Crop Production Under Changing Climate: Past, Present, and Future

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Abstract

Over the globe, crop production reduced under the influence of climate change with increased temperature, CO_2 concentration, variation in precipitation pattern, and water scarcity. Different mechanisms of climate change have tremendous effects on agriculture and its productivity. But phenomenon present between climate change and associated interaction with crops is much complex that we can rely on modeling for further prediction interlinked with agriculture on a local, regional, and global scale, while some projects like Agriculture Model Intercomparison and Improvement Project (AgMIP) have been started. However, some studies showed contrasting results as, by increasing CO_2 level, crop production should be high to 13%, but with this level, ozone layer might be damaged and reduce yield by 5% or maybe more. High level of CO_2 reduces usage of water which reduces rate of opening of stomata, while on other hand, high temperature increased transpiration rate which will lower water by evaporation. Future effects of climate on crop suitability and productivity have been developed by researchers; by those movements in Northern Europe, production has

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increased while it decreased in Southern Europe. However, it is already predicted that extreme events will be there like heat waves due to increase in temperature in 2003 and 2010, but again these shifts can occur. Therefore, there is a dire need to agricultural scientists (agronomists, breeders, soil scientists, entomologist, plant pathologists, and horticulturist) so that they should produce such agriculture products which can perform better even in high temperature and would bear all expected changes due to climate variability.

Keywords
Climate change · Climate variability · Climate shift · Crop productivity · Climate change adaptation

Abbreviations

AMeDAS	Automated Meteorological Data Acquisition System
ANOVA	Analysis of variance
ASRS	Automated storage and retrieval system
ATEAM	Advanced terrestrial ecosystem analysis and modeling
ENSO	El Niño-Southern Oscillation
FAO	Food and Agriculture Organization
GCM	Global Climate Models
GCMs	General Circulation Models
GDP	Gross domestic product
GHG	Greenhouse gas
JMA-NHM	Japan Meteorological Agency Non-Hydrostatic Model
MRIS	Moderate Resolution Imaging Spectroradiometer
RCMs	Regional climate models
REAP	Resources and Energy Analysis Programme
RPA	Robotic process automation
SRES	Special Report on Emissions Scenarios
SSA	Sub-Saharan Africa

9.1 Introduction

Over the globe under the influence of climate change resulted reduced crop production with increased temperature and water scarcity. There is a higher chance of systematic reduction of multiple sectors according to the Intergovernmental Panel on Climate Change (IPCC). Different mechanisms of climate change have tremendous effects on agriculture and its products (IPCC 2014). But the phenomenon present between climate change and associated interaction with crops is much complex that we can rely on modeling for further prediction interlinked with agriculture on a global scale (Gornall et al. 2010), while some projects have been started for agriculture production and improvement like AgMIP (Agriculture Model Intercomparison and Improvement Project). But some studies showed contrasting results (Jaggard et al. 2010) as, by increasing CO_2 level, crop production should be high to 13%, but with this level ozone layer might be damaged and reduce the yield by 5% or maybe more. High level of CO_2 reduces the usage of water which reduces the rate of opening of stomata, while on the other hand, high temperature increased transpiration rate which will lower the water by evaporation. So, the benefits of CO_2 on plants highly depend upon those varieties which brought value; this would be done by breeders. Future effects of climate on crop suitability and productivity have been developed by researchers; by those movements in Northern Europe, production has increased, while it decreased in Southern Europe (Olesen et al. 2002; Falloon and Betts 2010). However, it is already predicted that extreme events will be there like heat waves due to increase in temperature in 2003 and 2010 (Barriopedro et al. 2011), but again these shifts can occur. So, there is a dire need to European breeders that they should produce those agriculture products which can stand even in high temperature and would bear all expected changes due to climate variability. Most of the studies reported the possibilities caused by change in climate in 2050 and 2090 which describes surface temperature and impacts on different scenarios clearly. The objective of this chapter is to explore knowledge and data about the impact of climate and its variation on crop production mainly for rain-fed crops, so strategies and adaptability will be imposed to stand by even in harsh climate for the survival of human beings.

9.2 Effect of Climate Change on Crop Production and Food Availability Overview

Crop husbandry and food availability are the main components for determination of food security whether an entity, a family, or even a given district. But these components directly and indirectly affected by changes of climate. So, for food security, climate is the main component for a region. FAO (2008) reported that the climate will affect adversely on all types of local, national, and global food systems through its components. It brings opportunities and impacts on crop production. It is very important and relevant how climate would possess impacts on production of crops. This is not only for the production of those crops which we used but also for the employment purposes in an agriculture country. Most of the developing countries based on agriculture directly or indirectly and depend on it for their livelihood, like Pakistan, etc. However, if the agronomic crop yield is affected by any change in climate, it will ultimately affect the production and available food which increase the demand of supply due to shortage. By this chapter, we will go through the interaction effects of food correlated with climate change and relating ups and downs of production of crops (Fig. 9.1).

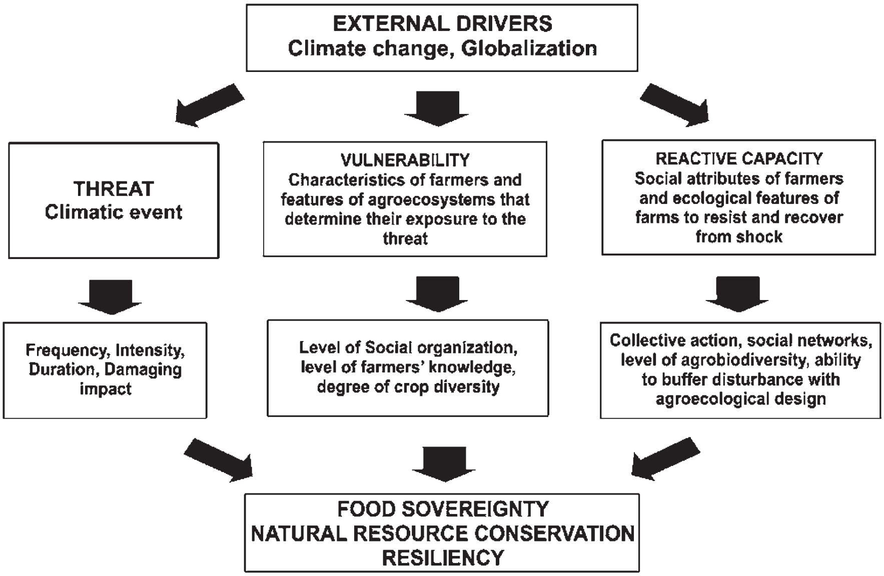

Fig. 9.1 Factors affecting the vulnerability of rural communities to climatic events and the reactive capacity to enhance socio-ecological resiliency

