COURSE GUIDE

ESM 345
APPLIED CLIMATOLOGY

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INTRODUCTION

Applied Climatology is the scientific analysis of climatic data in the light of a useful application for an operational purpose. “Operational” is interpreted as any specialised endeavour within such as industrial, manufacturing, agricultural, or technological pursuits (Landsberg and Jacobs, 1951). This is the general term for all such work and includes agricultural climatology, aviation climatology, bioclimatology, industrial climatology, and others.

Applied climatology examines the effects of climate on physical, biological and cultural environments. Specialist contributors from Europe, North America and Australasia examine the impacts of changing climates on the functioning and development of physical, biological environments including glaciers, water resources, landforms, soils, vegetation and animals. For instance, weather and climate affect day-to-day activities and lifestyles from the clothes we wear to the buildings we design, and the food and energy we produce.

This course focuses on the relationship between climate and a wide range of human activities and responses relating to health and comfort, building design, transport systems, agriculture and fisheries, tourism and social, industrial and legal issues. Climate-environment relationships and impacts on human activities are predicted to change dramatically if global warming accelerates at the rates currently proposed by scholars.

Applied climatology has been the foundation upon which the world's weather-sensitive activities and infrastructure have been developed. Applications of climate data and information have likely contributed more to the development of most nations than any other function of the atmospheric sciences. The recent development of useful weather forecasts has been important, but these developments have not overshadowed a parallel recent progress in applied climatology. A variety of scientific and technological advances, coupled with a changing society, have led applied climatology into its golden era.

COURSE AIM

The main aim of this course is to advance our understanding of the relationship between climate and human activities.

COURSE OBJECTIVES

To achieve the stated aim above, this course sets to achieve certain specific objectives. Therefore, at the completion of this course, students should be able to:

- explain how climate change can affect us
- discuss the relationship between climate and human activities
- describe the impacts of climate on human activities
- list some environmental hazards, their causes, effects and how they can be mitigated

WORKING THROUGH THE COURSE

The course on applied climatology would require that you spend a lot of time to read and understand it. The content of the material is quite detailed and that is the more reason you must find quality time to study it very well. Indeed, efforts have been made to break down the material into units that you will find readable and comprehensible. The latter notwithstanding, you will still need to put in a lot of effort to understand the technicalities involved. You are therefore, seriously advised to make sure you attend the tutorial sessions where you can rub minds together with your colleagues and even compare notes.

COURSE MATERIALS

In order to understand this course with little stress, you will be provided with the following materials.

- Course Guide and
- Study Units.

In addition, a list of recommended textbooks is given in a section of this Course Guide. Although they are not compulsory for you to acquire them or even read, they are necessary as supplements to the course material. Indeed, your reading some of them may give you a better understanding and make you tower above your peers.

STUDY UNITS

It is now necessary to give you the details of the study units that you will have to go through in this course.

Module 1

Module 2

Module 1 focuses on the relationship between climate and a wide range of human activities and responses relating to agriculture, health and comfort, building design, transport systems, economic, social and industrial issues. Climate-environment relationships and impacts on human activities are predicted to change dramatically if global warming accelerates at the rates currently proposed. It gives you a brief idea of what you are expected to know as you read this material. It is essential for you to know the significance of climate in our day-to-day life and define how it affects various aspects of our life.

The units provide the vocabulary for describing climatic events, consequences and human responses, a common framework for linking climate and societal impacts. These events impact on exposed social area or activity units of human leading to ordered biophysical, social or ecological consequences.

The first unit of this study material introduces students to the relationship between climate and agriculture. In general, climatology as applied to the effect of climate on crops. It includes especially the length of the growing season, the relation of growth rate and crop yields to the various climatic factors and hence the optimal and limiting climates for any given crop, the value of irrigation, and the effect of climatic and weather conditions on the development and spread of crop diseases. This unit is primarily concerned with the space occupied by crops, namely, the soil and the layer of air up to the tops of the plants, in which conditions are governed largely by the microclimate.

The second unit considers the relationship between climate and aviation. This unit discusses the application of the data and techniques of climatology to aviation meteorological problems. And the third units consider the **industrial climatology**—A type of applied climatology that studies the effect of climate and weather on industry's operations. The goal is to provide industry with a sound statistical basis for all administrative and operational decisions that involve a weather factor. In unit 4, you will learn about climate and human settlement. Unit 5 discusses how climate can affect human settlements in a variety of ways. Some of the impacts will be direct, others will be indirect.

Module 2 discusses human influence on the weather and, ultimately climate which can be intentional or unintentional. It also tells the students about the simple processes of weather modification and their implication. Unit 2 of this module will discuss the complex processes of acid rain and its implications. Geographic distribution and its potential problem areas in the future are also taken into consideration in this unit. Unit 3 will be concerned with drought, its causes and effects; and how it can be mitigated.

Unit 4 tells you about floods, causes, types, (primary, secondary and tertiary) and effects of floods. Trends in floods impact and how it can be mitigated are highlighted of this unit. Application of econo-climatic models in assessing the economic impacts of weather and climate are the focus of unit 5.

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ASSESSMENTS

There are two components of assessment for this course. There is the Tutor-Marked Assignment (TMA) while the course examination at the end of the course is the second and final one.

TUTOR-MARKED ASSIGNMENT

The TMA is the continuous assessment component of your course. You need to know that it accounts for 30% of the total score. Normally, you will be given 3 TMAs to answer. You must attempt all of them before you sit for the end of course examination. The TMAs would be given to you by your facilitator and returned to you after they have been graded.

END OF COURSE EXAMINATION

The course is concluded by the time you write the end of course examination. It constitutes 70% of the whole course. You will be informed of the time the examination will take place. Note that it may or may not coincide with the university semester examination.

SUMMARY

This course intends to provide you with some basic knowledge of applied climatology and its impact on human activities. By the time you complete the study of this course, you should be able to satisfactorily answer the following questions:

- Appraise the influence of climatic conditions on animal husbandry.
- In what ways is the knowledge of weather and climate important in agricultural planning and development?
- In what ways can weather and climate hinder or promote the industrial development of an area?
- Using specific examples assess the impact of weather conditions on both manufacturing and service industries.

- With reference to specific example(s), explain how the factor of climate can influence the location, growth and development of human settlements.
- Discuss the three major types of engineering problems in the building industry that are intimately linked to climate.
- Assess the impact of weather conditions on air transportation in Nigeria.
- Discuss the view that the main peril of weather for aviation in West Africa is ‘poor visibility’.
- What will you suggest as way forward for the aviation industry in the light of changing weather and climate?
- What is econo-climate and how relevant is it in understanding man-climate relations?
- Discuss the basis, principles and applications of econo-climatic models.
- Weather modification by man has a lot of serious implications. Elucidate.
- Discuss the problems and prospects of purposeful weather modification.
- Attempt a reasoned definition of acid rain. Discuss the causes and effects of acid rain.
- Write an essay on the processes and geographical distribution of acid rain. In what ways can acid rain be prevented?
- Define Drought? Identify the major causes and the mitigation option of drought.
- What are the correlations between climate and drought in the northern Nigeria?
- Examine the impact of climatic variations on man and his activities.
- Discuss the view that climate is an important determinant of human affairs.

I wish you success in this course. In particular, I hope you will be able to appreciate the importance of Applied Climatology in our day to day activities and in human affairs.

Hope you will enjoy the course

Best wishes.

COURSE GUIDE

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MODULE 1

UNIT 1 CLIMATE AND AGRICULTURE

CONTENTS

1.0 INTRODUCTION

Agriculture is perhaps the most weather-sensitive of all man’s economic activities (Ayoade, 1993). Climate determines whether or not rain-fed agriculture will be possible as well as the type of crops that can be successfully cultivated in a given area. In fact, all stages of agricultural production from land clearing and sowing through crop growth and management to harvesting, storage, transportation and marketing of agricultural products are subject to the prevailing influence of climate.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- discuss the relationship between climate and agriculture
- describe the impact of climate on agriculture
- explain the relationship between climate and agricultural development planning.

3.0 MAIN CONTENT

3.1 Climate-Crop Relations

An agricultural system is in fact a man-made ecosystem which depends on climate to function like the natural ecosystem. The main climatic elements that affect crop production are the same as those influencing natural vegetation. These include: solar radiation, temperature, moisture, wind, among others. They all largely determine the global distribution of crops and livestock as well as crop yield and livestock productivity within a given climatic zone. All crops have their optimal climatic requirements for their optimal growth and a range of climatic requirements outside which they cannot be successfully grown. In other words, they have their climatic limits for economic production. As such, it will therefore not be economically viable to grow a crop outside its climatic limits. However, to an extent, man can extend these limits via plant breeding and selection and by cultivation methods in respect of crops and by animal breeding and improved animal husbandry in respect of livestock.

In discussing some of the ways in which major climatic elements influence crop growth and yield, it is important to emphasize *first* that, climatic variables are closely interrelated in their influence of crops. The effect of a given climatic variable is modified by the others. The *second* point is that in considering the climatic environment in which crops grow, the microclimate immediately around the crop is of vital importance.

3.1.1 Solar Radiation

Solar radiation provides the warmth and the energy that powers the agricultural system. It determines the thermal characteristics of the environment, namely the air and soil temperatures, sunshine and day length or the photoperiod. Photosynthesis, the basic process of food manufacture in nature, and photoperiodism, the flowering response to daylight, are controlled by solar radiation.

If there is insufficient radiation, the root systems of the crop becomes underdeveloped, the foliage becomes yellowish and there is a tendency for the stalk to grow at the expense of the foliage. According to Griffiths (1976), the average plant begins to accumulate organic matter at about 0˚C; this indicates that, too little radiation or too much radiation is harmful to the process of photosynthesis.

In photoperiodism, the important solar rays are those between 0.5 and 0.7 micrometers. Some plants are indifferent to day length while others are very sensitive to variations in day length. Also, some plants are light-loving (e.g. pine, birch, and larch trees) while others love shade (e.g. beech and spruce). Vegetables like cabbage, lettuce and spinach which all originate in the middle latitudes, will have their flowering retarded if grown nearer the equator as the day length will be shorter than what they are accustomed to in the middle latitudes (Ayoade, 2004).

3.1.2 Temperature

The temperature of the air and the soil affects all the growth processes of plants. As pointed out earlier, all crops have minimal, optimum and maximal temperature limits for each of their stages of growth. Tropical crops like cocoa and dates require high temperatures throughout the year. Many crops such as coffee, bananas and sugarcane are very sensitive to frosts. On the other hand, winter rye has low temperature demands and can withstand freezing temperatures during the longer winter period of dormancy. Low temperatures kill or damage plants. Prolonged chilling of plants at temperatures above freezing retards plant growth and may kill those plants adapted only to warm conditions.

Generally, high temperatures are not as destructive to plants as low temperatures, provided the moisture supply is adequate to prevent wilting and the plant is adapted to the climatic region. Excessive heat can destroy the plant protoplasm.

Most crops cannot be grown successfully unless the temperature exceeds some critical threshold values. For instance, coconuts and pineapples thrive only when temperatures are always above 21˚C for at least part of the growing season. Citrus fruit, cotton, sugarcane and rice will not grow well if temperatures are below 15˚C. Many vegetables require temperatures of at least 8˚C. The critical temperature for wheat is 3˚C (Hobbs, 1980).

3.1.3 Moisture

Water in all forms plays a vital role in the growth of plants and the production of all crops. It provides the medium by which chemicals and nutrients are carried through the plant. Water is also the main constituent of the physiological plant tissue and a reagent in photosynthesis. Soil moisture is the source of water which is of primary importance to crop and the state of soil moisture is controlled by rainfall, the evaporation rate and soil characteristics. The supply of soil moisture may range from wilting point when no water is available for plant use to field capacity when the soil is fully saturated with moisture but is still well drained. When soil moisture is excessive, all the soil pores are completely filled with water and a waterlogged condition prevails. In such a situation, free movement of air within the soil is impeded and compounds toxic to the roots of plants may be formed. At the other extreme is the condition of drought in which the amount of water required for evapotranspiration exceeds the amount available in the soil. Unless this water deficit is made good by rainfall or irrigation, the plant will begin to wilt and die. Thus, like extremely low and high temperatures, too much or too little water is not good for agriculture.

3.1.4 Wind

On the positive side, wind (air in motion) is an effective agent of dispersal of plants. It helps in the transport of pollen grains and seeds of plants. Also, the carbon dioxide intake of plants and rates of transportation tend to increase with increasing wind speed up to a certain level. On the negative side, wind may cause physical damage to crops. By encouraging a high rate of transpiration, high winds can also result in plant desiccation. Wind erosion can damage good agricultural land by removing the top soil as shown in Oklahoma and Kansas states of the United States, during the ‘dust bowl’ period of the drought years of the 1930s. Also, high velocity winds in relatively dry areas or during the dry season in sub-humid regions can increase the risk of forest fires that can damage farm crops.

3.2 Weather Hazards to Agriculture

Crop growth is not only dependent on weather conditions but crops are at the mercy of weather until they are harvested. The major weather phenomena that constitute hazards to agriculture are: frost, drought, hailstones and high winds.

3.2.1 Frost

Frost is a major hazard to agriculture in temperate regions but largely unknown and rarely occurs in the tropics. It is said to occur if temperature of the air in contact with the ground (ground frost) or at screen level (air frost) is below 0˚C. It is the ground frost that is particularly considered relevant as far as agriculture is concerned. When it happens, soil moisture becomes frozen and soil nutrients become immobilised. Physiologic drought is then said to occur. If temperatures are below freezing point for long, the living matter of cells freezes and soil dehydration may result.

3.2.2 Drought

Drought constitutes a grave hazard to agriculture in both the temperate and tropical regions of the world. It is said to occur whenever the supply of moisture from precipitation or stored in the soil becomes insufficient to fulfill the optimum water needs of plants. Four types of drought can be recognised: permanent, seasonal, contingent and invisible droughts. Droughts can result in the wilting of crops or the lack of much vegetative growth.

3.2.3 Hailstones

Hailstones are hard pellets of ice of variable size and shape that fall from cumulonimbus cloud. It is therefore a solid form of precipitation. They occur both in the tropics and the temperate regions, and can physically damage young crops (especially) in the field; thus constitutes a major hazard to agriculture wherever they occur frequently. Crop losses due to hailstones may be considerable. Hence, various measures will have to be taken to prevent or minimise crop damage from hailstones.

3.2.4 High Winds

Wind may constitute a hazard to agriculture in one or more of the following ways:

- it can mechanically damage crops if the speed is too much as the pressure exerted on crops along its path increases with increasing speed
- hot wind will encourage high rates of evapotranspiration and may, therefore, cause desiccation in crops. Besides, the risk of fire is considerably increased
- wind may encourage soil erosion when the speed exceeds some critical threshold value for a given soil environment. Crops may

be buried by wind-blown sand or dust while the stems and leaves of the tall crops suffer abrasion by sand particles

- wind may speed the chilling of plants under conditions of low temperature just like it speeds the desiccation of plants under conditions of high temperatures.

However, crop damage by winds may be minimised or prevented by the use of wind breaks (shelter belts).

3.3 Weather Aspects of Crop Pests and Diseases

Agricultural (crop) production, especially in the tropics, suffers from periodic outbreaks of pests and diseases which are weather-dependent. Crop losses due to insect pests in Nigeria have, for instance been estimated to be of the order of 50-60%. The pests attack the crops in the field and after harvest in barns where they are stored. Some insects also act as vectors of disease-causing germs and should therefore be considered as deadly as the germs they carry.

In the humid tropics and the temperate region, temperature appears to be the critical factor influencing the outbreaks of crop pests and diseases. In arid, semi-arid and sub humid environments, moisture (rainfall) is the dominant factor. The optimum temperature for the reproduction of aphids is about 26˚C. A delayed spring is favourable to the outbreak of corn seed maggot while a hot dry spell will terminate such an outbreak. The major crop pests in the savanna land of West Africa are grasshoppers, locusts and weaver birds. The locusts breed in the areas bordering the Sahara desert where there is enough moisture for some vegetable growth for the larva to feed upon. The locusts then fly in swarms southwards aided by the prevailing north easterly winds particularly during the day when the temperatures are between 20 and 40˚C. The locusts also require for their flight wind speed of less than 20 km per hour as wind speed in excess of this amount makes it impossible for them to hold a course.

Other crop enemies like mildew, rusts, scabs, and blights reproduce and spread most rapidly when the weather is warm and very humid. In the cocoa-growing areas of southwest Nigeria, for example, it has been established that too much rainfall reduces the number of cocoa pods per tree and increases the degree of infection by the black pod disease (Adejuwon,1962). Also, in Nigeria the incidence of head mould which attacks sorghum in northern Nigeria has been partly attributed to high atmospheric humidity (Kassam *et al*, 1976). Spores of fungus diseases are spread by wind and this makes their control rather difficult.

