LAND USE CHANGES AND LAND USE PLANNING IN SIKKIM

DISSERTATION SUBMITTED TO THE JAWAHARLAL NEHRU UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

MASTER OF PHILOSOPHY

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CERTIFICATE

I, **BIKRAM DOLEY**, certify that the dissertation entitled **"LAND USE CHANGES AND LAND USE PLANNING IN SIKKIM"** submitted for the degree of **MASTER OF PHILOSOPHY** is my bonafide work and may be placed before the examiners for evaluation.

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DEDICATED TO

MY FAMILY MEMBERS, FRIENDS AND WELL WISHERS

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BIKRAM. DOLEY.

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CHAPTER-I

Introduction

Land resource comprises the physical environment; including climate, relief, soils, hydrology and vegetation, to an extent that these elements influence the potential for land use. It includes the results of past and present human activity, e.g. reclamation from the sea, vegetation clearance, and also adverse results, e.g. soil salinization, soil erosion etc. Economic and social characteristics, however, are not included in the concept of land; these form part of the economic and social context.

A land-mapping unit is a mapped area of land with specific characteristics. Land mapping units are defined and mapped by natural resource surveys, e.g. soil survey, forest inventory etc. The degrees of homogeneity or internal variations vary with the scale and intensity of the study. In some cases a single land-mapping unit may include two or more distinct types of land, with different suitabilities, e.g. a flood plain, mapped as a single unit but known to contain both well-drained alluvial areas and swampy depressions.

Land is, thus a wider concept than soil or terrain. Variation in soils, soils and landforms, is often the main cause of differences between land mapping units within a local area. It is for this reason that soil surveys are sometimes the main basis for definition of land mapping units. However, the fitness of soils for land use cannot be assessed in isolation from other aspects of the environment, and hence it is land that is employed as the basis for suitability evaluation.

Land use

Land use relates to human activity associated with a specific piece of land. The term land use is self explanatory, meaning the actual and specific use to which the land use could put to in terms of land use, namely forest land, pastures, cultivation settlement etc. Land utilization is a process of exploiting land for any demographical purposes ie the amounts of land resources are finite. Hence, land is scarce in supply. It is irreplaceable and irreproducible especially in the hill states like Sikkim. Land use is the mirror of ecological health and economic potential of an area. All agricultural, animal and forestry production depends on the productivity of land .In simple words it meets the community's demand for food, shelter cloth and other needs. Thus it determines all the productive and economic activities

Land use studies are of a great importance because it provides a picture about the intensively used, under –used and unused lands of the country. Land is but population dependent on the land and their needs are not limited. They have been increasing over the time. Per capita availability of this resource has declined in the state as a whole. The per capita land availability is given in table 1.1

Table 1.1

YEAR	1961	1971	1981
SIKKIM	1.237	0.956	0.637

Source: The Eastern Himalayas: Environment And Economy ed al , R.L.Sarkar, M.P.lama

Land use changes with time to meet the variable demand of the land by the society in its new ways and change in life style .The demand for new uses of land can be inspired by a technological change in the size, composition and requirement of a community. The overall objective of the land use planning is therefore to adjust the land utilization pattern of the area to suit the potential of land without causing deterioration in the ecological conditions and degradation of land. Land degradation coupled with human and cattle population pressure is the major problems in the area.

Regenerating the land and remodeling agro-eco zone are prime needs. The starting point should relate to scientific management of available land resource and afforestation programme on large scale. Suitability evaluation involves relating land map units to specified types of land use.

Multiple and Compound Land Use

The term multiple and compound land use, refer to situations in which more than one kind of land use is practiced within an area. In a multiple land use type each use has its own input, requirement and product. A compound land use type consists of more than one kind of use undertaken on areas of land, which are treated as a single unit for the purpose of evaluation. The different kinds of use may occur in time sequence (e.g. as in crop rotation) or simultaneously on different areas of land within the same organizational unit. Sometimes an appropriate land use type can be found by making several land units as the part of the same management unit, e.g. livestock management which combines grazing on uplands in the rainy season and on seasonally flooded lowlands in the dry season.

Land use types are defined for the purpose of land evaluation studies of a qualitative or reconnaissance nature. At detailed levels of evaluation, closely defined land use types can be extended into farming systems by adding other aspects of farm management. Conversely, farming systems that have already been studied can be adopted as the basis for land use types.

Land Use Categories

A major kind of land use is a major subdivision of land use, such as agriculture, grassland, forestry, or recreation etc. A land use type is a kind of land use described or defined in a detail, they are described with as much detail and precision as the purpose requires. Thus land use types are not a categorical level in a classification of land use, but refer to any defined use below the level of the major kind of land use.

The identification and description of the type of land use, which are to be considered, is an essential part of the evaluation procedure. The kinds of land use are specified at the beginning of the evaluation procedure and subjected to modification and adjustment in accordance with the findings of the evaluation procedure.

Classification And Definition of Land use categories

Reporting area for land utilization: The reporting area stand for The reporting area stands for the area for which data on land use classification of the area are available

. **Forests:** Area under forest cover includes all lands classed as forest under any legal enactment dealing with forests or administered forests, whether state owned

.Area Not Available For Cultivation:

(i)**Area Under Non- Agricultural Uses:** This stands for all lands occupied by building, roads and railways or under water, ie, rivers and canals and other land put to uses other than agriculture

(ii) **Barren And Unculturable land:** This covers all barren and unculturable land like mountains, deserts etc. Land which can not be brought under cultivation unless at high cost shall be classed as unculturable whether such land is in isolated blocks or within cultivated holding.

Other uncultivated Land Excluding current Fallows:

(i) **Permanent Pastures and Other Grazing Lands:** These cover all grazing lands, whether they are permanent pastures and meadows or hot village common grazing land shall be included under this head.

(ii) **Miscellaneous tree crops and groves not included in the net sown area:** Under this class is included all the cultivable land which is not included under net sown area but put to some agricultural use. Lands under grasses, bamboo bushes and other groves for fuel etc, which are not included under orchards

(iii) **Culturable waste:** These include all lands available for cultivation whether not taken up for cultivation once, but not cultivated during the current years or more in succession. Such lands may be either fallow or covered with shrubs and jungles, which are not put to any use.

5 Fallow lands

Fallow land other than current fallows: This implies all lands, which were taken for cultivation but are temporarily out of cultivation for a period of not less than a year and not more than five years. The reason for keeping a land fallow may be one of the following (i) poverty (ii) inadequate supply of water (iii) malarial climate (iv) silting of canals and rivers

(ii) Current fallows: This class comprises cropped areas which are kept fallow durong the current year.

6. Net sown area: This represents the area sown with crops and orchards counting area sown more than once in the same year only once.

. Each kind of land use needs different environmental conditions if it is to be practiced on a sustained and economically viable basis. For example, most perennial crops require available moisture within root range throughout the year, irrigated rice culture requires land which is level or can be made level at acceptable cost, and forestry requires a certain foothold for roots although it is usually tolerant of steep slopes.

The limitations for each type of land use are determined at the time of the requirements. These requirements and limitations indicate the types of data which are required for evaluation

LAND EVALUATION AND LAND USE PLANNING

Land evaluation is only part of the process of land use planning. Its precise role varies in different circumstances. In the present context it is sufficient to represent the land use planning process by the following generalized sequence of activities and decisions:

i). Recognition of a need for change;

ii). Identification of aims;

iii). Formulation of proposals, involving alternative forms of land use, and recognition of their main requirements;

iv). Recognition and delineation of the different types of land present in the area;

v). Comparison and evaluation of each type of land for the different uses;

vi). Selection of a preferred use for each type of land;

vii). Project design,.

viii). Decision to implement;

ix). Monitoring of the operation.

Land evaluation plays a major part in stages iii, iv and v of the above sequence, and contributes information to the subsequent activities. Thus land evaluation is preceded by the recognition of the need for some change in the use to which land is put; this may be the development of new productive uses, such as agricultural development schemes or forestry plantations, or the provision of services, such as the designation of a national park or recreational area.

The Aims Of Land Evaluation

Land evaluation may be concerned with present land performance. Frequently however, it involves change and its effects: with change in the use of land and in some cases change in the land itself. Land evaluation takes into consideration the economics of the proposed enterprises, the social consequences for the people of the area and the country concerned, and the consequences, benefits or adverse effects, for the environment. Thus land evaluation should answer the following questions:

- How is the land currently managed, and what will happen if present practices remain unchanged?

- What improvements in management practices, within the present use, are possible?

- What other uses of land are physically possible and economically and socially relevant?

- Which of these uses offer possibilities of sustained production or other benefits?

- What adverse effects, physical, economic or social, are associated with each use?

- What recurrent input e are necessary to bring about the desired production and minimize the adverse effects? What are the benefits of each form of use?

If the introduction of a new use involves significant change in the land itself, as for example in irrigation schemes, then the following additional questions should be answered:

- What changes in the condition of the land are feasible and necessary, and how can they be brought about?

- What non-recurrent inputs are necessary to implement these changes?

The evaluation process does not in itself determine the land use changes that are to be carried out, but provides data on the basis of which such decisions can be taken. To be effective in this role, the output from an evaluation normally gives information on two or more potential forms of use for each area of land, including the consequences, beneficial and adverse, of each.

Land characteristics, land qualities and diagnostic criteria

Land Characteristics: A land characteristic is an attribute of land that can be measured or estimated. Examples are slope angle, rainfall, soil texture, available water capacity, biomass of the vegetation, etc. Land mapping units, as determined by resource surveys, are normally described in terms of land characteristics.

If land characteristics are employed directly in evaluation, problems arise from the interaction between characteristics. For example, the hazard of soil erosion is determined not by slope angle alone but by the interaction between elope angle, slope length, permeability, soil structure, rainfall intensity and other characteristics. Because of this problem of interaction, it is recommended that the comparison of land with land use should be carried out in terms of land qualities.

Land Quality: A land quality is a complex attribute of land which acts in a distinct manner in its influence on the suitability of land for a specific kind of use. Land qualities may be expressed in a positive or negative way. Examples are moisture availability, erosion resistance, flooding hazard, nutritive value of pastures, accessibility. Where data are available, aggregate land qualities may also be employed, e.g. crop yields, mean annual increments of timber species. A land quality is not necessarily restricted in its influence to one kind of use. The same quality may affect, for example, both arable use and animal product

There are a very large number of land qualities, but only those relevant to land use alternatives under consideration need be determined. A land quality is relevant to a given type of land use if it influences either the level of inputs required, or the magnitude of benefits obtained, or both. Land qualities can sometimes be estimated or measured directly, but are frequently described by means of land characteristics. Qualities or characteristics employed to determine limits of land suitability classes or subclasses are known as diagnostic criteria.

EXAMPLES OF LAND QUALITIES

1. Crop yields (a resultant of many qualities listed below)
   - Moisture availability
   - Nutrient availability
   - Oxygen availability in the root zone

- Adequacy of foothold for roots
- Conditions for germination
- Workability of the land (ease of cultivation)
- Salinity or alkalinity
- Soil toxicity
- Resistance to soil erosion

Diagnostic Criteria: A diagnostic criterion is a variable which has an understood influence upon the output from, or the required inputs to, a specified use, and which serves as a basis for assessing the suitability of a given area of land for that use. This variable may be a land quality, a land characteristic, or a function of several land characteristics. For every diagnostic criterion there will be a critical value or set of critical values, which are used to define suitability class limits.

- Problems related to land use are very complex. As a result of population increase and development activities, there are competing demands for land, but available land is limited and unevenly distributed among regions/province. More ever land scarcity is ever increasing and conflicts among land users are becoming even more intense. Land use policy has become the focus of effort to relieve such conflicts by addressing the needs of the society. The potential of land depends on both biophysical and socio-economic condition.

ENVIRONMENTAL IMPACT

Consideration of the environmental impact, or probable consequences of change for the environment, should permeate the matching process. To provide environmental safeguards, it is essential that land suitability should normally be assessed. Environmental effects are not necessarily unfavorable; for example, if irrigation is established in an arid region, the soil organic matter content may be improved. The most important aspect is to assess the possibilities of environmental degradation, for example soil erosion, soil salinization or pasture degradation. Many changes in land use may result some degree of adverse effects on the environment, for example the lowering of soil organic matter levels, when forest is cleared for agriculture. What is essential is that environmental degradation should be neither severe nor progressive. Severe degradation is that in which the land resources are largely and irreversibly destroyed, as for example in severe gully erosion. Progressive degradation refers to the condition in which a resource is being continuously depleted by a land use practice; degeneration of vegetation by systems of pastoralism in which there is no control of livestock numbers is an example.

Where a hazard of severe or progressive degradation is identified, the technical measures necessary to prevent it should be determined. In special circumstances, some degree of land degradation is accepted as unavoidable. In such cases, the evaluation state that only short-term use is foreseen, and give information on the nature and extent of the degradation and on the expected condition of the land when the use ends.

In considering the environmental impact, off-site effects, i.e. consequences for the environment outside the area under study, is considered. Examples are the effects of forest clearance upon river flow regimes, of changes in river water and sediment content caused by reservoir construction upon navigation, fisheries, etc., and the influence of saline drainage water on the quality of irrigation water downstream.

LITERATURE REVIEW

Land use is a synthesis of physical, chemical, and biological systems and processes on the one hand and human/societal processes and behavior on the other. The monitoring of such systems includes the diagnosis and prognosis of land use changes in a holistic manner at various levels. Land use change may be examined by considering conversion of forest to crop and cane land; losses of productive land through various factors; conversion of wetlands to agriculture and urban use; and conversion of other types of land to various human uses. Land use is primarily a task of apportioning lands for various uses

Chatterjee (1953; 1956) who does not favour on sample surveys in a country where numerous in physical conditions occur from place to place. Gupta (1959) explains the methods of rapid land use survey which have been adopted by the National Atlas Organization under the directorship of S.P.Chatterjee.Deshpande, Bhatt and Maninkarve (1959) have suggested a micro regional approach of land planning. Singh (1960) suggests the need for proper land classification for better land use planning. Amani (1964) who has chalked out a tentative plan to carry on such land use studies. Ganguli (1964) studied the significance of land use survey and considered them to be essential for agricultural planning and for solving the food problem of India. Shafi (1966) presented a paper giving concrete suggestion regarding the techniques, which should be adopted for conducting land use surveys in India. Dr Chauhan (1966), highlighted the objects and concepts of land use in utilization of agricultural land. Indian society Of

Agricultural Economics brought out readings in land utilization (1957) discussed varying approaches to the problems of land utilization, its scope and methods and describes some important projects, which have been carried out, on land utilization in the world. Rao and Bhatt (1950) out that the geographers can contribute significantly to and use planning. Chatterjee (1945) studied the influence of physical environment and socio-economic factors on the utilization of land. Siddiqi (1946) analysed the physical setting to bring out the natural and cultural features in relation to physical factors. Lahri (1950) analysed the soil depletion and agriculture deterioration. Damodar valley corporation (1951) incorporated an outline plan to improve land use area to promote agriculture, economic and general well being. Honrao (1953; 1962) has attempted to analyse the influence of physical factors o land use. Singh (1955) studied the influence of physical and socio-economic conditions on land use. Ahmad (1959) has analysed the physical and various land use types and stress the slope factor analysis. Arunachalam (1959) suggested the method of land classification according to its inherent capabilities. Deshpande (1959) has brought out the influence of soil, drainage on the land utilization. Goswami (1960) analysed the influence of physical environment on the land use. Shafi (1960) woked extensively on land utilization. Sen and Guha (1960) suggested the influence of relief, soil and rainfall condition on land utilization. Roy (1961) studied the physical condition of occupational structures and its influence on changing land use pattern. Duggal (1961) emphasized the importance of historical factors on land use pattern. Raina (1962; 1962; 1963) emphasized climate and soil as the two important factor s affecting land utilization. Raina (1963) examined soil formation and its effect on land utilization. Mishra (1964) suggested various soil conservation methods. Singh calculated the land carrying capacity on the basis of land fertility and food grain out put. Kayastha suggested scientific land utilization act. Sharan highlighted the problem of mapping land use data. Yadav (1965) highlighted the role of desert environment on land use type. Bhardwaj (1965) evaluated the physical resource and agriculture land use. Bose (1965) presented the physical condition and related land use type. Amrita (1965) studied the impact of urban growth on land use. Singh (1966) highlighted the population pressure on crop land. Amani (1966) explained the influence of soil and climatic factors on crop distribution. Singh (1967) did a micro regional study of land use and cropping pattern. Ganguli and Nikhat (1967) emphasized that the proper utilization of arable land depend on the owner ship relations. Jadhav, Kulkarni and Bopegamage (1967) prepared a land classification map showing various land use pattern for urban or agricultural purposes. Bose (1967) pointed out that changes in landform, slope, altitude and degree of relief roughness has strong influence on land use. Ahmad (1968) emphasized the intensive use of land in arid zone. Raza (1968) stressed the importance of land reforms for increasing agricultural out put. India-Regional Studies (1968) focused on synthesis of physico-cultural environment and rural agrarian base. Chaudhary (1968) pointed out that land use planning can enhance the carrying capacity of land. Singh (1968) suggested a model to determine the land capability, Niyogi et al (1968) evaluated the effect of physical factor on land utilization. Rafiullah (1968) analysed the demographic factors and agriculture land use. Saxena (1968) highlighted the influence of physical factors on land use and suggested solution for better land utilization. Tewari and Chauhan (1968) laid down principles for future land use planning to restore the ecological balance. Chakerborty (1962) has given statistical method to analyse land use pattern of a region. Armani (1968) studied the agricultural land use pattern and concluded that the land use is out come of long process of interacton of physical and socio-economic factors. Siddiqi (1968) assessed the influence of physical, economic and social conditions on the evolution of cropping pattern.

