Lecture No. :1 AGROMETEOROLOGY

Agrometeorology is a term which is abbreviated form Agricultural Meteorology and also referred as Agroclimatology, has been defined in several ways. The name itself implies that it is the study of those aspects of meteorology which have direct relevance to agriculture.

Growth, development and productivity of plants depend on several factors. These factors can be broadly divided into two major groups viz., internal factors (Genetic or hereditary) and external or environmental (surrounding) factors. The environmental factors are

i) Climate (Meteorological elements)
ii) Edaphic (Soil)
iii) Biotic (living organisms)
iv) Physiographic (elevation)
v) Anthrophic (man)

This course on agrometeorology deals with the behaviour of the weather elements and their effect on crop production.

Definitions

Agrometeorology is a science investigating the meteorologic, climatologic and hydrologic conditions which are significant for agriculture owing to their interaction with the objects and processes of agricultural production.

A science dealing with climatological conditions which have direct relation or relevance to agriculture.

Meteorolgoy: It is a branch of physics dealing with atmosphere (Atmosphere is a deep blanket of gases surrounding the earth). Meteorology is often quoted as the “Physics of the lower atmosphere”. It studies the individual phenomenon of the atmosphere. In other words it is concerned with the study of the characteristics and behaviour of the atmospheres. It explains and analyses the changes of individual weather elements such as air pressure, temperature and humidity that are brought about due to the effect of insolation on the earth’s surface. (insolatin means radiation from the sun received by earth’s surface).

Climatology: The study of weather patterns over time and space. It concerns with the integration of day to day weather over a period of time.

Discuss average conditions of the weather (Austin miller).

Climate: The aggregate of weather conditions over a longer period of time. It includes details of variations - extremes, frequencies, sequences of weather elements which occur from year to year, particularly in temperature and precipitation.

Weather: The state of the atmosphere with respect to wind, temperature, cloudiness, relative humidity, pressure etc., at given time.

Agroclimatic regions: The grouping of different physical areas within the country into broadly homogeneous zones based on climatic and edaphic factors.

Scope of Agrometorology / The need for the study of agrometeorology

For optimum crop growth specific climatic conditions are required. Agrometeorology thus becomes relevant to crops production because it is concerned with the interactions between meteorological and hydrological factors on the one hand and agriculture, in the widest sense including horticulture, animal husbandry, forestry on the other.

Weather and climate are the important factors determining the success or failure of agriculture. Weather influences agricultural operations from sowing of a crop to the harvest and particularly rainfed agriculture depends on the mercy of the weather. In India every year there is a considerable damage by floods in one part of the country and a severe drought causing famines in another part. The total annual pre harvest losses for the various crops are estimated from 10 to 100 per cent; while, the post harvest losses are estimated between 5 and 15 per cent.

Need of Agrometeorolgoy

1. The crops are to be sown at the optimum period for maximum yield. In dry lands, the time of receipt of rainfall decides the sowing date. Predicted on set of monsoon - premonsoon sowing.
2. Study of agro-meteorology helps to minimise the crop losses due to excess rainfall, cold/heat waves, cyclones etc.
3. It helps in forecasting pest and diseases, choice of crops, irrigation and other cultural operations through short, medium and long range forecasts.
4. It helps to identify places with same climatic conditions (Agroclimatic zones). This will enable to adopt suitable crop production practices based on the local climatic conditions. It also helps in the introduction of new crops and varieties which are more productive than the native crops and varieties.
5. It helps in the development of crop weather models which enables to predict crop productivity under various climatic conditions.
6. It helps in the preparation of crop weather calendars for different locations.
7. It enables to issue crop weather bulletins to farmers.
8. It enables to forecast the crop yield based on weather to plan and manage food production changes in a region.
9. To make the farmers more “Weather concious” in planning their agricultural operations.

Development of Agricultural Meteorology

Climatology is compounded of two Greek words, klima + logos; klima means slope of the earth, and logos means a discourse or study. In brief, climatology may be defined as the Scientific study of climate. Climatology is at once an old and a new science premature man was greatly affected by the phenomena of weather and climate and was unable to explain logically. Superstition served to interpret atmospheric mysteries such as rain, wind and lightening. In the early civilization, Gods were often assigned to the climatic elements, Indians still hold ceremonial worships / dances to Gods to produce rains at times of drought.

The Greek philosophers showed a great interest in meteorological science. Infact the world “Meteorology” is of Greek origin, meaning, discourse or study on things about and included meteors and optical phenomena. Infact, the word “Meteorology has been borrowed from Aristotle’s Meteorological” dated about 350 BC. The period of weather lore and superstitions in the development of meteorology lasted untill the beginning of the 17^{th} Century when the invention of instruments for scientific analysis of weather phenomenan was made. In 1593, Galileo constructed a thermometer and in 1643,,his student Toricelli discovered the principles of mercurial Barometer. The climatological map was published by British astronomer ‘Edmund Hally’ in 1686. By 1800, dependable weather observations were made in Europe and USA.

An international Meteorological Organisation had been established in 1878. The world meteorological organisation (WMO) took its present form in 1951. It serves as a specialized agency to carryout the world wide exchange of meteorological informations with the head quarters in Geneva, Switzerland.

The India Meteorological Department (IMD) was established in the year 1875. The division of Agricultural Meteorology was started by the IMD in 1932 to meet the needs of agriculturist and researchers. The IMD has brought out many useful publications on rainfall. The Rainfall Atlas of India was published based on the rainfall data from 1901 to 1950. In addition to rendering advice from time to time, the IMD began to offer a regular weather service and farmers weather bulletins from 1945. The bulletins are broadcast daily in 20 regional languages in all the All India Radio stations (Dhoor Dharhan also do this service) on expected weather conditions during the next 36 hrs. Weather report is also broadcasted through television.

Atmosphere

Stratification and Composition of Atmosphere

The atmosphere is a mechanical mixture of many gases, not a chemical compound. In addition, it contains water vapor volume (4% of atmospheric composition) and huge number of solid particles, called aerosols. Some of the gases (N, O, Ar, CO_2) may be regarded as permanent atmospheric components that remain in fixed proportions to the total gas volume. Other constituents vary in quantity from place to place and from time to time. If the suspended particles, water vapour and other variable gases were excluded from the atmosphere, we would find that the dry air is very stable all over the earth up to an altitude of about 80 kilometers.

Composition of Atmosphere

Principal gases comprising dry air in the lower atmosphere.

Constituent	**Percent by volume**
Nitrogen (N2)	78.08

Oxygen (O_2)	20.94
* Argon (Ar)	0.93
Carbon dioxide (Co_2)	0.03
* Neon (Ne)	0.0018
* Helium (He)	0.0005
Ozone (O_3)	0.00006
Hydrogen (H_2)	0.00005
* Krypton (Kr)	Trace
* Xenon (Xe)	Trace
Methane (Me)	Trace

- Inert chemically never found in any chemical compounds.

shown the table gases, nitrogen and oxygen, make up about 99 per cent of the clean, dry air. The remaining gases are mostly inert and constitute about 1 per cent of the atmosphere generally homogeneous and it is called as homosphere. At higher altitudes, the chemical constituents of air is change considerably. The layer is known as the heterosphere.

N_2 : Relatively inactive chemically. Main function regulate combustion by diluting O_2. Indirectly helps oxidatior. Mainly diluent. Co_2: 0.03% plants take Co_2 in the processes of photosynthesis. Efficient absorber of heat from upper atmosphere as well as the earth. Emits half of the absorbed heat back to earth. Influences flow of energy through the atmosphere. The probation remain same but % increases due to burning of possid fuels. From 1890 to 1970 to 1970 - Co_2 content has been increased more than 10 times - warming of lower atmosphere - climatic changes. Ozone (O_3): It is a type of oxygen molecule formed of three atoms rather than two. It is found only in very small quantity in the upper atmosphere. It is less than 0.0006 per cent by volume. The maximum concentration of Ozone are found between about 30 and 60 km. Although it is formed at higher levels and transported downward. It is the most efficient absorber of the burning ultraviolet radiation from the sun acts as a filter. Absence of Ozone layer will make the earth's surface unfit for human habitation - for all living organisms. NO_2-from airlines - deterioration of O_3. Of all the gases, oxygen happens to be the most important for it is essential to all living organisms.

ii) Water Vapour: Water vapour is one of the most variable gases in the atmosphere, which is present in small amounts, but is very important. The water vapour content of air may vary from 0.02 per cent by volume in a cold dry climate to nearly 4 per cent in the humid tropics. The variations in this percentage over time and place are very important considerations climatically like Co_2, water vapour has insulating action of the atmosphere. It absorbs not - day the long wave terrestrial radiation, but also a past of the imcoming solar radiation. Thus it regulates energy transfer through the atmosphere. Water vapour is the source of all clouds and perceptions.

Dust particles: Dust particles are a major contributory factor in the formation of clouds and fogs. It is responsible for the red, orange clour of the sky at sunrise and sunset.

Layered structure of the Atmosphere: During the international Geophysical year (1957-62), important discoveries were made about the atmosphere and many new facts came to light. The earth's atmosphere consists of zones or layers arranged like spherical shells according to altitude above the earth's surface.

According to Peterson, the atmosphere is divided into the following more significant spheres.

1. Troposphere
2. Stratosphere
3. Ozonosphere (also called Mesosphere)
4. Ionosphere
5. Exosphere

1. **Troposphere:** It contains about 75 per cent of the total gaseous mass of the atmosphere. It has been derived from the Greek World 'tropos' meaning "mixing" or turbulence. The average height of this lowermost layer of the atmosphere is placed at about 14 km above sea level. Under normal conditions, the height of the troposphere at the poles is about 8 kilometers, while at the equator it is about 16 kilometers. A shallow layer separating troposphere from the next thermal layer of the atmosphere i.e., stratosphere. Tropopause (Greek Word) means where the mixing stops.

   Troposphere is marked by turbulence and eddies. It is also called connective region. Various types of clouds, thunderstorms as well as cyclones and anticyclones occur in this sphere because of the concentration of almost all the water vapour (4% of the atmosphere composition) aerosols in it. Wind velocities increase with ht. And attain maximum at the top. Most important is decrease in temperature with increasing elevation upto 14 km.

2. **Stratosphere:** The stratosphere begins at the troposphere which forms its lower boundary. The lower stratosphere is isothermal in character 16-30 kilometers. There is a gradual temperature increase with height beyond 29 km i.e., upper stratosphere. No visible weather phenomena occur above tropopause.

3. **Ozonosphere or Mesosphere:** There is maximum concentration of Ozone between 30 to 69 kilometers above the surface of the earth. Because of the concentration of ozone in this layer it is called the ozonosphere. It is a warm layer because of selective absorption of ultra violet radiation by ozone. In fact, it acts as a filter for ultra violet radiation from the sun.

   In this layer the temperature increases with height @ 5^oC/km. The maximum temperature recorded in the ozonosphere is higher than that at the earth's surface. Because of the preponderance of chemical processes, this sphere is sometimes called as chemosphere.

4. **Ionosphere:** Ionosphere, according to Pettersen, lies beyond the ozonosphere at a height of about 60 km above the earth's surface. At this level the ionization of

atmosphere begins to occur. Above ozonosphere, the temperature fulls again reaching a minimum of about 100^{o}C at a height of 80 km. Above earth's surface. Beyond this level the temperature increases again due to the absorption of short wave solar radiator by the atoms of) & N in this ionosphere.

Layers of ionosphere:

D Layer	:	60-89 km.
E Layer	:	90-130 km.
Sporadic Layer:		110 km.
E2 Layer	:	150 km.
F1 Layer F2 Layer	}	150-380 kms.
G Layer	:	400 km and above.

5. **Exosphere:** The outer most layer of earth's atmosphere is known as the exosphere which lies between 400 and 1000 kilometers. At such great height density of atoms in the atmosphere is extremely low. Hydrozen and helium gases predominate in the outer most region. Kinetic temperature may reach 5568^{o} celcius.

Modern Views Regarding the Structure of Atmosphere

On the basis of composition, the atmosphere is divided into two broad spheres.

i) **Homospheres:** Means zone of homogenous composition height - upto 88 kilometers.

The proportions of the component gases of the sphere are uniform at different levels.

Sub-divided into

a. Troposphere - Very shallow transition layer Tropopause
b. Stratosphere - Stratopause
c. Mesosphere - Mesopause

Heterosphere: The atmosphere above the homosphere is not uniform in composition.

(Heterosphere) Different layers of the atmosphere in this part differ from one another in their chemical and physical properties.

In this sphere gases are said to be arranged into the followng four roughly spherical shells, each of which has its own distinctive compostive.

1. Nitrogen layer - 200 km above earth's surface molecular N.
2. Oxygen layer - Average ht. 1120 km. - atomic oxygen. 3520 km.
3. Helium layer - ”
4. Hydrogen layer

Arranged according to the weight of the gases.

Lecture No. 2

Coordinates: Line

Latitude: Angular distance, measure in degrees, north or south from the equator.

Equator: An imaginary circle around the earth, equally distant at all points from both the North pole and the south pole. It divides the earth's surface into the northern Hemisphere and the southern Hemisphere.

Longitude: (Length) Distance east or west on the earth's surface measured as an are of the equator (in degrees upto 189^o or by the difference in time) between the meridian passing through a particular place and a standard or prime meridian, usually the one passing through Greenwich, England.

Meridian: A great circle of the earth passing through the geographical poles an any given point on the earth's surface. (Geographical)

Coordinates of India

India lies between 8^o N latitude and 37^o N latitude and the tropic of cancer 231/2^o N pauses almost through the middle of it.

Area of India	3.3 m sq. km.
Longitude	68^o C to 98^o E
Latitude	8^o N to 37^o N
Distance form North to South	: 3214 km.
Distance form East of West	: 2933 km.
Land frontiers	: 15200 km.
Coast line	: 6083 km.

Altitude: Height of a thing above the earth's surface or above sea level.