3.4 Climate and Animal Husbandry

Climatic conditions influence animal husbandry directly or indirectly in three major ways. First, the availability of feed is highly weather-dependent and since domestic animals are highly dependent on feed, climatic factors which influence the growth of pastures or feed crops exert influence, albeit indirectly, on livestock. Climatic conditions determine the type, quantity, and quality of the available feed. The climatic elements which affect animal feed supply are the same as those which influence plant growth or the spread of insects and diseases that attack grain or forage crops. These include rainfall, temperature, and radiation.

Second, climatic conditions have direct influence on domestic animals as they have effects on their normal body functions. For animals to survive in a given climatic zone, they must be physiologically adjusted to that climatic environment. All animals and various breeds of particular animals have their optimum climatic requirements to ensure maximum growth and development. When animals are moved to climatic environments they are not used to, they generally fall below minimum economic levels of production even though they may not die off like plants do (Critchfield, 1974).

Finally, climate influences livestock production indirectly by determining the types of animal diseases that would be prevalent in a given environment. For instance, the tse-tse fly which transmits the germs that cause human and cattle trypanosomiasis in Africa is the major control on cattle population distribution in the continent. The fly flourishes in three canopies where transpiration and shade maintain conditions of high humidity and moderate temperature necessary for its growth and reproduction. Consequently, most of Africa's cattle population is found in the tse-tse fly free zones of the African savanna. In the more humid and forested areas of the continent, only a few dwarf breed of cattle resistant to trypanosomiasis are kept. These include the *Ndama* and *Muturu* breeds found in southern Nigeria.

3.5 Climate and Agricultural Development Planning

It is clear from the foregoing that climate, whether directly or indirectly, affects agricultural production. Therefore, climate must be taken into consideration in the planning of agricultural operations and in the planning of agricultural development in general. Below are some ways in which knowledge of climate can be useful in agricultural planning and development.

- Good timing of agricultural operations such as land preparation, planting, weeding, harvest, storage, marketing, etc. can be facilitated by knowledge of local climate.
- Assessment of irrigation needs of crops, if any, and the application of irrigation water in the right amount as and when required.
- Selection of sites for crops or of crops for sites through agro-climatological studies of proposed sites and crops to ensure that the most suitable crops are grown in a given area. Such studies are required before new crops or new varieties of existing crops are introduced or the area under cultivation of a particular crop expanded.
- Control of pests and diseases through knowledge of crop microclimate and the climatic conditions that favour the propagation of such diseases and disease vectors.
- Proper management of weather phenomena such as frost and drought which pose serious hazard to agriculture.
- Advance estimates of anticipated crop harvest at the beginning of the growing season based on weather forecast. Such information is vital for the formulation of a nation’s agricultural policy regarding procurement and distribution of good imports on exports as well as the prices of agricultural produce to avoid shortages, post harvest losses or glut as the case may be.

4.0 CONCLUSION

The understanding of the relationship between agriculture and climate will enable agriculturists to fit crops to climate and avoid the unpleasant consequences of agricultural planning and development.

5.0 SUMMARY

In this unit, we have learnt that:

- climate is the most important variable in agricultural production
- animal husbandry development is climate-dependent
- the knowledge of climate should be taken into consideration in agricultural planning and development.

6.0 TUTOR-MARKED ASSIGNMENT

1. Appraise the influence of climatic conditions on animal husbandry.
2. In what ways is the knowledge of weather and climate important in agricultural planning and development?

7.0 REFERENCES/FURTHER READING

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UNIT 2 CLIMATE AND INDUSTRY

CONTENTS

1.0 INTRODUCTION

Weather and climate-related factors play a significant role in the overall economy of a country (Oludhe, 2002). The impact of climate upon economic life anywhere in the world is considerable, and in many cases, very obvious. Climate functions as an economic ‘timing mechanism’ (Hayward and Oguntoyinbo, 1987). Extreme weather and climate events have been found to significantly affect the activities in the industry as well as other key sectors of the economy. For instance, power rationing due to drought has negative impacts on the overall outputs from the industrial sector. Drought can also bring about loss of raw materials for the industries. Poor state of the transport system may cause damage to perishable products from industries among many others.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- describe the relationship between climate and industrial activities
- discuss the impact of climate on industrial activities
- outline the relationship between climate and industrial development.

3.0 MAIN CONTENT

3.1 Climate and Manufacturing Industry

Climate has been identified as one of the most important factors in industrial development and in some cases must be treated as a resource (Ayoade, 1993). Three of the major factors that influence the location of industry namely availability of raw materials, market and power can be climate-dependent. Agricultural raw materials needed in industries require favourable weather for their production. Minerals cannot be easily exploited if weather is too harsh on men and machines. Water, which is climate-dependent, is a basic raw material in virtually all manufacturing industries.

Agro-allied and agro-based industries are particularly sensitive to weather variations. They are adversely affected by drought-induced shortage of raw materials. For instance, during the 1972/73 Sahelian drought, many cotton ginneries and groundnut processing factories in northern Nigeria closed down because of lack of cotton and groundnut occasioned by poor harvest. During the same period, the fall of water level in Lake Kainji caused nationwide power rationing since most of the country's energy supply was, and is still provided from the Kainji hydro-electric power station. Many industries were consequently greatly handicapped and their production schedules were upset. In some cases, valuable equipment were lost as a result of unpredictable power cuts.

Water is required in manufacturing industries for washing of products, raising steam, cooling boilers and for general sanitation. Water is used as a raw material in some industries since it is incorporated in the manufactured products. Availability of water in sufficient quantities and of the right quality, which could be climate-dependent, can therefore be an important factor worthy of consideration in the location of industries. Earlier, it was said that water provides the source of electrical power used in many industries. In fact, it is not just hydro-electric power that is weather-dependent, solar and wind energies are obviously weather-dependent. Even when and where the power source is fossil fuel which may not be weather-dependent, weather can affect demand on power and consequently the capability of the power authorities to satisfy their industrial and other consumers.

Climatic conditions can provide the setting for some industries to develop or for some industrial processes to take place without ado. For instance, climate has been identified as one of the factors that has favoured the location of the film industry and aircraft manufacturing in the state of California in the United States. It is believed that the early aircraft manufacturers were attracted to California by its low heating degree days which calls for less heating of hangers and also by the good flying weather provided by its winds, warm winter and plenty of sunshine. The long hours of sunshine and light in southern California also attracted the film industry there as such conditions are ideal for outdoor film shooting. The dry climate with abundant sunshine of Tucson, Arizona has also played an important role in attracting light industry and other economic activities which have made the city one of the fastest growing cities in the United States.

Labour, which is another factor of industrial location, can be affected indirectly by climate. Climate can be an asset in attracting labour to an area but can also act as deterrent discouraging labour. Of course, people normally prefer living in warm sunny climates to living in cold cloudy or wet climate. Climate may also affect labour productivity since it determines human physiologic comfort and plays some role in human morbidity and mortality. Climate may therefore indirectly influence rate of absenteeism from work. The rate of absenteeism as well as lateness to work can increase when adverse weather conditions dislocate urban transportation system.

Many industrial processes are affected by weather conditions even when they take place indoors. For instance, cotton spinning requires moist air as cotton thread tends to snap under dry conditions. As such, artificial humidifiers must therefore be provided in relatively dry areas to facilitate cotton spinning. Weather conditions also affect the performance and durability of industrial machinery and equipment. Warm humid conditions tend to encourage weathering and deterioration of equipment as well as the deterioration of stock-piled agricultural raw materials.

The demand of some manufactured products is weather-dependent and so the industries concerned must take changing weather conditions into consideration in their production schedule. For instance, the demand for ice creams, soft drinks and beer is high during hot season or weather but low when it is cold. Manufacturers of footwear and clothing also have to be weather conscious. Fashions change with the season particularly in temperate regions of the world. Suntan location and deodorant are in great demand when the weather is hot and humid while the demand for raincoats and umbrellas increases with increasing frequency of precipitation. Manufacturers of all goods whose demand depends on weather conditions can therefore not afford to ignore weather.

In the light of what has been discussed so far, it could be deduced that the estimation of climatic costs in industrial production must consider the effect of climate on the following:

- heating and cooling requirements of the factory premises
- provision of water supplies
- warehousing, storage and transportation of raw materials and finished products
- weathering and consequent deterioration of equipment and machinery
- health and efficiency of workers
- activities to control air and water pollution arising from industrial processes
- all aspects of industrial production that take place outdoors.

Therefore, manufacturing industries cannot ignore weather and climate in their operations if they are to cut down costs arising from adverse climatic impact and maximise benefits arising from favourable climatic conditions.

3.2 Climate and Mining Industry

Although the mining industry is not seriously affected by the climate during the rains, the working of open-cast mines, quarries and transportation of minerals can be hampered. Much of the equipment used by the industry is permanently exposed to the weather, with all the related risk of rapid decay. In arid areas, dust may clog machinery and thicken lubricants (Hayward and Oguntoyinbo, 1987).

3.3 Climate and Construction Industry

The same problems of dust in dry conditions, of flood, mud and erosion in wet, apply to most aspects of the construction industry. Rainfall is probably the main problem, hampering access to sites and movement, spoiling newly finished surfaces and hindering drying (Hayward and Oguntoyinbo, 1987). It can damage excavations or turn them into ponds; it creates hazards for workers. And if such rains are accompanied by high winds, the damage and dangers are increased. Railway builders, for instance, must allow for flooding, landslides and mudflows, and seek to minimise dangers from these climatically induced phenomena not only to the tracks but also to signaling, embankments, gorges and tunnels.

3.4 Climate and Commercial Activities (Service Industry)

Of all tertiary activities, climate seems to play the most important role in commerce and tourism. Weather and climate can affect commercial activities in three major ways: they can affect the supply or availability of certain goods and services; they can also determine the magnitude of demand for some goods and services; and, they can favour or hinder commercial activities at a given location or at a given time in a given location. Dry, fine weather will encourage shoppers to go out while poor, rainy weather will tend to keep them indoors. Therefore, the volume of retail sales can indirectly be affected by weather conditions.

Weather has equally become a veritable resource in tourism. Many recreational activities especially sporting activities take place outdoor and they do not take place if weather is not suitable. Even where they are already taking place, they are abandoned when an inclement weather sets in. A good example is when rain disturbs the game of lawn tennis or cricket. Warm sunny weather is desired by practitioners of most recreational activities while cold cloudy or wet weather is considered unsuitable.

Climate offers two forms of attraction in tourism, namely, the need for sunshine and warmth for those living in cold countries and the specialised conditions for certain activities such as winter sports. The role of climate in tourism is underscored by the fact that tourism itself is a seasonal service industry which booms at a particular season, depending on the prevailing climatic conditions. Except for winter sports, the peak of most tourist activities is in summer.

It is not only sporting activities that suffer from inclement weather, other forms of outdoor recreational activities such as sight-seeing, nature-watching, visits to zoological gardens, amusement parks, etc. are also affected by inclement weather. Consequently, the proprietors of such recreational facilities suffer loss of income when inclement weather keeps off customers from patronising their services. Insurance business is one of the service industries that can benefit from the knowledge of climate.

3.5 Impact of Climate on Industry

Industries, generally, may be exposed to direct or indirect impacts of climate change. Such potential impacts of climate change will depend on a number of factors, which include:

1. The geographic location of an industry: Industries located in the coastal zone will suffer the negative impacts of sea-level rise and attendant coastal inundation and flooding. Significant sea-level rise will, for example, virtually eradicate beach-based tourism and recreation industries, as well as disrupt oil and gas exploration and extraction activities in the region. Industries located in the northern dry belt will be exposed to the effects of warmer climate on water supplies that make process cooling and environmental processes more difficult and unduly expensive.

This belt is equally prone to occasional devastating thunderstorms, floods and windstorms that can destroy industrial infrastructure, giving rise to cessation of activities and incurring costs for expensive repairs to damaged facilities.

2. The nature of resource inputs used by the industry: Industries that rely on inputs which are climate-dependent (such as agro resources) become vulnerable when those inputs experience any moderate or severe changes in production due to climate change. Harvest failure, for example, would directly impact the fruit juice manufacturing and food-processing industries.

3. The dynamics of consumer behaviour: Consumers respond to changing atmospheric temperatures in the clothing they choose to wear or buy. Industries that produce clothing may have to alter their production profile by producing more or less of warm/cool weather clothing in response to changing demands dictated by either rising or falling temperatures. Similarly, industries may have to design and produce more wind/storm-resistant umbrellas in both the northern and southern ecozones in response to rising incidence of severe windstorms. Other industries affected by climate change will have to adapt or fold up. The telecommunications industry, for example, is affected by heavy storms that fall cables. Sales slump under such circumstances and can seriously affect the industry as a result.

4. Government policies pertaining to climate change: The production inputs.

5. Other industries: such as construction, housing, transportation, energy generation and distribution, are all affected by the incidence of extreme weather and weather-related conditions. All economic activities are affected, as is quality of life and patterns of human settlement. Increased and higher rainfall days will damage roads and increase road maintenance costs. The southeastern ecozone will be the most vulnerable given the sedimentary rock profile of the area, its heavy rains, and its susceptibility to rapid soil wash and erosion. Total vehicular accidents nationwide will also be expected to rise, given a scenario of higher and more intense rainfall rates. At the same time, given a scenario of excessive temperature conditions associated with warmer climate, serious problems would also be experienced with the road infrastructure. Such high temperatures are usually known to soften asphalt roads, explode or buckle concrete roads, warp railroad rails, close airports because of lack of "lift" in extremely hot air conditions, and increase mechanical

failures in automobiles and trucks. Adverse weather conditions have equally been known to cause flight delays, flight cancellations, and flight re-routing, with attendant heavy financial losses to the airline industry.

4.0 CONCLUSION

From the above, it becomes obvious that weather and climate impinge on many aspects of our industrial as well as commercial activities. Considering the fact that weather and climate are variable and the economic losses they cause are considerable, we have no choice but to take cognizance of weather and climate in the planning and execution of our various industrial and commercial activities.

5.0 SUMMARY

In this unit, we have learnt that:

- climate functions as an economic timing mechanism
- climate is the most important factor in industrial development and must be treated as a resource
- the knowledge of climate should be taken into consideration in industrial planning and development.

6.0 TUTOR-MARKED ASSIGNMENT

1. In what ways can weather and climate hinder or promote the industrial development of an area?
2. Using specific examples assess the impact of weather conditions on both manufacturing and service industries.

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UNIT 3 CLIMATE AND AVIATION

CONTENTS

1.0 INTRODUCTION

Air transport, probably more than any other mode of transportation, is the most susceptible and greatly affected by weather as all phases of air transportation are influenced by atmospheric conditions. This is not surprising since the atmosphere is the medium in which air transport takes place. From thunderstorms and snow storms, to wind and fog as well as temperature and pressure extremes, every phase of flight has the potential to be impacted by weather. The close relationship between meteorology and air transportation is underscored by the simultaneous development of the two with development in one leading to research in another. As a matter of fact, most synoptic weather stations are located at airports. However, the aviation sector is a contributor to the global climate change, though that is not our focus in this unit.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- discuss climate as a dominant force in aviation
- explain weather and climatic data as essential ingredients in aviation and
- describe the relationship between climate and aviation development planning.

3.0 MAIN CONTENT

3.1 Effects of Weather on Aviation

The effects of weather conditions are felt at all levels of operation of air transportation from the construction of the runaways to the trip en route as well as take off and landing conditions. As noted by Hayward and Oguntoyinbo (1987), the main peril of weather on aviation especially in West Africa is poor visibility. Morning mists are not uncommon in the humid southern areas, harmattan dust can spread extensively, and dust storms are the menace in the north. Almost everywhere, the line squall or local thunderstorm with driving rain and low cloud will present a hazard despite modern technology. All storms are dangerous to aircraft, be it thunderstorm coming from stormy weather and lightning or others such as hurricane which could even be more disastrous (Ayoade, 1993).

On the ground, aircraft may have to be de-iced prior to departure, sometimes having to be coated with a fluid the night before to prevent snow or ice build-up. Icing can affect the aerodynamic stability of an aircraft when in motion. Runways have to be plowed or treated. Lightning in the area prevents ground handlers and fuelers from carrying out their work. And rules require that when temperatures/wind chills are too low, workers are allowed outside only for short periods of time.

Departing and arriving aircraft are slowed by Air Traffic Control (ATC) when cloud ceilings or visibilities are reduced, with aircraft acceptance rates lowered to 75-50% of normal. Surface winds which produce too much cross factor similarly force reduced acceptance rates, and lower level winds (below 15,000 feet) often dictate greater aircraft spacing, resulting in reduced acceptance rates. Low-level wind shear conditions can cause the cessation of takeoffs and landings. Weather has also been identified as the cause of approximately 70% of the delays in the National Airspace System (NAS). In addition, weather continues to play a significant role in a number of aviation accidents and incidents. It contributes about 23% of all aviation accidents (Kulesa, 2008).

During the en route phase of flight, jet stream winds and temperatures have a significant impact on fuel burn and on-time performance. In passenger-carrying aircraft, turbulence is a major concern, while thunderstorms can close air routes for hundreds of miles. Volcanic ash, especially hazardous to aircraft engines, forces costly re-routes.

