Develop water harvesting strategies to maximize irrigation water availability	2
Development of water use efficiency strategies to manage potentially low irrigation water availabilities	3
Develop integrated water management practices into specific institutional settings for all water regularities	4

Adaptation measure	Priority
Planning, policies and strategies, , Standards Guidelines, Procedures ,laws and by-laws, and coding	5
Identify responsibilities of the involved regulatories to avoid duplication ,develop and implement	6
Implement agriculture Policy along with action plan as response to climate change impacts	7
Develop and implement policies and programs to influence farm-level, land, water resource use and management practices in light of changing climate conditions	8
Sustain irrigation water in the highlands and Badia areas through, technical, Managerial and legislative actions	9
Restore trans-boundary water rights	10
Water Planning, allocation and pricing	11
Improve water conveyance system efficiency	
Minimize irrigation water losses , e.g., switch open canal systems to a pressurized pipe system	1
Establish a climate change unit	
Actions to prevent sudden impact on crops as frost and high temperature impacts related to Climate Change	1
Drought forecasting, and drought management and desertification control	2
Establish/extend climate information systems for irrigation water management	3
Capacity building and Training	4
Conducting climate change research including evapotranspiration reduction techniques and generating local crop coefficients	5
Water use association	
Farmers involvement in water supply management and understand the water budget available	1
Assisting and training water users for proper operation and maintenance of the system and for efficient use of water	2
Technology transfer and knowledge	
collect analyze distribute technical and scientific data suitable for Jordan conditions	1
Establish an integrated irrigation advisory services unit	2
Research and development	3
Monitoring program on water use efficiency	4

Irrigation with marginal and treated wastewater (TWW)	
Ensure a sound monitoring system when using treated wastewater in irrigation	1
Activate standards for wastewater discharges to sewers, treated effluent and water for irrigation uses	2
Use of all non-conventional water resources along with introducing and enforcing national standards to evaluate irrigation water quality	3
Introduce water Quality improvement e.g., desalinize brackish water, use solid water, magnetizing water, greywater, cloud seeding, fog harvesting, etc.)ity improvement technology such as softening	4

6.3.3 Land Resources

The following Tables (30) and (31) represent the adaptation measures to climate change risks on food productivity related to land resources in terms of priorities and ranking

Adaptation measure	Socio-economic	Institutio-nal	Financ-ial	Tech-nical	Environ-mental	Time frame	Total
	8	**5**	**5**	**5**	**4**	**3**	**30**
1- Improve and strengthen agriculture related laws mainly Land use laws	7	4	4	4	4	2	25
2- Land Development Projects as Soil conservation projects	8	4	3	4	4	3	26
3- Improve and extent dry land farming	8	4	3	4	4	3	26
4- Lease government lands	8	3	2	3	4	2	22
5- Enhance new land reclamation	7	3	2	3	4	1	20
6- Shifts in crops production areas	6	3	3	3	2	1	18

Adaptation measure	Priority
Land Development Projects as Soil conservation projects	1
Improve and extent dry land farming	2
Improve and strengthen agriculture related laws mainly Land use laws	3
Lease government lands	4
Enhance new land reclamation	5
Shifts in crops production areas	6

6.3.4 Livestock Production

The following Tables (32) and (33) represent the adaptation measures to climate change risks on food productivity related to livestock production in terms of priorities and ranking

Adaptation measure	Priority

Adaptation measure	Socio-economic	Institutional	Financial	Technical	Environ-mental	Time frame	Total
	8	**5**	**5**	**5**	**4**	**3**	**30**
1- Increased the feed productivity	8	5	5	4	3	2	27
2- Water harvesting	8	5	4	4	2	2	25
3- Livestock heath	8	5	3	4	3	2	25
4- Genetics and breeding	6	4	3	3	3	2	21
5- Institutional changes and policy changes	5	4	3	3	3	2	20

Increased the feed productivity	1
Water harvesting	2
Livestock heath	3
Genetics and breeding	4
Institutional changes and policy changes	5

6.3.5 Socioeconomic

The following Tables (34) and (35) represent the adaptation measures to climate change risks on food productivity related to socioeconomic in terms of priorities and ranking.

Adaptation measure	Socio-economic	Institutional	Financial	Technical	Environ-mental	Time frame	Total
	8	**5**	**5**	**5**	**4**	**3**	**30**
1- Mutual insurance against climate-related loss of crop yields	3	2	4	2	3	1	15
2- Public awareness	6	3	5	3	3	3	23
3- Community participation	5	3	4	3	3	2	20
4- Enhance community stabilization and stop internal immigration	7	4	4	4	3	2	24
5- Supporting water harvesting measures	8	5	4	4	4	3	28
6- Applied research to prepare farms for changing climate	7	4	4	4	4	2	25
7- Provide extension services to help farmers to cope with climate change	7	3	4	3	4	3	24

Adaptation measure	Priority
Supporting water harvesting measures	1
Applied research to prepare farms for changing climate	2
Enhance community stabilization and stop internal immigration	3
Provide extension services to help farmers to cope with climate change	4
Public awareness	5
Community participation	6
Mutual insurance against climate-related loss of crop yields	7

6.4 Conduct Adaptation Measure Test

This study represents an attempt to collect and integrate multidisciplinary information, directly and indirectly relevant to the impact and adaptation measures to climate change in Jordan. The study discusses the following core elements related to climate change impacts on food production in Jordan and possible adaptation measures

- The observed climatic trends in Jordan;
- Possible socioeconomic impacts of climate change: temperature, rainfall, and variability;
- Proposed adaptation measures for dry farming and irrigated agriculture in the light of the major climate change impacts that are projected for the coming decades;
- Policy implications which would help Jordan adapt to climate change while advancing socio-economic development aims; and
- The needs for further research on areas that contribute to long term adaptations and for efficient and effective planning of future research programs on climate change.

The agricultural adaptation measures involve various 'stakeholders' with different, yet often inter- related points of view. In order to evaluate and promote practically the possible adaptation measures, it is necessary to recognize which players are involved and what their roles are with respect to the adaptation. This includes the private decision – makers (farmers) and public adaptation decision makers (government). Although the adaptations are not necessary independent of each other, and often have inter – related roles in the adaptation process.

To evaluate and validate the different options for adaptations and their applicability for different agricultural areas, the study is based on the following:

① **A refereed review of literature to achieve the following**

- To compare the projected climate change in Jordan as reported in the First National Communication to the United Nations Framework Convention on Climate Change (UNFCCC), the Second National Communication to the UNFCCC, and the literature review on the Jordanian climate change to arrive to a description of the observed climatic trends in Jordan in the last decades, and projected climatic trends in Jordan in the coming decades;
- A general review on the assessment of the implications of global climate change for agriculture;
- A review on the socio economic implications of the climate change, impact, vulnerability and adaptations, policy implications of the climate change, and previous relevant research conducted in Jordan and in neighboring countries with similar agro-ecological conditions;
- A review on the state of agriculture in Jordan under rain-fed and irrigation during the last 20 years based on secondary sources, i.e.,

previous studies, and publications of the Department of Statistic to put the proposed adaptation measures into context.

