CLIMATE-CHANGE ASPERSIONS ON FOOD SECURITY OF PAKISTAN

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ABSTRACT

The economy of Pakistan is agrarian. The production system is predominantly irrigated that uses 90% of the available river-water and provides over 80% of agricultural produce. The productive resources of land and water, which are the base for food production, are limited, rather dwindling due, inter alia, to the changing climate. The climate change is exerting pressure on these resources, both directly (e.g. through increased glacier-melt, increased evapotranspiration, increased land-degradation, etc) and indirectly (e.g. via enhancing soil processes, such as, denitrification leading to emission of greenhouse gases, and unavailability of plant-nutrients, increasing crop-water requirements, etc). Not only this, but the frequency and intensity of extreme climate events of floods, drought, cyclones, etc., is on the increase with serious consequences for the standing crops apart from immeasurable damage to life and property.

These changes are expected to have significant impacts on food security of the country. Global assessment (projections) of the impact of climate change on agriculture suggests-losses in crop yields, reduction of growing-season length, increased water-requirements of crops and decreased irrigation water-supplies as a result of warmer temperatures. This paper presents results of some studies carried out at GCISC with the help of DSSAT-based crop-simulation models (CERES-Wheat and CERES-Rice) on impacts of climate change on the productivity of two major food crops, wheat and rice, of Pakistan. The paper also discusses food-security prospects of Pakistan towards the end of this century in the light of the above-mentioned analyses.

Keywords: *Climate Change, Food Security, Crop Simulation Modelling, Pakistan*

1. INTRODUCTION

To feed its inhabitants adequately and efficiently is the first and the foremost duty of a government. The national planners are always in need of data for assessment of the food-security situation, i.e. the food stocks required for their people in the short and long-term, in the background of prevailing state of the productive resources of land and water.

Food security can be defined in hundred and one ways in the light of objective for which it is to be used. The definition by FAO is the most comprehensive and appropriate one. It states "food-security exists when all people, at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food-preferences for an active and healthy life" (FAO, 2004). This definition embodies three dimensions; adequacy of food (effective supply), ample access to food (ability of individual to acquire sufficient food) and reliability of supply and access (equity of food distribution). This paper concentrates on the food-production aspect of food security.

2. CLIMATE CHANGE AND AGRICULTURE

Weather and climate are the key factors in the agricultural productivity. Being open to vagaries of nature, the agriculture sector is highly vulnerable to climate-change phenomena. Weather is defined as the 'state of the atmosphere at a given time and place, with respect to variables, such as temperature, moisture, wind velocity and barometric pressure (Dictionary.com 2009 http://dictionary. Reference.com/browse/weather). It is a short-term state, for a day or a week. Climate is the 'average weather' or statistical description of mean weather-conditions over a period of time, ranging from months to thousands or millions of years, typically 2 to 3 decades. The classical period is 30 years, as defined by the World Meteorological Organization (WMO).

"Climate change" refers to a statistically significant variation in the mean state of climate or its variability persisting for extended years (typically decades or longer). Climate change may be due to natural internal processes or external forcing, or due to persistent anthropogenic changes in the composition of atmosphere or in land-use. United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "A change of climate which is attributed, directly or indirectly, to human activity that alters the composition of global atmosphere and which is in addition to natural climate variability observed over comparable time periods". (http://www.wmo.int/pages/prog/wcp/ccl/faqs.html)

The climate-related parameters that influence agricultural productivity include: carbon dioxide (CO_2), temperature, solar radiation, precipitation, and others (wind speed and direction, soil moisture, water vapours, etc). A basic understanding of functions and mode of action of these parameters helps us to manipulate plants and management-practices to meet human needs of food, fiber, and shelter. The

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parameters also help understand impacts of climate change on productivity and devise adaptation/mitigation strategies to counter the negative impacts.

