TN-108

# LOKTAK LAKE STUDIES—PART-I

NATIONAL INSTITUTE OF HYDROLOGY
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# PREFACE

There is a wide spread realisation of the real value of lakes which provides benefits free of environmental cost if used wisely. Lakes play important role in the economic activities of people living around them. This is particularly so in developing countries like us, where our rural communities in the neighbourhood of a lake depend on wetlands for maintenance of traditional subsistence activities like live stock herding, fishing, farming etc. Lakes not only just supports the plant and animal life, but also provide quality environment by absorbing flood, sediments and pollutants. They are also used as a reliable source of irrigation and power generation. As the demand on the use of lake increases, abuse is also started if proper management policies have not been imposed. This causes reduction in some of their functions. Scientific studies are very essential for proper management.

Hydrology of a lake can be explained by three factors : i) input of water; ii) Output of water; iii) Storage. The inflow-outflow is influenced primarily by climate and by geological and geomorphological characteristics of the lake. Contributing drainage area influences the above characters. Application of remote sensing techniques over the catchment area can provide historical picture of the land use and consequent effect on the lake storage. Water balance studies can provide fluctuations of water level and storage.

Loktak lake receives world attention and finds a place in Ramsar convention. This lake assume a greater economic value to our country and hence a subject of greater concern. As the siltation in the lake interferes in its functioning especially in flood absorption; in power generation and in irrigation scientific studies on different management strategies are essential. Available data for such studies are meager. Hence continued observation and collection of data of the lake are essentially required. Studies have been initiated with the data made available by Loktak Lake Development Authority. An introductory part of these studies are given in this report which is expected to continue with support of LDA and other concern organisation.

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ABSTRACT

Lakes are distinguished from other terrestrial ecosystems in their predominance of water for significant period of time. Systematic and scientific study of this waterbody requires identification of its dynamic position in hydrologic cycle, which links different water entities and represents differenht path which water in nature circulates and is transformed. Water falling on land eventually finds a way to sea or atmosphere in their passage, water is temporarily stored in lakes or reservoir. Henoe lakes are sensitive to variations in the net rate of supply. These fluctuations are stochastic in nature and can be studied by water balance. Number of parameters have been identified for the study of lake morphology.

Most of the threat to a lake originate at a considerable distance from the lakes. Induced soil erosion due to indiscriminate felling of trees; exoessive demand on water upstream for different purposes; exploitation of ground water from aquifer supporting lakes.

In India numerous lakes can be seen with unusual geographic features. The fertile lands around these lakes are among the most densely populated are on Earth. Most of these lakes are subjected to major threat due to man made activities especially agriculture. Forest loss is continuing at a rate of about one million hectares per annum. Natural denudation of land also contribute in the production of transportable soil particles. As a result the natural storage space which supports lake is affected. This can be seen in the increase in the area liable to flooding.

Loktak lake in Manipur plains which is of international importance, where floating swamps of Keibul Lanjao provide a last refuge for the Manipur brownantlered is causing problems of increased flooding and hinderance in the normal functions. Hydrology of the lake has not yet been studied. Therefore Part-I of this lake studies aims at describing different aspect of lake in general and the study area. In this report, different hydrological aspects of a lake have been discussed before describing the study area.

# TABLE OF CONTENT

# LIST OF TABLES

# LIST OF FIGURES

## 1.0 INTRODUCTION

Lakes have been playing an important role in human life. This is more so, particularly in developing countries, where many communities depend on wetlands for the maintenance of traditional subsistance activities like livestock herding, fishing, farming etc. Lakes not only support plant and animal life but also, in maintaining the quality of the environment, by providing flood control, shoreline stabilization, sediment obsorbtion, nutrient and toxicant retention. Abuse of lakes means, a reduction of some of their functions. Degradation of wetlands are common seen throughout the industrial world. The results are: increase in cost of fish and water game; need for water purification; expenditure on flood-protection works; reduction of wild life.

In India, numerous lakes can be seen with unusal geographic features. The fertile lands around these lakes are among the most densely populated area on Earth. Most of these lakes are subjected to major threat due to man made activities especially agriculture. Forest loss is continuing at a rate of about one million hectares per annum. Natural denundation of land also. Contribute in the production of transportable soil particles. As a result the natural storage space which supports lake are affected. This can be seen in the increase in the area liable to flooding.

Loktak lake in Manipur plains of international importance, where floating swamps of Keibul Lanjao provide a last refuge for the Manipur brown antlered is also subjected to problems of increased flooding and hinderance in the normal functions. Hydrology of the lake has not yet been studied. Therefore part I of this lake studies aim at describing different aspect of lake in general and the study area.

## 2.0 GENERAL ASPECTS OF A LAKE

### 2.1 DEFINITIONS:

There are no universally accepted or scientifically precise definition of lakes. Most of the difficulties arise from different evolution means by which a lake may be formed. Obviously lakes are distinguished from other terrestrial ecosystems in their predominance of water for significant period of time. Surface water flooding or high ground water table, resulting conditions suitable for aquatic plants and animals could cause wetland development. Ramsar convention on wetlands uses a definition, giving essential characteristics as follows:

"Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt including areas of marine water, the depth of which at low tide does not exceed 6m."

Zumberge etal (1964) defined a lake as an "inland basin filled or partially filled with water whose surface dimensions are suficiently large to sustain waves capable of producing a barren, wave swept shore".

Mark etal (1982) define a lake as a body of surface water, in which flow velocities are two low to transport suspended sediments.

From the fact that, there exist several definitions, explains that not a single one could explain essential concepts of different lakes. However from the point of view of hydrologists it is sufficient to identify it as an inland waterbody with following requirement.

i. It should fill or partly fill a basin or connected basins.
ii. The water level in the body should be the same except during large flow or wind or ice etc.
iii. The inflow volume ratio should be small.
iv. The bulk of the sediment load entering in is trapped.
v. The volume of water is sufficient for any economic use of importance as a water resource i.e. small ponds are neglected.

## 2.2 CLASSIFICATION OF LAKES

Classification of lakes is suggested to make an estimate of certain lake properties, transfering the results of studies elsewhere made at one lake to similar lakes in other region. Most of the lakes have well defined origin. A classificaion made by Hutchinson (1957) is still widely in use which distinguishes 11 major types as given below:

| | | |
|---|---|---|
| 1. | Tectonic lakes | :Basins in graben between faults. |
| 2. | Volcanic lakes | :Formed by damming by lava flow |
| 3. | Landslide lakes | :Lakes held by rock slides, mud flows and screes. |
| 4. | Glacial lake | :a) Lakes in direct contact with ice.<br>b) Glacial rock basin.<br>c) Morainic and outwash lakes.<br>d) Drift basins. |
| 5. | Solution lakes | :Lakes formed in caves. |
| 6. | Fluvial lake | :a) Meander lakes (oxbow lakes)<br>b) Plunge pool lakes. |
| 7. | Aeolian lake | :Basins dammed by wind blown sand. |
| 8. | Shoreline lake | :Caused by wave and current action on the shore. |
| 9. | Organic lake | :Formed by the dead or living organism, damming streams or accumulation of coral fragments in oceanic region. |
| 10. | Anthropogenic lake | :Dams and excavations made by man. |

11. Meteorite lake : Caused by bombardment of meteorites on the earth surface.

An old descriptive classification is also worth mentioning here. This divides the lake into circular subcircular, elliptical, subrectangular, elongate, dentritic, lunate, triangular and irregular type. Although easy to adopt this classification, it does not directly consider the depth regime of the lake.

Hakanson (1981), based on the shape of relative hypsograpic curve has developed a classification . A convex lake has one or several areally limited deep holes, but is generally very shallow. A concave lake is a trough like basin with steep inclining walls and a very flat areally dominating bottom.

Thermal behaviour of a lake is important for the oxygen, content and thus for the ecology of the lake. One of the earliest thermal classification by Forel distinguishes between polar, subpolar, temperate and tropical lakes. (Kuusisto , 1985).

Classification based on the water balance has also been made which can help to detect man made or natural changes in water levels Szestay (1974) has presented one such classification based on three simple criteria:

1. The inflow factor (i): the percentage of inflow (I) of the sum of inflow and lake precipitation.
2. The outflow factor(o): the % of outflow (o) of the sum of outflow and lake evaporation. (E)
3. The magnitude of the mean annual flux (F) : the sum of inflow plus precipitation ($F_i$ ) or the sum of

outflow plus evaporation ($F_o$).

Exoreic lake, where throughflow is generally sufficient to flush out salts and maintain fresh water conditions. In endoreic lakes, water leaves the lake usually through evaportation only, which accumulates the salt in the lake.

## 2.3 HYDROLOGY OF A LAKE

Any systematic and scientific study of a waterbody or movement of any parcel of water requires identification of its dynamic position in hydrologic cycle, which links different water entities and represents different path through which water in nature circulates and is transformed. As water, evaporates from the oceans and land, becomes a part of atmosphere, movement of lakes palce much faster, and carried to different precipitating region either on land or in the ocean. The details of the different aspects of hydrologic cycle may be seen in Chow 1964, NIH publications.

Wolman (1962) has estimated that about 2.5% of all the water in the world is fresh water and estimated to be 36000000 Cubic Kilometer. About 75% of this is contained in polar ice and glaciers, about 10% in ground waters upto 800m depth, about 12% in ground water between 800m to 4000m depth; about 0.35% accounts for freshwater lakes about 0.17% is available in the soil moisture, rivers accounts about 0.003% and rest are in atmosphere, biosphere and earth minerals.

Water falling on land eventually finds a way to sea or atmosphere in their passage water is temporarily stored in lakes or reservior. Hence lakes are sensitive to variations in the net rate of supply. The history of this sensitivity can be extracted from rise or fall in lake level, which indirectly reflects the volumetric changes in the lake. The latter could have also been caused by water losses.

WATER LEVEL FLUCTUATIONS

Increased demand on the use of lake, urges quantitative studies of the variability of the water level. The meteorological and hydrological factors work together and cause fluctuations in the lake. The magnitude of any positive or negative element in the water balance equation (explained below), determines the rise or fall in the lake water level. In the case of poor rainfall in the rainy period, combined with intense summer heat can drop the lake water level considerably.

These fluctuations are stochastic component and are also studied by water balance. The characteristic of the time series of individual components are generally different and the measurement errors associated with the individual differ. Therefore developing a stochastic model is not always feasiable. Record of water level should be made through a network of gauges in the lake as water level variations can be seen due to wind or other factors like sudden rush of water etc.

Number of interesting studies on lake water level can be seen in the literature. Reimann etal (1973), studied the memory of lake Balaton as a physical system (i.e. the period over which it can remember its part) using 105 years of mean monthly water stages. The water level variations of lake Ferto in Hungary are found to be closely connected to solar activity by Bendefy (1973), using 350 years of data. It appears to be a general rule that a decrease of the water level is correlated to support maxima and its increase is correlated to sunspot minima. Kontur (1973) has studied 104 years data of Lake Balaton to establish the fundamental properties of the system. Kalimin (1971) showed that even if the hydrometeorological factors (runoff, rainfall, evaporation were of a random character the corelation coefficient of the adjacent water levels would have quite significant values, governed by morphometric characteristics and runoff.

## WATER BALANCE OF LAKES

A balance equation is written between three factors.

(i) input of water;
(ii) output of water;
(iii) storage;

The inflow - outflow is largely influenced by climate and catchment characteristics, whereas the storage is governed by initial formation, local geomorphology and geological characteristics. This hydrological aspect of a lake inturn exerts considerable influence upon the physical and chemical characteristics.

The above equation of a lake can be written as.

$$\Delta S = I_s + I_g + P - Q_s - Q_g - E - 1. \quad .....1.$$

where, $\Delta s$ is change of volume of water

$I_s$ is overland surface flow

$I_s$ is underground inflow

P is precipitation overlake surface

$Q_s$ is surface outflow

$Q_g$ is underground outflow.

E is lake evaporation.

