UNIT 4 IMPACT OF ENVIRONMENT ON AGRICULTURE

Structure

4.1 INTRODUCTION

It is not only the contribution of agriculture in the climate change process, but also the impact of climate change on agriculture that is of concern to farmers and policy makers. In Unit 3, you have studied about the impact of agricultural practices and operations on the environment, and have learnt that during the last century, farm mechanization, introduction of synthetic fertilizers and pesticides and improved cultivars have increased productivity and made many developing countries self sufficient in food grain production. However, these changes created new kinds of problems for the environment.

In this unit, we shall provide some details of the ways through which changes in the environment influence agriculture (production and productivity of crops) as a whole. Environmental problems to agriculture are caused by natural stresses such as drought, salinity etc. Some of these relate to human activities, which in turn affect the global climate. The climatic changes, such as rising temperature, increased CO_2 emissions, ozone layer depletion, and sea level rise etc., influence agriculture in many ways. This forms the subject of discussion in this unit.

Objectives

After studying this unit, you should be able to:

- define environmental stress, salinity stress and moisture stress and their impact on agriculture;
- describe how changes in temperature and rise in CO_2 level in the atmosphere influence agricultural productivity; and
- explain the effect of ozone layer depletion on agriculture and other living organisms.

4.2 ENVIRONMENTAL STRESSES

Plant environmental stress constitutes a major limitation to agricultural production and the farmer's livelihood. Crop production is rarely ever free of environmental stress. The major plant environmental stresses of economic importance worldwide are drought, cold (chilling and freezing), heat, salinity, soil mineral deficiency and soil mineral toxicity. Stress has potential to cause injury, brought about by the aberrant changes in physiological processes in plants. It may manifest itself as reduction in growth and yield, and sometimes lead to the death of the plant and plant parts.

Plant stress can be very obvious visually; but often it is so slight as to go unnoticed by the casual observer until the yield results are in. Adverse soil moisture and temperature conditions in combination with nutrient deficiencies, diseases, insects, and weeds interact to create complex crop stress (Table 4.1). And proper diagnosis of such stress under field conditions becomes difficult.

Table 4.1: Sources of environmental stress for plants

Physical	Chemical	Biotic
Drought	Air pollution	Human Activities
Temperature	Allelochemicals	Insect
Radiation	Nutrients	Pests
Flood	Pesticides	Diseases
Wind	Salinity	

Moisture stress

Water is one of the major elements for agriculture and its shortage will certainly decrease crop production and productivity. In most of the arid and semi-arid regions, precipitation is too low to produce crops.

While heat availability determines the probability that a crop will reach maturity in a region, moisture availability establishes yield potential.

The occurrence of moisture stress during flowering, pollination, and grain filling, is harmful to most crops and particularly so to corn, soybean and wheat. Increased evaporation from the soil and accelerated transpiration in the plants causes moisture stress; as a result there is a need to develop crop varieties with greater drought tolerance. Peak irrigation demands also rise due to more severe heat waves. Additional investment for dams, reservoirs, canals, wells, pumps, and piping are needed to develop irrigation networks in new locations. Finally, intensified evaporation increases the hazard of salt accumulation in the soil.

Frequent droughts not only reduce water supplies but also increase the amount of water needed for plant transpiration. Higher air temperatures can also be felt in the soil, where warmer conditions are likely to speed up the natural decomposition of organic matter and increase the rates of other soil processes that affect fertility.

Salinity Stress

Salinity and drought stress are the major causes of historic and modern agricultural productivity losses throughout the world. Both drought and salinity may lead to inhibition of plant growth. Soil salinity affects plant physiology through changes of water and ionic status in the cells. Ionic imbalance occurs in the cells due to excessive accumulation of Na^+ and Cl^- (sodium and chlorine ions) and reduces uptake of other mineral nutrients, such as K^+, Ca^{2+}, and Mn^{2+} (potassium, calcium and manganese ions).

The agricultural use of saline soils can benefit many developing countries. Salt tolerant plants can utilize land and water unsuitable for salt-sensitive crops (**glycophytes**) for the economic production of food, fodder, fuel and other products. **Halophytes** (plants that grow in soils or waters containing significant amounts of inorganic salts) can harness saline resources that are generally neglected and are usually considered impediments rather than opportunities for development.

There are three possible domains for the use of salt tolerant plants in developing countries. Theses are:

1. Farm lands salinised by poor irrigation practices,
2. Coastal deserts, and
3. Arid areas that overlie reservoirs of brackish water

You may like to attempt an SAQ to fix these ideas.

SAQ 1

What do you understand by moisture stress and salinity stress? What effect do these stresses have on plants, in general?

4.3 CLIMATE CHANGE AND AGRICULTURE

Climate is one of the primary determinants of agricultural productivity. Agriculture has been a major concern in the discussions on climate change. You have learnt in Unit 3 that the increased atmospheric concentration of greenhouse gases (GHGs) is contributing to the process of climate change and global warming (Fig.4.1). In fact, the United Nations Framework Convention on Climate Change (UNFCCC) cites maintenance of our societal ability for food production in the face of climate change as one of the key motivations.

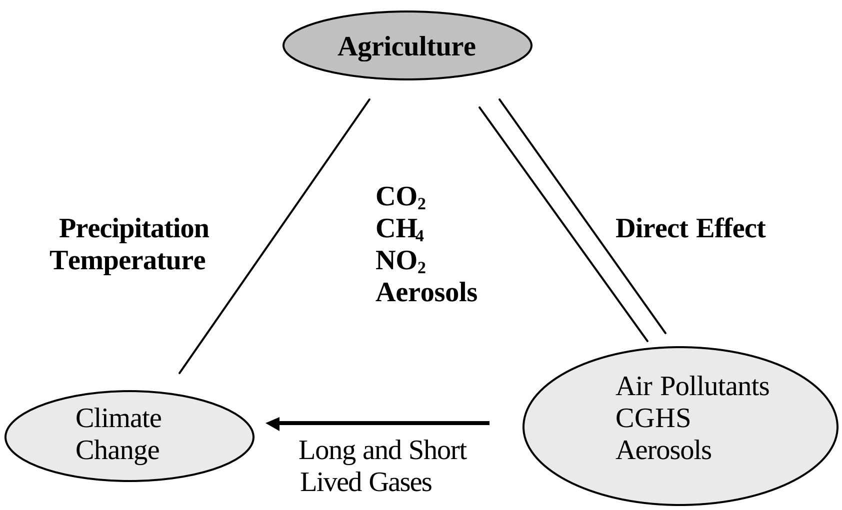

Fig.4.1: Changing atmosphere and agriculture

Our Changing Atmosphere

Energy from the sun controls the earth's climate and weather, and heats the surface of the earth; in turn, the earth radiates energy back into space. Atmospheric greenhouse gases (water vapour, carbon dioxide, and other gases) trap some of the outgoing energy, retaining heat somewhat like the glass panels of a greenhouse. Without this natural "greenhouse effect," temperatures would be much lower than they are now, and life as known today would not be possible. Instead, thanks to greenhouse gases, the earth's average temperature is a more hospitable 60°F. However, problems may arise when the atmospheric concentration of greenhouse gases increases.