9.3 Effects of Climate Change on Production of Crop

Crop production may be affected by climate change directly through physiological and biochemical factors, which are associated with growth, development, yield, and quality of crop (Schmidhuber and Tubiello 2007). This section will explore the direct effect of climate on yield and yield-related traits in crop production over the world. Study reveals that some climate impacts are occurring more rapidly than the previous (Parry et al. 1999). Crop production is directly affected by many features of climatic change, orienting primarily from:

- Increase in average temperature
- Fluctuation in rainfall duration and amount
- Increasing concentration of CO_2 in atmosphere
- Variation in climate and extreme events
- Rise of seawater level

9.3.1 Average Temperature Increase

Globally, temperature is increasing in most of the regions due to climate changes. Scientists assumed that countries present on regions having low latitude are on major risks in low crop production due to low availability of water even in fluctuation of temperature with 1 or 2 °C (Parry et al. 1999). This may be the result of high evapotranspiration rate and low moisture level in soils. So, this event would create irrelevant conditions for field crop productions and increased unavailability of grasses to pasture lands, especially in tropical agricultural lands in sub-Saharan Africa (SSA). These changes would create reduction in yield for specific area, but their extents are still unknown. Researchers presume that changes due to variation in climate would be drastic (Bals et al. 2008).

9.3.2 Variability in Rainfall Amount and Patterns

Climate change brings severe results with increasing temperature in tropical areas and decreasing in temperate regions. By this phenomenon, temperate regions are moving toward more wet and tropical toward more dry (FAO 2008). In addition, rainstorm intensity also increases with rate of precipitations which are unpredictable. Due to high rainfall, soil moisture is also fluctuating due to high erosion rates and affected crop growth and yield. In sub-Saharan Africa (SSA), the lowest precipitation was expected to 20%, due to which most of the arable land will destroy because of low soil moisture level, high aridity and salinity and main effect of decreased in groundwater (Bals et al. 2008). Reduction in water level will lead toward scarcity of water and increasing water costs and will limit the use of agriculture lands for crop production based on irrigation. It is opined by FAO that decrement of available water on critical stages of crops in agriculture land will impose negative effects on food supply. Sub-Saharan Africa mostly depends on rainwater irrigation, but fluctuation in temperature-imposed falsification of rainfall pattern will negatively impact on crop production, which would also cause socioeconomic and physical adversities among farmers.

9.3.3 Rising Atmospheric Concentration of CO_2

At present, CO_2 present in atmosphere is estimated to be 379 ppm, but it is expected to be 800 ppm in 2100 by IPCC prediction under business scenario. They predicted that the lowest emission scenario in the future will be 550 ppm (Schmidhuber and Tubiello 2007). High level of CO_2 is beneficial to plants, acting as a fuel in improving growth and development of plants. Concentration of CO_2 in air will accelerate photosynthesis and water use efficiency of plants and boost up the growth and dry matter production, ultimately yielding crops (Bazzaz and Sombroek 1996). On the other hand, an increase in the level of CO_2 is beneficial for crop yields but also caused greenhouse effect.

9.3.4 Variation in Climatic Conditions and Extreme Level

In agriculture, intense measures are not a new incidence, but they are fluently occurring and expanding in areas that may cause severe damage (Schmidhuber and

Tubiello 2007). In SSA, several studies showed an increase in frequency of extreme events, which would cause more drastic results in agriculture for food production as well as food security (Easterling et al. 2007). It is bothersome for the area that is totally dependent on rain. Variation in climate, especially in severe flood and droughts, is directly linked to reduction in economic activities (Brown et al. 2008). It was reported that sub-Saharan Africa has gone through a chain of severe precipitation processes that is linked with climate change (Wassmann and Dobermann 2007). According to recent information, flood which occurred in 2000 in Mozambique took a great population of humans along with destruction of irrigation infrastructure which ultimately affects 90% of crop husbandry. That causes unavailability of food to many households due to loss in food security.

9.3.5 Rise in Seawater Level

Due to change in temperature, the level of seawater rose up. Temperature and high seawater level would cause vulnerability of coastal and low-latitude agriculture lands. They may cause salinity, extreme rainfall, and coastal deluge. Consequences of high temperature melted the ice present on polar area and glaciers due to which seawater level already rose up to 15–20 cm (Douglas 1997). There is a noteworthy uncertainty regarding seawater level on how much it would rise. Recent possibilities show that sea level might rise to half a meter in the coming 2100 which is a remarkable change. Countries that would be at risk to high level of seawater are the Gulf of Guinea, Southern Mediterranean, Mozambique, sub-Saharan Africa, and Gambia. Coastal floods and salinity would affect agriculture crops and products in abovesaid countries. It may lead to loss in production rate, farmers' income, and food security. There is also another possibility of exposure of land to wastewater (ESCAP 2009).

9.4 Impact of Climate Variability on Food Security

- Average temperature increase.
- Extreme high temperature in night and day.
- Heat waves on most of the region.
- Countries present in SSA.
- Reduction of soil moisture due to high evapotranspiration.
- Severe attack of pest and high rate of damage.
- Larger threats for human because of scarcity of food and unavailability.
- Dire need to repair the refrigerator to keep food safe.
- Main danger in forest fire.

Extreme Events
- Droughts.
– Floods.

Semiarid and Subhumid Africa (Particularly the Southern Africa, Sahel, and Horn of Africa)

- Reduced crop yields.
- Threats to forests.
- Damage to agricultural inputs.
- High rate of land desertification and degradation.
- Damage to crops and food stores.
- Inability to cultivate land due to water logging.