Although writing of an equation of balance is simpler the estimation of each of the component is quite difficult. If the area of the lake varies considerably as a function of water level, a volumetric measurement of the components is preferable.

## LAKE PRECIPITATION

Precipitation into a lake is usually estimated from the raingauges located near and around the lake. Accuracy of the estimation of precipitation can be increased if there are islands or islets in the central part of the lake. Raingauges on raft have also been used. These measurements may be affected by the topography of the adjacent land, particularly if there is a steep rise from the shore. Excessive heating of the land surface in warm weather leads to the formation of convective precipitation. Several studies indicate that lake precipitation is lower than precipitation over surrounding land areas. Hence care should be taken to adopt point measurements made in the neighbourhood. It is better to assess the areal variability of precipitation.

## OVERLAND & SURFACE INFLOW

These flows are mainly due to streams falling into directly flow or inflows through numerous creeks draining small basins; Some times due to non channelized over land flow. continous discharge observations on all possible streams falling directly or indirectly, partly or fully are needed to be made.

## LAKE EVAPORATION

The methods of estimation of evaporation from a free water surface is still inadequate although it has gained increased importance in these days. Winter (1981) suggested three methods:

i. Balance methods; the application of energy and or water balance.
ii. Comparative method; the use of evaporation pans or tanks along with the use of a coefficient.
iii. Aerodynamic methods; eddy correlation, mass transfer and gradient method.

The method of balance requires the estimation or measurement of other components accurately. In case of energy balance equation, the measurement of incoming shortwave and long wave radiation, air temperature, dew point, wind velocity and periodic surface water temperature. In comparative methods, difficulties arise to establish a relationship between lake evaporation and pan evaporation as the thermal regime of pans and lakes are usually different. Seasonal changes in subsurface heat storage are not reflected in pan observations. The most commonly used coefficient to estimate annual or seasonal lake evaporation from a class A pan data is 0.7. It is widely recognised that the coefficient should be lower for lakes in arid regions than for lakes in humid climates. Aerodynamic methods are based on the work of Dalton in 1802 which relates evaporation to vapour pressure gradient between the evaporating surface and the air, with certain wind velocity coefficient.

SURFACE OUTFLOW

This component can be measured relatively better degree of accuracy than other components with drawal for different purposes should be accounted. For both regulated and unregulated lakes the error can be minimised to less than 5%.

UNDER GROUND COMPONENT

Water may enter a lake through the wetted surface, if the out crop aquifer has a water table sloping towards the lake bed. On the other hand, groundwater outflow occurs, when the lake bed is entrenched in permeable ground that slopes away from the lake. In certain cases bank storage can also be considered. In large lakes of humid low land regions, both underground inflow and outflow can usually be neglected. Underground inflow to many mountains, piedmont and steppe lakes is equally important as surface inflow. In the water budget of small lakes in arid regions underground inflow may be the largest gain. It can also be significiant for big lakes and for deep small lakes in humid regions, especially if the stream flowing into the lake (do not drain the entire thickness of the aquifer) is not fully penetrated, underground outflow will be very small. In some cases this is noticed from reservoir especially in the initial stage.

CHANGE IN STORAGE

Storage of a lake is estimated from measured water level. This estimation will contain errors due to inaccuracies in measurement and inaccuracy of hypsographic curve in the range of water level fluctuations. Other factors influencing this storage are sedimentation, aquatic vegetation etc. If there is a sudden rush of water, there could be a prism storage developed in an elongated lake, due to the rapid size of water level at outfalls.

## 2.4 LAKE MORPHOLOGY

This deals with the quantification and measurement of lake forms and form elements. They are fundamental importance in many hydrological studies. Kuusisto (1985) provides a list of morphometric parameters as given below :

1. Lake area (A) : the area of the water surface.
2. Total lake area($A_t$): the lake area plus the area of all islands islets and rocks within the limits of shoreline.
3. Lake volume (V) : the volume of water in the lake. Either of the following two formulae are used.

$$V = \sum_{i=0}^{n} l_c (A_i + A_{i+1})/2.$$

$$V = \sum_{i=0}^{n} l_c \left[A_i + A_{i+1} + (A_i \ A_{i+1})\right]$$

where $l_c$ - the contour line interval

$A_i$ - the cumulative area within the limit of the contour line i.

n - the number of contour lines.

4) Maximum length ($L_{max}$):-The line connecting the two most remot points on the shoreline. In regular basins the line is generally straight length ($L_e$.). In irregular lakes it is curved line.

5) Maximum effective length ($l_e$):- The straight line connecting the two most distant points on the shoreline over which wind and waves may act without interruption from land or islands.

6) Effective length ($L_s$) the straight line from an arbitrary position on the lake to the most distant point on the shore line without crossing land or islands, which may reduce the impact of wind - induced waves.

7) Effective fetch ($L_f$):- the length of straight lies from an arbitrary position on the lake to the shore line points average over directions, which deviate less than 45 degrees from the main wind direction.

8) Maximum width ($B_{max}$):- the straight line perpendicular to the maximum length, which connects the two most remote points on the shoreline without crossing land (islands may be crossed)

9) Maximum effective width ($B_e$):- the straight line perpendicular to the maximum effective length, which connects the most distant points on the shoreline without crossing land or islands.

10) Mean Width (B) :- the ratio of the lake area (A) to the maximum length ($L_{max}$)

11) Maximum depth ($D_{max}$):- the greatest depth of the lake

12) Mean Depth ($\bar{D}$) :-the lake volume (V) divided by the lake area.

13) Shore Line length ($l_o$):- the length of the circumference of the lake.

14) Total shore line length ($l_t$):- the shoreline length plus the length of the circumference of all islands islets.

15) Contour line length($l_i$); the length of the ith depth contour in the bathymetric map.

16) Slope ($\alpha_p$):- the slope between two contour lines can be determined from the formula.

$$\alpha_p = (l_i + l_{i+1})(l_c)/\left[20(A_{i+1} - A_i)\right]$$

where $\alpha_p$ = the slope %

$l_i$, $l_{i+1}$ = the length of two contour lines Km.

$l_c$ = the contour-line interval, m.

$A_i$, $A_{i+1}$ = the areas limited by the two contour lines, Km$^2$.

17. MEAN SLOPE ($\alpha_p$): for the entire lake area this can be determined from the formula

$$\alpha_p = \left[d \sum_{i=1}^{n-1} l_i + 0.5\,(l_o + l_n) D_{Max}\right] / 10nA$$

where, l,n,D,A are as defined earlier.

18. SHORE DEVELOPMENT ($S_d$) is a measure of the degree of irregularity of the shoreline:

$$S_d = l_o \,/\left[2(\pi\, A_t)^{0.5}\right]$$

The $S_d$- value illustrates the relationship between the actual length of shoreline and the length of the circumference of a circle with an area equal to total lake area. A perfect circular basin has an $S_d$ value of 1.0, irregular lakes have higher $S_d$ values

19. LAKE BOTTOM ROUGHNESS (R): a measure of the degree of irregularity of the lake bottom

$$R = \left(0.165\ (l_c + 2) \sum_{i=0}^{n} l_i\right) / (D_{50} \sqrt{A})$$

To obtain comparable R values for different lakes, it is necessary to utilize a constant number of contour lines.

20. Volume Development ($V_d$) a measure used to illustrate the form of the lake basin. V d is defined as the quotient between the lake volume of a cone whose base area is equal to the lake area (A) and whose height is equal to the maximum depth (D max of the lake):

$$V_d = 3\bar{D} / D_{max}$$

21. INSULOSITY ($I_n$) :the percentage of the to t al lake area ($A_t$) that is occupied by islands, islets and rocks.

$$I_n = \left[(A_t - A)/A_t\right] 100\ \%$$

Some of the morphometric parameters defined above are essential in many limnological and hydrological contexts. These include A, V, $L_c$, D, R and volume curve. It can be seen the most of the morphometric parameters have atleast a slight dependence on the fluctuations of water level. In such cases the water level should also be specified. The trapped sediments changes many of these parameters. In small lakes even the annual changes may be considerable.

## 2.5 SEDIMENTATION

The response of human activities in the catchment and of the climate can be seen in the extend of sedimentation in a lake. They are reflected in the quantity, type and the rate of sediments. Morphometric characteristic of the lakes are changed mainly due to sedimentation. As the circulation of water changes the distribution of sedimentation, the factors that affect the circulation like shape, depth of the lake are important in the process. Lake trap efficiency is a basic indicator of sedimentation rate. This can be seen in the inflow to volume ratio (R ) explained in Sec 13. The penetration of light into the water body is limited by the silt content brought down by streams. As they settle, depth of light penetration increases which permits the growth of phytoplankton. Soil erosion in the catchment forms the major source. Land slides stream bank failure are additional causes of huge sedimentation. Vegetational cover in the catchment reduces this siltation considerably. Further details on this will be discussed in the subsequent report.

## 2.6 ANIMAL AND PLANT LIFE

### ECO SYSTEM

Like all ecosystem, wetlands are maintianed by an energy flow. The process starts with the production of living matter by green plants and inflow of nutrients sediments etc. Herbivores consume living plants and inturn provide the food supply for carnivores. Dead organic matter provides the enery for a wide range of decomposition releases organic matters and important minerals.

Rabbits show some fascination to wetland life. Swamp rabbit (Sylvilagus aquaticus) has splayed feet which allow it to move with wet soil; it is an excellent swimmmer. The lechwe an antelope is able to graze while standing in water up to 500mm deep. It has elonagted hooves for moving through thick reed beds and soft mud, it can run faster through shallow water than on dry land. Alligators often excavate their own depressional wetlands (gator holes) to ensure permanent water body through the dry season. This concentration attracts fish eating birds such as egret and herons. Migratory birds take advantage of the productivity of wet lands. Number of parasites adopt their life with dynamics of a lake. Malaria, Filariasis, and numerous lung and liver with flukes are transmitted by wetland animals. Anopheles mosquito generally lay their eggs in still shallow water as per Finlayasan (1991). In tropics and subtropics they are preyed on by mosquito fish (cambusia).

Many plants and animals have evolved special life styles and strategies to survive or make best use of wetland environments. Nutrients are cycled in the lake eco system, which are strongly influenced by the hydrological regime. Water lilies, pond weeds, colonize the open water of shallow depth. In areas where lakes can frequently flood, reeds, rushes, grasses dominate. They typically occur in shallow water depth along the edges of a lake. Depending upon the depth of water and its period, floating and submerged water plants form different mosaics of different colour and textures. Their development depends on the oxygen, nutrient and light penetration apart from climatic conditions. They produce organic detritus which accumulates along with sediments that are washed into the system.

As a result the lake gradually fills the margins to the centre. The process is strongly influenced by organic decomposition rates hydrologic flushing rate. In shallow lakes the rushing reeds and grasses establish themselves. They impeded water movement, trap more sediments and shade out the floating water plants. The result is that the basin simply fills up, which means loss of storage capacity in due course of time.

Peat can be found in many lakes. Peat is formed when there is an inbalance between decomposition and production of organic matters. This may be caused by waterlogging, lack of oxygen or nutrients, high acidity or low temperature. Maintenance of peat land relies a particular hydrological regime and vegetation cover. Sometimes they grow upwards and even trees can get established.

Lakes serve in obtaining polutants. Aquatic plants such as water hyacinth (Eichornia Crassipes, purple colour flowering plants) are very effective in absorbing contaminants and nutrients. They spread rapidly over open water restricts navigation and reduces dissolved oxygen level. Floating rafts of emergent vegetation occur in many lakes. The mat can be upto 4m thick and with time gets consolidated, which can even support trees. They affect the dynamics of the ecosystem by suppressing the exchange of gases between air and water surface. The underside of the mat become deoxygenated and become toxic to lake fish.

Surface floating plants can grow well under sheltered conditions with a good nutrient supply for example the Kariba weed infested lake kariba in 1963 covering 1000 Sq.Km, and the water hyacinth plague on Hartebeespoort Dam, South Africa. Ancilary benefits of these plants, like production of fertilzers, bio gas and animal feed which could for example obtained from their harvest is yet not known.

