Agriculture, which is the backbone of our country, deals in the cultivation of plants, fungi, animals and other life forms for food, fodder, fiber, fuel wood, medicinal plants and other products used to sustain and enhance human life. Pre-industrial agriculture was typically subsistence agriculture in which farmers raised most of their crops for their own consumption instead of cash crops for trade. A remarkable shift in agricultural practices has occurred over the past century in response to new technologies, and the development of world markets.

Agriculture is closely dependent on the endowment of natural resources and environmental conditions of soil and climate. India is a land of many climates and varieties of soils, affording scope for much diversity in agriculture. In our country, more than 50 per cent of variation of crops is determined by climate. It is climate vis-à-vis weather plays an important role, probably more so in India where aberrant weather such as drought, flood, etc., is a rule rather than an exception.

With a geographic area of 328.76 million hectares, stretching between 8°N and 36°N latitude and between 68°E and 98°E longitude, its altitude varying from the mean sea-level to the highest mountain ranges of the world, India presents a range and diversity of climate, flora and fauna, with a few parallels in the world. The country presents a paradox of having highest mean annual rainfall in the world (Cherapunji in Meghalaya) and also dry, semi-desert area in Rajasthan. The variability of rainfall is most important in all the states, but especially where it is low. In parts of Rajasthan and the Deccan, such variability is more than 100 per cent of the mean. Years of drought account for a frequent history of crop failures, whereas the years of flood also cause very considerable loss of agricultural production. Temperatures also vary greatly, both geographically and seasonally. In northern and central parts of India during pre-monsoon months the maximum temperatures reaches over 40°C over a large area. Further frost may occur in winter in the plains, as far south as a line drawn through Madhya Pradesh and may be heavier in Kashmir and areas north of Punjab including various other parts of the Eastern Himalayan range.

Considering the fact that weather plays an important role in India, efficient crop planning and growth, proper understanding of agro-climatic conditions is essential for all concerned. With the 328.76 million hectares of the geographical area the country presents a large number of complex agro-climatic situations. For the sake of scientific management of regional and local resources to meet the demand of food, fiber, fodder and fuel wood without adversely affecting the status of natural resources and environment, Planning Commission, Govt. of India in its 8th Plan has delineated 15 agro-climatic regions or zones for agricultural planning in country (Table -1),
primarily on the basis of rainfall and evaporation which is the resultant effect of sunshine, temperature, wind and land use.
Table-1. Agro-Climatic Zones of India

<table>
<thead>
<tr>
<th>No.</th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Western Himalayan Region</td>
</tr>
<tr>
<td>2.</td>
<td>Eastern Himalayan Region</td>
</tr>
<tr>
<td>3.</td>
<td>Lower Gangetic Plains Region</td>
</tr>
<tr>
<td>4.</td>
<td>Middle Gangetic Plains Region</td>
</tr>
<tr>
<td>5.</td>
<td>Upper Gangetic Plains Region</td>
</tr>
<tr>
<td>6.</td>
<td>Trans-Gangetic Plains Region</td>
</tr>
<tr>
<td>7.</td>
<td>Eastern Plateau and Hills Region</td>
</tr>
<tr>
<td>8.</td>
<td>Central Plateau and Hills Region</td>
</tr>
<tr>
<td>9.</td>
<td>Western Plateau and Hills Region</td>
</tr>
<tr>
<td>10.</td>
<td>Southern Plateau and Hills Region</td>
</tr>
<tr>
<td>11.</td>
<td>East Coast Plains and Hills Region</td>
</tr>
<tr>
<td>12.</td>
<td>West Coast Plains and Ghat Region</td>
</tr>
<tr>
<td>13.</td>
<td>Gujarat Plains and Hills Region</td>
</tr>
<tr>
<td>14.</td>
<td>Western Dry Region</td>
</tr>
<tr>
<td>15.</td>
<td>The Islands Region</td>
</tr>
<tr>
<td>16.</td>
<td>Central Plateau and Hills Region</td>
</tr>
</tbody>
</table>

