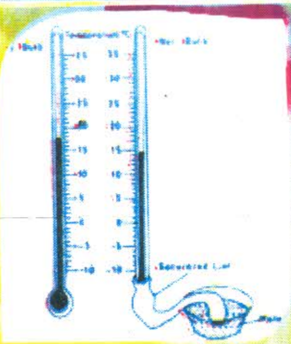
CLIMATE & AGRICULTURE

By

Olaniyi J.O. (Ph.D)
Kolawole, G.O. (Ph.D)
Aremu, C.O. (Ph.D)
Ajibola, A.T. (M.Sc)
Babajide P.T (M.Sc)



ISSBN: 978-311-770-130
1000-2-10-2007

Printed by:
Iyanda Bindery and Printing Press,
P.O. Box 1127, Ogbomoso, Oyo State.
08054823969, 08030947217.

CHAPTER ONE

AGRICULTURAL METEOROLOGY

1.1 INTRODUCTION

Climate directly affects-the daily life of every plant and animal on the earth's surface and therefore form an important feature of the environment. There's much controversy concerning the relationship between climate and racial characteristics among plants and animals.

Climatic elements are largely responsible for the detailed sculpture of the face of the earth such as weathering, running water wind and wind in action desert lands, even the storm waves which formed the coasts are all the results of climate. The mantles of soil and vegetation both natural and cultivated, owe much of their character to the climatic environment.

The various climates of the world today differ considerably from the past. This is because of warm periods, cold periods and arid periods brought about by the nature of the rocks and the character of the remains of plants and animals found there in.

The effects of weather are direct and significant. We address from it, plan picnics around it, suffer from it's extremes and construct our buildings for protection from it. Indoor and outdoor activities are planned as weather allow. From weather conditions atmospheric conditions for days, weeks end even seasons are predicted.

Climatologists have adopted several ways to study long term weather. Physical climatologists study physical laws as they relate to such weather elements as the average energy input and the subsequent conversions of energy to temperature, precipitational and atmospheric motion.

2.1 MEANING, SCOPE AND IMPORTANCE OF AGROCLIMATOLOGY OR AGROMETEOROLOGY.

Agroclimatology:- Is synonymous to agricultural meteorology or agrometeorology. It can be regarded as a relatively young science (developed in the 1920s) as a working branch of **CLIMATOLOGY**. Since 1950s, agroclimatology has been fully developed into an independent scientific field of study although it is a subset which overlaps other areas of study such as physiology and ecology in which the atmosphere (natural and or man-modified), is a significant environmental factor. Plants, animals and human being (even microorganisms) are weather and climate sensitive and therefore, respond actively in complex ways to the atmospherics environment.

Agroclimatology:- can be broadly defined as a scientific study of those aspect of climatology which are relevant to the problems of agriculture. Therefore, agroclimatology covers the collection, analysis and interpretation of climatological data which are useful in the practice of effective and efficient agricultural/farming activities. In agroclimatological studies, the interactions which exist between the atmospheric environment and cultivated plants and livestock are incessantly emphasized. More so, cultivars and livestock exist under both natural and artificial (man-modified) environment. An agrometeorologist or agroclimatologist is interested in the influences of these climatic or atmospheric environments on the cultivated crops (cultivars) and livestock (farm animals). The scope of agroclimatology equally covers the prevailing climatic conditions within the soils top layers and the interface between the soil and the underlying (lower) layers of the soil atmosphere/environment where crops and livestock are raised and the interactions between them.

Agroclimatology is aimed at achieving the following goals; (a) effective prediction and control agricultural production and management operations (b) reliable protection of cultivated crops and livestock against climatic hazards (e.g. extremely hot or cold temperature, torrential rainfall, storm, high solar radiation etc.) (c) Prediction of prevailing future pests and pathogens of crops and livestock so as to provide effective management and control measures. (d) effective appraisal of the climatic environment of an area, as required for introduction of specific crops and livestock. (e) provision of advisory information for the timeliness and appropriateness of agricultural operations as needed for achieving sustainable food production. The achievement of the aforementioned goals is not unconnected to the clear understanding of the complex interactions existing between the atmospheric environment and crops/livestock.

Independent existence of agroclimatology as a scientific field of study was recognized in the 1950s. Now, world meteorological organization exists, which is a commission engaged in the training and research in the field of agrometeorology. In Nigeria, most national meteorological services departments have agrometeorological units or divisions usually manned by experienced agrometeorologists with the view to improving agricultural production through application of agrometeorological knowledge and techniques. The achievements made so far include;

(i) Forecasting of weather hazards to agricultural production and the control or protection of crops against such hazards e.g. frost.

(ii) Determination of the time and amount of irrigation water needed to supplement rainfall (or to be used as the only source of water to crop) in a given area, to ensure optimal crop yield.

(iii) Control of pest's infestation and disease pathogens that affect crops and livestock.

(iv) Suitable and reliable site selections for crop and animal husbandry.

(v) Improvement of crop yield through micro-climatic modification or creation of artificial (man-modified) environment.

(vi) Adoption of timeliness and appropriateness in farming operations (starting for land clearing pre-planting operation) to weeding/harvesting (post-planting operations).

(vii) Prevention of post harvest losses by storing farm produce in man- modified micro environments (cribs, silos etc.) against pests and diseases.

(viii) Creation of research opportunities for plant breeders to breed for crop varieties that are a). Drought tolerant b). Pest and diseases resistant c). Early maturing (to escape certain environmental hazards that can set in if crops stay longer on the field). D). Making harvesting easier e.g. shorter height

(ix) Better understanding of the prevailing environmental factors and their possible effects on plants, animals and man.

(x) Differentiating between signs of weather effects and other non-weather dependent factors.

1.3 Components of agricultural meteorology

For the planning of programme for agro-meteorology researches and training. it is important to recognize the wide spectrum of problems encountered agriculture in relation to weather and climate. These components of agriculture meteorology are discussed below under twelve headings.

1.3.1 **Agrometeorological monitoring** (Techniques. data collection, networks. experiments)

The monitoring of meteorological conditions in the biosphere encompasses physical measurements over a range extending from the top of the troposphere down to the soil surface and the first few metres below. Besides the classic point-measuring techniques there are now new remote-sensing techniques available which provide instant information over large areas of the globe.

Agrometeorological observations are grossly inadequate on a worldwide basis. There is a need for an over all plan of agrometeorological observations networks and experiments in the important food-producing areas. The observations should be continuing, well documented to researchers and service personnel.

1.3.2 **Plant environment and crop production** (Effect of meteorological elements on growth and development of plant, quantity of yields, climatic requirements of crops, operational crop condition assessments)

Plants are affected in every stage of growth by environmental. The weather influence further extends to before planting and after harvesting. The quality of the seed sown depends on meteorological conditions furing the year in which it was produced, and even during previous years. Post-harvest operations, such as drying of grain and other crops, are affected by seasonal weather, as is also the storage quality of fruit; vegetables are giving fro wheat in Annex 1b and other farm products. Rational used of meteorological information requires the knowledge of two types of information (a) specific influences of climatic factors on the growth and development of living organisms throughout their physiological cycle; (b) climatic characteristics specific to a given farming are expressed in statistical terms. Such studies provide essential information, particularly in developing countries where the introduction of new varieties of food or industrial plants can be a major factor in the development of these countries of even for the well-being of their population.

As an example of the agroclimate requirements of crop climatic threshold values

1.3.3 **Plant injury and crop losses** (Pests and diseases, pollution, the effects of weather hazards on crops, cold haradiness, frost and freeze damage)

Here the meteorological effect is threshold. The weather influences the susceptibility of plants to attacks by air pollution (pests and disease. It also enters into the biology of the insects and disease organism themselves, and thus affects the nature, numbers and activity of pests and the extent and virulence of diseases. Finally, it has an impact upon the timing and effectiveness of control measures, and on the amount and toxicity of spray residues on harvested crops).

Good progress has been made in the meteorological aspects of integrated pest and disease control. Assistance from agricultural meteorologist is no longer in the experimental but rather in the operational stage. Biological and weather conditions should be considered so that the most efficient, most profitable, and least air polluting control method may be used. Weather factors play an important role in the occurrence of and defense against forest and grass firs. Frequency analysis of specific data such as the probability of drought frost or hail, and particularly the sequences of consecutive days with such events is more useful than ordinary statistical means.

1.3.4 **Livestock health and production** (Environmental problems of livestock housing, health and production).

Apart form its direct effects, weather affects farm animals through the crops on which they feed and the ground on which they are kept. It affects their feeding, growth, fecundity and health, their geographical distribution, the yield and quality of animal products, the preparation of these products and their capacity for storage and transport. Genotype-environment interaction is castle are generally assumed to exist. The performance of beef castle in relation to their environment may need more research on a world-wide basis. In temperate zones livestock is probably less sensitive than plants to climate stress. Some processes, however, such as milk production, are fairly closely related to temperature and moisture factors.

1.3.5 **Animal diseases and parasites** (Direct and indirect effects of weather on the various types of animal disease, injury and health; economic losses; forecasting incidence and intensity of animal diseases).

Meteorological factors can influence ánimal diseases in various ways by affecting.

(a) The resistance of host to germs or pathogens;

(b) The resistance and evolution of these germs or pathogens during their biological cycle, particularly when part of this cycle occurs outside the host animals;

(c) The conditions under which control measures are applied. Knowledge of the interrelations between animals, weather and certain diseases is adequate to provide animal disease forecasts which are available in some countries. These services should be extended to include other animal diseases and more countries.

1.3.6 **Climatic resources** (Climatological surveys, ecosystem essential, land use pattern, climatic analogue, climatic variability, climatological statistics and processed data. agroclimatic resources analysis).

Climatic resources have been analyzed in the past by the classic climatologically approach of means and normal. For a practical interpretation of climate for agriculture an analysis of the frequencies and amplitudes of the occurrences of weather hazards causing plant injuries or crop failures is more meaningful.

Fluctuations in weather and climate significantly affect energy use, water use and global food production. Because of the unequal distribution of these resources over the world, crisis situations have occurred in recent times. There is a growing warmness, of the need to asses these resources on a global scale. For the assessment of an area according to agrometeorological principles, the following methodology has been suggested:

(a) Determination of bioclimatological requirements of crop varieties:

(b) Classification of varieties into bioclimatic groups;

(c) Identification of bioclimatic indices which characterize crop growth, development and yield;

(d) Comparison of bioclimatic indices with the climatologically data available for a region in order to determine agro climatic types;

(e) Agroclimatic zoning by fitting bioclimatic type. The primary objective in agrometeorology should be a practical approach towards integrating agricultural ecosystems and climatic resources into research and development programmes to increase and stabilize production.

1.3.7 **Soil resources** (Soil classification soil deterioration and erosion, loss of farmland through urbanization sand-dune reclamation)

Weathering is an important factor in determining the nature of a soil, climate and weather affect the chemical, physical, physical and mechanical properties of the soil, the organisms it contains, and its capacity for retaining and releasing heat and moisture. Rainfall, on the one hand, adds chemical constituents to the soil but, on the other hand, washes out soil nutrients. The state of the soil as affecting cultivation, pest control and harvesting is much influenced by weather conditions. The worlds wide problem of erosion, its existence and extent is largely determined by local weather factors.

Data are required on erosion and soil deterioration in relation to specific wind statistics such as vectorial characteristics of wind, moderate and high wind speeds and wind in association with rainfall. Data are also required on snowmelt cycle, heavy rainfall (particularly intensities), and the occurrence of dew which is a important element in rock disintegration in arid regimes, urban and regional development results in loss of valuable farmland often situated in the best agricultural zones.

Field tests and sand-dune stabilization studies have shown that is not only possible to fix shifting sand dunes but also to exploit them for agricultural use-for example, they have been afforested economically for wood and wood by-product another challenge for such areas is the establishment of recreation centres which have high economic value, ensuring income form tourism.

1.3.8 **Water resources** (Agricultural water needs water used efficiency of crop, irrigation requirement, and scheduling water surplus and drainage, agricultural drought)

The water balance of the soil is a subject of greatest importance in many parts of the world but especially in frought regions as witness the many projects being conducted on this topic and its many components, rainfall, soil moisture, evaporation, runoff and drainage. These studies have very practical implications for developing water resources, planning water use amongst numerous types of consumer (towns, industry, and agriculture). Determine drainage requirement, and managing water resources for their most profitable use in crop production.

1.3.9 **Management operations** (weather climate analysis in relation to field workdays forage crop harvest conditions, hay drying, pest and disease control, weather forecasting requirement of agriculture)

Climate conditions must be taken into account in planning farm buildings and particularly in designing animal housing and storage space for agricultural products. Weather factors also influence the choice up taken and best use of farm machinery.