3. CHANGING CLIMATIC TRENDS

The Inter-Governmental Panel on Climate Change (IPCC), the apex international body on climate-change research, makes periodic assessments on the status of climate change. Based on its latest Assessment Report (AR4), published in November 2007, the future concentration of CO_2 was calculated. The concentration in the atmosphere has increased from the pre-industrial revolution value of 280 ppm in 1780 to 383 ppm in 2007, and is projected to increase to 550 ppm by 2050 (Iqbal and Arshad, 2008). The global average temperature has increased by 0.6°C during the last century and is likely to increase by 1.8° to 4°C, by the end of this century. The changes in rainfall are not uniform; in sub-humid and humid areas there will be increase in monsoon rainfall, whereas in the coastal and hyper-arid areas there will be decrease in winter and summer rainfalls (IPCC, 2007).

4. FOOD PRODUCTION IN PAKISTAN

Although agriculture's contribution to national GDP has decreased, from 53% in 1949-50 to 21.8 % in 2008-09, and that of industry has increased to 17%, agriculture is still the predominant sector of national economy. It provides food and fiber to the growing population of the country, hence is an important contributor to food-security and it presently employs 44.7 % of Pakistan's labour force (GoP, 2009).

The agricultural production system is predominantly irrigated. Out of the total cultivated area in Pakistan of 22.05 million hectares (mha), 19.12 mha or 84% is irrigated and the remaining totally rainfed. The irrigated agriculture uses more than 90% of the available fresh-water resources and provides over 80% of the produce (Bhatti and Akhtar, 2002).

A good part of Pakistan is classified as arid to semi-arid, where rainfall is not sufficient to grow agricultural crops (Waraich, 2005). The extent of dry areas in Pakistan is given in Table-1. About 11% of the area has annual rainfall of 250-500 mm, about one half has rainfall ranging from 150-250 mm and about one-third has less than 150 mm annual rainfall. The country on the whole is classified as Arid country.

5. PERFORMANCE OF AGRICULTURE SECTOR: 1990-2009

Pakistan's agriculture has seen many upheavals during the past 50 years. Some years have been of slow growth, while the others have registered good growth. During this period, the population has increased over four-fold, while wheat production has more or less kept pace. Wheat production grew from 14,585 m tons in 1990-91 to 21 m tons in 2007-08. Rice production rose from 0.86 m tons in 1950-51 to 5.56 m tones in 2007-08 (GoP, 2009). The dip in production during early 1990s and late 1990s has been attributed to dry spells related to climate change. Such spells can signal an increase in food-insecurity in the country. This is now becoming more and more significant.

6. IMPACTS OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTIVITY

It has been increasingly realized that climate change is the single important factor that is likely to exert pressing effect on productive resources and, ultimately, on agricultural productivity in a number of ways. These impacts include:

i. Shortening Length of Growing Period: Climate change increases the span of growing period, the

Table - 1: Extent of Dry Areas, Based on Aridity Index, in Pakistan

Area	Rainfall Regime	Million hectares	% of Total
Total Area	<150->1,000 mm	79.61	100
Semi-arid	250-500 mm (Aridity Index 16-31)	8.76	11
Arid	150-250 mm (AI 8-16)	38.21	48
Hyper-arid	< 150 mm (AI < 8)	26.27	33

Note: Aridity Index =Σ1.65(Precipitation/Temperature+12.2)x0.9

optimum period during which a crop can be raised, due to high temperature. It is represented as sowing window. The actual growing season length or cycle of growth of a crop, i.e. time taken from sowing to maturity, on the other hand, gets shortened as a result of rise in average temperature, which forces crops to mature earlier; hence full crop production cannot be realized. The growing season length is represented by 'Growing Degree Days'. These both (growing period and growing season length) are commonly used synonymously, but erroneously.