## 2.7 FUNCTION AND VALUES

lakes play an important role in the life style of the people living in the neighbouhood. Out of the many vital functions of the lakes, flood moderation is one of the most important. They act as sponges in obsorbing water; keep it in stores; and release it; thus reducing the flood peaks. As gifts of nature, they reduce the need for expensive structural measures like dams etc. for the above purpose. Lakes flood prevention values should be properly accounted in planning. The binding effect of the vegetation supported by lakes helps in stabilization of bank and shores against erosion. Sediment obsorbtion in lakes have a positive function against effect of ersoion in the rise of sea level. Regular deposition of nutrient rich silt contributes to agriculture. Apart from the sediments, lakes obsorb certain kinds of waste and soluable contaminants. Thus produces quality water for human consumption. Nitrate runoff from fertilized agricultural areas can be recycled to harmless nitrogen gas in the lake. Wetlands may also release methane and dinitrogen oxide (belong to the group of greenhouse gases). These gases absorb infrared energy, and changes in their concentration in the atmosphere may influence the earth's radiation balance and global climate.

Lakes support the flow of ground water, which may discharge into another wetland. Lakes form sources of water supply for domestic and agricultural purposes especially in periods of drought. They have also served to prevent salt water intrusion. Lakes also support generation of power at number of places.

Lakes provide number of edible fish and plant material, supporting people living around. Recreational and tourist values of lakes are well known.

## 2.8 MAJOR THREATS

Tampering with lakes can also damage their ability to provide useful service.

Lakes along the river margins are nowadays subjected to convertion into agricultural land by draining the former. this affects not only the flood absorbtion but also prevention of nitrate flow in streams.

Threat may also orginate a considerable distance for lakes. Excessive demand on water upstream for different purposes. Exploitation of ground water from aquifer supporting lakes. Induced soil erosion due to indiscriminate felling of trees etc. are acting forces against lake environment.

Almost all countries have laws; which provides for Wetland protection. Spain in 1985 water law establishes: the public character of terrestrial water; the planning of water according to the hydrological cycle; the public administration of river basin.

## 3.0. DESCRIPTION OF STUDY AREA

### 3.1. GENERAL

Manipur is a small mountainous State with a number of unusual geographic features in the North East region. Topographically the State can be divided into i) The Manipur Hills, ii) The Manipur Valley and iii) The Barak Basin. The Manipur Hills are the southward extension of the Naga Hills. Further south, the mountain chain continues in the parallel ranges extending from Naga Hills in the North to about 24 degree North parallel in the south, where they meet the Mizo and Chin Hills. The Manipur valley, also called Imphal Valley, is one of the Himalyan midlands of about 1800 Sq.Km of flat land which is nearly 8 % of the total geographical area of the state. Its height varies from 800 to 1000 metres above mean sea level and act as high level flood plain. A plain in the midst of hills is an attraction with number of features like alluvial fan, meander swamps, lakes. There are also small mounts in this valley (Langol Hill in the north of Imphal and Nongmaijing Ching jao Hill in the east). River Manipur and her tributaries Imphal, Iril, Thoubal, Nambal, Nambul and Nambol drain this valley to the south. It is about 60 Km long and 30 Km broad and enclosed by the Eastern and the Western Hills of manipur. The drainage pattern in the valley is centripetal. The inner stream tracts abound in swamps and marshes. A small plain, known as Khoupum Valley at an elevation of about 762m above sea level on the western site of the state beyond the Manipur western hills (about 250 Km.) is formed by deposits of river Barak and its tributary, Jiri. The index map is shown in the Fig. 1 indicates the study area in N.E. region.

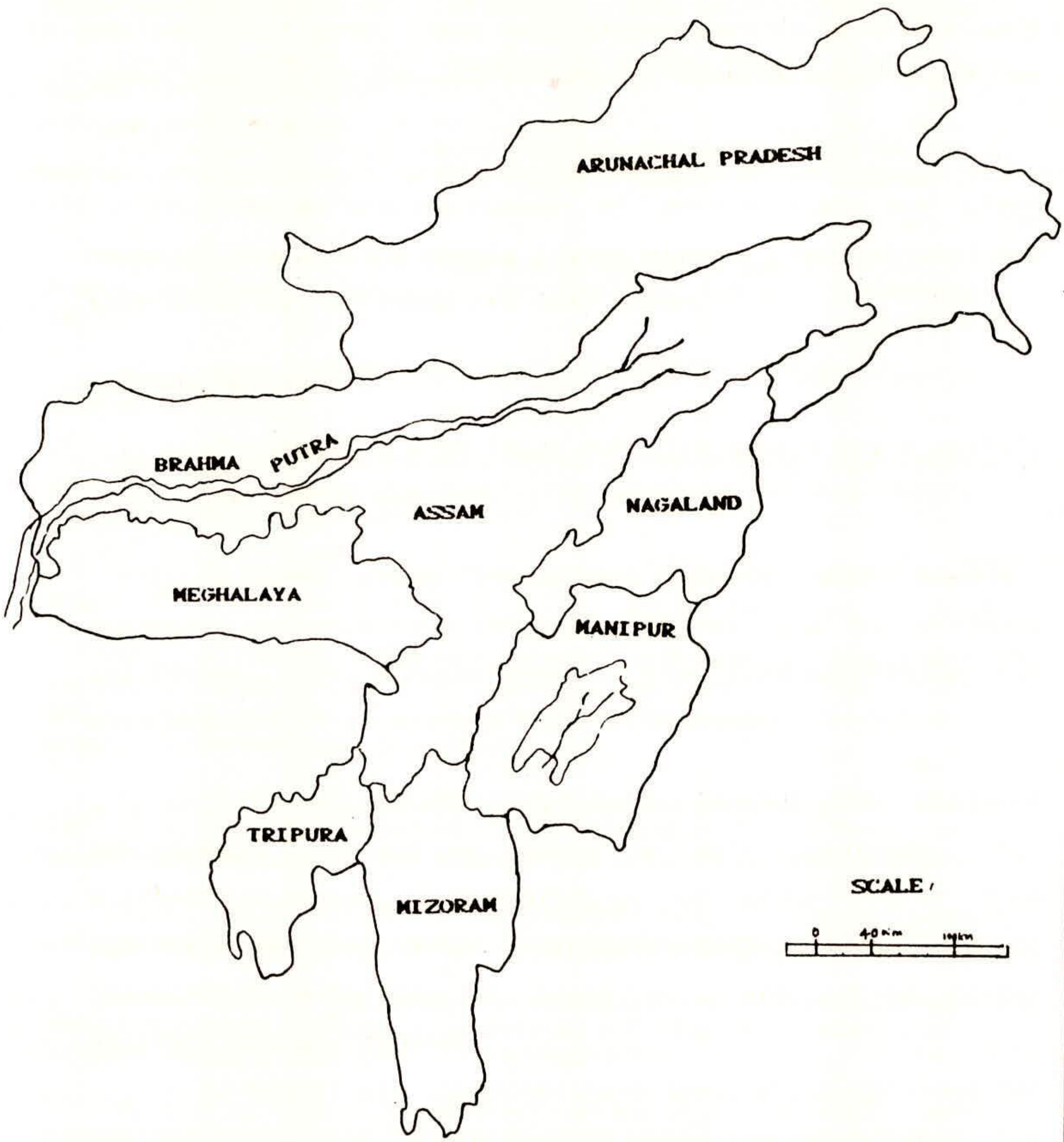


FIG. 1 NORTH EAST REGION SHOWING THE STUDY AREA

3.2. POPULATION

As per the draft census report of Manipur 1981, the population of Manipur is 14,33,691. Table shows some relevant information. Seventy percent of this live in the plains causing a density of population of about 135 per Sq.km. The same for hills is 30 per Sq.Km. The valley is generally inhabited by the Manipuris known as "Metei' and the hills by the Kukis, Mizos and other tribes.

TABLE-1 POPULATION DATA

| | 1971 census | 1981 census |
|---|---|---|
| Population | 1,069,555 | 1,433,691 |
| Males | 539,101 | 727,108 |
| Females | 530,454 | 706,583 |
| Density | 48/Sq.Km. | 64/Sq.Km. |
| Literacy | 32.8 % | 41.99 % |

3.3. CLIMATE

Manipur experiences a sub-tropical monsoon climate. As per classification of Wladimir Koppen the state belongs to the temperate rainy (humid mesothermal) climatic regime. It has distinct dry winter and hot summers, (a temperature of over 22 degree Centigrade). From November to February is the period of winter season. The summer begins in April and ends in September. Month of March and October are transition period. The climate of the state has largely been determined by her orthographical structure. A host of other factors including sub-continental pressure cells of north west India and the Bay of Bengal, the predominant moist maritime tropical airmass, periodic western disturbances, Valley winds, the nature and extend of forest cover and the water bodies, like Loktak lake,

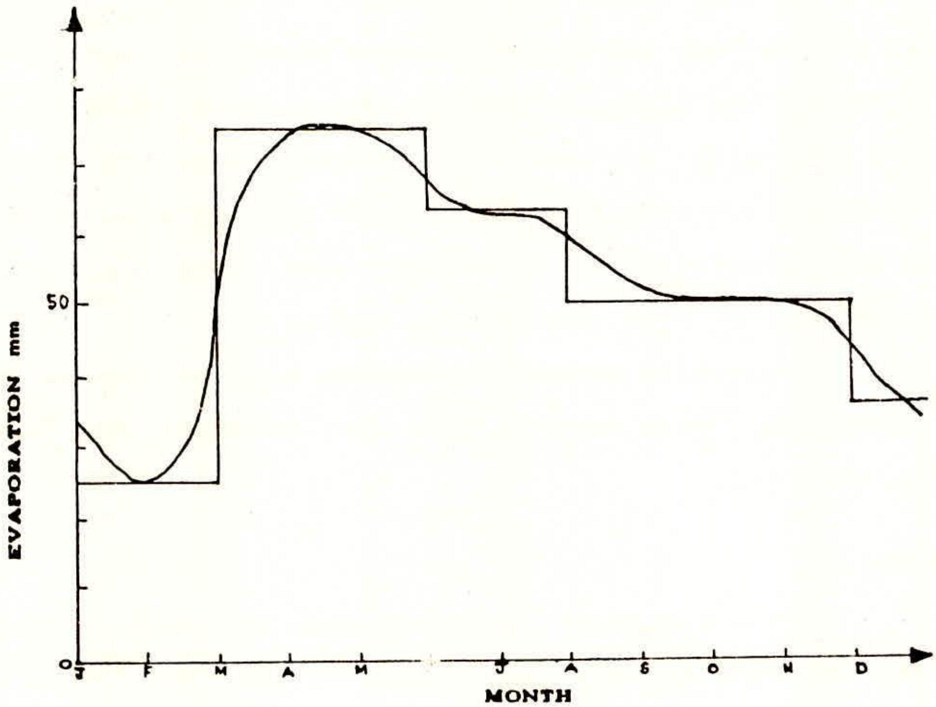


Fig. 2. MONTHLY EVAPORATION

influence the climate in the state. The western part of the state is more moist than the eastern because of its locations on the windward slopes of the hills.

Observations at Imphal show that minimum temperatures (1.7 C ) occur in the month of December or January and maximum temperature (31.9 C) in April or May. Table A-1 shows the maximum and minimum temperature observed at Imphal. Forest cover of the state influences the climate greatly. They reduce the intensity of solar radiation sriking the forest floor. Evaporation from these soil is considerably reduced as wind induced evaporation is also diminished. The Fig.2 shows the monthly evaporation from the Central Plains.

Humidity generally remains high throughout the year mostly above 50%. Mean monthly humidity observed at Imphal is given in Table A-2.

### 3.4. RAINFALL

The catchment is surrounded by high hills which causes the rainfall to vary very much. The available monthly rainfall is given in TABLE A-3. This region experiencing premonsoon locally heavy (Malurkar 1950) early from March to early June, which are associated with thunder and lightening.