SCENARIO OF RAINFED AGRICULTURE

In agriculture, water is an important climatic factor that affects or determines plant growth and development. Its availability or scarcity determines a successful harvest, or diminution in yield, or even total failure of a crop. Rainfall is the primary source of water for crop cultivation and allied agricultural practices. As agriculture in India depends on the vagaries of rainfall, its amount and nature of distribution are very important, which vary with location and climate types and thereby affecting growth and yield of crop. In fact, it is an absolute requirement for all living organisms. The importance of water is essential for efficient functions in both plant and animal life. But plant responses differ with the type of plant species. Most plants are mesophytes, that is, they are adapted to conditions with moderate supply of water. But some, called hydrophytes, require watery or water-logged habitats, while others called xerophytes, are more tolerant to dry conditions. Alike other climatic factors, water too causes detrimental effect on growth and development of both plants and animals. Excess water in the soil can injure flood prone plants like corn (Maize), due to lack of oxygen. In this case water stress due to flooding means oxygen stress by deficiency (hypoxia) or total absence (anoxia) of oxygen.
Globally 80 per cent of the agricultural land area is rainfed which indicates that agricultural practices and crop production are performed with water received through rainfall. The rainfed agriculture generates 65 to 70 per cent staple foods but 70 per cent of the population inhabiting in these areas are poor due to low and variable productivity. India ranks first among the rainfed agricultural countries of the world in terms of both extent and value of produce. Rainfed agriculture is practiced in two-thirds of the total cropped area of 162 million hectares (66 per cent) and it supports 40 per cent of the national food basket. The importance of such agricultural practice is obvious from the fact that 55 per cent of rice, 91 per cent coarse grains, 90 per cent pulses, 85 per cent oilseeds and 65 per cent cotton are grown in rainfed areas. These areas receive an average annual rainfall between 400 mm and 1000 mm, which is not only distributed unevenly, but also highly uncertain and erratic. In certain areas, the total annual rainfall does not exceed even 500 mm. As a result of such low and erratic monsoon rainfall significant fall in food production is often noticed. Due to climate change in last couple of years the country is experiencing shift of onset of monsoon from its normal date together with its erratic distribution and reduction in amount, which largely affected our crop production system vis-à-vis agriculture as a whole. Within agriculture, it is the rainfed agriculture that will be most affected by climate change. Besides, temperature is the other important weather parameters that also drastically affect productivity of rainfed crops. In last three decades our country has experienced sharp rise in mean annual temperature, although most of the rainfed crops can tolerate high temperatures. However, rainfed crops grown during rabi are vulnerable to changes in minimum temperatures (Venkateswarlu and Rama Rao, 2010). For example, in Karnataka state 82 per cent of the net sown area was under rainfed condition during 2009-10. Yield of most of the crops decreased (Table-2) to a large extent under such drought condition. Erratic rainfall and occurrence of frequent droughts bring tremendous change in both surface as well as ground water. Figure-2 indicates the nature of change of rainfall occurrences during pre-monsoon and monsoon seasons in India. Many scientists opined that region-specific analysis is required to evaluate in detail the agronomic and economic impact of weather changes.

Table- 2. Effect of Drought on yield(kg/ha) of few Rainfed Crops in Dharwad district, Karnataka

<table>
<thead>
<tr>
<th>Crop</th>
<th>Per cent loss of normal yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorghum</td>
<td>43.03</td>
</tr>
<tr>
<td>Maize</td>
<td>14.09</td>
</tr>
<tr>
<td>Tur</td>
<td>28.23</td>
</tr>
<tr>
<td>Groundnut</td>
<td>34.09</td>
</tr>
<tr>
<td>Wheat</td>
<td>48.68</td>
</tr>
</tbody>
</table>
In present day context, agriculture is most vulnerable to weather and climate changes because of its seasonality and narrow range of weather conditions influencing crop and livestock production. People across the globe witnessed above normal temperatures and more rapid warming that occurred during the last half of the 20th century. Climate change presents a profound challenge to food security vis-a-vis livelihood and all around development.

As climate is one of the main determinants of agricultural production, there is significant concern about the effects of its change and variability on agricultural production across the world. People are concerned with the potential damages and benefits that may arise in future from climate change impacts on agriculture, resource base and food security. The climate change is any change in climatic factors over time that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere in addition to natural climate variability observed over comparable time periods (IPCC, 2007). Since climatic factors serve as direct inputs to agriculture, any change in climatic factors is bound to have significant impact on crop growth, yields and production. Studies have shown significant effect of change in climatic factors on the average crop yield. India is likely to witness one of the highest agricultural productivity losses in the world as a consequence of climate change pattern observed and projected. Climate change projections made up to 2100 for India indicate an overall increase in temperature by 2-4°C with no substantial change in precipitation quantity (Kavikumar, 2010) as use of fossil fuels increased rapidly in one hand, and on the other hand, forests, the natural buffering system for climate change, are being destroyed indiscriminately for want of fuel, fodder, timbers and urbanization. These factors have been intensified by human in the past 250 years, which has tremendous impact on climate system. According to the IPPCC the greenhouse gas emission causes the mean
global temperature rise by another 1.4°C to 5.8°C. Already the symptoms of climate change are being observed at a faster rate in the artic and under artic regions through melting of the frozen ice will submerge coastal zones. The inundation of lands in the coastal zones as an effect of climate change will lead to salinization of land.