ii. Losses in Crop Yield: The shortening of growing season length, or the crop life-cycle, leads to concomitant loss in yield, as the crop is unable to realize its full production-potential. Also, the rise in temperature affects crop-yield directly. Crop simulation-modeling studies, based on future climate scenarios, carried out in Pakistan and in other countries, point to considerable losses in crop yields. Fischer et al. (2002) reported that substantial losses are likely in the rainfed areas of wheat production in South and Southeast Asia. In South Asia, the drop in yields in non-irrigated wheat and rice will be significant for a temperature increase greater than 2.5°C, incurring a loss in farm level net-revenue between 0 and 25% (Kumar and Parekh, 1998). The net cereal production in South Asian countries is projected to decline at least 4 to 10% by the end of this century, under the most conservative climate-change scenarios (Alam et al., 2007). However, regional differences in the response of wheat, maize and rice yields to projected climate change are likely to be significant (Parry et al., 1999, Rozenweig et al., 2001).

The work done in this regard at GCISC will be described and the major results presented in the subsequent sections.

iii. Changes in River-Flows: Pakistani rivers derive upto 80% or more of their water from Hindu-Kush Himalayas (HKH) glaciers (WAPDA-IDRC-WLU, 1990; http://www.idrc.ca/en/ev-5441-201-1-DO_TOPIC.html). Rising atmospheric temperatures are increasing the glacier melt. According to IPCC (2007), glacier melt in the Himalayas is projected to increase flooding within the next 2-3 decades. This will be followed by decreased river-flows, as the glaciers recede. Rapid melting of glaciers will have serious consequences for river- flows. The expected changes in river-flows will have the following implications for Pakistan:

- More water will be available in the first few decades, but the flows would decrease thereafter, due to reduced glacier volume (Malik, 2007).
- There will be total dependency on precipitation/rainfall
- There will be changes in the intra-annual pattern of river-flows
- Increased frequency and intensity of floods and droughts, due to reduction of natural reservoirs (ibid).
- There will be a need for increased water-storage in view of increased frequency of floods and droughts, and changes in intra-annual river-flow patterns.
- Energy-security will be threatened, as water storage in dams will be affected by changes in seasonal and total flows.

iv. Increased Evapotranspiration: A rise in average temperature causes more water to evaporate from the soil surface, as well as to transpire from the plant leaves, together called as "evapotranspiration losses". Higher evapotranspiration means that more water will be needed by the plant to perform its physiological functions and maintain optimum growth, hence increased requirements of irrigation or rain water.

v. Land Degradation: The deterioration of productive resources of land, which provide foundation for food production, is one of the major causes of low productivity. The land degradation may be due to various causes, namely:

a. Waterlogging: The continuous seepage of water from canals, percolation after heavy or extended rainfall events or water stagnation for long periods leads to rise in water table. The state of soil when it is saturated with water is called "waterlogging". Waterlogging may be transient or permanent. According to an estimate, about 2 mha of land is affected by waterlogging, of which about 0.8 mha is in Punjab and 1.1 mha in Sindh (GoP, 2007). Waterlogging per se is inhospitable to optimum crop-growth. It causes suffocation of plant-roots due to lack of aeration, unavailability of plant-nutrients due to development of anoxic condition and incidence of root-diseases due to dampness. The anoxic conditions in the rhizosphere lead to denitrification - a process wherein nitrogenous fertilizer in soil is lost to atmosphere in gaseous form, as N_2O. The N_2O is a GHG having warming potential of 2,100 times that of CO_2.

b. Salinity: Waterlogging eventually leads to salinity problems, particularly in the irrigated areas. The gradual rise of water, containing dissolved salts, upwards to the soil-surface, in response to evaporation, brings the dissolved salts to the surface. The high temperature obtaining at the surface causes water to evaporate, leaving the salts deposited on the surface, giving rise to salinity. This process is dictated by climatic parameters, such as, temperature, wind-velocity, solar-radiation and water-vapour content in the atmosphere, etc. Accumulation of salts at the soil-surface is characteristic of arid and semi-arid environments, especially where pumped groundwater irrigation is practiced. Salinization occurs both naturally (primary salinity) and as a result of human activity (Secondary salinity).