SELECTION OF THE STUDY AREA:

Sikkim is located in the Eastern Himalayas. It extends from 27° 04' to 28° 07' N and 88° 00' to 88° 55' E... It is bounded in the north and northeast by west Tibetan plateau and in the west by Nepal. In the east it is bounded by Bhutan and the Chumbi valley of Chinese occupied Tibet and in the southeast by Bhutan. It covers a geographic area of 7096 sq. km with a north south extension of 112 kms and east to west extension of 64 km

Sikkim has been selected for the present study for various reasons – firstly there are limited studies carried out in this area, especially from the viewpoint of spatial analysis; secondly its geo strategic location in itself is a reason to evoke concern for the region. It is Sikkim's vulnerable position, which has made it pass through different events in history, each having a marked effect in giving rise to a new identity to Sikkim. Thirdly Sikkim represents a unique case in terms of the loss of international status from a sovereign state, to a state in India.

Objective

The study aims to understand:

1. The present land use pattern of Sikkim
2. Monitoring of the land use and land cover changes
3. The Factors affecting major land use and land cover changes.
4. The implication of land use changes on environment.

Database

Any regional empirical study has to ready either on secondary data or field based primary data. Availability of secondary data over an extended period of time can facilitate a time series analysis and enable us to understand the process of changes. Availability of diversified secondary would also facilitate the study of a region at a given time flexibility of selection of a topic at varied scales and for different spatial units For the land use evaluation in Sikkim, the following materials were available in the absence of toposheet of sikkim (restricted zone)

1. Land use maps

2. Forest maps

3. Relief map

4. Climatic data

5. Soil map, scale 1:500000

6. Terrestrial Photos

Methodology

Knowledge acquisition is the gathering of the facts and the relationships between them from any available sources. The land use maps have been digitized. The temporal; change detection both spatially and quantitatively has been accomplished with the help of GIS techniques. Using NATMO maps, an attempt has been made to examine the land use changes in the state. Detailed maps showing the nature and extent of change and degradation of land use and land cover have been prepared.

Chapterization Scheme

In the first chapter brief introduction on land use pattern and importance of land use planning in Sikkim has been outlined. The aim and objectives of the study and the relevant source of the information for the present study have also been incorporated along with relevant literature survey.

Second chapter deals with the environmental setting of the region and the role of relief, drainage, climate, vegetation etc in the land us pattern of the area.

Third chapter deals with general land use pattern of the region that exist as on today.

Fourth chapter deals with general land use pattern of the region that exist as on today.

Chapter fifth deals with the land use planning of the region.

Last chapter summarizes and concludes the findings.

CHAPTER - II

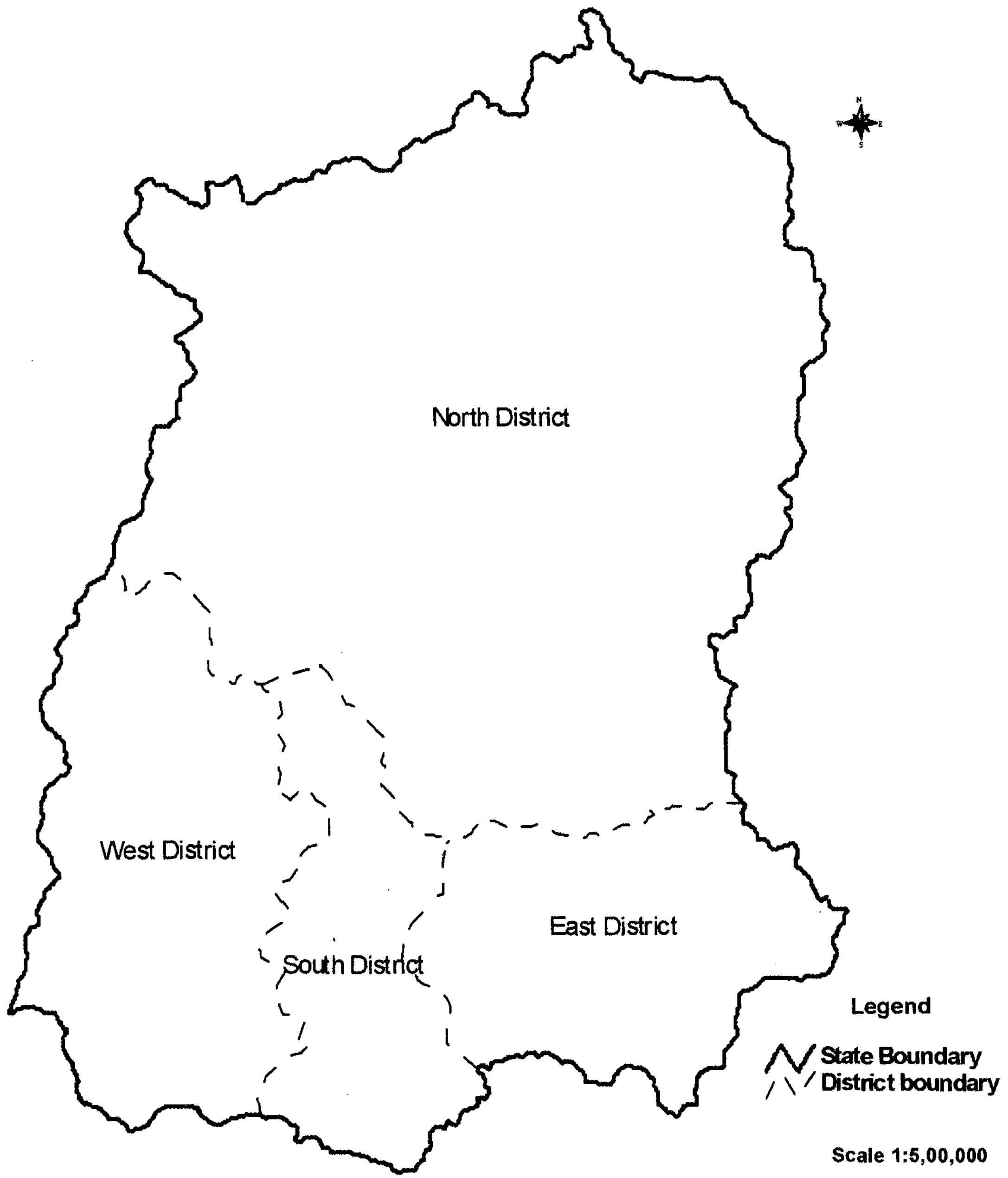
THE ENVIORNMENTAL SETTING

The location and environmental factors play a very important role in the development of a region. However, the degree and nature of such influences depend on the nature of linkages that develops between them. Such linkages are in turn determined by the environment and human factors. Environment does play an important role in the development process by providing opportunities or by acting as a restricting factor. These restrictions are in terms of natural resource constraints, limited factor mobility, etc.

2.1 LOCATION: Located in the Eastern Himalayas, Sikkim lies between lat. 27° 04' and 28° 07' N and long 88° 00' and 88° 55' E... It covers a geographical area of 7096 sq.km with a north south extension of 112 kms and east to west extension of 64 kms. It is bounded in the north and northeast by west Tibetan plateau and in the west by Nepal. In the east it is bounded by Bhutan and the Chumbi valley and in the southeast by Bhutan. The southern boundary is about 45 kms. Sikkim has four administrative divisions: North, East, South and West. The North district with an area of 4226 sq kms is the largest and the South with an area of 750 sq kms is the smallest district. The West district has an area of 1166 sq kms and East district has an area of 954 sq kms.

2.2 PHYSIOGRAPHY: The whole of Sikkim is mountainous without any flat land at all. It is essentially an enclosed basin between two deeply dissected north – south transverse ridges. The Singalile ridge extends for about 128 kms with Nepal and includes

District Map of Sikkim



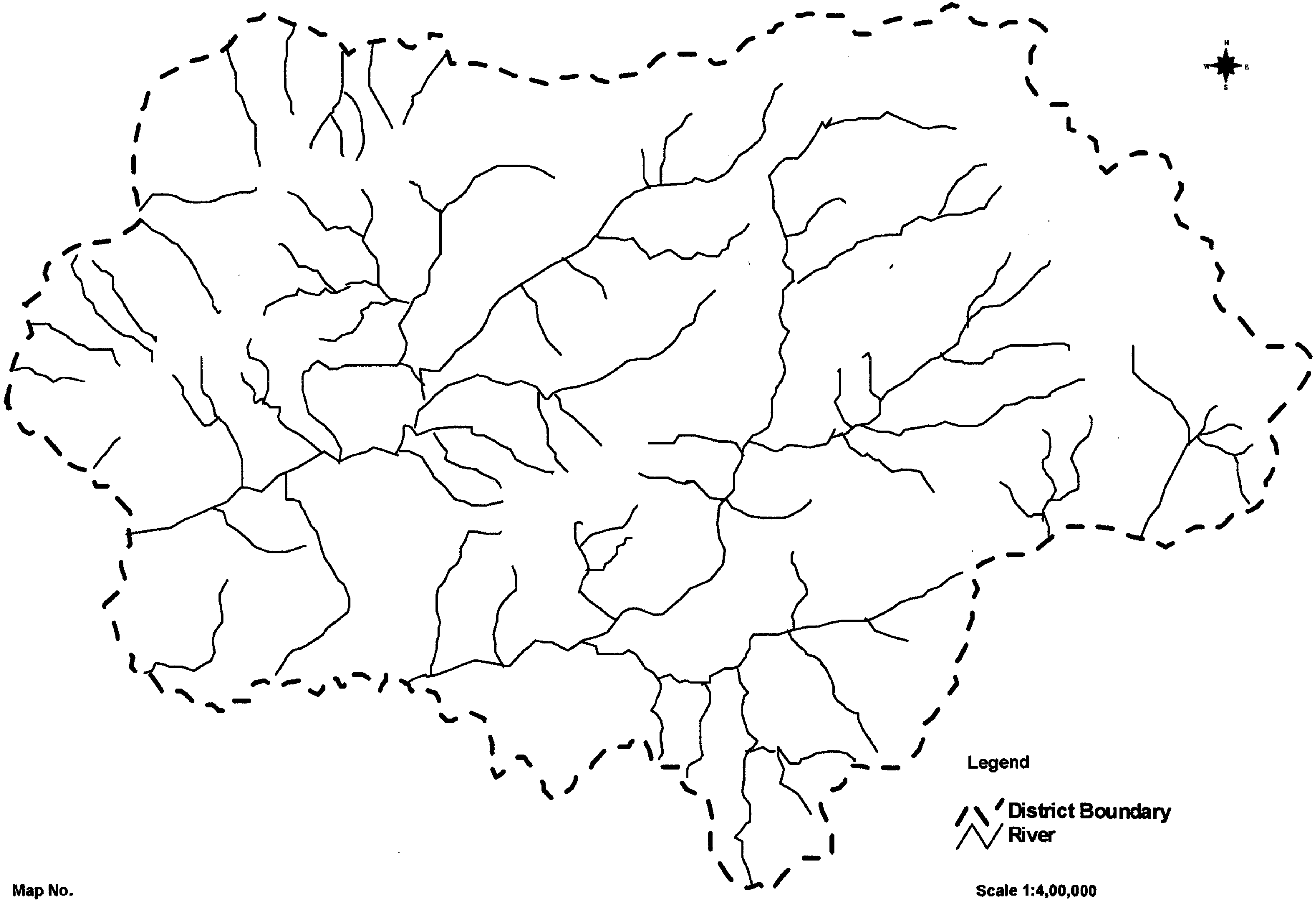
Map No.-1

Scale 1:5,00,000

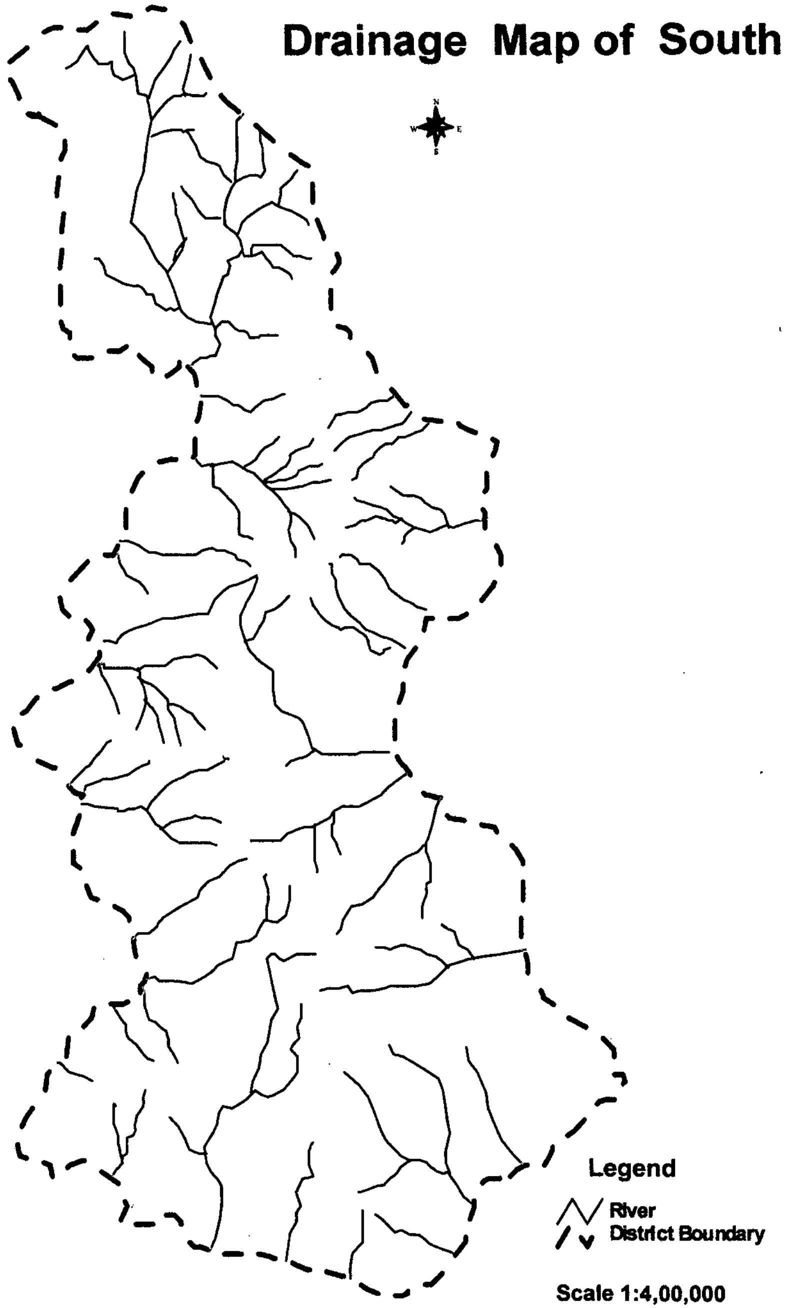
the peak of Kanchenjunga. The Donkya ridge lies in the east. In the north, the central basin is cutoff from the Tibet by broad convex area of the great Himalayan peak built up of crystalline rocks from which the Teesta has carved a deep narrow gorge running west to Kalimpong. This extends bawl like mountain-graded basin formed by erosive work of the Teesta system. It is inverted, occupying the axis of the enormous over folded anticline, the cone being represented by the Kanchenjunga. The violent dissection of the Sikkim. Himalaya and its location immediately opposite to the alluvial gap between the hills of the north east peninsular India and the Shillong plateau has been facilitated by excessive monsoon rain. The river system of Teesta has deeply dissected the central highlands of Sikkim, which are therefore underlain basin by softer rocks. Thus a narrow gorge and a large basin have been formed in the structurally weak and less resistant crustal part of the Sikkim Mountain. In the north snow clad areas the Action of glaciers have been important in distinctive landforms. The enclosed character of the ridges and valley within the Himalaya and its off snoots, Singalile and Chola was described by Risley as a gigantic amphitheatre.