The agricultural sector represents 35% of India’s Gross National Product (GNP) and therefore plays a crucial role in the country’s development. So, while the magnitude of impact of climate change on agriculture in India varies greatly by region, it is still believed to impact agricultural productivity and shifting crop patterns gradually each year. Climate change can affect crop yields (both positively and negatively), as well as the types of crops that can be grown in certain areas, by impacting agricultural inputs like water for irrigation, amounts of solar radiation that affect plant growth, as well as the prevalence of pests. And these changes in agriculture could then affect food security, trade policy, livelihood activities and water conservation issues, which indeed will have impact on large portions of the population in India. Scientists at IARI (The Indian Agriculture Research Institute) conducted studies to evaluate potential climate change impacts on crops wheat and rice (India’s primary and staple food crops), and also on sorghum and maize. This study indicated that the changes in the major factors like temperature, CO₂ levels, precipitation, and solar radiation affect significantly the agricultural sector. The Intergovernmental Panel on Climatic Change (IPCC) of the United Nations in its report for 2001, projected that the globally average temperatures may rise by 1.4°C to 5.8°C over the next 100 years. And for India, the area-averaged annual mean warming projected to be between 1.0°C and 1.4°C by 2020 and between 2.2°C to 2.9°C by 2050; though, the increase in temperatures would be less in *rabi* season (winter season). Further, the *kharif* (monsoon season) rainfall is expected to increase in most of the places whereas *rabi* rainfall may decrease in some areas. Though no immediate adverse impact of global warming is visible in India, experts feel the country should draw sharp strategy to deal with the long-term effects of climate change on agriculture. “Rise of 0.2 degrees in the temperatures now is not a cause of worry for agriculture in the country, but there could be a problem after 5-6 decades for which we need to be alert” says, S. Ayyappan, Director General of ICAR.

![Global Average Sea Level Changes, 1700-2002](image.png)

**Fig.-3. Global Average Sea level Change, 1700-2002**
But, in recent past, heavy rainfall events increased resulting floods, and occurrence of more intense droughts affecting agricultural and allied sectors (cropping cycle, population, and density of pollinators, flowering pattern, agricultural produce including animal production etc.) as an effect of climate change. On the contrary, modern agricultural practices (both above and below the ground) also play vital role in spurring climate change through release of greenhouse gases, depletion of soil carbon, desertification, salinization etc.

**POLLUTION AND AGRICULTURE**

Agricultural crops can be injured when exposed to high concentrations of various air pollutants. Injury ranges from visible markings on the foliage, to reduced growth and yield, to premature death of the plant. The development and severity of the injury depends not only on the concentration of the particular pollutant, but also on a number of other factors like length of exposure to the pollutant, the plant species and its stage of development as well as environmental factors conducive to build-up the pollutant.

*Effects of Air Pollution*

Air pollution injury to plants can be evident in several ways. Injury to foliage may be visible in a short time and appear as necrotic lesions (dead tissue), or it can develop slowly as yellowing or chlorosis of the leaf. There may be reduction in growth of various portions of the plant. Plants may be killed outright, but they usually do not succumb until they have suffered recurrent injury. Interaction between air pollution and climate is shown through figure-

![Interactions Between Air Pollution and Climate](image)

**Fig.-4. Schematic diagram showing pollution of different spheres**
Effect of few air pollutants on plant has been described in nutshell bellow for better understanding.

**Oxidants:** Ozone is the main pollutant in the oxidant smog complex. Its effect on plants was first observed in Los Angeles area in 1944. Ozonesymptoms characteristically occur on the upper surface of affected leaves and appear as a flecking, bronzing or bleaching of the leaf tissues. Although yield reductions are usually with visible foliar injury, crop loss can also occur without any sign of pollutant stress. Conversely, some crops can sustain visible foliar injury without any adverse effect on yield. High relative humidity, optimum soil-nitrogen levels and water availability increase susceptibility. Sensitive species include cucumber, grape, green bean, lettuce, onion, potato, radish, spinach, sweet corn, tobacco and tomato. Resistant species include pear and apricot.

**Sulfur Dioxide:** Sulfur dioxide enters the leaves mainly through the stomata (microscopic openings) and the resultant injury is classified as either acute or chronic. Acute injury is caused by absorption of high concentrations of sulfur dioxide in a relatively short time. The symptoms appear as 2-sided (bifacial) lesions that usually occur between the veins and occasionally along the margins of the leaves. The colour of the necrotic area can vary from a light tan or near white to an orange-red or brown depending on the time of year, the plant species affected and weather conditions. Recently expanded leaves usually are the most sensitive to acute sulfur dioxide injury, the very youngest and oldest being somewhat more resistant. However, different plant species vary considerably in their sensitivity to sulfur dioxide. These variations occur because of the differences in geographical location, climate, stage of growth and maturation. The crops those are generally considered susceptible to sulfur dioxide are alfalfa, barley, oats, pumpkin, radish, spinach, squash, and tobacco. Resistant crop plants include asparagus, cabbage, celery, corn, onion and potato.