Change in Rainfall Amount and Patterns

- Decrease quality and quantity of agricultural product.
- Scarcity of water.

Sea Level Rise: East Africa, West Africa, Southern Mediterranean

- -Because of salty water, less number of farms and fisheries survive.
- -Salinization of irrigation water and freshwater systems.
- Aquaculture.

9.5 Climate Change: Responsible for Crop Yield

Climate modeling predicted the effect of climate on crop by evapotranspiration and less amount of moisture in soil (Rosenzweig et al. 2002). Drought situation and development of unsuitable land for crops along with conversion of grass land into arid may be caused by these changes. Lobell et al. (2011) demonstrate chronological data from about 20 thousand maize field trails which were conducted in sub-Saharan Africa for the last 10 years; the result is that with each increase in 10 °C in temperature after 30 °C, the yield of maize decreased by 1%. Another factor which they described was water availability; shortage of water plant also imposes stress causing loss in yield at 30 °C. So, they argued that high temperature even in non-drought area caused low yield by 1% in maize field in the Africa region. With drought stress, 100% cultivated area would face yield losses. Due to rise in temperature, population of insects and pest also able to survive and continue their production will enhance the disease rate ultimately loss in yield percentage. In Africa, with the average estimation, 5–8% semiarid and arid regions will undergo the destruction process due to exasperation of climate change (Parry et al. 1999). About 2/3 of Africa's cultivated land turning into destruction in the coming 2025 will lead to loss in 3% agriculture GDP annually (UNSEC 2007). Furthermore, low rate of rainfall would result in negative impact on crop production in rain-fed areas with 50% reduction of total yield, and in some regions, maize production might cease by 2020.

9.6 Expected Impaction of Climate on Crop Production

Ringler et al. (2010) indicated that firstly wheat will be affected greater by climate change than sweet potato and higher yield would be reported for sorghum and millet. Precipitation and increase in temperature will emit higher concentration of CO_2 into atmosphere which leads to alteration in land suitability and yield of crops. IPCC has given a special report related to emission scenarios in 2000. They grouped affiliated emission and socioeconomic development into four different circumstances, i.e., A2, B2, A1, and B1, where A1 is the highest CO_2 emission scenario and B2 stands for the lower one, while A2 and B2 are intermediate between A1 and B1. According to these scenarios, different models are predicted in 2007 which describe the temperature range increase from 1.8 to 4 °C by 2100. Alteration of crop yield rate is the result of physiological changes which formed CO_2 at high rate as the result of high temperature and precipitation impacts (IPCC 2000). Predicted model showed that till 2020, cereals will be changed slightly, and these changes will continue depending on climate variability (FAO 2002). In general, low yield will be expected in Africa according to Special Report on Emissions Scenarios (SRES). The major downfall in yield is expected in 2080, with increase in temperature in A1 scenario; about 30% losses will be shown in SSA. Despite the beneficial effects of higher CO_2 concentration, effects of higher temperature and precipitation are so far. In B1 scenario, effects on cereals are less and would never go beyond 10%.

9.7 Available Irrigation Water Analysis

Possible panorama limitation includes both shortages of surface and groundwater in response to climate change. In this content, both sources of shortage of water will be analyzed. Reduction in groundwater level and the surface water which evaporates and loss in irrigation water are due to climatic variations. This is because of high temperature and fluctuation in precipitations.

9.8 Low Level of Groundwater

Fixed incline in groundwater which decreased over time was expected for the selected region of REAP, to determine the low level of groundwater. But the rates of decline of water in future are uncertain. For identification of model regions, Moderate Resolution Imaging Spectroradiometer spatial irrigation data were concealed with USGS aquifer delineation and REAP boundaries on regions. By this superimposition, an incredible presentation is provided about groundwater for use of model correlated with irrigated acreage. Data regarding groundwater use for irrigation is collected from USGS water sector for 1990, 1995, 2000, and 2005 (USGS 2013). By this data, they identify and draw the picture of other country's groundwater situation which declined over 1990–2005. Regions with high irrigation water are facing withdrawals of groundwater level in a nonlinear fashion in the next coming decades. Areas having possibilities of low water potential in the next decades are reported and informed by some researchers (Steward et al. 2013; Scanlon et al. 2012; UCCHM 2014). Areas of central high plains and southern plains are at risk for serious withdrawal of water level by 10% in 2020 and 50% in 2080, because they mainly depend on water source.

Reduction of 20–30% water level is reported until 2080; mostly this will happen in the central valley of California and lower Colorado River Basin, while eastern Rocky Mountains, Southern California, Southern Mississippi, and Northwest Pacific regions will face up to 10% reduction in water level.

Climate will directly or indirectly affect the quality and storage of food by increasing temperature which reduces the growth period. Some researchers analyzed the effect of climate on food security by using HadCM3, SWAP, and salinity model to determine the evapotranspiration rate, irrigation water depth, crop area, and quality of product. Results showed that crop area should be extended in order to increase grain yield (Droogers 2004). A study was conducted to evaluate the present and prospect scenario related to climate and food security and availability of water in 2020 and the 2070s. It is observed that greater crop potential will be obtained by expanding the rain-fed area with irrigated cultivated land (Alcamoa et al. 2007). SWAP and ADAPT models are formed to evaluate the impacts of climate change on food and its products. They noticed that increasing crop area will improve the quality but increase food insecurity. On the other hand, low cropping area will reduce the water level reduction and improve environmental security. Luo et al. (2003) discover the effect of change in climate with various CO_2 concentration levels by combining DSSAT 3.5 CERES and Global Climate Models (GCM). The results showed that the change in climate can decrease the wheat quality at parched sites. Meanwhile, in case of climate change, parched sites proved more useful than wet sites.

Khan et al. (2009) evaluate the crop production and water management in China for the purpose of food security. He remarked that it is necessary to sum up climate, environment, population, food, and energy to ensure the food security in China as well as the whole world. It is because water management and other related problems of water have many uncertainties due to climate change. All over the world, the importance of food security is increasing day by day. Due to climate change, food quality and food availability are still big provocations for scientists. Under climate change issues, food security is always studied with CO_2 concentration. To evaluate the food security systematically and completely, it is necessary to sum up population, crop production, change in climate, and water availability.