However, the inaccessible barriers have often been broken by strategically located passes, which have played a very important role in the history of Sikkim. These passes have decided Sikkim historical linkages with its neighboring countries. The three important passes in the north are NyimanlaNakul, Kungrala and Sesa la. The southeastern border of Sikkim with Bhutan is almost a mountainous region area. The total Sikkim Bhutan boundary is located on the Poungla range from north to south. Dakola pass connect Sikkim with Bhutan through the range. The important peak of the area is Gylmochin. The mountainous terrain of Sikkim consists of tangled series of

Drainage Map of East Sikkim



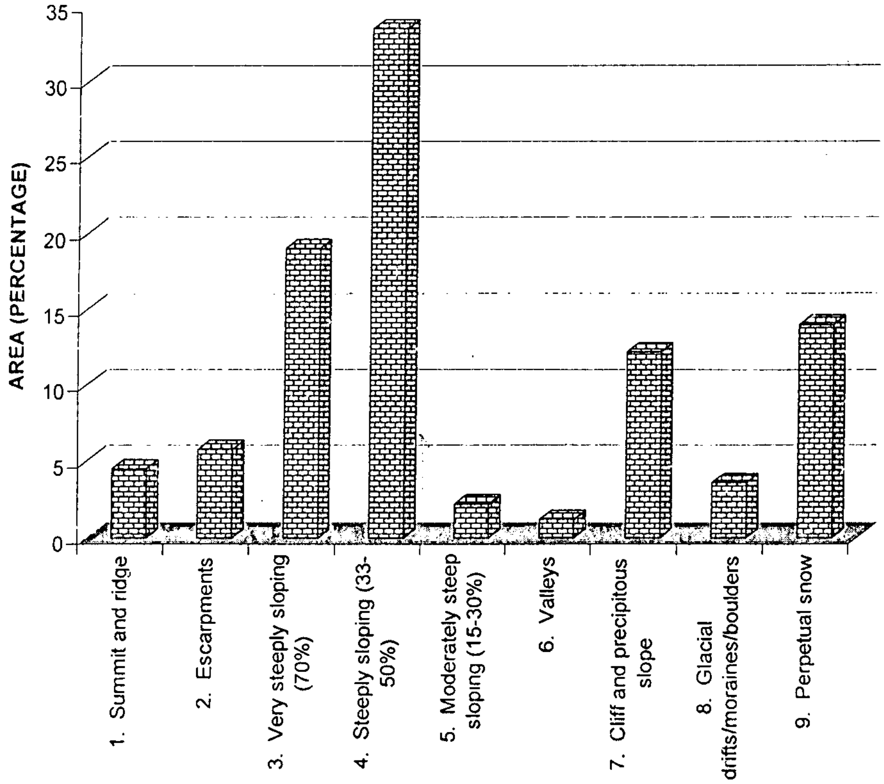
Drainage Map of South Sikkim



Map No.

Scale 1:4,00,000

interlacing ridges rising one above the other, from south to foot of the high peaks, which mark the abode of the snow in the north. The area of the Sikkim can be divided into 9 divisions



TH-12955

FIG 2.1 Physiographic Unit Of Sikkim

2.3 DRAINAGE: The state Of Sikkim is primarily a catchment area of the Teesta drainage system, which is the main river of the state. The Teesta divides the state into two parts, while flowing essentially north south. Teesta arises from the Zema glaciers. It is joined by another stream from the north near Lachan. Sometimes the later is referred to as the Teesta River and the stream coming from the Zemu glacier as Zemu Chuu. Another stream the Lachung Chuu originates from the Pau lunri range in the states eastern border and meets the Teesta river at Chunthung within a few kms of its origin, the river Teesta drops to 1000 m above mean sea level near Mangan in central Sikkim. The river Teesta is thus a very fast flowing river. Its peak flood velocity reaches 10 m/s carrying an estimated discharge of 2400 cumec.

The swift flow and perennial characteristics of these streams is the major natural resource base of Sikkim. If tapped properly the hydroelectricity generation can be a major source of revenue for the Sikkim state. Rivers are also the main source of accessibility in the mountainous terrain. They provide cheap mean of transportation and easy access to the mountains. Singh has used the river density as the measure of accessibility in Sikkim. The overall river density in Sikkim is 38 kms/sq km, which is quite low. The total number of rivers in Sikkim is estimated to be 64 with a total length of about 2993 kms. These 64 streams have 475 other tributaries. The main river having a total length of nearly 502 kms from north to south. It flows for 300 kms in the north 67 kms in the east and 135 kms in the southern district of the state. The second important river is Ringit, which is tributary of river Teesta. It has a total length of 200 kms out of which 30 kms is in the north and 170 kms in the south district.

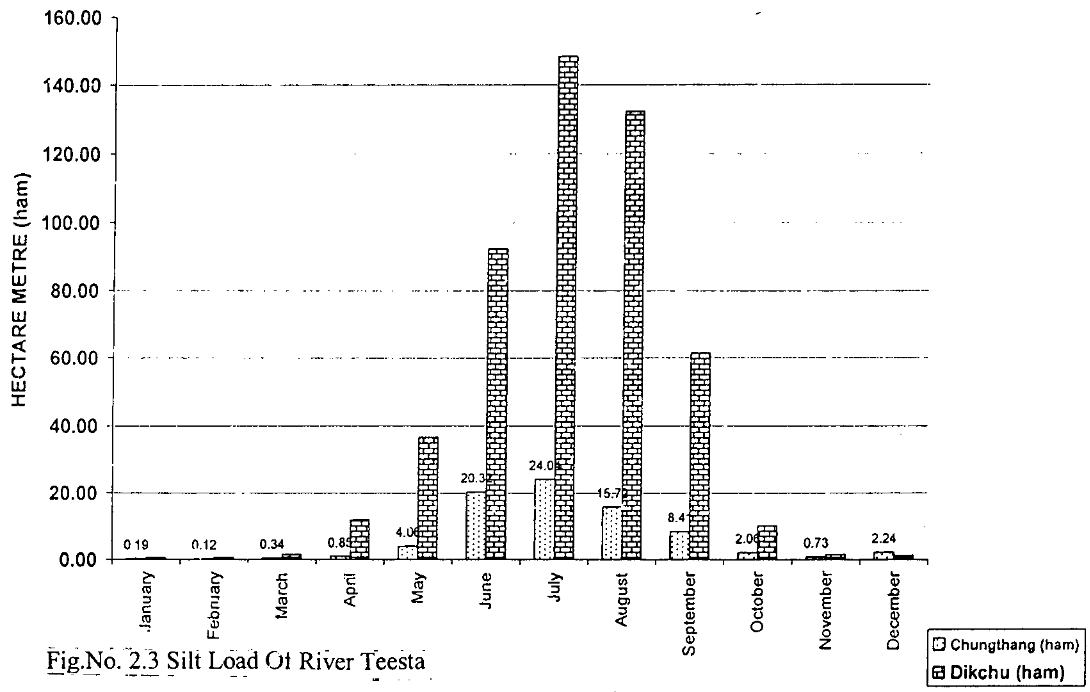


Fig.No. 2.3 Silt Load Of River Teesta

The north district has a river density of 0.2-kms/sq km, which is less than the other districts of the state .The total length of rivers in the north district is about 1522 kms with 36 main tributaries and 216 other streams. Accessibility in this area through the river is sometimes limited due to the snow bound nature of the high altitudes.

The East district contains the highest river density of 0.52-km/sq km. The total length of the rivers in this district is nearly 504 kms, with its 11 main tributaries and 76 other streams. This figure reveals the highest accessibility in the state throughout the district.

The south district contains 0.42-kms/sq km density. The no of main river is 6 and 76 small tributaries with 392 kms of length support these.

The west district has a river density of 0.49-kms/sq km .The total length of river in the district is 575 kms with 11 and 13 small tributaries. These rivers can provide good accessibility to the western border. However the upper part of this district has glaciated peaks, which considerably limit accessibility to the area. Moreover there are many lacustrine bodies among them lake Aritar, lake Changu, lake Mamenchu and lake Khechuperi are important from religious point of view. There has been very little exploitation of groundwater resources in the state .The reason being that (1) Except for a few areas in the south and west district which are drought prone, the rest of the state has an almost assured supply of water throughout the year. Also the terrain is such that most of the precipitation results in surface runoff and there is little percolation.

2.4 GEOLOGY AND MINERAL RESOURCES: The Sikkim region constitutes an important sector of the Eastern Himalayas. It is essentially a mountainous region without a flat piece of land of any extent anywhere. The altitude increases as we move northward. The serrated, snowcapped spurs and peaks culminating in the Kanchenjunga, which form such a characteristics and attractive feature in the scenery of Sikkim are found in this direction. The northern portion of the state is deeply cut into steep escarpment except in the lachen and Lachung valleys. Southern Sikkim is lower, more open and fairly well cultivated. This configuration of the mountain range is responsible for country is partly due to the direction of the main drainage, which is in south direction. The trend of the mountain system, is in general east-west direction. The chief ridges in Sikkim however run in a more or less north-south direction as for instance the Singalela and the Chola ridges. Another north -south ridge runs through the central portion of the Sikkim separating the Ringeet from o the Teesta valley; Tedong (8676feet) and Moinam (10637feet) are two of its bests of the known peaks. This north south direction of the ridge is due to the original southern slope of the Himalaya. The valleys cut by these rivers and their chief feeders are very deep. The valleys of the Ringeet, of the Teesta and of their chief tributaries are generally not less than 5000 feet in depth.

The snowcapped jagged ridges in the northern portion of the state send down glaciers, which at present usually come down to about 13500 feet; those from the Kanchenjunga appear to descend about 1000 feet lower. The perpetual snowline in the Sikkim may be approximately put down at 16000 feet, so that the glaciers descend 3500 to 2500 feet below that line. Formerly they used to descend much lower than at present. Lachung for instance of which the elevation is 8700 feet stands at the foot of an immense terminal moraine. The Bidangeho Lake on the road between Gnatong and the Jalep pass, at an elevation of 12700 feet is dammed at the southern end by a bank of boulders, which are distinctly of glacial origin

Foothills belt comprising essentially of the younger Siwalik group of sedimentary rocks is exposed near. The metamorphic and crystalline rock grouped under the inner and the axial tectonic belts predominantly occupy Sikkim. The higher regions to the north and beyond are covered under the inner and trans axial tectonic belts. The axial belt exposes the crystalline of the central region and intrusive granites.

Daling and Darjeeling group represents rock ranging from lower green schist facier to Kyanite silimanite gneises. The rocks belonging to gnessic group are oldest and constitute the main body of the Himalayas. From near Kursoong, south of Darjeeling to the northern frontier of Sikkim it is interruptedly traced over a distance of some 75 miles in a straight line; where as all the latter rocks – the sub metamorphic slate group, the

Damudas and the tertiary – together cover an area in the outer Himalayas nowhere more than six miles in width.

Two forms of the gneissic are met with:

In southern Sikkim approximately south of the parallel of Jongri and the Boktola (about lat 27 25) the gnesis is highly micaceous and frequently passes into mica schist. Both muscovite and biotite occur, the former predominating hornblende, garnet and schorl are the chief accessory minerals. Bands of quartzite are common. Veins of calcite occur at places as near Lingtu by the road to Gnatong. The gnesis is well foliated and exhibits strongly marked features of disturbances in that it is much folded and crumpled especially in the extreme south about Darjeeling

(a) In the northern Sikkim, as north and south west of jongri about Lachung, the gneises is not quite so micaceous. Muscovite is either rare or is entirely absent. Schorl and hornblende are the chief accessory minerals. Intrusive granitc rocks occur as dykes and sheet; in some of them muscovite is well developed. The northern gnesis agrees some of its pedological characters with the central gnesis of Stoliczka.

The Dalings group covers the central region covering the Teesta and the adjoining valley is occupied by the lower grade Daling rocks. This name was given by Mr. Mallet to a group of sub metamorphic rock after a place called Dalling in Darjeeling. Phyllites form the predominant rocks in this group. The Sikkim Daling occurs somewhat in the form of a dome shaped anticline. On the south side the dip is southern; east of the Rungeet it is chiefly east –north east, west of that river the inclination is northwestern; and on the side as near Ralong the dip is mainly northern. The Daling rocks have suffered considerable disturbance. The slates and the phyllites frequently exhibit crumbling and contortion and the dip are rather high being seldom below 45.

The physical configuration of the state is also partly due to its geological structure. The northern, eastern and western portions of the state are composed of hard gneissic rocks, capable of resisting denudation to a considerable extent. The central and southern portions on the other hand, chiefly consist of comparatively soft thin slate, half schistose rock which are easily denuded; this is area has the least elevation and is the most populated in Sikkim.

2.5 SOIL: The National Bureau of soil survey and land use planning Calcutta conducted survey to see the distribution of the major soil types in Sikkim (Report of high level team for land use planning of Sikkim, Planning Commission 1981, pp 87). They have established eight sub groups and fifteen soil series in Sikkim.

Table No2.3 Soil Classification of Sikkim

S.No	Soil Sub Groups	Soil Series
1	Typic Haplumbrepts	Markong, Hilley
2	Lithic Haplumbrepts	Gompea
3	Typic Dystrochprepts	Lingtse, Namthan losep
4	Lithic Dystrochrepts	Machongs
5	Umbric Restrochrepts	Thekabong, Chatrikola,Padamcha
6	Lithic Undorthents	Putchi,Simkara,Nandugaon
7	Aquifer undifluents	Magithar
8	Ultic Hapludalfs	Taraku

Source: National Bureau Of Soil Survey And Land Use Planning

In the absence of a regular soil survey very little information is available about soils. The rocks are generally of the Himalayan type –shale, schist and conglomerates therefore, the derived soil is sandy and progressively clayey in the lower reaches of the valley. Soil acidity is high, caused by heavy rainfall. The freshly cleared forest lands exhibits a thick layer of leaf mould rich in organic matter, but as a result of early rains the top soil is easily washed off.