Records of rainfall are available for long period (70 Years) for few stations and periods ranging between 3 - 15 for many stations. Table 2 shows the average annual rainfall and elevation.

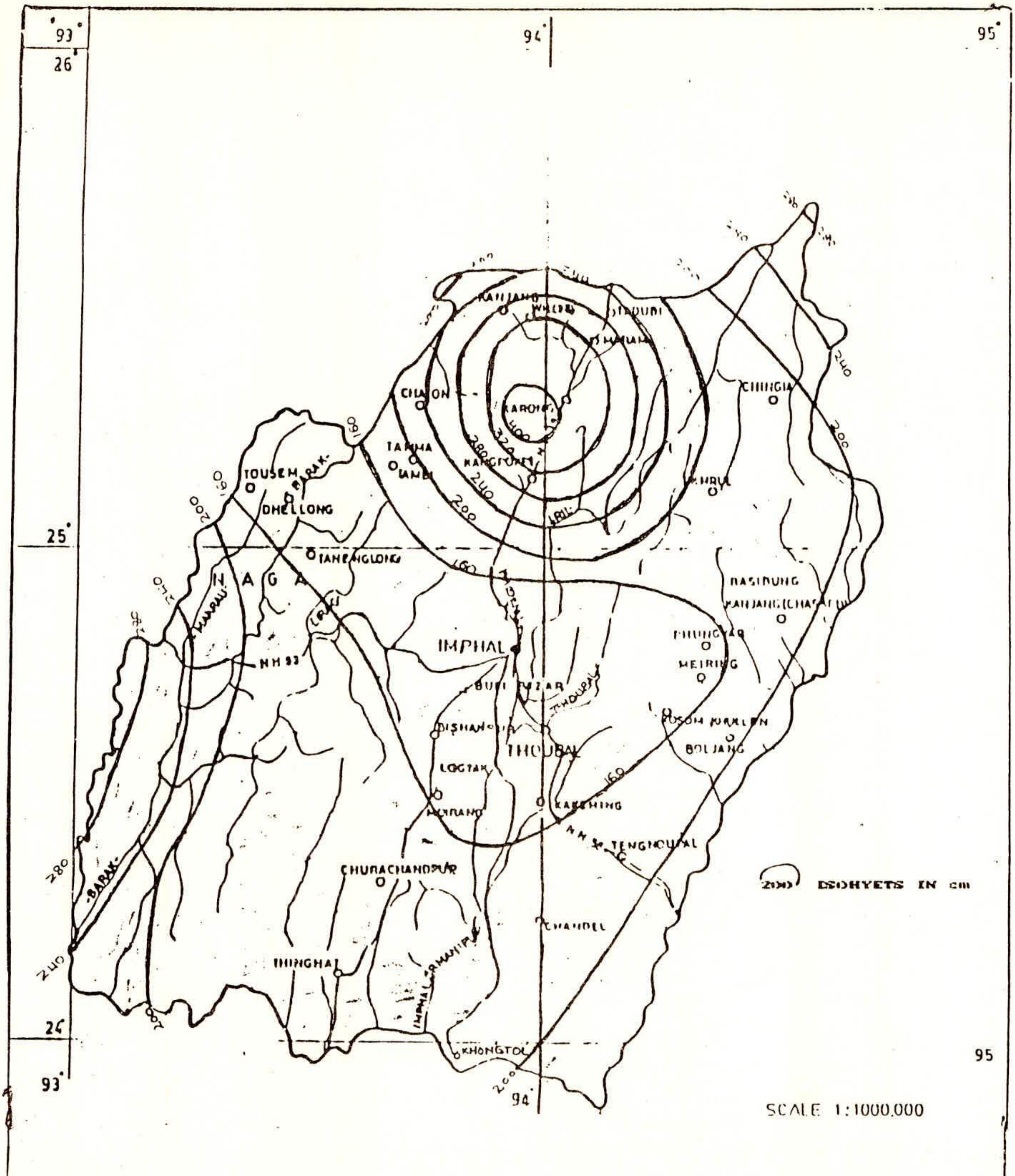


Fig. 3. MAP OF MANIPUR STATE SHOWING ISOHYETS

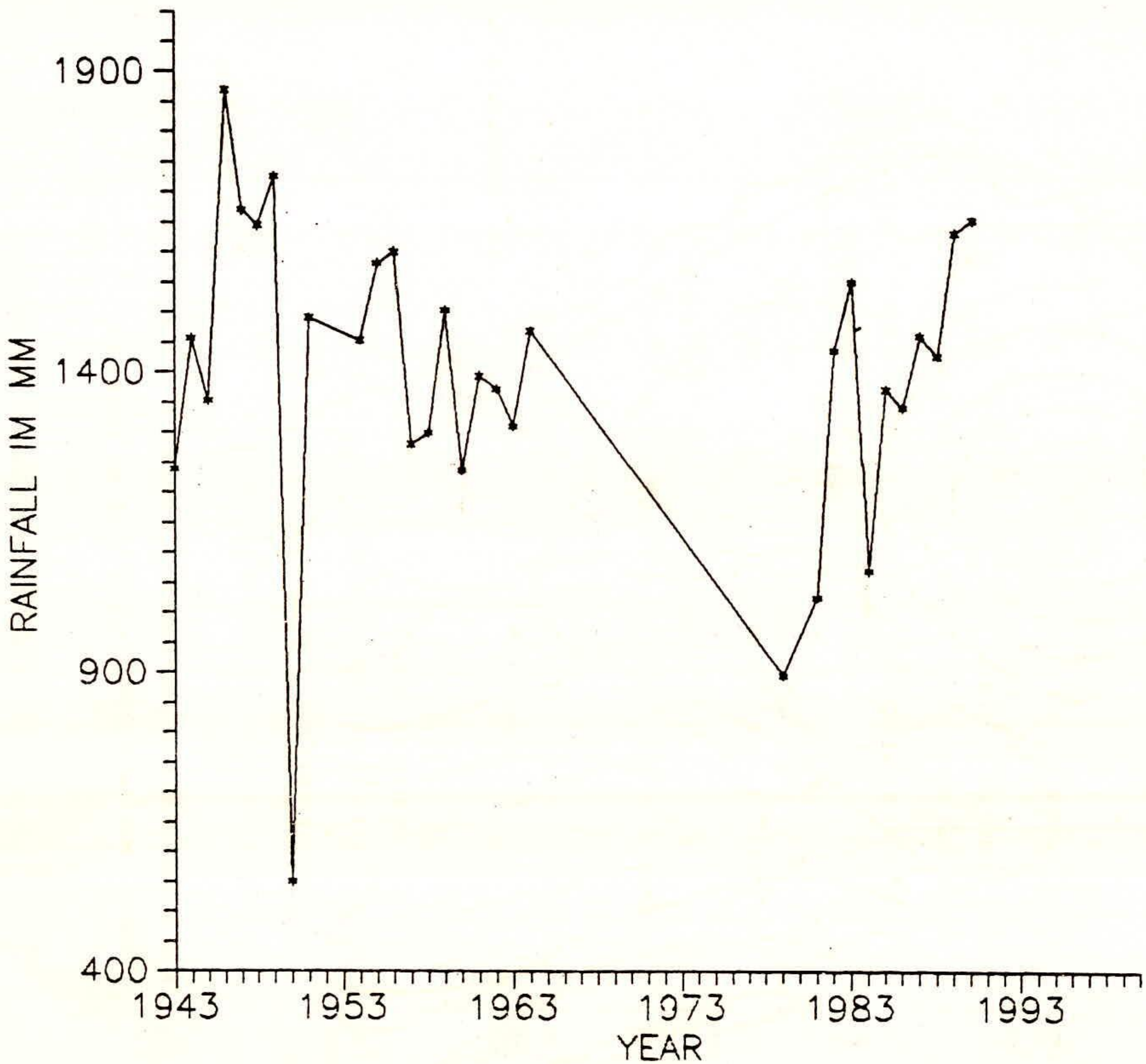


**FIG. 4. SHOWS THE VARIATION OF ANNUAL RAINFALL RECORDED AT IMPHAL**

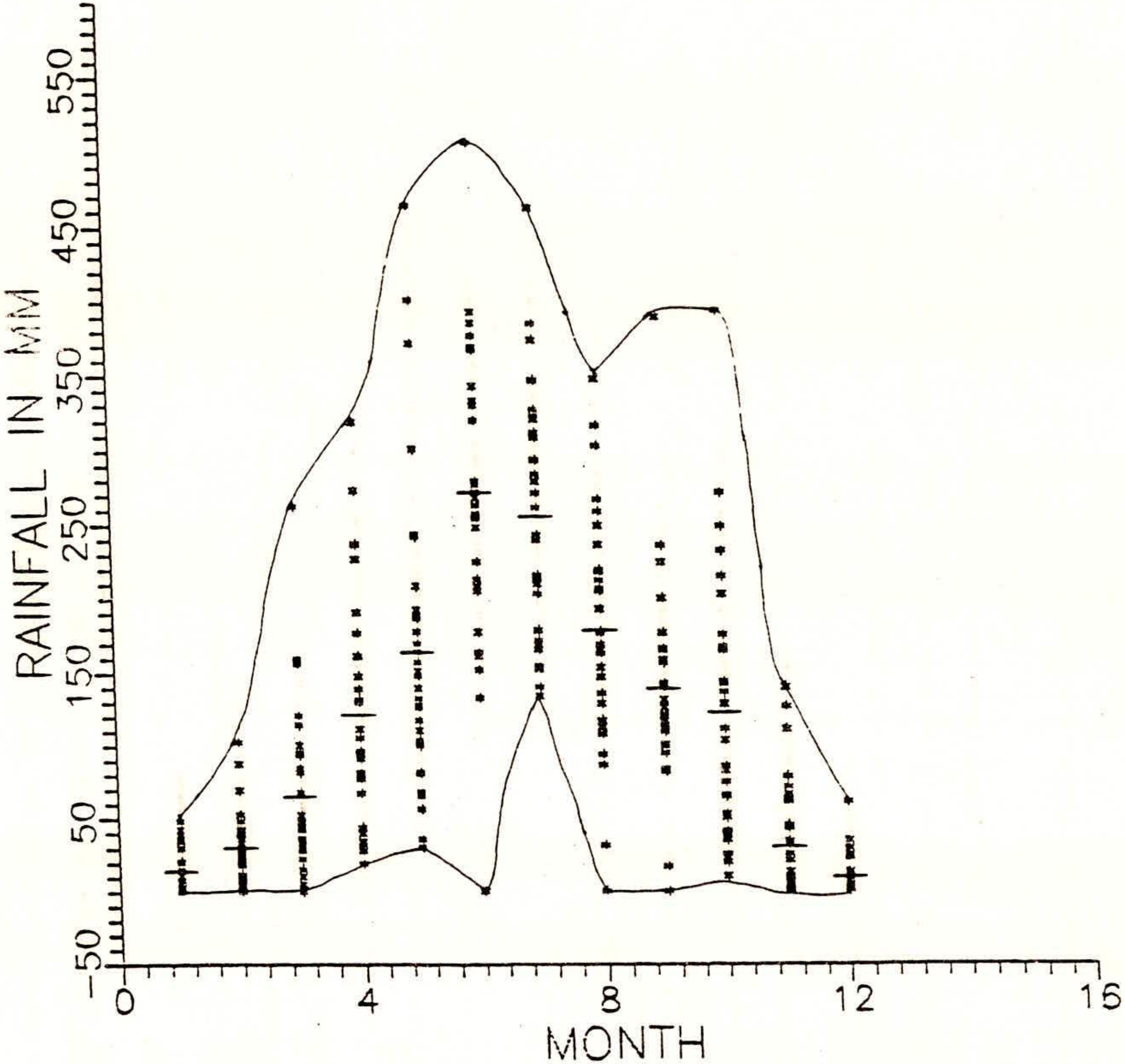


FIG. 5. SHOWS THE VARIATION OF MONTHLY RAINFALL RECORDED AT IMPHAL

TABLE - 2 ANNUAL RAINFALL AND ELEVATION

| Station | Rainfall (mm) | Elevation (m) |
|---|---|---|
| Imphal | 1413 | 790 |
| Ukhrul | 1799 | 1800 |
| Tamenglong | 4017 | 2560 |
| Churachand pur | 1760 | |
| Kangpokpi | 4030 | |

Tamenglong (northern part of the state) receives the highest rainfall in the state. The highest 24 hours rainfall recorded at this place is 236.5 mm on April 26, 1936, where as the same for Guwahati and for Cherrapunji are 232.9mm and 973.8mm respectively. Isohytel map of Manipur is shown in Fig 3. Relevant rainfall data made available by Loktak Lake Authority are given in Appendix. Fig.4 & 5 Shows the annual and monthly variation of rainfall recorded at Imphal

3.5. RUNOFF

The State is drained by a number of streams of varying size. These rivers have their source in the hills. The main stream of the western half of Manipur is the Barak. Other principal rivers are the Imphal, Iril, Thoubal, Nambul and the Nambol. These rivers carry down a good deal of silt which has raised their bed considerably. More about the river system of concern is explained subsequently.