9.9 Knockdown of Climate Change Scheme

The results of Global Climate Model (GCM) for climate's interdisciplinary research had been used (MIROC5; Watanabe et al. 2010). As climate data of Asia have been focused on Yamase airflow, therefore representative construction pathways were used (Kanno et al. 2013). In eastern Japan to sort out regional differences in climatological elements, the 15 km grid mesh resolution is insufficient. In regional climate model JMA-NHM, the data had been knocked down to 10 km mesh for eastern Japan (RCM: Saito et al. 2007). This model utilizes the Kain-Fritsch scheme for convective parameterization (Kain 2004). For turbulent parameterization, improved Mellor-Yamada level 3 scheme had been used (Nakanishi and Niino 2004). From May 28 to August 31, the knockdown of key growing period was conducted for present (1981–2000) and future (2081–2099) climate. For spin-up period, the first 4 days were used and excluded from analysis. The outputs of RCMs and GCMs by observed values are generally biased (Yoshida et al. 2012). Change in climatological mean had been used to avoid biasness (20 years mean for present climate and 19 years mean for future climate) rather than original data.

To compose the climate datasets, the following procedures were conducted on the basis of previous studies (Kimura and Kitoh 2007; Yoshida et al. 2012). First, in Automated Meteorological Data Acquisition System, for 1981–2000, the gridded and observed data was defined as the present climate (Seino 1993). Then, by using climate differences derived from the knockdown data and Mesh-AMeDAS data, the future climate was calculated. For daily maximum mean and minimum temperatures, the differences were calculated (i.e., difference = future–present). For downward shortwave radiation, relative humidity, and wind speed, multiplying ratios were calculated (ratio = future/present). To calculate the impact of summer climate change on rice production, this method was used.

9.10 Potential Cultivar Shift Due to Climate Change

9.10.1 Surface Water Shortage

The forest services of U.S is proposition of water yield and water needed progress for change patterns under 2010 RPA (Robotic Process Automation) is responsible for the shortages of surface water supply for irrigated agriculture. On the basis of downscale approximation of temperature and precipitation, the regional water yield was suggested annually through 2090. Water routing model of the US river system accounts for inter-annual reservoir storage and inter-basis transfer, in which surface water flows are simulated. Water is required in different sectors to use as public supply, domestic industrial, mining, thermoelectric, livestock, agriculture, and recorders of the sector level water withdrawals and consumptive use, and proposition of water we drive including adjustment in water use efficiency. Difference between proposed water demand and water supply by ASR after in stream flow needs are fulfilled is calculated as potential regional; water–reductions. Surface water shortage by Resources and Energy Analysis Programme (REAP) model region is based on a 20-year average of a reported annual shortage of renewable water supplies by ASR 2020, 2042, 2060, and 2080 (Foti et al. 2012).

Water supply shortfall is carried by irrigated field crop sectors. Ares which are facing the water shortage fully dependent on the irrigated agriculture while non-agriculture withdrawals having high marginal value of water as compared to irrigated agriculture.

- REAP model does not include the higher-valued crops, e.g., vegetables, orchard, and berry crops, and is considered to be secured by climate-induced reduction in surface water supplies.
- Uncultivated pasture and non-model field crops, e.g., dry beans, sugar beets, potatoes, peanuts, grass seed, etc., share regional water supply shortage with modeled field crops allowing irrigated acreage share.

In 2018, surface water supply in field crop production ranges from 20% to 75%, but these percentages are higher across Pacific and plain regions and mountains. The river system with headwater in the central Rocky Mountains and Sierra Nevada range is affected to varying degrees depending on the scenario. In other terms, with the passage of time, contrast of water supply is increasing for irrigated agriculture, but the most alarming impacts will occur after 2050. The irrigation water conditions are affected to purchase price of surface water through shifts in market and capital expenses of water supply development.

Climate change can also affect the groundwater demands with climate encouraged adjustment in availability of surface water and groundwater supply. The institutional limitations on groundwater and surface water distribution as well as the cost of groundwater and surface water access will affect how shortages play out in real time. Unfortunately, analysis cannot be alone of such detailed hydrological and institutional oppositions. We cannot estimate functions in cost per unit of water over water and climatic scenarios because of such complications of projecting surface water pricing and aquifer drawdown.

9.10.2 Climate Inconsistency and Its Extreme Situations

Variation in climate can easily damage or weaken the future efforts of food security achievement and maintain rate of natural resource-based agriculture. Livestock production and crops are strongly affected by the rising temperature, severity of extreme climatic events, the timing of rainfall, etc. Agriculture is already facing the challenges like degradation of lands, damage to agriculture biodiversity from pest, disease, and increasing pressure for resource base population.

The El Niño-Southern Oscillation (ENSO) has become the dominant mode of climate variability in many regions as it has the significant influence on the prevalence and seriousness of water stress and flooding tropics. Climate change is already affecting the food-insecure regions negatively. Over the course of this country, warming trends are proposed to accelerate intensity and frequency of severe events which are likely to shift upward in some subtropical regions like Southern Africa; North, South, and Southeast Asia; East Africa; the Mediterranean Basin; and Central America.

Precipitation is likely to become increasingly aggregated, with dry years projected to be drier and wet years as wetter. Due to greater atmospheric retention with increasing air temperature, rainfall intensity will increase, but rainfall percentage will decrease on a time scale. Crop growth could be affected by more hot days during a growing season, but less frequency rainfall and extensive period between rains, coupled with increased rate of evapotranspiration under hot temperature (Hungtingford et al. 2005).

Flooding is likely to be intensified by the proposed large storm and heavy precipitation circumstances in climate change (Kundzewicz et al. 2008). For example, South Asia could experience increased severity of flooding given the proposed intensification of Indian monsoon with land cover changes which can enhance the flooding effect coupled with climate change. In the last half of the twentieth century, a changing pattern from rainfall intensity toward a more extreme rainfall has enlarged flood risks in India (Goswami et al. 2006), and these effects are also observed in Latin America as well (Magrin 2007).