Since the beginning of the Industrial Revolution, atmospheric concentrations of carbon dioxide have increased by nearly 30%, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15%. These increases have enhanced the heat-trapping capability of the earth's atmosphere.

You may like to know: **Why are greenhouse gas concentrations increasing?**

Generally scientists believe that the combustion of fossil fuels and other human activities are the main reasons for the increased concentration of CO_2. Plant respiration and the decomposition of organic matter release more than 10 times the CO_2 released by human activities; but these releases have generally been in balance during the centuries leading up to the Industrial Revolution with carbon dioxide having been absorbed by terrestrial vegetation and the oceans.

An estimate of future emissions is difficult, because it depends on infrastructural, demographic, economic, technological, policy, and institutional developments. By 2100, in the absence of emissions control policies, carbon dioxide concentrations are projected to be 30-150% higher than today's levels.

Green House Gases and their Effects

The greenhouse effect plays a crucial role in regulating the heat balance of the earth. It allows the incoming short-wave solar radiation to pass through the atmosphere relatively unimpeded; but the long-wave terrestrial radiation emitted by the earth's surface is partially absorbed and then re-emitted by a number of trace gases in the atmosphere (Fig.4.2.). These gases known as **GHGs** (greenhouse gases) are: **water vapour, carbon dioxide, methane, nitrous oxide and ozone** in the troposphere and in the stratosphere. This natural greenhouse effect warms the lower atmosphere.

If the atmosphere were transparent to the outgoing long wave radiation emanating from the earth's surface, the equilibrium mean temperature of the earth's surface would be considerably lower and probably below the freezing point of water. Mere incidence of GHGs in the atmosphere, by itself, is no concern. What is more important is that their concentration should stay within reasonable limits so that the global ecosystem is not unduly affected.

However, by increasing the concentrations of natural GHGs and by adding new GHGs like chlorofluro carbons, the global average and the annual mean surface-air temperature (referred to as the global temperature) can be raised, although the rate at which it will occur is uncertain. This is the **enhanced greenhouse effect**, which is over and above that occurring due to natural greenhouse concentration. Such a rise in the atmospheric concentration of GHGs has led to an upward trend in global temperature.

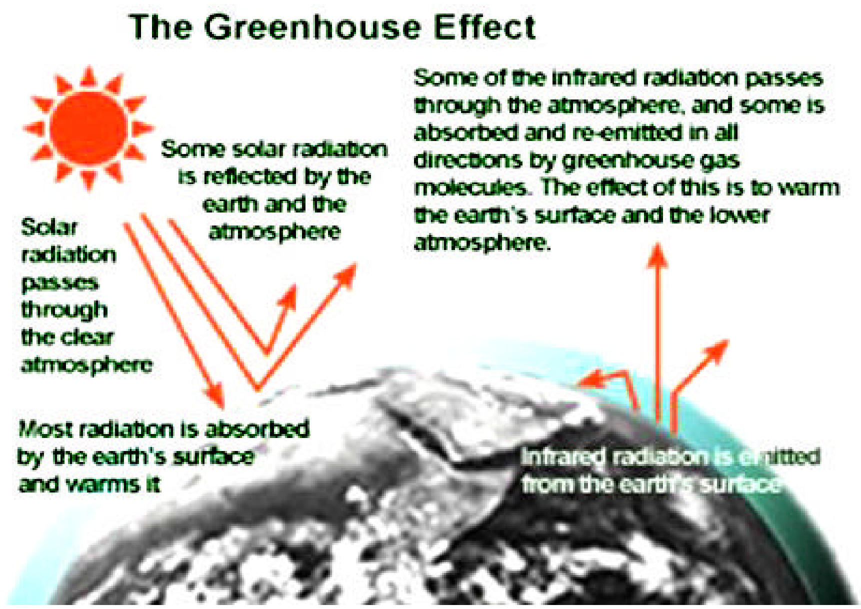

Fig.4.2: The Green House effect

Some sources of GHGs are:

- Energy production,
- Industries,
- Changes in land use patterns, and
- Agriculture and livestock.

However, sinks of GHGs like the following, help in removing them from the atmosphere:

a) Ocean is an important reservoir of CO_2.
b) Vegetation and soil sequester CO_2.
c) Major sink for methane (CH_4) is its reaction with OH in the troposphere.
d) There is no mechanism for the removal of halogenated halocarbons viz. (CFCs and HCFCs/ hydrochlorofluorocarbon); they are only removed by the photo dissociation in the stratosphere.

While it is required to follow the general commitments under the Framework Convention on Climate Change, many countries are not required to adopt any GHG reduction targets. Irrespective of international commitments, it seems prudent to be ready with

- Inventory of sinks and sources of GHG emission;
- Predictions of the cumulative impact of national and international GHG emissions to plan for temperature and sea level rise;
- Land use plans for the coastal areas likely to be affected;
- Water and land management strategies especially in the agricultural sector.

The atmospheric concentration of CO_2 has grown from about 280 to almost 370 ppmv, Methane (CH_4) from 0.70 to 1.72 ppmv (in 1994), Nitrous oxide (N_2O) from 280 to about 310 ppbv and CFC -12 from zero to 5.03 pptv since the industrial period (Table 4.2). This enhanced the naturally occurring green house effect.

Table 4.2: Green house gases influenced by anthropogenic activities

Gas	CO_2	CH_4	N_2O	CFC-12
Pre-industrial atmospheric concentration	280 ppmv	0.70 ppmv	280 ppbv	0
Current concentration	370 ppmv	1.72 ppmv	310 ppbv	5.03 pptv
Current annual increase (%)	0.5% (1.5 to 1.8 ppmv)	0.80% (0.013 ppmv)	0.25% (0.75 ppbv)	4% (18-20 pptv)
Atmospheric Life Time (Yrs.)	50-200	12-17	150	102
Global warming potential relative to CO_2	1	24.5	320	4000

Agronomic and economic impacts from climate change depend primarily on two factors:

1. The rate and magnitude of change in climatic factors and the agricultural effects of these changes; and

2. The ability of agricultural production to adapt to changing environmental conditions.

The snow cover in the Northern Hemisphere and floating ice in the Arctic Ocean have decreased. Globally, sea level has risen 4-8 inches over the past century. Worldwide precipitation over land has increased by about one percent. Increasing concentrations of greenhouse gases are likely to accelerate the rate of climate change. Scientists expect that the average global surface temperature could rise by 0.6-2.5°C in the next fifty years and by 1.4-5.8 ° C in the next century, with significant regional variation.