The salt-affected area in Pakistan is 6.67 mha (Khan, 1998), of which 80% lies in Punjab. About 6.14 mha of land is affected by salinity and sodicity, with Punjab having the highest share (3.9 mha), followed by Sindh (0.6 mha) and Baluchistan (0.2 mha) (GoP, 2007). Salt has always been part of Pakistan's environment. Accumulation of excessive salts at the surface is injurious to plant growth. The salts inhibit germination, lead to poor crop stand, to physiological drought and, in severe cases, to death of growing crops. Makhdum and Ashfaq (2008) showed that salinity and waterlogging were negatively associated with wheat production. Waterlogging and salinity have also adverse social (e.g. migration and diseases) and economic (increase in poverty) effects on communities in Pakistan, causing poor living-standards, crumbling mud and brick houses, health problems for humans and animals, and bad condition of roads.

c. Water and Wind Erosion: Soil erosion is universally recognized as a serious threat to land resources. The land resources are also being degraded in Pakistan due to erosion by water and wind. The climate of the country in arid and semi-arid areas has extreme variation in temperature. The watersheds in Upper Indus and its tributaries suffer from unfavourable soil and moisture regimes (http://www.nssd.net/country/pakistan/pamtr8b.htm), thereby exacerbating erosion. It has been estimated that 11.2 mha of land, mostly in northern mountainous region, are affected by water-erosion. About 3-5 mha are affected by wind-erosion in arid regions of Punjab (Cholistan), Sindh (Tharparker) and Baluchistan (Chaghai Desert and sandy areas along the coast). Some of the areas have 0.5 to 4m high moving sand-dunes, posing danger to cultivation and local infrastructure (GoP, 2009).

Wind erosion is the direct consequence of climatic parameter of wind-velocity and temperature. Water erosion is caused by high-intensity rainfall and deforestation, with the consequent water-runoff from the bare or slopy land. Geographic Information System (GIS) and Remote Sensing (RS) are efficient tools for assessment and management of soil-erosion for large catchments. Nabi et al. (2008) have estimated soil-erosion from Soan river catchment, using RS and GIS techniques.

vi. Extreme Climate Events: The incidence of extreme climate events, such as flash floods, heavy precipitation events, droughts, cyclones, hail storms, dust storms, has been on the increase in the recent past, with telling effects on life and property. The extreme events are hard to predict. According to IPCC (2007), their frequency and intensity is likely to increase in future. Such events can affect food-security in the following ways:

- By destroying the food-crops standing in the field that are otherwise bumper and healthy;
- By damaging stored grains in the godowns – due to roof leakage, fungus development, attack of diseases because of dampness; and
- By spoiling the quality of food grains.

7. GLIMPSES OF WORK DONE AT GCISC ON IMPACTS OF CLIMATE CHANGE ON PRODUCTIVITY OF CROPS

Global Change Impact Studies Centre (GCISC) is a public-sector organization dedicated to research on climate change. Simulation studies, using crop-growth simulation model CERES, were carried out on impact of climate change on life-cycle of crops. Growing-Season Length (GSL), and yield of wheat and Basmati rice (Iqbal et al. 2009a and 2009b). For wheat, the impact was studied in four agro-climatic zones of Pakistan (Figure-1). The zones are: northern mountainous region, northern sub-mountainous region, southern semi-arid plains and southern arid plains.

Wheat: The impact of temperature increases from baseline to 5°C, with increments of 1°C on GSL of