Corodinates of Tamil Nadu

Latitude	: 8^{o}5' and 13 ^{o} 10' North latitude
Longitude	: 76 ^{o} 15' and 80 ^{o} 20' East longitude
Costal line	: Approximately 1000 km.
Temperature range	: 29-38 ^{o} C Maximum 19-27 ^{o} C Minimum

Weather and Climate

In climatology the terms "Weather" and "Climate" have different connotations. Weather refers to the State of Atmosphere at nay give time denoting the short-term variations of atmosphere in terms of temperature, pressure, wind, moisture cloudiness, precipitation and visibility. Weather is highly variable. It is constantly changing, sometimes. From hour to hour and at othertimes from day to day. The afore-mentioned properties of the atmosphere are subject to constant change and their state at any time determines the state of the weather. However, weather elements are not separate rather they are closely related with each other.

David I. Blumenstock, an eminent climatologist has defined weather in more restrictive sense. According to him, weather is the behaviour of the lower atmosphere with particular emphasis on the atmospheric behaviour which affect the lands and oceans and have a marked influence on the organisms that live upon the lands, within the waters of the earth or in the lower air. For the geographer, this definition of weather is more satisfactory. Since he is interested more in the workings of the lower atmosphere which affects the life of man as well as his natural environment directly. Thus, we come across a great many varieties of weather covering a wide range of conditions.

Climate

Climate on the other hand, is the sum total of the variety of weather conditions of place or an area form day to day. Thus, climate may be defined simply as 'average weather'. The term climate denotes a description of aggregate weather conditions. True climate described an area's average weather, but it also includes common deviations from the average as well as the extreme conditions. For getting the vital climatic information the range and frequency of extremes are of great significance. Therefore, climate may be defined as the sum of all statistical weather informations of a particular area during a specified interval of time, usually several decades. The world Meterological Organizatins has suggested standard period of 31 years for calculating the climatic averages of different weather elements.

Different climatologists have defined the climate. But all are based on weather over of period of times.

The following are some of the most important elements of weather which in different combinations make up the climate of particular place or areas.

Weather parameters / Weather elements

1. Solar radiation.
2. Temperature, Air pressure
3. Wind velocity and wind direction
4. Moisture (humidity)
5. Cloudines (Sunshine hours)
6. Precipitation (Rainfall)

All this are highly variable and constitute the weather / climate a change n one of the elements generally brings about changes in the others.

Factors affecting Weather and Climate: (Climatic controls)

1. **Latitude:** The distance from the equator either south or north, largely create variations in the climate. Based on latitude the climate has been classified as (i) Tropical, (ii) Subtropical, (iii) Temperate and (iv) Polar.

   The tropical climate is characterised by high temperature throughout the year. Subtropical is also characterised by high temperature alternating with low temperature in winter. The temperate climate has low temperature throughout the year. The polar climate is noted for its very low temperature throughout the year.

2. **Altitude: Elevation):** The height form the mean sea level creates variation in climate. Even in the tropical regions, the high mountains have temperate climate. The temperature decreases by 1.8^{o}C for every 300 m from the sea level. Generally there is a decrease in pressure and increase in precipitation and wind velocity. The above factors alter the kind of vegetation, soil types and the crop production.'

3. **Precipitation:** The quantity and distribution of rainfall decides the nature of vegetation and the nature of the cultivated crops. The crop region are classified on the basis of average rainfall which are as follows:

Rainfall (mm)	**Name of the climatic region**
Less than 500	Arid
500-750	Semi Arid
750 - 1000	Sub humid
More than 1000	Humid

4. **Soil Type:** Soil is a product of climatic action on rocks as modified by landscape and vegetation over a long period of time. The colour of the soil surface affects the absorption, storage and re-radiation of heat. White colour reflects while the black absorbs more radiation. Due to differential absorption of heat energy, variations in temperature are created at different places. In black soil areas the climate is hot while in red soil areas it is comparatively cooler due to lesser heat absorption.

5. **Nearness to large water bodies:** (Nearness to sea) The presence of large water bodies like lakes and sea affect the climate of the surrounding areas. Eg., Islands and coastal areas. The movement of air from earth surface and from water bodies to earth modify the climate. The extreme variation in temperature during summer and winter is minimised in coastal areas and Islands.

6. **Topography: (Relief)** The surface of landscape (leveled or uneven surface areas) produces marked changes in the climate. This involves the altitude of the place, steepness of the slope and exposure of the slope to light and wind.

7. **Vegetation:** Kind of vegetation characterise the nature of climate. Thick vegetation is found in tropical regions where temperature and precipitation are high. General types of vegetations present in a region indicates the nature of climate of that region.

Other factors are

i) Semi permanent high and low pressure systems.
ii) Winds and air masses.
iii) Atmospheric disturbances or storms
iv) Ocean currents
v) Mountain barriers.

Lecture No. 3

Solar radiation - light energy , intensity, quality, day length and direction of light, their effect on crop production - instruments used for measuring solar radiation.

SOLAR RADIATION

The sun is the primary source of heat to the earth and its atmosphere. The heat received form other celestial bodies as well as the interior of the earth is rather too insignificant to merit our attention. The distance that separates the earth from the sun is about 1,49,000, 000 kilometers. The diameter of the sun measures roughly about 13,82,400 kilometers. The surface temperature of the sun is estimated between 5500^oC and 6100^oC. (or 5762^oK)- Interice $8x10^6$ to $40x100^6$ k.

Solar radiation provides more than 99.9 percent of the energy that heats the earth. Undoubtedly, the radiant energy from the sun is the most important control of our weather and climate. The most astonishing fact about the incoming solar radiation(insolation) that strikes the earth's surface is that it is equal to about 23 billion horse power. Actually it is this amount of energy received from the sun that acts as the driving force for all the atmospheric as well as biological processes on the earth. Besides, all other sources of energy found on earth such as coal, oil and wood etc. are nothing but converted form of solar energy.

The word 'insolation' is contraction of "incoming solar radiation". Radiant energy from the sun that strikes the earth is called insolation.

LIGHT

Solar radiation consists of a bundle of rays of radiant energy of different wave lengths. The sum emits radiant energy in the form of electromagnetic waves. The visible portion of the solar spectrum appears as light. Light travels with a speed of 2,97,600 km/ sec. It takes 8 minutes to 20 second. Reach the earth. Light is the total effect of the combination of the seven different colours, namely red, orange, yellow, green, blue, inido and violet. (VIBGYOR). The waves that produce the effect of red colour are the longest and those producing the violet are the shortest. Waves shorter than the violet are called ultraviolet rays, while those longer than the red are known as infra red rays. The ultra violet waves form only 6 per cent of the insolation, but have strong photochemical effects on some substances. The infra-red rays, even though invisible, form 43 per cent of the insolation. They are largely absorbed by water vapour that is concentrated in the lower atmosphere.

PROCESSES OF HEAT ENERGY TRANSFER

Radiation: Radiation is the process of transmission of energy by Electro magnetic waves and is the means by which energy emitted by the sun reaches the earth.

Conduction: Conduction is the process of heat transfer through matter by molecular activity. In this process heat is transferred from one part of a body to another or between two objects touching each other. Conduction occurs through molecular movement.
Convection: Convection is the process of the transfer of heat, through movement of a mass or substance from one place to another. Convention is possible only in gases or fluids, for they alone have internal mass motions. In solid substances this type of heat transfer is impossible.

Heat Budget: If the total solar radiation reaches the outer limit of the atmosphere, about 32 percent is reflected by clouds of scattered back to space by suspended particles and it is not used to heat the air. The earth surface reflects 2 percent of radiation to the space. The total reflectivity is known as earth's "albedo". The average albedo value for the earth is 34 percent. About 19 percent of solar radiation is absorbed by gases and water vapour, about 24 percent is absorbed the earth from scattering of clouds and atmosphere. Thus approximately two-thirds of the total radiation is effective in heating the earth.

Albedo: It is the capacity of any surface to reflect the incoming radiation (light) OR it is the ratio of incoming radiation to the outgoing radiation.

The total reflectivity is known as earth's albedo. Average albedo value for earth is 34%. The total energy coming to the earth over a considerable period of time is equal to the total outward losses. If this were not so, the earth would seen become either very hot or very cold. Actually there is a deficit of heat at higher latitudes and surplus in low latitudes.

Solar Constant: The sun is the source of more than 99 per cent of the thermal energy required for the physical processes taking place in the earth atmosphere system. Every minute, the sun radiates approximately 56×10^{26} calories of energy.

In terms of the energy per unit area incident on a spherical shell with a radius of 1.5×10^{13} cm (the mean distance of the earth from the sun) and concentric with the sun, this energy is equal to

$$S = \frac{56 \times 10^{26} \text{ cal. Min}^{-1}}{4 \quad \pi\,(1.5 \times 10^{13} \text{ cm})^2} = 2.0 \text{ langely min}^{-1}.$$

The solar constant (S) is a true constant, but fluctuates by as much as ! 3.5 percent abut its mean value, depending upon the distance of earth from the sun (Langley = gram calories cm^{-2}).

Solar constant = 2.0 gram calories $\text{cm}^{-2}\ \text{min}^{-1}$

Solar constant is defined as the rate at which solar radiation is received outside the earth's atmosphere on a surface perpendicular to the sun's rays when the earth is at an average distance from the sun.

The Smithsonian Institute, USA has come to the conclusion that the standard value of solar constant is 1.94 gram cabries per cm^2/minute.

Since there is fluctuation in the amount of radiant energy emitted by the sun due to periodic disturbances on the solar surface, the amount of solar constant, therefore, registers a slight increase or decrease. However, this variation hardly exceeds 2-3%.

The amount of insolation received on any date at any place on the earth is governed by

i) The solar constant which depends on (a) energy out put of the sun and (b) distance from the earth to sun.
ii) Transparency of the atmosphere.
iii) Duration of the daily sunlight period.
iv) Angle at which the sun's rays strike the earth.

The distance between the earth and the sun varies between 94.5 million miles (157.5 m km) at aphelion (July 1^{st}) and 91.5 million miles at perihelion (January 1^{st}). The amount of radiation received is seven percent greater at perihelion than at aphelion. This is a consequence of the increase sequence law which states, in effect, that the radiation received on any unit area decreases in proportion to the square of the distance to the sources.

Intensity $\frac{1}{d^2}$

A transparency of the atmosphere has a more important bearing upon the amount of insolation which reaches the earth's surface. The areas having heavy dust, clouds, water vapour and cloudiness or polluted air will receive less direct insolation. The transparency of atmosphere depends on the latitude of a place. At middle and high latitudes the sun's rays must pass through thicker layers of reflecting / scattering material and it is not so at tropical latitudes.

= earth nearer to sun,

Aphelion - The point farthest from the sun in the obit of a planet.

Perihelia - The point nearest from the sun in the orbit of a planet.

EFFECT OF LIGHT ON PLANTS

S.R. in the primary Electromagnetic spectrum showing the wavelength of different type of radiations is shown below. Type of radiation wavelength (Micm)

1. cosmic rays 10^{-7} to 10^{-4}
2. Gamma rays 10^{-4} to 10^{-3}
3. X rays 10^{-3} to 10^{-1}
4. U.V. 1 to 390
5. Visible 390 - 760
6. Infrared 760 - 10^{6}
7. Radiowave 10^{6}-10^{13}

Visible solar radiation is called as light. The shorter wave lengths is the solar spectrum is harmful to the plants when exposed to excessive amounts. The atmosphere, however, absorbs almost all the shorter wave lengths. The infrared radiation has thermal effect on plants by supplying necessary energy for evaporation of water from the plants.

The visible portion of the solar spectrum is the light with wave length ranging from 0.4 to 0.7 μ. Light is one of the important climatic factors for many vital functions of the plant. It is essential for the synthesis of the most important pigment i.e, chlorophyll. The cholorphyll absorbes the radiant energy and converts into potential energy of carbohydrates (Photosynthesis). The carbohydrate thus formed is the connecting link between solar energy and living world. In addition, it regulates the important physiological functions like transpiration.

Effect of light on plants can be studied under four headings (i) Light intensity (ii) Quality of light (iii) Duration of light and (iv) direction of light.

Light Intensity: The intensity of light is measured by a standard unit called candle. The amount of light received at a distance of one meter from a standard candle is known as "Metre Candle or Lux". The light intensity at one foot from a standard candle is called "foot candle" or 10.764 luxes and the instrument used is called as "Lux meter". About one per cent of the light energy is converted into biochemical energy. Very low light intensity reduces the rate of photosynthesis and may even result in the closing of the stomata detrimental to plants in many ways. This results in reduced plant growth. Very high light intermities are it increases the rate of respiration. It causes rapid loss of water, i.e., it increases the transpiration rate of water from the plants resulting in closure of stomata. The most harmful effect of high intensity light is that it oxidise the cell contents which is termed as "Solarisation". This oxidation is different from respiration and is called as 'Photooxidation".

Under natural conditions light intensity varies greatly and plants show marked response to changes of light intensities. Based on the response to light intensities the plants are classified as follows:

i) **Sciophytes:** (Shade loving plants) The plants that grow better under partially shadded (low light) conditions e.g., betevines, buckwheat, turmeric etc.,

ii) **Heliophytes: (sun loving Plants)** Many species of plants produce maximum dry matter under high light intersities when the moisture is available at the optimum level, e.g. maize, sorghum, rice etc. Except under glass house or shaded conditions, intensity of light cannot be controlled.

Quality of Light: When a beam of white light is passed through a prism, it is dispersed into different colours with their wave lengths partiude. This is called the visible part of the solar spectrum. The different colours and their wave length are as follows:

Violet & Indigo	400 - 435 mm
Blue	435 - 490 mm

Green	490 - 574 mm
Yellow	574 - 595 mm
Orange	595 - 626 mm
Red	626 - 750 mm

Visible rays 390 - 760 micron μ, nm

$$\text{Micron} = \frac{1}{1000000}\ \text{meter}$$

$$= \frac{1}{1000}\ \text{mm}$$

Milli micron : 10-9 ml-=narometer

The Principal wave lengths absorbed and used in photosynthesis are in the violet-blue and the orange - red regions. Among this, to plant growth. Red light is the most favourable light for growth followed by violet-blue. Ultra violet and shorter wave lengths are useful to kill bacteria and many fungi.

3. Duration of light: The duration of light has greater influence than the intensity. It has a considerable importance in the selection of crop varieties. The response of plants to the relative length of the day and night is known as *photoperiodism*. The plants are classified based on the extent of response to day length as follows.