More than a third of Earth prosperity is human population that is influenced by large-scale weather patterns generated by the Asian and Southwest African monsoons, and ENSO (El Niño-Southern Oscillation) are prominent climate features of low-latitude zone (Paeth et al. 2008). Future food security would be enormously influenced by changes in characteristics of these systems due to climate change. Although characteristics of the ENSO could be changed, there are substantial doubts as to how that change will be visible itself. There is also uncertainty about the future change in the intensity of West African Monsoon.

9.11 Effects of Temperature Rise

Rising temperature can affect the crop productivity which varies depending on the characteristics of crop in relation to crop development and condition under which crop is grown. At night, minimum temperature increases respiration losses, while at daytime crop maturity is accelerated by maximum temperature with reducing grain filling. The crop yield is highly affected by episodic heat waves particularly during sensitive stages of plant growth such as reproductive stage and seedling stage. Furthermore, crop biomass production could be suppressed by increasing the earth temperature resulting from greater cloud and aerosol formation. Damage to crop production caused by rising temperature remains highly uncertain even to the same extent CO_2 fertilization can offset that damage. In the light of recent evidences, N deficiency depends upon the reaction of plant to enhanced carbon dioxide concentration (Long et al. 2006). Under tropical conditions, combined crop weather simulation modeling has presented yield stimulation from higher CO_2 to be more offset by elevated temperature (Challinor et al. 2007). In the region of Northern China, East Europe, and South America where agriculture production is likely to benefit from climate change. However, these benefits may be diminished by water shortage and increased pest attacks.

9.12 How Important Is ENSO to Climate Change?

Large-scale weather patterns are affected by periodic (2–7 years) irregularities in sea surface temperature over a large range of eastern equatorial Pacific Ocean referred to ENSO. ENSO has two phases, El Niño (warm) and La Nina (cool), which have variable effects over land areas. In Africa La Nina events generally cause water stress in Eastern Africa and overflowing in Southern Africa, while El Niño events do the opposite.

ENSO is responsible for severe drought in northeastern Brazil, Mesoamerica, and flooding in the Andes. Indonesia is suffering from severe droughts, drought and flooding in Eastern and Southern China, respectively, due to prominent activities of ENSO from the last decades. In the late 1990s tandem agriculture, industrial output, and forests are severely affected by El Niño and La Niña impacts. In many regions of the developing countries like Pakistan, ENSO is positively interconnected with outbreaks of infections and waterborne disease.

ENSO became very active during the late twentieth century in areas of tropics and subtropics. ENSO is becoming prominent made of inter-annual climate variability. In the twentieth century, it also enhances effect over global weather patterns that prompted concerns about El Niño like weather changing in a greenhouse world, with serious consequences of society. Sea surface temperature is proposed to be increased by 50 °C by 2100 in the eastern equatorial Pacific, warm climate which can be compared with the one that is generated in ENSO.

9.13 Effect of Crop Water Stress

Severe water pressure on agriculture is expected due to the proposed increase in temperature change in frequency, severity of extreme events, and rainfall patterns. In the future, the region which is facing the water shortages will have to face more water scarcity. The intergovernmental panel on climate change expected that by 2020, 75–250 million more population in Africa will suffer from increased drought stress according to De Wit and Stankiewicz (2006). Decrease in rainfall (10%) in semiarid areas of this region could lower surface drainage volume by 50%. By the end of this century, water scarcity in Mediterranean Basin, parts of Mesoamerica, and Central China are proposed to go through long-term drying trends. In South America, Central Asia, and China increased flooding followed by severe shortage of freshwater is expected in the wake of glacier retreat. Climate change is also associated with intensively irrigated production system, where misuse of water is already causing shortage of regional water supply.

9.14 Climate Change Impacts

Agriculture systems are more sensitive to climate change and extreme climatic events as contending with a high degree of non-climatic stress, pest and disease pressure, soil and water degradation, as well as declining soil fertility. Productivity and food security are also suffered due to climate variability and extreme events. Climate impact models poorly represent the indirect effect of changing climate. On the long-term viability of agriculture systems, they are likely to create significant additional pressure, especially where factor efficiency is low or declining. Soil erosion, land degradation, increase in pest damage, and high rate of malnutrition and disease among agriculture communities are the secondary impacts of climate change.

9.15 Regions Vulnerable to Changing Climate

Africa, South and Central Asia, and the Mediterranean Basin are the regions which are more exposed to the negative effects of climate change (Easterling et al. 2007). The Andes, semiarid northeastern Brazil, and semiarid areas in Central America are more sensitive to climate change, but the whole Latin America is not predictable to experience a significant loss of GDP from climate change (Magrin 2007). Southern Africa, South Asia, West Africa, the Sahel, and Brazil have significant effects of climate change on food security, and it could occur as early as 2030 for several crops and regions.

9.16 Importance and Local Benefit of Traditional Farming System

At the start of the twentieth century, there are so many native people, families, farmers, and small landholders having 20% of land which are able to be plowed. But their contribution in the economy of world agriculture is not less than 50%. Thus, mostly agriculture products like wheat, rice, pulses, etc. are the output of small landholder people (ETC 2009). Resource-conserving agricultural farming system is a very reliable method for the local and traditional farmers. It is very difficult to estimate the real numbers of farmers that use resource-conserving system, but according to rough estimate, about 50% of peasants use this system. While with changing climate it's need of hour to use this farming system for food security at national, regional, and local level. Furthermore, without using agrochemicals mostly farmers grow consumed foods to fulfill the current demand of the population (Toledo and Barrera-Bassols 2008).