Soils in the foothills are alluvial in nature being loams mixed with pebbles brought down by rain from higher altitudes. Soil in the valleys is clayey alluvium and rich in organic content. The fertility status of the soils and their soil characteristics is as follows

Texture: Loamy sand to silt clay loam

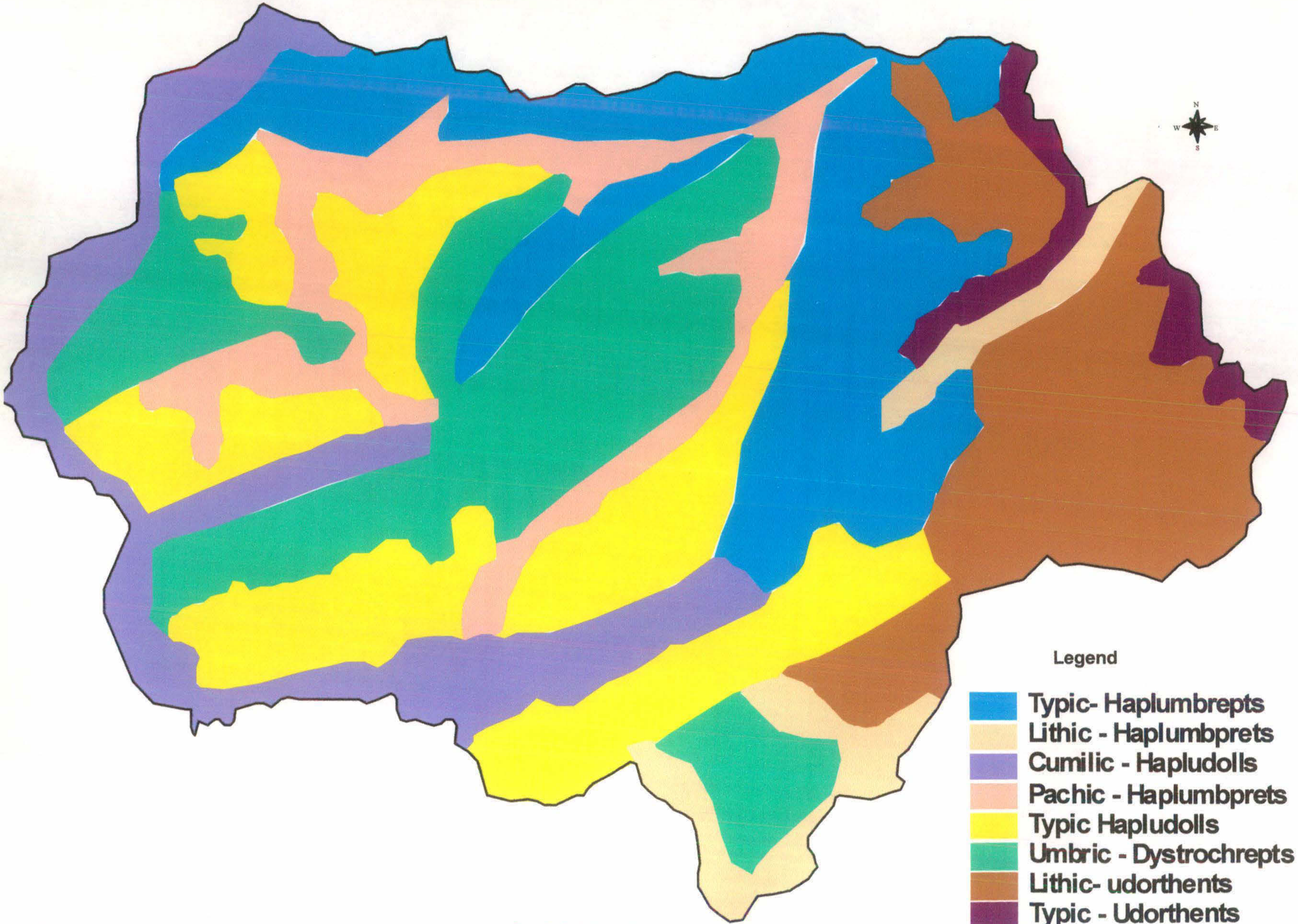
Depth: Depending upon the weathering process the depth of the soil ranges from several feet to few inches and in some places it becomes practically nil. All acidic; about 50% having ph50 or below. About 45% having Ph 5.0 to 6.0 and rest Ph 6.0 or above.

Organic content: The organic content is high mostly between 2-5% but low up to 1%and high up to 10% are also available.

The water holding capacity of the soil is medium and soil generally falls in the hydrological group B.

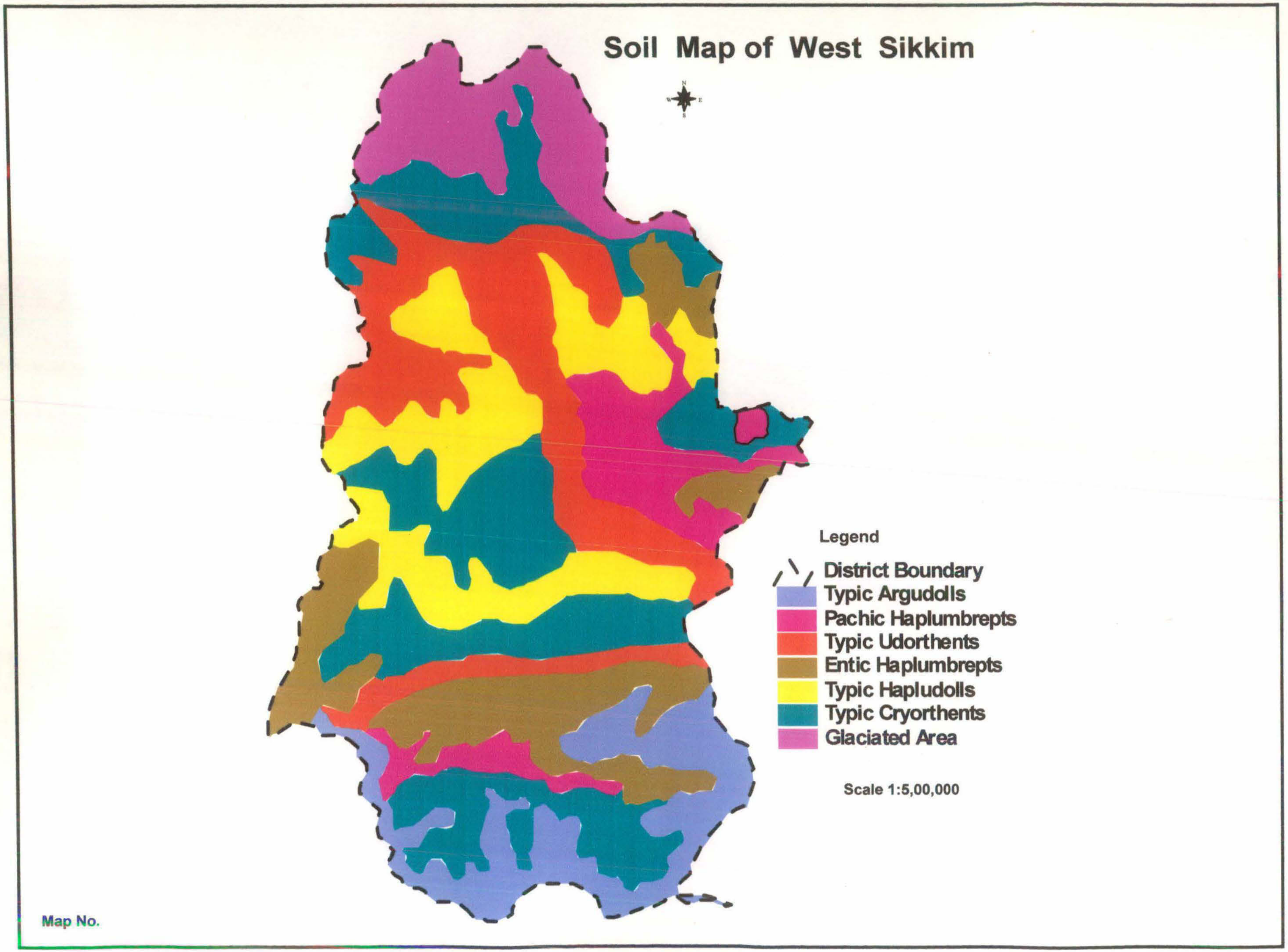
The steep mountainous land of the state fall within land capability classes IV to VIII (Agriculture in hillside Sikkim, Sikkim science society, Gangtok, J.R.Suba, 1984, pp 42-

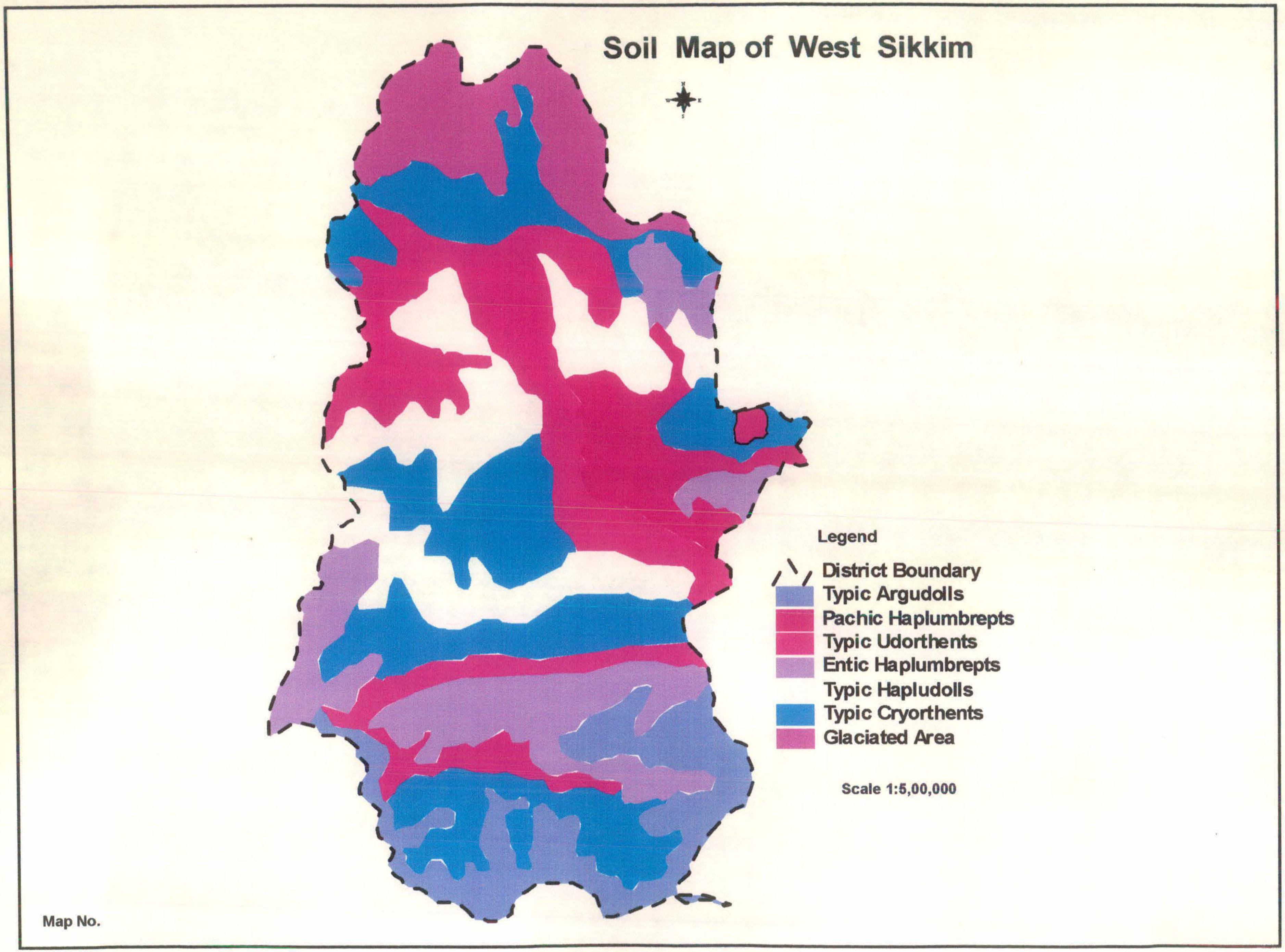
Soil Map of East Sikkim



Map No.

Scale 1:4,00,000


Soil Map of West Sikkim
N
W
E
S
Legend
District Boundary
Typic Argudolls
Pachic Haplumbrepts
Typic Udorthents
Entic Haplumbrepts
Typic Hapludolls
Typic Cryorthents
Glaciated Area
Scale 1:5,00,000
Map No.

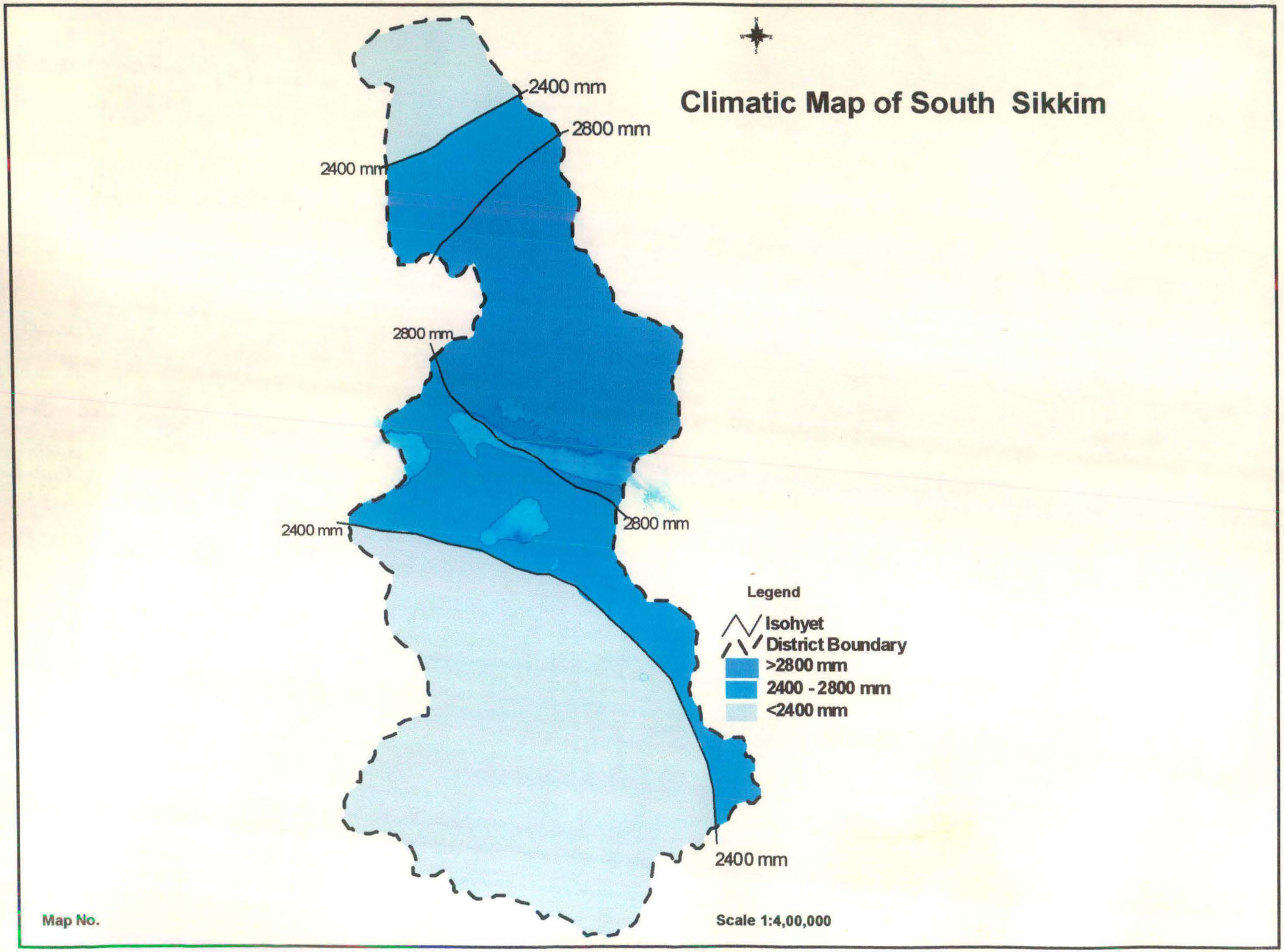

Soil Map of West Sikkim
Legend
District Boundary
Typic Argudolls
Pachic Haplumbrepts
Typic Udorthents
Entic Haplumbrepts
Typic Hapludolls
Typic Cryorthents
Glaciated Area
Scale 1:5,00,000
Map No.