② **A number of Jordanian agricultural experts, researchers and leading farmers, including the NCARE, General Director of the Department of Metrology, were interviewed and referred by name. The aim of the interviews was:**

- To identify the likely impacts of climate change on natural resources and farming activities; and
- To evaluate and validate the potential adaptations in the local contexts through their experience and the knowledge they generate through their ongoing research activities in the NCARE and universities.

③ **A focus group interview in the Jordan Valley was organized** with well experienced farmers who have long experience in the local conditions to assess the possible impacts and evaluate and validate the different options for adaptations. Drought is a normal part of a highly variable climate in Jordan. The aim of the interview was to discuss issues related to climate change such as increase in temperature, low rainfall, delayed winter rain, short rainy season, and extreme climate conditions, supply and quality of irrigation water in the last two decades and their projections for the coming years and the effects of these variables on agricultural marketing and pro1fitability of production to analyze and evaluate the likely impact and the potential adaptation measures.

Some of the adaptation measures are known to some farmers, and already experimented by some of them as presented in the study. These include technologies related to the protection against extreme weather, shortage of water, use of treated water, water harvesting and desalination to facilitate the maintenance and protection of rural areas during the periods of increasing climate stress and for early recovery of agriculture and long term sustainable production.

Based on the above strategic approaches, developing needed adaptation measures for food productivity in Jordan, conducting and testing the adaptation measures to select the appropriate ones were achieved. The methodology followed for selecting the adaptation measures is well presented in the deliverables from **3-5** annexed to this study.

6.5 Adaptation Scenarios for the Agricultural Sector

Three broad policy level adaptation strategies are suggested; adaptation in water allocation policy, in land policy, and improvements in agricultural technology

The goal of adaptation is assumed to be to maintain agricultural production in Jordan. We analyze the effects of climate change with and without the adaptation policies to see whether, and to what extent, policies can offset the impacts of climate change. A variety of potential adaptation actions and strategies exist (**See Table 36**). These three have been selected as illustrative of likely/realistic responses in three policy areas. Alternative perspectives would include other policy objectives for adaptation, e.g. ensuring sustainable production, or maintaining rural employment. The three areas identified for adaptation policies include many types of responses (e.g. across different scales, national or local programs, regulations, laws, 'hard' or 'soft', new technologies). It is unrealistic for this scale of analysis to quantify the details of adaptation strategies

We therefore use three broad level policies to put in a nutshell the details implicitly. For example, within the water sector, adaptation may turn on irrigation technology/efficiency, water demand management and large scale infrastructures such as the water transfer scheme and Jordan's extensive reservoir construction program. These developments and the future socio-economic decision making context in adaptation have major implications for water availability for agricultural purposes.

6.5.1 Results without Adaptation:

- Climate change produces negative effects on Jordan's potential agricultural production;
- Climate change combined with reduced water availability or the quality of water available for irrigation due to demand from sectors other than the agricultural sector would eventually produce a significant decrease in the farmed area that can be irrigated;
- Water availability will act as a significant limit to national total production in the future. The declining water availability for agriculture decreases the irrigated area; and
- Land use change leads to negative impacts on total production.

6.5.2 Results with Adaptation

The effects of three broad-level adaptation policies (in water, land and agricultural technology) were addressed. Allocating available water preferentially to non agricultural sectors could mean that less water is available for agriculture (e.g. cash crops and livestock) purposes. Much greater potential for adaptation in water use exists through e.g. efficiency gains and technology improvements.

- A combination of adaptation in water and land conservation policies offsets the negative impacts on production;
- Adaptation based on sustained improvements in agricultural technology results in significant increases in agricultural production. Only improvements in agricultural technology enable production to keep pace with population growth and to offset the negative effects of other drivers to maintain existing levels of production. Given the uncertainties in the climate change, the results will be affected by differences in precipitation patterns, extreme events and adaptation of agronomic practices.

For agricultural production in Jordan, water availability is a critical factor, and linkages between agriculture and water (management) policy will be critical for effective adaptation. There is a clear need to improve projections of future water availability.

Table 36: The three adaptation policy responses and their assumptions

Adaptation policy	No adaptation	Adaptation policy assumptions
Adaptation in water allocation policy : prioritizing water for agriculture	Without adaptation, we assume that all sectors have equal access to water according to the size of their demand relative to projected total demand.	Future national food supply is prioritized and, in line with current water allocation practices, agriculture is given the highest priority for water use after domestic demand has been satisfied.
Adaptation in cultivatable land : conservation of land	The current decline in cultivated land is assumed to continue in the future based on the rates of change observed in 1995–2009 (Table 10).	Implementation of policies to limit loss of arable land is successful through water harvesting and land development projects.
Adaptation in agricultural technology: continued improvement in agricultural technology	No assumption is made about increases in crop yields due to improvements in agricultural technology.	Considerable potential exists to continue making increases in crop yields. A half of the annual rates of change in yield due to technology improvement between 1975–2010 may be applied from 2011 to 2050.

7. AGRICULTURAL ADAPTATION to CLIMATE CHANGE; SOCIO ECONOMIC POLICY IMPLICATIONS and RECOMMENDATIONS

Climate change and management options need to be considered in government programs and policies. This will ensure that government initiatives do not prolong or aggravate climate-related damages, but encourage timely and effective adaptations in the agricultural sector. Such action may not require creating new programs and policies focusing on climate change, but may simply entail having climate change risks and adaptations incorporated, where appropriate, in existing programs or program reviews.

Adaptation to climate change and variability has occurred in the past and is occurring now. Local societies in Jordan and neighboring countries have always adapted to variations in climatic conditions (short droughts, longer drier periods and so on…), but not in specific or coordinated ways. Some regions have particularly variable climates, but none are immune from variability and most have witnessed long traditions in water shortages and drought conditions.

The negative effects of global warming, such as heat waves, storms, floods, changes to rainfall pattern, shortage of water and soil degradation, have potentially major implications for life essentials, i.e. food, water, land and the environment. Agriculture and human well-being will be negatively affected by climate change. Crop yields will decline, production will be affected, crop and meat prices will increase, and consumption of cereals and other crops will fall, leading to reduced calorie intake. Thus, climate change will have significant impacts on agriculture and human health, calling for an institutional and policy change to enable effective adaptation and mitigation to climate change. It is the role of the government to ensure that farmers, especially in the marginal areas, are not left without defenses against negative climate change impacts.

To be able to take decisions on how best to adapt, it is essential to have access to reliable data on the likely impact of climate change, the associated socio-economic aspects and the costs and benefits of different adaptation options. More knowledge is needed on climate impact and vulnerability so that appropriate policy responses can be developed. There is a range of possibilities for policy and institutional change and the ways in which institutions might react. The right combination will be context dependent, and implies different challenges of adaptation and reactions.

To enable adaptation, the Government are confronted with the following: whether climate change represents a new order of challenge for policy and institutional change, compared with existing variability and the broader agenda of sustainable development and identification of actual and possible reform options that would enable adaptation; how to adapt, in terms of specific, on-ground actions and the policy and institutional mechanisms to enable these actions and what guidance is available regarding institutional and policy design. The full range of possible adaptations to climate change include those that are autonomous in the sense that they can be done within the existing institutional and policy regime and those that might require changes in current institutions and policies for their development.