**Fluoride:** Fluorides are discharged into the atmosphere from the combustion of coal; the production of brick, tile, enamel frit, ceramics, and glass; the manufacture of aluminium and steel; and the production of hydrofluoric acid, phosphate chemicals and fertilizers. The fluoride enters the leaf through the stomata and is moved to the margins where it accumulates and causes tissue injury. The injury starts as a gray or light-green water-soaked lesion, which turns tan to reddish-brown. With continued exposure the necrotic areas increase in size, spreading inward to the midrib on broad leaves and downward on monocotyledonous leaves. The characteristic dark band separating the healthy (green) and injured (brown) tissues of affected leaves is the usual symptom of fluoride pollution. Studies indicate that apricot, barley (young), peach (fruit), gladiolus, grape, plum, sweet corn and tulip are most sensitive; whereas, alfalfa, asparagus, bean (snap), cabbage, carrot,
cauliflower, celery, cucumber, eggplant, pea, pear, pepper, potato, squash, tobacco and wheat are resistant.

**Ammonia:** Ammonia injury to vegetation usually occurs due to release of large quantities of ammonia into the atmosphere for brief periods of time and cause severe injury to vegetation in the immediate vicinity. Complete system expression on affected vegetation usually takes several days to develop, and appears as irregular, bleached, bifacial, necrotic lesions. Grasses often show reddish, interveinal necrotic streaking or dark upper surface discolouration. Flowers, fruit and woody tissues usually are not affected, and in the case of severe injury to fruit trees, recovery through the production of new leaves can occur. Sensitive species include apple, barley, beans, radish and soybean. Resistant species include alfalfa, beet, carrot, corn, cucumber, eggplant, onion, peach, and tomato.

**Particulate Matter:** Particulate matter such as cement dust, magnesium-lime dust and carbon soot deposited on vegetation can inhibit the normal respiration and photosynthesis mechanisms within the leaf. Cement dust may cause chlorosis and death of leaf tissue by the combination of a thick crust and alkaline toxicity produced in wet weather. Accumulation of alkaline dusts in the soil can increase soil pH to levels adverse to crop growth.

**Methane:** The Scientists observed that any further rises in temperature are likely to accelerate the release of methane from rivers, lakes, deltas, bogs, swamps, marshlands and rice paddy fields. Most of the methane in freshwater systems is produced by an important microbe called *Archaea* that live in waterlogged, oxygen-free sediments. Methane or natural gas is a greenhouse gas. It is 20 times more potent than carbon dioxide (CO$_2$) over a century, and researchers have repeatedly examined the contribution of natural gas emitted by ruminant cattle to global warming. Microbes, algae, freshwater plants and animals are all part of an active ecosystem and take their nourishment from and return waste to the atmosphere. Healthy plants take CO$_2$ from the atmosphere with photosynthesis. Plant uptake of CO$_2$ is affected by temperature, and so is microbial methane production. Scientists are in view that the ratio of methane to CO$_2$ also goes up with temperature, which is the same whether it is for the microbes or for the whole ecosystem. Methane fluxes are much more responsive to temperature than the processes that produce and consume carbon dioxide highlights another mechanism by which the global carbon cycle may serve to accelerate rather than mitigate future climate change.

**Effect of Water and Land Pollution**

Water Pollution is the contamination of streams, lakes, underground water, bays, or oceans by substances harmful to living things. Water is one of the most essential things that pertain to life
for all living things. Impure water kills plants and animals. It also causes humans to fall sick and acquire other illnesses like child-birth defects and cancer.

Land pollution is similar to that of water. It is the contamination of land with hazardous waste like garbage and other waste materials that do not belong to the land. These are consumed by plants and animals and then when the next consumer feeds on either the plant or the animal, it plies up and contaminates the body.

Usually land water bodies get polluted by deposition of pollutant in the sir. In addition the pollutants added in the land and/or soil through fertilizers, pesticides, herbicides, garbage and oil spills are deposited in the surface water bodies through run off and ground water through vertical movement of water inside the land mass, known as percolation. These pollutants affect soil directly changing its pH, structure, salinity and many more functions. Most of these found detrimental to plant and aquatic animals and finally affect us through food chain.

**Sustainable Agriculture**

As defined by FAO, sustainable development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for the present and future generations. Such Sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable.

It is well known that agriculture is the single largest user of freshwater resources, using a global average of 70% of all surface water supplies. Except for water lost through evapotranspiration, agricultural water is recycled back to surface water and/or groundwater. However, agriculture is both cause and victim of water pollution. It is a cause through its discharge of pollutants and sediment to surface and/or groundwater, through net loss of soil by poor agricultural practices, and through salinization and waterlogging of irrigated land. It is a victim through use of wastewater and polluted surface and groundwater which contaminate crops and transmit disease to consumers and farm workers. Agriculture exists within a symbiosis of land and water and, as FAO (1990a) makes quite clear, "... appropriate steps must be taken to ensure that agricultural activities do not adversely affect water quality so that subsequent uses of water for different purposes are not impaired."

**The Framework**
The charts (Fig.-5a and b) below will help in understanding and conceptualizing the framework.
Fig. 5. Conceptual Framework
WHAT IS TO BE UNDERSTOOD?