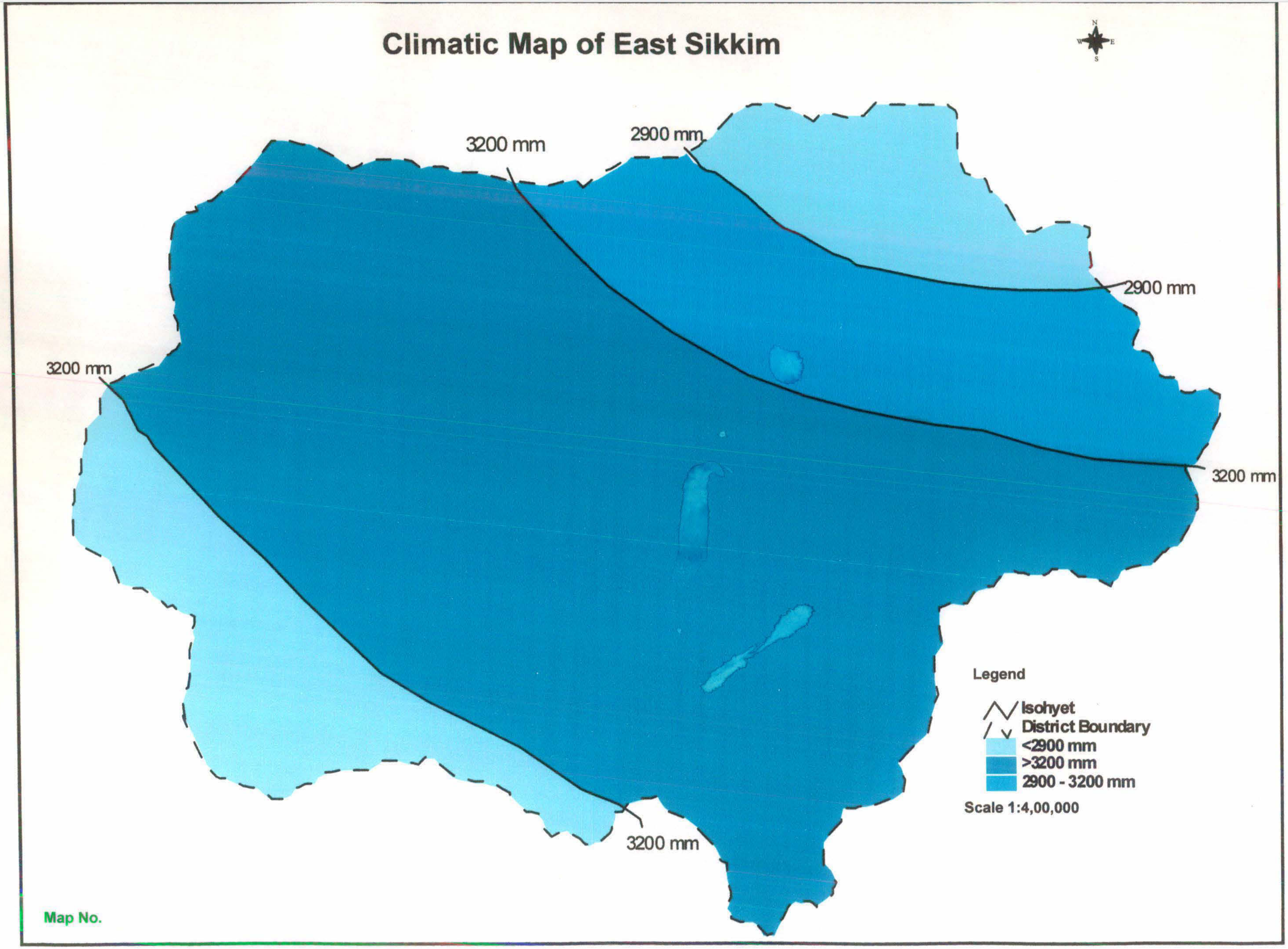
45), class IV soils can be used for cultivation but they are severely susceptible to erosion of shallow soils, low water holding capacity, poor drainage and severe alkalinity are the major limitations. Class VI and VII land have severe limitations that their use largely to pastures woodlands or wildlife and class VIII generally includes the barren mountain tops.

Due to abrupt rise of land from the drainage channel, areas of land capability classes I, II and III are very rare. It is obvious that except for the land near stream banks and in the valleys, the land is not suited for agriculture but for permanent vegetation and plantation. This calls for a very serious consideration for the proper use of these lands and points to the need of the taking great care for the maintaining sustained yields. Limited agriculture can be practiced on class IV lands and the state must specialize in using class VI to VII lands for free agro forestry system and plantations.

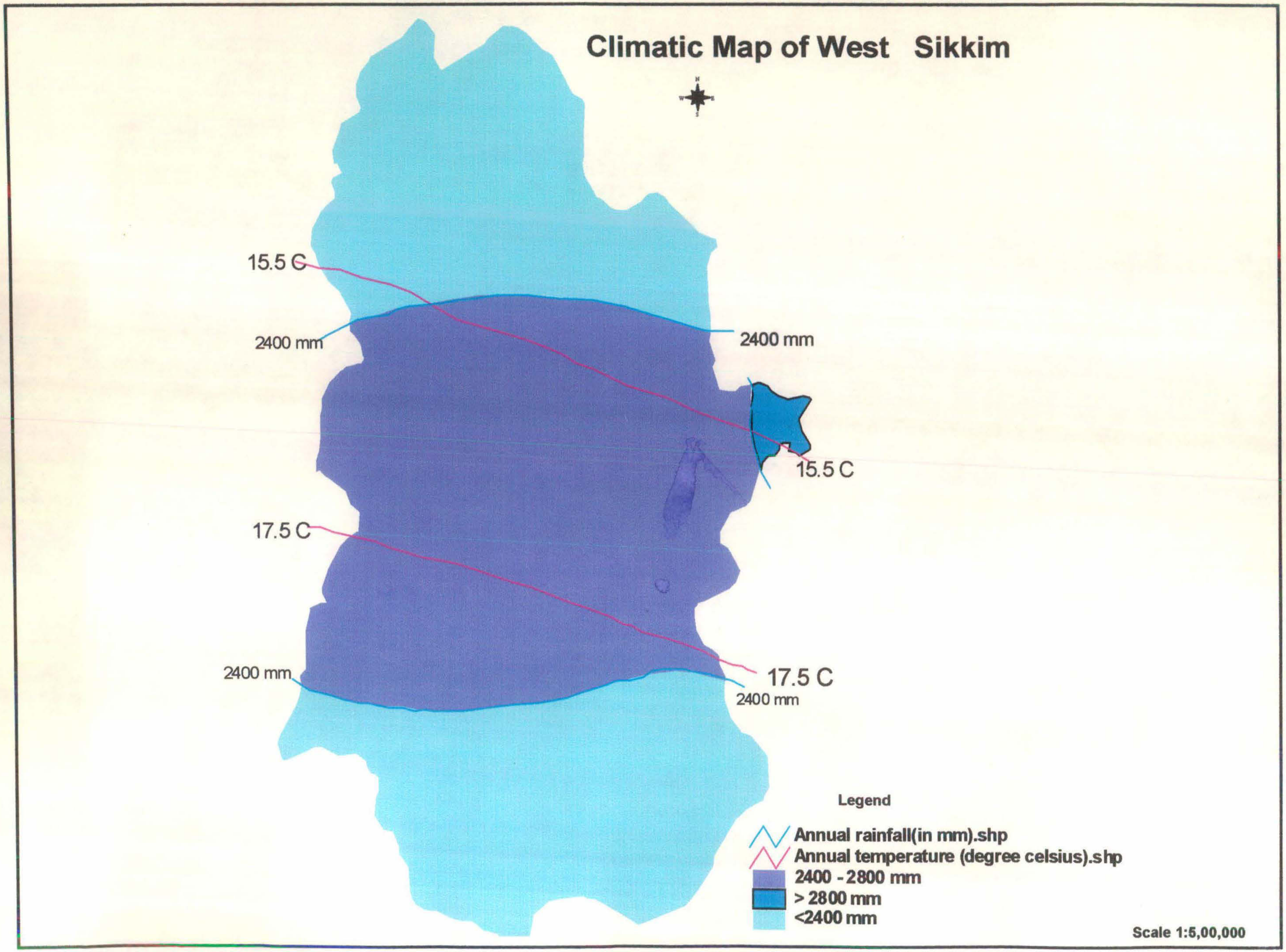
2.6 CLIMATE: Sikkim is a mountainous state consisting of a tangled series of interlocking hills rising from the south to the foot of the wall of high peaks, which marks the snowline on the north. Two major features, temperature and precipitation decide the climate of the region. These features in turn are influenced by three physical attributes of any particular --its location (longitude and latitude), altitude and exposure to powerful winds.

The climate of the state varies generally from sub-tropical to alpine depending on the elevation


Climatic Map of South Sikkim
2400 mm
2800 mm
2400 mm
2800 mm
2400 mm
2800 mm
2400 mm
Legend
Isohyet
District Boundary
>2800 mm
2400 - 2800 mm
<2400 mm
Map No.
Scale 1:4,00,000



Climatic Map of East Sikkim
N
W
E
S
3200 mm
2900 mm
2900 mm
3200 mm
3200 mm
3200 mm
Legend
Isohyet
District Boundary
<2900 mm
>3200 mm
2900 - 3200 mm
Scale 1:4,00,000
Map No.



Climatic Map of West Sikkim
15.5 C
2400 mm
2400 mm
15.5 C
17.5 C
2400 mm
17.5 C
2400 mm
Legend
Annual rainfall(in mm).shp
Annual temperature (degree celsius).shp
2400 - 2800 mm
> 2800 mm
<2400 mm
Scale 1:5,00,000

Table. No: 2.4 (a) CLIMATIC DIVISION OF SIKKIM

S.No	Range	Altitude (m)
1	Tropical	Below 610
2	Sub tropical	610-1524
3	Temperate	1524-2743
4	Sub-Alpine	2743-3962
5	Alpine	3962-5182

Source: Sikkim: A Statistical profile 2002

Within the same catchment of a stream it is possible to get subtropical or even tropical climate, is often observed at the lower end and temperate climate at the upper end of the watershed in the valley. Sikkim has an annual rainfall of about 1250 mm even in the dry upper valleys of Lachung and Lachen increasing to about 3500mm in other districts. Examination of available data from 18 stations in Sikkim shows that the mean annual rainfall is minimum at the Thangu, which is 821mm. The maximum rainfall of the area lies in the southeast quadrant including Mangan, Singhik, Dikchu, and Ganktok in the southwest corners including hills. In between these two regions there is a low rainfall region at Namchi. Rainfall in this area is about half of that in the former area. There is an area in northwest Sikkim which gets very little rainfall (even less than 409mm) and has mainly snow covered mountains.

Rainfall is very heavy and well distributed from May to September with July being the wettest month in most of the places and moderate rainfall is received in the month of April and October. It is generally low in the month of November, to February. The intensity of rainfall during the S.W. Monsoon season (Jun-oct) decreases from south to north, while the distribution of winter rainfall is in the opposite area. Some station in south may go dry for months during winter season. Average no of rainy days (day with rain of 2.5 mm or above) ranges from 100 at Thangu to 184 at Gnathang. Average annual rainfall ranges between 210 mm to 2,500 mm.

The temperature varies with the altitude and slope (generally 6*-10* per km). The trend of decrease in temperature with increasing altitude holds good everywhere. The temperature and humidity distribution show that the relative humidity is over 70% and is high in the east district. Maximum daily temperature is highest in the west district and the lowest in the north district, which is the coldest region in Sikkim. Temperature in lower altitudes varies between 4.5° C to 18.5° C. Three soil temperature classes have been identified – Thermic, Mesic and Isofrigid. It is the part of the per humid ecosystem and falls within agro-ecoregion 17 (warm per humid eco region with growing period of >210 days) in eastern Himalaya (Sehgal, et al 1990)

To obtain a better understanding of the climate with respect to land use pattern, the following climatic types may be distinguished:

(a) Alpine Type: It includes the areas above 4000 m mean sea level. The mountain peaks are mostly covered with snow. Precipitation is mainly through snowfall. Cultivable land is not available.

Sub- Alpine Type: This includes the areas between 2000- 4000 m above mean sea level. During winter it is mostly snow-clad and in summer there is intense rainfall.

Temperate Type: It comprises climate prevailing between 1500-2700 m above mean sea level. Precipitation is mainly in the form of rainfall. Snowfall is common during winter months (December and January). Heavy rainfall during June-July is the characteristic feature at elevation between 1700-2700m. Climate is dry with occasional drizzling during winter and heavy rainfall during summer.

Sub- Tropical Type: It includes climate at the elevation of 500-1500 m . The winters are dry and comparatively warm while summers are hot and have low rainfall.

Table No: 2.4 (b) Cliatic data of Sikkim

Station	Annual Rainfall	Highest rainfall as percentage of normal rainfall (in mm)	Lowest Rainfall as percentage of normal rainfall (in mm)
RONGLI	3220.6	142	82
GNATHANG	3289.6	117	108
CHANGU	2900.7	121	85
GANGTOK	3494.5	111	83
DIKCHU	3235.2	123	84
YOKSUM	2619.6	131	57
GEYZING	2392.2	116	86
CHUNGTHAN	2647.3	115	88
LACHEN	1652.4	115	78
MANGAN	3239.9	3239.9	111
THANGU	821.1	821.1	182
SINGHIK	2989.4	2989.4	136
LACHUNG	1703.5	1703.5	130
YUMTHANG	1417.4	1417.4	108
DENTAM	2338.5	2338.5	146
DAMTHANG	21970	2197	187

Source: Sikkim: A statistical profile 2002

2.7 VEGETATION: The diverse nature of the climate and soil is reflected in the flora of the region. The forest type ranges from tropical evergreen in the middle range to coniferous in the higher elevation and the high Himalayas in the extreme north. The state is rich in forest resources. Nearly 36% of the land area or about 2646 sq kms is forested.

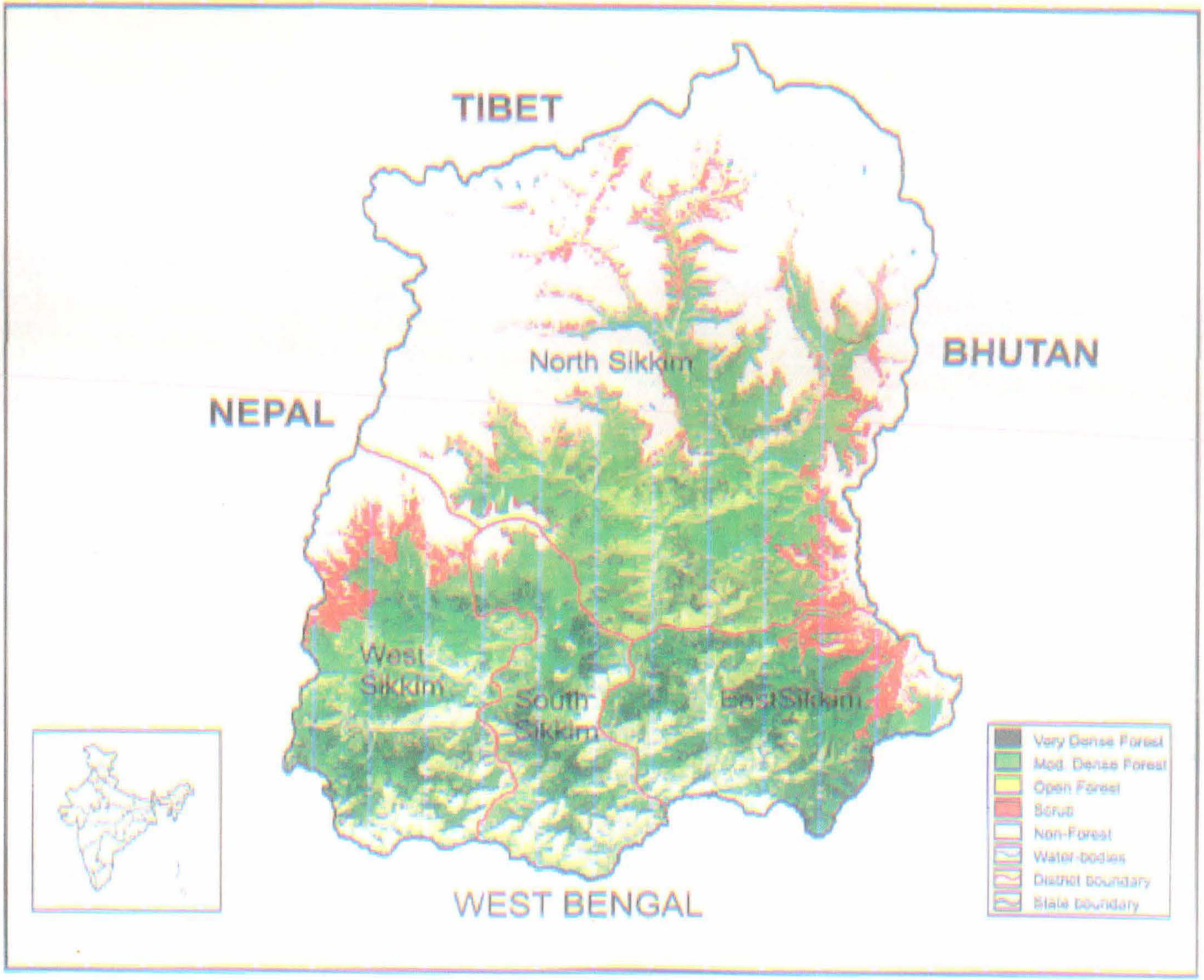


Fig. 2.7 Forest Cover Map of Sikkim

The State of Sikkim, a part of Eastern Himalaya has immense forest resource potential which has not been documented in recent times due to a number of constraints.