1. **Long day plants:** The plants which develop and produce normally when the photoperiod is greater than the critical minimum (greater than 12 hours) e.g. cereals, potato, sugar beet, wheat, barley etc.

   ii) Short day plants: The plants which develop normally when the photoperiod is less than the critical maximum (less than 12 hours) e.g. tobacco, soybean, millets, maize, sugarcane, etc.

   iii) Indeterminate or day neutral plants: Those plants which are not affected by photo period, e.g., Tomato, Cotton, Sweet potato, pineapple etc.,

   The photo periodism influences the plant characters such as floral initiation and development, bulb and rhizome production etc. If a long day plant is grown during periods of short days the growth of internodes are shortened and flowering is delayed till the long days come in the season. Similarly when short day plants are subjected to long day periods, there will be abnormal vegetative growth and there may not be nay floral initiation. (CO 38 rice) But now a days many crops do have photo-insuritive varieties.

4. Direction of light: The direction of sunlight has a greater effect on the orientation of roots shoots and leaves. In temperate regions, the southern slopes show better growth of plants than the northerns slopes due to higher contribution of sunlight in the southern side.

Orientation of leaves: The change of position or orientation of organs of plants caused by light is usually called as "Phototropisum". For e.g. the leaves are oriented at right angles to incidence of light to receive maximum radiation.

Photomorphogenesis: Change in the morphology of plants due to light. This is mainly due to ultra violet and violet rays of the sun.

Instruments used for measuring solar radiation

1. Bellanis pyranometer
2. Sunshine recroder
3. Line quantum sensor
4. Photometer
5. Lux meter measures the light intensity
6. Radiometer

Duration of daily sunlight period (Length of day)

Figure 2.2 (Page 14 of Gopalsamy book)

The vertical rays of the sun at noon day fall directly overhead at the equator on March 21st and this is called 'Vernal equinox'. The vertical rays continue to move nothward to the tropic of cancer and are overhead there on June 21st and this date is known as "Summer solstice" (in Northern hemisphere) Afterwards the rays return to the equator on September 23rd and this date is known as "Antumnal equinox". Then it reaches the Tropic of capricon on December 21st and this date is known as "Winter solstic" (In Northern hemisphere). The summer and winter solstics will be reverse in the southern hermisphers. At quinox, days and nights are of equal length throughout the world. In summer solistice the day will be longer inherces in winter solistice the day will be shorter than night. The Northen pole will be in day light for the full 24 hours on summer solstice and will be dark for full 24 hours on winter solstice of Northern Hemisphere.

Angle of the sun rays: The effect of varying angle at which the sun rays strike the earth can be seen daily by the march of the sun across the sky. At solar noon the intensity of insolation is the greatest but in the morning and evening hours when the sun is at low angle, the amount of insolation is also small.

Fig.

At equator the angle of incidence varieties from 23 ½^o North of the zenith to 23 ½^o South of the zenith. The intensity of solar radiation ranges from 92% on June 21st and December 21st to 100% on March 21st and September 23rd. The range in only 8%.

At 45^{o}N latitude the angle of incidence varieties from 21½^o South of zenith to 68½^o South or only 21½^o above the horizon. The variation in intensity due only to the change in the angle of incidence is from 93% of maximum on June 21st to 38% on December 21st.

Radiation balance

Fig.

19 units are received direct only
23 diffused through clouds.
5 scattered radiation.
47 + 19 unit Earth atmosphere 66 units - Heat atmosphere.

Effective solar radiation

In order to maintain the terrestrial heat balance, the 66 units of solar radiation gained must be balance by the same amount of energy radiated lack to space in the form of long-wave terrestrial radiation (transferred by conductive and connection)

In this way the overall heat budget of the earth is balanced.

Green house effect Artm. Admit entire insolation, retard 0 re-radiation from the earth GHE - similar to glasses covering G. House.

Factors affecting Weather and Climate: (Climatic controls)

8. **Latitude:** The distance from the equator either south or north, largely create variations in the climate. Based on latitude the climate has been classified as (i) Tropical, (ii) Subtropical, (iii) Temperate and (iv) Polar.

   The tropical climate is characterised by high temperature throughout the year. Subtropical is also characterised by high temperature alternating with low temperature in winter. The temperate climate has low temperature throughout the year. The polar climate is noted for its very low temperature throughout the year.

9. **Altitude: Elevation):** The height form the mean sea level creates variation in climate. Even in the tropical regions, the high mountains have temperate climate. The temperature decreases by 1.8^{o}C for every 300 m from the sea level. Generally

there is a decrease in pressure and increase in precipitation and wind velocity. The above factors alter the kind of vegetation, soil types and the crop production.'

10. **Precipitation:** The quantity and distribution of rainfall decides the nature of vegetation and the nature of the cultivated crops. The crop region are classified on the basis of average rainfall which are as follows:

Rainfall (mm)	**Name of the climatic region**
Less than 500	Arid
500-751	Semi Arid
750 - 1000	Sub humid
More than 1000	Humid

11. **Soil Type:** Soil is a product of climatic action on rocks as modified by landscape and vegetation over a long period of time. The colour of the soil surface affects the absorption, storage and re-radiation of heat. White colour reflects while the black absorbs more radiation. Due to differential absorption of heat energy, variations in temperature are created at different places. In black soil areas the climate is hot while in red soil areas it is comparatively cooler due to lesser heat absorption.

12. **Nearness to large water bodies:** (Nearness to sea) The presence of large water bodies like lakes and sea affect the climate of the surrounding areas. Eg., Islands and coastal areas. The movement of air from earth surface and from water bodies to earth modify the climate. The extreme variation in temperature during summer and winter is minimised in coastal areas and Islands.

13. **Topography: (Relief)** The surface of landscape (leveled or uneven surface areas) produces marked changes in the climate. This involves the altitude of the place, steepness of the slope and exposure of the slope to light and wind.

14. **Vegetation:** Kind of vegetation characterise the nature of climate. Thick vegetation is found in tropical regions where temperature and precipitation are high. General types of vegetations present in a region indicates the nature of climate of that region.

Other factors are

vi) Semi permanent high and low pressure systems.
vii) Winds and air masses.
viii) Atmospheric disturbances or storms
ix) Ocean currents
x) Mountain barriers.

Lecture No.4 **TEMPERATURE**

Air-temperature-factors affecting temperature-Diurnal and seasonal variation in air temperature- Isotherm-Heat unit concept-Heat and cold waves-role of temperature in crop production

Temperature refers to the degree of hotness or coldness of a substance or a thing. Temperature provides a measure of the intensity of heat energy.(Scales of temperature and relationship between scales – study practical record).

Daily cycle of Temperature /Diurnal variation

From sun rice until 2-4 pm, when the energy is being supplied by incoming solar radiation is faster than it is being lost by earth by re-radiation, the air temperature rises. From about 2 to 4 pm when the loss of radiation by earth exceeds receipt of solar energy the temperature falls. It is noticeable that the time of highest temperature (2 to4 pm) does not, however, exactly coincide with that of noon solar radiation. This lag occurs because temperature continued to rise as long as the amount of incoming solar radiation exceeds the outgoing earth's radiation. Although the energy receipts being to decline in the afternoon they continue to exceed the energy losses until about 3 pm.

The energy gained during the day is slowly lost to the atmosphere by re-radiation, resulting in the reduction of temperature. Hence, minimum temperature is reached between 2 to 6 am. Diurnal= pertaining to action that are completed within 24 hours and that recur every 24 hours. This variation is knows as diurnal variation. The temperature distribution varies with latitude, altitude and the seasons. It varies diurnally at a given location because of the rotation of the earth.

Vertical distribution of temperature (Altitude)

As a general rule throughout the troposphere, the temperature decreases with elevation. The rate of decrease with altitude is not uniform; it varies with time of the day, season and location. The average decrease is approximately 0.65^{o}C /100m. * 6.5 ^{o}C/km). This is knows as **normal lapse rate or vertical temperature gradient**.

Temperature Inversion

Although normally, the lower several miles of atmosphere show a decrease in temperature with increasing altitude, this condition is reversed at certain levels so that temperature temporarily increases with altitude when the colder air lies below warmer air and closer to earth's surface the normal lapse rate is reversed and this is called **temperature inversion.**

Horizontal distribution of temperature (Latitude)

The lines connecting places which have same air temperature are called **isotherms**. Thus, all the points on a map through which any one isotherm passes have identical average temperature for the period indicated. There is general decrease from equator to poles (increase in latitude).

Seasonal variations

Temperature (Diurnal, mean and range) vary according to the season. The main factors contributing to seasonal variations are:-

1. The angel of inclination of solar rays which decides the intensity of radiation.
2. Distance between earth and sun
3. The movement of seasonal winds which contributes to rain and precipitation.

Effect of Temperature on Plant growth / Crop Productivity

Air temperature is the most important weather parameter which affects the plant life. The growth of higher plants is restricted to a temperature between 0 to 60 ^{o}C and the optimum i.e., 10 ^{o}C to 40 ^{o}C. Beyond these limits, plants are damaged severely and even get killed. The maximum production of dry matter occurs when the temperature ranges from 20 and 30 ^{o}C.

As already seen the temperature of a place is largely determined by latitude and altitude. Based on the above the vegetations are classified as tropical (rain forest, desert, grassland), temperate (Grassland,d eciduous forest),taiga (coniferous forest), tundra (low shrubly growth, lichens) and polar. Some investigators have classified the vegetation of the world into four classes based on the prevailing temperature conditions. The four classes are

1. Megatherms – Equatorial and tropical, tropical rain forests
2. Merotherms – tropicl and sub tropical, tropical deciduous forests
3. Microtherms – temperate and high altitude, alpire vegetation and mixed coniferous forests and
4. Hekistotherms- arctic and alphine regions

High night temperature favours growth of shoots and leaves and it also affects plant metabolism. On the other hand low night temperature injure the plants. Tender leaves and flowers are very sensitive to low temperature and frost.

Temperature is of paramount importance for organic life because of the following factors:-

1. Temperature governs the physical and chemical processes within the plants which in turn control biological reactions that take place within the plants.
2. The diffusion rate of gases and liquids changes with temperatue.
3. Solubility of different substances is depend upon temperatures.
4. The rate of reactions varies with variations in temperature.
5. Equilibrium of various systems and compounds is a function of temperature and
6. Temperature affects the stability of the enzyme system.

Every plant has its own minimum, optimum and maximum temperature limits for its normal growth and reproduction. The vital physiological activities of a plant stop both at below the minimum level and at above the maximum level, whereas physiological activities will be at its maximum at optimum temperature levels. These three levels of temperature are known as cardinal temperature points.

Cardinal temperature for the germination of some important crops (Bierhyizen, 1973)

S.No	Plant	Cardinal temperature ^{o}C		
1	Rice	Minimum	Optimum	Maximum
2	Sorghum	10-12	30-32	36-38
3	Maize	8-10	32-35	40
4	Wheat	8-10	32-35	40-44
5	Barley	3-4.5	25	30-32
6	Sugarbeat	3-4.5	20	38-40
7	Tobacco	4-5	25	28-30
8	Carrot	13-14	28	35
9	Pumpkin	4 –5	8	25
10	Peas	12	32-34	40
11	Oats	4-5	25	28-3
12	Lentils	4-5	30	36
In General				
	Cool season crops	0-15	25-31	31-37
	Hot season crops	15-18	31-37	44-50

Apart from yield reductions, many visible injuries on the plants are seen due to very low or very high temperatrure.

Cold Injury: (Low Air Temperature and Plant Injury)

1. Chilling injury: Plants which are adapted to hot climate, if exposed to low temperature for sometime are found to be killed or severely injured. Some effects of chilling are development of chlorotic condition (Yellowing)
   Example: Chlorotic bands in the leaves of sugarcane, sorghum an maize in winter months when the night temperature is below 20 ^{o}C.

Based on the reaction to chillnes, plants can be divided into five categories.

i. Plants killed by exposure to temperature in the range of 0.5 to 5.0 ^{o}C for 60 hours- rice , cotton, cowpea.
ii. Plants injured by the above condition but recovered after being placed in favourable conditions-Sudan grass, Spanish and Valencia peanut.
iii. Plant not likely to suffer serious injury-Corn, sorghum and pumbkin.
iv. Plants injured by prolonged chillnes- Buck wheat and soybean
v. Plants not injured by prolonged chillness-Sunflower, tomato and Potato.

In temperate climate two types of injures occur because of low temperature. They are delayed growth and sterility.

Example: In Japan , rice yield decreases due to insufficient grain maturation caused by low temperature during the ripening period. Flowering is delayed by low temperatures at a certain stage before heading.

Rice yield decreases due to sterility of spikelets caused by low temperature at the booting stage or at anthesis. The observed injuries may be stoppage of anther development, Pollen unrippeness,Partial or no dehiscence, Pollen grains remaining in anther loculi, Little or no shedding of pollen grains on stigma and Failure of germinatin of pollen on stigma.

2. **Freezing Injury:** Plant parts or entire plant may be killed or damaged beyond repair as a result of actual freezing of tissues. Ice crystals are formed first in the intercellular spaces and then within the cells. Ice, within the cells, causes more injury by mechanical damage on the structure of the protoplasm and plasma membrane.

   Freezing of water in intercellular spaces results in withdrawal of water from the cell sap due to dehydration and causes death of cells.Eg., Frost damage in potato, tea, etc.,.

3. **Suffocation:** In temperate regions, usually during the winter season, the ice or snow forms a thick cover on the soil surface. As a result the entry of O_2 is prevented and plants suffer for want of O_2. Ice coming in contact with the roots prevents the diffusion of CO_2 outside the root zone. This prevents the respiratory activities of roots leading to accumulation of harmful substances.

4. **Heaving:** This is a kind of injury caused by lifting up of the plants alongwith soil from its normal position. This type of injury is common in temperate regions. The presence of ice crystals increases the volume of soil. This causes mechanical lifting of the soil.

Effect of high Temperatures

Cells of most plant species get killed when the temperature ranges from 50 to 60 ^{o}C. This point of temperature is called **Thermal death point**.

But it varies with
1. the species
2. the age of tissue and
3. the time of exposure to high temperature

It is reported that most plant cells are killed at a temperature of 45 to 55 ^{o}C. Some plants tissues withstand a temperature of upto 105 ^{o}C.

The aquatic plants and shade loving plants are killed at comparatively, lower temperature (40 ^{o}C); where as, for xerophytes it is 50 ^{o}C.