Evaporation will also increase, which will increase average global precipitation. Soil moisture is likely to decline in many regions, and intense rainstorms are likely to become more frequent (Fig.4.3).

Climate change can impact agricultural sustainability in two interrelated ways:

- First, by diminishing the long-term ability of agro ecosystems to provide food and fibre supply for the world's population; and

- Second, by inducing shifts in agricultural regions that may encroach upon natural habitats, at the expense of floral and faunal diversity.

Global warming may encourage the expansion of agricultural activities into regions now occupied by natural ecosystems such as forests, particularly at mid- and high-latitudes. Forced encroachments of this sort may thwart the processes of natural selection of climatically-adapted native crops and other species.

While the overall, global impact of climate change on agricultural production may be small, regional vulnerabilities to food deficits may increase, due to problems of distributing and marketing food to specific regions and groups of people. For subsistence farmers and more so for people who now face a shortage of food, lower yields may result not only in measurable economic losses, but also in malnutrition and even famine.

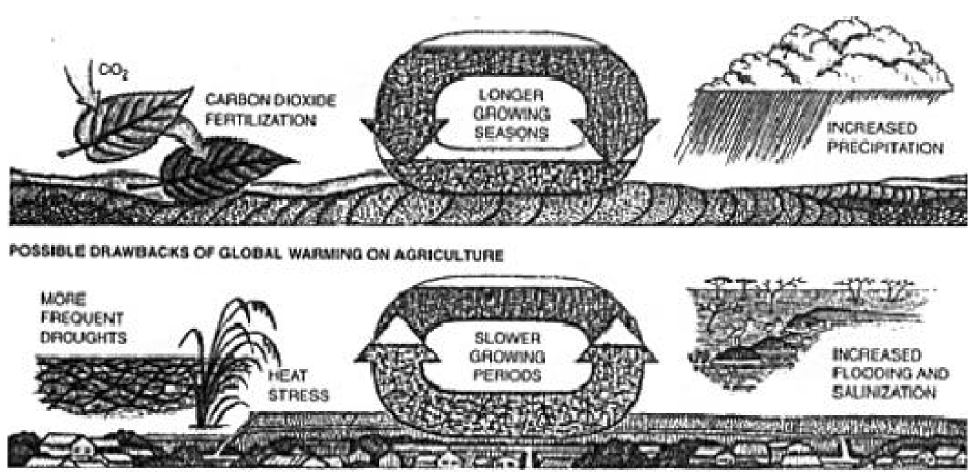

Fig.4.3: Advantages and disadvantages of global warming

4.3.1 Changes in Temperature

The Intergovernmental Panel on Climate Change (IPCC) in its latest assessment report projects that the earth's average surface temperature could rise by 1.4 – 5.8 degrees C over the next 100 years (Fig.4.4).

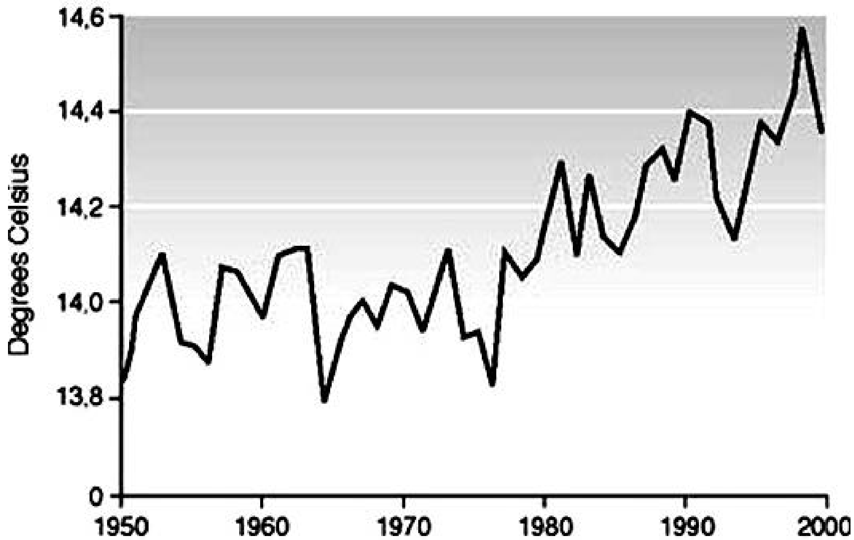

Fig.4.4: Average temperature at the Earth's surface, 1950-99
Source: *Goddard Institute for Space studies number 70 (GISS).*

The panel has concluded that this would result in:

- Severe water stress in the arid and semiarid land areas in southern Africa, the Middle East and southern Europe.
- Decreased agricultural production in many tropical and subtropical countries, especially countries in Africa and Latin America.
- Higher worldwide food prices as supplies fail to keep up with the demand of an increasing population.
- Major changes in the productivity and composition of critical ecological systems, particularly coral reefs and forests.
- Tens of millions of people at risk from flooding and landslides, driven by projected increases in rainfall intensity and, rising sea levels in coastal areas.

Rising global temperatures are expected to raise sea level, and change precipitation and other local climate conditions. Changing regional climate could alter forests, crop yields, and water supplies. It could also affect human health, animals, and many types of ecosystems. Deserts may expand into existing rangelands, and features of some of our National Parks may be permanently altered.

Most of the United States is expected to warm, although sulphates may limit warming in some areas. Scientists currently are unable to determine which parts of the world will become wetter or drier, but there is likely to be an overall trend towards increased precipitation and evaporation, more intense rainstorms, and drier soils. Unfortunately, many of the potentially most important impacts depend upon whether rainfall increases or decreases, which cannot be reliably projected for specific areas.

It has also been observed that the warming has not been globally uniform, Northern hemisphere is experiencing more warming than Southern hemisphere (Fig.4.5). The most obvious feature of the global average temperature record is that of considerable variability, not just year to year but from decade to decade. However, there is still a lot of uncertainty on temperature changes.