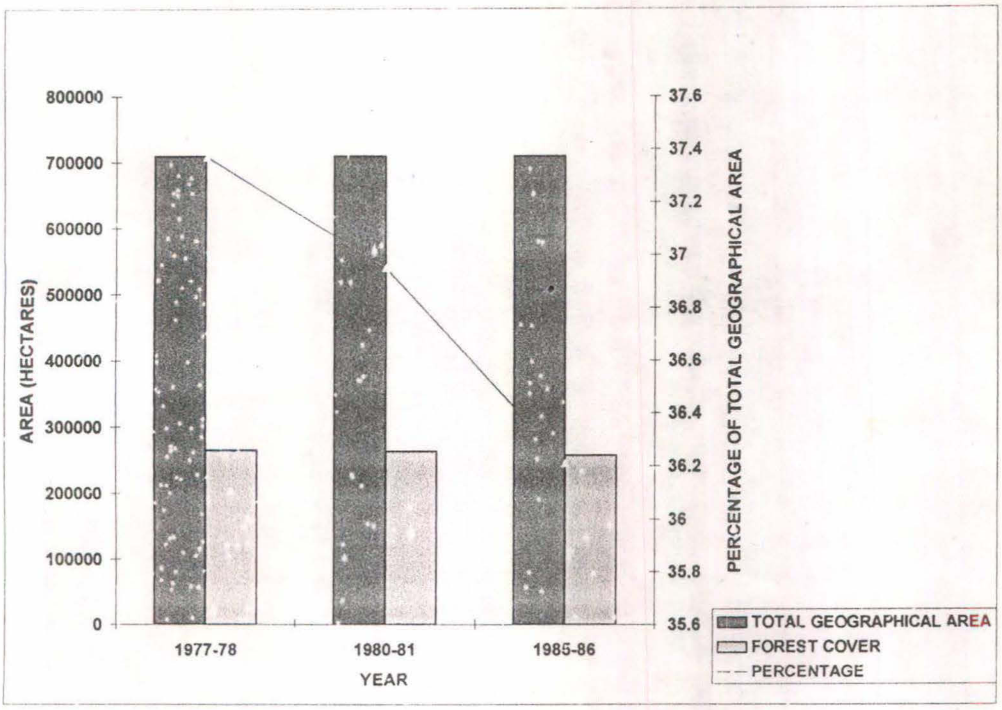


Fig 2.5 Forest cover To geographical area

Forests, the source of renewable energy has been over-exploited due to various pressures despite the recognition of their role for ecological stability and balance. As per the statistical data, the forest resources are depleting at a faster rate than the regeneration by afforestation schemes. In Asian itself, the rate of deforestation is 1.8 m. ha as against the afforestation of only about 0.4 m.ha (Rao 1990). The National Forest policy proposes that the total area under forests in the country be increased steadily to cover at least one-third of the total land area, the proportion aimed at being 560 per cent in hilly area and 20 per cent in the plains. The natural vegetation consisting of evergreen trees, grasses and bushes extends up to 5000m MSL only. At elevation above 5000m MSL hardly any vegetation is found. Distribution pattern of natural vegetation in the state may be divided into 5 mixed forest zones – Lower Hill Forest (<900m), Middle hill Forest (900-1800m), Upper Hill Forest (1800-2450m), Rhododendron and Oak Forest (2450-3350m) and Conifer and Alpine pastures (>3350m).

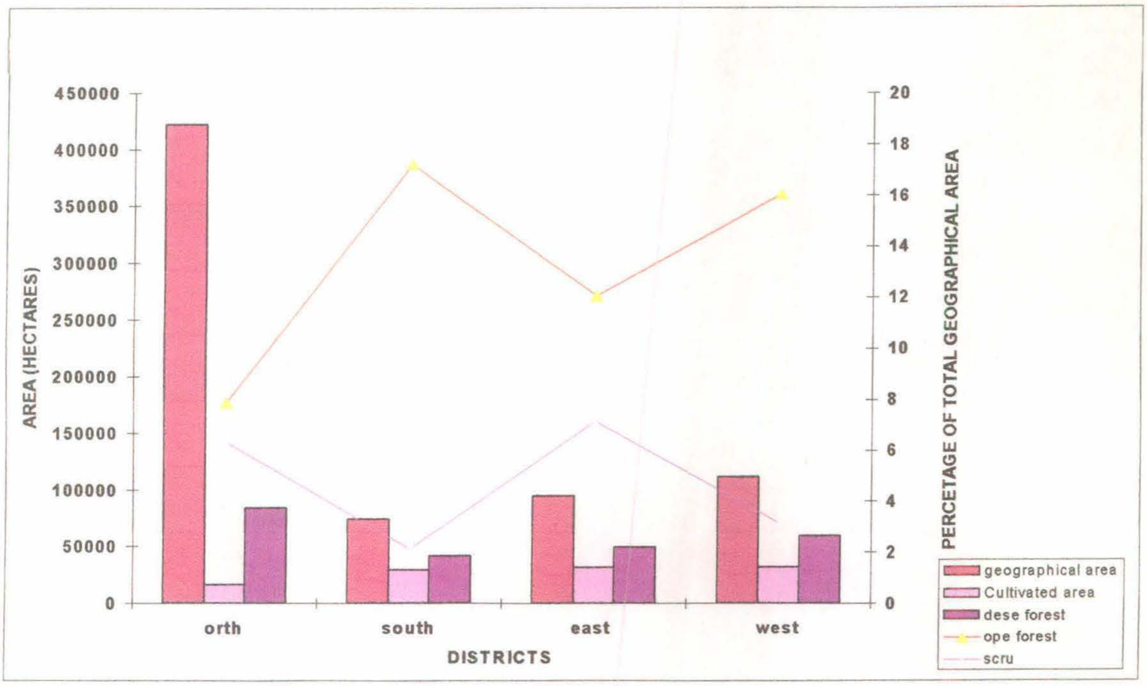


Fig. 2.5District-wise Forest Cover

The satellite remote sensing technology with its synoptic view, repetitive coverage and less cost for generating reliable, upto-date information with more than 90 per cent accuracy, paved the way for frequent utilization of this technology for forest cover mapping in various parts of the world including India (Madhavan Unni 1990). The State Forest Department of Sikkim in association with RRSSC, Kharagpur, has taken up forest cover mapping of the entire Sikkim using IRS-1A LISS-II data pertaining to Nov. 1988. A part of the scene covering 18x18 sq. km. around Chungthang (Lat. 270 -

40' N and Long. 880 - 35' to 880-45' E) North District, Sikkim has been taken up as a case study to formulate classification strategies for forest cover mapping. The present discussion highlight the methodology adapted for the classification of forest cover of Sikkim using different strategies to achieve better accuracy.

The forest cover of the state, based on satellite data of November 1998, is 3,118 sq.km, which constitutes 43.94% of the geographic area. Dense forest accounts for 2,363 sq.km. and open forest 755 sq.km. The forest cover of the state is given in table 2. 5 There has been a net decrease of 11 sq.km in the forest cover of the state as compared to the previous assessment. The difference between the data periods of the two assessments is about 4 years.

2.8 POPULATION: With a total population base of 540493 (2001) persons the state is one of the most sparsely populated area of the country it has an average density of 76 persons per sq km. Over the centuries, the narrow fertile valleys and the arable hillsides of the Himalayas have been populated by tribes who have adopted themselves to the rugged topography and the rigorous climate.

The general pattern of the population distribution follows the physical and the climatic zones from north to south, (i) The virtually empty great Himalayan region in the north (ii) The zone of relatively settled country in the middle Himalayan valleys (iii) The most densely settled southern zone characterized by a scattering of population clusters.

TABLE No: 2.6 DISTRICTWISE POPULATION OF SIKKIM (Source: Census Of India, Various issues)

Year	East District	North district	South District	West district
1981	138762	26455	75976	75192
INCREASE(1971-1981)	5341	13441	22791	17169
1991	178452	31240	98604	98161
INCREASE(1981-1991)	39690	4785	22682	22964
2001	244790	41023	131506	123174
INCREASE(1991-2001)	66338	9783	32902	25013

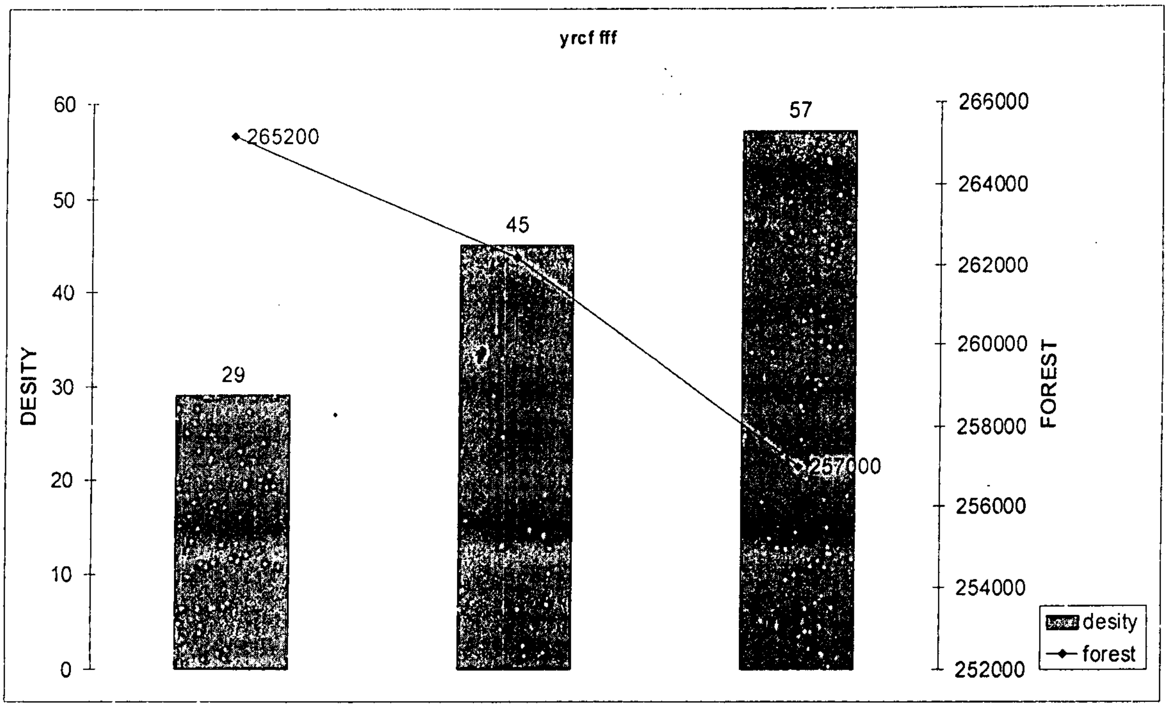


Fig 2.6 Density And Forest Cover

CHAPTER-III

LAND USE CHANGES AND ITS IMPLICATION ON ENVIRONMENT

Land cover modification and conversion is driven by human use rather than natural changes. In general, land use is viewed to be constrained by biophysical factors such as soil, climate, relief and vegetation. On the other hand, human activities that make use of or change land attributes are considered as the primary sources of land use/cover change. Interpretations of how such land use/cover driving forces act and interact is still controversial, especially with respect to the assessment of the relative importance of the different forces and factors underlying land use decisions in specific cases

Last few decades has witnessed growing concern for the land degradation and over exploitation of natural resources due to the increasing growth of human and livestock population leading to the environmental degradation. A mountain ecosystem is not a stable system, as it represent a stage of cycle of development of land tending towards a balanced stage. All stages change gradually so that different parameters of the system are continually adjusting themselves to these changes. Vegetation and soil play a vital role in this dynamic system (G.Savitri. Burman).

The present mode of resource utilization of the state and the consecutive removal of vegetative cover, accelerate the processes, which lead to the environmental degradation of the region. Although environmental degradation is caused by a host of interacting factors of which deforestation is a major factor of the problem. One of the main reasons for this progressive deforestation is the increasing population pressure. Population pressure expresses itself in several ways, the most important of which are as follows:

1. Increased land demand for cultivation.

2. Increased livestock population and

3. Increase resources for meeting the rising demands of fodder, fuel and timber.

Besides natural weathering and erosion caused by the geological and climatic conditions in Sikkim, man-made erosion is also a cause. Land use and forest mismanagement is contributing to most of the soil erosion. However, ecological imbalances and environmental degradation in the state is perceptible in the form of excessive silt load in the rivers, eroded and denuded hills as a consequence to overgrazing, low percentage area under forest cover with much less density than optimum, gradual disappearance of humus from forest, lack of natural regeneration, drying of the ephemeral springs, reduction in miscellaneous and broad leaved species with ecological retrogression and increased land slides, rock falls and debris etc. The clearing of the forest is continuously under attack from clearing for cultivation, grazing for livestock, lopping, and firewood extraction. Also, the increase winter runoff in the hilly areas due to erosion of the slopes, which increases the danger of floods during rainy seasons because of less infiltration.

Owing to considerable variation in altitude, topography, climate and edaphic condition of the soil, the area has been very complex ranging from tropical or sub tropical valleys to perpetually snow capped mountains among which the Kanchenjunga, rising to 8585 m in Sikkim Himalaya, ranks the third highest mountain in the world. Land, water and soil related problems in the state are not alike in all parts. Their nature and extent vary with elevation, slope and the climatic factors of the region. In general the soils in the forest experience high rainfall and low to moderate temperature which are responsible for wide variation of the plants life and its extent including the cultivation of large scale of agro-horticultural crops. The annual rainfall of the area ranges from 2800mm to 4000mm and the temperature varies from 0 degree centigrade to 30 degree centigrade in Sikkim. Exploitation of timber has aggravated the problem of forest degradation thereby aggravating the ongoing problem of land degradation and upsetting the water/soil equilibrium.

Environmental problem of the state are varied as well as interlinked and owe its origin to ignorance and lack of integrated approach in socio-economic development based on various consideration of the environment. The process of urbanization and industrialization has exerted pressure on the available resources and affected the depletion of the existing resources. Soil, water and land resources, which are under continuous, state of degradation due to indiscriminate felling of trees and unscientific land use system prevalent in the state.

Soils of the state are the results of the prolonged weathering of the Tertiary rocks of sedimentary character. In general acidity in different proportion is associated with most of the soil of the region. Another problem associated with the soil is high intensity of the water erosion. These are the results of steep slopes, indiscriminate grazing, erratic land use pattern, and lopping of the forest twigs. The problem of soil erosion has aggravated too much and an environmental liability of the region.