High temperature results in desiccation of the plants and disturbs the balance between photosynthesis and respiration. Higher temperature increases the respiration leading to rapid depletion of reserve food in plants resulting in growth stunted due to incipient or starvation.

Heat Injuries:

i. ***Sun clad****:* Injury caused by high temperature on the sides of bark is known as sun clad. This is nothing but exposure of barks of the stems to high temperature during day time and low temperature during night time.

ii. ***Stem girdle:*** It is another injury associated with high temperature. High temperature at the soil surface scorches the stems at ground level. This type of injury is very common in young seedlings of cotton in sandy soil where the after noon soil temperature exceeds 60 ^{o}C to 65 ^{o}C. The stem girdle injury is first noticed through a discoloured band a new millimeter wide. This is followed by shrinkage of the tissues which have been discoloured. The stem girdle causes the death of the plant by destroying the conductive and cambial tissues or by the establishment of pathogens in the injury. As direct effects on crop plants high temperature causes sterility in flowers. The general effects of excessive heat are defoliation, pre-mature dropping of fruits. In extreme cases, death of the plants may also occurs.

Lecture No. 7

Temperature aberrations

Heat Wave: A region is considered to be in the grip of moderate heat wave when it recorded maximum temperature exceeds the normal by 5^o to 8^oC. Heat wave is common in UP (54% Probability) in the month of June. Incidence are maximum in Western UP. Persistence is 5-6 days particularly more in June.

Effect of Heat wave: Already dealt in effect of temperature on crop growth. Thermal death point affects photosynthesis and respiration. Increased respiration depletion of reserve food, sun clad, stem girdle.

Soil Temperature: In many cases soil temperature is more important to plant life than air temperature. It influences the germination of seeds and root activities. It influences the soil-borne diseases like seedling blight, root rot etc. The decomposition of organic matter will be higher in higher soil temperature with necessary moisture. It controls the nutrient availability. In tropics high temperature of soil causes regeneration of potato tubers. It also affects nodulation in legumes.

Gold Waves: A region is said to be in the grip of a moderate cold wave when it recorded minimum temperature falls short of the normal by 6^oC to 8^oC and severe cold wave is prevailed when the minimum temperature short falls upto 8^oC. Generally experienced from Nov. to March.

Severe clod wave generally prevail form Jan. to March common in U.P. Western U.P-1 day, Eastern UP- 2-7 days.

Storm: A marked atmosphere disturbance characterised by a strong wind, usually accompanied by rain, snow, sleet (rain that freezes as it falls-mixture of rain with snow or hail) or hail and often thunder and lighting.

Thunder Storm: A storm invariably produced by a cumulonimbus cloud and always accompanied by thunder; usually attended by strong wind, gusts, heavy rain and sometimes hail. It is usually of short duration, seldom over 2 hour.

- Vertical motion is having many weather modification.
- Upward motion results due to expansion that it gets cooled and eventually condensation.
- Cumulonimbus cloud types are closely related to the strength of the vertical motion.
- A thunder storm is as the name implies a storm accompanied by thunder and therefore lightning. As Benjamin Franklin demonstrated in 1750 lightning discharges giant electrical sprakes.
- Cumulonimbus clouds, therefore are great electrical generators. The cloud produce '+' and '-' value charges by charged poles.
- The lower part of the cloud is negatively charged and upper part is positively charged.

Hail: Precipitation in the form of balls or irregular lumps of lice.

Hail Storm: Small round pieces of ice 9hail) that sometimes fall during thunder storms (frozen rain drops, hail storms).

- Hails may be sometimes greater in size than a large marble.
- It falls from cumulonimbus clouds.
- Hails are destructive to crops - mechanical damage, structures etc.

Hurricane: A violent tropical cyclone with wind speed of 73 or more miles per hour or 134 and more km/h usually accompanied by torrential (very heavy fall) rain, originating usually in West Indian regions.

Tornado: Tornado - Spanish word - Tornas means "to turn".

- The smallest vortex (whirlpool, whirl or powerful eddy of air, whirl wind - a whirling mass of water forming a vacuum at its centre, into which anything caught in the motion are drawn).
- Eddy - current of air, water, etc., moving against the main current and with circular motion.
- But most powerful one.
- The intense rotation is confined normally to a diameter of a kilometer or less.
- But its wind speed can reach even 300 km/h.

Water spouts

- The tornado occassionally forms over water.
- Because of high moisture content of the air, the funnels are heavily laddened with water drops, so, they look somewhat like a stream of water pouring from the base of the cloud. For this reason they are called water spouts.

Dust Devil: A whirl wind that frequently forms on very hot days especially over desert is the dust devil. Normally there are no clouds associated with it.

Cyclone means closed circulation about a low pressure centre which is anti clockwise in the Northern Hemisphere.

- Cyclonic whirls are the "Storms" of middle latitude.
- In the temperate latitude they produce much of the winter precipitation.
- Around the low pressure centres.
- Air circulates anti clockwise direction in Northern Hemisphere.
- The air is heterogenous in relation to temperature and moisture.

Anticyclone: Circulation clockwise in northern hemisphere and anti clockwise in Southern hemisphere.

- This circulation subside whirling @ 10-15 cm/sec. And fair weather generally prevail.
- The air masses are homogenous with respect to temperature and moisture.

Typhoon: Any violent tropical cyclone orginating in the western pacific especially in the south China sea.

Forest: When the dew point is below 0^{o}C moisture passes directly form the gaseous to solid state. This results in the formation of ice crystals, called Frost. Frost ocurs mostly in lower places like vallegs of the mountain where there is no outlet. The cold heavy air drains along the sloping surface with such low places create temperature inversions.

Conditions required for the formation of dew and frost are

a. clear sky b. cool air and sufficient moisture to reach dew point with a moderate amount of cooling.

Dew Point: The temperature to which air has to be cooled in order to reach saturation.

Dew point: The temp. at which dew starts to form or vapour to condense into liquid.

Plant growth: Resultant of all the environmental factors-climatic, physiographic, edaphic and biotic.

For a particular field - it is primarily a function of climate with temperature and light - being the most important factors.

- close relationship exists between plant phenology and both latitude and altitude.

Degree days: At a given location, the period between planting and harvesting is not a specific number of calender days but rather a summation of energy units, which may be represented as degree days.

A degree day for a given crop is defined as a day on which the mean daily temp. is one degree above the zero temp. (that is the minimum temp. for growth) of the plant.

Zero temp. : Spring wheat 32-40^{o}F (depending on variety)
Oat: 43^{o}F; Fiedl Corn: 54-57^{o}F Sweet Corn: 50^{o}F,
Potatoes : 45^{o}F, peas : 40^{o}F cotton 62^{o}F-64^{o}F
(0-5^{o}C) 15-18^{o}C) hot season.

The period required for achieving maturity is also a function of the length of day is photo period. Crop, planted in early in the spring requires more calendar days to mature than the same crop planted later.

Lecture No.8 **SOIL TEMPERATURE**

The surface of the soil is exposed to the direct radiation and air movement. It gains heat during the day time and losses some parts during the night to the atmosphere.

Diurnal variation of soil temperature

- As depth of soil increases –temperature increases upto 20 cm/ remains unchanged beyond 30 cm.
- Surface temperature is doubled in the afternoon compared to morning due to insolation.
- Variation but morning and afternoon temperature beyond 30cm depth is negligible.
- Variations beyond 30 cm is only seasonal changes / variation.

Effect on crop growth

In many instances soil temperatures is of greater importance to plant life than air temperature. For example, beach and oak trees can withstand air temperature of -25 ^{o}C but roots of these trees cannot tolerate even upto 16 ^{o}C. It influences the soil borne disease like seedling blight, root rot etc. and decomposition of organic matter. Input = storage + output causes changes below surfaces. Conductive ofheat to lower layer depends on thermal properties of the soil. Specific heat thermal conductivity , thermal diffusivity of the soil Influences of germination of seeds and root activities.

Greater the soil temperature higher will be the decomposition of OM. It controls the nutrient availability. In the tropics high temperature of soil causes degeneration of potato tubers. It affects nodulation in legumes.

Cardinal Temperature – Temperature of vital activities

	Cool season crops	Hot season crops
Minimum	0-5 ^{o}C	15-18 ^{o}C
Optimum	25-31 ^{o}C	31-37 ^{o}C
Maximum	31-37 ^{o}C	44-50 ^{o}C

Lecture 10

Atmospheric pressure, diurnal and seasonal variation - pressure system of the world - causes for variation - Isobar - low depression, anticyclone, Tornado, hurricane and storms.

Atmospheric pressure : is the weight of the air which lies vertically above an unit area centered at a point. The weight of the air presses down the earth with the pressure of 1.034 g/cm^2. The weight of air mass is over 56 trillion tons. (56 x 10^{14} ton) (56 x 10^{14} tons)

Slight variation at earth's surface in pressure as a climatic element does not seem to make a great difference to life forms. Small pressure changes are imperceptible to human beings. But they induce remarkable variation in general weather condition. Pressure mainly affects temperature and precipitation.

Types of pressure systems of the world

Pressure system differ greatly in both size and duration. Pressure System are of 2 types

i. High
ii. Low pressure system

Centres of low pressure are called as depression, cyclones of lows. Prolonged low pressure, centres are called troughs. The equitorial belt of low pressure is called doldrums (5^{o}N & 5^{o}S of Equator). It is because

i) Sun falling vertically all round the year
ii) Water vaporisation being high
iii) Rising of air

The doldrums belt is spread over Amazon, Congo, Passion and Guniea belt etc.,

The centres of high pressure are called anticyclones or highs. An elongated high pressure is called as ridge. Near 30^{o}N and 30^{o}S the pressure is called as ridge. Near 30^{o}N and 30^{o}S the pressure is always high because i) intensive hot air from the equator descends down in this belt and ii) polar air from the sub-polar belts also descents here.

Figure

Factors controlling pressure: Pressure never remains constant - changes with temp., altitude water vapour content and rotations of the earth.

i) **Temperature:** Hot air expands and exerts low pressure. Cold air contracts and exerts high pressure the equator has a low pressure due to prevalence of high temperature but poles have a high pressure.

ii) **Altitude:** At sea level, the air column exerts its full pressure, but when we go up, we leave a portion of the air which cannot exert pressure. At sea level high pressure and at high altitude low pressure. For every 1000' of altitude, the pressure gots reduced by 1" mecury column.

iii) **Water vapour:** Moist air of high temperature exerts less pressure. When compared to moist air of low temperature. Because water vapour content is lighter in cold area than air which is dry.

iv) **Rotation of the earth:** Due to rotation of earth the pressure at 60-65^{o}N and S becomes low. The air to escape from these belts which more towards the horse latitude (30-35^{o}N&S) These belts absorb air from the sub-polar belts making the pressure high.

v) **Seasonal variation:** Pressure system changes according to the season. Season changes according to the position of the sun. When the sun moves to the tropic of cancer, pressure belts move to the North by 5^{o} away from their normal. When sun moves to tropic of Capricorn, the pressure belt also move south and shift by 5^{o} away from their original position. This is known as **"Swing of pressure belts"**.

Sea breeze and land breeze due to seasons

During summer horse latitudes receive the direct sun rays and an area of low pressure increases over the continent masses and they enlarge a small high pressure centre over the continents. But surrounding seas have a vast high pressure area . in summer the wind blows from sea (high pressure) towards the lands. (Low pressure)

In winter season, a major area of high pressure covern the land masses. The sea areas are comparatively at low pressure. So winds stant moving form the land towards the sea.

Diurnal variations

To find out the mean daily change in air pressure, the average of hourly observed pressure for a long period of time is calculated. The mean value of the daily pressure is free from the temporary effect of atmospheric disturbances. There is a definite rhythm in the rise and fall of mercury. Insolational heating and radiational cooling are the principal reasons for diurnal variations of air pressure. In other words, pressure changes are mainly due to the expansion and contraction of the air.

Seasonal or annual variation

This is clearly the effect of annual variation in the amount of insolation received in a particular region. Annual pressure variation in the tropical region in larger than other region of the world. The equatorial regions record the smallest amount of variation in their seasonal pressures, because there is practically no variation in the amount of insolation received at the equator throughout the year

High pressure - cold season

Low pressure - warm season rot of 1 sq. in column of air from sea level to top of the atmosphere weights nearly 15lb. This rot is balanced by column of mercury 29.92 inches or 760 mm tall having the same cross sectional area. This is the pressure at sea level at latitude 45^o. Another unit of measurement millibar - widely adopted by national weather service of the world millibar = 1000 dynes / cm2. Ayne is a unit of free approximately equal to the rot of a milligram. Sea level pressure under this system is 1013.2m bars (mb). One tenth of an inch of mercury is approximately equal to 3.4 mb.

Isobars: These are lines connecting places having the same atmospheric pressure at a given elevation. Pressure distributive charts are constructed for sea level and for no. of constant pressure surfaces in the atmosphere.

700 ml - at 10,000
500 ml - at 18,000

In sea level pressure chart all pressures at different elevation are reduced to pressure receiving to sea level.

Pressure gradient: Isobars - rapid change in pressure in a direction at right angles to the isobar's. The rate of change in atmospheric pressure between 2 points at the same elevation is called the pressure gradient or isobaric slope it is proportional difference in pressure horizontal movement air.

Lecture No. 11

Relationship of wind and pressure

- Earth rotates from west to east along with atmosphere. Atmosphere is fixed to earth by gravitational equilibrium.
- Wind therefore moves in addition to rotation.
- Horizontal motion is greater than vertical motion.
- Wind takes several days to cross the ocean but up and down movement is only in few minutes.
- The vertical component of movement is much greater in small scale circulation's such as thunder storms and tornadoes. In thunderstorms, air may extent to the top of troposphere (6 miles) in half to one hour.

Factors affecting Wind movement:

i) Barometric slope : the wind blows towards the direction the barometric slope i.e., from high pressure to low pressure.

ii) The isobaric gradient - determines the steepness and gentlensess of the wind.

iii) Rotation of earth causes the wind to be deflected towards right of tis path in the northern hemisphere, but causes the wind to deflected to left in southern hemisphere.

Lecture No. 12

Atmospheric Humidity

Moisture present in the atmosphere plays a significant role in weather and climate of a region. There are three major components in the atmospheric moisture.

i. Humidity
ii. Precipitation
iii. Evaporation

Hmidity: The terminology related to humidity and concerned with gaseous form of water i.e., water Vapour, several expression of the amount of water vapour in the air are used.

