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Impact of climate change on Agricultural productivity

Introduction of Weather and Climate Change

Atmospheric condition which remains for some days is called weather, whereas, if such condition prevails for a season, decade or a century, it is termed as climate. To keep the pace of growth fossil fuel has been used in order to meet the energy requirement. However, fossil fuel adds some gases in the atmosphere which are altering the climate with the passage of time.

Climate Change and its causes

Climate change refers to change in climate due to natural or anthropogenic activities and this change remain for a long period of time. [IPCC (2007)]

The gases responsible for the global warming are known as Greenhouse Gases (GHGs), which are comprised of Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O) and water vapors. These gases are produced by a number of anthropogenic activities. CO_2 is mainly produced during the combustion of wastes, carbon, wood and fossil fuels. Methane is produced during the mining of coal, gas and oil and during their transportation, whereas, Nitrous Oxide is produced during agricultural and industrial activities.

Man is responsible for this newly emerging CO_2 enriched world because since the pre- industrial time CO_2 concentration has increased from 300 ppm to 400 ppm due to deforestation, massive use of fossil fuels etc. The concentration of GHGs as a result of anthropogenic activities is increasing at a rate of 23 ppm per decade, which is highest rise. Percentage contribution of different sectors in the

atmospheric concentration of GHGs is from energy sector 63 percent, agriculture 13 percent, industry 3 percent, land use and forestry 18 percent and waste 3 percent. Climate change is an externality which is mainly caused by particular economic activities, and the geographical position of many developing countries makes them very much vulnerable to climate change. According to the IPCC prediction, in the absence of any policy to abate the GHGs emission, GHGs would increase from 550 ppm to 700 ppm at the mid of current century and this level of GHGs would cause to accelerate the temperature from 3^{o}C since the pre-industrial era to 6^{o}C.

Agriculture is the most vulnerable sector to climate change. Agriculture productivity is being affected by a number of factors of climate change including rainfall pattern, temperature hike, changes in sowing and harvesting dates, water availability, and evapotranspiration and land suitability. All these factors can change yield and agricultural productivity. Global warming is a real issue which is directly caused by the higher level of CO2 in the atmosphere, whereby GHGs trap the sun rays and do not let them go back to space. Higher level of CO2, produced by anthropogenic activities, intensifies concentration of GHGs, traps more light and causes to increase earth's overall temperature. Some of the consequences of global warming may appear in the form of more frequent floods and drought, food shortage, non-supporting weather conditions, newly borne diseases, sea level rise, etc. The concentration of these GHGs are mounting in the atmosphere through number of ways like anthropogenic activities, deforestation etc. It is expected that up to 2100 this concentration would become 3 times as much as the pre-industrial time causing 3 to 10^{o}C hike in temperature.

Possible Effects of Climate Change on Agriculture

The impact of climate change on agriculture is many folds including diminishing of agricultural output and shortening length of growth period for crops but climate

change increases the span of growing period, the optimum period during which 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.

The Countries lying in the tropical and sub- tropical regions would face callous results, whereas regions in the temperate zone would be on the beneficial side.

Wheat, which is a winter crop, also requires long cold season in order to hasten plant development before flowering occurs, so higher temperature delay the vernalization process in wheat (Vernalizaion is the process of exposure to the prolonged cold of winter in order to accelerate flowering when it is planted).

CO_2 is regarded as the driving factor of climate change; however its direct effect on plant is positive. CO_2 enriches atmosphere positively affects the plants in two ways. First, it increases the photosynthesis process in plants. This effect is termed as carbon dioxide fertilization effect. This effect is more prominent in C3 plants because higher level of CO_2 increases rate of fixed carbon and also suppresses photorespiration. Second, increased level of CO2 in atmosphere decreases the transpiration by partially closing of stomata and hence declines the water loss by plants. Both aspects enhance the water use efficiency of plants causing increased growth.

The crops which exhibit positive responses to enhanced CO_2 are characterized as C_3 crops including wheat, rice, soybean, cotton, oats, barley and alfalfa whereas, the plants which show low response to enhanced CO_2 are called C_4 crops including maize, sugarcane, sorghum, millet etc.

Regarding the impact of increase in temperature on the wheat productivity indicates that impact of increase in temperature is catastrophic (causing sudden great damage) in terms of yield losses because higher temperature accelerates the evapotranspiration process creating moisture stress. It also shorten the growth period duration of wheat crop and this becomes more severe regarding yield losses if it occurs during the canopy formation because less time will be available for vernalization process and the formation of kernels. Wetter conditions are beneficial for wheat yield whereas drier are harmful and cause to decrease the productivity.