3.1.1 Thunderstorms

Hazards associated with convective weather include thunderstorms with severe turbulence, intense up and downdrafts, lightning, hail, heavy precipitation, icing, wind shear, microburst, strong low-level winds, and tornadoes. According to National Aviation Safety Data Analysis Center (NASDAC) analysis, between 1989 and early 1997, thunderstorms were listed as a contributing factor in 2-4 per cent of weather-related accidents, depending on the category of aircraft involved. Precipitation was listed as a factor in 6 per cent of commercial air carrier accidents, roughly 10 per cent of general aviation accidents, and nearly 19 per cent of commuter/air taxi accidents. American Airlines has estimated that 55 per cent of turbulence incidents are caused by convective weather.

In addition to safety, convective weather poses a problem for the efficient operation of the NAS. Thunderstorms and related phenomena can close airports, degrade airport capacities for acceptance and departure, and hinder or stop ground operations. Convective hazards en route lead to rerouting and diversions that result in excess operating costs and lost passenger time. Lightning and hail damage can remove aircraft from operations and result in both lost revenues and excess maintenance costs. The vast majority of the warm season delays of aircrafts are due to convective weather.

3.1.2 In-Flight Icing

In the period 1989-early 1997, the National Transportation Safety Board (NTSB) indicated that in-flight icing was a contributing or causal factor in approximately 11 per cent of all weather-related accidents among general aviation aircraft. Icing was cited in roughly 6 per cent of all weather-related accidents among air taxi/commuter and agricultural aircraft. The percentage was 3 per cent for commercial air carrier accidents. The 1994 crash of an ATR-72 near Roselawn, Indiana, which claimed 68 lives, took place during icing conditions.

In-flight icing is not only dangerous, but also has a major impact on the efficiency of flight operations. Re-routing and delays of commercial carriers, especially regional carriers and commuter airlines, to avoid icing conditions lead to late arrivals and result in a ripple effect throughout the NAS. Diversions en route cause additional fuel and other costs for all classes of aircraft.

Icing poses a danger to aircraft in several ways, among which are:

- structural icing on wings and control surfaces increases aircraft weight, degrades lift, generates false instrument readings, and compromises control of the aircraft
- mechanical icing in carburetors, engine air intakes, and fuel cells impairs engine performance, leading to reduction of power.

Small aircraft routinely operates at altitudes where temperatures and clouds are most favorable for ice formation, making these aircraft vulnerable to icing for long periods of time. Larger aircraft are at risk primarily during ascent from and descent into terminal areas.

3.1.3 Turbulence

Non-convective turbulence is a major aviation hazard. All aircraft are vulnerable to turbulent motions. Non-convective turbulence can be present at any altitude and in a wide range of weather conditions, often occurring in relatively clear skies as clear-air turbulence. Any aircraft entering turbulent conditions is vulnerable to damage; smaller aircraft (both fixed- and rotary-wing) are susceptible at lower levels of turbulent intensity than are large aircraft.

The effects of turbulence range from a jostling of the aircraft that is mildly discomforting for passengers and crews to sudden accelerations that can result in serious injury and temporary loss of aircraft control.

Clear-air turbulence is not only dangerous; it also has a major impact on the efficiency of flight operations due to re-routing and delays of aircraft.

3.1.4 Ceiling and Visibility

Low ceiling and reduced visibility are safety hazards for all types of aviation. The NASDAC study of NTSB statistics indicated that ceiling and visibility were cited as contributing factors in 24 per cent of all general aviation accidents between 1989 and early 1997. They were also cited as contributing factors in 37 per cent of commuter/air taxi accidents during the same period. Low ceiling and poor visibility accidents occur when pilots who are not properly rated or are flying an aircraft not equipped with the necessary instrumentation encounter such conditions, resulting in loss of control, or controlled flight into terrain.

Low ceiling and poor visibility are not just a safety issue. They can also severely degrade the efficiency of commercial and military aviation.

Reduced ceiling and/or visibility can severely reduce the capacity of an airport and lead to airborne or ground delays that result in diversions, cancellations, missed connections, and extra operational costs.

3.1.5 Ground De-icing

Aircraft on the ground during periods of freezing or frozen precipitation and other icing conditions are susceptible to the build-up of ice on control surfaces, instrument orifices, propellers, and engine inlets and interiors. Aircraft that are moving along taxiway and runway surfaces in slush or standing water at near-freezing conditions are also susceptible to surface contamination, even after precipitation has stopped. Even a very small amount of ice on a wing surface can increase drag and reduce airplane lift by 25 per cent. This type of ice accumulation has been a cause or a factor in 10 commercial aircraft takeoff accidents between 1978 and 1997. Ice blockage of airspeed or altitude measurement instrumentation can cause loss of control or navigation errors.

Ice and snow also have an impact on terminal operations. Boarding gates, taxiways, and runways may become unusable. Airport operational capacities may be sharply reduced.

3.1.6 Volcanic Ash

Volcanic ash is pulverized rock. It is composed largely of materials with a melting temperature below the operating temperature of a jet engine at cruise altitude. Volcanic ash in the atmosphere is usually accompanied by gaseous solutions of sulphur dioxide and chlorine. The combination of the pulverized rock and acidic gases can significantly affect the performance of jet engines at cruise altitudes. Ash clouds are often invisible, particularly at night.

To put this problem in perspective, the ash from the Mount Pinatubo eruption in 1991 circled the globe within a matter of days and affected a multitude of air traffic routes. Consequently, aircraft that traversed this thin layer of ash required more maintenance. Statistics show that there are 575 active volcanoes globally which normally contribute to 50 eruptions, resulting in 50-75 “danger days” per year. Volcanic ash exceeds 30,000 feet on active air routes 25-30 days per year. There have been over 100 damaging encounters to aircraft in the last 20 years costing more than $250m in damages.

Within the United States, a particular area of concern is along the Aleutian Islands and the Alaskan Peninsula. The density of active volcanoes in this area, lying as it does adjacent to the heavily-traveled North Pacific Air Traffic Routes, makes the ash threat especially acute.

The generally westerly flow of winds in the region means that ash can be transported easily into airspace over the Canadian and U.S. Pacific Northwest regions. Ash from volcanoes on the Kamchatka Peninsula of Russia also poses a threat because it tends to drift into the heavily traveled North Pacific airways, which are within U.S. Flight Information Regions.

3.2 Use of Weather Information and Forecast

Considering the potential impacts mentioned above, the two major impacts of weather are safety and efficiency of operation. To enhance safety while attempting to maintain flight schedule integrity, airlines are highly dependent upon accurate weather information.

They rely on weather information and forecasts from a number of sources. The National Weather Service (NWS) issues forecasts addressing the terminal and enroute area and these are the basis for decisions made by most airlines. Up-to-date and accurate information about thunderstorms, the location of lightning, the beginning time of snow or ice at an airport, temperature and pressure data are crucial for safe and efficient operations. NWS charts depicting this information are displayed in all Flight Dispatch and airport operations offices. Data and forecasts for airports are communicated from government sources to the airlines. Both upper air and surface weather data are sent via land-line and satellite to airlines' mainframe computers.

Reports of actual conditions from airports increasingly rely upon Automated Observing Systems (ASOS). It is imperative that reports from these systems are accurate and representative of the weather conditions at an airport. Any loss of the credibility of the ASOS reports by users could lead to increased fuel loads and flight delays.

After ensuring a safe weather environment, it is incumbent upon airlines to meet their schedules as frequently as possible. This underscores the need for timely and accurate weather information.

3.3 Costs Associated with Weather

Before addressing the costs which weather has on the airlines' operations, it is worth noting the cost of acquiring weather data and forecasts. For instance, in United States the monthly fees for the communication of upper air and surface data alone, per airline, are approximately $6,000. Add to that the cost of acquiring graphical weather data, NWS DIFAX charts, lightning data, and radar and satellite imagery: approximately $7,000. There are four passenger and two cargo airlines which have their own staff of meteorologists. Salaries alone range from $750,000 to more than $1 million annually. Many airlines without meteorologists contract with a weather data and forecast vendor. Costs, though lower than a paid staff, can run well over $100,000 per year.

Direct costs due to weather on airline operations can be separated into several categories: diversion, cancellation, delay and insurance. The cost of a diverted flight can be as high as $150,000 and a cancellation close to $40,000 (Qualley, 2008). A report from the Air Transport Association (ATA) states that the direct annual costs to sixteen member airlines of the first two categories listed above are $47 and $222 million, respectively. Delay costs vary greatly depending upon the type of aircraft and airport affected so are a bit more elusive to pin down. However, they are not insignificant. Annual insurance payouts for encounters with turbulence are well into the millions of dollars across the industry, while lost time due to employee injury (e.g. flight attendants) is similarly high.

The direct costs sometimes are eclipsed by the cost of rub-off factors. For example, one diverted flight can cause anywhere from 2 to 50 flight delays, while one canceled flight can result in 15 to 20 flight delays. The costs listed are from a variety of areas, some fixed and than others not: fuel, crew time, aircraft operating costs, lost passenger and cargo revenue, hotels and meals, ground-based employee overtime pay, insurance. Though the costs associated with delays and cancellations vary, airlines taking such actions risk eroding passenger goodwill and that results in lost future revenue.

To help mitigate the disruption to airline operations caused by weather, some airlines have developed intricate computer programs. The payback on the development cost, though difficult to quantify, is significant. These systems are capable of displaying the down-line effects of off-schedule operations, assisting the airline planners in determining the optimum solution to achieve an on-schedule airline as quickly as possible after an adverse weather event.

3.4 Future Direction

The airlines have a very real need for accurate forecasts of the parameters listed above. Information about the arrival of thunderstorms at a given hub airport, especially those which contain damaging winds or hail, is required at least four hours ahead of time to allow airline planners to re-schedule flights. When addressing a snowstorm, extremely low temperatures, abnormally high pressure or high surface winds, the lead time extends to eight hours, to allow time for personnel staffing. Timing of the arrival of a tropical storm is needed nearly a day in advance in order to protect company resources, e.g. staging aircraft at an airport safely distant from such a storm. Accurate information about upper air conditions, necessary for flight planning, is required as much as eighteen hours in advance of a flight's departure.

The location and design of airport must take into account the weather conditions such as wind speed and direction, visibility and the frequency of temperature inversion conditions. The approach to an airport must be free from all obstructions, natural or man-made. Visibility should be reasonably good most of the time. The design of runaways must take cognizance of the prevailing wind patterns in terms of both direction and speed. Since cross winds are dangerous to aircrafts be it at landing or take-off, this should therefore be avoided. To achieve this objective, runaways must be aligned in the direction of the prevailing winds. The ground condition must also be good; hence, swampy areas or areas liable to flooding should be avoided in the sitting of airports. Advance knowledge of fog occurrence through reliable and up-to-date forecast will help prevent or control dust haze.

With the above comments in mind, it is not difficult to understand the need for a range of highly accurate forecasts, from storm-scale to meso-scale to synoptic-scale.

4.0 CONCLUSION

The understanding of the relationship between climate and aviation will enable operators to plan their mode of operation to climate and avoid the unpleasant consequences of aviation planning and development.

5.0 SUMMARY

In this unit, we have learnt that:

- weather and climate are the most important in aviation operation
- aviation operation depends heavily on accurate weather information and forecast
- the knowledge of climate should be taken into consideration in aviation planning and development.

6.0 TUTOR-MARKED ASSIGNMENT

1. Assess the impact of weather conditions on air transportation in Nigeria.
2. Discuss the view that the main peril of weather for aviation in West Africa is ‘poor visibility’.

3. What will you suggest as the way forward for the aviation industry in the light of changing weather and climate?

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UNIT 4 APPLICATION OF CLIMATE IN BUILDING AND HUMAN SETTLEMENT

CONTENTS

1.0 INTRODUCTION

Human beings are gregarious and like living in groups rather than on their own. Living in groups provides companionship and security. Thus, the desire of man to live in settlements is not dictated by climate neither does climate directly influence the choice of location of most settlements. However, one of the objectives of man in providing shelter for himself is to ward off or protect himself against weather elements (Ayoade, 1993). In this unit, we shall explore some aspects of the interrelationship between climate and human settlements. We shall equally consider the various aspects of the similar relationships that exist at the micro level between climate and individual buildings (Building Climatology).

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- describe the interrelationship between climate and building
- discuss the impact of weather and climate on building activities
- explain the effect of climate on human settlement and the mitigation option.

3.0 MAIN CONTENT

3.1 Climate-Building Relations

Buildings are required to perform two basic functions namely: protection of man against weather elements; and, creation of suitable indoor climate for living accommodation, working, storage, etc. However, buildings themselves are exposed to the weather elements. So, for buildings to perform the two functions mentioned earlier satisfactorily during their anticipated lifetime, they must be structurally safe and be able to withstand the stresses posed by climatic extremes.

Three stages are involved in the process of erecting a building for whatever reason and at each of these stages, sound knowledge of weather and climate is required, as will be shown later in this unit. The stages are:

- planning and designing of the building
- actual construction of the building
- maintenance of the building in general and of a satisfactory indoor climate within it in particular.

Architects and builders need a sound knowledge of the prevailing climatic conditions to achieve some, if not all, the symbiotic relationships found in the natural habitats of the animal world. The possible effect of the building being planned on the microclimate of the site and the surrounding area must also be anticipated for successful planning. Three major types of engineering problems in the building industry that are intimately linked to climate can be identified, thus:

- how to design against the structural failures of buildings arising from climatic extremes such as high winds, and excess precipitation-induced floods
- how to design buildings to minimise running costs of maintaining satisfactory indoor climate
- how to plan for safe and economic construction of buildings in the face of adverse weather conditions at the construction sites.

3.2 Climate and Settlement Location

The physical factors of climate and topography have influenced the location, growth and development of human settlements in diverse ways in different parts of the world. For instance, availability of portable water has been one of the major factors determining the location of settlements, while there has been preference for elevated well-drained sites because they provide protection from floods. Nearness to means of communication like road, rail and water has also played a significant role in the location, growth and development of many settlements.

Despite the obvious importance of the need for healthy and safe environment, very few settlements have been located where they are primarily on account of favourable climatic conditions. But it is now increasingly being realized that climatic factors can play an important role in our quest for functional, pleasant and liveable cities. Attention must therefore be given to such issues as physiologic comfort as well as the health and safety of inhabitants in the location of new settlements.

Knowledge of the climate of possible sites for a new settlement is required in order to make a wise choice of site. Usually, indices of physiologic comfort are used in assessing the suitability of a site for a settlement. For instance, the committee set up in 1975 on the location of the new Federal Capital Territory in Nigeria gave high premium to the question of health and climate as well as water supply in arriving at the choice of Abuja (Table 5.1).

Table 1: Criteria Considered and their Weights in the Choice of a New Federal Capital Territory for Nigeria

S/N	*Criterion*	*Weight by %*
i	Centrality	22
ii	Health and climate	12
iii	Land availability and use	10
iv	Water supply	10
v	Multi-access possibilities	7
vi	Security	6
vii	Existence of building materials locally	6
viii	Low population density	6
ix	Power resources	5
x	Drainage	5
xi	Soil	4
xii	Physical planning convenience	4
xiii	Ethnic accord	3
	Total	100

Source: Ayoade, 1993

Since human settlements are subject to natural hazards, the hazardousness of a site must also be anticipated and taken into account in locating settlements. The major atmospheric hazards worthy of consideration in site selection for settlements include drought, flood, air pollution, fog, cold, heat and high winds. The hazardousness of a potential site for settlement can be assessed by examining the frequency, timing, duration and magnitude of the above hazards. The objective will be to avoid locations of high potential hazardousness. Natural hazards impose a lot of burden on people. They can cause death and damage to properties when people fail to or cannot adjust. Even when adjustment is possible, the cost in terms of money, energy and time may be considerable. It may therefore be better to avoid such hazards rather than hope to minimise their impacts.

The ideal location for a settlement will depend on several factors such as accessibility, good climate and agricultural land, good drainage and water supply, as well as healthy environment among others. These factors obviously constitute the environmental resources of an area that can help sustain healthy and prosperous inhabitants. All these conditions may not obtain simultaneously in any given location and so there is usually a kind of trade off between and among these desirable conditions. And as a matter of fact, climate has usually not featured prominently among the factors that have determined the locations of present-day cities and towns.

It is now generally recognised, however, that human settlements are artificial environments subject to many processes operating in the natural environment. Besides, they interact with and affect natural processes with some unpleasant consequences. To avoid such undesirable consequence, knowledge of the atmospheric environment and processes is vital in the search for suitable sites and for human settlements and in the effective and purposeful planning of these settlements.

3.3 Designing Buildings against Climatic Extremes

The nature of the structural stresses experienced by buildings varies with the climatic environment. Stresses arise from electrical storms, exposure to driving rain, excess precipitation, floods and poor drainage and excessive wind speed. Thunderstorms occur frequently in the tropics. Lightning conductors are therefore desirable to control electrical storms.