This is an area where the usefulness of applying agrometeorological knowledge and expertise to overall farm planning, management and operation can be demonstrated most effectively. Good progress has already been made these efforts should be stepped up using climatological data in agrometeorological technique to determine, on a probability basis, for planning purposes: (a) soil surface conditions in terms of field workdays: (b) use of machinery for harvesting an drying grains forage, legumes seed crop, etc: (c) application and effectiveness of pest and disease control measures.

For real-time agrometeorological forecasts, regular generalized weather forecasts is crucial. Agriculture, probably more than other human activity, would benefit most form extended weather forecasts. There is also a need to specify the synoptic situations which are conductive to good drying efficiency disease and pest control and other farming operations, so that forecasters without special agricultural expertise can still provide useful guidance.

1.3.10 **Artificial modification of the meteorological and hydrological regimes**

(Protection against adverse weather conditions, controlled climate, weather modification)

Protection can take the form of: (a) planning (i.e. selecting) crops, varieties and sites to avoid or reduce the relevant meteorological extremes detrimental to plants; (b) improving sites to avoid or reduce the impact of these extremes.

The extremes normally to be avoided are those of temperature (especially frost), radiation, precipitation, drought and wind. Irrigation, windbreaks and shelterbelts, the storage and conservation of snow and water as well as cultural practices, also have important influences on certain elements of the local environment such as soil moisture, wind velocity and atmospheric humidity.

Controlled climate facilities, such as growth chambers, greenhouse and phytotrons, are important research tools which provide basic data on crop responses to their environment. This information supplements our knowledge of crop-weather relationships as obtained form filed experiments or statistical data.

The assessment, in both quantity and quality, of weather modification due to man's activity is an important task of agrometeorological research.

1.3.11 Forest meteorology

Man's increasingly intensive utilization of forest land for agricultural and other purposes may cause weather and climate effects in both space and time. The correct application of meteorological information can be of considerable benefit to the protection and conservation of forest resources. Increased attention should be given to research needs in forest meteorology and to the training of suitable agrometeorologists to deal with problems connected with forest meteorology. At its sixth session, in 1974, the commission for Agricultural Meteorology expressed its active interest in this important subject and of meteorology to forestry have been well stressed.

1.3.12 Economics value of agrometeorological information and advice (services used in farm planning (past weather) and operations (present and forecast weather).

The evaluation of the economic significance of agrometeorological services is a difficult problems, but modern management needs this type of information. The value of such information depends on the meaningful interpretation of the effects of weather and climate on agricultural activities and production. Typical examples are cost benefit studies of farming operations such as irrigation, frost protection weather integrated pest and disease control and use of farm machinery. These evaluations are based on probability statistics relating the occurrence of weather events (e.g. frost) or derived climatologically elements (e.g. soil moisture) to agricultural production.

1.4 Climatic threshold values of wheat

Wheat is adapted to a range of environmental conditions. Most favourable climatic conditions are a cool, moderately moist growing season, favouring the development of basal leaves and tillerings, merging gradually into a warm, sunny and dry harvest period. Wheat successfully over winters in a wide range of climatic conditions, depending on variety, climate and agrotechnical practice.

Table 1: Climate threshold values of Wheat

Plant development Stage (days)	Agroclimatic requirements					
	Light (nanometers; lux)		Temperature (°C)		Evapotranspiration (mm day⁻¹)	
	Min. Opt. Max	See Ref. No. in list overleaf	Min. Opt. Max	See Ref. No. in list overleaf	Range	See Ref. No. in list overleaf
Germination5-45			4 25 30/32	(7)	2.0-2.5	(3) (5)
Over wintering 30-150			0 5 20/25	(2)		(13)
Growth 40-50	400 650 750nm 0.37-0.56 lux	(9) (4) (11)	12 20 25/30	(6)	4.0-5.0	(3)
Reproduction 25-35			25-31/33	(1) (14)	5.2-6.5	(3) (5)
Harvesting 10-15			25/28	20 21		
Total crop requirement					Min. Opt. Max 250 -500-700	(8) (12) (10)

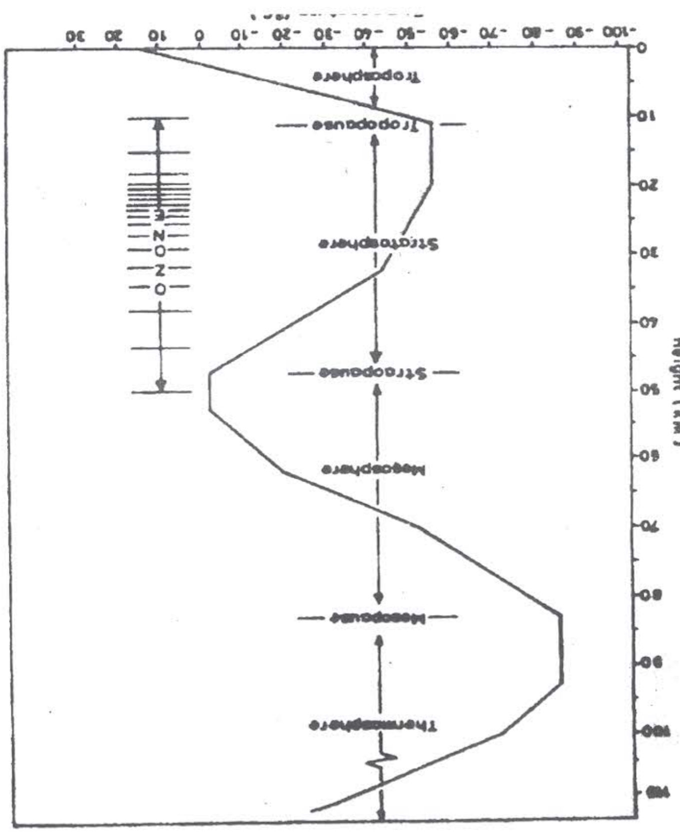
Source: (WMO Publications No. 396)

CHAPTER TWO

2.1 THE ATMOSPHERE

Most of the planets have atmosphere but each planet envelope of gases evolved under different circumstances. On earth, photosynthesis changes the composition of the atmosphere by removing carbon-dioxide and adding free oxygen.

THE ATMOSPHERIC STRUCTURE



Temperature (°C)

Fig. 2.1: The structure of the Atmosphere

The dynamism of the lower atmosphere called the troposphere produces weather, the short-term atmospheric conditions at any locate.

Above the troposphere lies the ozone-rich stratosphere which filters incoming vitraviolet light. The mesosphere and thermosphere lie above the stratosphere and are identified by temperature and pressure characteristics. Each of the atmospheric layer ends in a "pause" which is a transition zone marked by a steady state temperature. The troposphere is the site of moving air masses that acquire identifiable characteristics. The atmospheric component that is most influential to weather formation is water vapour. Its presence in a mass of air can turn a sunny day into a stormy day. It is largely responsible for the transfer of heat.

The Earth atmosphere is dominated by Nitrogen. The mixture of gases make up to form the atmosphere. The lower atmosphere called the troposphere produces weather, the short term atmospheric conditions at any location. The atmosphere is a major influence on natural landscapes and life.

Table 2: Volume of gases in the atmospheric dry air

ELEMENTS	PERCENTAGE %
Nitrogen	78.02
Oxygen	20.93
Carbon dioxide	0.93
Neon	0.03
Helium	0.0018
Krypton	0.00524
Hydrogen	0.0001
Xenon	0.00005
Ozone	0.000008
Radon	6×10^{-18}

2.2 RADIATION AND HEATING

2.2.1 RADIATION AND HEATING OF ATMOSPHERIC SYSTEMS

Radiation is a method of heat transfer through space by involving electro magnetic waves.

The sun: The most influential body in the solar systems is the sun. Its gravity holds the system together and its energy illuminates the planets. The sun has energy that is the principal influences on the weather. The reactions generating the energy that eventually drives earth's atmosphere occur in process known as proton - proton fusion. When two protons are driven very closely together under the intense heat of the sun score the strong nuclear force binds them.

Kinetic energy is produced in core of the sun. This energy produced is used in driving the earth atmosphere through electromagnetic energy. The energy changes form as it travels from the sun's interior to our planet. The energy produced by the sun must travel through the sun's layered structure and across the vacuum of space changes the form in which the energy is transferred.

2.2.2 How heat radiation is transferred?

Fusion of the proton - proton generates energy in form of short wave electromagnetic radiation. This thus begins a sequences of atomic - scale events that produces a spectrum of energy which includes gamma rays, x-rays, radio-active waves, ultra violent and infrared radiation. It is this radiation that eventually makes its way throughout the solar system and heats the atmosphere. The sun is the ultimate source of energy for the atmosphere. It energy arrives at the earths planet in two forms: Electro-magnetic radiation and corpusular radiation (solar wind as a result of charged atomic particles). The sun's electro magnetic radiation takes about eights minutes to reach Earth. The Earth is not stationary but in a constant motion, this motion helps to control incoming solar radiation so sun does not light one side of the sphere.

The rotation distributes the energy every 24 hours. The side turned away from the sun loses energy. The rotation gives day and night hence basis for hours.

2.3 CONDENSATION AND PRECIPITATION PROCESS

Condensation is a heat release process that turns water vapour into liquid water. It is a heating process. As the gaseous water turns liquid water it releases its latent heat into the surrounding environment. Therefore, when the evaporated water migrates in air currents and then condenses, it transfers heat from one place to another and forms water droplets when air is cooled to and beyond its dew - points. Air cooling takes places by direct radiations from earth surfaces, during night, movement of warm air over a cold surface, mixing of two air currents of markedly different temperature, movement of air from warmer to cooler latitudes and by ascent.

Condensation brings about the following:

1. Fog
2. Clouds
3. Dew

2.3.1 FOG

This is a type of water droplets suspend in the air and reduces visibility. It obstructs free movement in air, sea and land. Visibility in this case is less than 1km.

Mist occurs when visibility is reduced to 2 km.

2.3.2 CLOUDS

This is made up of tiny particles of water or ice which floats in masses at various heights ranging from ground - level to the highest level of the atmosphere. The amount of cloud cover is recorded in terms of the proportion of the sky which is covered expressed in eights and indicated on the weather - map by a shaded disc. There are 3 types of clouds according to forms and appearance, these are:

a. Cirrus: feathery or fibrous cloud
b. Cumulus: Globolar or heaped types
c. Stratum: sheet or layer types.

Clouds can be high medium or low in terms of high.

2.3.3 **DEW:** This occur when condensation take place on the surface of bodies to a temperature below the dew-points of earth's surface air layer. Dew occurs after a warm day when evaporation had taken place.

2.4 PRECIPITATION

This is an act of liquid, water returning or descending into earth surface (atmosphere) after evaporation. This type of liquid goes into lakes, rivers, oceans and land soil. The presences of moisture in the atmosphere are termed humidity. It may be expressed absolutely or relatively.

Absolute humidity: This is the actual amount of water - vapour present in certain quantity of air. When the amount of water molecule entering and leaving the air is the same, saturation vapour pressure is reached.

Relative humidity: This is the amount of vapour present in the air and expressed in percentage of total amount present in saturated air. Relative humidity varies with absolute humidity and temperature of the air.

2.5 RAINFALL

This occur when minute droplets of water collapse to form larger drops and are heavy enough to overcome gravity of the ascending air currents and finally fall as rain. There are three types of rainfall.

1. Convectional
2. Orographical rainfall
3. Cyclonic rainfall

2.5.1 Convectional Rainfall

This type occurs throughout the year near the Equator where there's high temperature. This rain occur mainly in the hot afternoon. When the air is warm and humid and the upper air is abnormally cold a condition of instability will result in turbulence of the up-currents and eventually drops as rain.

2.5.2 **Orographic rainfall:** This occurs near mountains when air is forced to ascend the side of a mountain range. The air creates differences between windward and leeward sides of the mountains. The orographic factor increases precipitation, produced by other causes.

2.5.3 Cyclonic (Frontal) rainfall:

This occurs along the frontal zones of convergence at the polar fronts and the intertropical convergence zone (ITCZ). Under warm humid conditions, there's build up of massive cumulonimbis clouds with torrential rain and thunderstorms. This rainfall is intensified by the effect of relief as the depressions crosses the coasts. Other forms of precipitation are:

SNOW: When water-vapour condenses and passing from the gaseous to the solid state and forming minute particles of ice.

Sleet: This is a mixture of rain and snow.

Soft hail: This is an aggregate of tiny ice particles deposited by freezing from water vapour.

Hail: This is precipitation with extreme instability. This forms after exceptional local heating and convectional overturn. Rain-fall has a marked effect on the geographical distribution of plants.

Table 3: Geographical distribution of plants as affected by rainfall.

TYPES OF PLANT	RAINFALL
Evergreen forest	Abundant
Deciduous forest	Moderate or low
Shrub	Scanty

Availability of rain-water depends on the water-retaining capacity of the soil.