In the developing countries, major populations are engaged in the practices of traditional agriculture. While in Latin America almost 16 million farmers sections that produce 41% agriculture product for local use and 21% arable land. Farmers' areas in the Latin America are responsible for generating 61% potatoes, 77% beans, and 51% maize at regional level. European countries like “Africa” have only 33 million farms; all these small farms represent the whole farm which is 80% in the state. In most of the farmer communities in Africa, females are regulating the small farms. Meanwhile, two-thirds of farms are under 2 hectares and 90% of farms beneath 10 ha. There are many peasants that belong to poor class family, but by using limited resources, these small landholders’ farmers produce common grains and legumes to fulfill the demand of the nearby community. Similarly, in China region more than 75 million rice-cultivating farmers followed thousands of years of traditional method, but after using primitive techniques, they achieved rice yield in bulk quantity as compared to the Asian rice-growing farmers (Koohafkan and Altieri 2011).

In the present time, each region of the world has a particular agriculture system and habitat for the growing of crops. The common phenomena of all the regions are sharing likewise plant height, structural diversity, microclimate crop varieties, and animal diversity. To increase the flexibility and constancy of farming system, various scientists have used common features of world agriculture. The most important issue of the current situation is changing of climate day by day, so this climate issue leads to shortage of food and energy crises. On the other hand, it is necessary to adopt self-determination and agroecological system for gaining worldwide attention (Altieri and Toledo 2005). Several researchers reported that latest and efficient farming system for the improvement and production of healthy food (IAASTD 2009; de Schutter 2010). They also purposed that agroecology is the best way to move toward better quality food and also improve the poorest situation of the farmers. The scientists, civil society, and consultations with industry representatives reported that by using agroecological system, small land-holding farmers attain double food production within 10 years.

For the protection of future climatic scenarios such as energy crises, economic issues, and food deficiency, agroecology is the best and easy way to overcome future problems against sustainable development of food. Characterization by an incredible variety of farm crops and animal species conserved and improved by artless soil, water, and biodiversity management promoted by difficult system of old knowledge that used many years ago. For the sustainable supply of food in parts of the earth, climate-smart agricultural policy is the adoptable practice for worldwide population, although according to ecologists, traditional agroecosystems have the potential to overcome the climate change and against financial crises for the people that are facing many problems (Altieri 2004).

9.17 Climate Models for Traditional Agriculture

9.17.1 Establishment of Raise Fields

According to biofacts record offers the example of regularity and flexibility by using agricultural system data. For example, researchers revealed that this system contains the residue of other than 170,000 hectares in Surinam field (Denevan 1995). In savannas, most of the systems are raised on highlands and flooded lands.

Thus, in many areas of the world, bad growing system used by farmers is raised. Water management issue has been associated with this system to managing the effect of surplus water quantity on production of different crops to actively flooded crops during scarcity of rainfall. The source and practice have conventionally been related to water issues and their management, either by given that prospects to minimize the adverse influence of surplus water on production of various crops to actively irrigate crops during stress period. For example, in the Valley of Mexico, "chinampas" (floating and rectangular island used for growing of crops) are used for the cultivation of crops under water stress condition (Wilken 1990).

The raised platform of "chinampas" (10 m long and 2.5–10 m wide) was built with the nearby mud of superficial lakes. So, the Aztecs made their raised area that height near about (0.5–0.7 m) upstairs from water and all the boundary of this raised platform are covered with trees (Armillas 1971). Thus, chinampa beds were made of discontinuous layers of bottom muck and weeds. The inside rectangular area of the bed is firmly embedded to the lake floor. Furthermore, the thinness of the bed guaranteed that nearby plots are evenly filtered at root level through bed. So, the regular uses of manure, swamp muck, and marine plant conserved the soil fertility because manure enhances the organic matter in the soil which also increases the fertility rate. The rectangular area of "chinampas" detached from 1–3-m-wide canal, developing a network of islands accessible only through water (Gliessman et al. 1981). Most of the farmers on the "chinampas" focused on the production of their simple vegetables as well as food crops such as maize, wheat, rice, etc. One hectare of chinampas area produced food crops that fulfill the need of almost 15 people per year. For example, yield of maize crop in that area ranges from 4 to 6 t/ha. Furthermore, three to four crops were grown on chinampa land every year that increased the quality of life of some aquatic organisms such as turtle, frog, and salamanders.

Waru Waru is an agricultural technique used for the growing of agricultural crops and making of platforms of soil. The soil under fence is filled by using water to produce immense crops under water stress and flooded conditions and the killing frosts common at elevations of almost 4 thousand meters, However, these bed and canal arrangements have demonstrated the distressing effect of frost and moderation effect of temperature by encompassing the growing season of crops (Vietmeyer 1984). By using this system, during flooding excess amounts of water escape through furrows and plant roots that remain free from injury. Similarly, during dry season roots absorb water through capillary action from the canal. Thus, canal and raised bed show a different effect during day and night; canal water absorbs maximum sunlight at daytime and emits heat into the atmosphere by night time; on the other hand, raised bed temperature becomes higher than surrounding temperature (Erickson and Chandler 1989). Using Waru Waru technique during harsh climatic conditions leads to maximum production as compared to chemically fertilized soil of Pampa city (Erickson and Chandler 1989).

9.17.2 Dryland Agriculture

Farmers used model over generation to increase the potential of soil to retain its water that plant can use and ultimately reduce the drought condition and soil erosion along with degradation in arid or semiarid situation (Barrow 2014). Land with shortage of water, furrows, and ridges are made around the plant bed to store maximum water. These are called tied ridges which help in holding rainwater, preventing runoff and enhancing the infiltration ability. In teff production, mostly farmers of Tigray (Ethiopia) make contour furrows to store water in the edges. These are 2–4 m wide and after the storm help in saving water for later crops instead of running off (Boers and Ben-Asher 1982).

A generally used method is rainwater harvesting, consisting of the compilation and application of runoff from small drainage areas. Simple method for tarp rainfall water is small earthen basins, also hold soil in situ conditions. In Dogon Plateau (Mali), basins are made with semipermanent ridges. These types of basins are also found in the Jos Plateau of Nigeria. In West Africa, they make pits and enlarged planting holes for flat semiarid areas. In Burkina Faso, customs of hand-dug pits for land therapy have been effectively invigorated by plans. On steeper slopes, deep pits are made mostly found in southwest Tanzania and many other countries spreading over 18,000-hectare lands (Stigter et al. 2005).