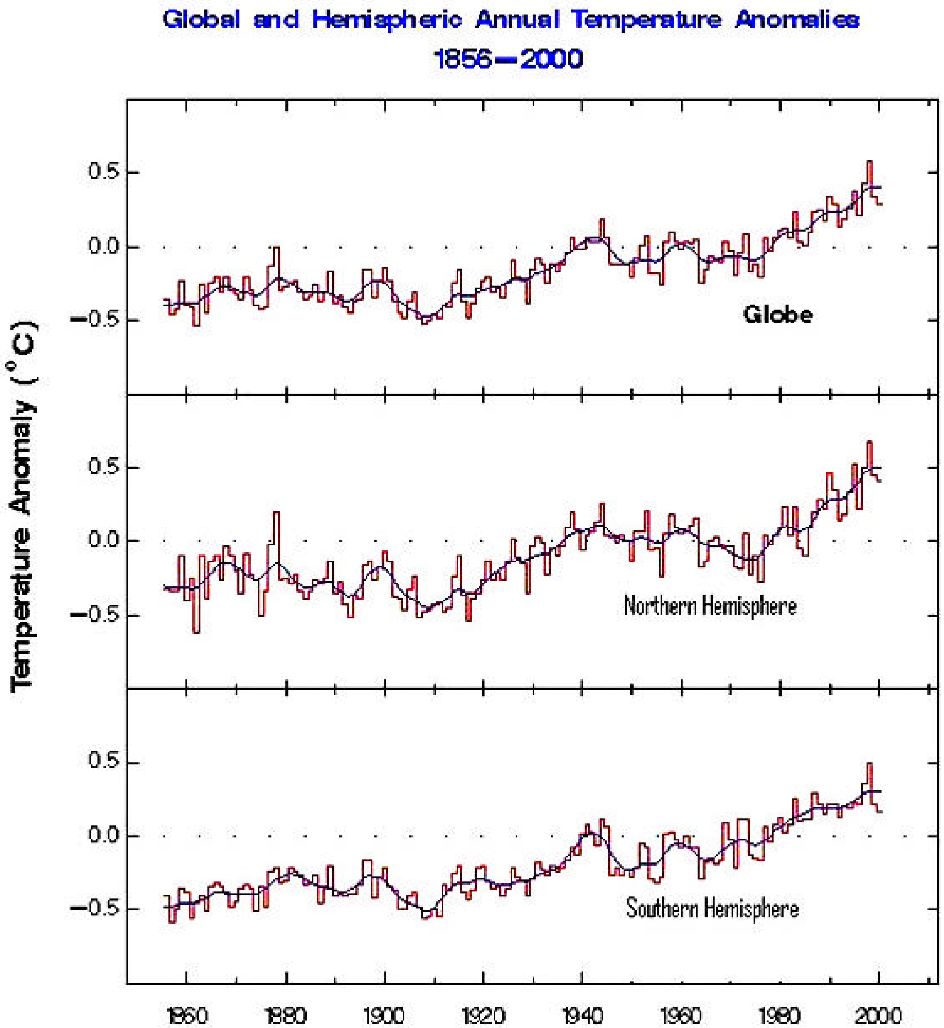

Fig.4.5: Temperature changes over the years

Climate and agricultural zones would tend to shift towards the poles. Because average temperatures are expected to increase more near the poles than near the equator, the shift in climate zones will be more pronounced in the higher latitudes. In the mid-latitude regions (45 to 60º latitude), the shift is expected to be about 200-300 km for every degree Celsius of warming. Since today each one of the latitudinal climate belts is optimal for particular crops, such shifts could have a powerful impact on agricultural and livestock production. Crops for which temperature is the limiting factor may experience longer growing seasons. For example, in the Canadian prairies the growing season might lengthen by 10 days for every 1ºC increase in average annual temperature.

While some species would benefit from higher temperatures, others might not. A warmer climate might, for example, interfere with germination or with other key stages in their life cycle. It might also reduce soil moisture; evaporation rates increase in mid-latitudes by about 5% for each 1ºC rise in average annual temperature. Another potentially limiting factor is that soil types in a new climate zone may be unable to support intensive agriculture as practiced today in the main producer countries. For example, even if sub-Arctic Canada experiences climatic conditions similar to those now existing in the country as southern grain-producing regions, its poor soil may be unable to sustain crop growth.

Longer growing seasons and warm winter will enable insect pests to complete a greater number of reproductive cycles and also allow larvae to winter-over in new areas and cause greater infestation during the following crop season. Altered wind patterns may change the spread of both wind-borne pests and of the bacteria and fungi that are the agents of crop diseases.

Climate models suggest that potential evapo-transpiration tends to rise most where the temperature is already high (i.e., low to mid latitudes), while precipitation tends to increase most where the air is cooler and more readily saturated by the additional moisture (i.e., in higher latitudes and near seacoasts). Thus, drier conditions may occur in many of the world's most important agriculture regions, a consequence that could have great practical importance. Both demand for and the supply of water for irrigation will be affected by changing hydrological regimes. Water quality tends to deteriorate under conditions of low flows and higher water temperatures, predicted for arid areas. In such areas, the effect of climate change on water quality may be especially significant.

Mid-latitude yields may be reduced by 10-30% due to increased summer dryness. Climate models suggest that today's leading grain-producing areas – in particular the Great Plains of the US– may experience more frequent droughts and heat waves by the year 2030. Extended periods of extreme weather conditions would destroy certain crops, negating completely the potential for greater productivity through "CO_2 fertilization". During the extended drought of 1988 in the US Corn Belt region, for example, corn yields dropped by 40% and, for the first time since 1930, US grain consumption exceeded production. The pole ward edges of the mid-latitude agricultural zones– northern Canada, Scandinavia, Russia, and Japan in the northern hemisphere, and southern Chile and Argentina in the southern one – may benefit from the combined effects of higher temperatures and CO_2 fertilization. But the problems of rugged terrain and poor soil suggest that this would not be enough to compensate for reduced yields in the more productive areas. In a $2 \times CO_2$ climate, an overall decline in production of wheat may be expected as a consequence of increase in temperature in the mid-latitudes.

The impact on yields of low-latitude crops is more difficult to predict. While scientists are relatively confident that climate change will lead to higher temperatures, they are less sure of how it will affect precipitation – the key constraint on low-latitude and tropical agriculture. Climate models do suggest, however, that the intertropical convergence zones may migrate pole ward, bringing the monsoon rains with them. The greatest risks for low-latitude countries, then, are that reduced rainfall and soil moisture will damage crops in semi-arid regions, and that additional heat stress will damage crops and especially livestock in humid tropical regions.