2.6 SOURCES OF MOISTURE

The earth surface is covered with water-most of the moisture source are through the expanses of oceans, large lakes and rivers. Even plants supply water to the atmosphere through the process of transpiration. The energy require to evaporate water is stored as the latent heat of vapourization. This can be returned to the environment by condensation. Bulk of the moisture that precipitates on to the earth surface is derived from the oceans.

Another source of moisture is through the process of evapotranspiration. This is an act moisture release into the atmosphere through evaporation and transpiration. Evapotranspiration moisture content is lower in quantity than that produced by evaporation from the sea.

CHAPTER THREE

3.0 BASIC PRINCIPLES AND PRACTICES OF WEATHER OBSERVATIONS

3.1 Climate and Weather

Weather: is simply the term used to describe the state of the atmosphere at a given point in time, over a given area or location whereas, **Climate** is referred to as a synthesis or cumulative or summary of weather elements or data over a long period of time (usually 30 to 35 years) over a given area or location. It is important to note that meteorology (scientific study of weather) and climatology (scientific study of climate) are both observational sciences and that information about weather is directly obtained from the weather observations over a long period of time in a given area/location. Weather is therefore a current and specific atmospherics characteristics at a given time while climate id representing the general characteristics of the atmosphere over a given period of time (usually long and up to 30 years and above).

Meteorology is regarded as the science of atmosphere which is concerned with the scientific study of the numerous properties of the atmosphere and the interactions between the atmosphere and the earth's surface. Climatology is simply the scientific study of climate. A climatologist studies the climate while a meteorologist studies the weather. Although there is a very close relationship between weather and climate a meteorologist differs in methodology from a climatologist. A meteorologist applies basically the laws of classical physics and mathematical techniques in studying the atmosphere/weather processes and phenomena while a climatologist employs statistical techniques to obtain information about climate from weather observations or measurements.

Table 4: Summary of weather data from January 1994 to December 2000

	Total Monthly Rainfall								Ave. Relative Humidity				Ave. Monthly Temperature				
Month	1994	1995	1996	1997	1998	1999	2000	1998	1999	2000	1994	1995	1996	1997	1998	1999	2000
	-------------Mm-------------								------%------				------°C------				
January	39.3	0.0	0.0	0.0	0.5	0	34.8	41.3	53.3	65.0	33.1	33.5	34.5	33.5	29.4	21.3	26.2
February	0.0	2.1	0.9	0.0	0.5	15.1	00	45.3	57.1	35.0	35.5	35.8	36.0	33.5	31.1	21.0	25.9
March	19.8	33.3	61.4	50.7	50.7	68.0	19.6	47.0	69.9	61.0	36.3	35.6	35.8	35.9	33.3	23.0	28.0
April	233.0	122.0	25.8	179.5	179.5	118.3	45.9	66.7	62.5	73.0	31.5	34.4	34.2	35.0	33.4	32.0	28.0
May	156.0	209.6	143.2	216.9	216.9	171.3	105.6	79.3	75.8	76.0	35.1	31.0	31.9	30.6	31.8	31.5	27.1
June	131.2	171.3	152.8	229.5	229.5	296.2	194.2	77.1	65.7	84.0	30.2	30.5	30.9	29.5	30.2	29.6	25.1
July	89.6	218.7	104.2	102.9	102.9	179.4	81.0	84.5	82.2	82.0	28.2	28.7	29.3	28.5	28.9	28.6	24.7
August	87.0	232.1	131.4	86.0	86.0	138.1	185.0	83.9	80.9	89.0	28.2	28.6	28.7	28.5	28.3	27.4	23.7
September	260.6	188.5	262.7	334.8	334.8	268.9	281.7	81.5	79.5	87.0	29.6	29.5	29.0	29.5	27.6	27.3	24.6
October	234.9	154.6	62.9	121.7	121.7	218.5	42.5	80.8	70.3	83.0	30.3	30.9	29.8	30.0	28.1	27.7	25.7
November	0.0	46.8	0.0	0.8	0.8	35.7	00	65.3	84.6	72.0	33.1	32.4	33.0	32.6	29.4	28.9	27.7
December	0.0	30.2	0.0	11.6	11.6	0	00	53.1	70.3	55.0	32.8	33.0	32.5	33.2	30.1	29.1	25.7
Total	1251.4	1409.2	945.3	1334.4	1334.4	1539.3	990.3	-	-	-							-
Average	139.0	128.1	105.0	133.4	133.4	128.3	82.5	67.2	71.0	71.8	31.6	31.9	32.1	31.8	30.1	27.3	26.1

Source: Ilorin Airport Meteorological Department, Ilorin, Kwara State.

3.2 Climatic Factors and Elements

The term climatic elements is a convenient label for each of the constituents which make up the sum total of climate. Climatic elements includes temperature, rainfall, humidity, cloud, wind and sunshine. These elements are controlled by a number of factors which interplay to have a cause and effect relationship on the climate.

These factors are:-

1. Latitude and sun angle
2. Distribution of land and water
3. Altitude
4. Orographic barriers
5. Semi permanent highs and lows
6. Oceans currents
7. Storms

Table 5: Climatic factors and their effects.

FACTORS	EFFECTS
i. Latitude and sun angle	Influences the amount of energy available for troposphere.
ii. Altitudes	Influence temperature and adiabatic changes.
iii. Distribution of land and sea	Influence the rapidity of heat gain or loss from earth surface and the availability of moisture.
iv. Orographic barriers	Reduces moisture content.
v. Physical features (semi permanent high and low)	Influences wind direction and air mass development and movement.
vi Ocean current	Influences pressure systems plus the amount of moisture available to an area.
Vii. Storms	Transfer energy and moisture between and Across latitudes and longitudes.

3.3 A Weather Station

Is any specially designed place where one or more weather-measuring instruments are placed. It is an enclosure containing various instruments used for measuring weather elements such as (i) precipitation/rainfall (ii) atmospheric temperature or ambient temperature (iii) wind speed (iv) wind direction (v) solar radiation (vi) evaporation (vii) soil temperature (viii) relative humidity (ix) air pressure (x) duration of sunshine.

3.4 Layout of station instruments

To minimize tampering by animals and people, it is very desirable to fence the weather station. A sample layout is shown in figure 1.

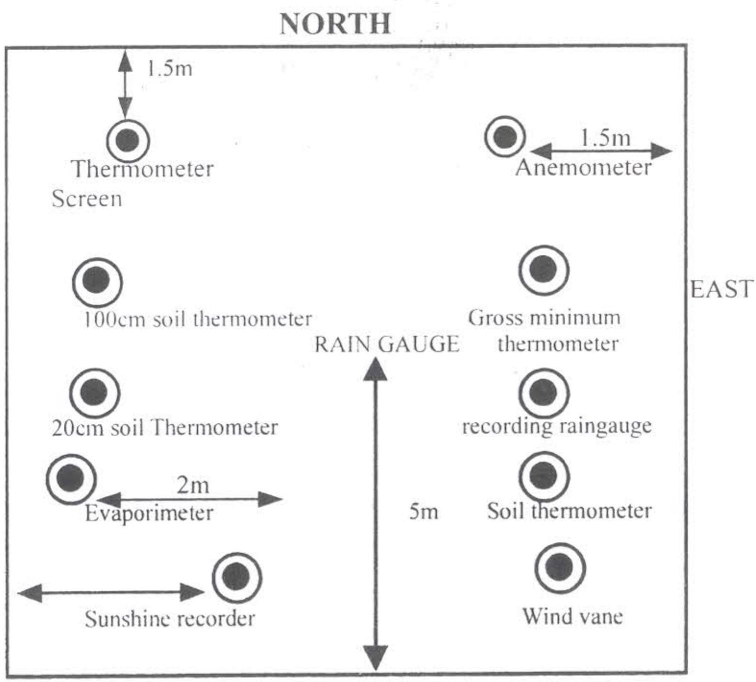


Figure 1 - Sample layout of station.

This layout for northern hemisphere stations is designed to eliminate as far as possible the shadowing effect of fence posts on instruments and to ensure that direct sunlight does not enter the thermometer screen during observation. In the southern hemisphere the general orientation of instruments will be the reverse, the door of the thermometer screen for example, will open to the south. At equatorial and tropical stations of course, the thermometer screen will have doors opening to both the north and the south. All radiation instruments and sunshine recorders should be carefully mounted in a position free all shadows at all times. The minimum distance between instruments is also indicated in the figure. A larger area is recommended when other instruments and small plants for phenological observations are used.

3.5 Inspection and supervision of agricultural meteorological stations

Agricultural meteorological stations maintained by the national meteorological service should be regularly inspected sufficiently frequently to check whether the exposure has changed significantly and to ensure that observations conform to the appropriate standards and that the instruments are functioning correctly. The time interval between successive inspections of an individual station will depend upon the programme of the station and the qualifications of the local personnel responsible for the programme.

If agricultural meteorological observations are made by other authorities, co-operative arrangements or special agreements should be made to ensure suitable supervision and maintenance of the network.

3.6 QUALITIES/REQUIREMENTS OF A GOOD WEATHER STATION

1. It should be sited on a flat/gentle slope or leveled ground to prevent water logging.
2. The size should be 10m x 7m.
3. Ground coverage by Bahama grass essential to prevent undesirable soil heating/evaporation.
4. It should not be site very close to obstructions (natural or man-made) e.g. broad and tall rock, very big trees, mountains or hills mutli-storey buildings etc., which may interfere with accurate weather readings or measurement.
5. Proper fencing required to prevent animals trampling, manvaiders etc. (fencing round the station with wire gauze is desirable for the security of instruments and proper air movement i.e. aeration).
6. Concretions or cementation of the floor or walls of the station is undesirable since these can prevent aeration and encourage abnormally high temperature
7. Provision of at least a security man required.
8. Provision of highly skilled personal(s) needed for regular and accurate measurements of weather variables.
9. Proper sanitation of the station required.
10. Repairs and replacement of instruments.

3.7 Basic aspects of agricultural meteorological observations

Observations of the physical and biological elements in the environment are essential in agricultural meteorology. Without quantitative data, agrometeology planning, forecasting and research will not be able to fulfill their full role in assisting agriculturalists to meet the ever-increasing global demands for food and agricultural by-products. The following sections provide guidance on the types of observation required, their extent, organization and accuracy as well as on the instruments needed to obtain the data.

3.7.1 **Physical climatic element**

Physical elements of climate are observed in order to evaluate the potential crop and animal production and to asses environmentally caused or favoured damage of agricultural products. Agricultural meteorology is concerned with every aspect of local and regional climates and the causes of their variations, thus making standard observation of climatic elements a fundamental necessity. It is also concerned with all climatic modification which may be introduced by human management of agriculture, animal husbandry or forestry operations. Such management includes determining the time, extent and manner of cultivation and other agricultural operations (sowing, harvesting, planting, shearing, mating, application of biocides and herbicides, ploughing, harrowing, rolling, irrigation, suppression of evaporation, repair and construction of buildings for storage and animal husbandry), and the different methods of conservation, industrialization and transportation of agricultural products.

3.7.2 **Biological element**

Besides the proper observation of the physical environment, the simultaneous evaluation of its effect on the objects of agriculture, i.e. plant, animals and trees, both as individuals and as communities, is also a prerequisite of agricultural meteorology. The routine observations provide by climatologically and agrometeorological stations should be supplemented by routine biological observation. For best results these observations should be comparable with those of the physical environment in extent, standard and accuracy. Non-routine biological observations, such as those required for research, surveys and special services are more precise and accurate than standard observations.

Biological observation should generally be of a phenological or phenometric nature, or both. Phenological observations are made to evaluate possible relations between the physical environment and the development of plants and animal while the phenometric type are made to relate the physical environment with biomass changes.

3.8 TYPES OF WEATHER STATION

The weather station is often called **meteorological station** or **meteorological enclosure** amongst other names. Therefore, based on the range of elements measured or observed and the frequency or intervals at which these elements are measured, the following types of weather station are identified;

(a). **RAINFALL STATION**: Rainfall is the only weather element measured here. It is usually manned by a part-time observer who takes daily readings of rainfall only. For this reason (measurement of only rainfall as the weather element), it is not mostly recognized as a reliable weather by meteorologists.

(b). **CLIMATOLOGICAL STATION**: It is also manned by a part-time observer who measures once or twice daily air temperature and humidity in addition to daily rainfall.

(c). **AGROCLIMATOLOGY STATION**: It manned by part-time observers who make twice or more daily instrumental observations like temperature, humidity, soil temperatures at various depths. Also, daily measurements of rainfall, wind speed and direction, evaporation, sunshine duration and radiation. Some of these weather elements may be autographically recorded.

(d). **SYNOPTIC STATION**: This is a station usually manned by full-time professional observers who maintain a continuous weather watching and record hourly instrumental observations of temperature, humidity, pressure, duration of sunshine, rainfall, cloud amount, wind speed and direction. These are the major climatic elements usually observed in synoptic stations. Some of these weather observations are autographically recorded. More so, some weather elements (such are evaporation, radiation and soil temperature), which are not required in the compilation of synoptic weather maps used for weather forecasting, are also recorded in a typical synoptic station.