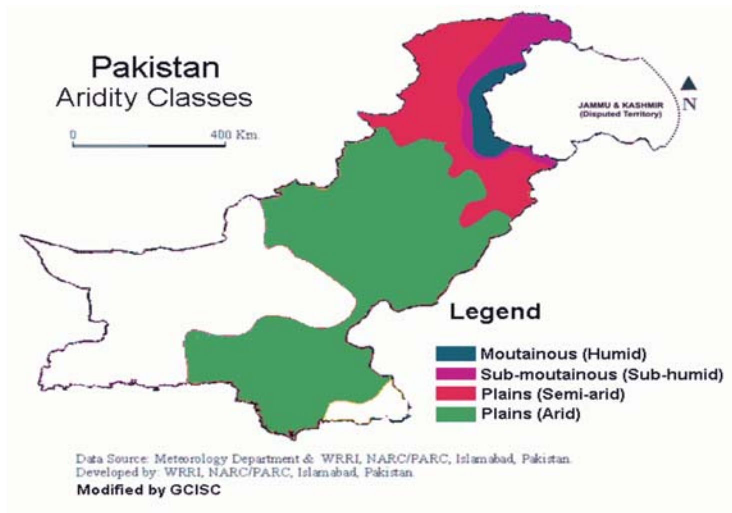

Figure - 1: Agro-climatic Zones used by GCISC for Climate Change Impact Studies on Agriculture in Pakistan

wheat is presented in Table-2. It can be seen that GSL decreases in all the agro-climatic zones, even with 1°C increase in temperature, but the magnitude of decrease is different. The largest decrease occurs in the northern mountainous region, where GSL decreases by 14 days (from 246 to 232 days) for 1°C increase in temperature and 52 days (from 246 to 194 days) for 5°C increase in temperature. The corresponding decreases predicted in other zones were relatively less.

The impact of increasing temperature (keeping other climatic factors constant) on yield is shown in Figure-2. The hypotheitical scenarios of increase in temperature above the baseline are used. As per IPCC (2007), the temperature is likely to increase by 1.8 to 4°C by the end of this century.

The yield increases in the northern mountainous region with each degree rise in temperature until 4°C whereafter the yield levelled off. The yield in the other three zones (northern sub-mountainous, southern semi-arid plains and southern arid plains) consistently decreased with each degree rise in temperature.

The projected impact of climate change on wheat-yield, under IPCC scenario A2 [developed for Pakistan by GCISC from the outputs of six Global Circulation Models (which embodies changes in climatic parameters of CO_2 concentration, temperature and precipitation in the four agro-climatic zones under study), towards end of this century] is presented in Figure-3. The IPCC A2-scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Economic development is primarily regionally oriented and the per-capita economic growth and technological change is more fragmented and slower than for other

Table - 2: Impact of Rise in Temperature on Growing Season Length of Wheat in Northern and Southern Parts of Pakistan

Temperature ˚C (increase over baseline)	Growing Season Length (Days)			
	Northern Pakistan		Southern Pakistan	
	Mountainous (Humid)	Sub-Mountainous (sub-humid)	Plains (Semi-arid)	Plains (Arid)
Baseline	246	161	146	137
1	232	155	140	132
2	221	149	135	127
3	211	144	130	123
4	202	138	125	118
5	194	133	121	113