Driving rain can be a problem especially in the tree-less urban areas. Another effect of heavy, intense rainfall common in the humid tropics especially in the urban areas is the high amount of runoff that is generated. Rainfall absorption by the roofs of buildings, concrete pavements and asphalt surfaces of roads is minimal. There is therefore great need for efficient and adequate storm water drains to evacuate the high amount of runoff that is generated.

The wind exerts pressure on any object in its path and buildings are no exceptions. The pressure exerted by wind on a building is proportional primarily to the square of the wind velocity although other factors such as shape, size, height, openings in the building and its location relative to other buildings do exercise some control.

3.4 Designing Building for Comfortable Indoor Micro-Climate

For optimum bodily comfort and efficiency, it is necessary to maintain a suitable indoor climate within buildings. This can be done by artificial heating or cooling or by proper design that will ensure adequate ventilation and through wise choice of building materials. Since artificial heating or cooling is expensive both in terms of capital costs and maintenance, emphasis in the tropics should be on climate conditioning within buildings through proper design and choice of building materials. This will obviate the need for expensive artificial cooling.

Climate conditioning is concerned with landscaping and the placement of other buildings as well as the design of the building itself. The aim of climate conditioning is to create a suitable climate in and around the building. In site selection for a building, air flow and drainage should be carefully considered. As mentioned earlier, the wind produces direct effect on a building by exerting pressure on it. Air flow also helps to modify temperature and humidity conditions. This is particularly important in warm, humid environment where there is need to lessen the effect of excessive humidity and high temperatures. The local relief is the most important factor that determines the wind condition at a given site. Windward slopes, summits and plains are usually well aerated. The local relief also coupled with the characteristics of the soil and rainfall will determine the drainage condition of the site. Areas of poor drainage are also often areas susceptible to flooding. If such areas are to be used for building for whatever reason, the need for provision of good drainage and flood proofing should be seriously considered in the design and construction of building.

Apart from suitable sitting of buildings, good design and wise choice of building materials can enhance good indoor climate in a building, the orientation of the building in relation to the prevailing wind direction and position of the sun is of utmost importance. Because the effects of weather elements are strongly directional, orientation of building with respect to wind and sun can influence wind force, precipitation, temperature and sunlight on different external surfaces.

In the humid tropics, windows should be large and on opposite walls, 0.5 to 1.5m above the floor, facing north and south. During northern hemisphere summer, the north facing windows can be closed with blinds or shutters and in winter, the south facing ones. The use of glass windows and doors should be avoided since glass increases the greenhouse effect of buildings. Curtains reduce ventilation and may also absorb radiation especially dark-coloured ones. Mosquitoes netting though necessary to keep off insects especially mosquitoes may reduce air velocity by 35 to 70% (Hayward and Oguntoyinbo, 1987). Verandahs are highly recommended as they provide relatively cool extra living space as well as protection from driving rain. The use of shade trees around buildings is recommended. Tall trees are to be preferred because they interfere less with ventilation unlike short trees. But shading must not be excessive to the extent that the interior of buildings will need artificial lightning during the day.

The type of materials used in building construction is of utmost importance in any climate for two main reasons. First, construction materials play an important role in determining the nature of indoor climate and by implication the need for and extent of artificial heating or cooling that would be required to obtain a desirable indoor climate. Second, building materials are subject to wear and tear by weather elements especially temperature, precipitation and humidity. Climate therefore affects the durability or otherwise as well as the cost of maintaining such buildings.

3.5 Weather and Building Construction

Safe and economic construction of buildings depends on the weather conditions prevailing at the construction sites throughout the period of construction. Adverse weather conditions will delay construction and interfere with the work schedule. More importantly, adverse weather conditions may even damage the buildings under construction. The weather elements that are important during the construction phase of a building according to Oke (1978) are as follows:

- **Rain:** Too much rain will interfere with construction schedule. Mixing of concrete will be adversely affected and newly laid concrete will be destroyed. Earth-moving equipment will not be able to function well and labour will not be fully utilised
- **High wind**: This poses danger to life and limbs at the construction sites, especially on building requiring the use of scaffold
- **High temperature and humidity:** These will adversely affect the physiologic comfort of workers who will not be able to give off their best

- Snow and extremely low temperature interfere with construction work in temperate countries in diverse ways.

It is clear from the above that the construction industries require information about weather to be able to estimate the length of time over a given period during which weather will not interfere with construction work. Such length of time is usually given in terms of number of workable days per month or season. So, knowledge of the number of working days at the construction site is required for proper planning and costing of construction programme. Lack of such knowledge can result in overtime costs and/or financial penalties arising from weather-induced lateness in the completion of construction projects.

3.6 Effects of Climate on Human Settlement

There are many ways through which climate change could affect human settlements. Some of the impacts will be direct, others will be indirect. Urban populations are growing and contributing to environmental degradation, loss of biodiversity, environmental decay, and water/air/environmental pollution. According to Nest report, human settlements in Nigeria will be affected by climate change in a variety of ways. The report showed further urban and rural population concentrations will be disrupted, particularly along the coastline due to sea-level rise and related phenomena while some settlements are known to have already relocated farther inland from their original sites in response to sea incursion over some decades. Population displacement and migration from, and to, various human settlements will arise from either or both of drought incidence in the Northern states of the country and accelerated sea-level rise in the coastal regions. Rises in sea-level will also threaten urban and rural infrastructural facilities in low-lying coastal regions.

Extreme climate conditions such as high wind, heavy rainfall, heat and cold can result in wide-ranging scenarios such as tropical storms, floods, landslides, droughts and sea-level rise. Climatic catastrophes induce populations to be displaced (or decimated by death), which in turn can lead to conflict and civil unrest. As well, the public health infrastructure would be eroded if resources are diverted from its maintenance to disaster recovery. Communities and government would be burdened with having to make reparations to individuals for property damage and loss, unemployment, clean-up, and reduced socioeconomic viability of the communities affected.

3.7 Mitigation Option for Human Settlement

The IPCC (1995) report on climate change provides an assessment of historical trends of greenhouse gas (GHG) emissions from human settlements, analyzes the potential for emissions reductions, identifies various policy options, and discusses future scenarios of energy-efficiency improvements and associated GHG emissions reductions. It was reported that the largest portion of GHG emissions in human settlements is in the form of carbon dioxide (CO_2) from energy use in buildings (including emissions from power plants that produce electricity for buildings), amounting to about 1.7 billion tonnes of carbon. According to this report, three other major sources of GHG emissions are methane from urban solid waste (equivalent to 135-275 million tonnes of carbon in the form of CO_2), methane from domestic and industrial wastewater (200-275 million tonnes of carbon equivalent), and a variety of GHGs produced through the combustion of biomass in cook stoves throughout the developing world (estimated to be 100 million tonnes of carbon equivalent).

The report further revealed that in 1990, residential buildings contributed 19% of total global emissions of CO_2 while commercial buildings contributed an additional 10%. Industrialised countries produced 63% of global CO_2 emissions in 1990, while the former Soviet Union and Eastern Europe produced 19% and developing countries produced 18%. Overall growth in emissions of CO_2 from buildings was about 2% per year from 1973 to 1990. Almost all of this growth took place in developing countries and in the former Soviet Union and Eastern Europe (Fig. 5.1).

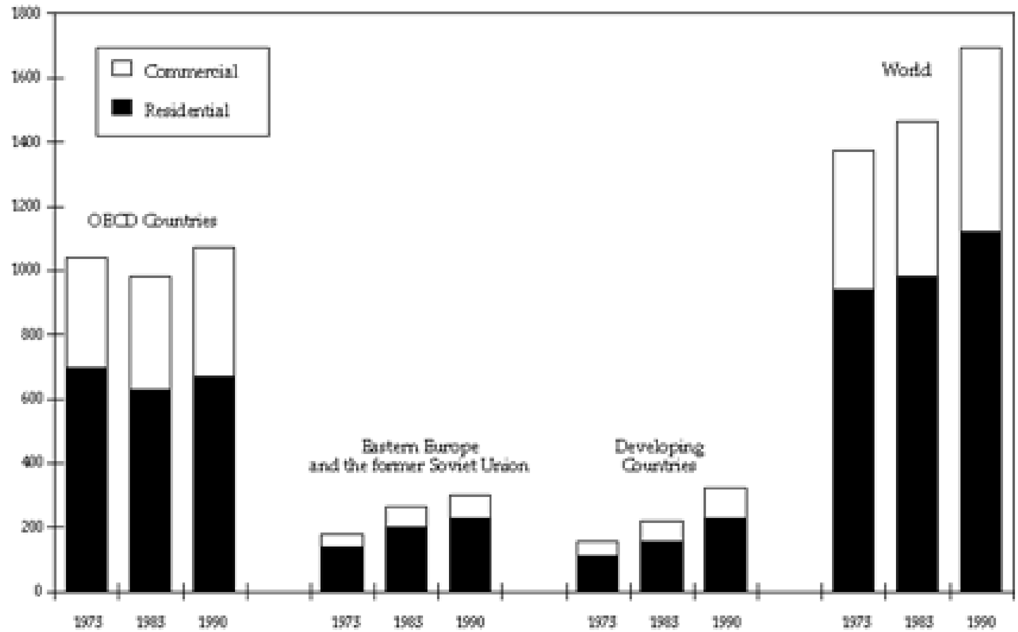

Fig. 5.1: Carbon Emissions from Residential and Commercial Buildings by Region, 1973, 1983, and 1990(after IPCC 1995)

The IPCC Report further revealed that the potential for the greatest growth in CO_2 emissions-in both percentage and absolute terms-is in the developing world, where per capita energy consumption in human settlements is currently very low. Even in the industrialised countries, however, if policies to minimise such emissions are not enacted and rigorously carried out, the already high levels of CO_2 emissions can increase. The most significant factors influencing the growth of GHG emissions in human settlements are efficiency of energy use, carbon intensity of fuels used directly in human settlements or to produce electricity, population growth, the nature of development in developing countries, the nature and rate of global economic growth, and implementation of policies that are directed toward fulfilling national commitments to reducing GHG emissions.

According to IPCC report on climate change the cost-effective technologies that are available to reduce energy consumption and hence CO_2 emissions include:

- more efficient space-conditioning systems
- improved insulation and reduced air leakage in windows, walls, and roofs
- more efficient lighting and appliances (refrigerators, water heaters, cook stoves, etc.).

It was also suggested that increased vegetation and greater reflectivity of roofing and siding materials can yield significant reductions in space-cooling energy requirements in warm climates in urban areas.

Policy options for reducing the growth of carbon emissions from human settlements include energy-pricing strategies, regulatory programmes, utility demand-side management programmes, demonstration and commercialisation programmes, and research and development. Each type of program has been carried out, primarily in industrialised countries, and many have achieved significant energy savings. Resources, such as collaborations in training activities and institution-building, are especially needed in developing countries.

4.0 CONCLUSION

In this unit, we have examined the impact of climate on human settlements and we have shown that climatic conditions need to be considered in the location and planning of new settlements to avoid unnecessary climatic hazards. We have equally examined the close inter-relationship between climate and building as well as how man with knowledge of weather and climate can design and build comfortable structures both safely and economically too. Although buildings primarily protect man against weather elements, the buildings themselves need to be protected against weather extremes. Their indoor climate also needs to be comfortable for them to perform their second major function- that of creating a suitable indoor climate for some specified purposes.

5.0 SUMMARY

In this unit, we have learnt that:

- climate is very important in planning and designing of building
- weather and climate is very important in actual construction of building
- sound knowledge of weather and climate is essential in maintenance of building and of satisfactory indoor activities
- climate change could affect human settlements in many ways, which may be direct or indirect
- climate change impact on human settlement could be mitigated through more efficient space conditioning; improved insulation and reduced air leakage in windows, walls, and roofs; and through more efficient lighting and appliances and
- carbon emissions from human settlements could be reduced by energy-pricing strategies, regulatory programmes, utility demand-side management programmes, demonstration and commercialisation programmes, and research and development policy.

6.0 TUTOR-MARKED ASSIGNMENT

1. With reference to specific example(s), explain how the factor of climate can influence the location, growth and development of human settlements.
2. Discuss the three major types of engineering problems in the building industry that are intimately linked to climate.

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UNIT 5 CLIMATE AND HUMAN AFFAIRS

CONTENTS

1.0 INTRODUCTION

Climate is never static and its variability both in space and time is an inherent characteristic of weather and climate (Ayoade, 1993). Variations in weather and climate are often complex and exercise noticeable impact on man and his activities. Climate acts as background, occasionally determines critical outcomes, often presents hazards or triggers disasters, and is a basic resource to human activities. Research on the ways climate, biomes, and society interact is framed by abiding views of the relationship between humans and their environment. Extreme episodes in the early 1970s fostered a resurgence of expressions of human vulnerability to climate, reminiscent of the `climatic determinism' voiced in the early decades of this century. As will be shown in this unit, climate, especially its variability and change largely influences almost the totality of human affairs in a number of diverse ways.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- describe the relevance of climate in human affairs
- explain the relationship between climate and human activities and
- discuss the effect of climate on human affairs.

3.0 MAIN CONTENT

3.1 Climate as a Determinant of Human Affairs

The sense of climate as a pervasive, powerful element of the environment forms a basis for climate determinism, the view that climate is a dominating influence in the molding of natural and social systems. Early historians and geographers, blending natural and human scientific exploration and description, lent a scholarly basis to determinist views. They described vegetation, animal, and even human populations as adapted to climatic constraints. This perspective is exemplified by Alexander von Humboldt's *Kosmos* (Otte,1849). In the first decades of the twentieth century, Ellsworth Huntington (1915) extended this view, claiming that climate is all-pervasive in molding social structure, settlement patterns, and human behaviour.

The contention that climate molds human behaviour and development has continued to gain prominence even among the contemporary social scientists. For example, Carpenter (1968) and Bryson *et al.* (1974) argued that drought caused the decline of Mycenaean Greek civilisation during the late Bronze Age. Writing about contemporary disparities in the development of nations, Lambert (1975) and Harrison (1979) attribute to global climate patterns a range of sociotechnical characteristics, from labour productivity to agricultural efficiency. Some modern analysts continue to invoke climate to explain the slow economic development of particular regions, especially the tropics (see, for example, Oury, 1969; Myrdal, 1972). A contemporary natural science approach that has a determinist flavor is found in Chang (1970). Chang explored the temperature-dependence of net photosynthesis and concluded tentatively that in warmer climates yields are smaller.

3.2 The Impact of Climate on Society

Climate and climatic variations exert a tremendous influence on society. The impact of climate and climatic variations on society may be positive (benevolent or desirable) or negative (malevolent or undesirable). Societies have often viewed climate primarily as a hazard and neglected it as a resource. Yet climate is both a hazard and a resource depending on time, location and the values and type of climatic parameters involved. The climate/society interface may be thought of in terms of adjustment, that is, the extent and ways in which society functions in a harmonious relationship with its climate. Man and his activities are vulnerable to climatic variations. At the same time, the activities of man in certain locations and over a period of time may lead to diminishing adjustment or increasing maladjustment of man to his climatic environment.

The extent to which a society is susceptible to damage by climatic causes is termed vulnerability. On the other hand, the ability of a society to 'bounce back' when adversely affected by climatic impacts is termed its resilience (Ayoade, 2004). Generally, a society is more vulnerable:

- the more its economic activities depend upon weather-sensitive factors of production
- the greater the unreliability and variability of certain key climatic variables like precipitation and temperature
- the lower its level of reserves of food and other materials
- the less developed the capacity of its transport system to move supplies from areas of surplus to areas of deficit
- the less the society has planned and prepared to deal with adverse climatic impacts.

Resilience of society in the face of adverse climatic impacts also depends on a number of similar factors. A society is likely to bounce back more effectively if it has:

- accumulated stocks or reserves of foods and other materials
- spare capacity built into the design of its infrastructure like power and water supplies and
- command of financial and material resources, technology and transportation with which to combat the impact. Intangible factors like social cohesion, morale and public confidence and trust in government and social institutions may also be important. Where these are lacking, resilience may be reduced considerably.

3.3 Impact of Climatic Variations on Human Activities

Since the essentials of life for mankind on this planet, namely air, water, food clothing and shelter, are weather-dependent or weather-related, it could be said that climate and climatic variations exercise an influence on man and his various activities. In terms of socio-economic activities, drought-induced famines can lead to migration and abandonment of settlements, a fact attested to by events following the 1972-73 sahelian droughts in West Africa and subsequent droughts in the same area and in Ethiopia and other countries in the Horn of Africa (Ayoade 1993). Variations in climate also affect national economies particularly those that are based on agriculture. Poor harvest of export crops will cause a decline in foreign exchange earnings and the income of the farmers. Poor harvest of food crops may cause food scarcity and high prices of foodstuff unless urgent ameliorative actions are taken by the government. Such actions usually involve food importation. But where the financial resources to import are lacking, a serious food crisis may result and food aid programme may need to be established to avoid starvation and death among the populace. Again, Ethiopia's situation in recent years demonstrates the adverse impact of unfavourable climatic conditions on the well-being of man (Ayoade, 1993).