Uncertainty pervades adaptation and presents assessors and policy makers with difficulties. It is difficult to plan for and justify expensive projects when the magnitude, timing, and even the direction of the climate changes are unknown, especially on smaller regional scales such as in Jordan. How much adaptation is needed and/or justified is difficult to answer given uncertainties surrounding shifts in climate variables to enable adaptation. Hamdi, et. al. (2009) indicated that there are no visible trends indicating an increase or decrease in the annual precipitation and maximum temperature. A proactive policy response could be argued on the basis of the precautionary principle. It is often stated that early adaptation will be more effective and likely cheaper than delay. If so, then it would make sense to seek pragmatic, existing and thus quicker mechanisms for policy and institutional change.

Agricultural adaptation to climate change requires support on the part of the government in major areas. These areas include programs and policies, i.e. for promoting water harvesting measures and afforestation activities, technology research and development, availability of agricultural extension services, climate risk reduction programs and public education policy. Fiscal policy can encourage more efficient use of land and water resources, thereby promoting their allocation to more climate-resilient uses. Raising public awareness of the problem of climate change contributes to building public support for climate policies and community participation.

7.1 Policy Formulation, Implementation and Review

A strategy consists of a combination of policy instruments which reinforce one another in meeting the objectives and in overcoming barriers. It is a tool with which long-range future plans and courses of action (activities) are constructed and a means to achieve objectives within existing parameters of law, policy, and governance. Single policy instruments will rarely be sufficient; rather portfolios of approaches are needed. The design of these is challenging such as environmental policy. Formulating strategies involve adopting policies and translating them into programs and operational activities. Policies act as guidelines; enabling decision makers to achieve their goals. They are general statements that guide the process of decision making. The statement of issues will provide the basis for the formulation of a set of goals and objectives, designed to address the problems identified and to exploit the opportunities which present themselves. Policy instruments are the tools which can be used to overcome problems and achieve objectives.

Commitment from the highest decision maker's hierarchy is essential in the planning and eventual implementation process. Commitment and support of the strategic-planning initiative must spread at all levels of decision making. Each component of the strategy needs to be discussed with community and government stakeholders to ensure that local communities understand, contribute to, and support objectives for their community, and that the strategy has the backing of the government stakeholders important to its implementation. Effective participation can help reduce the difficulty of institutional and political barriers, and encourage joint action to overcome them.

A strategy objective is to conserve natural resources by way of vulnerability reduction and enhancing adaptive capacity to climate change. To make this strategy operational, policies need to be adopted; adaptation measures and projects are planned, prioritized, and proper finance and Implement-
ation arrangements are made.

Policy formulation involves policy design, development, Implementation and policy review:

Policy formulation: This has to be based on an adequate and up to date social, environmental and economic data base, and be evaluated in light of the existing policy, legal, and institutional framework. The challenge is to understand the information needs, to assess impact and vulnerability, identify and analyze the various policy options (the means) which can be applied to achieve the set of goals and objectives (the ends). That is, it is important to consider the ends before selecting the means to achieve those ends in analyzing and policy formulation.

Objectives needs to be specific and technically measurable, for example: to reduce quantity of water for irrigation by 20%. The objectives must be exhaustive, in that they cover the whole range of activities, provide sufficient information to decision-makers, and be sensitive to changes in the strategies that are tested. Objectives, however, are abstract concepts, and it is thus difficult to measure performance against them. Indicators are ways of quantifying objectives or sub-objectives. Indicator system includes environmental, social and economic indicators. Types of indicator include **(a)** input indicators: expenditure, resources consumed, **(b)** output indicators: actions taken (to measure what has been done), **(c)** intermediate outcome indicators: describe how the system is responding to changes in cropping or land use patterns and **(d)** outcome indicators are the most informative, since they measure directly performance against the specified objectives.

Assess opportunities and threats/ barriers: SWOT analysis for the internal and external environment may be carried out, to evaluate strengths and opportunities.

Implementation: An implementation program for realizing the policy recommendations must then be prepared, addressing budgetary and programming requirements, allocation of resources towards performance of those activities, and allocating roles and responsibilities to be sure that the necessary resources in place to make the strategy and policy achievable Resources are likely to include dedicated staff time, and training for staff.

Monitoring: It involves establishing a control mechanism to determine whether actual performance is consistent with the strategies and policies formulated. The implementation of the policy needs to be systematically monitored and evaluated against the stated goals and objectives, and the various components of the policy modified or strengthened, as required.

7.1.1 Translating Strategy into Action

Central to the problem of coping with the adverse impacts of climate change is the translating of strategic objectives into action at the operational level through policy management. Translating strategy into action policy management is concerned with four primary tasks; it focuses on establishing main objectives, translates them into activities and daily operational activities and provides for a structured review of their progress (strategies ⇨ policies ⇨ activities).

The operational strategy outlines three categories of activities:

- Enabling activities which generally cover planning and capacity building, e.g., institutional strengthening, training, research, education and implementation reports;
- Adaptation activities to cope with climate change impacts; and
- Mitigation measures for reducing GHG emissions over the long-term.

7.1.2 Operational Programs

Operational programs are designed around ecosystem/agriculturalzones types which include:

- Mountain ecosystems; these projects target mountain ecosystems and support sustainable land use of mountain slopes (9-25%);
- Forest ecosystems; these projects in public land (mostly >9% slope), involve establishing and strengthening systems of conservation areas, and demonstration and development of sustainable use methods in forestry. Projects will focus primarily on forest ecosystems that are at risk; and
- Arid and semi-arid ecosystems; these projects use integrated approaches to the conservation, sustainable use, and rehabilitation of dry land and the arid ecosystems.

7.1.3 Policy Review

- Output indicators can be of the following types(the Highland Development Project (HDP) as an example):

    ×***Effectiveness*:** the extent to which the objective has been achieved or the likelihood that it will be achieved; i.e. the conservation structures were effective in protecting soil from erosion and storing moisture; water harvesting measures were effective in bringing more water to the root zones of the trees.

    ×***Efficiency***: the outputs in relation to inputs, costs, implementing time, and economic and financial results, i.e. undertaking the types of soil and moisture conservation measures that are effective with the lowest cost, and the activities are financially feasible (i.e., long term benefits exceeds all costs).

- Outcome indicators measure the success of adaptation strategies; coverage, impact, sustainability and replicability:

    ×***Coverage*:** the extent to which the HDP reached vulnerable farmers to climate change in the highlands areas with annual rainfall above 250 mm, and the targeted ecosystem, i.e. areas with 9-25% slope;

    ×***Impact***: the extent to which the HDP reduce the vulnerability, i.e. impact of climate change under drought conditions, and enhance adaptive capacity through undertaking soil and moisture conservation, water harvesting measures and planting fruit trees resistant to dry conditions;

- ***Sustainability***: the ability of farmers to continue to maintain the conservation structures in their farms beyond project lifetime, thereby sustaining development benefits;

- ***Replicability***: the extent to which the HDP project activities are imitated in other, similar areas with annual rainfall above 250 mm, and 9-25% slope.