(i) ***Absolute humidity:*** It denotes the actual mass of water vapour in given volume of air. It may be expressed as the number of grams of water vapour in a cubic meter of moist air or mass of water vapour per unit volume of air.

(ii) ***Sepcific humidity:*** It is defined as the moisture content of moist air as determined by the ratio of the mass of water vapour to the mass of moist air in which the mass of water vapour is contained.

(iii) ***Relative humidity:*** Relative humidity is a common parameter for expressing water vapour content of the air. It is the percentage of water vapur present in the air in comparison with saturated condition at a given temperature and pressure. The R.H. can be expressed as

$$RH = \frac{100r}{rw}$$

Where "r" is the mixing ration of moist air at pressure (p) and temperature and "rw" is the saturation mixing ratio at same temperature and pressure.

(iv) ***Mixing ratio:*** The mass of water vapour per unit mass of dry air is a convenient parameter to express the relative composition of the mixture. It is defined as the ratio of the mass of water vapour to the mass of dry air with which the water vapour is associated.

(v) ***Dewpoint:*** The temperature at which saturation occurs in a given mass of air. The dewpoint temperature is often compared with the temperature of free air and also used to predict the occurrence of fog, dew, frost or precipitation.

(vi) ***Vapour pressure:*** This is the amount of partial pressure created by water vapour in the air expressed in the units of millibar (or) inches of mercury.

Effect of RH on Plant Growth

Increase in RH - decreases the temp. This phenomenon increases heat load of the leaves. Since transpiration is reduced - not much heat energy used. Excessive heat due to closure of stomta entry of Co_2 is reduced. Reduction in transpiration reduces the rate of food translocation and uptake of nutrients.

Very high RH is beneficial to - Maize, Sorghum, Sugarcane (C^4 Plants)

Harmful to - Sunflower, Tobacco.

Affect water requirement of crops:

For almost all the crops it is always safe to have a moderate R.H. of above 40%. 60-80% conducive for growth and development of plants.

LECTURE No. 13

Clouds

Clouds has been defined as a visible aggregation of minute water droplets and / or ice particles in the air, usually above the general ground level.

Classification of clouds

Though confusion apparently arise from the number of kinds or species, the genera seems reasonably clear -but, if we are able to recognize their main characteristics.

Clouds are usually classified according to their height and appearance. For convenience we list them in descending order. High clouds, middle clouds and low clouds. Since for one do not fit in any of these categories. But fortunately their particular characterists make them easily, identifiable as vertical development clouds. Genera with common distinguishing characteristics main sum division of a family. We must exercise some caution in relying on height data. There is some seasonal as well as latitudinal variation and there is some overlapping form time to time. However, the appearance of clouds are quite distinctive for each height category.

The main cloud genera are defined and described in the International cloud atlas of the WMO genera 1957. That can be listed according to their heights as under.

A. High (mean heights 5 to 13 km) (Mean lower level 20000 ft)
   Clouds
   - i) Cirrus (ci)
   - ii) Cirrocumulus (cc)
   - iii) Cirrostratus(cs)

B. Middle (Mean heigths 2 to 7 km) (6500 to 20000')
   Clouds
   - i) Altostratus (As)
   - ii) Altocumulus (Ac)

C. Low (mean heights o to 2 km) (Close to earth's surface to 6500')
   Clouds
   - i) Nimbostratus (Ns)
   - ii) Stratocumuls (Sc)
   - iii) Stratus (St)
   - iv) Cumulus (Cu)
   - v) Cumulonimbus(Cn)

Clouds with vertical development

1. **Cirrus:** Detached clouds in the form of white, delicate filaments or white or mostly white patches or narrow bands. Those clouds have a fibrous (hair like) appearance or a delicate silky appearance or both. All the cirrus or cirro-type clouds are composed of ice crystals. Cirrus clouds have brillient colurs of sunset and sunrise. These clouds do not give precipitation.

2. **Cirro-Stratus:** "Transparent, whitish cloud veil of fibrous (hair like) or smooth appearance, totally or partly covering the sky and generally; producing halo phenomena". This type of cloud is so thin that it gives the sky a milky appearance.

3. **Cirro-cumulus:** Thin, white flakes, sheet or layer of cloud without shading. Composed of very small elements in the form of grains, ripples etc. This type of cloud is not common and is often connected with cirrus or cirrostratus. When arranged uniformly, it forms a "Mackerel sky". Macrel - Fish in has Greenish blue stripped back and silvery white belly.

4. **Alto-Stratus:** A uniform sheet cloud of " Grayish or bluish cloud frequently showing a fibrous appearance, totally or partly covering the sky, and having parts thin enough to reveal the sun at least wavely as through ground glass. Alto-stratus does not show halo phenomena. This type of clouds may cover all or large portions of the sky. Precipitation may fall either as fine drizzle or snow.

5. **Alto-Cumulus:** "White or grey, or both white and grey, patch, sheet or layer of cloud. They have develt shedding on their under-surfaces. Sometimes referred to as "Sheep clouds" or "Woolpack clouds".

6. **Nimbo-Stratus:** "Grey cloud layer, often dark, the appearance of which is rendered diffuse by more or less continuously falling rain or snow. Which in most cases reaches the ground. It is thick enough throughout to blot out the sun. It is a rain, snow or sleet cloud. It is never accompanied by lightening, thunder or hail. Streaks of water (rain) or snow falling from these clouds but not reaching the ground are called "Virga". Wisps or streaks of water or ice particles falling from base of a cloud but evaporating completely before reaching the ground. Wisps = bundle as of straw.

7. **Strato-Cumulus:** "Grey or whitish or both grey and whitish patch, sheet or layer of cloud which almost always has dark parts, composed of tessellation's, rounded masses, rolls, etc.

8. **Stratus:** Generally grey cloud layer with a fairly uniform base, which may give drizzle, ice prisms or snow grains, sky may be completely covered by this type of cloud. Sum is visible through this cloud.

9. **Cumulus:** "Detached clouds, generally dense and with sharp outlines, develop vertically in the form of rising mounds, domes or towers, of which the bulging upper

parts often resembles a cauliflower. Cumulus is generally found in the day time over land areas. They dissipate at night. They produce only light precipitation.

10. **Cumulonimubs:** "Heavy and dense cloud, with a considerable vertical extent, in the form of a mountain or huge towers. This type of cloud is associated with heavy rainfall, thunder, lightening, hail or tornadoes. This type of cloud is easily recognised by the fall of a real shower and sudden darkening of the sky.

Cloud formation: Air contains moisture - this is extremely important to the formation of clouds.

- Cloud are formed around microscopic particles such as dust, smoke, salt crystals & other materials that are present in the atmosphere.
- These materials are called "Cloud condensation Nucleus" (CCN)
- Without these no cloud formation will take place.
- Certain special types known as "ice nucleus" on which cloud droplets freeze or ice crystals form directly for water vapour.
- Generally condensation nuclei are present in plenty in air.
- But there is scarcity for special ice forming nuclei.
- Generally clouds are made up of billions of these tiny water droplets or ice crystals or combination of both.

There are two rain forming process viz.,

$$\left.\begin{array}{l}\text{1. Warm}\\ \text{2. Cold}\end{array}\right\}\text{Rain process}$$

Warm rains: It refers rainfall process in the tropics.

- Rain occur when the temp is above $0^{o}C$ never colder than $0^{o}c$.
- When larger droplets collide and absorb smaller cloud droplets.
- They grow larger and larger & become raindrops.
- This process is known as "Coalescence cold rain process.
- Occurs when the cloud temperature is colder than $0^{o}C$.
- Clouds are usually with ice crystals and liquid water droplets.
- These crystals grow rapidly drawing moisture from the surrounding cloud droplets until their weight - causes them to fall.
- Falling ice crystals may melt and join with smaller liquid cloud droplets.
- Resulting in rain drops if ice crystals do not melt, they may grow into large snow flakes and reach the ground as snow.

Conditions favourable for the occurrence of precipitation

i) The cloud dimension (vertical -7 km horizontal 60-70 km)
ii) The life time of the cloud (atleast 2-3 hrs.)
iii) The size and concentration of cloud droplets & ice particles.
iv) RH should be 75%
v) Wind velocity 20 km.

vi) Cloud seeding

Cloud Seeding: It is the process by which the conditions of the cloud, (dimension, life time and size) are modified by supplying them with suitable nucleius at proper time and place. For accelerating the warm rain process seeding with very large nuclei such as salt crystals can be used. In the case of cold rain process, seeding with ice nucli such as silver iodide are used to make good the deficiency in the clouds.

Evaporation: The change of state of water from solid and liquid to the vapour and its diffusion into the atmosphere is referred to as evaporation. In Agricultural Meteorology Evaporation is defined as the maximum possible loss of moisture form a wet, horizontal, flat surface exposed to weather parameters which exist in the visinity of plants.

Factors affecting Evaporation

1. Those affecting water supply at the evaporating surface. I.e., soil and plants including soil storage capacity, rainfall and irrigation and
2. Those affecting energy supply to the evaporating surface like solar radiation.

Transpiration: Most of the water absorbed by plants is lost to the atmosphere. This loss of water from living plants is called transpiration. It can be stomatal, cuticular or lenticular.

Factors affecting Transpiration: Light, Humidity, Temperature, Wind, Root/shoot ratio, Humilability of water to plants, Leaf characteristics.

Evapotranspiration (ET): As noted earlier, it is a combined losses of water through evaporation from the soil and transpiration from the plants.

Potential Evapotranspiration (PET): is defined as the amount of water which will be lost from an extensive water surface or soil completely covered with vegetation where there is abundant moisture in the soil at all times.

Evapotranspiration is also called water use (WV) or consumptive use (CU). The factors influencing ET are climate and management practices.

Evaporation:

- One of the four components of the endless hydrological cycle (Evaporation-Transpiration-Condensation-Precipitation).
- Most of the water vapour comes form ocean.
- It is also important in agriculutre as it affects.
- Soil Conditions.
- Plant growth - crops.
- Water storage - dams.

Evaporation depends upon:

- temperature of the water surface
- vapour pressure of the air

The pressure exerted by the water vapour in the air is known as "vapour pressure". Evaporation is more when there in greater pressure difference between vapour pressure and saturation vapour pressure.

- Wind movement (Removes moisture) - Evaporation increases with wind velocity.
- Salinity - presence of dissolved minerals salts reduce Evaporation from sea is 5% less than pure water.

Factors which affect ET from Plant & Soils are:

i) Those affecting water supply i.e.,

- Soil storage capacity.
- Rainfall.
- Irrigation.

ii) Those affecting energy supply

1. Light: Stomata open is light and close in the dark.
2. Temperature: Humidity / vapour pressure function of temperature.
3. Relative Humidity: Less humidity higher temperature. Increases difference - incurred. Decrease temperature increase vapour pressure - reducing the saturation deficit. Therefore higher temperature - increase in Temperature.
4. Wind: Saturated unit is replaced by dry air around the plant - increased temperature cooling effect on leaves vapour pressure different decreases.
5. Plant characters:
    a) Root/shoot - ratio
    b) Leaf characteristics
    c) More AI- Transpiration high
    d) Thick cuticle - epidermal hair - less transpiration.

When R/S ratio is more or equal then Transpiration will be more.

PE - Evaporation form a free water surface.

AE - Actual Evaporation.

AE is always less than PE

Condensation: The physical process by which a vapour becomes a liquid or solid - opposited of evaporation.

Precipitation: Precipitation has been defined as water in liquid or solid forms falling to the earth. Precipitation occurs in a variety of forms such as rainfall, snow, hail, gog and dew. Fog, dew and front are condensation forms and are not considered to be precipitation. Common precipitation forms are Rain, Drizzle, Snow, Hail and sleet etc., are the common forms of precipitation.

Precipitated moisture falling on the ground takes various forms which depend on the following conditions.

a. The temperature at which condensation takes place.
b. The conditions encountered as the particles pass through the air.
c. The type of clouds and their heights from the ground.

d. The processes generating precipitation. All forms of precipitation regardless of appearance are collectively termed "hydrometers".

Rain: It is "Precipitation of liquid water particles, either in the form of drops of more than 0.8 mm diameter or in the form of smaller widely scattered drops.

Sleet: Transparent, globular, solid grains of ice freezing of rain drops.

Hail: Precipitation in the form of halls or irregular lumps of ice.

Drizzle: It is "fairly uniform precipitation composed exclusively of fine drops of water (diameter less than 0.8 mm) very close to one another". In some places drizzles is called mist. According to Donn, if the droplets in a drizzle completely evaporate before reaching the ground, the conditions is referred to as mist. However, in the International codes for weather reports, the term 'mist' is used when the hydrometer - mist or fog- reduces the horizontal visibility at the earth's surface do not less than one km.

Snow: It is "precipitation of white and opaque grains of ice. "In winter, when temperature are below freezing in the whole atmosphere, the ice crystals falling from the alto-stratus" do not melt and reach the ground as snow. Heaviest snowfall is reported to occur when the temperature of air form which snow is falling is not much below 0^oC. Because under such a condition the moisture content is fairly high.

A snow cover is a poor conductor of heat and koops the soil temperature higher. It prevents soil freezing and thus protects the roots of the plants. Snow accumulated during winter on the mountains and melts in summer which supplies water for maintaining flow in the rivers.

Sleet: In English-speeking countries outside the united states, sleet refers to precipitation in the form of a mixture of rain and snow. But in American terminology, sleet means a form of precipitation consisting of small pellets of transparent or translucent ice, 5 mm or less in diameter is called as 'Frozen rain'.

Hail: It is "Precipitation of small balls or pieces of ice (hailstorms) with a diameter ranging from 5 to 50 mm or sometimes more, falling either separately or agglomerated into irregular humps. It is always produced by convective clouds, usually cumulonimbus.

Condensation (Dew, Frost, Fog)

Dew is a common form of condensation in the environment.

- Dew forms on the ground and on solid objects before condensation occurs in the air.
- Because the ground cools rapidly than the air.
- Same way.

Air curing in contact with cold surface may be cooled before its dew point and gets condensed and deposited.

Dew pint: Temperature to which air must be coded at constant pressure and moisture content for saturation to occur.