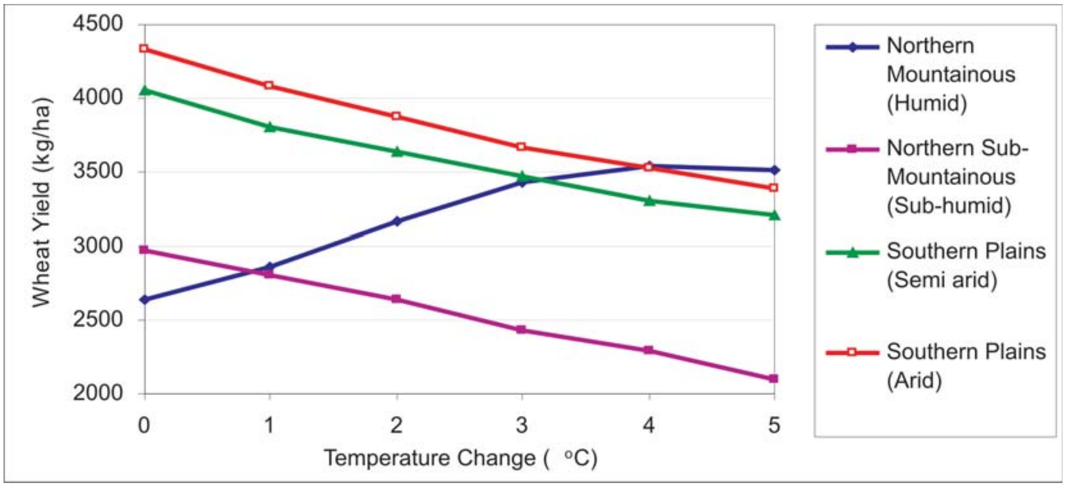

Figure - 2: Effect of increase in temperature (keeping other climatic factors constant) on wheat-yield in different agro-climatic zones of Pakistan

storylines. The B2-scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change.

It will be seen that the yield will increase in northern mountainous region, whereas it is likely to decrease in the remaining three zones by 2080s. The wheat-production situation in these areas towards the end of this century (Table-3) shows that, by 2085, there will be about 6% reduction in wheat production in Pakistan even though there will be an increase in production in the northern mountainous region by 50% under A2 and 40% under B2-scenario. But, given a meager (2%) share of this area in national production, it will not make any significant impact on wheat-production in Pakistan. The increase will, however, be beneficial locally from view-point of food self-sufficiency and livelihood of the dependant communities.

Rice: In case of rice, only the fine-grain aromatic Basmati rice was studied. The Basmati rice is grown chiefly in the central Punjab in semi-arid plains of the country. The impact of climate change on Basmati rice was studied, under IPCC A2 and B2-scenarios, using crop-growth simulation model CERES-Rice. The results (Figure-4) show that rice will suffer reduction in yield, and the reduction will be greater than that in wheat. There will be an expected shortfall of 18%

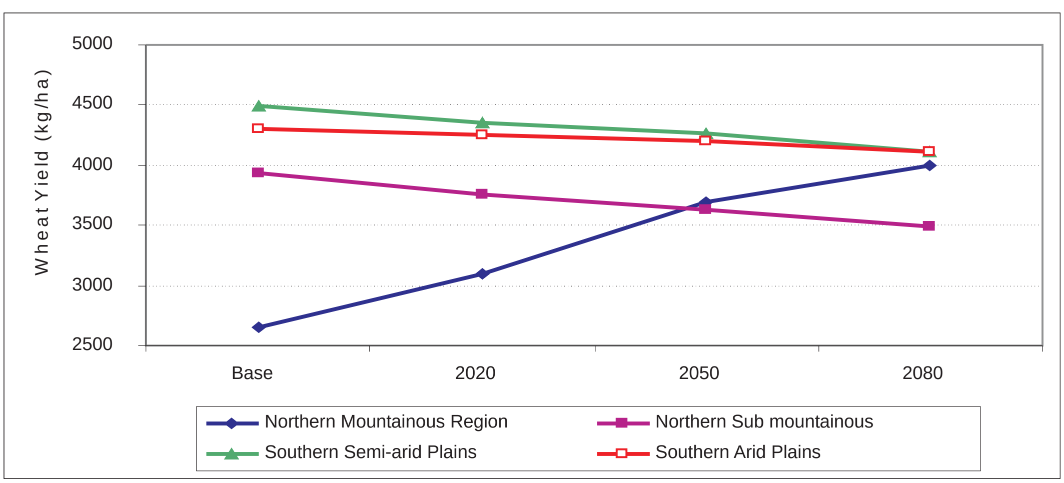

Figure - 3: Wheat yield in Different Agro-climatic Zones of Pakistan, at Different Time-slabs Towards end of this Century, under IPCC A2-Scenario

Table - 3: Climate-Change Impact on Wheat Production in Pakistan by 2085, under the IPCC A2 and B2 Scenarios

Region	% Share in National Production	Baseline Yield (kg ha^{-1})	% Change in yield in 2085	
			A2 Scenario	B2 Scenario
Northern Mountainous	2	2658	+50	+40
Northern Sub-mountainous	9	3933	-11	-11
Southern Semi arid Plains	42	4306	-8	-8
Southern Arid Plains	47	4490	-5	-6
Pakistan	100	4326	-5.7	-6.4