- Evaluation methods include performance under climate change impacts (e.g. in case of lower rainfall, higher temperature or an extreme event; the overall impact in the developed area is lower than undeveloped areas);
- Sound evaluations involve careful examinations of success, relative to what was expected:
  - Have the negative impacts of climate change continued, or grown worse because the adaptation was ineffective or controlled (i.e., the adaptation was effective);
  - Have the project activities enhanced coping with climate change; and reduced sensitivity to extreme events, has it worked, and how?
- The root causes of both successes and failures of the adaptation strategy, the project contributions and cross sectoral implications should be analyzed through detailed evaluation (i.e. through a survey among the population, expert interviews, site visits, etc).

7.2 Major Policy Areas

Agricultural adaptation to climate change requires support in three major areas:

7.2.1 Programs and Policies

Climate change and management options need to be considered in government programs and policies. The question is how to integrate considerations of adaptation into policy and institutional systems at national and regional levels, consistently rather than in fragmented ways. This will ensure that government has proactive climate change adaptation strategies, and its initiatives contribute to the reduction of climate-related damages, and encourage timely and effective adaptations in the agribusiness sector. Agribusiness investment, know-how and technology will be essential to respond to the challenge of adapting to climate change. Such action may not require creating new programs and policies focusing on climate change, but may simply entail having climate change risks and adaptations incorporated, where appropriate, in existing programs or program reviews. Thus, *there is a need to incorporate climate change adaptation into the Jordanian agricultural policy of 1997 (MOA, 1997)*. Some degree of future climate change will occur regardless of how stringent future mitigation policies will be. Adapting to or coping with climate change will therefore become necessary in certain regions and for certain socioeconomic and environmental systems. Efficiency and cost-effectiveness of measures and win-win policies should be key considerations for policy makers.

7.2.2 Research

Agricultural agencies, particularly NCARE need to establish and support targeted research programs for agricultural adaptation to climate change. It is ideal for such research to be established and supported by public agencies, agribusiness organizations and regional and international agencies (GEF, UNDAF, and international compensation fund to support disaster mitigation and preparedness at the seventh conference of the parties to the UNFCCC in 2001).There is a case for maintaining a broader policy and research agenda of sustainable development, to ensure coordination of policy and institutional responses to climate change and other major sustainability issues.

7.2.3 Communications and extension

Communication about climate risk management and effective adaptation strategies needs to promoted and facilitated among researchers, extension agents, producers, and policy makers. Researchers need to take advantage of the wealth of knowledge about climate risks and adaptation opportunities in their fields of specialties. Progressive farmers have more adaptive capacity to climate change such as shortage of water and extreme weather conditions.

7.3 Policy and Institutional Recommendations

The following adaptation measures for climate change are recommended. The availability of human, financial and technological resources is essentialfor developing and implementing these measures within the national institutional and legal frameworks:

7.3.1 On-farm Management in a Changing Climate

7.3.1.1 Preparing Farms for a Changing Climate

Drought damages can be reduced by supplementary irrigation, improving irrigation infrastructure or improving farming techniques. As temperatures and precipitation levels change, the NCARE can provide agricultural extension services (public education and technical support) to help farmers cope with climate change.

The amount, intensity and frequency of rainfall prescribe planning of suitable crops and carrying out farm operations consistent with the rainfall patterns. These include:

- Adjusting cropping systems; planning cropping patterns consistent with rainfall patterns; choose new crops, i.e. plants resistant to droughts;
- Breeding stress-resistant varieties;
- Selecting high value crops for maximizing the income;

- Adjust planting seasons / sowing times according to the probable rainfall so that drought sensitive stages of growth do not synchronize with periods of inadequate rainfall;
- Timing other farm operations such as tillage, fertilizer application, applying insecticides, and fungicides and herbicides etc, in relation to rainfall probability periods;
- Following mixed cropping of shallow and deep rooted crops for full exploitation of stored soil moisture;
- Developing bio-technologies and other adaptive measures, to protect agricultural land degradation, desertification and salinity;
- Avoiding floods through erosion control and reforestation;
- Proper land management, water harvesting and improving rainfall use efficiency in dry land farming are of utmost importance, given that about one third of the number of holdings, and two thirds of the rain-fed land in farms (Table 9) receive less than 350 mm of annual rainfall;
- Adopt a more efficient use of water and water saving technologies;
- Irrigation based on water requirement for crops; and
- Use of grey water as the Water Strategy (MoWI, 2009) envisages allocating more than a third of the water requirement of agriculture (39%) in the form of treated water.

7.3.1.2 Agro-climatic Zones

Knowledge of the distribution of holdings by rainfall zone, and by governorate helps to identify areas most vulnerable to climate change, and where policy measures are needed to modify land use, and where measures to staff and to improve extension services to help farmers improve their farming practices and land management are most needed. Information such as 80% of farms in the less than 200 mm are located in the southern governorates helps in adopting policy measures to modify land use and to improve extension services.

More than 40% of the area and one quarter of holdings under rain-fed farming receive less than 250 mm of rain, which cannot support dry farming. This is an indicator of the absence of guiding policy, which aims to use land according to its capability.

Fruit growing is largely olives under rain-fed conditions, and in more than 350 mm zones. Field crops (mostly wheat and barley) are almost entirely under rain-fed conditions, and two third were in the less than 350 mm zones. Rain-fed vegetable were more likely to be small, and grown in summer in the higher rain-fall areas, while irrigated farms were significantly larger, and more likely to be in the low rain-fall zones. As a general rule, small farms are located in the high annual rainfall areas, or under irrigation in the Jordan Valley, whereas the large farms tend to be found in the marginal lands in the arid areas, where underground water is available and if the farms are irrigated.

7.3.1.3 Land Use Policy

The main objectives of land use policy are to use it according to its capability which in turn will increase agricultural production, protect the soil from erosion and maintain an ecological balance. With the climate change, limited land resource base and improper land use, protecting soil from erosion is of utmost importance in addition to the highly positive effects on the environment.

Improper land use contributed to the deterioration of the rangeland and to major soil erosion problems. Ploughing arid lands to be used for wheat or barely production may produce a good crop once in every 5 years, but it destroys the life cycle of weeds. Similarly, overgrazing in the range land has also contributed to the same negative effect. Hence, regeneration capacity of grass would be substantially reduced, and the most needed animal production will be hampered. Besides, the soil will be subjected to water and wind erosion which reduce its fertility, and adds to the desertification problems.

Lands with slope between9-25 represent more than 60% of the cultivable lands (Table 4).Growing grains on hilly lands, increase soil erosion substantially through frequent disturbance of soil. The practice of tilling the hilly lands against the contour lines accelerates erosion. Forest and fruit trees require less soil movement, the roots hold the soil, the green foliage reduce the intensity of rain, and hence soil capacity to hold moisture will be enhanced. Thus, hilly lands (9-25% slope) are most suitable to fruit trees, and hilly lands with higher slope (>25% slope) are most suitable to forest trees, if proper, drought resistant trees are selected.