From the foregoing discussions it is clear that the most important climatic factors influencing growth, development and yield of crops are solar radiation, temperature and water and not less important is the function of land and soil. Each of these factors has been found to have limiting effects on various growth processes. However, these climatic factors always operate together and interact with each other under natural conditions. So, children, in particular, are to understand functions of all the factors in relation to crop growth, functions of soil and also the interaction of atmosphere, soil and plant.

(A) Climatic Factors

Solar radiation

Of the solar radiation or electromagnetic spectrum, light is the visible portion. It is a form of kinetic energy that comes from the sun in tiny particles called quanta or photons, travelling in waves. Three properties of this climatic factor that affect plant growth and development are light quality, light intensity, and day length or photoperiod. Light quality refers to the specific wavelengths of light; light intensity is the degree of brightness that a plant receives; and day length is the duration of the day with respect to the night period.

Light is a climatic factor that is essential in the production of chlorophyll and in photosynthesis, the process by which plants manufacture food in the form of sugar (carbohydrate). Other plant processes that are enhanced or inhibited by this climatic factor include stomatal movement, phototropism, photomorphogenesis, translocation, mineral absorption, and abscission. Any impedance on reduction on the availability of light will affect plant.

Water

Water is an important climatic factor that affects or determines growth and development of plant. Its availability, or scarcity, can mean a successful harvest, or diminution in yield, or total failure. The importance of water relates to its essential functions in perpetuating both plant and animal life. It is an absolute requirement for all living organisms. But plant responses differ depending on plant species. Most plants are mesophytes, that is, they are adapted to conditions with moderate supply of water. But some, called hydrophytes, require watery or water-logged habitats, while others called xerophytes are more tolerant to dry conditions. Nevertheless, water participates directly or indirectly in all metabolic processes in all living organisms. As a solvent, it also serves as a transport medium for mineral nutrients from the soil, as well as in the translocation of organic substances within the plant. It is a chemical reactant in photosynthesis and hence vital to life. It is also responsible for regulating temperature of plants through the process of transpiration. However, as with other climatic factors, water can also cause detrimental effects on plant growth and development. Excess water in the soil can injure flood prone plants like...
corn (Maize), due to lack of oxygen. In this case water stress due to flooding means oxygen stress by deficiency (hypoxia) or total absence (anoxia) of oxygen.

Rainfall is the most common form of precipitation and other forms of precipitation are freezing rain, sleet or ice pellets, snowfall, fog and hail. The amount and irregular occurrence of rainfall vary with location and climate types and affect crop growth and yield. So, occurrence of excess (flood) and deficit (drought) rainfall as an effect of climate change will lead to affect crop yield drastically.

**Temperature**

The degree of hotness or coldness of a substance is called **temperature**. This climatic factor influences all plant growth processes such as photosynthesis, respiration, transpiration, breaking of seed dormancy, seed germination, protein synthesis, and translocation. At high temperatures the translocation of photosynthate is faster so that plants tend to mature earlier. Moreover, due to prevalence of high temperature, plants try to complete its life-cycle by early flowering that causes yield loss.

In general, plants survive within a temperature range of 0 to 50°C (Poincelot 1980). Enzyme activity and the rate of most chemical reactions generally increase with rise in temperature. Up to a certain point, there is doubling of enzymatic reaction with every 10°C temperature increase. But at excessively high temperatures, denaturation of enzymes and other proteins occur.

Conversely, excessive low temperatures also cause limiting effects on plant growth and development. For example, water absorption is inhibited when the soil temperature is low because water is more viscous at low temperatures and less mobile, and the protoplasm is less permeable. At temperatures below the freezing point of water, there is change in the form of water from liquid to solid. The expansion of water as it solidifies in living cells causes the rupture of the cell walls. Favorable or optimal day and night temperature range for plant growth and maximum yields varies among crop species.

<table>
<thead>
<tr>
<th>Climatic condition</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cool</td>
<td>60-70°F (15.55-21.11°C)</td>
<td>50-55°F (10-12.77°C)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>70-80°F (21.11-26.66°C)</td>
<td>55-65°F (12.77-18.33°C)</td>
</tr>
<tr>
<td>Warm</td>
<td>80-90°F (26.66-32.22°C)</td>
<td>65-70°F (18.33-21.11°C)</td>
</tr>
</tbody>
</table>

It is important to note that for growth and development an optimum temperature is required for maximum dry matter accumulation. High night temperature affects growth of shoot. All plants have maximum, optimum and minimum temperature limits. The limits are cardinal temperature points. Optimum temperature range is very important. High temperature adversely affects not only mineral nutrition and shoot growth but also affects pollen development resulting in low yield. The critical temperature above which plants gets killed is called thermal ‘death point’ and temperature above 50°C may kill many annual crops.
Soil temperature also influences crop growth regulating concentration of soil solution and its availability to the plants for nutrition. Soil surface temperature increases with the increase in atmospheric temperature, although it is regulated to a large extent by crop canopy.