Dew forms on automobiles and other metal objects first. Metals cools rapidly than soil (or) vegetation.

- Dew can form at any temperature above freezing point in tropics, often it forms at as high temperature at 21^{o}C.

2. Frost

Frost is a form of condensation that occur on solid surfaces when the dew point is below freezing point. (0^{o}C).

- Water vapour sublimates as a solid on solid (passing directly from a gas to solid).
- Frost can form at a point below freezing point.
- Occationally, vegetation is damaged.
- Frost occurs mostly in low places like valleys of the mountains where there is not outlet.

Conditions required for the formation of dew & frost are

a. Clear sky b. Cool air and sufficient moisture to reach the dew point with a moderate amount of cooling.

3. Fog: is condensed water droplets suspended in air in the lower atmosphere (surface of the earth)

(Condensed water droplets around nucli is called cloud)

- Fog reduce the horizontal visibility.
- They frequently occur in super cold. Liquid at temperature much below the freezing.
- Accumulation of dust or smoke fog in air are called dust fogs or smoke fogs.
- Thick fogs are more frequent in smoke cities.
- The bled of smoke and fog is called "smog".

Hydrologic cycle:

- in book Agroforesty

Hydrologic cycle involves four major steps viz., Evaporation, Transpiration, condensation and Precipitation. Though the cycle has neither a beginning nor and end, the concept of cycle begins with the water of the oceans, since it covers nearly ¾ of the earth's surface. Radiation for the sun evaporates the water as water vapor from the oceans into the atmosphere. The water vapour rises and collects to form clouds. Under certain conditions, the cloud moisture condenses and falls back to the earth as rain, snow, hail etc., precipitation reaching the earth's surface may be intercepted by vegetation, o enter into the soil, may flow as run off or may evaporate. Evaporation may be from the surface of the ground or from free water surface. Transpiration may be from plants.

Figure:

Types of Precipitation: There are three types of precipitation.

1. Convectional precipitation - due to convection in the form of truning of moist air. Heavy and showery precipitation is most likely, Rain, Snow showers, hail and snow pellets.
2. Orographic Precipitation.
3. Fronts from as the result of confluent motion between contrasting air masses.

Orographic: Precipitation resulting from raising and cooling of air masses when they are blocked by a topographic barriers (mountains). Barrier is an important factor in increasing the rainfall on winward slopes. Highest annual Rain fall - where the mountain barriers lie across the paths of moisture bearing winds. (Chirrapunji) - Indirect effect - force moist air upward, they hinder the passage of low pressure areas and also promote convection (due to differential heating along the slopes.)

According to type of low pressure systems and its stage of development.

Precipitation characteristics

a. Rainfall intensity
b. Aerial extent of rainstorm
c. Frequency of rainstorms

Monsoons of India

Monsoon represents one of the phenomena in the category of secondary circulation of the atmosphere. The term monsoon is derived from an Arabic word 'Mausim' or from Malayan word 'monsin' which means 'season'. The word monsoon is applied to such a circulation which reverses its direction every six months i.e. from summer to winter and vice-versa.

Economic Importance of Monsoon

The economic significance of monsoon is enormous, because a population of more than 2000 million lives, i.e, roughly about half the world's population (54 per cent), depends on the monsoon rains for their crops. Moreover, a large percentage of total population in the monsoon region derives its income from agriculture. In India monsoon means life-giving rains. Rice is their major crop which provides food for millions of people, hence monsoon rains are so essential for its growth. Failure of monsoon rains cause loss of food crops. Erratic behaviour of monsoon cause disastrous floods in some parts of the country while in other parts there is severe drought.

During the hot, dry season (April-May) when temperatures rise rapidly and pressures over land decrease, the warm and moist air form over the adjacent seas starts blowing, towards the above-mentioned low pressure centre. However, in the beginning the maritime air masses are drawn only from a short distance. But by the end of May or the first week of June, when the low pressure centre has fully developed, the pressure -gradient is steepned so that even the trade winds from southern hemisphere are drawn towards the thermal low poisitioned in north-western region of the sub-continent. The sooutherly trades on crossing the equator are deflected to their right in accordance with Ferrel's Law. Now, the originally south-east trade winds become south-westerly blowing towards north-east.

South-westerly on-shore winds blowing towards the centre of low pressure over northern India traverse thousand of miles over the warm tropical ocean. They are, therefore, full of moisture and have a great potential for heavy precipitation. The south-west monsoon, as it is called in this region, is split into two branches by the shape of Peninsular India. They are known as :-

a. the Arabian Sea branch, and b. the Bay of Bengal branch.

Arabian Sea branch

The arabian sea branch strikes the elevated Western Ghats of India at almost right angles. The windward slopes of Western Ghats receive heavy orographic precipitation. However, the westerly current from the Arabian Sea continues its journey across the Indian Peninsula, but the amount of rainfall on the leeward side goes on diminishign with increasing distance from the sea cost. The Western Ghats have 100-250 cm of rainfall on their windward slopes, while there is a well-marked rain-shadow to the leeward. Towards the north, where Western Ghats are not very high, the difference in the amount of rainfall between the windward and leeward side is rather negligible. Some of the air currents from the Arabian Sea branch manage to proceed towards Chhota Nagpure Plateau through the Narbada and Tapit gaps. These air currents ultimately unite with the Bay of Bengal Branch.

Bay of Bengal branch

One current of the Bay of Bengal branch, which is more southerly, moves towards Assam where Mausinram (near Cherapunji), situated on the southern slope of Khasi hills, has the unique distinction of recording the highest annual average precipitation (965 cm) in the world. This is because of its peculiar geographical location. A current of the Bay of Bengal branch recurves westward and advances upto the Gangetic plain towards the Punjab. It may be mentioned that the westward movement of monsoon current takes place around the eastern end of a trough of low pressure developed over northern India. The movemetn of winds is, of course, parallel to the Himalayan Ranges. The rainfall occuring in the Gangetic Plain is partly controlled by the relief, and partly by the cyclonic storms or monsoon depressions which followed the track of low relief and low pressure along southern fringe of the plains. It is to be noted that in this region the monsoon current blows from a southeasterly direction. The rainfall decreases from east to west and from north to south. The main reason why the amount of rainfall decreases westwards is the increasing distance from the source of moisture. The southward decrease in rainfall is due to the increasing distance form the Himalayas which cause the forced ascent of rain-bearing air currents.

Winter Monsoon

A secondary high pressure system develops over Kashmir and the Punjab. The high pressure area controls the prevailing wind direction over the rest of the subcontinent. Contrary to the pressure condition over land, there are low pressure centres formed over the India Ocean, the Arabian Sea, and northern part of Australia. In the cool season, therefore, there is pressure gradient from land to sea as a result of which winds begin to move from land to sea. These are the northeast or winter monsoons of northern hemisphere.

The southern part of Indian Peninsula receives rainfall from north east monsoon currents. These currents while travelling over the Bay of Bengal pick up moisture from warm ocean surface. The amount of winter rainfall on the eastern side of the peninsula is much heavier than that on the other side. It is also known as retreating monsoon.

Flood: High degree of runoff is known as flood. Runoff is that portion of precipitation that returns to the oceans and other water bodies over the land surface or through the soil and water table. May be direct return of rainfall or the flow form melted snow and ice fields - which have temporarily stored water.

Flood differs from simple runoff only in degree. Distinction between the two depends upon how they affect surface features. River floods result whenever the channel capacity is exceeded by the runoff due to excessive runoff of rainfall or snow melt. But, the channel capacity may also be affected by barriers to flow, sudden change of direction of stream, red need gradient, siltation of the stream bed, or sudden releave of water due to broken dam.

Factors affecting run off

1. The amount and intensity of precipitation
2. Temperature
3. Characters of the soil
4. Vegetative cover of the area
5. Slope of the land.

When rain occurs the proportion of runoff will depend on capacity of the soil and vegetation to absorb. Plants retain some rainfall on their external structures and slow the velocity of rain drops. They also detain water in its horizontal movement. Plants improve soil structure and their roots provide channels to move water to greater depths. The high humus content of soils with dense grass cover enhances absorption, for it acts something like a sponge porous soils absorb more water by infiltration than dense clays. Impervious sub-soil redness the amount of water that can be stored.

Climatic causes of flood

The predisposition of a climate to storms producing excessive precipitation is the fundamental basis of the flood. In some climates flood-producing storms occur irregularly; in others they follow a seasonal pattern.

Two types storms causing flood are

a. Violent thunder showers which is of short duration and produces a flash flood.
b. Prolonged wide spread rain which through sheer quantity of water, creates extensive flooding over entire water sheds.

Damages due to flood

1. Loss of human life

2. Loss of field crops - may vary according to the duration and intensity of flooding.
3. Loss of cattle wealth.
4. Loss of soil.
5. Loss of properties.

Not all floods are "bad" for centuries agricultural areas in the lower - Nile flood plain and Mesopotamia depended on annual river flooding and the accompanying deposits of fertile silt. What is gained in this way in the lowlands must be lost at higher levels in the watershed.

Management of Flood

1. Conserve water in the soil where it falls by increasing porosity of the soil and growing vegetations i.e., reduce runoff.
2. Increase the capacity of channels (rivers) to carry excess water direct to the ocean or to the water bodies for storage.
3. Avoid silting of water courses by conserving soil by adopting sol conservation techniques such as by vegetative barriers, counter bunding, contour cultivation allowing grassy water ways etc.,

Management of crops affected by flood

Too much of water may be just as harmful to plants as too little. The most injurious aspects of flooding or too much of water are lack of aeration and reduction in oxygen supply. In wet soil nitrification suffers which causes yellowing and stickly appearance of plants.

Management practices

1. Drain away excess water as early as possible.
2. Give a foliar spraying of nutrients especially nitrogen for immediate relief. (Rice: 1.0% urea + 0.5% Zn So_4).
3. Spray fungicides to protect the crop from fungal diseases which are common under high moisture condition.

Weather aberrations and their effect on Agriculture

Dry spells: The interval between the end of a seven day wet spell, beginning with the onset of effective monsoon and another rainy day with 5 e mm of rain (Where"e" is the average daily evaporation) or the commencement of another seven day rainy spell with four of these as rainy days (Satisfying the third criterion) and with a total rain of 5 e mm or more during this spell is called the first dry spell. If the duration of this dry spell exceeded certain value, depending on the crop-soil complex of the region, this dry spell was called a critical dry spell.

Criteria for forecasting rainfall characteristics (like onset of effective monsoon)
(Ashok Raj, 1979.)

1. The first days rain in the 7-day spell signifying the onset of effective monsoon, should not be less than "e' mm where "e" mm was the average daily evaporation.
2. The total rain during the 7-day spell should not be less than 5 e + 10 mm.
3. Atleast four of these seven days should have rainfall, with not less than 2.5 mm of rain on each day.

Wet spell

A wet spell is defined as a rainy day with "X" mm of rainfall or a 7 day spell where the total amount of rainfall equals "x" mm or more and the condition that three out of these seven days must be rainy with rainfall more than 2.5 mm on each day. In this "x" is the amount of rainfall which brings the top 50 cm soil layer to field capacity. The water holding capacity varies with the type of soil as also the value of "x'.

For example, the value fo "x" is equal to

83 mm for light soils
125 mm for medium soils and
166 mm for heavy soils of Punjab

Critical Dry Spell (CDS)

CDS is defined as the duration between the end of a wet spell and the start of another wet spell during which a 50% depletion of available moisture occurs in the top 50 cm soil layer.

It is calculated by

$$CDS = \frac{AMD}{ET}$$

Where CDS in day

AMD = 50% of the available soil moisture in the top 50 cm soil layer, expressed in terms of depth (mm)

ET = Average maximum daily ET of a crop (mm/day)

Drought

Drought has varied meanings for different people.

In general drought may be defined as a complex phenomenon which results from the prolonged absence of precipitation in conjunction with high rate of evaporation. This causes abnormal loss of water form water bodies, lowering of the water table and dehydration of the root zone of the soil, thus upsetting water supply to plants.

Classification of Drought

Drought can be broadly divided into three categories.

1. Meteorological drought: is a situation when the actual rainfall is significantly lower than the climatologically expected rainfall over a wide area.
2. Hydrological drought is associated with marked depletion of surface water and consequent drying up of lakes, rivers, reservoirs etc. Hydrological drought occurs when meteorological drought is prolonged.

3. Agricultural drought is a condition in which there is no rainfall and insufficient soil moisture availability in soil to the crop.
4. Atmospheric drought - It occurs when the rate of transpiration exceeds rate of absorption of water due to low RH, high temperature and moderate to high wind velocity even through available soil moisture is high in the soil. The drought is temporary and reversible.
5. Soil drought - Condition when the soil moisture supply exceeds - 15 hours (Permanent wilting point). It is gradual and progressive. It is highly detrimental than others.
6. Physiological drought- even though the available soil moisture is high in the soil, the plants are not able to absorb due to 1. …… and 2. Low soil temp.

Drought: Under normal condition excessive moisture is far less a problem than drought. Thornthwaite defines drought as "a condition in which the amount of water needed for transpiration and direct evaporation exceeds the amount of moisture available in the soil".

1. Permanent drought - arid climate
2. Seasonal drought - climate with annual periods of dry weather
3. Drought due to precipitation variability.
   a. Moderate drought - lower quality or yield
   b. Severe drought - failure of crop.

Aberrations in rainfall: Aberration means the deviation from the normal behaviour of the rainfall. As we all know the principal source of water for dry land crops is rain, a major portion of which is received during the monsoon period. Bursts of rain alternated with "Breaks" are not un common. There are atleast four important aberration in the rainfall behaviour.

1. The commencement of rains may be quite early or considerably delayed.
2. There may be prolonged breaks during the cropping season (Intermittent drought).
3. The rains may terminate considerably early (early cessation of rain) or continue for longer periods.
4. There may be spatial and or temporal aberrations.

1. **Early or delayed onset of monsoon:** To quantity the aberrations in the onset of monsoon, 50 years of data to be analysed for the dates onset of monsoon has to be studied for different regions of the country. (For example, it was seen that the normal date of onset of monsoon in the Madhya Pradesh and Maharashtra region is 10th June. In 8% of the years onset of monsoon can occur during last week of May (May 28th in 1925) and in 10% of the years it is as much delayed as beyond 21st June) The aberrations require changes in crops and varieties with the normal onset of NEM in September, October - Crops like Sorghum, Bajra, Pulses and Oil seeds can be grown in Kovilpatti tract of Tamil Nadu. If monsoon is delayed upto late October, Bajra, pulses, sunflower etc., can be raised. If it is very much delayed upto first week of November only sunflower can be sown.