3.8.1 Agroclimatology Station

According to paragraph (A 1.1) 2.5 of WMO Technical Regulations, each agricultural meteorological station belong to one of the following categories.

(a) **A principal agricultural meteorological station** is a station which provides detailed simultaneous meteorological and biological information and where research in agricultural meteorology is carried out. The instrumental facilities, range and frequency of observations, in both meteorological and biological fields, and professional personnel are such that fundamental investigations into agricultural meteorological questions of interest to the countries or regions concerned can be carried out.

(b) **An ordinary agricultural meteorological station** is a station which provides, on a routine basis, simultaneous meteorological and biological information and may be equipped to assist in research into specific problems; in general, the programme of biological or phenological observations for research will be related to the local climatic regime of the station.

(c) **An auxiliary agricultural meteorological station** is a provides meteorological and biological information. The meteorological information may include such items as soil temperature, soil moisture, potential evapotranspiration, duration of vegetative wetting, detailed measurements in the very lowest layer of the atmosphere; the biological information may cover phenology, onset and spread of plant disease, etc.

(d) An agricultural meteorological station for specific purposes is a station set up temporarily or permanently for the observation of one or several elements and or of specified phenomena.

Stations corresponding to (a) are not common because of their requirements for trained professionals, technical personnel and equipment. In most countries the majority of agricultural meteorological stations belong in categories (b), (c), and (d).

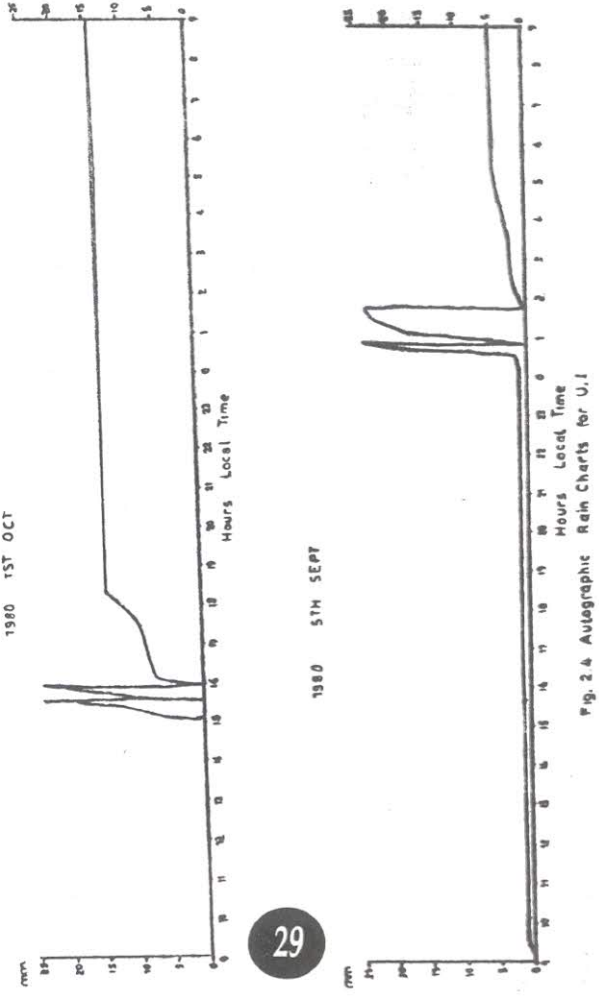


Fig. 2.4 Autographic Rain Charts for U.I

CHAPTER FOUR
WEATHER MEASURING INSTRUMENTS

4.1 INTRODUCTION

It is very important to note that weather elements vary with respect to time and space to be covered. Therefore, achieving a relatively and reliable data from these weather elements over time at a given location or area, measurements of the weather elements must be cumulatively done over a fairly long period of time range of between 30to 35 years. Homogeneity and consistency of data or records are crucial in order to achieve provision of reliable time series from which the synthesis of weather (i.e. climate) from such a given are or location can be accurately deduced. However, heterogeneity and inconsistency in the time series can be easily attributed to; (a) shifting of weather station from one place to another or an arbitrary changes in the location of a weather station (b) changes in the natural and or artificial (man-modified) environment which surrounds a weather station (c) breakdown of instruments (d) negligence or incompetence on the parts of the weather observers who record unreliable and irregular data for the weather elements (e) improper sanitation and maintenance which may create room for undesirable environments that can alter accuracy of instrumental readings at a given location and time.

It is therefore very important to ensure that a weather station is well located in a place whereby undesirable shifting/movement or erection of giant buildings or other structures around the station will be totally averted, over a given period of time. Also, proper maintenance of the station and regulation data collection (using appropriate well functioning instruments by dedicated observers or workers) is highly relevant to acquisition of consistent data from a weather station.

Geographical variations influence the values recorded from different weather parameters. So, many weather stations will be required to take care of such geographical variations in any agrometeorological study of a given location or area. **NETWORK DENSITY** which relates to the issue of the number and distribution of weather stations that will be required as being adequate for a spatial sampling of the weather elements to be measured in a given area and time. Furthermore, in a given area of uniform terrain a number of weather stations should be uniformly or randomly distributed whereas, in an area with irregular or varied topography the hilly area expected to have more weather stations than areas with flat terrain. This is simply because more rapid geographical variations are observed in the values of weather elements over an area of varied topography than of flat topography, as shown in the table below.

Table 6: Minimum density of rainguage network

Types of region	Normal tolerance (Area of one station)	Tolerance under difficult conditions (area for one station)
Flat areas of temperature Mediterranean and tropical zones mountainous areas of Temperature.	600-900km^2	900-3000km^2
Mediterranean and tropical zones	100-250 km^2	250-2000km^2
Small mountainous islands with irregular precipitation	25km^2	
Arid and polar zones	1,500-10,000km^2	

Source: (W.M.O 1970).

It is very important to state that besides inherent geographical variability, other factors which affect network density include: (a) availability of manpower (b) finance (c) accessibility of the weather stations (d) security of weather instruments and (e) level of sophistication of the instruments and (f) competence and dedicativeness of the observers. In recent years, use of automatic (self-recording) weather instruments has become very common particularly in remote locations. These self-recording (autographic) instruments can be left on the field to work on their own for about three (3) months. The most common problems associated with these automated instruments are; (a) high cost of purchase (b) security e.g. from theft, animals trampling vandalization, fire outbreaks etc. among others, particularly in the developing countries.

4.6 DETAILED WEATHER MEASUREMENTS

Weather elements are generally measured with the aid of weather instruments which have different levels of sophistication. Such measurements therefore may be manually carried out or autographically (automatically or self-recording) done. The autographic instruments present the continuous measurements of weather elements (usually for 24hours) in form of graphs.

Table7: Differences between manual and autographic weather instruments

MANUAL INSTRUMENT	AUTOGRAPHIC INSTRUMENTS
1. It is usually hand-operated.	It works by itself (antomatic).
2. Requires services of more personnel's	Lesser personnel are required.
3. It provides only the record of the measured parameter at a given period of time.	It provides a continuous record of the measured parameters for up to 24hours without human interference.
4. It is usually cheaper	It is very expensive.
5. It is more sturdy and less fragile than automatic	Usually more fragile than manual.
6. It provides lesser information because it measures lesser parameters	It measured many weather elements at a time and provides more information.

4.2 SYNOPTIC HOURS

These are referred to as the universally acceptable hours for measuring weather variables or elements. At these hours distinct variations in the values of the parameters measured are usually expected. These hours are:

1. 0600 Green Meridian Time (GMT) or 6a.m.
2. 1200 Green Meridian Time (GMT) or 12p.m.
3. 1800 Green Meridian Time (GMT) or 6p.m.
4. 0000 Green Meridian Time (GMT) or 12a.m

4.3 MEASUREMENT OF PRECIPITATION

Precipitation simply refers to any aqueous particles or deposits descending from the atmosphere e.g. rainfall, snow, hail, dew, frost etc. However, in the tropics precipitation is often regarded as rainfall i.e. they can be used interchangeably (because rainfall is the commonest form of precipitation). Rainfall is measured by a RAINGUAGE. The first rainguage was made by CASTLLI in Italy in the year 1939. Castelli's rainguage provided the basic relevant features from which modern rainguages are now designed. Modern rainguages are strictly the improved modifications of the Castelli's rainguage. A typical rainguage will collect rainfall over a funnel of known specific area (usually limited by its rim), over a given period of time. The collected quantity of rain water is then poured into a graduated measuring jar graduated in units of millimeters (mm). Rainguage provides accurate information on the total quantity or volume of rain that falls between two observations of times. The size of rainguage orifice and the exposing height of the rim of the guage vary from one country to another but the United Kingdom meteorological office mark II guage with a 125mm aperture and 300mm rim above the ground respectively are commonest. The amount of rainfall caught by a rainguage can be affected by:

(a) sitting of the rainguage (b) exposure of the rim (c) wind speed (d) available obstructions e.g. tall trees, buildings etc. (e) biological interference e.g. animals, insects, birds etc. may cover the orifice (f) evaporation losses usually in the tropics or during summer season in the temperate zone usually accounts for 1% reduction of the total amount. This amount is somehow negligible but incessant re-evaporation of the collected rain can be a serious problem in a hot sub humid environment.

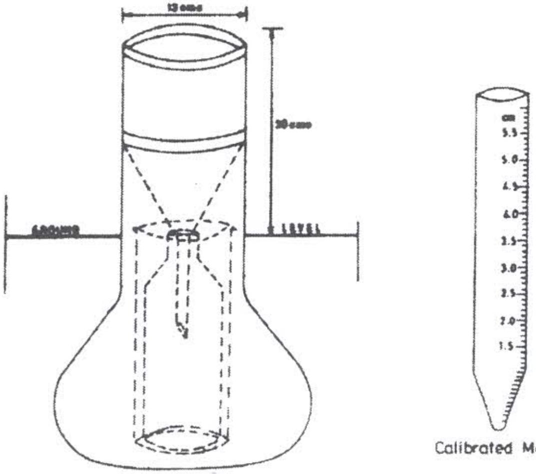
An ordinary rainguage or manual rainguage provides information only on the total amount of rain that falls between two observation times but, autographic rainguage or self recording will in addition to the total amount of rainfall within a specified period, supply other information such as the beginning, the end, intensity and duration of the rainfall.

We can compute the rainfall intensity, duration of the rainfall and the total rainfall contrary to the ordinary rain gauge.

By calculation, rainfall intensity = $\frac{\text{rainfall amount}}{\text{Duration}}$

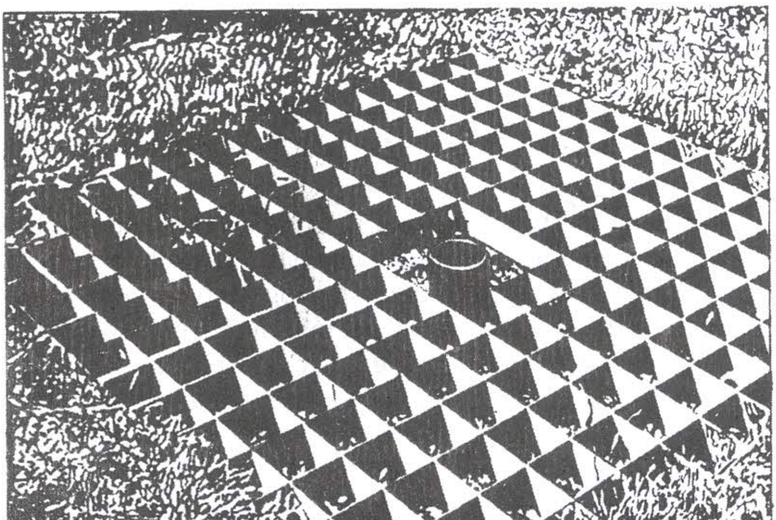
The rainfall intensity tells us more about the soil erosion. High intensity rainfall may cause flooding. The precaution to take when using rain gauge.

The height of the rain gauge above the ground should be 1 feet 6 inches. The higher the height above the ground, the less the amount of rainfall collected. If the rain gauge is on ground level runoff water or flooded water may get into the funnel. To avoid this, dig the ground and allow some space between the rain gauge and the ground and place at 1ft 6 inch above ground level.