Warm temperatures may expand crop producing lands but crops that have become adapted to the growing-season day lengths of the middle and lower latitudes and may not respond well to the much longer days of the high latitude summers. Less than optimal conditions for net growth are more likely in warmer lower latitude regions.

Agriculture in low-lying coastal areas, where impeded drainage of surface water and of groundwater, as well as intrusion of seawater into estuaries and aquifers, might take place, would be threatened by sea-level rise. Adaptations may come in the form of switching crop varieties, introduction of high-efficiency irrigation which may involve major investments. Another way would be to breed heat and drought-resistant crop varieties by utilizing genetic resources that may be better adapted to new climatic and atmospheric conditions. Genetic manipulation may also help to exploit the beneficial effects of CO_2 enhancement on crop growth and water use. Adaptation may not be easy since major shifts in crops need to be made. Grain farmers may find themselves more exposed to marketing problems and credit crisis brought on by higher capital and operating costs of fruit and vegetable production.

In several areas where temperature is the limiting factor in crop production, growing seasons will lengthen by several days. This shift could also have disastrous effects on the economy of some smaller countries whose climate belts are optimal for a particular crop. The global warming trend would also increase evaporation from soil and plants. Also, it is true that warmer air holds more water vapour than cooler air, so global warming will bring about more precipitation on a global scale. This increased precipitation, however, does not necessarily mean more precipitation in certain regions. There would tend to be more frequent droughts in some areas and more frequent flooding in others.

In Africa, right on the edge of the world's largest, driest desert, the Sahara, there is a large freshwater lake, Lake Chad. This is a great example of effects on an area due to agricultural use. Lake Chad was once the sixth-largest lake in the world, but constant drought since the 1960's has shrunk it to 1/10 its size. The Chari River, at the southeast, which provides 90% of Lake Chad's water, now averages only about half of its original 40 billion cubic meters per year in the 1930-60s. The recent low levels are a concern, and have been monitored through satellite and other means by the Lake Chad Basin Commission and others.

Crops respond to increased temperature in complex ways – above a minimum level, response to a rise in temperature tends to be positive up to a characteristic optimum range. Similarly, experiments in India reported by Sinha (1994) found that higher temperatures and reduced radiation associated with increased cloudiness caused spikelet sterility and reduced yields to such an extent that any increase in dry-matter production as a result of CO_2 fertilization proved to be no advantage in grain productivity. Similar studies conducted recently in Indonesia and the Philippines confirmed these results.

But when temperature exceeded, crops tended to respond negatively, resulting in a steepening drop in net growth and yield (Fig.4.6).

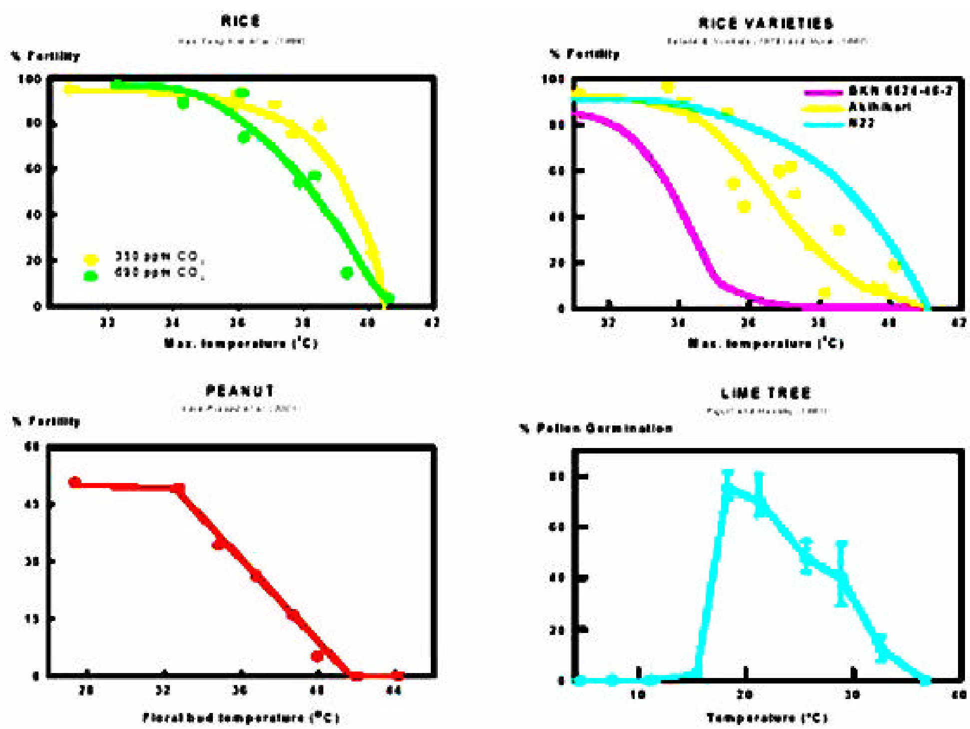

Fig.4.6: Temperature response of panicle fertility (rice and peanut) and pollen germination (lime tree)

The accelerated growth due to warmer temperatures results in quicker maturation and can actually reduce the yield of annual crops. Since many weeds are associated with major C_4 crops (maize, sorghum, sugarcane, and millet), the weed/crop competition for such crops may favour the weeds. Feeding requirement for insects may increase:

- Higher CO_2 may increase the carbon-nitrogen (C:N) ratio in crop leaves, stimulating the feeding of some insects.
- Some insects may need to eat more C-enriched leaves to gain adequate nutrition.

Impacts depend on how the hydrological regime changes the total seasonal precipitation, its within-season pattern, and its between-season variability. In Fig.4.7 we summarise the impact of global environmental factors on food production.