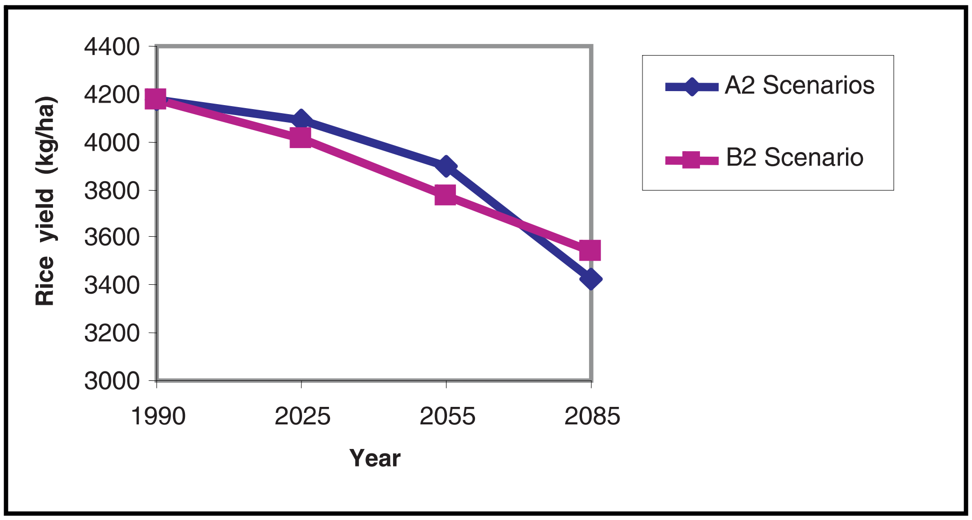

Figure - 4: Basmati Rice Production in Central Punjab in Semi-Arid Plains, by 2085 under IPCC A2 and B2 Scenarios

under A2 and 15% under B2-scenario in rice production by 2080s, if the climate change is allowed to go unchecked.

8. SOME ADAPTATION POSSIBILITIES

The studies reported above and those reported in literature elsewhere point to the need of adaptation to counter the negative impacts of climate change (Iqbal et al., 2009c). Some adaptation possibilities are indicated below:

- Alteration in sowing dates to escape the intense heat at the time of sowing, or at other sensitive

growth-stages.
- Use of new crop-varieties, which have been designed to be high-temperature tolerant and are of short duration.
- Advance seasonal weather forecast in order to take appropriate adaptive measures.
- Changes in irrigation methods for making the most efficient use of the available water- resources.
- Changes in planting techniques – for sowing rice by dry method, as in wheat, instead of conventional transplanting technique.
- Use of resource-conservation technologies, such as bed and furrow sowing, laser land-leveling, furrow irrigation, to save on water and cost of cultivation.

Some of these adaptation possibilities are presently being studied at GCISC.

9. CONCLUSIONS

The agriculture production system of Pakistan is predominantly irrigated, which derives 60-80% of its water from snow/ice melt. It is under threat from climate change which has both positive and negative impacts; the negative impacts outweigh the positive impacts. The major impacts include:

- The large variability of river flows caused by glacier-melt will make irrigated areas highly vulnerable.
- Variability in frequency and intensity of rainfall will adversely affect productivity of rainfed areas.
- Drop in crop-yield due to rising temperatures is likely to cause shortfall: in wheat production by about 6-8%, and in rice by about 15-20%, towards the end of this century.
- The land resources are likely to be degraded further, due to (a) water-logging and salinization, and (b) water and wind erosion.
- Added to the above will be the loss in production caused by increased frequency and intensity of floods and droughts.
- Most of the above-mentioned challenges can be met by developing appropriate adaptive measures well in time to counter the negative impacts.
- This will require coordinating long-term efforts.

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