Against this background, several land development projects were basically designed to achieve more proper management of the limited natural resources, soil, water, forests and range-land. The ultimate objective was to create a secure long term basis of existence for the population through improvement of its agricultural potential, especially under climate conditions.

The broad guidelines of this long standing land use policy, which have to be put into effect, can be summarized as follows:

- In rain-fed areas with an average annual rainfall *below* 250 mm, the policy is to use flat areas (< 9% slope) with 200-250 mm rainfall for barley production, which is the only feasible crop under these conditions, and to use areas below 200 mm for grazing. Projects implemented in this area are mainly range development to promote meat and dairy production. However, crops production is possible in low lands (*marabat*) where water is naturally accumulated.

- The use of areas with average annual rainfall over 250 mm depends on the topography of the land.
  - Flat farms or semi-flat with good soil and less than 9% slope, are encouraged to be used for field crops;
  - Farms with slope between9-25 were actively encouraged to grow fruit trees.

- For areas under irrigation, the policy is to use these lands according to the following guidelines:

- To use land with less than 9% slope for field crops and summer vegetables production;
- To use land with slope between 9-25% for planting fruit trees, this is the best use under the local conditions.

Several projects were implemented to promote fruit production and to control soil erosion.

Most of the rain-fed hilly area in the highlands was reclaimed by land development projects of the MoA, and are largely planted with fruit trees through these projects, and olives accounted for 85% of the fruit area in the highlands in 2009(DOS, 2010). The general objectives of these projects were to conserve soil and moisture, planting fruit trees in the private hilly lands.

Farming practices promoted by the project were technically sound, economically feasible and could be performed within the capability of the average farmer.

The government of Jordan has long viewed highland development activities as an effective adaptation strategy for stabilizing rain-fed farming systems through implementing land development projects.

To use public land with slope over than 9% for afforestation. The government, through direct involvement, has implemented several afforestation projects throughout the country (with annual rainfall over 250 mm) during the last five decades. Estimates indicate that the afforested area is equivalent to the natural forest, together they occupy more than half of the registered forest land (130 thousand ha; MoA website), which isabout one percent of the total area of Jordan. The agricultural policy stresses the need the need to enact legislation and adequate implementation of agricultural policies to ensure the preservation and protection of forest lands (MoA, 1997).

About two thirds of land in farms (67.6%), and one third of the rain-fed holdings (as Table 9 shows) are located in the less than 350 mm zones, the most vulnerable to adverse climate changes (Rimawi 2009). This makes increasing the effectiveness of rainfall to increase production per units of land, of utmost importance. The approach to increasing effective rainfall in agriculture includes:

Land and soil management

- Reducing surface run-off; this is achieved by altering the topography of land through land grading and levelling, erecting barriers to the flow of water such as terraces, and by increasing the opportunity for infiltration through retaining crop residues after harvest;
- Increasing infiltration; this is achieved by improving the soil structure through initial deep ploughing, sub-soiling or breaking hard pans, or condition at the surface, as well as in the subsurface, through adding organic matter and soil conditioners to improve the texture of the growing pasture or grass legume mixtures and using mulches to prevent breaking of aggregates which seal the soil surface. Organic materials give far more lasting improvements in soil structure;

- Minimizing percolation losses; this can be achieved by practices such as increasing the water holding capacity of light textured soils by the addition of clays or organic matter, if this is economically feasible, and indirectly by extending the root zone though selecting deep rooted crops; and
- Building water storage structures; these can be constructed at suitable places and are very useful to collect run-off water for use during periods of low rainfall at critical stages of crop growth.

7.3.2 Livestock adaptation strategies

According to Thornton et al (2008) the following measures have been adapted by several experts (FAO 2008), Thorton et al 2008, and sid Ahmad 2008) to promote adaption in the livestock sector:

7.3.2.1 Production adjustment by :

- A diversification, intensification integration of livestock and pasture;
- Changing the land use by irrigation;
- Changing and altering the agricultural operation;
- Conservation and enclosure the range;
- Changing the management of grazing , destocking and routine movement; and
- Introducing forage livestock feeding especially for dairy farms

7.3.2.2 Breeding strategies: (Hoffman 2008) mentioned that adaptation strategy should address the tolerance of animals to heat stress and also their ability to survive, grow and reproduce in condition of poor nutrition, parasites and diseases. the measures to be taken include:

- Identifying and strengthen the local breeds that are adapted to climate change and feed resources; and
- Cross breeds with other breeds that are tolerant to heat stress and to certain disease.

7.3.2.3 Market responses: This is by promoting the local production in the local market or through interregional areas especially foe the meat which is preferred in the area. The Awassi and Shami goat meat and for the local white chesse should be studied.

7.3.2.4 Institutional and policy change:

This includes the subsidies, insurance system, income diversification and early warning system.

7.3.3 Water Resources

7.3.3.1 Maintaining Water Infrastructure

Maintaining and improving existing water infrastructure in the context of current and future temperatures and precipitation levels are "no regrets" measures because the advantages of investment appear to be justified in the current climate conditions and would help with adaptation to future climate change.

Maintaining water infrastructure (dams, water channels….) produces profound results: an expansion of irrigated agricultural land; increased economic security for farmers during times of drought; and protection from future climate impacts that will decrease the supply of water while increasing the demand for these utilities.

7.3.3.2 Promote Water Efficiency

The 2009 water strategy (MOWI, 2009) stressed the rational development and optimized allocation of water resources, and strengthening measures for water conservation and hydrological monitoring. With the ongoing growth of population numbers, attention should be given on how to manage demand in order to minimize use and exploitation of the resources. Reducing demand is an important step towards avoiding the water shortages made more likely by climate change. Policies or taxes should be introduced that cut waste and constrain demand. Besides, achieving more efficient utilization of agricultural irrigation water by introducing mechanisms for farmland water conservancy help to cope with climate change. The Government can promote efficiency through using monetary incentives, free equipment, public education, regulations on new building designs, and providing technical support. This is a "no regrets" measure because it would save money and resources in the near and long term as well as increase the well-being.

7.3.3.3 Independent Water Cooperatives

The focus group in annex (1) mentioned that Independent water with lower quality of water if farmers are provided with enough quantity cooperatives can cope of water, and be allowed to organize themselves in an independent cooperative to treat or modify the quality of water[68].

7.3.4 Forest Management in Climate Change

7.3.4.1 Promoting Forest Preservation Activities

Jordan has a longstanding policy for promoting afforestation and strengthening natural forest conservation and nature reserve management. In the past six decades, thousands of hectares of trees have been planted every year with financial support from the government and UN agencies, particularly World Food Program. Besides, the MoA also encourages citizens, civil societies and public agencies to take part in tree planting. A well publicized basic rational for adopting this policy was for strengthening the capacity of carbon sinks.

Yet, further efforts are needed to conserve forests by funding eco-protection projects, reforestation, acceleration natural ecological restoration, establishing important ecosystems and reserve areas to protect threatened species, pest management, erosion control, water harvesting and fire-risk reduction. As climatic zones shift, careful management and replanting can prevent the creation of dead

[68]Focus Group Interview with progressive farmers in the United Farms Society at the Jordan Valley on October 20, 2010.

zones. Providing alternative sources for heating (olive cake residues, subsidized fuel) contributes to protecting forests from use of firewood.