3.6 GEOLOGY & SOILS

In Manipur, the oldest rock found along the eastern part of the state belong to cretaceous group. Limestone of cretaceous age occur at number of places around Ukrul. The rock type in this region are shales, mudstones, silt stones and sandstones of Disang series. The Barails occur over considerable

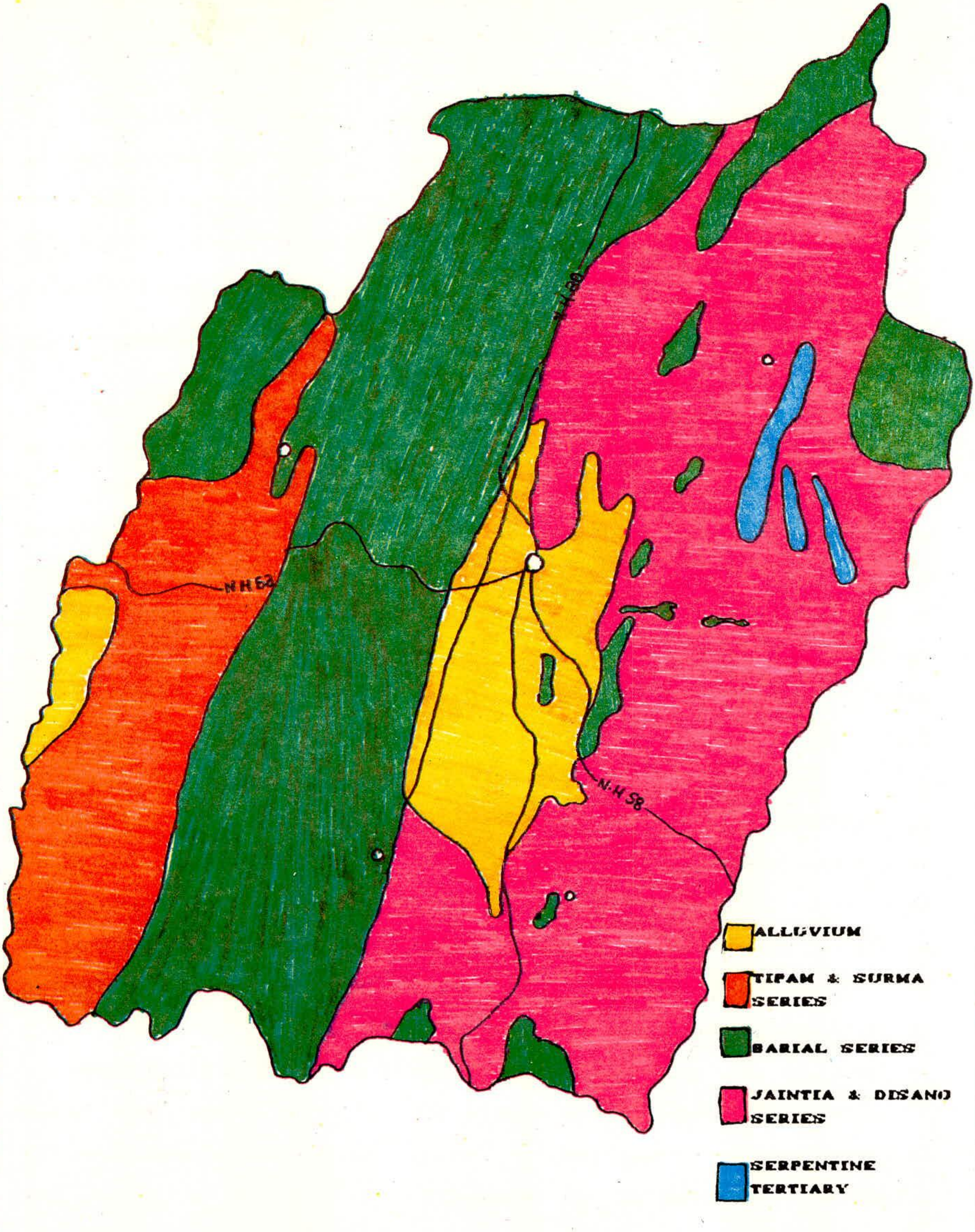


Fig. 6 GEOLOGICAL MAP OF MANIPUR

Source: Ansari (1970)

tracts of Manipur North, Manipur West and Manipur South districts. in Tamanglong area the rock types are shale sound stone of Barail series Central plains and Khoupum valley provide alluvium formation at high elevation. Fig. 6 shows geological formation of Manipur. Soils are mostly fine textured consisting predominantly silty loams, silty clay loams and silty clays. The soils are rich in organic matter and do not contain Calcium Carbonate. The pH value of the soil varies between 4.2 to 7.2 (acidic to neutral). The salt content of the soil is below 0.2%

3.7. GROUND WATER

Water is met within 1.2 to 2m from ground surface. Water tables are high during the monsoon particularly in areas adjoining to the lake. Open wells provide little quantity of water for domestic purposes. Water is also drawn from confined aquifer at a depth of 50m. Number of springs can also been seen in the valley with a flow of approximately 300-400 litres/hr. Spring water quality at some villages are brackish. The ground water movement is generally from North to South.

3.8. AGRICULTURE

About 70% of the population depend upon agriculture. Out of the total land area of the valley, (1,81,300 Hec) about 14800 hec. are not available for cultivation as they were put to non agricultural uses. The cultivable waste, permanent pastures, and other grazing land accounted for 32300 hec. As per village records the net area sown in 1957-58 was about 66.7% of geographical area. Three types of cultivation viz., wetland, terracing and shifting cultivation are practiced here.

Rice is the staple food of the state and hence increasing the production of paddy as much as possible is attempted. At present, only a single crop of paddy is grown all over the state during the monsoon months. The preliminary operations are commenced in the month of May and the crop is harvested in October, November. after the harvest, most of the land is left fallow as there is no water to carry on further cultivation. Pulses of different kinds are also grown but not in great quantities. Potatoes are generally very inferior. It is necessary to mention about the shifting cultivation as it has greater bearing upon the lake & river environment.

3.9. SHIFTING CULTIVATION

Though precise data on the extent of shifting cultivation (see appendix B) in different regions of India are not available, a number of important studies have been carried out on socio economic life of the tribes practicing the same. Table below gives some facts on this practice in 1950 and in 1978 in this state reported by (Sachchidananda (1989)and NEC (1981) respectively.

| TRIBES | LOCATION |
|---|---|
| Kuki Angami | Largely in the Manipur South |
| Tangkhul Maring | Manipur East districts. |
| Kabuire and Kachanga | |

TABLE -3 SHOWING SHIFTING CULTIVATION IN MANIPUR

| | |
|---|---|
| Total area of the State in (hac) | 2,235,947 |
| Area Consisting Valley proportion in (hac) | 181,300 |
| Area consisting hills in (hac) | 2,055,942 |

| Year | Area annually cut (in hac) | Population | TRIBES |
|---|---|---|---|
| 1950 | 54,181 | 1,82,902 | Kuki Angami |
| 1961 | 38,851 | 2,00,000 | Tangkhul Maring |
| 1978 | 60,000 * | | Kabuire and Kachan |

* NEC (1981)

In Manipur the tribals have got the right of jhumming even in protected forest area. The Government of Manipur has also provided incentives to the shifting cultivation for adopting terrace cultivation and bring further improvement in it. The teak forest along the Manipur border perhaps suffered less than other area. This area is well protected from jhum activities not only because of the terrain condition but also by the rulers of Manipur. An attempt to regulate jhum was made in 1923 by banning on the establishment of new villages in the hills. In 1932 a legislation was passed for the first time to deal with the problem of jhuming. All forest but for the neighbourhood of the villages were brought under State Forest Reserve.

### 3.10. LAND USE

Manipur has mountains covering 92% of the total geographical area. In this hilly area 67% is forest and 25% (5000 Sq.Km.) in wasteland a product of shifting cultivation and deforestation. Annually about 2.25% of land is cut and burnt under jhuming. Some part of the hills (Manipur East, Manipur North districts) are also used for terrace cultivation. About the rest of the 8% land in high level plain occupying the central part of the state, supporting 2/3 rd of the population of Manipur.

Southern portion of the valley has numerous "Jheels" (depression submerged underwater and mostly covered with water hyacinth and other aquatic plants). Many of the jheels that Manipur had in the past have silted up as for example Lambphel Pat. Important lakes in this territory are Ikop, Waitou and Loktak.

### 3.11. SOIL EROSION

The mountainous part of Manipur consists of young Tertiary folds, composed of unconsolidated sandstone, shales, slates etc. as per Ansari (1985). The hill slopes are steep. In general the topography consists of sharp parallel ranges separated by deep narrow valley. In the upper sections, the hill torrents have very steep slope and deep channels and draw in all the soil form above their sides in the form of sheets and gullies. Soil forming on such steep slopes remains poised at a precarious state of balance. In slopes exceeding 45 of angle, soil cannot normally rest but subjected to gravity pull. Only vegetation can protect soil at such places.

Torrential downpours are caused by thunderstorms which have great potential of causing flashy surface runoff and huge amount of soil is washed down in the rivers of Manipur during monsoon month. In forested area erosion is limited due to little water flowing over surface. But gullies result in slopes greater than 2%.

Land use pattern described above affect the soil erosion status of the State very much. Erosion is most severe in this 25% of the total geographical area where shifting cultivation and deforestation have caused bare and waste lands. Ansari (1970) heavy deposits of sand and silt in river beds (Iril, Imphal, Thoubal etc.) in alluvial plains cause a rise in flood levels. Jhum lands are subjected to sheet wash and gully erosion, in spite of all possible man made protections to keep soil intact by plugging the gullies or keeping logs along the contour to arrest sheet wash. The soil is lost in 2-3 years.

## 3.12. GENERAL RIVER SYSTEMS

The state is drained by a number of streams of varying size. The main stream of the western half of Manipur is the Barak river. This and its tributaries have their source at the great mountains called Japyo. Important tributaries of Barak are the Jiri, the Makru and the Irang.

The drainage of eastern half of manipur passes to Chindwin-Irrawaddy system. The Mapithel range divides this into two. Many streams flow west of this range through the central plains of Manipur. Important rivers in this plain are the Imphal, the Iril, the Thoubal, the Khuga and the Chakpi. There are number of streams flowing east joining the Chindwin. More details of Manipur river system are given below as the Loktak lake occupies this basin.

3.13. MANIPUR RIVER BASIN

It is improper to consider the Loktak lake without considering also that of Manipur river basin in its present condition. In this connection it is worth to note a passage from the records of the Indian museum Vol.XXII part IV, No.28 on the origin of the lake.