As noted by Critchfield (1974), human health, energy and comfort are affected more by climate than any other element of the physical environment. The physiological functions of the human body respond to changes in the weather. Certain illnesses are climate induced while several diseases that affect man show a close correlation with climatic-conditions and season in their incidence. The climatic elements which directly affect the physiological functions of the human body include radiation (sunshine), temperature, humidity, wind and atmospheric pressure. Human physiological comfort is determined mainly by temperature, wind and humidity.

Human physical vigour is influenced by temperature, humidity and wind. Generally, high temperature and humidity tend to decrease physical vigour as well as mental vigour. Very dry air or extremely low temperatures may also impair physical vigour and adversely affect attitude to mental work. Extremely low pressure will result in a decreased supply of oxygen to the brain with consequent decrease in mental vigour or alertness. Moderate fluctuations in weather are generally regarded as stimulating to physical and mental vigour. Weather also appears to influence human emotions and behaviour. For instance, crimes, riots, insanity and other individual as well as group emotional outbursts seem to reach their peak at the onset of or during hot unpleasant weather (Critchfield, 1974).

Climate influences in varying degrees the various economic activities that man engages in. These include agriculture and animal husbandry, manufacturing industry, commerce and tourism. Climate also influences utilities, transport, and communication systems; often impairing their efficiency and usability. Activities which are carried out outdoors are extremely weather-vulnerable. Such activities include mining, construction, tourism and various leisure activities such as games and sports. These activities can only be successfully pursued if suitable climatic conditions prevail (Ayoade, 2004).

Activities carried out indoors are also vulnerable to climatic variations. Weather conditions influence the performance and durability of machinery. The tropical climatic conditions, for instance, tend to encourage rusting of machinery. Besides, certain industrial processes can best take place under certain temperature and humidity conditions. If such conditions do not naturally exist, they have to be artificially created at additional cost through air conditioning. The supply of materials used in the manufacturing processes may also be weather-dependent. For instance, agro-allied industries (mainly food processing or fruit canning industries) depend on good harvest as well as adequate and efficient transportation to bring in supplies. Some industrial goods are also seasonally required by the people. The output of such goods will therefore be determined by prevailing climatic conditions.

Retailing and commerce are favoured by climatic conditions that encourage people to go out for shopping. Precipitation and/or extreme cold tend to reduce sales as many would-be shoppers stay at home. Poor visibility and heavy snowfall will also adversely affect sales as well as supply of goods. This is because transportation system will be disrupted under such weather conditions. All forms of transportation- road, rail, air and water- are vulnerable to weather conditions although in varying degrees. The most vulnerable is perhaps air transport. Adverse weather conditions may cause accidents, delays, diversions, and even outright cancellation of journeys with concomitant inconvenience, loss of revenue, time or even lives in some cases. Poor visibility is the single most important weather hazard to all forms of transportation. Others include heavy precipitation (be it rain or snow), high winds or blizzard, violent storms, and ground frost (for road and rail transport only).

Climate also partly determines the way we build our houses and the way we dress. Type of clothing varies from one culture to another and also from one climatic zone to another. The world has been divided into seven zones according to the clothing requirements that would maintain a comfortable heat balance in a normal human body, the: minimal clothing zone; long flowing robe clothing zone; one-layer clothing zone; two-layer clothing zone; three-layer clothing zone; four-layer clothing zone; and, arctic zone (Griffiths,1976). Weather and climatic conditions are relevant factors in the efficient sitting of buildings, choice of materials, design and air-conditioning of the structure (Critchfield, 1974). All the three stages involved in the building industry namely: design, construction and air conditioning (the maintenance of satisfactory indoor climate through thermal and ventilation control) are all weather and climate-dependent. Construction is an outdoor activity and is consequently directly affected by prevailing weather conditions. Rain, snow, high winds, temperature extremes have adverse effects on construction activities.

4.0 CONCLUSION

From the above, it is obvious that climatic variations can influence human affairs in several ways including the survival of man and his socio-economic structures. Man therefore needs to show interest in the problems of climatic variations especially their causes and mechanisms.

5.0 SUMMARY

In this unit, we have shown that climate is never static and that variability is an inherent attribute of climate. Climate acts as background, occasionally determines critical outcomes, often presents hazards or triggers disasters, and is a basic resource to human activities. We have equally shown how climate and its variability affect the numerous activities of man. Man therefore needs to show interest in the problems of climatic variations especially their causes and mechanisms so as to know how to prepare adequately and cope satisfactorily with such variations.

6.0 TUTOR-MARKED ASSIGNMENT

1. Examine the impact of climatic variations on man and his activities.
2. Discuss the view that climate is an important determinant of human affairs.

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MODULE 2

UNIT 1 WEATHER MODIFICATION AND THEIR IMPLICATIONS

CONTENTS

1.0 INTRODUCTION

Human influence on the weather and, ultimately, climate can be either intentional, as with cloud seeding to clear fog from airports or to increase precipitation, or unintentional, as with air pollution, which increases aerosol concentrations and reduces sunlight. Weather is considered to be the day-to-day variations of the environment—temperature, cloudiness, relative humidity, wind-speed, visibility, and precipitation; while climate, on the other hand, reflects the average and extremes of these variables, changing on a seasonal basis. Weather change may lead to climate change, which is assessed over a period of years.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- explain climate as dominant force in aviation
- explain weather and climatic data as essential ingredients in aviation

- describe the relationship between climate and aviation development planning.

3.0 MAIN CONTENT

3.1 What is Weather Modification?

Weather modification is the term used to describe man's attempts at influencing the climate, which could be deliberate or inadvertent. Inadvertent weather modification occurs as a result of certain human actions and activities designed to achieve goals totally unconnected with the weather. Such activities include: urbanisation, cultivation, lumbering and cattle grazing, among others. Meanwhile, weather modification is deliberate or purposeful when man intentionally sets out to influence or modify weather for whatever reason. Usually, man attempts to modify weather when he considers it detrimental to his economic and social life objectives. Such purposeful weather modification by man is known as weather control and it is one of the ways by which man responds to the vagaries and hazardousness of weather (Ayoade, 1993). This unit is mainly concerned with purposeful weather modification, or simply put, weather control.

3.2 Why Weather Modification?

There are several motivations for weather modification by man (Ayoade, 2004). Man attempts to modify weather to achieve one or more of the following:

- to reduce the economic and social losses that result from severe weather events like hurricanes, hailstones, frosts, droughts, fogs, lightning-caused fires, etc. Drought, frost and hailstones can damage crops and lower yield with consequent losses of income to the farmers and scarcity of food. Fogs and high winds can dislocate transport systems and aid accidents with consequent losses of income and lives. Controlling weather will enable man to avoid or drastically cut down such losses in materials and men. Table 1 below shows the annual estimated losses from the effect of adverse weather conditions in the United States of America for which some data were available
- to augment the supply of those weather elements that serve as input in the production of particular commodities or services. For instance, the supply of water may be augmented by cloud seeding or by suppressing evaporation from reservoirs by the use of acetyl alcohol, microscopic beads, or shelter belts.

- to improve health as well as mental and physical efficiency. This involves the creation of an artificial microclimate conducive to the maintenance of physiological comfort in human beings.

Table 1: Annual Average Losses from Weather Hazards

Weather hazard	Loss (in millions)
Hurricanes	Over $250
Lightning-caused fires	$200
Hailstones	$300
Fog and Snow	$66

(Source: Ayoade, 2004).

3.3 Weather Modification Processes

Man's ability to control weather is still very much limited and confined to local climate. The control of weather by man first began when he started building shelter to protect him against weather elements and maintain a suitable indoor microclimate. The use of fans, heaters and air conditioners is nowadays quite common. All these devices are used by man to control the microclimate inside buildings. Other weather control activities of man include: cloud seeding to stimulate precipitation, suppression of hail and lightning, clearance of fog at airports, prevention of crop damage by frosts, reduction of evaporation from reservoirs and suppression of violent storms such as hurricanes. Some of these activities are scientifically based as discussed below.

Experiments carried out in the United States in the mid 1940s indicated that precipitation can be stimulated by seeding suitable clouds with dry ice (solid CO_2) or silver iodide which has a structure similar to that of ice. The input of these additional condensation nuclei into the cloud helps to precipitate the Bergeron-Findeisen process of precipitation formation in cold cloud. It was later shown that the coalescence process can be similarly encouraged in warm cloud by seeding such cloud with salt particles such as calcium chloride or water droplets. Seeding can be done from above the target cloud using airplanes or from the ground using artillery shells containing silver iodide or dry ice.

Experimental results in the United States have demonstrated that lightning and hail can also be suppressed by cloud seeding and explosion rockets. Although, the formation of hailstones cannot really be prevented, but with seeding, it is believed that the silver iodide or ice crystals will create many more centers of condensation within the cloud thus encouraging more but smaller crystals of ice to develop.

Control of hurricanes and other violent storms seems not possible in practice yet. But since the energy that powers the hurricanes is derived from the release of latent heat, it is believed that the rate at which the latent heat is released can be controlled by seeding the cloud with dry ice or silver iodide. It has also been suggested that the ocean ahead of a developing hurricane can be covered by some materials to prevent evaporation and uptake of latent heat into the storm.

Reduction of evaporation from a reservoir is desirable where high amounts of water is lost through the process as is often the case in semi-arid and arid environment. Several techniques are available for reducing the rate of evaporation off a reservoir. Some of these are:

- use of shelterbelt to reduce wind velocity over the reservoir. The effectiveness of the shelter belt will depend on its height, lateral extent, distance from the reservoir and the degree of permeability. If the trees forming the shelterbelt are tall enough and close enough to the reservoir surface and shut off part of the incident solar radiation
- use of evaporation suppressants such as acetyl alcohol, hexedecanol and octadecanol. The efficiency of these suppressants tends to vary with wind speed and reservoir size and inversely with water temperature. White microscopic beads have also been used as evaporation suppressants in several experiments. Generally speaking, these suppressants appear to be more effective in the temperate region than in the tropics where lower evaporation reductions have been observed.

3.4 Implication of Weather Modification

Deliberate or inadvertent, weather modification has a lot of serious implications or impacts on climate especially in urban than surrounding rural areas. In urban areas, the chemical composition of the atmosphere is altered. The thermal and the hydrological properties of the earth's surface as well as its aerodynamic roughness parameters are altered by the process of urbanisation and industrialisation. Marshes are drained and natural surfaces are replaced by more impervious surfaces of pavements, tarred roads, and roofs of buildings. As a result, both long wave and short wave radiation are reduced over urban areas. Temperatures are raised even though the duration of sunshine is reduced. Humidity is reduced but there is some increase in precipitation. Cloud amount is increased. Fogs are thicker, occur more frequently and more persistent, thus impairing visibility. Turbulence is increased. Strong winds are decelerated and light winds are accelerated as they move into urban areas.

Two aspects of urban climate as a consequence of weather modification are particularly noteworthy because of their wider implications. These are:

- increase in temperature over urban areas (the so-called heat island phenomenon). Studies of this phenomenon have been carried out mainly in cities in the temperate region, and the results indicate that urban areas are much warmer than their rural environs particularly at nights. The heat island effect also tends to speed up the process of chemical weathering of building materials

- pollution of the city air. As in the case of urban heat island, air pollution (the introduction into the air of any substances different from any of its natural constituents) has a number of biological, economic and meteorological implications. Studies have shown that fruit trees in polluted areas are 10% smaller and produce 10% less fruits with diminished vitamin C content compared to trees in clean air (Maunder 1970). Buildings suffer from corrosion as a result of air pollution. There is evidence that air pollution is an important factor in certain respiratory and lung diseases so common in industrialised cities of temperate latitudes. It can also result in the formation of acid rain which has a lot of serious environmental effects such as biomass decline and premature loss of leaves and leaching of leaf nutrients, among others.

3.5 Problems of Weather Modification

Weather control activities face problems of diverse nature. There is the scientific problem of whether man can as a matter of fact successfully control climate and without undesirable side effects. For example, the augmentation of precipitation through cloud seeding to solve the problem of drought has been challenged and misplaced for three reasons. First, is that there is need for suitable cloud to exist before seeding can take place, and in reality, such suitable (or even any) clouds rarely exist during drought periods. Second, is that even where suitable clouds exist and are seeded, the amount of precipitation obtained may be negligible and it may fall outside the target area, i.e. where it is not needed. Third, it has been argued that cloud seeding does not cause additional precipitation in reality but causes a spatial redistribution of precipitation. And that once the moisture in a given cloud is forced to precipitate such moisture is lost to the area downwind.

Weather control, especially artificial rain-making is bedeviled with both political and legal problems (Maunder, 1970). The main reason behind this has been that the results of such weather modification are not universally beneficial as well as the undesirable effects it brings sometimes. In fact, several court cases have arisen out of weather control activities in the United States especially in the 1950s. An example was that in which Mr. Stutzky, a resort owner, sued the city of New York in 1950 when the latter wanted to stimulate rainfall by cloud seeding so as to improve water supply to the 10 million inhabitants of New York then during a period of drought. Mr. Stutzky argued that such rainfall would interfere with his resort business. The city of New York won the cloud seeding litigation then because the court was not prepared to protect a possible private injury at the expense of a public advantage.

Weather control is no doubt an expensive and very technical operation. It requires expensive basic research and skilled personnel. Cost-benefit analysis of weather control may therefore be unfavourable. Even where favourable, there may still be political and legal problems. Besides our knowledge of the atmosphere, its working processes are still rather limited. It is virtually impossible yet to forecast all consequences of any weather control activity.

4.0 CONCLUSION

The unit concluded that there is still the need for proper understanding of the working of the atmosphere before we can meaningfully and profitably control weather. Through better understanding there will be great ability to predict weather and climate with a high degree of accuracy. Until we are able to do this, purposeful weather modification especially on a regional or global scale will remain a meteorologically unrealistic dream.

5.0 SUMMARY

In this unit, we have learnt that:

- weather modification could be deliberate or inadvertent
- inadvertent weather modification occurs as a result of certain human actions and activities designed to achieve certain goals unconnected with the weather
- weather modification is deliberate or purposeful when man intentionally sets out to influence or modify weather
- weather control is an expensive and very technical operation that requires expensive basic research and skilled personnel.

6.0 TUTOR-MARKED ASSIGNMENT

1. Weather modification by man has many serious implications. Elucidate.
2. Discuss the problems and prospects of purposeful weather modification.

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UNIT 2 ACID RAIN

CONTENTS

1.0 INTRODUCTION

Acid rain is a popular term for the atmospheric deposition of acidified rain, snow, sleet, hail, acidifying gases and particles, as well as acidified fog and cloud water (Davis *et al* .2007). It is a term used to describe rain or any other form of precipitation that is unusually acidic. Acid rain can also refer to the deposition of wet (rain, snow, sleet, fog and cloud water, dew) and dry (acidifying particles and gases) acidic components. It is not pure acid falling from the sky, but rather it is rainfall or atmospheric moisture that has been mixed with elements and gases that have caused the moisture to become more acidic than normal. Pure water has a pH of 7, and, generally, rainfall is somewhat on the acidic side (a bit less than 6). But, acid rain can have a pH of about 5.0-5.5. A more accurate term is “acid deposition”. Distilled water, which contains no carbon dioxide, has a neutral pH of 7. Generally, liquids with a pH less than 7 are acidic, and those with a pH greater than 7 are basic.

"Clean" or unpolluted rain has a slightly acidic pH of about 5.2, because carbon dioxide and water in the air react together to form carbonic acid, a weak acid (pH 5.6 in distilled water), but unpolluted rain also contains other chemicals.

$$\mathbf{H_2O\ (l) + CO_2\ (g) \rightarrow H_2CO_3\ (aq)}$$

Carbonic acid then can ionize in water forming low concentrations of hydronium ions:

$$\mathbf{2H_2O\ (l) + H_2CO_3\ (aq) \rightleftharpoons CO_3^{2-}\ (aq) + 2H_3O^{+}(aq)}$$

The extra acidity in rain comes from the reaction of primary air pollutants; primarily sulfur oxides and nitrogen oxides, with water in the air to form strong acids (like sulfuric and nitric acid). The main sources of these pollutants are industrial power-generating plants and vehicles.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define acid rain
- identify the sources and causes of acid rain
- explain the chemistry of acid rain
- explain the effects of acid rain.

3.0 MAIN CONTENT

3.1 What is Acid Rain?

Acid rain is rainfall or atmospheric moisture that has been mixed with elements and gases that have caused the moisture to become more acidic than normal. In a nutshell, it is a term used to describe rain or any other form of precipitation that is unusually acidic.