7.3.4.2 Forest Fire Management

Forest adaptation to climate change requires support in the following areas:

- Implement a training program for the firefighting officers, forest guards and local stakeholders about forest laws and forest fire management and prevention;
- Establish fire prevention and fighting management plan for forest fire risk areas. This would include undertaking specific prevention measures in the sensitive forest areas such as cleaning, pruning and establishing of fire breaks;
- Provide fire fighting tools and equipment for early intervention in fire fighting; and
- Organize awareness activities and public events to increase locals' involvement in the prevention against forest fires.

7.4 Building Adaptive Capacity: Research, Communications and Extension

7.4.1 Support Essential Research Needs

- Climate-change-related research should be promoted. With the limited agricultural resource base, further agricultural development under unfavourable climate change will have to be based on more efficient use of resources and the adoption of improved practices to achieve higher productivity. Sstrengthening basic research on climate change is a basic adaptation policy measure. There are numerous gaps in Jordan research that – if filled – would reduce uncertainties about likely climate impacts and, therefore, would reduce the costs of climate adaptation. Adaptation measures, however, are specific to particular locations and situations. Thus research and adaptation practices need to be tailored to each case and developed to fit each farming situation.

- In the rain-fed areas, some of the main research issues are the basis for the development of grain, fruit trees and livestock sub-sectors;
  - Water harvesting;
  - Use of conservation agriculture approach; improved or reduced tillage practices to conserve soil and moisture, managing the top soil to create a permanent organic soil cover and the practice of crop rotation;
  - Drought resistant varieties of grains and fruit trees seedlings; and
  - Better range management and veterinary services.

- In the irrigated areas, some of the main research gaps are;
  - Crop water requirement;

×Water quality and use of treated water as more treated water will be allocated to agriculture according the water strategy 2009;
×Rational fertiliser application based on soil testing; and
×Disease and pest control.

7.4.2 Communications and Extension

Communication about climate risk management and effective adaptation strategies needs to be promoted and facilitated among researchers, producers, and policy makers. Some researchers are beginning to use the wealth of knowledge of producers, but there is much to learn. Research findings about climate risks and adaptation opportunities have to be communicated to policy makers, producers, and to agribusinesses.

Promoting applied research and providing effective extension services are given higher priority by the Government based on the adoption of national strategies for research and extension were adopted. The National Centre for Agricultural Research and Extension (NCARE) is responsible for the identification, testing, adoption and transfer of technical information, and to coordinate with all research institutions in Jordan. The NCARE provides technical backup for extension agents, training of extension personnel, provides technical information for printed materials, and organize on-farm trials in cooperation with the extension agents(MOA, 1996, 1998). It is to be noted that some adaptive research is undertaken by the private input supply companies to promote their sales of seeds, fertilizers and pesticides.

The extension organization provides a linkage between researchers and producers to orient their research work towards farmer's problems, and to keep them well informed about the results and problems created rom adopting new technologies. Efforts need to be made to make sure that technologies to be transferred are technically and environmentally sound, and economically feasible to the farmer (MoA, 1998).

With the frequent dry years, the need for conducting experiments and demonstrations on using varied methods of water harvesting, and promoting the use of water saving irrigation methods, is imminent. The culture of water harvesting should be gradually integrated into the farming practices. The water harvesting techniques have the advantage to increase the amount of water available for agricultural and other purposes, and to ease water scarcity in arid and semi-arid areas. They have the potential to increase the productivity of field crops and fruit tree planting and grazing land by increasing the yields and by reducing the risk of crop failure. They require relatively low input and, if planned and managed properly, can contribute to the sustainable use of the precious resource water. They are relatively cheap to implement and can therefore be a viable alternative where irrigation water from other sources is lacking.

- Socio-economic factors have to be taken into consideration. Traditional rules on the water and land rights influence strongly the development of the water harvesting scheme. Thus, scientific research has to be carried out in collaboration with farmers;
- As most farmers or herders practicing water harvesting are resource-poor, some intervention of state authorities is needed, e.g. financing the construction of small reservoirs; and
- Only, well established methods of water harvesting have to be used. Further research and experimentation is required before a certain method can be recommended.

Policy making with respect to land use, research and extension works should aim to supporting properly targeted farm operators and livestock owners with well founded, technically sound and financially feasible technologies for the varied agro-climatic zones and socio-economic groups of farm holders.

7.4.3 Provide Public Education

The public awareness of the importance of tackling climate change should be enhanced. People will have to be sensitized to the problems of water shortages and wastages. The Jordanian citizens have to be prepared for the unfavorable impacts of climate change and the need for water conservation to gain their support for adaptation measures. Thus, public awareness of the value of water and the actual pressure that is posed upon quality as well as quantity of the resource is crucial.

Public education should bring together stakeholders from academia, governments, NGOs and private sector. It involves awareness raising activities to provide information to the public in a variety of forms, through a series of workshops and conferences. *An awareness raising campaign "you control climate change" is proposed that would aim to inform individuals about their role in controlling climate change.*

7.4.4 Training

Achieving more proper management of the limited natural resources and further agricultural development under unfavourable climate change will have to be based on more efficient use of resources and the adoption of improved practices to achieve higher productivity.

Jordan aims to keep up with international advanced level in fields related to climate change, so that it will have solid scientific ground for drafting national strategies and policies on climate change, and in participating in international cooperation in this regard. Intensifying the training of professionals and decision-makers in relevant fields, and a well trained state supported extension service is a must, if new tools are to be successfully applied. Training is essential to strengthen the technical and managerial capacity of planning and operating staff on basic principles and practical aspects of different adaptation measures, formulating policies, project design and implementation.

7.4.5 Retraining Programs for Workers Who May Lose Jobs Due to Climate Change

The percentage of holders who declared that their main occupation was not farming increased from 35% in the 1975 Agricultural Census to 87% in 2007 Agricultural Censuses. Similarly, the percentage of holders who derive more than 50% of their income from farming decreased from 24% in the 1997 Agricultural Census to 18% in 2007 Agricultural Census. The trend is more evident in the highlands. This suggests the number of holdings cultivated by part time farmers were increasing (Rimawi, 2001, 2009). Most of the work in the farms is carried out by family, and male labour. Few hired permanent labour in the highlands. Thus, farming is largely a family business, but family farming is the norm in the highlands.

The farm structure is characterised by the dominance of small farms as Table 5 shows that cannot be expected to generate reasonable income to satisfy farm operators' needs, especially under the adverse impact of climate change. The options which are open to the farmers are to abandon their farms, leasing the land to other farmers, which would contribute to improving the productivity of land and its economic viability, or to resort to part time farming as full time farming cannot be expected to generate reasonable income from farming their land alone, and operators have to supplement their incomes by off-farm work.