Calibrated Measuring Jar

Fig. 2.2 : Rain Gauge



4.3.1 MEASUREMENT OF AIR TEMPERATURE

Ambient temperature or air temperature is usually manually measured with the aid of MINIMUM AND MAXIMUM THERMOMETERS. Also, it could be measured autographically by using a THERMOGRAPH. Generally, the thermometers and the thermography are housed in a STEVENSON SCREEN, which is a white wooden louvred cupboard with a hinged door usually mounted on a steel or timber stand to raise its base to about 1metre above the ground level. The white painting prevents undesirable absorption of solar radiation by the shelter while the louvred sides and hinged door allow proper ventilation and openings of the Stevenson screen. These thermometers give a very close approximation measurements to the true undisturbed air temperature at a given period of time i.e. true air temperature prevented from the unwanted effects of direct solar or terrestrial radiation. The maximum thermometer is a specially built thermometer i.e. a mercury-in-glass thermometer having a small glass index which the mercury pushes along when the air temperature rises but leaves behind when temperature falls. The maximum temperature is therefore read at the terminal end of the index nearer the mercury. The index is then brought back to normal mercury level by tilting the thermometer after every observation or reading and recording. The minimum thermometer is called an alcohol-in-glass thermometer in which the alcohol expands and flows past the index whenever the temperature rises. The alcohol contracts and drags the index back (because of its surface tension) whenever the temperature falls. The minimum temperature can therefore be easily read or observed at the end of the index nearer the meniscus. Simple tilting of the thermometer will reset the instrument. In conclusion, the maximum and minimum thermometers are used at weather stations to measure the HIGHEST and LOWEST temperatures within the day respectively. More so, an ordinary mercury-in-glass thermometer (with or without index) can be used at any given time to measure the air temperature.

Thermograph (a self-recording thermometer) measures continuously the air temperature. The commonest type is BIMETALLIC THERMOGRAPH containing a bimetal strap wound into a spiral shape which uncoils as the temperature rises. However, tracing of a graph of the air temperature on a graph which is equally wound round a clock-driven drum is perfectly done by a pen which is permanently attached to the spiral movement.

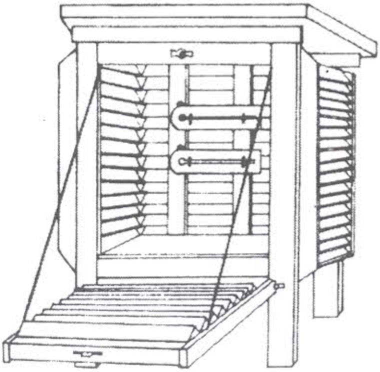
Generally on thermometers temperatures are marked in one or two ways. For most scientific purposes the centigrade ^{0}C scale id preferred. Its freezing point is $0^{0}C$ and it's boiling - point is $100^{0}C$. In ^{0}F (Fahrenheit) the freezing - point is $32^{0}F$ and the boiling - point is $212^{0}F$. For rapid conversion of one scale to another, the following formulae may be used.

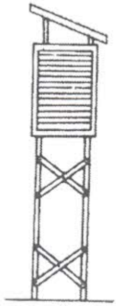
To obtain centigrade = $(^{0}F - 32 \div 1.8)$ e.g. to convert $120^{0}F$to centigrade:

$(120^{0} - 32^{0}) \div 1.8 = 88 \div 1.8 = 48.9^{0}C$

To obtain Fahrenheit = $(1.8 \times {}^{0}C) + 32^{0}F$ e.g. to convert $60^{0}C$ to Fahrenheit $(1.8 \times 60^{0}C) + 32^{0}F = 108^{0} + 32^{0} = 140^{0}F$.

Precautions must be taken when using thermometer in the open field to exclude the intensity of the sun's radiant heat. This is done by placing the thermometers in a standard meteorological shelter known as the Stevenson screen.





Side View of the Stevenson Screen

Fig-2-6: The Stevenson Screen

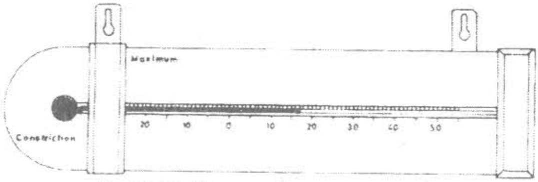


Fig 2 7 The Maximum Thermometer

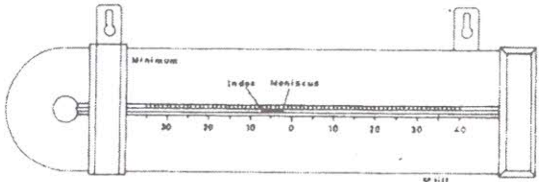


Fig. 2.8: The Minimum Thermometer

4.3.2 MEASUREMENT OF HUMIDITY

The water vapour content of the atmosphere is usually termed HUMIDITY. Humidity is therefore measured as follows (based on some indices);

(a). **RELATIVE HUMIDITY**:- This refers to the ratio of the actual amount of water vapour in a sample of air to that which the same volume sample of air can hold at the same temperature and pressure when fully saturated. It is usually expressed in percentage (%).

(b) **ABSOLUTE HUMIDITY**:- Refers simply to the total mass of water vapour in a given volume of air expressed in grammes per cubic meter of air.

(c). **SPECIFIC HUMIDITY**:- The mass of water vapour per kg of air including the water vapour in it.

(d). **VAPOUR PRESSURE**:- Refers to as the exerted pressure by the water vapour content of the atmosphere. It is usually expressed in millibars.

(e). **DEW POINT TEMPERATURE**:- This refers to the temperature of a parcel of air at which full saturation will take place. provided it is cooled at constant pressure without the addition or removal of water vapour.

(f). **MASS MIXING RATIO OR HUMIDITY MIXING RATIO;** Refers to the mass of water vapour per kg of dry air (i.e. the air containing no water vapour).

However, the most commonly used index for measuring humidity is relative humidity. It is easier to understand and compute relative humidity with the aid of dry and wet bulb thermometers. R.H gives the degree of saturation of the air i.e. indicates how closely the air is to full saturation or how close to saturation the air is the relative humidity of air increases as the temperature decreases or decreases as the temperature increases even though there has not been any increase or decrease in its moisture content. It should be noted that, relative humidity provides no information about the quantity of moisture in the atmosphere but only indicates how close to saturation the air is manual measurement or relative humidity of the air is done with the aid of WET and DRY-BULB thermometers together in the same container also known as PSYCHROMETER. It is kept in the Stevenson screen. The dry bulb thermometer is the ordinary mercury-in-glass thermometer which measures the normal air temperature (Td) while the wet bulb, which has its bulb covered with musclin or wick perpetually wetted with pure water, gives the wet bulb reading (Tw) which in unsaturated air is less than the dry bulb temperature. This is because the latent heat required to evaporating water from the musclin wick is supplied by air in contact with the wet bulb.

Therefore, Td-Tw = wet bulb depression i.e. the difference between the two readings (Td-Tw) is simply referred to as the wet bulb depression. So, the drier the atmosphere, the greater the difference or the wet bulb depression. Hygrometric tables are used to obtain the actual values of vapour pressures, dew point and relative humidity from the dry and wet bulb thermometers readings. HYGROGRAPH is a self-recording hygrometer which measures the relative humidity of air at a given location and time. HAIR HYGROGRAPH which uses the principle of increasing relative humidity in its design. It records in form of graph the continuous variations in air humidity over a 24-hour period or possibly a week depending on the graph paper type that is wound round the clock-driven drum or pen contained in the hygrograph.

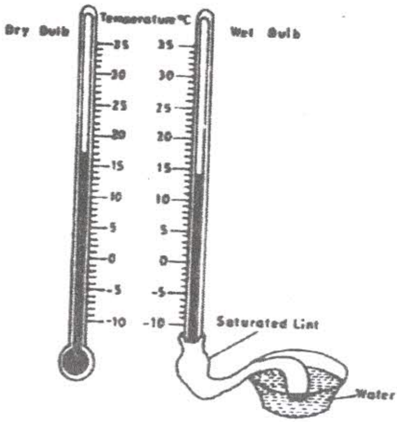
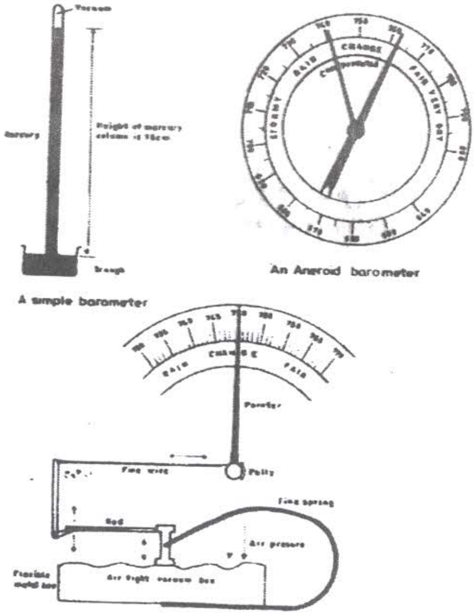


Fig.2·9: The 'wet' and 'dry' bulb hygrometer



A simple barometer

An Aneroid barometer

The mechanism of an Aneroid barometer

Fig. 2·10: Barometers

4.3.3 MEASUREMENT OF WIND SPEED

CUP ANEMOMETER which consists of three or four cups (which may be hemispherical or conical in shape) is used for measuring the wind speed in a given area or location of a particular time. These cups are normally mounted symmetrically about a vertical axis and rotate the according to the prevailing wind speed. In the cup generator anemometer the rotating cups will generate a voltage that records on a dial calibrated in knots, miles or kilometers per hour. More so, in the CUP-COUNTER or RUN-OFF WIND anemometer, the integrated flow of the air in miles or kilometer, the registered on a COUNTER. However, in the case of cup-counter or run-off-wind anemometer, the actual wind speed is obtained by dividing the differences in wind runs between two observation times by the intervening period of time, usually 24hours. ANEMOGRAPH is a self-recording anemometer which produces (in form of graphs) a continuous record of wind speed or velocity over a given period of time. in a given location.

4.3.4 MEASUREMENT OF WIND DIRECTION

Wind direction is observed as the direction of wind blowing. This is measured with the aid of WIND VANE, which consists of a horizontal arm pivoted on a steel spinite with a pointer placed at one end, which shows the direction of wind movement at a given location and time.

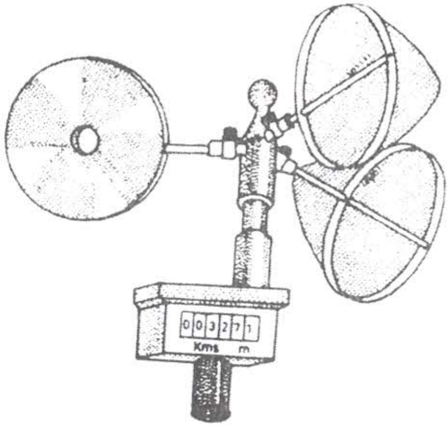


Fig. 2.11a : A three - cup anemometer.

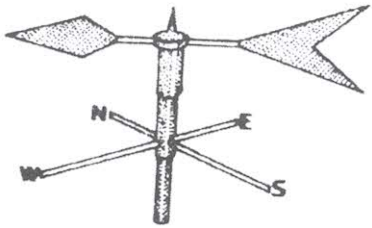
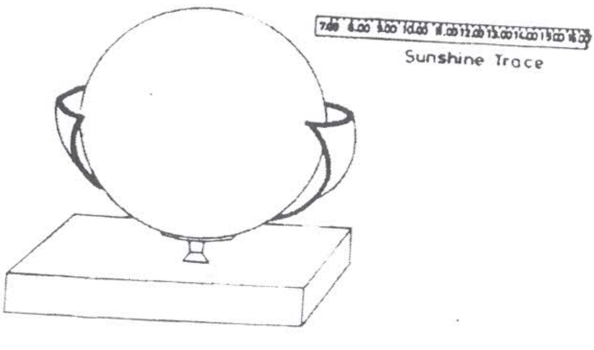


Fig. 2.11b : Wind direction Indicator (Wind vane)



4.3.5 MEASUREMENT OF SUNSHINE DURATION

The duration of sunshine in a day (in hours and minutes) can be easily measured with the aid of CAMPBELL - STOKES SUNSHINE RECORDER. This instrument consists of a glass sphere which focuses directly at the sun rays. The glass sphere is placed on a sensitized card, which is usually graduated in hours and minutes and held in a metal half-bowl with which the sphere is concentric. The instrument is mounted in the open on a concrete pillar of about 1.5m above the ground. More so, whenever there is sunshine, the intensity or the brightness of the solar radiation activity traces/creates a burnt line along the sensitive card i.e. the bright sunshine radiating at a given time leaves behind a sharp burning line which indicates the duration of such active sunshine radiation, whereas the sensitized card remains blank and unaffected throughout the cloudy periods. Measurement or determination of the total length of the burnt traces on the sensitive card will now be regarded as the total duration of sunshine (in hours and minutes) for the day, in a given area.