" Two different views have been held on this, one that the whole valley is comparatively recent lake bed and that the lake once filled in has shrunk to its present size, perhaps in historical time; the other is that the valley is of comparatively ancient date and has been filled in gradually to its present level by debris brought down from the hills by the tributaries of the Imphal river". The rocks found here are said to be Disang series. The fine soils of these rock are found in the valley. It is only on the east and probably also on the south side (Bhattacharyya 1963), that large deposit of peat are being formed. The peat deposits on the eastern shore, represent swamps that were recently larger than they are now.

The following information are from Kingdom ward (1946) as reported by Bhattacharyya (1963).

" Manipur was ringed in by ice. Along its high eastern frontier Manipur shows ample evidence of glaciation. The long level ridges between 6000 ft, and 8000 ft indicate an ancient plateau which may once have been considerably higher. There are several 'U' shaped valleys, a shape which they assumed as a result of continued glaciation. It is therefore probable that the plain of Manipur was formerly a lake, the water of which was derived from the melting snows of the plateau and the moist winds which blew during the last phases of the ice age. And in the not too distant past the rivers rushing down from the plateau poured silt into the lake, filling it up and making it a dry land".

Manipur plains occupies the central part of the state covering about 1800 Sq.Km. The southern part of the plain is occupied Loktak lake. The plain as well as the lake has a number of hills. Alluvial deposit of depth varying between 100m to 150m are found in this plain. The lower part of the hills are found to have burried under the alluvium. Combination of features like alluvial fans, levees, meanders, abandoned channels, floating reed forests, lakes, swamps, small mounts, hills and hill ridges in close proximity presents special attraction to geomorphologists. The drainage, of the plain passes southward through the Manipur river, which has developed narrow gorge in the mountains south of the plain. The plain is drained by a number of streams namely Iril, Imphal and Thoubal. The combined water of the three, flows south ward and gets the name the Manipur river. The Nambul river, the Nambol river and many other small streams from Loktak lake from the north covering about 650 Sq.Km. Three other streams namely Chakpi, Sekmai and Khuga have their orgin in

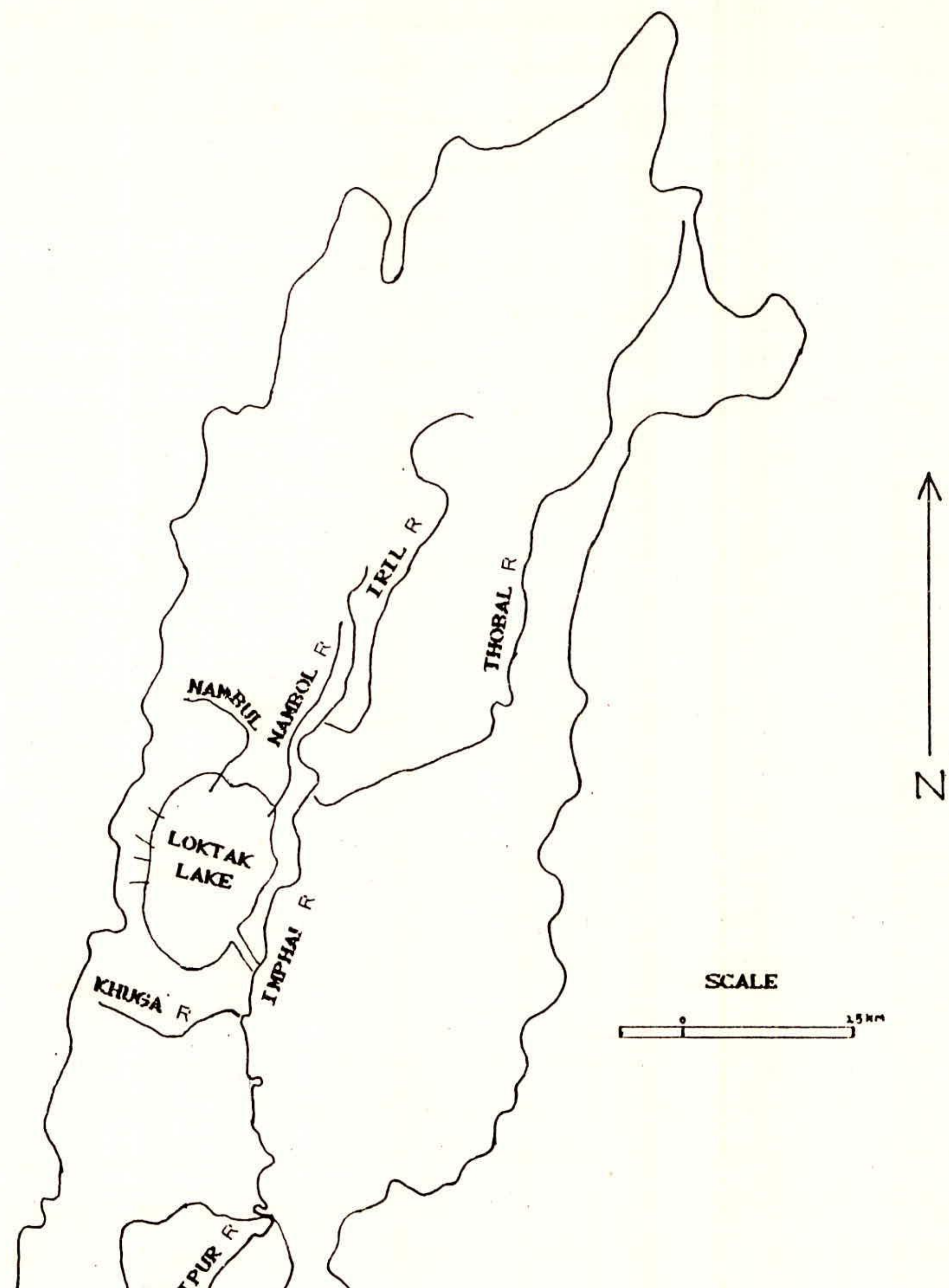

Fig. 7 CATCHMENT MAP OF IMPHAL RIVER FEEDING LOKTAK LAKE

the mountains south of the plain. They follow a northerly course and join the Manipur river from opposite direction. The sediments carried in these streams chock the only outlet of the plain near Shugnu where plain ends and cause flooding in the southern half of the plain. In the southern part while tributaries of the river Manipur flow northerly direction, the river Manipur could maintain its southerly course, due to its degrading capacity (Ansari 1985). The longitudinal profile of this reach of the river is almost horizontal. The reversal of the drainage in the southern part is caused by the uplift of the mountains there. This also led the formation of numerous lakes or swamps. The Imphal river basin is shown in Fig. 7.

River Imphal originate from the hills north of Kangpokpi and flows southwards with the initial name of Tiki. The river Imphal has a course of about 75 Km, draining about 500 Sq.Km. before receiving, the discharge of the river Iril brought from a drainage area of about 1300 Sq.Km. The river Thoubal originating from high ranges in Ukhoul, joins river Imphal. Although the Imphal river bed is below the loktak lake, the backwater effects causes the water from the river imphal to flow to the lake through the Khordak channel.

The khuga river, which originates in the Singhat Hills in the Manipur South district, flows northwards and joins River manipur at Ithai. The bank level on either side of the Manipur river vary from about 780 m at Lilong to 770.8 m at Ithai. The bed level of the Manipur river which lies at 773m at Imphal and at 768.6m at lilong, falls down steadily to 762m at Ithai. The sudden rush of water from the river Khuga flowing in the northerly direction (i.e. upstream direction to the river Imphal) meeting the main river north of Ethai causes the impoundment and

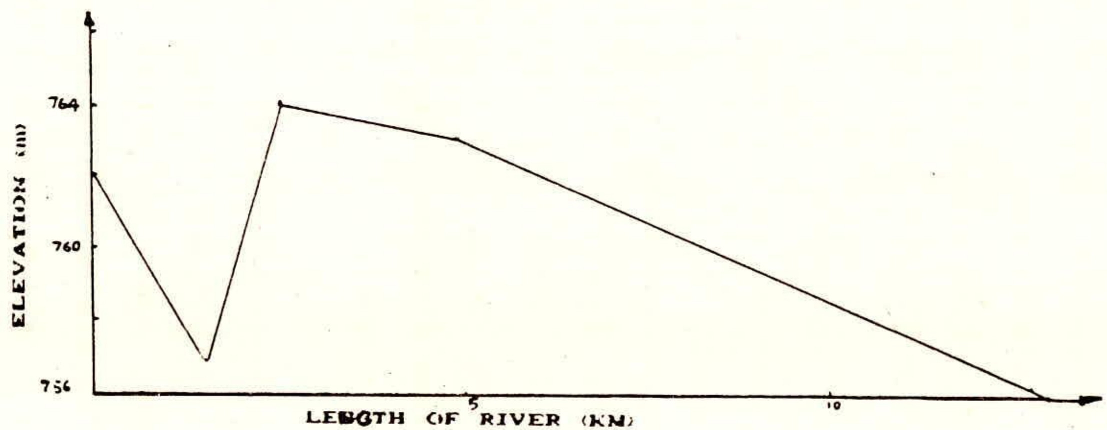


Fig. 8 LONGITUTIDAL SECTION OF THE RIVER IMPHAL D/S OF ITHAI BARRAGE SHOWING SUGNU HUMP

the excess water flow to the lake. When the river Khuga recedes, the river Imphal revives its south ward flow. In certain situations the lake also drains the excess water to the river Imphal through Kordak Channel. Here the river passes through a narrow gap of about 50m wide through a range of hills and thereafter traverses through a range of hills and thereafter traverses through relatively hilly terrain with small patches of plain ground on either bank. The river bed continues to fall up to a point about 1.5 Km, downstream of Sugnu village, to its deepest bed level of 756.8 m. Thereafter, in a short stretch of less than a km the bed level rises steeply to 764 m for a distance of 2.5 km. The river bed level at about 8 km downstream of Sugnu is 756m. The river chakpi meets the river Imphal south of Shugnu. Shugnu area presents a bottle neck in the flow of the main stream. It is in this area the river encounters the famous Shugnu hump. The Fig.8 provides a rough idea on longitudinal profile and the stream network of the river Imphal.

TABLE - 4

IMPORTANT TRIBUTARIES OF THE RIVER IMPHAL

| Sl.No. | Name | Area (Sq.Km) | Length (Km) | Elevation MSL |
|---|---|---|---|---|
| 1. | Iril (LT) | 1300 | 120 | 2600 |
| 2. | Thoubal (LT) | 1050 | 105 | - |
| 3. | Khuga | 620 | 80 | - |
| 4. | Chakpi | 800 | 60 | - |

The available longitudinal section of the river from Lilong to the Sugnu hump is given in Fig 8 Shugnu hump obstructs the flow and the water level in the river rises. This causes bank over flow not only on the river but also on the

Fig. 9  THE LOKTAK LAKE SHOWING THE PHUMIDS

tributaries. A regular embankment at 1.5 to 3 m in height has been constructed on both banks of Manipur from about 8 km of Imphal upto sekmaijin

Further downstream Manipur River finds the confluence with River Myittha (a tributary of river Chindwin) after passing through deep gorges. The Chindwin River not only collects water from Manipur River but also from number of rivers like Akonglok River, River Yu orginating from Manipur Eastern Hills and washing eastern slopes of the State. The Chindwin, finally joins the Irrawaddy which confluences into Andaman Sea.

## 3.14. LOKTAK LAKE

There are number of lakes and marshes in the southern part of the valley of which the Loktak is the largest which is on the right of Imphal/Manipur river. It is a shallow expanse of water covered with aquatic vegetation, weeds and water hyacinths. Vegetable "trapa" which grow under water are harvested and sold throughout the valley. Floating weed masses locally known as 'Phumdis' are used by fisherman for making floating islands for catching fish as shown in fig 9. Floating huts can also be seen on these. The lake surface is covered to the extent of 30-65% of by floating weeds. Water hyacinth, accounting 30% of all weeds affects the uses of lake. It is said that the lake is being silted up by the voluminous sediments brought by numerous streams. This process is further accelerated by the landuse practices prominently by shifting cultivation. Apart from Loktak Lake, the Waithou, the Ikop, the Kharungpat and the Pumlen all (left side) east of the Imphal/Manipur River are important water bodies. Few islands, Thanga, Ithing and Karang, rising steeply above the lake surface, provide best fishing grounds in the state.