Therefore, part time farming would be the most viable alternative opened to the holders under the rain-fed conditions and the present socio-economical and environmental considerations. Part time farming should be looked at as a way of adaptation to conserve the agricultural land, to protect the environment against the adverse impacts of the climate change, to improve the income of the rural population, and to curb the tendency to migrate from the rural to urban areas.

Job retraining may be necessary if industries like agriculture, food processing or forestry decline with climate change.

7.5 Supportive Policy Environment

7.5.1 Climate Change Forecasts

Improved climate forecasts are central to improved assessments of the impacts of climate change. Better forecasts are needed to evaluate whether and how the frequency and magnitude of events such as extreme heat, early or late frosts may change. There is a need to develop an early warning system that generate and disseminate regular weather predictions and seasonal forecasts in full cooperation with the Meteorological Department. Improving early warning mechanisms strengthens the capability of monitoring and forecasting meteorological disasters and enhances the capacity to monitor, warn about and cope with meteorological disasters, and reduce the damage from them. It helps local farmers predict conditions for agriculture. Actions that promote adaptation include integration of climate information into environmental data sets, vulnerability or hazard assessments and broad development strategies.

The NCARE is implementing a project for Information Management Irrigation System (IMIS) to establish a climate and agriculture data base. The system will help in planning and programming irrigation activities on the bases of climate information for irrigated areas, and to support research works for estimating water requirements. The NCARE compared the quantity of water used normally to irrigate onions in Der Ala / Jordan Valley (during the period 05-2008) and the quantity of water based on the IMIS climatic information. It was found that 60% of water can be saved when the irrigation program for the crop is based on climatic information[69]. Similarly, a unit for an early warning system of drought is established in the NCARE to assess the rainfall season, and to monitor drought conditions and the most affected areas[70]. Therefore, cooperation and coordination of such activities between DJM and NCARE is a key to the success of the system.

7.5.2 Crop Insurance

There is a need to empower people against climate change risks. Such policies can take the form of financial support to help manage risks or to develop a private insurance to reduce climate-related risks to farm-level production, private infrastructure and income. This includes supporting establishing mutual insurance against climate-related loss of crop yields. Such privately managed societies are sustainable if well founded and can reduce the risks of income loss.

Adaptation in agriculture includes government programs. Crop insurance and safety net programs are part of climate risk management. Government programs can facilitate adaptation, and they can also work against adaptation. Safety net programs include compensation and assistance programs and income stabilization programs. These programs should be based on regular small contribution of participating farmers. Government however, has to share programs which address the risk of farm-level income loss associated with disasters and extreme events. Other risk management measures include encouraging farm operators to diversify of the sources of household income in order to address the risk of changing climate conditions and variability.

Crop insurance and safety net programs are part of climate risk management. Government programs can facilitate adaptation.

7.6 Mainstreaming Climate Change Adaptation into Development Activities

7.6.1 Mainstreaming Climate Change

There is a need to set a national adaptation framework to assign the responsibilities of mainstreaming to the relevant public agency for the purpose of coordination of policy across sectors; public and community participation and macro and sector policies in development of project design and implementation. The agriculture policy (MOA, 1997) has to be amended to incorporate climate change adaptation into the Jordanian agricultural policy. The amended policy should serve as an ideal vehicle to promote sustainability of the agricultural sector with proactive climate change adaptation strategies.

Policy integration can be horizontal or vertical. Horizontal policy integration is coordination across sectors and involves responsibilities and actions across multiple agencies, and mainstreaming is an imperative. Many traditional structures exist—ministerial councils, cross-agency task forces, policy units in central agencies, national policies and plans for sustainable development, etc. Thus, mainstreaming through achieving policy integration add to adaptation. The adaptation literature stresses the need for community and

[69]Dr. Mohammad Jitan and others of the NCARE.
[70] Researcher Muna Saba and others of the NCARE

public participation in developing and implementing strategies, based on practical issues of effectiveness. Vertical policy integration is coordination across political and organizational levels such as national, governorate and local.

7.6.2 Integrating climate change adaptation in planning for economic development

The sustainable development and climate change are interrelated. Poor levels of human development constrain adaptive capacity and increase vulnerability; sustainable development can reduce vulnerability to climate change by enhancing adaptive capacity and increasing resilience. This calls for integrating climate change and sustainable development. By implementing mainstreaming initiatives, the adaptation to climate change has to be part of or consistent with other well established programs, for short or long term sustainable development planning. Examples include the HDPs and afforestation activities such as soil conservation, water harvesting measures and growing crops and fruit and forest trees more tolerant to drought. Low-cost structural and managerial modifications that ensure against the possibility of a range of climate-induced impacts should be sought.

It is likely that climate change can slow the pace of progress towards sustainable development, either directly through increased exposure to adverse impact or indirectly through erosion of the capacity to adapt. Development activities for promoting sustainability should either explicitly include adaptation to climate change impacts, or contribute to promoting adaptive capacity such as afforestation activities and water harvesting measures.

Other adaptive capacity that are consistent with sustainable development planning include adjusting building codes to the use of water saving networks, use of more tolerant trees and plants and use of grey water for the irrigation of home gardens and for the irrigation of plants within the urban areas.

7.6.3 Low or No Regrets Adaptation Measures

Some adaptation measures that do not directly aid economic development can be characterized as no-regrets because of their low or no costs and high probability of leading to much larger positive economic outcomes given changes in climatic conditions, or without which some of the potential climate damages will be much larger. Examples include reduced deforestation, controlling grazing and improved rangeland management.

Many of the best climate adaptation measures that Jordan can pursue are also important steps for economic development; these are “no-regrets” adaptation measures – no extra cost is imposed by climate change, or low-regrets measures for which the benefits of avoiding climate damages outweigh the costs of new infrastructure or other responses. They are measures that will improve economic and social outcomes regardless of climate change. These include climate adaptation that has to be incorporated in the long term in decision making with impacts decades away. Examples include water harvesting measures and growing crops and more tolerant to drought fruit and forest trees.

The agricultural policy and the national strategy for agricultural research (MoA, 1996, 1997, and MoP, 1999) calls for more environmentally sound and sustainable utilization of land for agricultural purposes. Measures included implementing projects which promoted soil conservation, afforestation activities, improvements of range management and countering desertification problems. These projects are "no-regrets" adaptation measures to climate change. They have contributed to the general national objective of increasing the area under vegetation, beautifying the rural areas, promoting internal tourism, and have helped in encouraging holders to remain in the rural areas and in reversing migration. These projects are perhaps the biggest contributor in promoting ecologically friendly agricultural production. Some areas have been almost fully terraced and planted with trees, which have positive environmental effects on the micro-climatic and general ecological status of the developed areas (the natural fauna, conserving water resources...).

7.6.4 Promoting Low-Carbon Economy

Jordan contribution to CO_2 emission is minimal. Thus, it is unlikely to be called upon to reduce its greenhouse gas emissions in the next one or two decades. Yet, Jordan is striving to mitigate greenhouse gas emissions through application of energy conservation technologies, enhancing public awareness of the importance of energy conservation, and accelerating the building of a resource-conserving society (MoE, 2009). Longer term global mitigation efforts will require lower per capita emissions from Jordan.