4.3.6 MEASUREMETNT OF AIR PRESURE

Millibars are generally the units of measurement of atmospheric or air pressure. Air pressure is measured with the aid of MERCURY or ANEROID BAROMETER. Also, a self-recording barometer known as BAROGRAPH can be used to provide a continuous record of the air pressure measured in a given location. Aneroid barograph is commonly used but a non-portable barograph found in some weather stations is the FLOATING TYPE BIOGRAPH in which the movements of the embedded mercury in a recording pen through a float. As earlier indicated, manually determined air pressure is by mercury or aneroid barometer. The two most common types are FORTIN TYPES and FIXED

CISTERN TYPES (or KEW pattern barometer). Mercury barometer balances the atmospheric pressure against that of mercury column weight whose length is usually graduated in pressure units. More so, aneroid barometer is very portable compact and easier to use at seas or in the field than the mercury barometer but its operation is less reliable. Aneroid barometer containing a closed metal chamber (which is completely or partially evacuated) and a strong spring system that strengthtens the chamber against collapsing from the external atmospheric pressure. An equilibrium is always maintained between spring force and external pressure which is well indicated on the dial.

4.3.7 MEASUREMENT OF SOIL TEMPERATURE

Soil thermometers are used for measuring the soil temperature at various depths. The most common types are MERCURIAL THERMOMETERS, which contains bulbs embedded in paraffin wax. In operation the thermometers are usually suspended in STEEL TUBES and carefully inserted into the soil at desirable depths. The are usually 5cm, 10cm, 20cm, 50cm and 100cm. Mercurial thermometers with stems bent at a right angle (for easy readings) are used for a shallow depth range of 5-20cm while a stronger mercurial thermometer are used for a deeper depth range.

THE GRASS MINIMUM THERMOMETER is used for determining the grass minimum temperature. This thermometer is usually placed in an opened field at night and its bulb is then allowed to directly touch the tips of grass blades in a given meteorological enclosed. If the temperature recorded by the thermometer is below $0^{0}C$, a ground frost is said to occur. Determination of soil temperature is essential since it affects areas like seed germinations, root development, microbial activities, nutrients availability etc.

4.3.8 MEASUREMENT OF EVAPORATION

Evaporation simple means the removal of water molecules (in form of water vapour) from soil surfaces and water bodies which will be transported up wardly into the atmosphere i.e. evaporation takes place on a bare ground and water surfaces. However on vegetated ground or surfaces, both evaporation and transpiration takes place concurrently. Transpiration is the removal of excess water (in form of water vapour) from plant surfaces e.g. stomata of leaves lenticels of stems. The process of water losses from a vegetated surface is called EVAPOTRANSPIRATION. Evapotranspiration therefore involve water losses (sum total) by evaporation (water and soil surfaces) and transpiration (plant surfaces).

Evaporimeters are used for measuring evaporation. Two major types of evaporimeters are available (i) those whose evaporation takes place from a free water surface such as tanks or pans e.g. evaporation pans tanks and (ii) those in which evaporation takes place from a continuously wetted porous surface of blotting-paper, fabric or ceramic materials e.g. piche evaporimeter. Piche is kept in a Stevenson screen. It contains graduated measuring cylindrical tube closed at one end (with certain volume of water). A disk of filter paper is attached to the open end. The paper is kept continuously moist by a wick connected to a small water container. The amount of water lost by evaporation in a given by the interval can be calculated/determined of water successive measurements of the quantity of water remaining in the graduated tube. Piche evaporimeter has been criticized as measuring the drying power of the air not the desire amount of water lost by evaporation to the atmosphere. This creates a better room for more appropriate and reliable instruments called EVAPORATION PANS, which are now commonly, used most of the weather station. Evaporation pans vary n sizes shapes and exposure mode and manner. Three commons types are; (a) United State weathers Bureau (USWB) class a pan (b) the raised tank and (c) the sunken tank. World Meteorological Organization (WMO) has recommended the USWB class a pan for world-wide use.

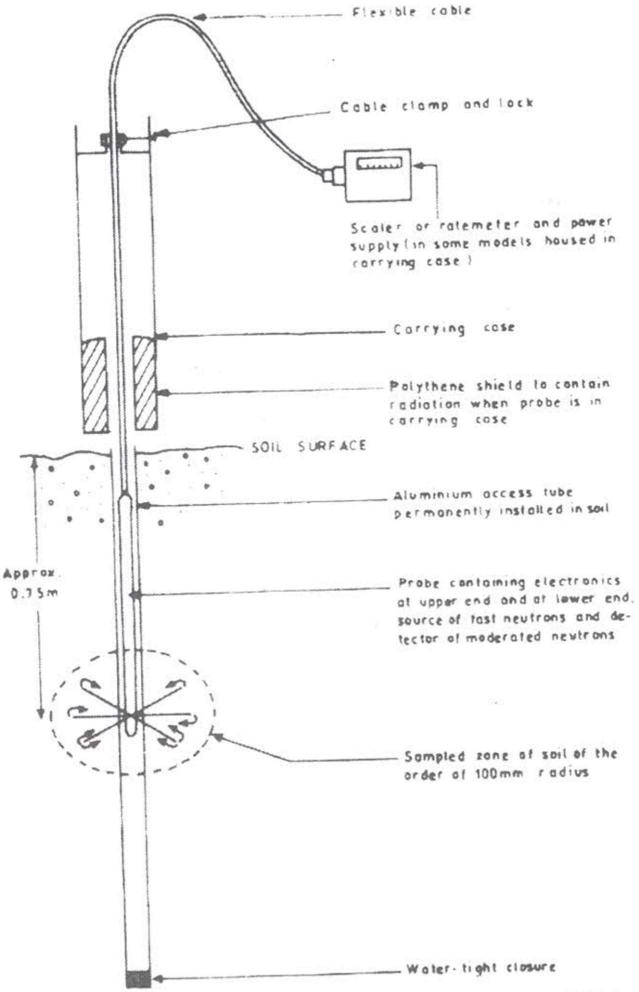
(a). It has a cylindrical pan with a diameter of 1206mm and 2-54mm deep. It is filled with water to within 51mm of the rim and mounted on a wooden platform so that the water surface within the pan is 305mm above the ground. It is usually painted aluminum white

(b). The raised tank is a rectangular tank 1270mm long, 915mm wide and 432mm deep, filled with water to within 76mm of the rim and raised above the ground on a wooden platform so that the water surface is about 457mm above the ground. It is usually painted black.

(c). The sunken tank is 1829mm square with the water level at the ground level and a rim of 76mm protruding above the ground to disallow rainwater inflow.

All evaporation pans employ the same principle to measure evaporation rate. The pan or tank is filled with water to the required level and left in an open place free from obstructions, in the meteorological station. After 24hours, the water level is checked. The water level is expected to have reduced, due to evaporation (except rain falls). The pan is reset/refill with water to the appropriate level/original level the amount of water added for resetting is referred to as the amount of water lost by evaporation, during the intervening period.

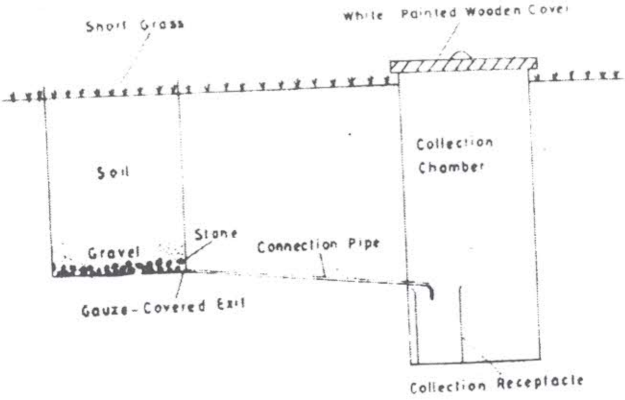
Apart from wind and rainfall, other sources of error in pan-measured evaporation values comes from the activities of birds, lizards and frogs which may drink from the water available in the evaporation pans. Also, animals (castle, sheep and goat) may trample on or drink the water wire fencing or covering of evaporation pan with wire mesh can control this quality of water poured in the pan may be a source of error in the measurement of evaporation. Saline only dirty or turbid water tends to affect the evaporation process. Fresh and clean water is therefore recommended.

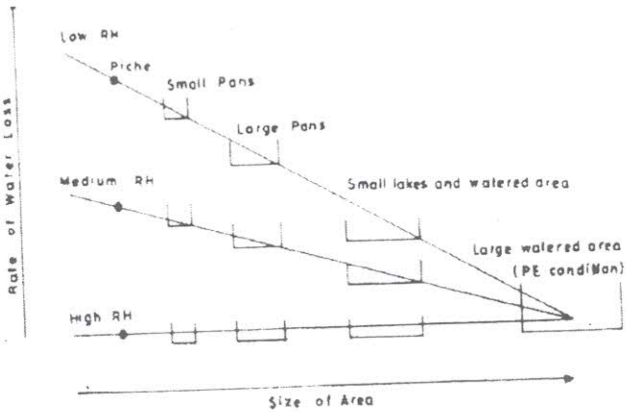


(after Winter 1974)

14.3.9 MEASUREMENT OF EVAPOTRANSPIRATION

The rates of evapotranspiration over a given surface area are measured with the aid of LYSIMETERS. Two types exist; (a) the weighting lysimeter and (b) the drainage lysimeter. The weighting lysimeter consist of a tank filled with both soil and vegetation similar to that in the surroundings and it is supported by a weighting mechanism. It is a sophisticated device in which evapotranspiration values are obtained indirectly by calculating changes in the weight of the SOIL-VEGETATION system within the tank over a specified period of time (usually 24hours), to obtain daily values of evapotranspiration. It is used to measure the actual evapotranspiration since the soil-vegetation system in the tank and the surroundings are not necessarily kept at field capacity. The drainage lysimeter can be easier constructed and it is more widely used. The drainage lysimeter is also called the EVAPOTRANSPIROMETER or the PERCOLATION GUAGE. It operates on a simple water balance basis which is that evapotranspiration is the difference between water input in form of rainfall and irrigation if necessary and water output in form of percolation and runoff in a soil plant system. Oil drums and pipes can be used to construct thornthwaite model which is a popular design. The drainage lysimeter is normally used for measuring the rates of POTENTIAL EVAPOTRANSPIRATION. Hence, it is important to keep the tank and the surrounding area continuously moist by irrigation.


Short Grass
White Painted Wooden Cover
Soil
Collection Chamber
Stone
Gravel
Connection Pipe
Gauze-Covered Exit
Collection Receptacle


Low RH
Piche
Small Pans
Large Pans
Medium RH
Small lakes and watered area
Large watered area
(PE condition)
High RH
Rate of Water Loss
Size of Area

4.3.10 **MEASUREMENT OF RADIATION**

Different instruments are used in measuring radiation in diversed ways. These instrument measure different components of the earth's radiation balancing the equation viz.

$$Rn = (Q + q)(I - \&) + I \quad - I$$

Where Rn = net radiation (Q + q) = sum of the shortwave direct (Q) and diffuse (q) solar radiation incidents on the earth's surface; & = albedo of the earth's surface, I = counter radiation from the atmosphere which is long-wave (infrared) and I = terrestrial radiation which is also long-wave or infrared.

Five (5) basic types of radiation measuring instruments are identified.

(a). NET RADIOMETERS: They measure only the net radiation.

(b). ALBEDOMETERS: This measures only the albedo of a surface.

(c). PYRANOMETERS: These measure the total short wave radiation from the sky incident on a horizontal surface at the ground.

(d). PYRRADIOMETERS: These measure both infrared and short-wave solar radiation together.

(e). PYRGEMETERS: These measure infrared or long-wave radiation from the earth's surface or the atmosphere depending upon.

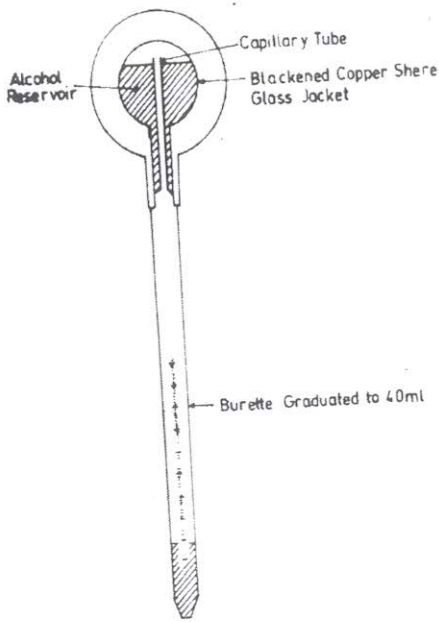

Capillary Tube
Alcohol Reservoir
Blackened Copper Shere
Glass Jacket
Burette Graduated to 40ml

Table 8: Some weather elements and the instruments used in measuring them

WEATHER ELEMENTS	INSTRUMENTS FOR MEASUREMENT
1. Rainfall	Rain gauge
2. Wind speed	Anemometer
3. Wind direction	Wind vane
4. Air temperature	(a) minimum and maximum thermometer (Manually) (b) Thermography (Autographically).
5. Relative humidity	(a) Psychrmometer (containing wet and dry bulb thermometers) i.e. manually. (B). Hygrometer or Hygrograph (i.e. autographically).
6. Air pressure	Mercuric or aneroid barometer.
7. Duration of sunshine	Campbell-stokes sunshine recorder
8. Soil temperature	Soil thermometers
9. Evaporation	Evaporimeters.
10. Evapotranspiration	Lysimeters
11. Radiation measuring instruments (a) solar intensity or direct beam solar radiation (b) infraved and short-wave solar radiation (c) Net radiation (d) Albedo of a surface (e) Total short wave radiation from the sky incident on a horizontal surface at the ground (f) infrared and Long-wave radiation.	(a) Pyrheliometers (b) Pyrradiometers (c) Net radiometers (d) Albedometers (e) Pyranometer (f) Pyrgeometers.