Loktak lake stretching from 5 km downstream of Iril confluence with the river Imphal near Lilong and extending upto the khuga confluence with the same river near Ithai. The Nombol river, from Western hills directly flows into the lake. A table of rivers flowing into the lake are given below:

i. The river Imphal.
ii. The river Nambul.
iii. The river Nambol.
iv. The river Oinam.
v. The river Awang Khujairok.
vi. The river khuman Lok.
vii. The river Awang khrok.
viii. The river Kaborok.
ix. The river Thabakhong.
x. The river thangjao Rok.
xi. The river Kha-Rok.
xii. The river Potsangbam.
xiii. The river Ning Thouk Hong.
xiv. The river Kha-Khujai Rok.
xv. The river Santhoibi.
xvi. The river Irumi.

Loktak lake gets water flowing from Western hills, from direct rainfall over the lake itself. Water also flows from imphal river through Khordak cut. This khordak cut is about 11 Km long natural water course with a well defined channel about 15 m, wide 6m deep at its outfall. The capacity of the channel is 100 cumecs. The Loktak lake and Pumlen lake together have 320 sq.km at an elevation of 771m which is normal flood level, according to Project Report of Loktak Lift Irrigation. Lake level also rises 772m in years of very high floods submerging 490 Sq.km. water level raises above 771.3 m the Loktak lake, the Lamjao Khong and Pumlen lake, the Khuga river and the Manipur river form a single sheet of water. The manipur river at this stage drains water from the huge lake.

There are also a number of marshes known locally as pat; (Utrapat, Laphupat, leningangpat, Ungampat, lamphelpat, Porompat, etc.) found throughout the valley in the inter riverine tracts. Some of these (pat & part of lakes) are reclaimed and brought under cultivation. Some of them remain dry for the major part of the year but filled with water during the rainy season.

3.15. MULTIPURPOSE PROJECT

Considering the periodic flooding of vast area along the periphery of these lake, Loktak multipurpose project has been conceived to harness the flood water. It is aimed at irrigating 24,300 hec of land in Manipur and generation of 70,000 KW of power at 60% load factor. It is also expected that drainage characteristics of the river Manipur will also improve.

The whole scheme is based on Water to be diverted to the lake from manipur river at Ithai. All the streams flowing into the lake brings in the sediments. On the basis of the observation (Project report 195) during 1953-59, it has been found that Imphal river brings in annually 75Mcm per year. Silt carrying capacity is limited by the Kordak cut. The Nambol and the Nambul bring silt from 720 Sq.Km. of catchment area. Assuming a rate of 0.09 Mcm per 259 Sq.Km it has been reported that the dead storage (below 767m i.e. 39-2 M Cu.m.) would be filled in 159 years. But dredging or deepening of the lake has become essential due to siltation at present.

3.15 SEDIMENTATION

All the streams flowing into the lake brings in the sediments. On the basis of the observation ( Project report 1965) during 1953-59. It has been found that Imphal river brings in

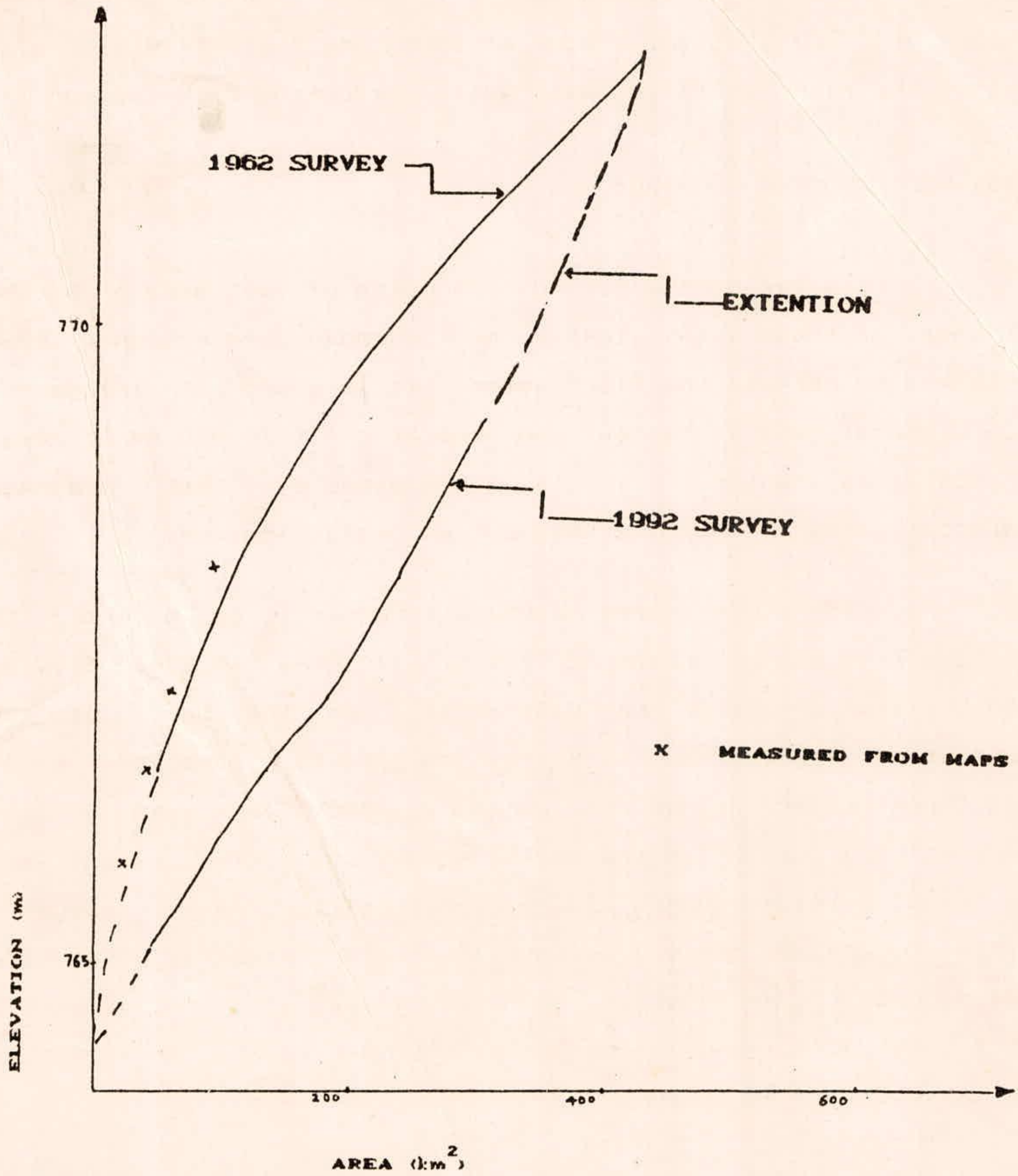


Fig. 10 AREA - ELEVATION CURVE

annually 75 Mcm per year. Silt carrying capacity is limited by the Kordak cut. The Nambol and the Nambul bring silt from 720 Sq.Km. of catchment area. Assuming a rate of 0.09 Mcm per 259 Sq.Km. it has been reported that the dead storage (below 767 m i.e. 39-2 M Cu.m.) would be filled in 159 years.

A comparison of Area-Elevation curve is made with the data supplied by Loktak Development Authority as shown in Fig.10. The 1962 curve is extended down to 764.5 m for near zero area. Similarly 1992 data is also extended on either side. The latest curve indicate larger storage than 1962, probably due to inclusion of nearby lakes as a single water body. Hence available sketch of the lakes is used to measure the area of water spread for different elevation which was possible only up to 768 as shown in Fig.10. Sketching of future contours is not possible with available data at present. A marginal sedimentation up to the depth 768.0 m can be seen in the Figure. It may be possible that heavy sedimentation occurred between elevation 768 m to 771 m causing loss of storage and problems of flooding. The same might also be equally possible that increased encroachments due to agricultural activities.

## 4.0 CONCLUSION

As a gift of nature, lakes play many useful role in the life style of people living in the neighbourhood. Flood moderation capacity, flood production capacity of lakes are well known. Lakes support the flow of ground water; Shore stabilisation and sediment absorption are important function of a lake, because of its economic values in power generation; drinking and irrigation water supply there arise a need for quantitative studies on the variability of water level and its store space in a lake. The fluctuation in these hydrological parameters are stochastic in nature and can be studied by water balance. Different components involved in such studies have been discussed. Most of these component can be measured and some requires estimation.

The response of human activities and other general degradation can be seen in the extent of sedimentation in a lake. They are reflected in the quantity, type and the rate of sediments. Morphometric characteristics of the lakes are changed mainly due to sedimentation which need to be studied as an indicator.

Loktak lake situated in the southern part of the central plain of the State Manipur forms an important source of economic activities. Number of rivers contributing to the lake brings lot of sediments along with them. But the sediment outflow is limited by Kordak cut.

A comparison of area elevation curve is made with the data supplied by Loktak Development Authority has been made and certain data error have been indicated.

Further studies can be made only if relevant data on rainfall, discharge are made available. It is proposed to study and provide proper measures on catchment treatment to effectively reduce the siltation of the lake in the second part of the study.

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APPENDIX A

TABLES OF HYDROLOGICA

**APPENDIX A-1.**

## MONTHLY RAINFALL IN MM AT IMPHAL

| Month | 1943 | 1944 | 1945 | 1946 | 1947 | 1948 | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 43.12 | 39.37 | 40.13 | Nil | 0.25 | 0.51 | 7.87 | 20.32 | Nil | n.a. | n.a. | 3.30 | 5.33 | 20.83 | 49.28 | 11.43 | 29.97 | Nil | 13.72 | 7.11 | Nil | 2.29 | 11.94 |
| Feb | 20.57 | 18.54 | 23.62 | 36.32 | 9.65 | 103.30 | 5.33 | 49.02 | Nil | n.a. | n.a. | 42.67 | 7.11 | 0.51 | 51.05 | 40.89 | 72.10 | 5.33 | 29.21 | 26.67 | 7.37 | 30.45 | 37.34 |
| Mar | 2.79 | 33.53 | 40.77 | 159.51 | 35.31 | 22.86 | 10.41 | 63.83 | 84.84 | n.a. | n.a. | 36.83 | 121.41 | 47.75 | 5.33 | Nil | 156.97 | 15.49 | 263.14 | 3.05 | 29.46 | 42.93 | 57.66 |
| Apr | 77.98 | 81.79 | 34.04 | 132.84 | 130.05 | 96.77 | 191.26 | 34.80 | 236.73 | n.a. | n.a. | 95.25 | 177.04 | 95.25 | 130.30 | 68.07 | 44.20 | 28.19 | 19.30 | 161.54 | 82.01 | 143.03 | 107.95 |
| May | 82.30 | 100.33 | 110.74 | 102.36 | 164.34 | 401.32 | 243.59 | 127.25 | 68.33 | n.a. | n.a. | 193.04 | 157.40 | 464.31 | 151.38 | 372.11 | 169.93 | 103.89 | 168.98 | 81.28 | 187.28 | 133.10 | 173.56 |
| Jun | 392.61 | 330.45 | 342.90 | 332.99 | 506.22 | 151.89 | 369.06 | Nil | 257.89 | n.a. | n.a. | 385.32 | 257.05 | 254.51 | 262.89 | 256.03 | 213.11 | 320.04 | 209.04 | 368.30 | 267.97 | 376.94 | 265.73 |
| Jul | 140.46 | 386.36 | 345.95 | 373.89 | 327.15 | 292.86 | 335.06 | 154.18 | 214.12 | n.a. | n.a. | 271.27 | 311.91 | 210.31 | 261.11 | 283.97 | 168.91 | 243.08 | 212.60 | 293.88 | 176.82 | [illegible] | 249.43 |
| Aug | 316.48 | 266.70 | 135.64 | 112.78 | 176.28 | 258.32 | 236.47 | Nil | 162.56 | n.a. | n.a. | 107.70 | 193.04 | 217.93 | 153.42 | 117.35 | 383.09 | 207.26 | 212.68 | 249.17 | 347.73 | 147.07 | 194.56 |
| Sep | 142.75 | 224.75 | 120.14 | 177.55 | 82.30 | 128.32 | 235.97 | Nil | 200.41 | n.a. | n.a. | 101.35 | 166.37 | 121.92 | 140.97 | 119.89 | 114.05 | 159.26 | 156.46 | 17.53 | 102.03 | 95.00 | 129.54 |
| Oct | 20.32 | 53.34 | 143.76 | 393.45 | 232.16 | 103.63 | 41.91 | 82.80 | 175.26 | n.a. | n.a. | 215.39 | 35.56 | 129.03 | 75.18 | 23.15 | 232.16 | 111.25 | 40.89 | 165.10 | 65.85 | 141.99 | 109.73 |
| Nov | 0.25 | 0.25 | 7.11 | 13.21 | Nil | 78.74 | Nil | Nil | 62.23 | n.a. | n.a. | 2.03 | 139.95 | 34.54 | Nil | Nil | 0.51 | 43.43 | 44.96 | Nil | 1.52 | 32.00 | 37.05 |
| Dec | Nil | Nil | Nil | 35.05 | 7.62 | 6.60 | Nil | 13.46 | 29.46 | n.a. | n.a. | Nil | 9.40 | 4.06 | Nil | 6.35 | Nil | Nil | 3.56 | Nil | 24.89 | 7.62 | 8.13 |
| Ann | 1139.70 | 1583.69 | 1352.80 | 1871.22 | 1684.02 | 1645.16 | 1726.95 | 550.67 | 1591.82 | n.a. | n.a. | 1455.17 | 1591.56 | 1600.71 | 1289.81 | 1348.74 | 1522.98 | 1237.23 | 886.45 | 1373.63 | 1396.49 | 1336.55 | 1370.65 |