3.2 History of Acid Rain

Since the Industrial Revolution, emissions of sulphur dioxide and nitrogen oxides to the atmosphere have increased. In 1852, Robert Angus Smith was the first to show the relationship between acid rain and atmospheric pollution in Manchester, England. Though acidic rain was discovered in 1852, it was not until the late 1960s that scientists began widely observing and studying the phenomenon. The term "acid rain" was generated in 1972. Canadian Harold Harvey was among the first to research a "dead" lake. Public awareness of acid rain in the U.S increased in the 1970s after the New York Times promulgated reports from the Hubbard Brook Experimental Forest in New Hampshire of the myriad deleterious environmental effects demonstrated to result from it. Occasional pH readings in rain and fog water of well below 2.4 (the acidity of vinegar) have been reported in industrialised areas. Industrial acid rain is a substantial problem in Europe, China, Russia and areas down-wind from them. These areas burn sulfur-containing coal to generate heat and electricity. The problem of acid rain not only has increased with population and industrial growth, but has become more widespread. The use of tall smokestacks to reduce local pollution has contributed to the spread of acid rain by releasing gases into regional atmospheric circulation. Often, deposition occurs at a considerable distance down-wind of the emissions, with mountainous regions tending to receive the greatest deposition (simply because of their higher rainfall). An example of this effect is the low pH of rain (compared to the local emissions) which falls in Scandinavia.

Acid rain was discovered in 1963 in North America at the Hubbard Brook Experimental Forest, site of the Hubbard Brook Ecosystem Study in the White Mountains of New Hampshire, in rain that was some 100 times more acidic than unpolluted rain. Innovations for reducing fossil fuel emissions, such as scrubbers upstream of the tall smokestacks on power plants and factories, catalytic converters on automobiles, and use of low-sulfur coal, have been employed to reduce emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x). As a result of increasing global economies, fossil fuel combustion is increasing around the world, with concomitant spread of acid rain.

3.3 Causes of Acid Rain

Acid rain is a uniquely human-related phenomenon. The burning of fossil fuels (coal and oil) by power-production companies and industries releases sulfur into the air that combines with oxygen to form sulfur dioxide (SO_2). Exhausts from cars cause the formation of nitrogen oxides in the air. From these gases, airborne sulfuric acid (H_2SO_4) and nitric acid (HNO_3) can be formed and be dissolved in the water vapor in the air. Although acid-rain gases may originate in urban areas, they are often carried for hundreds of miles in the atmosphere by winds into rural areas. That is why forests and lakes in the countryside can be harmed by acid rain that originates in cities.

As noted earlier, acid rain is mostly caused by human emissions of sulfur and nitrogen compounds which react in the atmosphere to produce acids. The increased acidity of these depositions, primarily from the strong acids, sulfuric and nitric, is generated as a by-product of the combustion of fuels containing sulfur or nitrogen, especially fossil fuel power plants. The heating of homes, electricity production, and driving vehicles all rely primarily on fossil fuel energy. When fossil fuels are combusted, acid-forming nitrogen and sulfur oxides are released to the atmosphere. These compounds are transformed in the atmosphere, often traveling thousands of kilometres from their original source, and then fall out on land and water surfaces as acid rain.

3.4 Processes of Acid Rain Formation

Several processes can result in the formation of acid deposition. Nitrogen oxides (NO_x) and sulfur dioxide (SO_2) released into the atmosphere from a variety of sources can fall to the ground simply as dry deposition. This dry deposition can then be converted into acids when these deposited chemicals meet water. Most wet acid deposition forms when nitrogen oxides (NO_x) and sulfur dioxide (SO_2) are converted to nitric acid (HNO_3) and sulfuric acid (H_2SO_4) through oxidation and dissolution. Wet deposition can also form when ammonia gas (NH_3) from natural sources is converted into ammonium (NH_4).

The source of the acids released to the atmosphere is largely the combustion of fossil fuels that produce waste by-products including gases such as oxides of sulfur and nitrogen. Ammonia (NH_3) is a by-product of some natural processes, as well as agricultural sources (e.g., application of nitrogen fertilizers; confined animal feedlots). In its dissolved form (NH_4^+) it contributes acidity to surface waters through the process of nitrification. Oxidized sulfur and nitrogen gases are acid precursors in the atmosphere. For example, SO_2 reacts with water in the atmosphere to yield sulfuric acid:

$$\boldsymbol{SO_2 + H_2O = H_2SO_4}$$

An analogous reaction of water with nitrogen oxides, symbolized as NO_x, yields nitric acid (HNO_3).

In addition to wet deposition (rain, snow, and fog), acidic deposition includes the deposition of dry, particulate, and gaseous acid precursors that become acidic in contact with moisture. This dry deposition is difficult to quantify and expensive to measure. Inferential methods indicate that dry deposition represents 20 to 80% of the total deposition of acids to the landscape, depending on factors such as location, season, and total rainfall.

Natural sources can also contribute additional acidity to precipitation. Natural emissions can come from wetlands and geologic sources. Major natural sources of NO_x include lightning and soil microbes. Organic acidity may arise from freshwater wetlands and coastal marshes. It is these natural sources that lead to the inference that pre-industrial precipitation in forested regions had a pH around 5.0. If true, then modern precipitation in the North and East is two to three times more acidic than pre-industrial.

The acidity of precipitation is still subject to misunderstanding. Even in pristine environments, precipitation pH is rarely controlled by the carbon dioxide (CO_2) reaction that has an equilibrium pH of 5.6:

$$H_2O + CO_2 = H_2CO_3$$

Because of the many sources of acidity in precipitation, pH 5.6 is not the benchmark 'normal' pH against which the acidity of modern precipitation should be compared. Precipitation is a variable and complex mixture of particulates and solutes derived from local sources and long-range transport. For example, in arid or partly forested regions, dust from soil and bedrock typically neutralises both the natural and human sources of acidity in precipitation, yielding a solution that may be quite basic (pH greater than 7).

3.5 Effects of Acid Rain

Acid rain has harmful effects on plants, aquatic animals, and infrastructure. However, the environment can generally adapt to a certain amount of acid rain. Often, soil is slightly basic (due to naturally occurring limestone, which has a pH of greater than 7). Because bases counteract acids, these soils tend to balance out some of the acid rain's acidity. But in areas, such as some of the Rocky Mountains and parts of the northwestern and southeastern United States, where limestone does not naturally occur in the soil, acid rain can harm the environment.

Some fish and animals, such as frogs, have a hard time adapting to and reproducing in an acidic environment. Many plants, such as evergreen trees, are damaged by acid rain and acid fog. I have seen some of the acid-rain damage to the evergreen forests in the Black Forest of Germany. Much of the Black Forest was indeed black because so much of the green pine needles had been destroyed, leaving only the black trunks and limbs! You also might notice how acid rain has eaten away the stone in some cities' buildings and stone artwork.

Acid rain has been shown to have adverse impacts on forests, freshwaters and soils, killing insect and aquatic life forms as well as causing damage to buildings and having impacts on human health.

3.5.1 Surface Waters and Aquatic Animals

Surface waters become acidic when the supply of acids from atmospheric deposition and watershed processes exceed the capacity of watershed soils and drainage waters to neutralize them. Surface waters are defined as 'acidic' if their acid neutralizing capacity (ANC, analogous to alkalinity) is less than 0, corresponding to pH values less than about 5.2. The chemical conditions that define acidity are that acid anion concentrations (sulfate, nitrate, organic acids) are present in excess of concentrations of base cations (typically calcium or magnesium), the products of mineral weathering reactions that neutralize acidity in soil or rock.

Acid deposition degrades water quality by lowering pH levels (i.e., increasing acidity); decreasing acid-neutralizing capacity (ANC); and increasing aluminum concentrations.

Both the lower pH and higher aluminum concentrations in surface water that occur as a result of acid rain can cause damage to fish and other aquatic animals. At pH lower than 5 most fish eggs will not hatch and lower pH can kill adult fish. As lakes and rivers become more acidic biodiversity is reduced. Acid rain has eliminated insect life and some fish species, including the brook trout in some lakes, streams, and creeks in geographically sensitive areas, such as the Adirondack Mountains of the United States.

However, the extent to which acid rain contributes directly or indirectly via runoff from the catchment to lake and river acidity (i.e., depending on characteristics of the surrounding watershed) is variable. The US EPA's website states: *"Of the lakes and streams surveyed, acid rain caused acidity in 75 per cent of the acidic lakes and about 50 per cent of the acidic streams"*.

Sensitive species may be lost even at moderate levels of acidity. For example, some important zooplankton predators are not found at pH levels below 5.6; sensitive mayfly species (e.g., *Baetis lapponicus*) are affected at pH levels near 6.0; and sensitive fish species, such as the fathead minnow, experience recruitment failure and extinction at pH 5.6 to 5.9.

Decreases in pH and elevated concentrations of aluminum have reduced the species diversity and abundance of aquatic life in many streams and lakes in acid-sensitive areas of the Northeast. Fish have received the most attention to date, but entire food webs are often adversely affected. Decreases in pH and increases in aluminum concentrations have diminished the species diversity and abundance of plankton, invertebrates, and fish in acid-impacted surface waters in the Northeast. In the Adirondacks, a significant positive relationship exists between the pH and acid-neutralising capacity (ANC) of lakes and the number of fish species present in those lakes. Surveys of 1,469 Adirondack lakes conducted in 1984 and 1987 show that 24 per cent of lakes (i.e., 346) in this region do not support fish. These lakes had consistently lower pH and ANC, and higher concentrations of aluminum than lakes that contained one or more species of fish. Even acid-tolerant fish species such as brook trout have been eliminated from some waters in the Northeast.

Acid episodes are particularly harmful to aquatic life because abrupt changes in water chemistry allow fish few areas of refuge. High concentrations of aluminum are directly toxic to fish and are a primary cause of fish mortality during acid episodes. High acidity and aluminum levels disrupt the salt and water balance in fish, causing red blood cells to rupture and blood viscosity to increase. Studies show that the viscous blood strains the fish’s heart, resulting in a lethal heart attack.

The absence of fish and the presence of aluminum in lakes provide important information about the condition of soils within a watershed. The release of aluminum from the soil into rivers and streams usually indicates that the available calcium in the soil is low and has been depleted. Furthermore, trees growing in such soils may experience greater nutritional stress.

3.5.2 Soils

Soil biology and chemistry can be seriously damaged by acid rain. Some microbes are unable to tolerate changes to low pH and are killed. The enzymes of these microbes are denatured (changed in shape so they no longer function) by the acid. The hydronium ions of acid rain also mobilize toxins, e.g. aluminum, and leach away essential nutrients and minerals.

$$\mathbf{2\underline{H}^{+}\,(aq) + \underline{Mg}^{2+}\,(clay) \rightleftharpoons 2H^{+}\,(clay) + Mg^{2+}(aq)}$$

Soil chemistry can be dramatically changed when base cations, such as calcium and magnesium, are leached by acid rain thereby affecting sensitive species, such as sugar maple (Acer saccharum).

Acid deposition has altered and continues to alter soils in three ways. Acid deposition depletes calcium and other base cations from the soil; facilitates the mobilization of dissolved inorganic aluminum (hereafter referred to simply as aluminum) into soil water; and increases the accumulation of sulfur and nitrogen in the soil.

3.5.2.1 Loss of Calcium and other Base Cations

In the past 50-60 years, acid deposition has accelerated the loss of large amounts of available calcium from soils in the Northeast. This conclusion is based on a limited number of soil studies, but at present, calcium depletion has been documented at more than a dozen study sites throughout the Northeast, including sites in the Adirondacks, the White Mountains, the Green Mountains, and the state of Maine. Depletion occurs when base cations are displaced from the soil by acid deposition at a rate faster than they can be replenished by the slow breakdown of rocks or the deposition of base cations from the atmosphere. This depletion of base cations fundamentally alters soil processes, compromises the nutrition of some trees, and hinders the capacity for sensitive soils to recover.

3.5.2.2 Mobilization of Aluminum

Aluminum is often released from soil to soil water, vegetation, lakes, and streams in forested regions with high acid deposition, low stores of available calcium, and high soil acidity. High concentrations of aluminum can be toxic to plants, fish, and other organisms. Concentrations of aluminum in streams at the Hubbard Brook Experimental Forest, New Hampshire (HBEF) are often above levels considered toxic to fish and much greater than concentrations observed in forested watersheds receiving low levels of acid deposition.

3.5.2.3 Accumulation of Sulfur and Nitrogen

Acid deposition results in the accumulation of sulfur and nitrogen in forest soils. As sulfate is released from the soil, it acidifies nearby streams and lakes. The recovery of surface waters in response to emission controls has therefore been delayed and will not be complete until the sulfate left by a long legacy of acid deposition is released from the soil.

Similarly, nitrogen has accumulated in soil beyond the amount needed by the forest and appears now to be leaching into surface waters in many parts of the Northeast. This process also acidifies lakes and streams. Forests typically require more nitrogen for growth than is available in the soil. However, several recent studies suggest that in some areas, nitrogen levels are above what forests can use and retain.

3.5.3 Forests and Other Vegetation

Adverse effects may be indirectly related to acid rain, like the acid's effects on soil (as shown above) or high concentration of gaseous precursors to acid rain. High altitude forests are especially vulnerable as they are often surrounded by clouds and fog which are more acidic than rain.

Other plants can also be damaged by acid rain but the effect on food crops is minimised by the application of lime and fertilizers to replace lost nutrients. In cultivated areas, limestone may also be added to increase the ability of the soil to keep the pH stable, but this tactic is largely unusable in the case of wilderness lands. When calcium is leached from the needles of red spruce, these trees become less cold-tolerant and exhibit winter injury and even death.

The 1990 National Acid Precipitation Assessment Program (NAPAP) report to Congress in the U.S. concluded there was insubstantial evidence that acid deposition had caused the decline of trees other than red spruce growing at high elevations. More recent research shows that acid deposition has contributed to the decline of red spruce trees throughout the eastern U.S. and sugar maple trees in central and western Pennsylvania. Symptoms of tree decline include poor crown condition, reduced tree growth, and unusually high levels of tree mortality. Red spruce and sugar maple are the species that have been the most intensively studied.

3.5.3.1 Red Spruce

Since the 1960s, more than half of large canopy red spruce in the Adirondack Mountains of New York and the Green Mountains of Vermont and approximately one quarter of large canopy red spruce in the White Mountains of New Hampshire have died. Significant growth declines and winter injury to red spruce have been observed throughout its range. Acid deposition is the major cause of red spruce decline at high elevations in the Northeast. Red spruce decline occurs by both direct and indirect effects of acid deposition. Direct effects include the leaching of calcium from a tree's leaves and needles (i.e., foliage), whereas indirect effects refer to changes in the underlying soil chemistry.

Recent research suggests that the decline of red spruce is linked to the leaching of calcium from cell membranes in spruce needles by acid rain, mist or fog. The loss of calcium renders the needles more susceptible to freezing damage, thereby reducing a tree's tolerance to low temperatures and increasing the occurrence of winter injury and subsequent tree damage or death. In addition, elevated aluminum concentrations in the soil may limit the ability of red spruce to take up water and nutrients through its roots. Water and nutrient deficiencies can lower a tree's tolerance to other environmental stresses and cause decline.

3.5.3.2 Sugar Maple

The decline of sugar maple has been studied in the eastern United States since the 1950s. Extensive mortality among sugar maples in Pennsylvania appears to have resulted from deficiencies of base cations, coupled with other stresses such as insect defoliation or drought. According to research studies, the probability of the loss of sugar maple crown vigor or the incidence of tree death increased on sites where supplies of calcium and magnesium in the soil and foliage were the lowest and stress from insect defoliation and/or drought was high. In northwestern and north central Pennsylvania, soils on the upper slopes of unglaciated sites contain low calcium and magnesium supplies as a result of more than half a million years of weathering combined with the leaching of these elements by acid deposition. Low levels of these base cations can cause a nutrient imbalance and reduce a tree's ability to respond to stresses such as insect infestation and drought.

3.5.4 Human Health

Scientists have suggested direct links to human health. Fine particles, a large fraction of which are formed from the same gases as acid rain (sulfur dioxide and nitrogen dioxide), have been shown to cause illness and premature deaths such as cancer and other diseases.

3.5.5 Other Adverse Effects: Effect on Statues

Acid rain can also cause damage to certain building materials and historical monuments. This results when the sulfuric acid in the rain chemically reacts with the calcium compounds in the stones (limestone, sandstone, marble and granite) to create gypsum, which then flakes off.

$$CaCO_3\,(s) + H_2SO_4\,(aq) \rightleftharpoons CaSO_4\,(aq) + CO_2\,(g) + H_2O\,(l)$$

This result is also commonly seen on old gravestones where the acid rain can cause the inscription to become completely illegible. Acid rain also causes an increased rate of oxidation for iron. Visibility is also reduced by sulfate and nitrate aerosols and particles in the atmosphere.

3.6 Geographic Distribution of Acid Rain

Acidity in rain is measured by collecting samples of rain and measuring its pH. To find the distribution of rain acidity, weather conditions are monitored and rain samples are collected at sites all over the country. The areas of greatest acidity (lowest pH values) are located in the Northeastern United States. This pattern of high acidity is caused by the large number of cities, the dense population, and the concentration of power and industrial plants in the Northeast. In addition, the prevailing wind direction brings storms and pollution to the Northeast from the Midwest, and dust from the soil and rocks in the Northeastern United States is less likely to neutralise acidity in the rain.