CHAPTER FIVE
CLIMATE AND AGRICULTURE

5.1 Climate types and Agriculture

There are 5 major climate groups which correspond to 5 principal vegetation groups. This classification is according to copper. These are as follows:

Table 9: Classification of vegetation as affected by climate.

CLIMATE TYPES	LOCATION	TEMPERATURE	VEGETATION
i. Tropical Forest	Central Africa Asia Central America, South America	Uniformly high	Dense, broad leaf, evergreen tress, epiphytes
ii. Tropical Savanna	Northern Australia south and Eastern Asia, Central And Southern America	Temperature is controlled by tropical location Sun angle and day Length	Savanna grass land with spaced tree.
Iii. Tropical Monsoon	India, South America South-east Asia.	As in (ii)	Forest type with 10k Density trees shrib.
2. Dry Climate			
i. Stappe	Africa, South America, Australia	Temperature controlled by Interior location.	Grassland with scattered shrubs and stinted trees.
ii. Desert	Africa, South America Australia	Temp. Controlled by dry air and Radiational cooling	Xerophytes structures and texture inhibit evaporation.
3. Mesothermal			
i. Humid subtropical	South East America, Australia China	By sun angle, warm and Ocean	Broad leaf and conifers
ii. Dry Summer	California South Australia, South Africa	By cold current	Dense cover moderate trees
iii. Marine West coast	North Europe, Columbia South Africa.	By marine influe-nce of onshore	Soft woods e.g. Douglas fire, hemlocks.
4. Humid microthermal	East Europe, China, USA	By day length	Mixed forest.
5. Highland	Greenland	By land water Distribution	Sparse trees and shrubs

The climates 1, 3, and 4 are relatively wet whereas the 2 and 5 climates and are relatively dry. The semi-permanent high and low pressure systems influence the longitudinal distribution of climate patterns.

Cool weather predominates in high latitudes and warm weather in the low latitudes because distance from the equators is the major control of climate. The angle of incidence for isolation changes with changing latitude so the sun shines with less intensity on an area at higher latitudes than or lower latitudes. Altitudes offsets the effects of latitude.

5.2 **Effect of climate change on Agriculture**

Analysis of the impacts of climate change suggests that agro-ecological systems are the most vulnerable sectors. Agriculture in low latitude developing countries is expected to be especially vulnerable because climates of many of these countries are already too hot. Further warming is consequently expected to reduce crop productivity adversely. These effects are exacerbated by the fact that agriculture and agro-ecological systems are especially prominent in the economies of African countries and the systems tend to be less capital and technology intensive. Predictions of impacts across regions consequently suggest large changes in the agricultural systems of low latitude (mostly, developing) countries.

Agriculture is undoubtedly the most important sector in the economies of most non-oil exporting African countries. It constitutes approximately 30% of Africa's GDP and contributes about 50% of the total export value, with 70% of the continent's population depending on the sector for their livelihood.

Production is subsistence in nature with a high dependence on the rain. The debate on climate change and its impacts on agriculture are therefore very crucial to the very survival of the continent and

hange because it includes some of the world's poorest nations. The climate in Africa is predominantly tropical in nature, which is broadly classified into three main climatic zones:
humid equatorial, dry, and humid temperate. Within these zones, altitude and other localized variables also produce distinctive regional climates. The climate also varies cyclically over periods of decades, centuries, and millennia as well as from year to year. Climate change, especially indicated by prolonged drought is one of the most serious climatic hazards affecting the agricultural sector of the continent. As most of the agriculture activities in African countries hinges on rain fed, any adverse changes in the climate would likely have a devastating effect on the sector in the region, and the livelihood of the majority of the population.

Though changes in the climate may affect the whole continent, its distribution may vary across the continent. Climate change in the already arid northern sub-region of the continent is expected to enhance desertification and bring a gradual decrease in forest cover. In the Sahara and Sahel sub-regions, rainfall is predicted to drop, resulting in soil degradation and an increasing number of dust storms. In northeast Africa, more intense dry periods and shorter wet seasons are expected to affect even huge river systems such as the Blue Nile, leading to serious water shortages and adverse consequences for the agriculture and forestry sectors throughout the region. East and Central Africa will also see its agricultural capacity decline. In West Africa, more frequent and longer dry periods are expected, again threatening crop failures. Coastal areas may also be affected by rising sea levels and intrusion of salt water into inland freshwater resources. Southern Africa also faces similar threats. The staple food for the region, maize, is particularly susceptible to drought. Wetlands of international importance and wildlife are also under threat from drought in Southern Africa. Climate change, therefore, is expected to worsen the food supply, hence, exacerbate

The widespread poverty in the region. Five main climate change related drivers: temperature, precipitation, sea level rise, atmospheric carbon dioxide content and incidence of extreme events, may affect the agriculture sector in the following ways:

- Reduction in crop yields and agriculture productivity: There is a growing evidence that in the tropics and subtropics, where crops have reached their maximum tolerance, crop yields are likely to decrease due to an increase in the temperature.
- Increased incidence of pest attacks: An increase in temperature is also likely to be conducive for a proliferation of pests that are detrimental to crop production.
- Limit the availability of water: It is expected that the availability of water in most parts of Africa would decrease as a result of climate change. Particularly, there will be a severe down trend in the rainfall in Southern African countries and in the dry areas of countries around Mediterranean Sea.
- Exacerbation of drought periods: An increase in temperature and a change in the climate throughout the continent are predicted to cause recurrent droughts in most of the region.
- Reduction in soil fertility. An increase in temperature is likely to reduce soil moisture, moisture storage capacity and the quality of the soil, which are vital nutrient for agricultural crops.
- Low livestock productivity and high production cost: Climate change will affect livestock productivity directly by influencing the balance between heat dissipation and heat production and indirectly through its effect on the availability of feed and fodder.

- Availability of human resource: Climate change is likely to cause the manifestation of vector and vector born diseases, where an increase in temperature and humidity will create ideal conditions for malaria, sleeping sickness and other infectious diseases that will directly affect the availability of human resources for the agriculture sector.

The impact of these adverse climate changes on agriculture is exacerbated in Africa by the lack of adapting strategies, which are increasingly limited due to the lack of institutional, economic and financial capacity to support such actions.

Africa's vulnerability to climate change and its inability to adapt to these changes may be devastating to the agriculture sector, the main source of livelihood to the majority of the population. The utmost concern should therefore be a better understanding of the potential impact of the current and projected climate changes on African agriculture and to identify ways and means to adapt and mitigate its detrimental impact.

5.3 How will climate change affect agriculture?

5.3.1 Soil processes

The potential for soils to support agriculture and distribution of land use will be influenced by changes in soil water balance:

Increase in soil water deficits i.e. dry soils become drier, therefore increased need for irrigation but:
Could improve soil workability in wetter regions and diminish poaching and erosion risk

5.3.2 Crops

The effect of increased temperature and CO_2 levels on arable

Crops will be broadly neutral:

*	The range of current crops will move northward
*	New crop varieties may need to be selected
*	Horticultural crops are more susceptible to changing conditions than arable crops
*	Field vegetables will be particularly affected by temperature changes
*	*Phaselous* bean, onion and sweet corn are most likely to benefit commercially from higher temperatures
*	Water deficits will directly affect fruit and vegetable production.

How will climate change effect cropping in tropical and arid Countries?

5.3.3 **Grasslands and livestock**

*	There is unlikely to be a significant change in suitability of Livestock
*	Pigs and poultry could be exposed to higher incidences of heat stress, thus influencing productivity.
*	Increase in disease transmission by faster growth rates of pathogens in the environment and more efficient and abundant vectors (such as insects)
*	Consequences for food quality and storage

5.3.4 **Weeds, pests and diseases:**

Weeds evolve rapidly to overcome control measures; short-lived weeds and those that spread vegetatively evolve at the greatest rate:

Grassland and arable weeds could become more tolerant to control measures

*	Rate of evolution will increase in hotter, drier conditions and in 'extreme years', could lead to some types of herbicide tolerance becoming more common
*	Possible increase in the range of many native pests, and species that at present are not economically important may become so
*	Surveillance and eradication processes for other significant Pests, will become increasingly important

TABLE 10: Predicted effects of climate change on agriculture over the next 50 years

Climate Element	Expected change by 2050's	Confidence in prediction	Effects on agriculture
CO2	Increase from 360 ppm to 450-600ppm	Very	Good for crops: increa-sed photosynthesis: Reduced water use.
Sea level rise	Rise by 10-15cm Increased in south and offset in north by natural subsistence /Rebound	Very high	Loss of land, coastal erosion, floodin, salinisation of ground-water
Temperature	Rise by 1-20C. Winers warming more than Summers. Increased Frequency of heat Waves	High	Faster, shorter, earlier growing seasons, range moving north and to higher altitudes. heat stress risk. increased Evapotranspiration. Impacts on drought risk
Precipitation	Seasonal changes by ± 10%	Low	Workability, water logging irrigation supply transpiration.
Storminess	Increased wind speeds especially in north. More intense rainfall Events.	Very low	Lodging, soil erosion, reduced infiltration of rainfall
Variability	Increases across most climatic variables. Predictions uncertain	Very low	Changing risk of dama-events (heat waves, frost, droughts floods) which Effect crops and timing Of farm operations.

It should by now be very clear that climate affects agricultural production in diverse ways either directly or indirectly. Climate must therefore be taken into account in the planning of agricultural development of an area. Apart from knowledge of the amount and temporal and spatial patterns of the major climatic elements such as radiation, air and soil temperatures, precipitation, sunshine duration, evaporation and relative humidity which influences agriculture, knowledge of derived climatic indices from water and heat balance studies is also required. For example, through water balance studies we can obtain information on the water relations in a given area and derive measures of actual evapotranspiration, water deficit, water surplus, soil moisture deflect and other parameters useful in agricultural decision making regarding choice of crops sowing dates and irrigation scheduling amongst others.

Knowledge of the microclimate of crops can assist in creating a better environment for the growth of crops. This can be done through:

(i). Application of irrigation water in the right amount and at the right time.

(ii). Planting of shelter belts to reduce wind speed, reduce rates of transpiration or trap snow and in temperature region by.

(iii). Increasing soil temperatures in spring by dusting with soot and

(iv). Planting in favoured slopes to intercept more radiation for crop growth. Knowledge of agroclimatology can also assist in changing the response of a crop species to its environment or selecting species, which will give the best yield in a given climatic environment.

In summary, the usefulness of agro-climatological studies in agricultural planning and development can be summarized as follows:

- Optional timing of agricultural operations such as land preparation, planting, weeding, harvest storage, marketing.
- Selection of suitable sites for given crops or of suitable crops for given sites.
- Control of crop and animal pest and diseases.
- Control and management of weather phenomena which constitute hazards to agriculture.
- Assessment or determination of the desirability or otherwise of irrigation agriculture and the irrigation needs of crops.
- Forecasts of crop yield to assist the formulation of polices relating to the procurement, distribution, imports, exports and prices of foodstuffs.
- Forecast of impact of climate change on agricultural production and
- The design of appropriate response strategies to ensure food security.

There is therefore great need for agroclimatological studies to improve agricultural production and ensure food security particularly in the less developed countries of the world where food shortages and food insecurity are rampant. Meteorologists and agriculturists must work hand in hand to exploit available climatic resources for optimal agricultural production while at the same time control climatic constraints and hazards to agriculture. Climate can no longer be regarded as static or a constant. It is a variable that is subject to fluctuations and change. Appropriate strategies have to be put in place to reduce or eliminate the undesirable impacts of climatic change and variations on agriculture as well as exploit to the fullest the desirable impacts. Such strategies must be based on improved knowledge via research and appropriate data collection of the complex interactions between climate and agriculture at local, national, regional and global levels.