### Cardinal Temperatures of Wheat and Rice

<table>
<thead>
<tr>
<th></th>
<th>Wheat</th>
<th>Rice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Minimum</td>
</tr>
<tr>
<td>3 – 4°C</td>
<td>10 - 12°C</td>
<td></td>
</tr>
<tr>
<td>25°C</td>
<td>30 - 32°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Optimum</td>
<td>30 - 32°C</td>
</tr>
<tr>
<td>30 - 32°C</td>
<td>Maximum 36 - 38°C</td>
<td></td>
</tr>
</tbody>
</table>

### Low temperature Injuries

- **Chilling injury**: If the plants grown in hot temperature are exposed to low temperature, they will be killed or severely injured. When the night temperature is below 15°C field crops may show yellowing symptoms (e.g. Tropical annuals).

- **Freezing injury**: When the plants are exposed to how temperature, water freezes into ice crystals in the intercellular spaces (e.g. Cell dehydration) Temperate crops (potato, tea etc.,)

- **Suffocation**: Formation of thick cover of ice/snow on the soil surface presents the entry of oxygen and crop suffers. This presents the respiration and lead to accumulation of harmful substances.

- **Heaving**: Lifting of plants along with soil from its actual position by ice, crystals. This is a mechanical lifting.

- **Frost damage**: If the cell size is large the probability of frost damage is high due to Low temperature near the canopy resulting from earth’s re-radiation.

### High temperature Injuries

**Mineral Nutrition**

- High temperature stress causes reduction in absorption and subsequent assimilation of nutrients.

  - Absorption of calcium is reduced at temperature (Example, at 28º C calcium absorption is reduced in Maize).
  - Nutrient uptake is affected by both soil and air temperature in rice.
  - Nitrate reductase activity decreases under high temperature.

**Shoot growth**

- High temperature, even for short period, affects crop growth especially in temperate crops like wheat.

  - High air temperature reduces the growth of shoots and in turn reduces root growth.
  - High soil temperature is more crucial as damage to the roots is severe resulting in substantial reduction in shoot growth.
  - High temperature at 38º C in rice reduced plant height, root elongation and smaller roots.

**Pollen development**

- High temperature during booting stage (stage between flowering and grain formation stages) results in pollen abortion.

  - In wheat, temperature higher than 27º C caused under-development.
A temperature of 30º C for two days at reduction division stage decreased grain yield by drastic reduction in grain set.

<table>
<thead>
<tr>
<th>Scorching</th>
<th>High temperature lead to dehydration and leaves are scorched.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High temperature causes injury on the exposed area of the plant (eg) Barcks, it is known as ‘Sun scald’.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physiological activities</th>
<th>High temperature disturbs the photosynthesis and respiration.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burning off</td>
<td>Due to high soil temperature the seedlings are killed.</td>
</tr>
<tr>
<td>Stem gridle</td>
<td>High soil temperature causes stem scorches at the ground level (eg. in cotton).</td>
</tr>
</tbody>
</table>

**Air**

The **air** is a mixture of gases in the atmosphere; about 75% of air is found in the **troposphere**, the innermost layer of the atmosphere which extends about 17 km above sea level at the equator and about 8 km over the poles. In addition, about 99% of the clean, dry air in the troposphere consists of 78% nitrogen and 21% oxygen. The remainder consists of argon (slightly less than 1%), carbon dioxide (0.036%), and traces of other gases. Oxygen (O₂) and carbon dioxide (CO₂) in the air are of particular importance to the physiology of plants. Oxygen is essential in **respiration** for the production of energy that is utilized in various growth and development processes. Carbon dioxide (CO₂) is a raw material in photosynthesis.

The air also contains water vapour (H₂O), suspended particles of dust and chemical air pollutants such as carbon monoxide (CO), carbon dioxide (CO₂), sulfur dioxide (SO₂), sulfur trioxide (SO₃), nitrogen oxides, methane (CH₄), propane, chlorofluorocarbons (CFCs), solid particles of dust, soot, asbestos and lead, ozone and many more. However, the composition of this climatic factor is susceptible of variation.
Air within the soil is also very important as it is used by roots of the plants and animals living underground for their respiration. Any change in the composition of stratospheric air due to climate change will affect quality of soil air too.

**Humidity**

The amount of water vapor that the air can hold depends on its temperature; warm air has the capacity to hold more water vapor than cold air. There is almost one-half reduction in the amount of water vapor that the air can hold for every $10^0$C drop in temperature.

But, we are concerned mostly with **Relative humidity (RH)**, which is the amount of water vapor in the air, expressed as the proportion (in percent) of the maximum amount of water vapor it can hold at certain temperature. For example, an air having a relative humidity of 60% at $27^0$C temperature means that every kilogram of the air contains 60% of the maximum amount of water that it can hold at that particular temperature.