Particularly badly affected places around the globe include most of Europe (particularly Scandinavia with many lakes with acidic water containing no life and many trees dead) many parts of the United States (states like New York are very badly affected) and South Western Canada. Other affected areas include the South Eastern coast of China and Taiwan.

3.7 Potential Problem Areas in the Future

Places like much of South Asia (Indonesia, Malaysia and Thailand), Western South Africa (the country), Southern India and Sri Lanka and even West Africa (countries like Ghana, Togo and Nigeria) could all be prone to acidic rainfall in the future.

3.8 Technical Solutions/ Prevention of Acid Rain

In the United States, many coal-burning power plants use Flue gas desulphurization (FGD) to remove sulfur-containing gases from their stack gases. An example of FGD is the wet scrubber which is commonly used in the U.S. and many other countries. A wet scrubber is basically a reaction tower equipped with a fan that extracts hot smoke stack gases from a power plant into the tower. Lime or limestone in slurry form is also injected into the tower to mix with the stack gases and combine with the sulfur dioxide present. The calcium carbonate of the limestone produces pH-neutral calcium sulfate that is physically removed from the scrubber. That is, the scrubber turns sulfur pollution into industrial sulfates.

In some areas the sulfates are sold to chemical companies as gypsum when the purity of calcium sulfate is high. In others, they are placed in landfill. However, the effects of acid rain can last for generations, as the effects of pH level change can stimulate the continued leaching of undesirable chemicals into otherwise pristine water sources, killing off vulnerable insect and fish species and blocking efforts to restore native life.

The use of automobile emissions control has been and can still be employed to reduce emissions of nitrogen oxides from motor vehicles.

4.0 CONCLUSION

In this unit, we have examined the concept of acid rain as any other form of precipitation that is unusually acidic. The historical perspective of acid rain, causes, processes, effects, and geographical distribution of acid rain were equally examined. The potential problem areas in the future were identified. Technical solutions towards preventing the scourge of acid rain in the future as demonstrated in the developed world were not left untouched.

5.0 SUMMARY

In this unit, we have learnt that:

- acid rain is a term used to describe rain or any form of precipitation that is unusually acidic
- acid rain is the deposition of wet or dry acidic components
- acid rain is not pure acid falling from the sky but rainfall or atmospheric moisture that has been mixed with the elements and gases that have caused the moisture to become more acidic than normal
- acid rain is uniquely human-related phenomenon i.e. mainly caused by human activities
- acid rain can also be naturally induced when natural emissions originate from wetlands and geologic sources
- acid rain has harmful effects on human health, plants, soil, vegetations, aquatic animals, infrastructure, etc
- acid rain can be minimised technically.

6.0 TUTOR-MARKED ASSIGNMENT

1. Attempt a reasoned definition of acid rain. Discuss the causes and effects of acid rain.
2. Write an essay on the processes and geographical distribution of acid rain. In what ways can acid rain be prevented?

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UNIT 3 DROUGHT

CONTENTS

1.0 INTRODUCTION

Drought means different things to different people. Their perspective about “drought” depends on who they are and the kind of work they do. For instance, the farmers and ranchers are concerned with agricultural drought, for example, an agricultural drought is also the type of drought that worries people in the grocery and meat business or people in farm communities that depend indirectly on agricultural income for their livelihoods. Urban planners usually mean hydrological drought when they talk about drought, because water supplies and reserves are key components in managing urban growth. The most common use of the term “drought” refers to meteorological drought, because that is the drought condition most familiar to the general public and the one most easily identified.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define drought
- discuss the causes of drought
- identify the types of drought
- describe the effects of drought and the mitigation measures.

3.0 MAIN CONTENT

3.1 What is Drought?

Drought is not purely a physical phenomenon that can be defined by the weather. Rather, at its most essential level, drought is defined by the delicate balance between water supply and demand. In that sense, drought is a process whereby human demands for water exceed the natural availability of water. That is, a period in which a region has a deficit in its water supplies. It is a normal feature of climate which happens in all climatic zones from time to time. In a nutshell, it is "the deficiency of precipitation over a prolonged period of time, usually a season or more”.

3.2 Causes of Drought

Drought can be caused by too little precipitation (rain and snow) over an extended period, as most people assume, but drought can also be caused by increased demand for the available supply of usable water even during periods of average or above average precipitation.

Another factor that can affect water supply is a change in water quality.
If some of the available water sources become contaminated--either temporarily or permanently--that decreases the supply of usable water, makes the balance between water supply and demand even more precarious, and increases the likelihood of drought.

3.3 Types of Drought

The various definitions of drought differ in their interpretation relative to their impacts and must be region and impact-specific. Both the natural and social components of drought need to be better understood and addressed in national, regional and international policy planning (Abrams,1997). Wilhite and Glantz (1985) describe four basic categories or types of drought:

- **Meteorological drought:** A reduction in rainfall supply compared with a specified average condition over some specified period; defined as a period during which less than a certain amount (e.g. 70 per cent) of the normal precipitation is received over any large area for an extended period.
- **Agricultural drought:** A reduction in water availability below the optimal level required by a crop during each different growth stage, resulting in impaired growth and reduced yields. Agricultural drought relates to an imbalance in the water content of the soil during the growing season, which although influenced

by other variables such as the crop water requirement, the water-holding capacity and degree of evaporation, is also largely dependent upon rainfall amount and distribution.

- **Hydrological drought:** The impact of a reduction in precipitation on natural and artificial surface and subsurface water resources. It occurs when there is substantial deficit in surface runoff below normal conditions or when there is a depletion of groundwater supplies. Hydrological drought reduces the supply of water for irrigation, hydroelectrical power generation, and other household and industrial uses.
- **Socio-economic drought:** The impact of drought on human activities, including both indirect and direct impacts. This relates to a meteorological anomaly or extreme event of intensity and/or duration outside the normal range of events taken into account by enterprises and public regulatory bodies in economic decision-making, thereby affecting production and the wider economy.

3.4 Effects of Drought

Drought can have serious health, social, economic and political impacts with far-reaching consequences (Table 9). The consequences of drought may include:

- **Hunger and famine**: Drought conditions often provide too little water to support food crops, through either natural precipitation or irrigation using reserve water supplies. The same problem affects grass and grain used to feed livestock and poultry. When drought undermines or destroys food sources, people go hungry. When the drought is severe and continues over a long period, famine may occur.
- **Thirst**: All living things must have water to survive. People can live for weeks without food, but only a few days without water.
- **Wildfires**: The low moisture and precipitation that often characterise droughts can quickly create hazardous conditions in forests and across range lands, setting the stage for wildfires that may cause injuries or deaths as well as extensive damage to property and already shrinking food supplies.
- **Social conflict and war**—When a precious commodity like water is in short supply due to drought, and the lack of water creates a corresponding lack of food, people will compete—and eventually fight and kill—to secure enough water to survive.
- **Migration or relocation**: In rural developing countries population migration can begin when one area experiences drought because often people will go to areas where water and its benefits are more prevalent. This then depletes the natural

resources of the new area, can create conflicts among neighboring populations, and takes workers away from the original area. Over time, increased poverty and social unrest is likely to develop

Table 9: Impact of Drought in Southern Africa

Primary impacts	**Secondary impacts**
SOCIAL	
Disrupted distribution of water resources	Migration, resettlement, conflicts between water users
Increased quest for water	Increased conflicts between water users
Marginal lands become unsustainable	Poverty, unemployment
Reduced grazing quality and crop yields	Overstocking; reduced quality of living
Employment lay-offs	Reduced or no income
Increased food insecurity	Malnutrition and famine; civil strife and conflict
Increased pollutant concentrations	Public health risks
Inequitable drought relief	Social unrest, distrust
Increased forest and range fires	Increased threat to human and animal life
Increased urbanization	Social pressure, reduced safety
ENVIRONMENTAL	
Increased damage to natural habitats	Loss of biodiversity
Reduced forest, crop, and range land productivity	Reduced income and food shortages
Reduced water levels	Lower accessibility to water
Reduced cloud cover	Plant scorching
Increased daytime temperature	Increased fire hazard
Increased evapotranspiration	Crop withering and dying
More dust and sandstorms	Increased soil erosion; increased air pollution
Decreased soil productivity	Desertification and soil degradation

	(topsoil erosion)
Decreased water resources	Lack of water for feeding and drinking
Reduced water quality	More waterborne diseases
ECONOMIC	
Reduced business with retailers	Increased prices for farming commodities
Food and energy shortages	Drastic price increases; expensive imports/substitutes
Loss of crops for food and income	Increased expense of buying food, loss of income
Reduction of livestock quality	Sale of livestock at reduced market price
Water scarcity	Increased transport costs
Loss of jobs, income and property	Deepening poverty; increased unemployment
Less income from tourism and recreation	Increased capital shortfall
Forced financial loans	Increased debt; increased credit risk for financial institutions

Source: Adapted from Vogel, Laing and Monnik (1999).

- **Economic impacts:** This are associated with agriculture and the income generated from crops. In times of drought, the lack of water can often cause a decline in crop yields, and thus a reduction in income for farmers and an increase in the market price of products since there is less to go around. In a prolonged drought, unemployment of farmers and even retailers can occur, having a significant impact on the economy of the area and those with economic ties to it.
- **Environmental problems:** Drought can result in insect infestations and plant diseases, increased erosion, habitat and landscape degradation and a decrease in air quality. In short-term droughts, natural environments can often rebound, but when there are long term droughts, plant and animal species can suffer tremendously, and over time desertification can happen with an extreme lack of moisture. Drought often creates a lack of clean water for drinking, public sanitation and personal hygiene, which can lead to a wide range of life-threatening diseases.

3.5 Drought Mitigation Measures

There are several mitigation measures that can be used to reduce the impacts felt by drought. Some of these are:

- **Soil conservation**: By protecting soil, it is better able to absorb precipitation, but it can also help farmers to use less water because it is absorbed and not as much runs off. It also creates less water pollution by the pesticides and fertilizers present in most farm runoff.
- **Water conservation**: by water conservation, public water use is regulated. This includes watering yards, washing cars and outdoor fixtures such as patio tables, and swimming pools. Cities such as Phoenix, Arizona and Las Vegas, Nevada have also implemented the use of xeriscape landscaping to reduce the need to water outdoor plants in dry environments. In addition, water conservation devices like low-flow toilets, shower heads, and washing machines can be required for use inside the home.

Finally, desalination of seawater, water recycling, and rainwater harvesting are all things that are currently under development to build on existing water supplies and further reduce the impacts of drought in dry climates. Whatever method is used, however, extensive monitoring of precipitation and water usage are the best ways to prepare for a drought, inform the public on the problem, and implement conservation strategies.

3.6 Geographic Distribution of Drought

Droughts usually occur in hot dry areas of land. In most cases, the area is dry because there is very minimal rainfall. The rain that does fall will be quickly absorbed into the ground or blown away by the dry air flow that moves along the ground. Therefore, the land is very dry and not many things can live there.

Major Droughts

Year	Place	Cause	Destruction
1931 - 1938	Great Plains of the USA	Severe wind storms dried out the land and blew the top layer of soil away	Cars, homes and farms destroyed in dust storms
1982 - 1983	Australia	No rain for more than one year	60% of Australian sheep and cattle died

1972 - 1974	Africa	Decreased Rainfall	The countries financial business went down
1976	Britain	It did not rain from June 1975 to September 1976. Droughts are very rare in England	Water rationing was greatly needed in the larger cities of Britain

4.0 CONCLUSION

It can be concluded that holistic approach is very essential in drought mitigation, while the following approaches should be taken into consideration:

- an effective early-warning system is invaluable for timely implementation of drought mitigating and relief measures, but must be accompanied by adequate infrastructure for implementation
- the severity of drought cannot be judged only from the reduction in total annual rainfall; the interseasonal distribution is important, especially for crops
- a rigorous definition of drought is needed in order to distinguish between impacts caused primarily by low rainfall and those exacerbated by poor land management.

Drought should not be viewed as merely a physical phenomenon or natural event. Its impacts on society result from the interplay between a natural event (less precipitation than expected resulting from natural climatic variability) and the demand people place on water supply. Human beings often exacerbate the impact of drought. Recent droughts in both developing and developed countries and the resulting economic and environmental impacts and personal hardships have underscored the vulnerability of all societies to this “natural” hazard."

5.0 SUMMARY

In this unit, we have learnt that:

- drought is a normal feature of climate which happens in all climatic zones
- drought can be caused by too little precipitation over an extended period and by increased demand for the available supply of usable water
- the major types of drought are meteorological, agricultural, hydrological and socio-economic drought
- the major effects of drought are hunger and famine, thirst, wildfires, social conflict and war, economic impacts, environmental problem and
- the mitigating measures of drought include soil and water conservation, water recycling and rainwater harvesting.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define drought? Identify the major causes and the mitigation option of drought.
2. What are the correlations between climate and drought in Northern Nigeria?

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UNIT 4 FLOOD

CONTENTS

1.0 INTRODUCTION

Natural hazards and flood events are part of nature. They have always existed and will continue to exist. A flood is an overflow of an expanse of water that submerges land, a deluge. In the sense of "flowing water", the word may also be applied to the inflow of the tide. Flooding may result from the volume of water within a body of water, such as a river or lake, exceeding the total capacity of its bounds, with the result that some of the water flows or sits outside of the normal perimeter of the body. It can also occur in rivers, when the strength of the river is so high it flows out of the river channel, particularly at bends or meanders. With the exception of some floods generated by dam failure or landslides, floods are climatological phenomena influenced by the geology, geo-morphology, relief, soil, and vegetation conditions. Meteorological and hydrological processes can be fast or slow and can produce flash floods or more predictable slow-developing floods, also called riverine floods.

Since the start of history the world has been plagued by natural disasters (WMO, 1990a). Few regions seem to have escaped the impact of one extreme or another; fewer are likely to be free from them in the future. It is important, of course, to recognise that an extreme natural event only becomes a natural disaster when it has an impact on human settlements and activities. There is a strong social as well as natural science component to natural disasters and while the events themselves cannot be prevented, their disastrous consequences can often be reduced by appropriate advance planning, the preparation of emergency measures on the part of the community at risk. Floods are one of the most widespread and savage of natural disasters. They can be defined as overflowing by water of the normal confines of a stream or other body of water, or the accumulation of water by drainage over areas which are not normally submerged (WMO, 1990b). On a large river system, a flood may take several weeks or a month or more to subside, but in headwater regions and in small river systems, a flood may last for only a few hours. These are *flash floods* which are common in mountainous areas and arid regions. The combination of storm surge and river floods is particularly hazardous for low-lying areas.

2.0 OBJECTIVES

At the end of this unit, you should be able to:
-define flood
-identify the causes of flood
-state the different types of flood and their typical effect

3.0 MAIN CONTENT

3.1 What is Flood?

3.2 Causes of Flood

Floods are caused by both natural and man-made factors. Heavy rainfalls like the ones experienced in Nigeria in 1994 are natural factors which man cannot control. 1999 was another year of unusual heavy rainfall in Nigeria which led to flooding in several places. Other natural factors are: low-lying locations with a high water table; hilly areas where water flows at high speed; and areas where water infiltration is poor e.g. rocky or clayey soils. The man-made factors include:

- the cementing of extensive areas within cities which impedes infiltration and leads to excess run-off
- deforestation which exposes the soil to erosion and run-off. forests help rain water to infiltrate gently into the ground, so when it is removed, run-off develops
- haphazard constructions of dwellings in cities without regard to town planning regulations. Some of such houses are built on flood plains or other areas liable to flood. Others are built to block the normal flow of channels of water

- the dumping of refuse on river channels especially in cities leads to the narrowing of the channels thereby impeding the flow of rivers. In an attempt to find alternative routes, the river veers off, causing flooding
- weak dams constructed by unqualified or inexperienced or unscrupulous engineers often collapse; leading to disastrous floods.

3.3 The Principal Types of Floods

- **Riverine floods**. This refers to the flooding of creeks due to heavy monsoonal rain and high tide. It could be in slow or fast form. An example of slow kinds is when runoff from sustained rainfall or rapid snow melt exceeds the capacity of a river's channel. Causes include heavy rains from monsoons, hurricanes and tropical depressions, foreign winds and warm rain affecting snow pack. An example of fast kinds is flash flood resulting from e.g. intense thunderstorms.
- **Estuarine floods**. This is commonly caused by a combination of sea tidal surges caused by storm-force winds.
- **Coastal floods** caused by severe sea storms, or as a result of another hazard (e.g. tsunami or hurricane).
- **Catastrophic floods** caused by a significant and unexpected event e.g. dam breakage, or as a result of another hazard (e.g. earthquake or volcanic eruption).
- **Muddy floods**. A muddy flood is generated by runoff on cropland.
- **Flash Floods.** This is a type of flood that occurs in headwater region and in small river systems. It may last for few hours.
- **Others.** Floods can occur if water accumulates across an impermeable surface (e.g. from rainfall) and cannot rapidly dissipate (i.e. gentle orientation or low evaporation). A series of storms moving over the same area. Dam-building beavers can flood low-lying urban and rural areas, often causing significant damage.