CHAPTER SIX

THE CLIMATE, VEGETATION AND CROP ECOLOGICAL ZONES IN NIGERIA

Nigeria has a tropical climate with all year roud high temperature that t post no serious limitation to the growth of the agricultural crops. The climatic and vegetational zoning is therefore governed by the balance between rainfall and evaporation (or H_20 requirement of the vegetation). Rainfall comes from the moist southwest wind which flow over the country as inter tropical Discontinuity zone (ITDZ) moves north and the rainfall stop as the ITDZ later more south.

The southern most part therefore received higher rainfall over a longer season than the North (e.g. Akasa in delta). The rainy season is as short as 3month in the far north with only 50cm of rain and as long as 11month in the far south with over 400cm of rain. The intermediate values are found in the middle belt. South of the Benue-Niger rivers the rainfall has two maximal but this is merged to a single maximum further north. We have August break in the south). In the south, the temperature and humidity are high with small annual ranges. The range increase steadily to the north where the dryness of the dry season is accentuated by the North desiccating harmattan winds coming from the cooler Sahara desert.

The seasonality is which characterizes rainfall distribution in Nigeria, the duration and the regime of the wet season and the number of months with less than 10cm rainfall per mouth, all these have greater impact on agricultural activities than rainfall total alone. The timing of planting operations and the number and type of crops which can be grown are influence by the onset of the rain and the regime and duration of the wet season. Planting operation start in the south in April and July in the North. The onset of the rain which marks the beginning of the intense planting operation varies from March in interior location of Southern part to April in larger part of the middle belt and May and June in Sudan zone.

Temperature is not a limiting factor to crop growth in any part of Nigeria. The variation in its regional and seasonal distribution are of limited important to agriculture. However it plays an indirect role through its effect on evaporation, photosynthesis and soil temperature. Higher mean annual temperature in the north than in the south encourages higher evapo-transpiration and consequent lower water balance level. The high evaporation rate from water surfaces in rivers and lakes in the Sudan and southern and Sahelian zones caused by high temperature, also deplete the water resources and render them inadequate for large irrigation project. The vegetational zone is largely a reflection of climatic zoning apart from the lowlying mangrove forest which parallels the southern post line. Consequently, 3 broad vegetational zones can be delimited:

1. Tropical rain forest of the south with its luxurian tree growth
2. Northern Sudan savannah with tall grasses and Acacia trees
3. Guinea savannah of the middle belt which is a belt of deciduous trees mixed with grasses with dry season varies from about 80 days in the southern half to about 140days in the northern half. In between this broad vegetation zones are transitional zones found in the southern part of the guinea savannah has flewer trees than the northern part, arks the transition between forest in the south and the savannah in the north. Such as derived savannah between the forest zone and the guinea savanna. Broadest vegetation zone and occupying half Nigeria area, located in the middle of the country. Wet season last for 6-8month.

The Guinea savannah itself is divided into southern and northern savannah. Rainfall is between 25 are 40 inches, dry season is about 6-8month. Economic crops are groundnut, Cotton millet etc. and livestock's. At the extreme of the Sudan savannah is the Sahel vegetation zone annual rainfall drops below 25 inches, dry season exceed 8months. Acacia and date palm found. The local people are nomadic herdsmen.

The farming systems of the forest zone are considered to be ecologically more balance than those of the savannah. This is particularly true of the food production system. In the forest zone mixed vegeculture farming is predominant and characterizes by root crops with cereals playing a secondary role in cultivation. This is a close representation of the natural ecosystem and implies the substitution of the require domesticated plant species but the wild one destroyed during the process of clearing. The flow of energy or matter through the original system is therefore little disturbed. Erosion is checked because the ground is well covered during the rainy season when run-off is most intense. Although, ecological stability achieved by permanent tree crops is lower and the nutrient level decline, the micro climatic features of tropical forest are maintained. This is strengthened by the practice of leaving some forest tress undisturbed on peasant plantation and the planting of cover crops with in the trees.

In contrast, seed culture cultivation which characterizes savannah farming is base on the highly productive combination of cereals, leguminous, grain, cotton and a host of other small crops. The dominance is cereals and other nutrient demanding crops such as grains, the less complex stratification and the open canopy of vegetation which increases opportunity for weed invasion all combined to make this type of cultivation less conservative of soil resources and more prone to shift from one temporary clearing to another

The land area for each vegetational zones are as follows:-

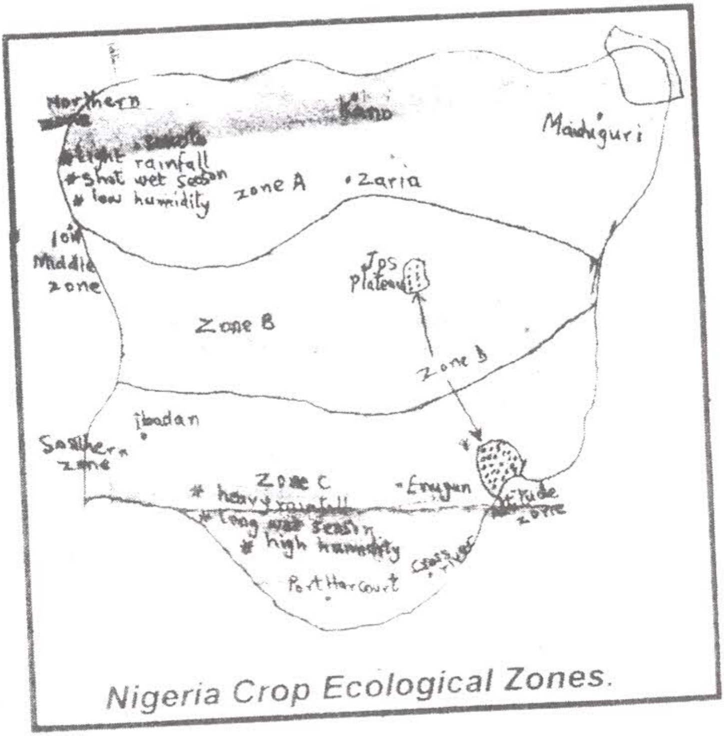
Sahel	-	31,463km^2	i.e.	3.2 %
Sudan Savanna	-	342,158km^2	i.e.	34.8
Guinea Savanna (Including Bauchi and Plateau)	-	400,168 km^2	i.e.	40.7
Derived Savanna	-	75,707km^2	i.e.	7.7%
Lowland rain forest	-	95,372 km^2	i.e.	9.7
Fresh water swamp	-	25,563 km^2	i.e.	2.6
Mangrove forest and coastal vegetation		2,782 km^2	i.e.	1.2
		983,213 km^2		**100.0 %**

CROP ECOLOGICAL ZONES IN NIGERIA

	Ecological Region	States	Ecological Crop specialization
1.	Sudan Savanna	Sokoto, Kaduna Bauchi, Borno	Cereals, Grain Legumes, L/S, Vegetables seeds and Nuts.
2.	Guinea Savanna	Niger, Kaduna Benue, Plateau Kwara, Oyo North	Cereal, Grain Legumes, Root crops Tubers, Seeds. Nuts, Livestock's
3.	Forest Savanna	Kwara, Edo, Anambra (North) vegetables,	Root crops, tubers, cereals, Grain Legumes, Livestocks
4.	Tropical Rain Forest	Oyo, Ogun Ondo, Bendel Anambra, Imo Cross river (north), Rivers	Tree crops, Root crops Vegetables, Fruit, Grain, Legumes, Pisciculture, Poultry, piggery.

5.	Mangrove	Lagos, Ogun Ondo (South) Bendel (Delta) Rivers, Cross River	Fruit, Vegetables, swam price, Grain Grain, Fisheries, Poultry

Map 1: Food crop zones:



Nigeria Crop Ecological Zones.

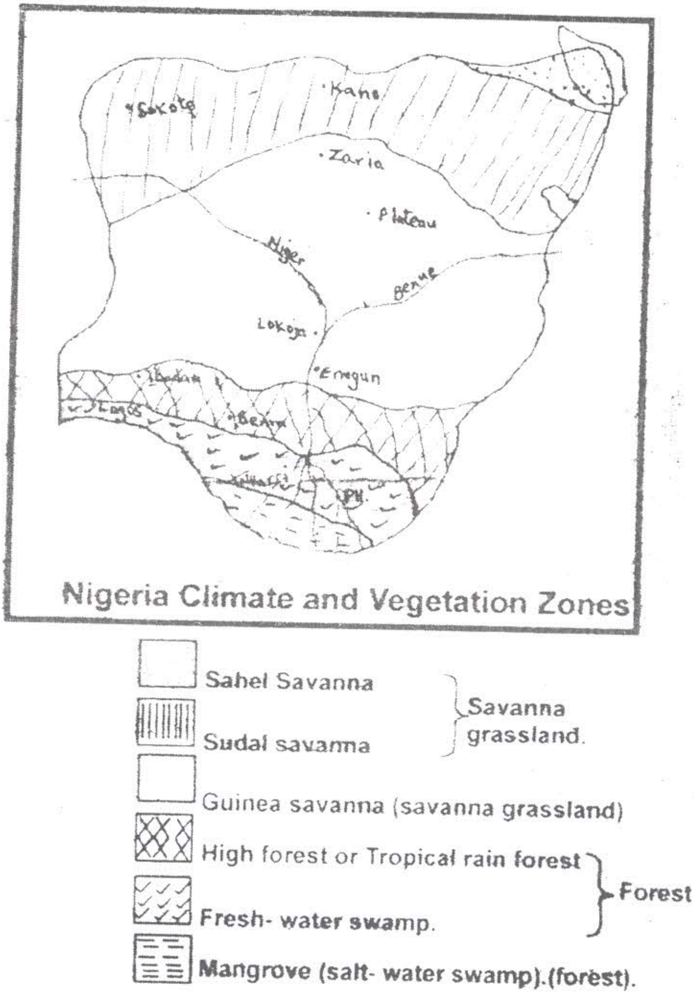
Zone A - Grain crops and livestock zone Grain crops, irrigated cane sugar, market garden crops, around large towns.

Zone B - Mixed crop zone Grain crops, Surplus yams, rice, and some livestocks.

Zone C - Root and tree crops zone, also vegetables.

Zone D - High altitude zone Temperate and subtropical crops at top altitudes.

Map 2: vegetational belt.



Nigeria Climate and Vegetation Zones

FURTHER READING

Adejuwon, J. O. 1962. Crop - Climate relationship. Nigerian Geographical Jurnal, 5 (1), 21-32.

Adetunji, I.A., J.O. Olaniyi, C.O. Aremu and G.O. Kolawole. 2005. Agro-climatology. Iyanda Bindery and Printing Press, Ogbomoso, Oyo State, Nigeria.

Ayodele, J.O. 1983. Introduction to climatology for the tropics. John wiley and Sons Ltd.

World meteorological organisation 1982. Guide to Agricultural Meteological Practices. Second Edition. Wmo - Number 134.

Wang, J.Y. 1972. Agricultural Meteorological. 3rd edition. Millieu information service, San Jose.

TUTORIAL QUESTIONS

1. How does weather alter the human environment?

2. What is the primary source of energy for earth's atmosphere?

3. What is the source of sun's energy?

4. What is the relationship between solar energy and kinetic energy?

5. What is the importance of the earth's constant motion to day living?

7. What is the significance of evaporation on man and plant after a very sunny/hot day?

8. List 5 crops found in areas of abundant rainfall in Africa.

9. List 4 sources of moisture to the atmosphere.

10 What type of rainfall is predominant in island areas?

11. List 2 state in Nigeria where such rainfall is dominant.

12. What are the human activities contribute to the potential changes in temperature and precipitation patterns (list 4).

14. Two weather elements that determine climates are:

15. What are the major crops prevalent in tropical rainyolimate?

16. Can xerophytes be grown in tropical monsoon climate? Why?

17. Identify the major controls of climate that influence your geographical area.

TUTORIAL QUESTIONS TWO

Activity 1:

- Draw a map of Nigeria and label the climatic regions
    - Using the map drawn above, complete the table below

Name of Town	Climatic Region	Type (s) of agriculture
Lagos		
Ibadan		
Ogbomoso		
Benin		
Minna		
Makurdi		
Sokoto		
Maiduguri		
Sapele		

Activity 2: Climatic effects

In a small group, choose a region to study. Make sure that each region is studied by at least one group in the class. Make notes about the effect of the climate on the following aspects of the region:

Region: --

Climate: --

In which part of the region do most people live?--------------------

----

What sort of work do people do here -----------------------------------

----

Where do people get their water? --

What other things about this region are affected by its climate? ---

----

Activity 3: What's different around Nigeria?

Research the climatic region and fill in the information below

Climatic Region: --

What are the characteristics of this climate? -------------------------

--------------------------------Rainfall is ----------------------------------

----

- heavy (over 1000 mm per year)
- medium (between 300 mm and 1000 mm per year)
- light (less than 300 mm per year)

Most rain occurs:

- Between April and September
- Between June and September
- Evenly right through the year

What sort of agriculture happens in this climatic region? ------------

----