## APPENDIX A-2.

MONTHLY MEAN MAXIMUM AND MINIMUM TEMPERATURES AT IMPHAL
(in degree centigrade)

| | Jan | | Feb | | Mar | | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Oct | | Nov | | Dec | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min |
| 1958 | 22.0 | 04.7 | 21.4 | 06.9 | 28.7 | 09.4 | 30.0 | 15.8 | 28.2 | 19.1 | 29.3 | 21.4 | 28.8 | 22.1 | 28.3 | 21.5 | 29.1 | 20.7 | 28.4 | 16.0 | 25.2 | 09.6 | 21.1 | 05.9 | 26.8 | 14.6 |
| 1959 | 13.4 | 04.7 | 28.3 | 06.7 | 25.1 | 11.3 | 29.5 | 15.9 | 28.2 | 18.9 | 28.5 | 21.2 | 29.1 | 22.0 | 29.5 | 21.8 | 28.5 | 20.4 | 25.7 | 18.2 | 24.1 | 06.6 | 22.4 | 04.9 | 25.4 | 14.5 |
| 1960 | 22.1 | 03.2 | 25.2 | 07.0 | 25.4 | 10.1 | 31.9 | 16.3 | 30.9 | 19.2 | 29.5 | 21.2 | 27.9 | 21.8 | 29.3 | 22.3 | 28.3 | 20.6 | 28.1 | 17.3 | 24.6 | 11.0 | 22.4 | 05.8 | 21.1 | 14.6 |
| 1961 | 23.5 | 05.0 | 21.0 | 06.1 | 24.6 | 12.7 | 29.1 | 16.0 | 28.8 | 19.3 | 28.7 | 21.8 | 29.4 | 22.1 | 28.9 | 22.1 | 28.5 | 21.4 | 28.0 | 18.4 | 24.2 | 11.1 | 21.1 | 04.8 | 26.3 | 15.1 |
| 1962 | 28.8 | 03.0 | 23.8 | 08.1 | 27.6 | 10.6 | 28.7 | 16.4 | 29.1 | 18.5 | 28.1 | 21.5 | 29.3 | 22.2 | 27.9 | 21.8 | 30.4 | 21.0 | 28.0 | 17.2 | 24.2 | 08.9 | 22.0 | 04.4 | 26.7 | 14.5 |
| 1963 | 21.7 | 02.8 | 25.1 | 07.8 | 27.9 | 10.9 | 28.7 | 15.2 | 27.9 | 18.5 | 28.9 | 21.7 | 29.5 | 22.5 | 28.4 | 22.0 | 29.4 | 21.4 | 26.2 | 17.4 | 24.4 | 10.4 | 21.5 | 06.5 | 36.6 | 14.7 |
| 1964 | 28.3 | 04.4 | 23.6 | 07.2 | 28.2 | 10.9 | 26.8 | 14.9 | 28.6 | 17.0 | 28.4 | 19.7 | 28.4 | 20.4 | 29.0 | 20.1 | 29.4 | 19.7 | 28.4 | 17.2 | 25.9 | 11.3 | 21.6 | 04.6 | 26.5 | 14.0 |

# APPENDIX B

# SHIFTING CULTIVATION

## SHIFTING CULTIVATION

Because of human influence in the tropical forest, the vegetative cover has been greatly changed which has become a great concern for ecologists. Shifting cultivation also known (different names in use are given in Table B-1) popularly as Jhumming or Swidden Cultivation (slash and burn), still in practice in many parts of the country by several tribal communities. These cultivators are usually found to be hill tribes or mountain people, who are serving on subsistence economy and are not influenced appreciably by the main current of cultivation.

Number of studies have been conducted by anthropologists and agricultural scientists. Anthropologists view this as an image of primitive life and study different cultural aspects associated with it. Agriculturist look at the cropping pattern and farming aspects. Recently the subject has also attracted the attention of hydrologists as significant alterations are noticed in river and lake environments where such practice exists.

TABLE B-1 

Different names in usage with different tribes region for shifting cultivation.

| Sl.No. | Region/Tribes | Name |
|---|---|---|
| 1. | North East India | Jhum |
| 2. | Meghalaya | Bogma |
| 3. | Garos | Lyngkhalum |
| 4. | Khasis | Shyrti |
| 5. | Mikirs Assam | Rit |
| 6. | AO nagas of Manipur | Tekonglu |
| 7. | Adis of Lushai Hills | Adiabik |
| 8. | Reangs of Tripura | Hookuismong |
| 9. | Koya | Lankspadsenad |
| 10. | Bhuinyas of North Orissa | Biringa |
| 11. | Southern Orissa | Podu, Bagda |
| 12. | Birjhia | Beonra |
| 13. | Maler of Chotanagpur | Kurwa |
| 14. | Madhya Pradesh | Bewar, Dahiya or Pendra |
| 15. | Hill Reddis of Andhra Pradesh | Podu |

DEFINITION : (Sachidanda 1989)

(a) "Shifting field agriculture may be defined as an agricultural system which is characterised by a rotation of fields rather than of crops, by short period of cropping (one to three years) alternating with long fellow periods (up to twenty and more years, but often as short as six to eight years) and by clearing by means of slash and burn" Pelzer (1958).

(b) "Shifting cultivation implies an aimless, unplanned nomadic movement or an abrupt change in location, either of which may refer to the cropping area, the agriculturists or both". Conklin (1957).

Definitions do not really reflect the essential features. Burning and discontinuous cultivation by shifting the plot are two important aspects of morphological concern.

FEATURES

1) Practiced mainly by hill tribes almost secluded from the main stream.
2) Clearing the forest plot by felling, cutting, slashing and burning, and drying of vegetative debris and disposing by means of fire.
3) Intensive human labour, using a few hand tools.
4) Frequent shifting of cropped fields.
5) Land control varies, mostly community owned.
6) Co-operative labour is involved but working structure differs from region to region.
7) Multiple cropping and specialised cropping patterns.
8) Annual and short term food crops are grown long term shrub and tree crops is also common.
9) Crop product are chiefly for subsistence but some time sale of total product can also be seen.
10) Use of natural capacity to support crops i.e. vegetation is used as soil conditioner and source of plant nutrients. No fertiliser is applied
11) Fields in operation do not produce soil erosion more than other system of cultivation.
12) According to the level of primitive nature permanent/semipermanent or otherwise rotational residence can be seen with these tribes.
13) Most of the area under this system of cultivation are not amenable economically for more technologically advanced system of agriculture.

Ordinarily, a plot remains under cultivation for one or two years before abandoning. After a lapse of a number of years varying from 5 or 6 to 12 or 15 or at times even more, they may return to the same plot. It is not always that the same family cultivates the same plot of land. Individual family can hold the land so long as they make effective use of it. As soon as they stop their operation, their rights cease. In the next cycle any other person belonging to the same community may take up the plot. In many communitiies, however, if a person plants a tree on a plot of land, his right over the tree continues.

This labour intensified cultivation, consumes about 43% of labour in felling and clearing of jungle. Other aspects like tillage and sowing (20%) weeding (12%) harvesting (24%) takes similar labour as that for settled cultivation in the region.

## ECOLOGICAL SITUATION

Food and Agriculture Organisation of the UN (FAO 1957) explains the situation as follows :

i) Low absorptive capacity for exchangeable bases of the soils clay fractions;
ii) The tendency of these clay to immobilize phosphates;
iii) The heavy percolation of rate of tropical rain through generally very porous soils and the resulting leaching of plant nutrients;
iv) The rapid destruction of organic matter by bacterial action under conditions of high temperature. A number of tree trunks may remain unburnt in the operation of firing. Such unburnt trunks are removed and are sometimes kept horizontally on the slopes to prevent soil erosion. The burning of debris makes the soil capable of receiving seeds without preparatory tillage. Further, if the soil is stirred by any implement it gets loose. One or two showers are sufficient to settle down the ash in the field.

## JHUM CYCLE

Time lapse between consecutive cultivation of the same plot is known as jhum cycle. This differs from region to region and depends on the following :

1. The population density.
2. Availability of suitable hill slope.
3. Composition of soil and capacity to recoup its fertility through natural process.

TABLE A-2 JHUM CYCLE

| State | Tribe | Period of cultivation | Fallow | Period |
|---|---|---|---|---|
| Manipur | AO Naga | 2 Year | 10 | Year |
| | Angami Naga | 2 Year | 5 to 15 | Year |
| | Mao | 1 Year | 10 | Year |
| | Kabul, Maring | 1-2 Year | 10 | Year |
| | Chero | | | |

CLIMATE & LAND

The tropical regions with a mean temperature of about 18.30 C and a minimum of 610 mm of annual rainfall and with a thin population have been found (Saikia (1979)) to be favourable for shifting cultivation. The following situations are preferred for shifting cultivation by AO Nagas.

1. Land which was left fallow for long period (about 20 years)
2. Land which has more sun and where fewer weeds grow
3. Land facing East
4. Level land where soil does not erode

Kamar select suitable leveled patches of land lying in between two slopes having a regular supply of water Lushai prefer bamboo forests. Elephant tracks are avoided. The availability of water resource is also a major consideration. A plot close to a stream is much preferred.

CONCLUDING REMARKS

When swiddening is the only possible way left to the tribes this cultivation does not become uneconomical. Most of the tribes are aware of danger of soil erosion and they take care of it to reduced it to the minimum. The furrows are kept horizontal and not vertical; logs and woods are placed to check soil erosion. Moreover this knowledge of cultivation on high altitude gained

...

over centuries appears to be the only viable form.

Some agricultural experts feel that it is a wasteful system of land use as it leads to continuous depletion of scarce forest resources and leads to adverse effects on the environments. Some others accept that this is the only possible method of land use, which is also the view of the bulk of the people practicing this cultivation.

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