2. **Breaks in the monsoon rains (Intermittant drought):** The breaks can be of different durations. Breaks of shorter duration (5-7 days) may not be a serous concern, but breaks of longer duration of 2-3 weeks or even more, lead to plant -water stress causing reduction in production. These breaks intermittant droughts, can be different magnitude and severity and effect different crops in varying degrees. The yield of many drought resistant crops are not seriously affected, but in several sensitive crops the yield reduction was heavy.

   Another aspect of the breaks or intermittant drought is the stage of the crop at which the drought occur. The effect on crop will be different at different stages.

   Another important factor is the effect of breaks or intermittant drought depends on the physical properties of the soil particularly its water holding capacity. Deep black soils have capacity to store as much as 300 mm of available soil moisture in one meter depth, whereas light soils like desert soils can store only as little as 100 mm or so. Hence drought is more pronounced in the soils having less storage capacity.

3. **Early withdrawal of monsoon:** For example, the normal withdrawal of W=SWM in Rayalaseema region will be between 25th Sept. and Oct. 15th . But is 4% of the years out of 55 years monsoon can withdraw during first fortnight of September and in 10% of the years it withdraws during the month of December.

   Since, crops and varieties in any given region are selected based on the normal length of growing season. Persistence of rains much beyond normal dates creats an extraordinary situation.

   Under Kovilpatti (TN) condition short duration bajra and sunflower will be suitable under early withdrawal of monsoon.

   Cultural practices to mitigate the effect of moisture stress due to intermittant drought and early withdrawal of monsoon are

   1. Shallow interculture to eradicate weeds
   2. Maintain soil mulch to conserve soil moisture
   3. Application of surface mulch
   4. Thinning of crops by removing alternated rows as in sorghum and bajra.
   5. Recycling of stored run off water.
   6. Ratooning in crops like sorghum and bajra.
   7. For indeterminate crops like castor and redgram give 2-3% Urea spray after a rain.

4. **Uneven distribution of monsoon rains, in space and time over different parts of the country:**

   Such as situations are encountered almost every year in one or another part of the country during monsoon period leading to periodical drought and flood situations.

   High variability of rainfall (or more precisely the soil-water) is the single factor which influences the high fluctuations in the crop yields in the different parts of the country.

Lecture No.14 AGROCLIMATIC ZONES

Climate is general is the totality of weather during a longer period and over wider area. An agroclimate can be defined as the conditions and effects of varying weather parameters like solar radiation, rainfall, etc.,. on crop growth and production.

Climatic classification is a method of arranging various data of climatic parameters to demarcate a country or region into homogenous zones, i.e., places having similar conditions.

Advantages of Agroclimatic classifications

1. This would enable in exploring agricultural potentiality of the area.
2. Locating similar type of climate zone will enable in identifying the specific problems of soil and climate related to agriculture.
3. This will help in introduction of new crops from other similar areas. E.g., introduction of oil palm in Kerala from Malaysia.
4. Development of crop production technologies, specific to the region.
5. To take up research work to solve the regional problems and
6. To transfer the technology easily among the farmers

Agroclimates of India

Krishnan and Muktar Singh (1969) have classified India into eight major agroclimatic zones using Thornthwaite moisture index and thermal index.

The moisture index is given by the following formula.

$$MI = \frac{P-PE}{PE} \times 100$$

MI = Moisture Index
P = Precipitation /rainfall
PE = Potential evapotanspiration

Based on the indices, eight moisture and four thermal belts were formed. All together there are 32 sub zones.

During the year 1989, the Planning Commission made an attempt to delineate India into different agro-climatic zones. Based on the similarity in rainfall, temperature, soil topography, cropping, farming system and water resource, India has been divided into fifteen agro-climatic regions. This was done mainly to identify the production constraints and to plant future strategies.

Agro-climatic zones of Tamil Nadu

Geographical location of Tamil Nadu.

$8^{o}5'$ and 13^{o} 10' North Latitudes
76^{o} 15 and 80^{o} 20'East Longitudes

Coastal line 1000 km (approximate)

Climate : Temperature Range : 29-38 ^{o} C
Minimum : 19-27 ^{o} C

Efficient crop zones

The new different crop zone approach should aim in utilizing the natural resources to the fullest extent. The uneconomical crops should be replaced by more economical ones. The crops should create more employment opportunities and economic stability of the farmers.

Based on the productivity , efficiency of the crops, each state has been divided into five categories.

1. Efficient zone	: The productivity of the crops is high and also stable due to the prevalence of the optimum conditions.
2. Potentiality efficient zone	: The productivity is high but unstable.
3. Moderately efficient zone	: Stable, medium productivity.
4. Less efficient zone	: Unstable, medium productivity
5. Inefficient zone	: Low productivity

Lecture No.15 **AGROCLIMATIC NORMALS FOR FIELD CROPS**

Crop yields are influence by external (environmental) and internal (physiological processes)factors that occur during the crop growing period. The external environment is the climate which regulates and determines the growth and development and final output of crop plants. But man has no control over weather alone, hence its dominance over the success or failure of agricultural enterprises. According to the World Meteorological Organisation the weather induced variability in crop yields is as high as 50 per cent. Therefore, weather should be taken as one of the inputs in agricultural planning.

Under optimum climatic conditions, the plants mainfest their maximum growth and production. Different crop growth cycles demand different climatic condition for fulfilment. Experimentally determined optimum climatic parameters for maximum production of a crop are not available in plenty as these require costly and time consuming studies employing phytotron (a green house where every growth factor can be controlled) and growth chambers. Alternatively, the climate of a region where a particular crop is best grown with less pest and diseased incidence can be studied elaborately.

Definition: Climatic normals means the degree of temperature amount of rainfall, humidity, etc.,. which distinguish optimal conditions from those defined as abnormal, both because of excess and insufficiency.

Uses of study of Agro-climatic normals for field crops can be as follows:-

1. Useful for Agricultural Planning
2. Useful in introduction of any crop. If the climate in which a crop is introduced matches to the requirements of the crops, then the benefit will be the maximum.

   Examples: a. Introduction of groundnut in Peninsular India from Africa
   b. Long grained patnai rice into California
3. Will be useful to forecast the abnormal weather.

CLIMATIC NORMALS FOR CROP PLANTS

Rice

Besides rainfall, temperature and solar radiation influence rice yield, directly affecting the physiological processes involved in grain production and indirectly through the incidence of pest and diseases.

Tempertaure: The difference in yield is mainly due to temperature and solar radiation received during its growing season. It requires high temperature, ample water supply and high atmospheric humidity during growth period. This crop tolerates upto 40^{o}C provided water is not limiting. A mean temperature of 22 ^{o}C is required for entire growing period. If high temperature drops lower than 15 ^{o}C during the growth phase, the rice yield is greatly reduced by formation of sterile spikelets. The period during which low temperature is most critical is about 10-14 days before heading.

The optimum temperature requirements for the different stages of rice crop are given below:-

Growth stage	Temperature units in ^{o}C		
	Low	High	Optimum
Germination	10	45	20-35
Seedling establishment	12-13	35	25-30
Rooting	16	35	25-28
Leaf elongation	9-18	38	31
Tillering	9-16	33	25-31
Panicle initiation	15-20	38	33
Anthesis	22	35	30-32
Ripening	12-18	30	20-25

Solar Radiation: Low sunshine hours during the vegetative stage have slight ill effect on grain production, whereas the same situation during reproductive stage reduce the number and development of spikelets and thereby the yield. For getting higher grain yield of 5 t/ha, a solar radiation of 300 $cal.cm^2$ /day is required. A combination of low daily mean temperature and high solar radiation during reproductive phase has given higher yield.

Rainfall: Rice requires high moisture and hence classified as hydrophyte. Rice requires a submerged condition from sprouting to milky stage. The moisture requirement is 125 cm. An average monthly rainfall of 200 mm is required to grow low land rice and 100 mm to grow upland rice successfully.

Wheat

Temperature: Optimum temperature for sowing is 15 –20 ^oC. At maturity it requires 25 ^oC. At harvest time wheat requires high temperature of 30-35 ^oC and bright sunny period of 9-10 hours.

Moisture: One hectare of wheat consumes about 2500-3000 tonnes of water. Water deficiency at the heading stage results in shrivelled grains and low yield. In Punjab, 35 to 40 cm of well distributed rainfall in the entire crop season or irrigations, one at crown initiation stage and subsequently three at 40 days interval, result in good yield in wheat.

Maize

This crop is best suited for intermediate climates of the earth to which the bulk of its acreage is confined.

Temperature: Maize requires a mean temperature of 24 ^oC and a night temperature above 15 ^oC. No maize cultivation is possible in areas where the mean summer temperature is below 19 ^oC or where the average night temperature during the summer falls below 21 ^oC. However, high night temperature also result in less yield. The crop gave 40% lesser yield at 29 ^oC night temperature as compared with 18 ^oC.

Moisture: Maize is adapted to humid climates and has high water requirements. It needs 75 cm of rainfall during its life period. The average consumptive use of water by maize is estimated to range between 41 and 64 cm. From germination upto the earing stage, maize requires less water. However, at flowering it requires more water and the requirement reduces towards maturity.

Groundnut

It is a tropical crop distributed between 45 ^oN latitude to 30 ^oS.

Temperature: It can be raised under a wide range of temperature. However, both very high and low temperature adversely affect it. A temperature range of 14-16 ^oC is necessary for the seeds to germinate. Higher temperature results in better performance in terms of length of stem, number of flowers and the number of pods. Maximum of pods have been harvested at a mean soil temperature of 23 ^{o}C. The number of pods decrease as the temperature increases.

Moisture: An ideal rainfall consists of 75-125 mm during summer months preceeding sowing, 125-175 mm during a fortnight after sowing and 370-600 mm of well distributed rainfall during the crop growth.

Cotton

It is not season crop. It requires 4-5 months of uniformly high temperature (28- 45 ^{o}C) during its crop growth period.

Mean air temperature of 21 to 29 ^{o}C is required at vegetative period. The optimum air temperature for reproductive phase is 27-32 ^{o}C; mean sunshine hours is 8-9 hrs./ day; and mean RH is 70%. But at boll development and boll opening period (September to November) RH less than 70% and 8 hrs. of sunshine are ideal for good cotton production.

The growth rate of cotton crop is increased at 25-30 ^{o}C. Temperature below 15 ^{o}C retards growth and reduces the square (bud) formation.

Moisture: The minimum rainfall required for cotton is 500-650 mm. Heavy rainfall during early stage is undesirable. Dry autumn months are desirable for good quality produce. Excess rainfall at later stage may cause shedding of leaves, squares and bolls. It also stimulates top growth and delays maturity and discolours lint. High humidity favours many pests and diseases.

Sugarcane

i. Mean air temperature for optimum germination is 30 ^{o}C.
ii. Mean air temperature for optimum growth is 35 ^{o}C.
iii. At temperature less than 20 ^{o}C growth is reduced.
iv. Ideal climate is 4-5 months of hot period with temperature of 30-35 ^{o}C followed by 6-8 weeks of cooler period for better maturity.

WEATHER FORECASTING
(Forecast : to predict or seek to predict)

Weather is the major factor which influences agricultural operations and farm production. A substantial portion of crop is lost due to aberrant weather. The pre-harvest loss may range between 10 and 100 per cent in various crops. In Punjab, a single rainy spell in April-may of 1982(maturity stage) damaged wheat crop worth Rs.1238 million. The post-harvest loss mainly due to rains and excessive humidity was worth Rs.9.42 million.

Usefulness of weather forecasting

1. Though the losses due to weather factors cannot be avoided completely, the loss could be minimised by making adjustment with coming weather through timely and accurate weather forecasting. In Punjab, it is estimated that crops worth Rs.176 million could be saved through better weather forecasting.
2. The weather forecasts also provide guidelines for long range seasonal planning and selection of crops suited to the anticipated climatic condition.
3. By forecasting anticipated heavy rains
   i. irrigation from wells can be avoided by which we can save electricity
   ii. the harvesting could be advanced if the crop is in maturity stage
   iii. threshing of harvested produce could be done before rains by which crop losses can be avoided.
4. Loss of seed, diesel, labour and time can be avoided by not sowing in unsuitable weather.
5. Fertilizer losses can be avoided by not applying during unsuitable weather condition for fertilizer application.
6. Similarly pesticide wastage can also be minimised.

Types of weather forecasting

There are three types of weather forecasting for agriculture.

1. **Short range forecast:** It is valid for 24-48 hours with 70-80% accuracy.
   Short range forecast gives emphasis on temperature, wind velocity and directions, duration of sunshine, time and amount of precipitation, R.H.

Uses (Applicability)

i. Scheduling of irrigation
ii. Adjusting of time of agricultural operations
iii. Protection of plants from frost

2. **Extended forecast:** It is valid within 5 days 60-70% accuracy.

   It gives emphasis on type of weather, sequence of rainy days, normal weather, sequence of rainy days, normal weather hazards in farming such as strong winds, extended dry or wet spells.

   Uses:
   i. Useful to determine sowing time
   ii. Useful to determine depth of sowing
   iii. Planning of irrigation
   iv. Decision on harvesting
   v. Decision on time of spraying to get higher efficiency
   vi. Management of labour and equipment

3. **Long range forecast:** It is valid upto four weeks to the season. It has emphasis in abnormality of temperature and precipitation.

   Uses:
   i. To decide on soil moisture management

ii. to decide on irrigation scheduling
iii. decision on selection of crops
iv. decision to manage irrigation with limited water supply
v. decide on cropping pattern and
vi. to determine crop yield

Weather forecasting organisation

Suitable organisations have been setup in most parts of the World for weather forecasting. Accepted international norms for measuring weather elements and representing them in international code are being adopted by all the participating countries. There are about 300 meteorological observatories of different types, distributed all over India, for the purpose of forecasting.

Synoptic charts and crop weather calender are the tools for making weather forecasts.

Lecture No.16 **REMOTE SENSING**

Remote sensing is defined as the art and science of gathering information about objects or areas from a distance without having physical contact with objects/ areas being investigated.