1.1 OVERPOPULATION:

The population of any region plays a vital role in the overall land use pattern and thus affect the environmental changes on spatial dimension. It becomes necessary to incorporate population of the state to be considered in studying the land use changes and its implication on the surrounding environment. The alarming growth in population has always been an imminent threat to the conservation and development of the natural primarily because good agriculture land is being cornered for commercial cultivation and, pushing cereal cultivation into higher and marginal lands. Land encroachment in protected/reserved forest is on increase thus threatening the forest cover of the state. The practice of monoculture has been another major environmental problem leading to decrease in fertility of the topsoil and leading to further soil degradation.

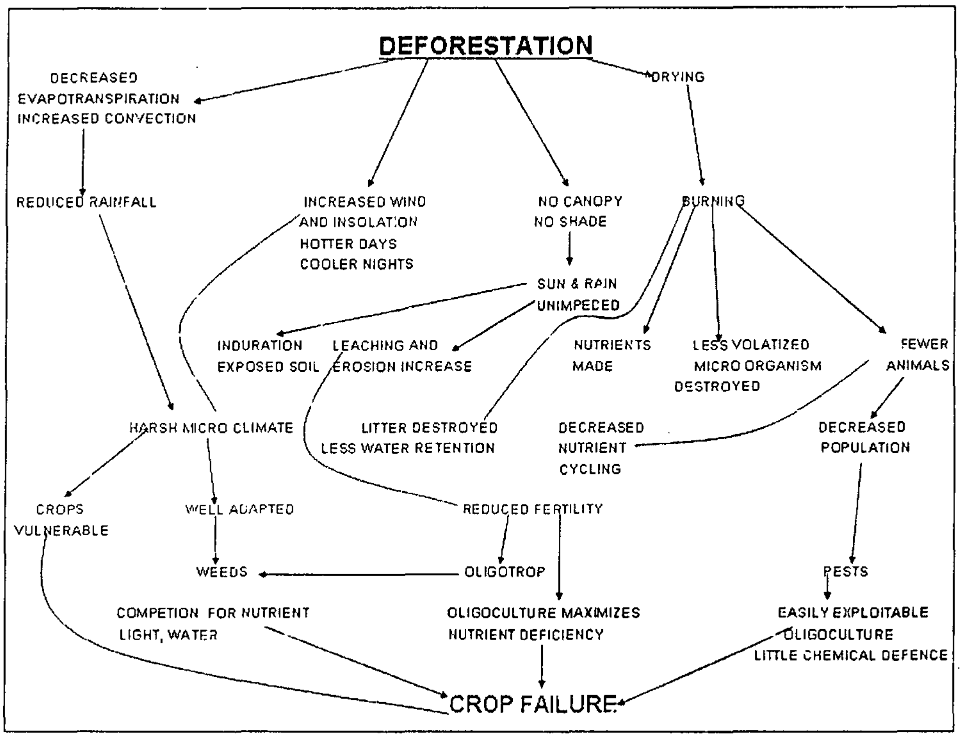
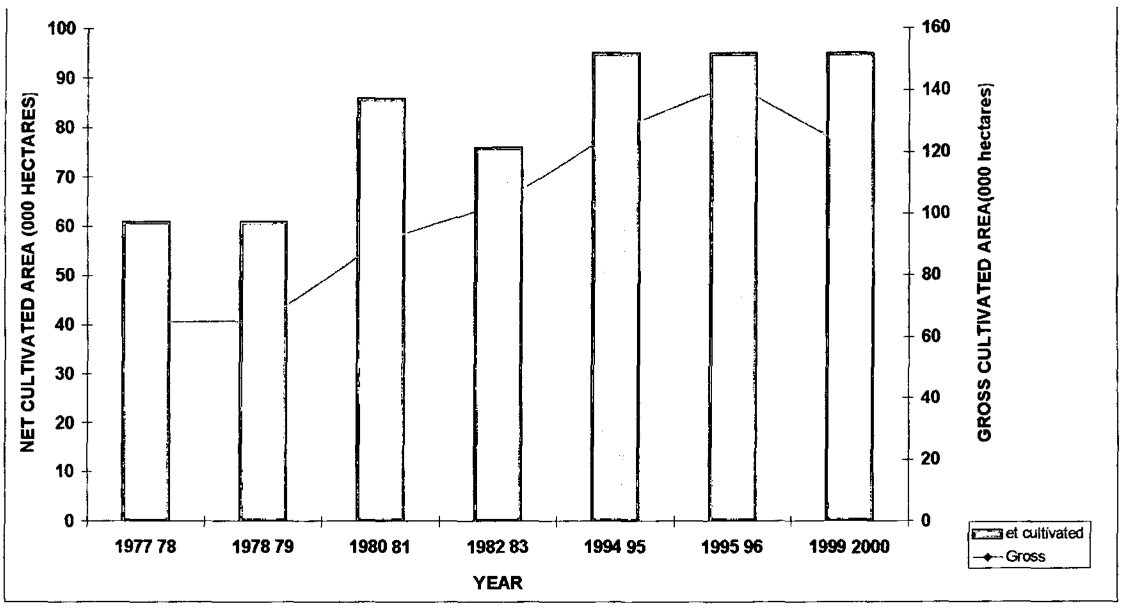


Fig-3.1

In the last few years a trend has been examined in the area that the agriculture is being extended on the marginal soils, on steep slopes and rocky and unstable hillsides without the sufficient vegetation cover which aggravates the problem of soil erosion. With the growing demand for commercial and horticulture cultivation the better soil have been occupied by these causes the food and other crops to be shifted to higher slopes and exhausted soil. The increased utilization of chemical fertilizers for growing food crops in turn leads to environmental degradation. It has been noticed that in many areas of the state the topsoil or even all of the soil is already lost but cultivation is still being practiced on the Parent material leading to further land degradation. Abandoned agricultural fields are another indication of lost and exhaust soil.

Fig: Total Cultivated Area (In 000 Hectares)



Source: Fertilizer Statistics of India

The ploughing of the agricultural fields makes the soil loose, which increases the risk of soil erosion. The efficiency of the existing system of agricultural practices can be managed in several ways without effecting land fertility of the top soil.

3.3 DEFORESTATION: The heavy dependence of human and animal population on timber, fuel wood and fodder has led to depletion in resources. In addition to depletion in resources, the deforestation results into many other degradation of water, land, wildlife and other related resources and also accelerating disastrous phenomenon like soil erosion and landslides **fig** 3.3a- 3.3d

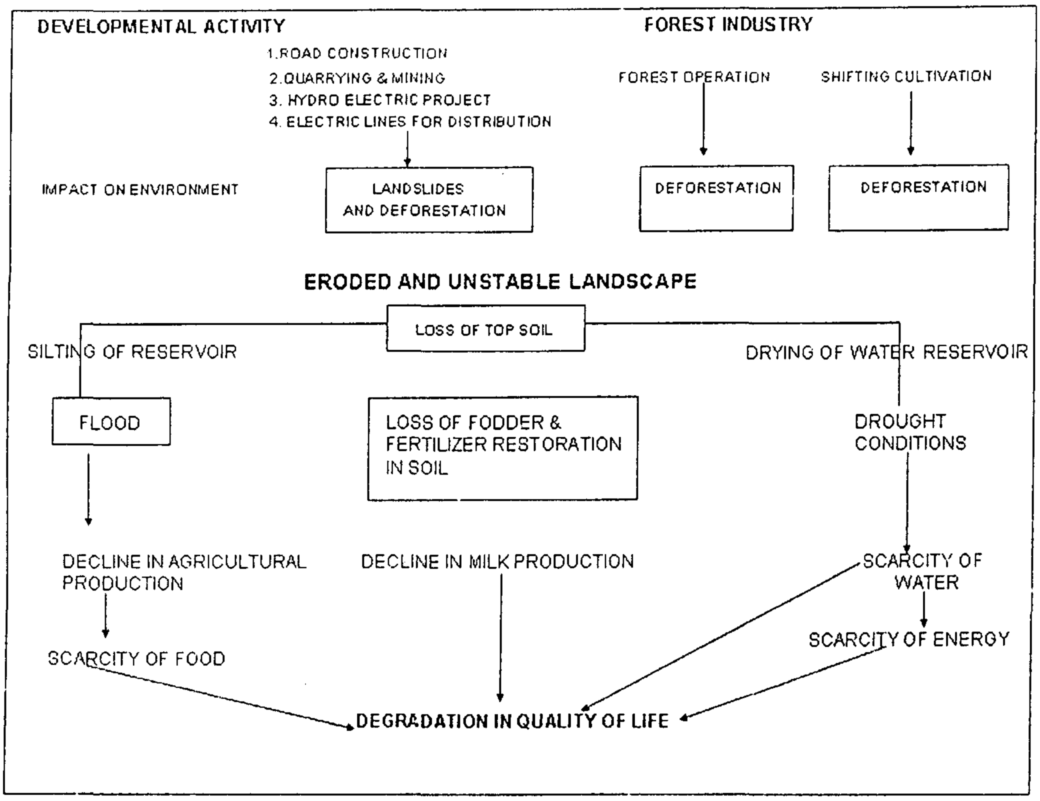


Fig-3.2 Fig 3.3 b Socio-ecological Impact Of Deforestation (R.K.Gupta,)

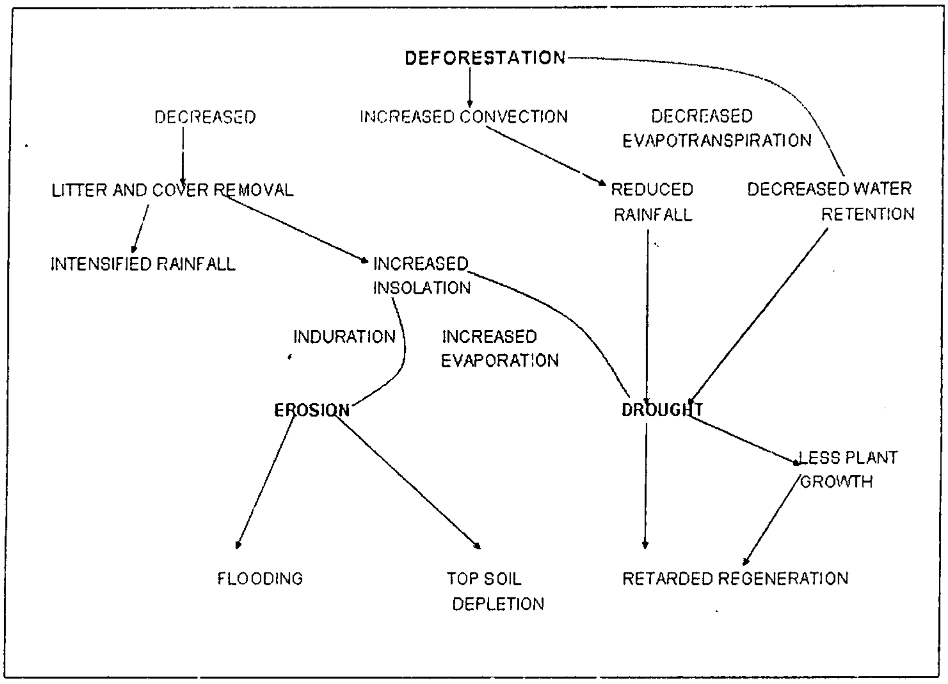


Fig No3.3 a Environmental Disruption Caused By Deforestation (Goodland and Jookman , 1977

Fig 3.1

Degradation of vegetation can be noticed in terms of decreased biodiversity, decreased woody biomass, loss of useful (grazing) species and increased presence of (unpalatable) invader species. The main reasons for degradation is overgrazing and increased population, leading to increased use of woody biomass for cooking, fencing, building materials, etc. Water resources are limited and experience has shown that there is a need to consider different spatial and temporal dimensions, while analyzing resource use issues and searching for solutions. The pine and oak forest has been worst affected as pine tree are the major sources of timber wood and resin extraction and oak fulfills the basic need of fuel and fodder. Due to the selective felling and cutting of several important plants have resulted into considerable changes in forest composition and rarity of certain species. In many areas virgin forestlands have been cleared and converted into scrub forest due to excessive lopping. The reducing forest cover has directly influenced the under shrub and other canopies with severe hydrological and edaphic changes, leading to lowering of moisture and accelerating the rate of soil erosion. The environmental degradation has restricted the distribution of no of endemic plant species (Pauri and Sahni1970) and is under great constraints.

Rapid depletion of forest is environmentally the most destructive force affecting the state. The main reasons for clearance of forest are short-term commercial benefit. Dependence on forest for fuel and fodder, uncontrolled grazing and theft and pilferage of trees, extension of cultivation and encroachment due to increasing population pressure on the limited land resource. One of the most common reasons behind the destruction of forests cover is the steady increase in the commercial exploitation of the forest resources.

Indiscriminate road construction activities are impairing the lush green forest cover of the state. Often the road passes through the virgin forest cover where hairpin bends are created to gain altitude as the road ascends. With tremendous increase in population, the people are compelled to encroach upon the forest cover for their fodder and fuel needs. In the state, areas that were once covered with lush green trees up to 4200 m or so are now beginning to show bare patches along many slopes and gradually moving upward. This transformation in the state has taken place within the past few decades or so. In many parts of the state well-defined changes have been brought about in local vegetation cover of the state. Broad leaved trees, which once occupied the state, have been replaced by coniferous trees. The broad leaved trees form rich humus, which is no more available. The natural vegetation is adulterated and even overlapped by numerous plants.

The vegetation cover provides protection to the soil against the direct effect of the rainfall. Due to steep slopes, the forest cover protection is very crucial. The forest are the home of a large variety of wild animals and the cutting down of vegetative cover disturbs their habitat forcing them to move to other areas, thus, effecting the ecological balance.

A very large-scale deforestation over the fragile hill ecosystem has brought about sudden changes in the ecosystem in many areas of the state. The disappearance of forest cover with increase in carbon dioxide content can adversely affect our ecosystem. In addition to the loss of soil and oxygen, deforestation has lead to the drying up of natural water springs and fall in ground water table level due to decreasing infiltration of the water into the soil thus affecting the water table . The studies carried out have shown permanent and near permanent changes in the climatic conditions, tendency towards erratic precipitation, rising temperature, desert conditions and drying of natural springs. Decreasing soil nutrient is another environmental impact of deforestation.