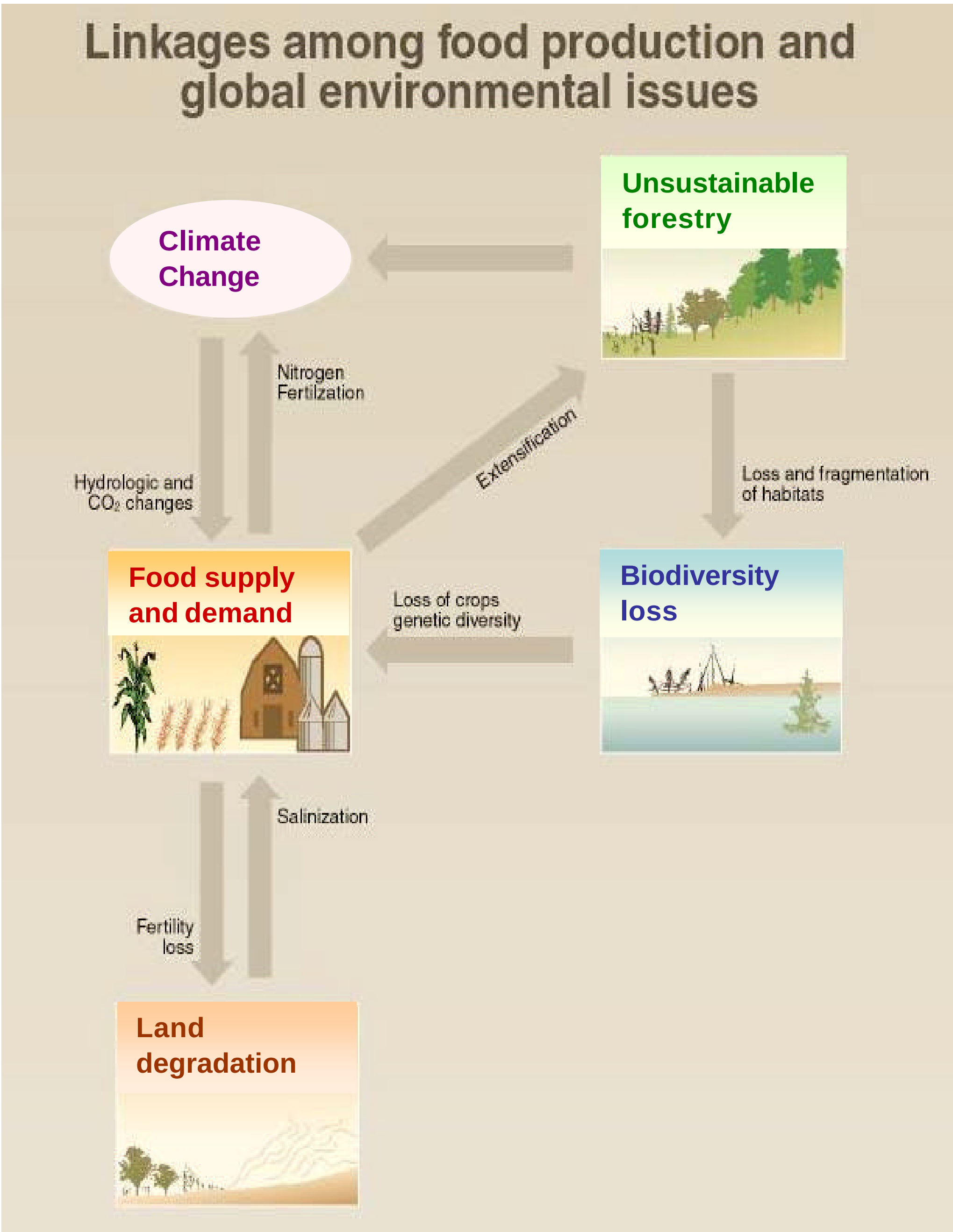

Fig.4.7: Linkages among food production and global environmental issues

SAQ 2

List the factors affecting global climate change. How does the increase in temperature affect agriculture?

4.3.2 Rising Atmospheric Carbon Dioxide (CO_2)

Increasing atmospheric CO_2 levels are expected to influence crop production in many different ways. The response to an initial increase in temperature by itself in isolation should generally be positive for crop yields. (The magnitude of the response varies from crop to crop and can change from positive to negative if the temperature change is too high.)

In terms of plant growth and development, higher rates of photosynthesis are found in entire canopies placed in a CO_2-enriched atmosphere due to the CO_2 "fertilization" effect.

Effect of increased concentrations of CO_2 on crop productivity

In principle, higher levels of CO_2 should stimulate photosynthesis in certain plants; a doubling of CO_2 may increase photosynthesis rates by as much as 30-100%. Laboratory experiments confirm that when plants absorb more carbon they grow bigger and more quickly. This is particularly true for C_3 plants (so called because the product of their first biochemical reactions during photosynthesis has three carbon atoms). Increased carbon dioxide tends to suppress photo-respiration in these plants, making them more water-efficient. C_3 plants include such major mid-latitude food staples as wheat, rice, and soybean. The response of C_4 plants, on the other hand, would not be as dramatic (although at current CO_2 levels these plants photosynthesize more efficiently than do C_3 plants). C_4 plants include such low-latitude crops as maize, sorghum, sugar-cane, and millet, plus many pastures and forage grasses.

Increased concentrations of CO_2 boost crop productivity. Yields of crops grown under drought conditions also respond to higher CO_2 concentrations. The greater the drought stress the greater is the relative response to CO_2 even in C_4 species. Thus crops grown in semi-arid environments would be expected to have as great or greater percent yield increase under high CO_2 – as do well watered crops. Crops with nutrient deficiencies can also respond positively to higher CO_2 concentration, though the extent of response and its mechanism need further investigation. The C: N ratio of the vegetation is greater for higher-CO_2 grown plants. Moreover, there have been indications that increased CO_2 concentration reduces the severity of yield reduction by soil salinity stress.

Most of the studies on climate change and agricultural production have been confined to temperate crops and hence such studies on tropical and sub-tropical crops need to be undertaken. A systematic effort to develop cost effective CO_2 enrichment technology in relation to crop production, may be made.

Effects on Weeds, Insects, and Diseases

Rising atmospheric CO_2 and climate change will also affect the associated agricultural pests. Distribution and proliferation of weeds, fungi, and insects are determined to a large extent by climate. Much more research has been done on the potential changes in weed growth than on changes in the spread of insects and diseases.

Weeds will be directly affected by changes in climate and in CO_2 levels. Insects and diseases are not likely to be directly affected by CO_2 changes, but may be affected indirectly because of altered host plant metabolism, development and morphology. New, previously unobserved combinations of climate, atmospheric constituents, and soil conditions may result and lead to new infestations of various pests. The overall importance of such developments is unclear at this point, but crop losses due to weeds, insects, and disease are likely to increase.

In general, populations of herbivorous insects are held in check by their ability to acquire enough nitrogen compounds from healthy unstressed plants. In longer term, vegetation grown in higher concentrations would be unable to support large insect population (as flea beetle, pink ball worm, leaf hopper on CO_2- enriched crop with low available nitrogen).

Overall impact of climate change

Temperature, precipitation, atmospheric carbon dioxide content, the incidence of extreme events and sea level rise are the main climate change related drivers which impact agricultural production.