Principles of remote sensing

Every material on the earth absorbs and reflects the solar energy. In addition, they emit certain amount of internal energy. The absorbed, reflected and emitted energy is detected by remote sensing instruments or sensors which are carried in aircraft or satellites. The detections are made by characteristic terms called " Spectral signatures" and "images". Remote sensing systems in common use, record radiation in the form of electromagnetic spectrum (sunlight), i.e., visible range (0.4 - 07 nm), near infrared (0.7 - 1000 nm) and microwaves (1nm - 0.8 nm). Artificial sources of illumination such as radar's are also used in some seasons.

Sensors used in remote sensing

i. Photography: Photographic systems are the most commonly used sensing systems. The film records the energy reaching it at the exposure time in the visible and near infrared ranges of the spectrum. The photographic technique is used to identify soil types, plants grown, disease incidence and drainage patterns.

ii. Line scan and related system: Uses the visible and near infrared portion of the spectrum. In this system a minor is rotated parallel to the direction of the movement of the aircraft or satellite. The minor reflects the radiation received on to a detector and the data are recorded.

The multi spectral scanners have different channels for different colours of visible hand and IR portions. The IR sensors also recorded the thermal infrared radiation emitted by the earth proportional to the surface temperature. The infrared imagery is used to study the extent of vegetation, soil moisture, etc.,.

iii. Microwave system: The microwave radiation emitted from earth/s surface in small quantities are used by microwave sensors in a wave length of about 1 nm to 1000 nm. The sensors record the microwave radiation through a complex antennae. These are used in weather satellites. The active microwave systems are known as radars.

Radars are used to study soil characters, plant condition, soil moisture and runoff slopes.

A. **Areas of general application:** i. Agricultural land used mapping; ii) Agricultural population distribution; iii) Land used potential and iv) Soil and water resource surveys.

B. **Areas of specific application:** i. Crop identification ; ii) Crop acreage, vigour and density; iii) Crop growth rates and maturity; iv) Yield estimation and forecasting; v) Soil problems like salinity; vi) Soil moisture, water quality and irrigation effectiveness; vii) Drought prediction ; viii) Insects, diseases and nematodes ; ix) Frost damage; x) Storm and flood warning; xi) Fire surveillance and control ; xii) Water availability and location of canals; xiii) dates of planting and harvesting and xiv) Areas of fertilizer application and effect of fertilizers.

II. Application to range surveys:

i. Identification of forage species and their yield;
ii. Delineation of forest types and condition of range;
iii. Carrying capacity of ranges;
iv. Soil fertility and soil erosion
v. Identification of poisonous species
vi. Pest, disease and weed infestation
vii. Wild life inventory and
viii. Fire surveillance

III. Application of livestock surveys

1. Population studies
2. Distribution of animals

3. Animal behaviour
4. Health of animals and
5. Types of farm buildings

Remote sensing in India

In 1920, the first air survey using aerial photography was conducted.
In 1926, Aerial photography was used to asses flood situation.
In seventies, ISRO (Indian Space Research Organisation) used remote sensing for resource inventory.
In 1979, Satellite Bhaskara -I
In 1981, Satellite Bhaskara -II
In 1981, ISRO launched Rohini - I
In 1983, ISRO launched Rohini - II

Organisation using remote sensing techniques in Agriculture

1. National Remote Sensing Agency (NRSA), Hyderabad
2. Space Application Centre (SAC), Ahmedabad
3. National Bureau of Soil Survey and Land Use Planning (NBSSLUP), Nagpur
4. Central Ground Water Board (CGWB)
5. National Institute of Oceanography (NIO) and
6. All India Soil and Land Use Survey (AISLS), New Delhi.

Crop Weather Modeling

Variation in crop yields between years are associated with many factors. This is mainly due to weather , soil and management factors. There is complex reaction of weather variables among themselves as well as with other factors. Therefore, many attempts were made to study the effect of weather variables on crop yields through simulation modeling.

What is a model ? Model is mathematical representation of a system. The process of developing such representation is termed as modeling.

A model is a schematic representation of our conception of a system. In a general term, a model brings into mind the thoughts about the form and functional form of a real objets, like childrens toy, tailors dummies and mack-ups of buildings and structure to be later constructed in the real forms. Models also construct the objects or situations not yet in existence in real form. A model can also be referred as a representation of relationship under consideration and may be defined as an act of mimicry.

Types of models

1. Simple statistical or Empirical statistical models

This model rely mainly on the statistical techniques such as correlation or regression of the appropriate plant and environmental variables. The regression co-efficients are not necessarily related to the important processes, but estimate the yield alone. Therefore, many studies are required to produce the regression equations necessary for the wide spread application of this kind of models. A great advantage of these simple crop weather models is that they use readily available weather data.

2. Dynamic crop simulation models:

Predict changes in crop status with time. As example, model which predicts soil water content at a certain depth throughout the season or the one which predicts changing number of bolls on a cotton plant with the march of season are dynamic simulation models. Crop simulation model predicts the final yield and also provides a quantitative information on intermediate steps like daily weight of different plant parts, which is verified through experimentation. The model acts like a real crop be gradually growing leaves, stems, roots etc., during a season.

In other words, simulation is the process of using a model dynamically by following a system over a time period. A dynamic crop simulation model is most successfully developed by a multi-disciplinary team consisting of Agro-meteorologists, Agricultural Engineers, Plant Pysiologists,.

3. A model based on physiological and physical aspects:

These are mechanistic models where plant and soil processes are described with respect to physiological or physical or chemical aspects. For example, N may be takenup from the soil by the root system depending on soil N content and rate of availability of solution to the roots. Thus physical place of N in the visibility of root system and transformation are important.

4. Phenological Model:

That predicts the crop development from one growth stage to another. These prediction are generally based on the accumulated heat limits.

Uses of crop weather modeling

1. The models can be used as a research tool in planning alternative strategies for cropping, land and water management practices for a range of agro-climatic conditions.
2. Helpful for economists to work out cost benefit ratio analysis.
3. In enables plant breeder to develop crop varieties tailored to different agro-climatic conditions.

4. Help to make appropriate management decision for production.
5. Help to identify most potential area for research.

Advantages of crop weather modeling

1. Modeling relates plant growth and development from seedling to maturity.
2. The variability of growth and development is understood by basic concepts explained on mathematical basis.
3. The response of plants to their macro and micro environments are quantified.
4. It provides an understanding of the development process in plants and also helps in knowing missing data to have complete picture of the processes.
5. It will give new ideas leading to experimental approaches.
6. Modeling enables the researchers to understand the effect of single factor and combination of several factors in one experiment. As such separate adhoc experiments can be avoided.
7. Models will indicate priorities for applied research
8. It will help managers in making suitable decisions.

CLIMATE CHANGE

The earths atmosphere has never been free of change (in its composition, temperature, self-cleaning ability). Due to change in atmosphere the world is warming, climatic zones are shifting; glaciers are melting and sea level is rising. We anticipate these changes to accelerate over the next few years to come.

Greenhouse effect: The theory of "greenhouse effects" was conceived by the French Mathematician J.B. Fourler over a century ago. It was supported by Tyndall's studies on the absorption of heat by gases. The Swedish Physical chemist, Svante-Arrhenius had calculated in 1896 that there would be a global warming by3.2 - 4.0^{o}C due to doubling of carbondioxide concentration in the atmosphere. This level could be attained sometime in the next century, due to large industrial emissions and large population which has changed the land and increased the use of fossil fuels.

Some gases change the heating rates in the atmosphere. Like one way filter they allow the energy from the sun to pass through them, but trap the heat that the earths surface sends back. This is similar to what occur in a green house, where the glass on the roof is transparent to solar radiation but absorbs long wave radiation. Due to this analogy the term " green house effect" has been given.

Increased human activities increase carbon dioxide, methane, nitous oxide, chloro flurorocarbons (CFC) etc., which lead to increase in temperature and sea level rise. These gases which are in traces cause environmental parturbations (distrubances) such as green house effect (global warming), stratospheric ozone depletion , acid deposition, smog and corrosion.

Environmental Perturbations	**Responsible gases**
1. Green house effect	Co_2,CH_4(Methane, N_2, CFCS, Ozone
2. Ozone depletion in the stratosphere	Chloro-fluoro carbons (CFCS)
3. Acid deposition	SO_2, NO, NO_2, S, O_3
4. Smog corrosion	SO_2

Impacts of green house effect

i. Global warming and ii) sea level rise

The green house effect will disturb the climate by changing rainfall , wind, cloud, ocean currents and the extent of polar ice caps. The global impact of these changes could be very large.

Effect of Ozone depletion: Already seen in composition of atmosphere.

EL Nino and La -Nina

Sir Gilbert walker 1920, discovered there is a see-saw pattern in the atmospheric pressure between the Pacific ocean and Indian ocean. Where the pressure was high over the Southern Pacific, it was low over in the Indian ocean, but once in every few years the pressure pattern was reversed, that is, the pressures over the Indian ocean because high, while lower pressures prevailed over Southern pacific. Sil Gilbert called it the Southern Oscillation, Dr. Bjerknes 1958-59 who found that the Southern Oscillation was closely linked to the sudden appearance of warm waters off coastal park in South America-due to raise in sea surface temperature (557). This abnormal warming of sea surface in off the coast of few and equator is called Elinino which is highly related with Southern Oscillations and these two phenomenon are collectively called ENSO it has highly variable effect on global and Indian weather. EL-Nino (warm phase) event has a negative correlation with Indian South-West monsoon, rainfall, while positive association with NEM rainfall in extreme peninsular India.

Towards the end of 1972 as series of catastrophic events in different parts of the world drew attention to their possibility of global teleconnection in weather, the monsoon off 1972 was poor-severe drought in Northern Africa. Around the same period of this are abnormal current of warm waters off the coast of few in the Eastern pacific separately developed the fishering indusry of the South America. EL-Nino is associated with poor or indifferent monsoon. Out of 24 warm phase EL-Nino years only 6 years recorded more wider the average rainfall.

La-Nina refers the cold event, sudden reduction in the sea surface temperature in the Pacific ocean causes the change in Indian winter monsoon, Selvaraja et al., (1998) showed that when La-nina event occures (cold event), the winter monsoon rainfall is going to be below normal. In the 11 out of 16 years, where La-nina occurs (cold phase) the NEM rainfall of Coimbatore was found to be below normal.

Lecture No. 17 AGRICULTURAL SEASONS OF INDIA

Season is a period in a year comprising few months during which the prevailing climate does not very much. Growing season for a crop is more important for its yield and other management practices to be followed.

Indian Meteorological Department has divided the year into four seasons.

i. Summer	: March- May
ii. Monsoon	: June- September
iii. Post Monsoon	: October- November
iv. Winter	: December - February

The monsoon season is designated as Kharif, whereas the post monsoon and winter seasons are together designated as "Rabi" throughout India.

Based on temperature ranges three distinct crop season have been identified in India.

i. Hot weather (Mid February-Mid June)
ii. Kharif or rainy season (Mid June-Mid October)
iii. Rabi (Mid October to Mid February)

In Southern states (Tamil Nadu, Andhara Pradesh and Karnataka) there is slight variation in the season based on rainfall duration as

1. Winter	- January and February
2. Summer	- March to May
3. Rainy season	- a. South West monsoon - June to September
	b. North East monsoon - October- December

Based on the criteria, monthly precipitation and temperature, the growing season is broadly divided as follows:-

i.	Hot month	- if the average temperature is above 20°C
ii.	Cold month	- if the mean temperature is between 0-10°C
iii.	Warm month	- if the mean temperature is between 15-20°C

Agronomic concepts of the growing seasons

Agronomically the growing season can be defined as the period when the soil water, resulting mainly from rainfall, is freely available to the crop. This condition occurs when the water consumed by the crop is in equilibrium with rainfall and water storage in the soil.

The growing season for a rainfed crop involves three different periods during which the soil moisture conditions depend on the rainfall received.

a. Pre-humid period: During this period the precipitation will always remain lower than the potential evapotranspiration for the corresponding period. This period corresponds to the sowing period of the crop. Sowing can be done when the precipitation during the week is > 0.5 PET.
b. Humid period: During this second period the precipitation remains higher than the PET. The crops in this period will be in active vegetative and flowering phase and the water requirement will be at its peak. At the end of this period water balance is on the positive side and the water storage in the soil is on the increase, since the rainfall is higher than the water needs.
c. Post-humid period: This period follows the humid period. During this period there is a gradual reduction in the water stored in the soil due to the utilization by the crop plants. The crops will also make use of the rainfall received. This period usually coincides with maturity stage of the crop.

Types of growing period

There are four types of growing period.

1. **Normal :** In this type, rainfall is in excess during the humid period. At the end of the pre-humid period when precipitation is higher than the 0.5PET sowing the crops are taken up. This type of growing season is prevalent in semi arid tropics.
2. **Intermediate type:** The precipitation is lower that the PET all round the year. The growing season is limited to the period when rainfall is in excess of 0.5PET. Only drought hardy crops like pearl millet, castor, etc., can be grown. Dry farming is highly risky.
3. **All year round humid:** In this type, the precipitation is more than PET all round the year, indicating the moisture sufficiency for cropping. This type occurs in high rainfall areas and mostly perennial crops are raised.
4. **All year round dry:** The precipitation is lower than 0.5 PET throughout the year. Cropping is not possible in these areas. This type of growing season is found in extremely arid areas, mostly the deserts.

The fluctuations in the crop yields depend on the following conditions.

1. The length of the rainy seasons i.e., from sowing to the end of the rains
2. The quantity and distribution of rains during the pre-humid and humid periods
3. The excess rainfall during humid period should go to soil storage. It may cause water logging and crop lodging
4. The amount of rainfall received during post humid season, may supplement the soil moisture during maturity. This may favourably influence the yield.

In India, four cropping seasons have been identified by IMD in dry farming areas.

S.No	Name of the season	Duration	Water need from RF	Crops
1	Short duration	Upto 10 weeks	75%	Very short duration crops
2	Medium duration	10-15 weeks	75%	Medium duration crops with intercrops
3	Extended medium duration	15-20 weeks	75%	A medium duration crop followed by short duration crops if soil type is suitable
4	Long duration	20-30 weeks	75%	Medium duration crops followed by short duration crops.