The amount of water vapor in the air ranges from 0.01% by volume at the frigid poles to 5% in the humid tropics. In relation to each other, high RH means that the air is moist while air with minimal content of moisture is described as dry air. Compared to dry air, moist air has a higher relative humidity with relatively large amounts of water vapor per unit volume of air. The relative humidity affects the opening and closing of the stomata which regulates loss of water from the plant through transpiration as well as photosynthesis. The amount of humidity in air influences incidence of pest and diseases in plants resulting severe yield loss.

**Wind**

**Wind**, the air movement, is due to the existence of pressure gradient on a global or local scale caused by differences in heating. On a global scale it consists of the jet stream flow and movement of large air masses. On the local scale only a smaller quantity of air moves. Surface winds are lower and less turbulent at night due to the absence of solar heating.

When air is close to the ground it cools, and subsequently it contracts and the pressure rises; when it warms, it expands and pressure drops. Where both cold and warm air occur in proximity, as over a lake and its adjacent shore, the cold flows to the direction of the warm air or from high to low pressure area to correct the pressure imbalance. This also happens in tropical Asia but in a larger and more complex way, as the monsoon winds. Moderate winds favor gas exchanges, but strong winds can cause excessive water loss through transpiration as well as lodging or toppling of plants. When transpiration rate exceeds that of water absorption, partial or complete closure of the stomata may ensue which will restrict the diffusion of carbon dioxide into the leaves. As a result, there will be a decrease in the rate of photosynthesis, growth and yield. This climatic factor serves as a vector of pollen from one flower to another thus aiding in the process of pollination. It is, therefore, essential in the development of fruit and seed from wind-pollinated flowers as in many grasses.
(B) Function of Soil

Soil performs multiple functions starting from providing physical, chemical and biological support for plant growth. It provides habitat for variety of flora and fauna including human. Lives. It acts as natural filter and buffer media against abrupt changes occurring in it. It also acts as a sink of organic carbon and thus global CO$_2$ flux.

The upper thin layer (usually 15 cm depth) of land surface is the most favourable medium for plant growth. Plant anchors and draws nutrients and water from this layer. Soil in this layer performs a number of ecosystem services like storage, decomposition, transformation, and detoxification and thereby provides right soil condition for crop/plant growth. Numbers of biogeochemical cycles like carbon, nitrogen, phosphorus and sulfur cycles are being operated and nutrients are being released for plant and soil organisms and thus biomass production are sustained in the earth.

(C) Atmosphere-Soil-plant System

It is to be very much clear to the children that all the component of the earth system i.e. atmosphere, lithosphere, hydrosphere and biosphere are interdependent and act by the influence of solar energy (Fig.-3). Moreover, nature maintains a balance among them. So any change at any level may lead to the catastrophe to the crop production system vis-à-vis the agriculture as a whole.

![Fig.-3. The Earth System](image)

It has further been explained through figure-4 that there is strong relationship between physical climate system and biogeochemical system.
So, under this sub-theme, children can observe changes in the weather regulating factors and their impact on agricultural system in their own area and find out some method/technique to mitigate. Moreover, there are many practices related with seed selection, irrigation, soil management etc., which can help in adaptation process.

**PROJECT IDEAS**

**Project 1: Conservation agriculture for sustainable land use**

**Introduction:**
Conservation agriculture is application of modern agricultural technologies to improve production with concurrent protection and enhance the land resources on which the production depends. It promotes the concept of optimizing yield and profits with minimal disturbance of land resources along with balanced application of chemical inputs and careful management of crop residues and waste.

**Objectives**
- To promote minimal mechanical disturbance of soil through zero/minimum tillage.
- To maintain permanent soil cover with available crop residues and other wastes.
- Efficient nutrient management practices through balanced application of organic and inorganic source.
• Effective utilization of residual soil moisture.

Methodology
1. Selection of field
2. Selection of crop (Cereals/Oilseed/Pulse/ leafy vegetables)
3. Divide the field into two equal halves and mark as (a) and (b)
   a) Dig lines of 2” – 3” depths with equal distance between the lines, place the fertilizer, cover it with loose soil, place the seed on it and cover the lines.
   b) Plough the soil and apply fertilizer (as per local practice) and sow the seeds.
4. Doses of fertilizer, pesticides etc. will be as per practice followed by farmers.

Observation:
1. Record economic yield/biomass data of the crops
2. Workout the economic benefit.
3. Determine bulk density of soil at the time of harvest of the crops from all the plots.
4. Find out porosity of soil and compare the differences.