9.18 Effect of Thrilling Climate on the Biodiversity of Agroecosystem

In Central America, a study was shown in hillsides for checking the feature for water storage practices. They use various types of practices like intercropping, agroforestry, and use of cover crops. This survey is led by the Campesino with the name Campesino Movement, under which 100 farmer technicians are involved to hold out similar observations of specific agroecological indicators on 1804 adjoining sustainable and predictable farms. The study revealed that Guatemala, Nicaragua, and Campesino cover 360 groups in the form of communities and 24 departments. The results revealed that defensible plots have 20–40% topsoil, having great moisture contents with low erosion rate; due to this they faced low economic losses (Holt-Giménez 2002). Correspondingly in Soconusco, Chiapas, coffee systems exhibiting high levels of vegetational complication and plant diversity suffered less damage from Hurricane Stan than more simplified coffee systems (Philpott et al. 2008). According to the survey conducted by researchers in the province of Holguin and Las Tunas 40 days after Hurricane Ike hit Cuba in 2008, diversified farms exhibited losses of 50% compared to 90 or 100% in neighboring monocultures. Likewise, monoculture farms give less productivity as compared to agroecologically managed farms, because agroecological farms showed faster production which is 80–90% 40 days after the hurricane (Rosset et al. 2011).

All survey showed that in farming system plant diversity is more important to overcome the effects of climatic events and its vulnerability to plants. Biodiversity is essential to maintain ecosystem and its function in crop diversification used by farmers as buoyancy for agroecosystem (Lin et al. 2008). Diversity can be brought about by traditional farming, through new varieties. So traditional farming can form diversity.

Traditional agriculture has several modifications in forms like genetic variety and species variety and over different scales (inside field and landscape level as in the case of agroforestry, crop- corridors, livestock integration, hedgerows, etc.), giving growers a wide variety of options and combinations for the application of this strategy. Thus, traditional farmers create temporal and spatial assortments (Perfecto et al. 2009). Farming containing diversity showed how agroecosystem is adapted and resisted to climatic measures.

9.19 Conservative Farming System and Its Mitigation Perspective

On farm level, increasing diversification may reduce greenhouse gas (GHG) emission and thus participate in global warming mitigation (Tscharntke et al. 2005). Resultant of pesticide and fertilizers are being known as GHG and significantly lessen by traditional farming in which agrochemical and other inputs don't use on farmlands (Niggli et al. 2009): & lower N_2O emissions (due to lower nitrogen input)—it is usually assumed that 1–2% of the nitrogen applied to farm systems is emitted as N_2O & less CO_2 emissions through lower erosion (due to better soil structure and more plant cover)— in diversified farming systems than in monocultures.

Tropical small farmers used agroforestry system which is diversified and spread in livestock farms in combination with trees used for fire wood. Traditionally, small area of land consists of high diversity by protective soil from erosion and provides litter as organic matter in some system of agroecosystem (Montagnini and Nair 2004).

Through different observations, it had been noticed that SAFS systems are greatly involved in increasing growing potential of crops and mitigate GHG by reducing soil erosion (Mutuo et al. 2005). Carbon stock is found high in tree-bearing farmlands as compared to others without farms. Agroecosystem has a tendency to restore carbon stock in field as other pasture lands. It is due to trees sequestering more carbon in their surrounding as compared to others below and above the ground (Albrecht and Kandji 2003).

It was studied earlier that carbon sequestration potential for SAFS was 2.6 for semiarid, 3.9 for temperate, 6.1 for subhumid, and 10 $\mathrm{MgCha^{-1}\ yr^{-1}}$ for humid areas. *Erythrina poeppigiana* was found good for agroforestry by adding C 0.4 $\mathrm{MgCyr^{-1}}$ in roots, 0.3 $\mathrm{MgCyr^{-1}}$ in trunks, and 1.4 $\mathrm{MgCyr^{-1}}$ in branches, and leaves give mulch to soil (Mutuo et al. 2005). Good range of carbon for small holder SFAS is 1.5–3.5 $\mathrm{MgCha^{-1}\ yr^{-1}}$ (Montagnini and Nair 2004). SFAS with perennial trees and crops, i.e., cacao and coffee, might be more prominent carbon sinks than other annual crops. Research revealed that SFAS system can also mitigate CO and NO from soil increasing methane sink potential than other annual crops in humid areas

(Mutuo et al. 2005). Peruvian Amazon study was conducted which resulted in SFAS with tree plantation emitting less NO as compared to other annual crops and fertilizers. It was observed in several other countries which also recommend that SFAS can emit CH_4 partially where other cropping systems have emitted at high rate (Montagnini and Nair 2004).

Many scientists and researchers thought that agricultural practices done by traditional farming enhanced carbon sequestration in soil, i.e., use of agricultural manure, intercropping, and use of trees in farms as hedges (Stigter et al. 2005). Practices such as application of green manure and use of cover crops can boost up the soil fertility by increasing organic matter and improve soil structure.

IPCC pointed out the mitigation process enhanced through soil organic carbon in SFAS. It is roughly estimated that CO_2 was reduced by the rate of 3.5–4.8 through carbon sequestration in agriculture farming, while N_2O was reduced by 2/3 (Niggli et al. 2009).

Soil which is formed through oxisols by high rate of black carbon, remaining portion of burning materials, is known as "terra preta." In Brazil, intense population formed poor oxisols for 2500 years by converting soil to terra preta. Black carbon is assumed to be persistent in the environment for centuries or may be for millennia because of its aromatic structure that can be chemically stable. Fertility level of terra preta is calculated or estimated by organic matter present in it; values of nitrogen, calcium, phosphorus, and pH; and its moisture and nutrient holding capacity relative to other soils. These soils are considered as a good source of storage and potential sink of carbon dioxide. In Amazon, dark earth region carbon stocks are measured about 147–506 $\text{MgCha}^{-1}\ \text{m}^{-1}$, while Belterra Regions have fewer stocks with 72–149 $\text{MgCha}^{-1}\ \text{m}^{-1}$ in nearby ferralsols. These results showed significant amount of carbon in Amazon dark earth especially in topsoil (Sombroek et al. 2003).