Temperature alterations can take many forms: changes in average temperature; changes in daytime high and nighttime low temperatures; and changes in the timing, intensity and duration of extremely hot or cold weather. In general, crops are most sensitive to high temperatures at the reproductive stage and grain-filing/fruit maturation stage. However, plant responses to each type of temperature alteration are specific and mediated through both photosynthetic activity for biomass accumulation, which is responsible for plant growth, and the phenological and morphological changes, which occur during plant development. Each type of temperature stress has a different effect on crop duration and overall plant productivity. The increase in average temperature during the growing season typically causes plants to use more energy for respiration for their maintenance and less to support their growth. With a 1°C increase in average temperatures, yields of the major food and cash crop species can decrease by 5 to 10 percent. With higher average temperatures plants also complete their growing cycle more rapidly. With

less time to reproduce, reproductive failures are more likely and this will also lower yields. In general, photosynthesis in C_3 plants is more sensitive to higher temperatures compared with C_4 crops. Most crops can tolerate higher daytime temperatures during vegetative growth, with photosynthesis reaching an optimum at between 20°C and 30°C. During the reproductive stage, yields decline when daytime high temperatures exceed 30°C to 34°C.

During the reproductive stage, higher night time temperatures may increase respiration at night causing declines in yield (e.g. rice) and flowering or reproduction (e.g. beans).

Higher temperatures can also affect the marketability of fruits and vegetables. The increased rates of respiration caused by higher temperatures lead to a greater use of sugars by the plants. As a result less sugar remains in the harvested product, and this can reduce its market value. These affects become more serious as temperatures continue to rise during the grain-filling or fruit maturation stage.

Changes in Precipitation (rainfall) regimes

Changes in precipitation regimes include changes in seasonal mean, the timing and intensity of individual rainfall events, and the frequency and length of droughts. Each of these factors is critical to crop productivity. The impact of changes in precipitation will be particularly marked when they are combined with temperature alterations that affect the crop's evaporative demands. This may lead to different forms of moisture stress depending on the phonological stage the crop has reached. The general prediction is that, with climate change, areas that already receive high levels of rainfall will receive more, and those that are dry will become drier. Heavy rain, hail storms and flooding can physically damage crops. Extremely wet conditions in the field can delay planting or harvesting. Prolonged droughts can

cause complete crop failure. The reduction in seasonal mean precipitation will have a greater impact on areas with degraded soils. Soils with lower levels of organic carbon retain less water at low moisture potentials. Furthermore, crops grown in nutrient-poor soils, especially those lacking potassium, recover less quickly from drought stress once water is again available. For photosensitive species, a change in the duration of the rainy season may cause a mismatch between their reproductive cycle, which is determined by day length, and the availability of sufficient soil moisture to produce good yields.

To help their crops use water more efficiently, farmers must pay attention to improving and maintaining soil fertility for sustainable soil and land management for climate-smart agriculture, by crop residue management for soil carbon conservation and sequestration. (**Carbon sequestration** describes long-term storage of **carbon** dioxide or other forms of **carbon** to either mitigate or defer global warming and avoid dangerous climate change. It has been proposed as a way to slow the atmospheric and marine accumulation of greenhouse gases, which are released by burning fossil fuels. **Carbon sequestration** is the long-term **storage** of **carbon** in plants, soils, geologic formations, and the ocean. **Carbon sequestration** occurs both naturally and as a result of anthropogenic activities and typically refers to the **storage** of **carbon** that has the immediate potential to become **carbon** dioxide gas.). (Soil **conservation** practices that enhance the storage of **carbon** (such as restoring and establishing new forests, wetlands, and grasslands) or reduce **CO2** emissions (such as reducing agricultural tillage practices)

We are considering three scenarios for the year 2060. In first scenario we are assuming that both the temperature and precipitation increase and in second scenario we assume that temperature increases and precipitation remains constant

whereas, in third scenario we assume that temperature increases but precipitation decreases. Besides temperature and precipitation we assume double level concentration of CO2 in all the three scenarios. We do not assume any increase in water availability on the basis of water scarcity [IPCC (2007)] and take the current level of water availability. The Climate change has both positive and negative impacts; the negative impacts outweigh the positive impacts. In order to cope with any type of emerging hazard of climate change the agriculture sector in Pakistan needs some adaptation strategies. In this regard some strategic measures are mentioned below:

(1) Water conservation management and the irrigation system have to be improved.

(2) New heat and drought resistant seeds and plants of wheat have to be produced.

(3) Wheat cultivation methods shall be adjusted according to the changing pattern of climate change.

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