Procedure to measure bulk density:
1) Cut 4-6” length pieces (core) from a G I Pipe with > 2” diameter
2) Place the core on the soil surface.
3) Place a wooden block (approximately 4” width, 5” length, 1” thickness) on the top of the core.
4) Hammer the wooden block to push the core into the soil
5) Cut the soil around the core with spade and take out the core with soil in it.
6) Cut the excess soil at both ends of the core with knife so that volume of the core will represent volume of the soil
7) Take the weight of core plus soil
8) Push the soil out, wash and clean the core and make it dry.
9) Take the weight of the core
10) Measure the inside diameter and length of the core, which will be used in calculating the volume of soil
11) Divide the mass of the soil by the volume of soil this will give the bulk density of the soil.

Follow up:
1) Show the crops condition to others.
2) Discuss the results with the farmers/students.

Note:
Density is the mass of an object per unit volume. It is expressed as gm/cm$^3$.
Soil has got two densities – Particle density and Bulk density.
• **Particle density (pd)** is the density of the solid soil particles (sand, silt and clay). For all practical purposes and on-farm studies average particle density is considered as 2.65 gm/cm$^3$
• **Bulk density (bd)** is the density for a volume of soil as it exists naturally, which includes any air space and organic materials in the soil volume. Science bulk density is calculated for the dried soil, moisture is not included in the sample. It is calculated using the following formula

$$bd = \text{weight of soil/ volume of soil core}$$

$$\text{Volume of soil core} = \pi r^2 h \quad (\pi = 22/7 = 3.14)$$
Where, \( r \) is the radius of the core = \( d/2 \) (d is the diameter of the core)

\( h \) is the height of the soil core

Suppose, in the figure of the cylinder, \( AB \) is the diameter (d) and \( AB/2 \) or \( d/2 \) is the radius (r). BC is the height (h) of the cylinder.

Calculate (i) cross sectional area(A) of the cylinder \( A = \pi r^2 \)

(ii) Volume of the cylinder \( V = A \times h = \pi r^2 \times h = 3.14r^2 \times h \) \((\pi = 3.14)\)

Soil porosity, \( \% = (1- bd/2.65)\times100 \)

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Project 2: Mitigate soil and water loss through runoff with suitable control measures.

Introduction:

Land degradation refers to the loss of inherent capacity of land to produce healthy and nutritious crops. It may occur with various forms – physical, chemical and biological. Soil erosion is the most important forms of land degradation as the vast area of our country suffers due to such process. It is, therefore, necessary to protect this shrinking valuable land resource to meet the demand of ever increasing population. Some of the common measures are practiced for preventing the loss of runoff water and soil particles from the sloppy land, which includes terracing, bunding, cover cropping, strip cropping, conservation tillage, cultivation along or across the slope etc.

Objectives:
1) Quantify loss of soil and water through runoff.
2) Implement control measure to check the loss of soil and water.
3) Sustainable land use practice in areas prone to erosion.

Methodology:
1) Selection of a suitable sloppy land.
2) Divide the land into at least 3 parts along with the slope.
   (Minimum width of each part shall be 3m)
3) Treatments
a) Keep fellow or undisturbed.
b) Grow cover crops.
c) Grow strip crop as per local practice.

4) Separate the adjoining parts by erecting suitable barriers with non porous inert materials.
5) Place suitable notch at the middle part of the lower end through which runoff water and soil particle will pass.
6) Place a large bucket or suitable tank to collect the run off water and soil particles.

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**How to calculate slope of a land?**

![Diagram of a triangle with labels A, B, and C.]

Suppose BC is the length of a land and AB is the height of the land; 
So, **Slope, % = (BC/ AB)x 100**

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**Observation:**
1) Length of slope
2) Percent of slope
3) Amount of water added at the upper end to initiate the runoff process
4) Measure the amount of water and soil collected in the tanks at lower end.

**Follow-up:**
1) Transfer the results of the experiments to the farmers and local people.
2) Demonstrate the experiment to students of the area.

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**Suggested Projects:**
1. How does organic component influence different Soil Properties?
2. Determining maximum loading limit for copper in agricultural land
3. Evaluating filtration capacity of soil
4. Influence of vegetation cover on microclimate
5. Influence of mulch on soil physical properties
6. Study of the influence of tillage on soil physical properties
7. Effect of land use options on erosion loss of surface soil
8. Influence of tillage on ground water recharge from rice field.
9. Impact of saline water on soil properties like pH etc.
10. Germination of crop in soil with varying salinity level
11. Organic matter addition and crop growth
12. How pollutants affect soil biota?
**Evapotranspiration (ET)** is the sum of evaporation and plant transpiration from the Earth's land and ocean surface to the atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception, and waterbodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapor through stomata in its leaves. Evapotranspiration is an important part of the water cycle.

**Potential evapotranspiration (PET)** is a representation of the environmental demand for evapotranspiration and represents the evapotranspiration rate of a short green crop, completely shading the ground, of uniform height and with adequate water status in the soil profile. It is a reflection of the energy available to evaporate water, and of the wind available to transport the water vapour from the ground up into the lower atmosphere. Actual evapotranspiration is equal potential evapotranspiration when there is ample water.