Briefly the main categories of implications for agricultural productivity are **crops and forage productivity and production cost** where temperature, precipitation, atmospheric carbon dioxide content and extreme events are likely to alter plant growth and harvestable or grazable yield. Changes in wheat yield as affected by climate change with time are projected in Fig.4.8. Extreme events also play a role. For example, where droughts and floods become more severe or frequent, agricultural losses would increase.

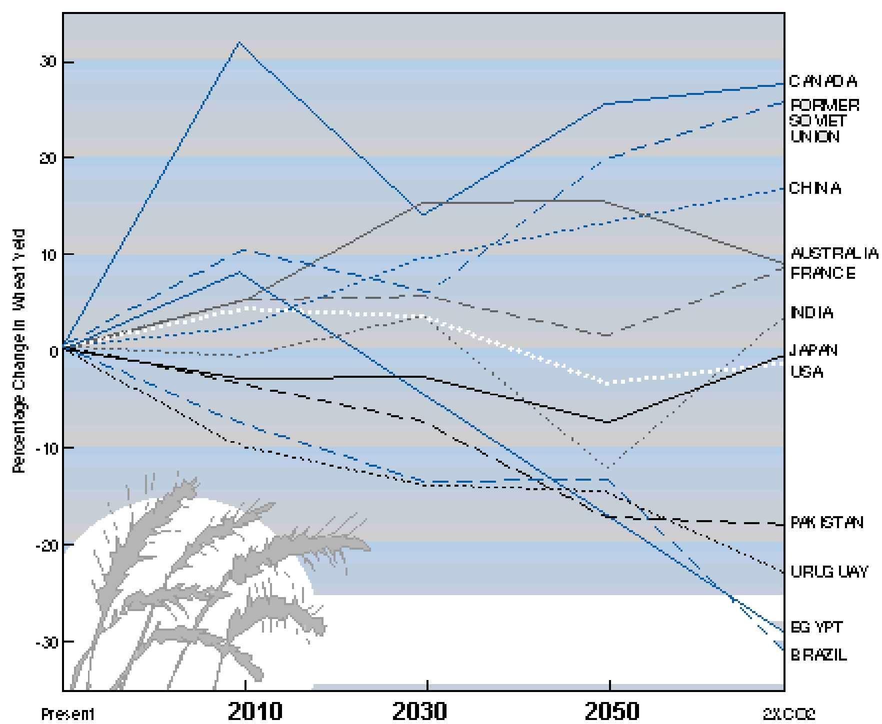

Fig.4.8: Calculated change in wheat yield resulting from a "business as usual" increase in atmospheric CO_2 and modelled climate change scenario, as applied to present conditions in the 12 countries shown.

Irrigation water supply will be influenced by changes in the volume of water supplied by precipitation as well as by temperature alterations effects on evaporation. Also changes in temperature regimes can alter the timing of snow melt based runoff and thus both the seasonality of available water supply and the needed size of impoundments holding water for summer supplies. Groundwater recharge rates and aquifer exploitation may also be altered. Non-agricultural water demand by municipalities and possibly some industries is also likely to be increased by increases in temperature. Extreme events also play a role where, for example, some studies indicate that the hydrologic cycle will be intensified such that droughts and floods will become more severe in low to mid-latitude regions again altering water availability seasonally and the need for impoundments.

Other Effects: In addition to the direct effects of climate change on agriculture, there are important indirect effects that can affect production. For example, sea level rise can inundate or require mitigation efforts along low-lying coastal regions. Indirect effects may also arise from alterations in the growth rates and distribution of weeds, pests and pathogens, rates of soil erosion and degradation, and alterations in ozone levels or UV-B radiation.

Effects on soil resources

Soil is a complex and dynamic system, consisting of a solid phase (both mineral and organic, particulate and amorphous), a liquid phase (water and solutes), and a gaseous phase (air with associated water vapour, often enriched with carbon dioxide and sometimes with methane as well). Soil responds to both short-term events such as the episodic infiltration of rainfall and long-term processes, such as physical and chemical weathering.

Only rough, qualitative estimations of the predicted climate change effects on soil are practical now, due to the uncertainties in the forecasts but also to the complex, interactive influences of hydrological regime, vegetation, and land use. Factors that need to be considered include:

- Temperature effects on soil nutrients;
- Hydrological effects on soil nutrients;
- CO_2 effects on soils; and
- Soil carbon accretion/depletion.

Soil suitability for agricultural production is affected in terms of available soil moisture for plant growth, moisture storage capacity and fertility. In particular, soil moisture loss is determined by temperature and maintenance of a constant water supply. Of course, any temperature increase needs to be offset by precipitation increases and/or expansions in applied irrigation water. Furthermore, microbial decomposition is stimulated by warmer temperatures. Therefore, the availability of soil nutrients and organic matter which helps hold the soil moisture may be negatively affected by warmer temperatures.

Livestock productivity and production cost are affected both directly and indirectly. Direct effects involve consequences for the balance between heat dissipation and heat production. In turn, a change in this balance can alter: a) animal mortality, b) feed conversion rates, c) rates of gain, d) milk production, and e) conception rates. Appetite may also be affected. Finally, carrying capacity in a region is altered by changes in the availability of feed and fodder.

SAQ 3

Explain the impact of rising atmospheric CO_2 on agricultural production.

4.4 OZONE HOLE AND ULTRAVIOLET RADIATIONS

Ozone is an unstable molecule formed by lightning and when free oxygen atoms are released in an oxygen-rich atmosphere. In atmosphere, most ozone is created when normal oxygen molecules are split apart by the action of ultraviolet light in normal sunshine. Ozone remains at the top of the atmosphere where it absorbs ultraviolet light, forming a “protective layer.” Ozone decays naturally. It is broken apart faster in the presence of CFCs (refrigerants and propellants), oxides of nitrogen (auto emissions, power plants, forest fires, and volcanoes), and methane (agriculture and volcanoes). Thus, ozone that drifts into the lower atmosphere is destroyed. The "hole" refers to a thinning of this layer because of chemical reactions in the upper atmosphere, especially at the Earth's poles. The Antarctic ozone hole is defined as thinning of the ozone layer over the continent to levels significantly below pre-1979 levels. Ozone blocks harmful ultraviolet "B" rays. Loss of stratospheric ozone has been linked to skin cancer in humans and other adverse biological effects on plants and animals.

> The size of the ozone hole reached 10.9 million square miles on September 11, 2003. It was slightly larger than the North American continent, but smaller than the largest hole ever recorded, on September 10, 2000, when it covered 11.5 million square miles.