9.20 Conclusions

Traditional farming systems highlight the significance of improving plant diversity and complexity in farming systems to increase yield stability and reduce liability to extreme climatic events. Undoubtedly, the myriad of traditional systems and indigenous technologies still existing throughout the world comprise a globally important ingenious agricultural heritage that reflects the value of the diversity of agricultural systems adapted to different environments and the vagaries of a changing physical and material environment from generation to generation (Koohafkan and Altieri 2011).

Studies showed that different plant communities are more resistant against environmental distress (Lin et al. 2008). Crop variation also provides the strategy for farmers who suffer windstorm, increasing temperature predictability, and decreasing rainfall. Similarly, aeration, infiltration, and adding the organic matter in the soil increase the water use efficiency (WUE) and water holding capacity of the soil. Thus, green manure and cover crops like grasses and legumes are also added biomass in the soil which increases soil organic matter. Furthermore, these cover crops to protect the soil from erosion (Madgoff and Weil 2004). The main objectives of traditional agroecosystems are focused on such systems to enhance ability against climatic stress.

It also gives the impact of climate change on crop yield, water availability, food security, and crop water productivity. To predict the impact of change in climate, various climate models have been developed, as climate models help to give precise projections for future climate scenarios. These predictions indicate that temperature will increase but change (either increase or decrease) in relative humidity depending on the location of research. The impact of change in climate on crop production is frequently sum up with soil water balance and water productivity. Temperature and relative humidity will be affected by global warming, and it will have direct effect on groundwater level and status of soil moisture. During the growth period of crop, its yield is restrained to variety of crop, soil degradation, planting area, water availability, and growing climate. With increasing temperature and changing ambient relative humidity, the production of crop will decrease in the future. By increasing the irrigated area, total yield will increase but with the degradation in the quality of food and environment. With the change in climate, plant transpiration rate and soil evaporation will be decreased. Thus, water use efficiency (WUE) may be decreased in the future. It will be important for food security to maintain a stable connection with global food supplier and improvement in water productivity. Furthermore, the aggregated distortion to agriculture from climate change over the next few decades and across the region is more likely to arise from increased intra-annual and interannual climate changes from an increased frequency of extreme events than from changes in mean climatic conditions.

Climate scenario makes a reasonable description of the future climatic based on a range of climatological relationships and assumption of radioactive forcing. These future climate scenarios can be visualized by GCMs. There are tedious three-dimensional mathematical exemplifications to show the collaborations between lands and surface sea ice atmosphere which resulted from climate (Mearns 2000). However, GCMs still have a significant role to motivate the aspects of current and future climates (Solomon 2007). So, resultantly they pro-sights into climate change impacts on a regional scale and estimate the impact of climate change on crop production. When regional climate models (RCMs) are used to reproduce the observed duration of less rainfall (%) monthly, it causes some troubles by Blenkinsop and Fowler (2007). Climate models are needed to be integrated with other modeling approaches to predict the vulnerability and climate parameters like rainfall (mm), temperature (°C), etc.

Advanced terrestrial ecosystem analysis and modeling (ATEAM) is provided by Metzger (2005), to qualify the vulnerability of climate change using GCM and to protect climate change in 2080. In Australia, statistical methods were used to select 15 best models to drive annually and seasonal average projections of rainfall and temperature by Suppiah (2007). According to historical data, climate variability, and water stress conditions, some reasonable policy approaches are suggested to treat the extreme climate change variability. Prediction model is used to adjust water distributions of surface and groundwater, to improve water use efficiency in agriculture and to build a national legal framework to manage water resources (Khan 2008).

Based on robust decision-making to quantify the SRES, Groves and Lempert (2007) provided a new analytical method to develop using the scenario-axis method for decision-maker. To drive rainfall climate information using the stochastic simulation method, Fowler et al. (2005) studied the Neyman-Scott Rectangular Pulse (NSRP) rainfall scenario generation model. Xu et al. (2006) used the PRECIS climate model to predict mean temperature and rainfall increase across China. To predict climate scenarios, GCMs have been used and impacts in many cases using the downscaling approach. GCM lacks the spatial and temporal precision necessary for detailed regional analysis and in many cases has errors to simulate even present-day climate and also typically has low degree of resolution. GCMs can provide reasonable accuracy about large-scale features and other variations due to impact of climate change while having uncertainties about future climatic conditions. Different climate models have different uncertainties. So further study on GCM will be dependent on how to improve the sensitivity and evaluate feedback of the factors influencing climate model.

In order to reduce the spatial and temporal error for the accurate regional climate study, future climate models will require more detail of factors and have higher precise latitude and longitude. Human prosperity and crop production are fully dependent on water resources. The agricultural land and water resources in the world depend upon the different hydrological cycles which further include natural replacement of surface and groundwater resources. The main problem of water shortage is its divergence. Water accessibility is an essential part of human life, environment, and biodiversity which is also a concern of water authorities. However, shortage of water is a great burden on the world's population, use of land, and different factors.

It is a need of the hour to take important steps for effective use of available water and developing new resources of water due to factors (climate change, demand of water, socioeconomic effects) influencing water availability. The accessibility of water will be susceptible to climate change due to lowering resources of water by growing and melting of snow.

Food and Agriculture Organization (FAO) defined the impact of climate change on food security. According to FAO food security has four different aspects like food availability, food stability, food access, and food utilization. In agriculture, this organization is mainly focused to protect all these four aspects. Furthermore, FAO provides the safe healthy and nutritious food that meets their dietary needs for an active and healthy life (Schmidhuber and Tubiello 2007). However, FAO mentioned that biotechnology is a very effective approach to improve food security and minimize the environmental pressure on damaging food. Meanwhile, to fulfill the demand of future food availability, resistance and modified crop varieties, waterlogging, salinity, and thrilling climate can develop the crop planting area such as in the degraded soil. Nowadays climate change is the biggest threat to the present and future food demand. These climatic threats to food caused very hazardous effect on human health. If all abovementioned approaches are adopted regularly, there will be an increase in food availability in the future (FAO 2002).

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