Possible mitigation measures include a wide range of issues, such as: improved farming techniques, minimum soil tillage, using cleaner energy, striving to increase the forest coverage and rangeland management to promote carbon sinks, the technology of application of fertilizers according to the results of tests of local soil, strengthening management of animal waste, waste water and solid waste, expanding the utilization of methane and conservation agriculture etc. However, many mitigation options entail additional costs to farmers, calling for cost-effectiveness to be given the highest attention.

7.7 International Cooperation

Climate change cannot be solved without global cooperation and concerted efforts. Developed countries are committed to promote international technological cooperation and transfer of technology, and to provide financial and technological support to developing countries. Thus, promoting international cooperation enhances the capability in coping with climate change through financing and transfer of clean technology and application of climate-friendly technologies. This helps to achieve the goal of win-win strategy by addressing climate change within the framework of sustainable development. Jordan adheres to the principles of the fundamental policy of resources conservation and environmental protection, and is committed to the protection of the world environment through control of greenhouse gas emissions to the lowest degree and fulfills its duties in addressing climate change.

The Global Environment Facility (GEF) provides financial resources to developing countries. The OECD members as of 1992 - have a number of specific responsibilities regarding developing countries. These include providing financial support, as appropriate through the GEF mechanism, in order to (a) define emission reduction programs, and (b) promoting the transfer of environmentally-sound technologies to assist them in doing so. Jordan can make use of this mechanism and seek assistance to carry out emission reduction programs, and for the transfer of environment friendly technologies.

7.7.1 Efforts to Acquire Greenhouse Gas Reduction Credits

The Kyoto Protocol provides for three mechanisms that enable countries in developed countries to acquire GHG reduction credits:

- Under Joint Implementation, a developed country with relatively high costs of domestic greenhouse reduction would set up a project in another developed country;
- Under the Clean Development Mechanism (CDM) a developed country can sponsor a GHG reduction project in a developing country. The cost of GHG reduction project activities is usually much lower, but the atmospheric effect is globally equivalent. The projects earn certified emission reduction (CER) credits, each equivalent to one ton of CO_2. These CERs can be traded and sold, and used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol. The developed country would be given credits for meeting its emission reduction targets, while the developing country would receive the capital investment and clean technology or beneficial change in land use;
- (closing the gaps, recommendations+ Cancun conference recommendations); and
- Under International Emissions Trading (IET) countries can trade in the international carbon credit market to cover their shortfall in assigned amount units. Carbon credit is a permit that allows the holder to emit one ton of carbon dioxide. Credits are awarded to countries or groups that have reduced their green house gases below their emission quota. Carbon credits can be traded in the international market at their current market price. Countries with surplus units can sell them to countries that are exceeding their emission targets. For example, if a farmer or group of farmers plants enough trees to reduce emissions by one ton, the group will be awarded a credit. If a steel producer has an emissions quota of 10 tons, but is expecting to produce 11 tons, it could purchase this carbon credit from that group.

Efforts should be made to study these options by the MoA and groups of farmers to make use of these options. By the end of 2009, 46 projects were presented for approval to Israel's Designated National Authority (DNA) for the CDM in the areas of waste, agriculture, fuel switch, energy and industrial efficiency.16 CDM projects have been registered with the United Nations during 2006- 2009, with a potential annual reduction of 1.8 million tons of CO_2.CERs issued by Israel to date have reached 249,843 tons (MOEP, 2009).

7.8 Further Research

Agricultural systems have evolved to cope with modest variations in drought severity (within the coping range), but they are vulnerable to the extremes. With climate change, drought is now becoming a one in every three or two years instead of one in five to seven years. There is a need to document and analyze actual adaptive behavior in rain-fed and irrigated areas, as well as food industries. Such surveys will ensure the research is relevant and useful, and will help with communication of research findings.

This would identify key insights to workable adaptations and for efficient and effective planning research programs for adaptations to climate change instead of resorting to adaptations in modeling analyses. Improving the communication about climate change risks and opportunities, including lessons and success stories in the agri-food sector would benefit all farmers and food industries.

Already small changes in climate change can have significant impacts on agricultural productivity. Current variation in crop productivity and yields among different regions, are likely to become greater as the effects of climate change are felt by farmers. Preparing agriculture for adaptation should therefore go hand-in-hand with pro-active mitigation measures. Research is needed to develop varieties of crop plants which can successfully grow under conditions of drought stress, water scarcity, heat shock and higher levels of water and soil salinity, as well as being inherently resistant to certain diseases and pests.

While conventionally breed crops and currently-available genetically engineered crops, where appropriate, hold the potential to reduce CO_2 emissions, certain crops are being developed to make more efficient use of scarce resources such as water and nutrients. This has the potential to result in more agricultural productivity and contribute to higher yields and better product quality. These would allow farmers to maintain high output even with less water and soil, thereby contributing to the development of best practices for environmental sustainability.

Studies to ensure the use of sustainable farming methods, that would ensure culturally and ecologically sensitive land preservation, and protection of biodiversity.

Studies on the use of energy-efficient and low carbon energy technologies, such as organic farming and use of chemical fertilizers on the basis of soil testing.

Agriculture directly impacts the climate and is impacted by climate change. It should therefore be given due attention, both with regard to mitigation and adaptation, which should be closely linked. Agriculture is a source of global greenhouse gas emissions accounting for 13% of global anthropogenic emissions, in particular in the areas of methane and nitrous oxide. Without preventive measures, emissions are likely to increase due to population growth, changing food consumption patterns and other factors which raise the demand for intensive animal production and more use of chemical fertilizers. Further research is needed to more fully incorporate climate change considerations in agriculture. Emissions reductions should be sought in sectors where the control is more cost-effective as compared to other sectors.

The vulnerability and resiliency of water availability should be integrated in water-use planning and water strategy in the event that climate change has its predicted impacts.

Climate change Impacts Assessments

Literature review indicates that various studies on impacts cost assessments have been made[71], but operational use of these assessments is not yet established. Annual loss Global adaptation cost estimates from more recent studies range from around $25 billion a year to well over $100 billion by 2015-2030. The wide range is symptomatic of the poor state of knowledge (Fankhauser, 2010).This represents 0.04 - 0.17% of the global GDP (58.13 trillion in 2009 according to the World Bank figures). According to the UNFCCC, UN annual cost estimates for climate change impacts, vulnerability and damage control from 2002 to 2008 were $171 billion. These include $14 billion to the agriculture sector as a result of warming temperatures and $11 billion for water[72]. This represents 0.29% of the global GDP.

The problem of the lack of knowledge and well established methodologies are limiting factors to the research. Methodology used in these studies differs according to the goal of the study and sometimes, even if the objective is the same, the methodology can differ from one study to the other one. Thus, inconsistency makes the results incomparable. Research is needed to assess the impact of climate change on agriculture, and the direct and indirect impact to society of climate change on land-use and farming practices and the consequent economic costs and to be compared with the costs of adaptation itself. Research needs to take into account important elements such as uncertainty of climate impacts, benefits of climate change, indirect costs and autonomous adaptation for assessments. Technical and financial support from the relevant UN agencies has to be sought (such as GEF).

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