Life at the Earth’s surface is protected from the harmful ultraviolet (UV) radiation from the Sun by the stratospheric ozone layer. Over the last several decades, synthetic chemical compounds, such as chlorofluorocarbons (CFCs) and halons, were developed to provide a new generation of refrigerants, insulating foams, fire retardants, and other products. Unfortunately, after extensive use of these compounds, it was discovered that they remain inert in the atmosphere until they reach the stratosphere, where they break down into an active form that destroys ozone (Fig.4.9). One chlorine atom originating from a CFC molecule can destroy thousands of protective ozone molecules.

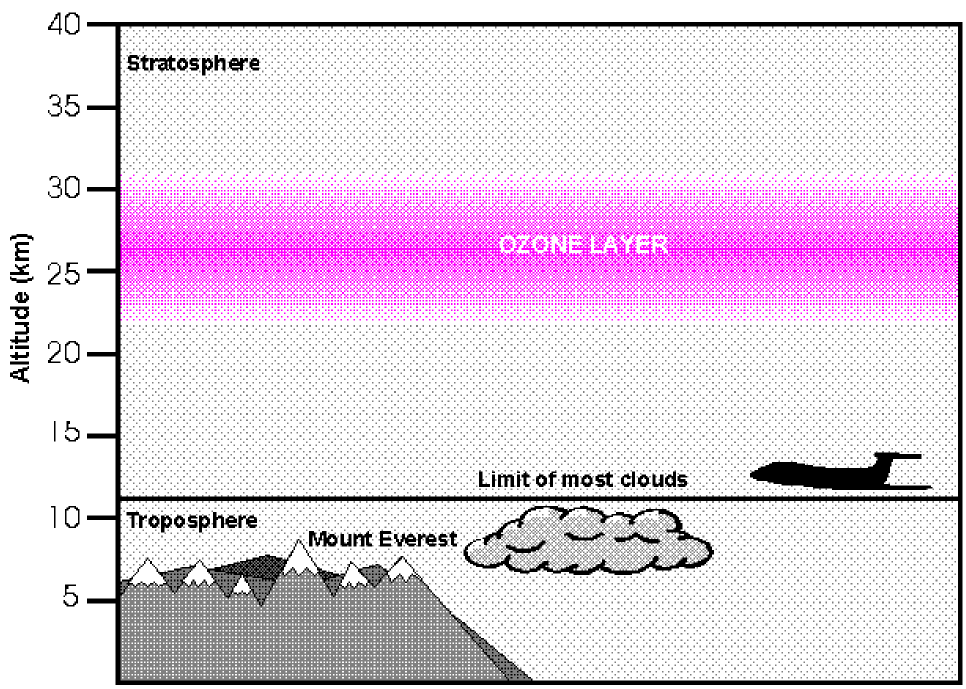

Fig.4.9: The location of the ozone layer

Satellite and ground-based observations confirm that losses of ozone are occurring seasonally, particularly in the springtime polar vortex of the Antarctic stratosphere, leading to what is known as the ozone "hole." Also of concern is the more moderate ozone depletion observed in mid-latitudes, where a large portion of the Earth's population resides.

A one percent reduction in ozone concentration in the upper atmosphere results in roughly a two percent increase in the amount of harmful UV-B radiation that reaches the earth's surface. This will have substantial negative impact on growth and yield of terrestrial plants as well as the health of many organisms that inhabit our planet including humans and animals.

- For every 1% decrease in stratospheric ozone, non melanoma skin cancers are predicted to increase by about 3%, and the mortality rate due to malignant melanomas among light skinned populations is expected to increase by roughly 1%.

- Increased UV-B radiation reduces the ability of the body's immune system to fight foreign substances that enter the body through the skin. It is also associated with various diseases of the eye, such as cataracts and deterioration of the cornea and retina in both humans and animals.

- Increased UV-B radiation negatively affects the growth of terrestrial plants, including many agricultural crops. It also penetrates the ocean surface and can damage fish larvae and juveniles. Studies performed in Antarctica during the appearance of the springtime ozone hole have shown that these short duration increases in UV-B radiation are already having an effect on natural populations of tiny microscopic plants called phytoplankton, which form the base of the ocean's food web. Reduction in the productivity of marine phytoplankton can have broad ranging implications for the entire marine ecosystem.

UV-B can damage plant and animal life on earth. More UV-B reaches the earth as ozone levels decline because stratospheric ozone is the primary absorber of UV-B. This thin blanket shields us from the sun’s harmful rays.

High levels of UV-B radiation (280 to 320 nm wavelength) are responsible for many biologically harmful effects in both plants and animals.

Increasing UV-B irradiance and irradiation time decrease photosynthetic activity (thus production) in seedlings of common crops like radish (*Raphanus sativus*), soybean (*Glycine max*), bean (*Phaseolus vulgaris*), and loblolly pine (*Pinus taeda*). Also UV-B causes these plants to increase their flavonoid leaf content (apparently protective pigments). Furthermore, as the UV-B/photo synthetically active radiation (PAR) ratio increases with decreasing total irradiance (for instance, with increasing cloud cover), low radiation levels are potentially dangerous to some plants even though the UV-B levels may seem negligible. In the beginning of this decade, the US Environmental Protection Agency and International Rice Research Institute have initiated a co-operative programme to investigate the effects of UV-B and global climate change on rice. Rice is the world's most important food crop which responds to both UV-B and climate change.

We now summarise the contents of this unit.

4.5 SUMMARY

- Environmental factors that affect agriculture directly and indirectly include drought, salinity and global climate changes. **Moisture and salinity stresses** significantly affect agricultural productivity.

- **Climate change** affects agricultural production and productivity. In particular, accumulation of greenhouse gases (GHGs) leads to rise in temperature and influences agriculture. Rising atmospheric CO_2 on agricultural productivity is a subject of detailed investigation.

- When increased variability is included, significant increases in the variability of food supplies are foreseen. This leads to many concerns that need to be addressed by the International community:
  - Perception of increased risk may discourage adoption of new technologies and slow the growth of agriculture,
  - Diversification of crop production system,
  - Higher instability of food supplies on regional basis,
  - Frequent droughts and floods over larger areas,
  - Increased destabilizing effects of agricultural prices on food production and consumption.
- The **depletion of ozone (O_3) layer** allows the penetration of harmful UV-radiations through the atmosphere. This affects crop production and human health.

4.6 TERMINAL QUESTIONS

1. What is environmental stress? Name various sources of stress for plants. Describe two major environmental stresses in plants.
2. Describe sources and sinks of greenhouse gases (GHGs).
3. Explain the impact of ozone layer depletion on agriculture.

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