3.4 Typical Effects of Flood

3.4.1 Primary Effects

- Physical damage can range anywhere from bridges, cars, buildings, sewer systems, roadways, canals and any other type of structure.
- Casualties: People and livestock die due to drowning. It can also lead to epidemics and diseases.

3.4.2 Secondary Effects

- Water supplies. Flooding can lead to contamination of water. As such, clean drinking water becomes scarce.
- Diseases- Unhygienic conditions. Spread of water-borne diseases.
- Crops and food supplies- Shortage of food crops can be due to loss of entire harvest.
- Trees - Non-tolerant species can die from suffocation.

3.4.3 Tertiary/Long-Term Effects of Flood

- Economic hardship, due to: temporary decline in tourism, rebuilding costs, food shortage leading to price increase etc.

3.5 Trends in Flood Impacts

3.5.1 Economic Impacts

Using data compiled by the National Weather Service from 1903 to 1993, Yen and Yen (1996) conclude that average annual flood damages in the U.S. are $2.41 billion. They report that 10-year moving averages of the data show an increase in losses over time in constant dollars. Their linear regression of the damage data shows a 1.17% annual increase in damage value. Pielke and Roger (1996)'s analysis of the same data over a 25-year moving average reveals a similar, steadily increasing trend in losses due to floods.

The Natural Hazards Center's (NHC) review of storm data records on damage due to floods indicates between $19.5 and $195 billion (in 1994 dollars) of property was lost to floods during the 20-year review. Seven of those years had property damages exceeding $1 to $10 billion. The most costly year was 1993 when floods damaged between $3.3 and $33 billion of property. Not surprisingly, 1988, the most costly year for droughts, was the least costly year for floods. During 1988, property damages ranged from $30 to $300 million dollars.

In addition to these property losses, between $8.1 and $81 billion damage was done to crops. The trend line indicates this is an escalating figure. Again, 1988 had the fewest crop losses due to flooding. By adding property and crop losses together, a total of some $27.6 billion to $276 billion dollars in 1994 dollars were lost to floods.

3.5.2 Loss of Life and Injuries

In a study carried out in Colorado, USA, the number of deaths per year due to floods from 1975-1994 as reported in storm data shows a trend indicating a slight reduction in the number of deaths. Pielke and Roger (1996) draw the same conclusion though also point out that a review of a longer record of data over a moving 25-year period beginning in 1927 suggests that the number of deaths due to floods have been increasing in the second half of the century. The U.S. Army Corps of Engineers (1996) reported an average of 94 deaths per year due to floods from Fiscal Year 1986-95.

An important point noted by this study is that many flood deaths and injuries occur in single catastrophic events. For example, the number of deaths in 1976 is largely due to the Big Thompson Canyon, CO flash flood that killed 156 people and the 1985 peak is chiefly due to a flood in Puerto Rico that killed 180 people. In contrast, the 1993 Midwest floods that affected millions of more people over a much longer time killed far fewer people than these flash floods.

3.5.3 Environmental Impacts

Floods are naturally-occurring phenomena that are part of the physical and biological processes which have shaped our nation's landscapes. Smith claims that "More than any other environmental hazard, floods bring benefits as well as losses." He points especially to the importance of floods in maintaining ecosystem habitats and soil fertility. Consideration of the negative impacts of floods on the environment more often appraise the detrimental aspects of human attempts to manage flood-prone areas which, in turn, disrupt the natural flood cycle. For example, the Federal Interagency Floodplain Management Task Force (FIFMTF) (1992) reports that human activities have deeply affected floodplains and the nature of flooding. Activities such as drainage of wetlands and land clearance for farming; upstream development that replaces natural vegetation with paved asphalt; and construction of channels, levees, reservoirs change the flood cycle and often result in increased runoff, destruction of riparian habitat, and increased water pollution-all of which can be considered destructive to the natural environment. However, systematic assessment of the environmental benefits and costs of flooding and the environmental benefits and costs of floodplain management programmes has not been done.

3.5.4 Indirect Impact

In addition to the impacts described above, floods also have an indirect impact that disrupts society. As is the case for all disasters, these impacts and their costs (or value) are not well documented. However, they include such things as business disruption and loss of income, loss in tax revenues, transportation delays, and spread of illness--both physical and mental. There is also the indirect impact on other government-funded programmes. Each tax money spent on flood response, relief, and recovery is money not spent on other public-funded programmes such as education.

3.6 Prevention of Floods

Today, there are many ways to help prevent and control floods. Flood-control dams have been constructed throughout history across rivers. Dikes and levees are built alongside rivers to keep them from overflowing during periods of high water. Canals are also used to help drain off extra water. Streams and rivers can be diverted to avoid highly populated areas. Regulation of floodplain development and urbanisation would reduce flood losses. Prevention of soil erosion also helps control flooding, which is why it is a good idea to plant many trees, treats slopes and grads, and creates reservoirs to catch sediment and debris.

Scientists continue to study lowland areas. People have gradually filled in wetlands to create land for roads, houses, and cities. About 200,000 to 400,000 acres of wetlands are lost in the United States each year, but the bottomlands, bogs, marshes, and swamps are very valuable in preventing and controlling floods. The wetlands act like giant sponges that soak up huge amounts of water and let it run off slowly. When these areas are filled in and built over, floods are more likely to occur.

In China, where most flooding occurs when the Yellow or Yangtze River overflows, people have tried to maintain control by building higher levees, dredging, digging channels, and building dams. The work has paid off, for progress in the last 50 years seems to have stopped serious flooding from the Yellow River. However, the river, like a sleeping dragon, may still overflow and cause much destruction.

Experts are also warning people not to build in high flood risk areas. However, many people continue to live next to the coast, by rivers and streams, or in the middle of wetlands. Ultimately, people cannot control nature. Tropical storms, hurricanes, thunderstorms, and melting snow will cause floods. People with homes in low-lying places, by rivers, or in coastal regions are in danger of being wiped out by floods. In the past, these disasters have caused millions of dollars' worth in damage. They have taken numerous lives. To survive, man needs to keep and prepare himself with the supplies and knowledge necessary for survival. However, the following measures can be taken to minimise floods:

- proper channelisation of rivers, especially those flowing through towns. This will help to divert the flow of rivers away from areas of potential danger
- construction of well-planned drainage systems in towns. This will help to direct the flow of water along desired directions
- a more effective control and regulation of building constructions by town planning authorities. This will help to prevent houses from being built to block natural route ways for water without creating a desired alternative flow route
- areas prone to flooding e.g. low-lying areas and river valleys should be avoided in the construction of buildings
- only well-qualified and tested engineers should be awarded contracts to construct dams
- the dumping of refuse along river valleys should be prohibited to avoid the river channel being blocked or narrowed
- embankments could be constructed to raise the river bank. This means that the river cannot easily overflow its channel
- for areas that are prone to floods, studies should be intensified to determine flooding regime. And adequate preparations should be made against predicted floods
- too many drainage channels should not be allowed to drain into any single stream so that such a stream is not over-supplied leading to flooding
- improved hydro-meteorological forecast and early warning should be put in place.

4.0 CONCLUSION

In this unit, we have examined the concept of flood as an overflow of an expanse of water that submerges land, a deluge. We have equally examined the causes, principal types, typical effects, trends in flood impacts, as well as the prevention/control measures against flood events. And to minimise the adverse effects of floods on communities and people, a comprehensive flood management programme is required for each newly proposed development zone. This measure together with river training structures will lead to a decrease in erosion and sediment transport and certainly alleviate the flood problems as well.

5.0 SUMMARY

In this unit, we have learnt that:

- floods are caused by both natural and man-made factors
- flood effects can range from primary to tertiary or long-term effects
- the major types of floods are riverine, estuarine, coastal, catastrophic, muddy, and flash floods
- the major impacts of floods are, economic, loss of life and injuries and environmental impacts and
- the mitigating measures of floods include public enlightenment, improved hydro-meteorological forecast and early warming, land use planning, etc.

6.0 TUTOR-MARKED ASSIGNMENT

1. Examine the concept of flooding *vis-à-vis* causes and effects.
2. In what ways can flooding be controlled, minimised and/or prevented?

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UNIT 5 ECONO-CLIMATES

CONTENTS

1.0 INTRODUCTION

In economic analysis of weather, problems relating to measurement and quantification are faced. The dynamic nature of weather and the fact that the atmosphere is a common property resource make economic analysis of weather rather difficult. Also, the relationships between weather and economic activity are very complex, whether on local, regional or national scale.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- state the economic analysis of weather
- explain the complex relationships between weather and climate and human economic activities
- discuss how to improve the social and economic outcomes of weather-sensitive activities.

3.0 MAIN CONTENT

3.1 What is Econo-climate?

Econo-climate is simply the economic analysis of weather (Ayoade, 1993). It has to do with quantification and analysis of weather information to determine its value or worth in economic terms. It is equally concerned with how we can use our knowledge of weather to improve the economic and social outcomes of our weather-sensitive activities. The idea of economic analysis of weather is predicated on the following notions. That:

- the atmosphere is an important natural resource
- its resource availability may be forecast
- given sufficient information about the atmosphere and a good understanding of its interactions with human activities, man can use his management skill to improve the performance of his weather-sensitive activities and,
- as a resource, information about weather can be subjected to tools of economic analysis such as input-output and cost-benefit analyses to aid conscious management decisions involving the use or non-use of atmospheric resources.

The economic analyses of man's adjustments to weather constitute aspects of econo-climate. The type of adjustment adopted will no doubt depend on the results of such thing as cost-benefit analysis which must have been carried out. The ultimate objective of econo-climate studies is to assist man in using his management ability to improve the social and economic outcomes of his weather-sensitive activities. This is based on the idea that adequate knowledge of the atmosphere and its interactions with human activities constitute an important resource.

The perception of the climatic environment plays a major role in economic decisions particularly where a high degree of risks is involved as it is the case in agriculture and transportation. But the perception of climate may not be identical with the realities of climate. It is better to base decision on scientific analysis and prognosis of climate rather than human perception of climate. Such decisions will be more rational and are more likely to be more beneficial than those based on perception.

Econo-climate based as it is on the concept of climate as a resource that can be used or misused underscores the importance of climatology as a key component in our understanding of man's physical environment and his interaction with this environment.

3.2 Econo-climatic Models

Econo-climatic models provide the analytical framework for examining in economic terms the complex relationships between weather and climate and human economic activities. As noted by Maunder (1970), econo-climatic models are concerned with the socio-economic aspects of the atmosphere particularly the economic analysis of weather in economic terms.

The development of an econo-climatic or weather model hinges on the satisfactory resolution of three related questions. These are:

- the determination of the weather attributes required by a given economic activity in terms of the weather elements, their amount, frequency, timing, etc
- the assessment of the economic costs of variations in weather parameters to a given economic activity
- development of a means of tracing and measuring the impact of a given weather variation through the economic system.

Furthermore, in developing any econo-climatic model therefore, the following problems have to be tackled:

- incompatibility of economic and climatic data. Economic data usually relate to areas whereas climatic data relate to places. Some form of transformation will be needed to make the two data sets compatible
- lack of suitable economic indicator data on time scale less than a month. Most economic data refer to the financial year, the quarter or at best, the month. Economic data on weekly, daily or hourly basis are usually not available whereas climatic data on those time scale are available
- the lag between the time a given weather is actually experienced and the time its impact is felt on economic production. This lag time varies with the nature of economic production
- the multivariate and complex nature of climate as a phenomenon. People and economic activities and production often react to weather as a whole rather than to the individual weather elements.

Various analytical techniques used by economists to model the total economy of any area may also be used in assessing the economic impacts of weather and climate. These include input-output analysis, simulation analysis, linear programming, cost-benefit analysis and regression analysis. The economic analysis of weather can be done on local, regional and international scales as evident in the extensive review by Maunder (1970) on the subject.

3.3 Application of Econo-climatic Models: Regression Analysis

Regression analysis is perhaps the most commonly used analytical model in the economic analysis of weather, particularly in looking at the impact of weather on agricultural production. Since several climatic variables are involved in explaining agricultural production, the multiple regression analysis is the one that is used.

Crop yield depends on several factors namely climate, soil and management practices such as the application of fertilizers and/or irrigation water. In order to evaluate the impact of climate on crop yield, all these other factors must be held constant. This implies that crop yield data must come from farms located on the same soil type and subjected to the same management practices. The strain of crop grown must also be of the same type as this can also influence yield. The type of data described above can be obtained in two ways:

- one way is to have experimental plots that have been continuously cropped over several years. This will bring about time series yield in which soil and soil management practices can be regarded as constant
- the other way is to have crop yield data from several farms located on similar soil types and managed the same way in terms of fertilizer and irrigation water application. This will yield a spatial series data. Climatic data are similarly obtained to allow the crop yields to be regressed on the climatic variables.

The climatic data must be for the growing season of the crop under study not necessarily for the whole year. Usually, the period used extends from two or three weeks before planting time to harvesting time. The step-wise regression analysis option is often favoured as it allows us to know the relative importance of each of the climatic variables we include in our computation.

The regression model eventually obtained can be used for explaining variations in the values of the dependent variable or to estimate values of the dependent variable given some values of the independent variables within statistically known margins of error. If the value of the coefficient of determination (i.e. the square of the multiple correlation coefficients) is very high, the model can be used for prediction. In the case of crop yield, this implies that crop yield can be predicted in advance of harvest using forecast values of the relevant meteorological elements. Such a predictive model has obvious usefulness in agricultural planning. If a bumper harvest is predicted, arrangements can be made in advance regarding anticipated surplus whether to export them or store them for use in future when adverse weather decreases yield. On the other hand, if the predicted crop yield is poor, arrangements can be made to meet the shortfall in demand for the particular crop through importation. Such advance knowledge will also allow the government to intervene meaningfully in influencing commodity prices.

The usefulness of this kind of analysis is not limited to agriculture. It is equally useful in other commercial activities such as retail trade, energy consumption and industrial production. For instance, volume of retail trading in a particular good can be related to critical weather conditions that affect its demand and influence the turn out of shoppers. Such relationship, if strong, can then be used to predict the turn out of shoppers as well as volume of sales. Energy consumption usually increases in temperate countries during cold weather. So the more prolonged the cold weather, the more will be the demand on electricity particularly for heating. Since the winter period is also characterised by longer nights, hence the need for lightning is more than during summer with longer days. Electricity generating companies must therefore show more than a passing interest in weather in order to be able to plan to meet the energy requirements of their customers. Regression analysis can thus be used to trace the impact of weather variations on agricultural and non-agricultural aspects of the economy.

3.4 Other Econo-climatic Models

Apart from regression analysis, other analytical techniques used in assessing the economic impacts of weather and climate are:

- input-output analysis
- simulation analysis
- linear programming
- benefit-cost analysis.

Input-output analysis is used to quantitatively analyse the interdependence of producing and consuming units in an economy. Once the linkages among various industries are known, it is possible to trace the impacts of a change in output of one industry on other industries in an economy. Variations in weather can result in changes in the production functions of various activities. Thus, input-output analysis can provide a useful means of identifying which activities may gain or lose as a result of given weather variations, whether natural or man-made.

Simulation analysis can be used to examine the effects of weather and climate on economic activities and on the economic system as a whole.

This is computer-based simulation which allows the effects of chosen critical factors to be monitored. The use of such models has increased with advances in computer science and technology.

Linear programming is a mathematical technique used to determine optimal solutions to various kinds of allocation problems. First, the relationships between the relevant variables are expressed in linear mathematical form. These expressions with appropriate constraints constitute a set of equations having several solutions. The linear programming technique is designed to identify a particular combination of variables which will produce the optimal results. The application of this technique to econo-climatic problems is still relatively undeveloped though promising.

Benefit-cost analysis allows us to weigh the merits of alternative courses of action by comparing potential benefits with potential costs. This technique is particularly useful in evaluating weather modification activities or investment in weather forecasting or weather information. Benefit-cost analysis can also be used to determine comparative social costs and benefits of several approaches of weather modification.

The application of the various analytical techniques briefly reviewed above for evaluating weather, weather forecasting and weather modification are however fraught with problems of measurement and quantification.

4.0 CONCLUSION

From the on-going, the ultimate objective of econo-climate model is to assist man in using his management ability to improve the social and economic outcomes of his weather-sensitive activities, which is based on the idea that adequate knowledge of the atmosphere and its interactions with human activities constitute an important resource. However, the application of econo-climatic model and other analytical techniques for evaluating weather, weather forecasting and weather modification are, however, fraught with problems of measurement and quantification.

5.0 SUMMARY

In this unit you have leant that:

- the economic analyses of man’s adjustment to weather constitute an aspect of econo-climate
- econo-climate is very important in management decisions involving use and non-use of atmospheric resources

- econo-climate provides framework in economic terms for examining the complex relationship between weather and climate and human activities
- applicability of econo-climatic model is not restricted to agricultural planning.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is econo-climate and how relevant is it in understanding man-climate relations?
2. Discuss the basis, principles and applications of econo-climatic models.

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