In the hilly areas, the National Commission on Agriculture has prescribed for at least 60 % forest cover of 30 % or less are to be treated as extremely fragile and areas with 30 % or more but less than 60 % forest cover could be treated as vulnerable areas a forest cover. A forest cover helps the rainfall water to seep into the soil, thus aiding in its storage as under ground water. Negi (1981) states, "Water absorption powers of a soil depend on its permeability. This is maintained by the roots (which act as disintegrating agent) leaf, litter, humus etc. In the steep Himalayan slopes where the soil is shallow the forest floor litter plays a major role. It absorbs about four times more water than ordinarily soil and by easy decomposition, adds to the depth of the soil"

3.4 OVER GRAZING: Grazing by the domestic animals has become an important factor for increasing biotic pressure on the forest and pasture ecosystem of the state (fig3.4). The quantitative increase in the cattle population has brought forest degradation. The animal population is greater than the carrying capacity of land

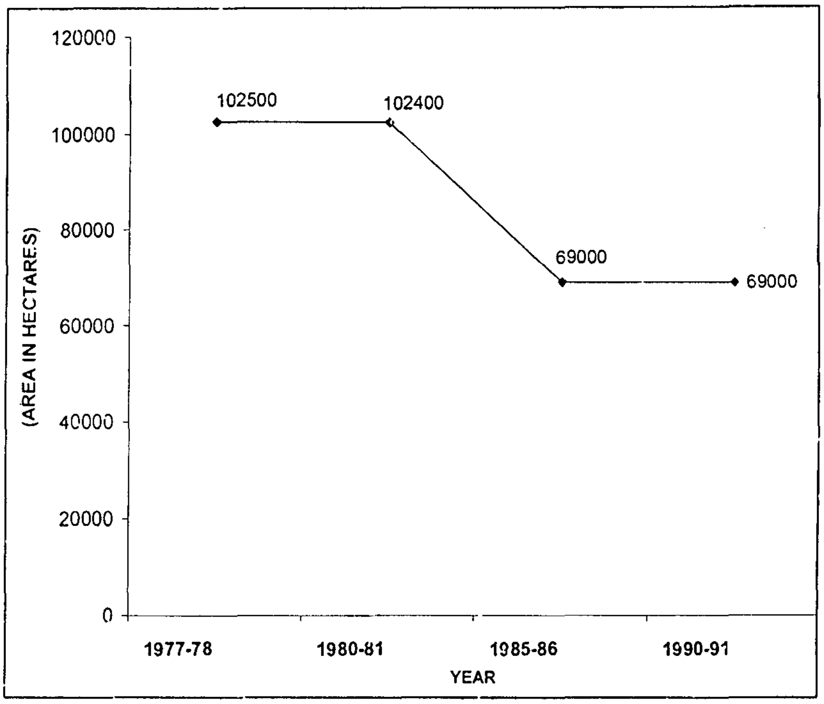


Fig 3.4: Deforestation In Sikkim

The nomadic and semi nomadic shepherds' populations create the main problem as they dwell in the forest and alpine areas throughout the years. They move up to the alpine meadows in summer and migrate to the lower hills in the winter for grazing their herds of cattle. In addition to grazing they indiscriminately damage the vegetation cover by lopping for their requirements. Due to the overgrazing and uncontrolled grazing of the cattle large no of species eliminated gradually the soil of the area becomes rugged by the cattle population which accelerates the rate of erosion and thins of the vegetation cover causing formation of barren patches of forest and alpine meadows.

Though the quality of the hill pastures/forest has bearing on the per hectare requirement of each animals, it can be safely assumed that one mature animal require 5 – 8 hectares of forest pastures land to support it. Thus one hectare of the cultivated land indirectly needs about 50 hectares of forest/pastures lands has lead to the problem of gullies formation in the tracks, which are frequented by the herds of the cattle. These are common in the areas where gully formation is aided by the weak nature of the country rocks, zone of disturbances and highly erosive nature of the streams. Due to selective grazing of the young and succulent grasses, only coarse and poor grasses are left.

The herds of the cattle adversely affect the quality of the grasses growing on the pastures by keeping them below the optimum height for metabolic activity. The heavy movement of the herds on the pastures damages the seedling and saplings and thus limiting the regeneration of forest covers. The movement of the cattle's up and down in the hilly slopes loosens the soil, thus aiding the process of the soil erosion.

3.5 CONSTRUCTION ACTIVITIES

Construction of roads, canals, irrigation, buildings, etc has lead to number of environmental problems by changing the land use pattern. The construction activities without proper evaluation and unscientific construction have further degraded the land resource.. The road construction activity involves large-scale removal of debris, loose earth materials and rubble. This material is pushed down slope, which covers all the vegetation both natural and planted in its path and produces bare land right down to valley flat. These loose earth materials and rubbles drops in the stream below causing siltation problems. Due to large-scale removal of debris along the side of hilly areas and loosening of the base support of the upper soil base, landslides or mudflow especially during the heavy downpour occur. Even in the dry seasons the loose material are blown with the winds and are deposited on the vegetation cover. The excavated debris adds to the problem of accelerated erosion by either directly entering the streams or rivers that drain the area or by being washed away by the surface runoff.

DEGRADED AND SHALLOW DEPTH OF SOILS: One of the most prominent is the problem of degraded and shallow depth of soil of the state. Land degradation affects the yields but the larger impacts are often off-site, *e.g.*, degradation of water quality, loss of habitat, loss of biodiversity, etc. In large part of the state, the soils are in the gradual process of degradation. The fertility and the water holding capacity of the soil have been reduced greatly. The increasing number of cattle being kept by the rural population reflects low crop yields of the state. Compact and exhausted soils are prone to large-scale problem of erosion. Consequently soil erosion is widespread, sheet wash, gully erosion and soil creeping. The high rainfall of the state has been responsible for leaching away of the clayey component of soil leaving the coarse and unproductive soil behind. The shallow depth of the soils is another problem faced. With growing food and other demands, the crops are being carried out in shallow soil depth as a result the roots of the crops can not penetrate deep into the soil with the result the soil moisture at shallow depth is being depleted which demands frequent irrigation. Another soil problem, which is commonly observed in the hilly areas, is the formation of clod, which is common in rice fields. This soil becomes very hard and making agriculture difficult.

SOIL EROSION: The soil erosion is a perennial environmental problem of the state. Basically caused by natural agents. These natural agents of soil erosion are river, wind and glacier. But in last few decades the rate of erosion has been accelerated. This acceleration has been caused due to the increasing human and cattle population pressure on the existing land resources. The soil erosion may take many forms and these are basically classified into gravity flows like soil creep and rolling of materials, scouring effect and transportation of debris by running water. In the hilly areas like Sikkim the developmental process and construction of new roads and buildings and the areas under the kitchen gardens are the major source of soil erosion. The research on soil erosion hazard associated with the various land use systems practiced in the state indicate that except forest land use none of the land use are safe and lead to land degradation. The erosion of the fertile topsoil is one of the major land degradation of the land resources by decreasing the productive capacity of the soil.

Enormous amount of soil from the mountain of Sikkim is being lost to the two major river of the state namely Teesta and Ringit rivers every year. The accelerated rate of the soil erosion in the last few decades has been induced due to the following reasons:

- The traditional agriculture system practiced in the state in which the cultivation is done by ploughing and irrigating the agricultural fields which makes the soil loose and more prone to the erosional activities.
- Removal of forest covers especially in the steeper slopes of the area, where by soil is exposed to the direct effect of the weathering.

- Road construction and mining activities through a measure of development process causes denudation of the area through soil erosion and landslides. These activities involves earth cutting and rock blasting that renders the hill slopes unstable, especially mining activities, without taking effective soil conservation measures is leading the soil degradation including land slips and land slides. The consequences of neglect of soil conservation measures are:

(a) Loss of fertile topsoil and decreasing agricultural production.

(b) Increase in flash floods.

(c) Sedimentation of reservoirs thus decreasing its

Soil erosion is a disastrous phenomenon in the hilly areas. Besides land degradation, it also causes gradual disappearance of the natural spring water and silting of the riverbeds thus causing floods in the plain areas. The most serious effect of soil erosion results loss of most fertile top soil and exposure of infertile acid subsoil, decrease of plant available water capacity, degradation of soil structure, non uniform removal of soil surface and ultimately decrease of economic return on production. Soil conservation not only includes control of erosion, but also recognizes equally the importance of soil fertility maintenance.

Landslides and Subsidence

Landslides involving very large quantities of material of all sizes are caused in the unstable materials with aid from both water and gravity. Land subsidence is caused from the loss of support from below, though the immediate cause may be different in each case.

Although landslides are natural phenomenon of erosion, they have escalated by leaps and ever since the road building process has started in Sikkim, miles and miles of road keep slumping as the highly chemically weather materials keeps flowing out from under the road bed. Deforestation in the river catchments area is the major cause for triggering landslides & land subsidence. The barren hills facilitate soil erosion while cracks result into land slides during rainy seasons. Other common causes, which accelerate landslides, are overgrazing, mining activities, etc. The remedial measure to check landslides & land subsidence includes proper road designing, afforestation, scientific measure of grazing lands and all round development of mining to check the land slides and subsidence in the hilly regions. A number of land slides occur in the following areas:-

(a) Siliguri –Gangtok national highway: The larger landslides are located at the ninth milestone & have been a source of trouble since 1957. This slide is active even today. The high degree of slope, weak country rocks and a degraded vegetative cover had led to the severity of landslide problem in the area. Recurrent floods and cloud burst are a great threat to slope stability in this zone.

(2) North Sikkim highway: This road joins Gangtok and Changthang. A major landslide zone is located in the rocks of Daling series. Pulverized rocks, heavy rains, steep slopes and erosion are some of the causative factor of landslides in this tract.

ALTERATION OF HYDROLOGY: Sikkim has suffered the worst affect of deforestation. The natural have become seasonal and sprigs have dried up, Sub-soil water level has gone down which has adversely affected the agricultural production and thus straining the existing source water. In spite of high rainfall in the state, the crops in most of the hilly region suffer from soil moisture stress due to erratic rainfall behavior.

The destruction of the internal hydrological system is reflected in the fact that spring sources have either dried up or registered a sharp decline in the discharge characteristics. When the water holding capacity of the land/soil vegetation cover is diminished, the discharge time profile of the river increases. This means more and faster runoff in shorter time duration leading to silt discharge, high rate of erosion and flooding the down stream. The drying of water source and discharge reduction has adversely affected several segments of the economy. Firstly the loss of fertile agricultural land due to the loss of irrigation sources as well as grazing land. And secondly the urban water supply has been affected seriously. The most significant hydrological alteration caused only by land use changes is the decrease of wetland areas. The reasons for the wetland's degradation are mainly the expansion of the farming land and the progressive lowering of the lake's water level. This has been caused by unsustainable management practices and by the construction of an artificial canal. The results indicated significant variations in the hydrologic regime including a 6% increase in the annual evapotranspiration and a 10% increase in the soil water deficit that impose substantial impacts on the regional wetlands. The land use changes actually increases evapotranspiration. The seasonal evapotranspiration pattern illustrates high increase rates during warm months (March to August) whereas during the winter period the change rates are relatively low on a spatial basis, Evapotranspiration reaches its maximum value in farming areas during the summer period but forests and urban areas represents low rate of evapotranspiration. During the winter period the evapotranspiration pattern is different. This time forests present the highest evapotranspiration rate and urban areas lower values. The water quantity stored on the ground surface has been reduced. This is mainly due to the expansion of agricultural land that increased water infiltration to the unsaturated zone and consequently reduced the water quantity that remains on the ground surface. The overland flow maps estimated by the models' simulations have indicated relatively higher values. This is expected due to the significant urban development. Since in wetland areas subsurface and underground flows are the dominant hydrologic phenomena while large-scale water runoff is not expected. The water deficit in the unsaturated soil profile has increased due to land use changes, which is a significant hydrologic alteration. The seasonal pattern of this alteration indicates a high decrease of water deficit during the summer months and relatively low increase during the winter months. This is due to higher demand for soil moisture during the crop growth due to the expanded agricultural areas. This effect is significantly reduced during winter periods, since there is no agricultural consumption. The underground water flow is a very important hydrologic component for an area since it recharges lakes and provides the necessary soil moisture for the wetlands subsistence. There is an estimated reduction in underground outflow due to increase of evapotranspiration and the water deficit in the soil. These alterations are only caused by the land use changes, enhance the estimated hydrological modifications. Therefore, serious implications for the local water storages and their management, since a decreasing soil and groundwater level has been observed due to the increasing agricultural water demands due land use changes. The increase of the urban areas causes a increase of the overland flow in an area and decrease of water stored on ground surface. This is a significant alteration of the hydrological regime caused by urbanization. The impact of land use and land cover change on surface runoff. increase in runoff volume indicates as much as 50% of the land surface may become impervious to water infiltration in an urban watershed, while the water excess in urban and sub-urban areas may affect the discharge profiles of water courses in a basin directing to increased erosion of stream banks and increased sedimentation. Water stored under ground surface playing a very important role for the regional ecological status, have undergone substantial reduction due to increased water losses (increased evapotranspiration and water abstraction) and due to the highly modified water flow/infiltration conditions on a local scale. The extended farming areas and the commercial agricultural system increase the water abstractions significantly in the farming areas while development of urban districts raise overland flow rates and obstruct water storages. The underground outflow that supplies water to the lake and to the associated wetlands have resulted in considerable reduction that occurred mainly due to the estimated increase of the area's remaining water losses (evapotranspiration and water abstractions). This indirect impact of the land cover changes on regional hydrology has serious implications for the water dependent wetlands, since the groundwater level falls approximately

CONCLUSION: Environmental implications are circular sequences which if approached randomly will result resource degradation. The increasing population pressure on the available resources for food and fodder has resulted into over exploitation of resources and environmental degradation. Although environmental degradation is caused by host of inter related factors of which deforestation is a major one.

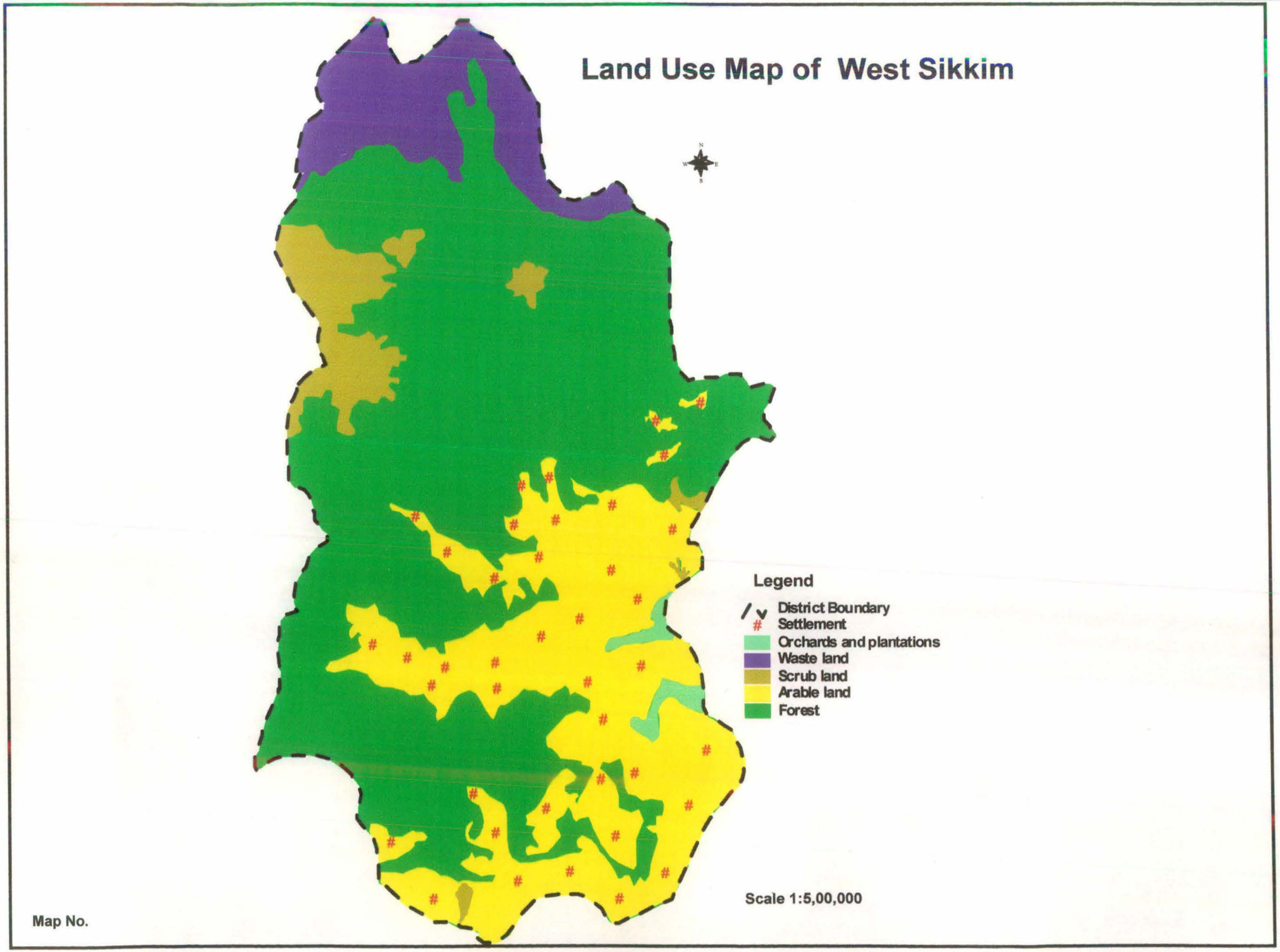
CHAPTER IV

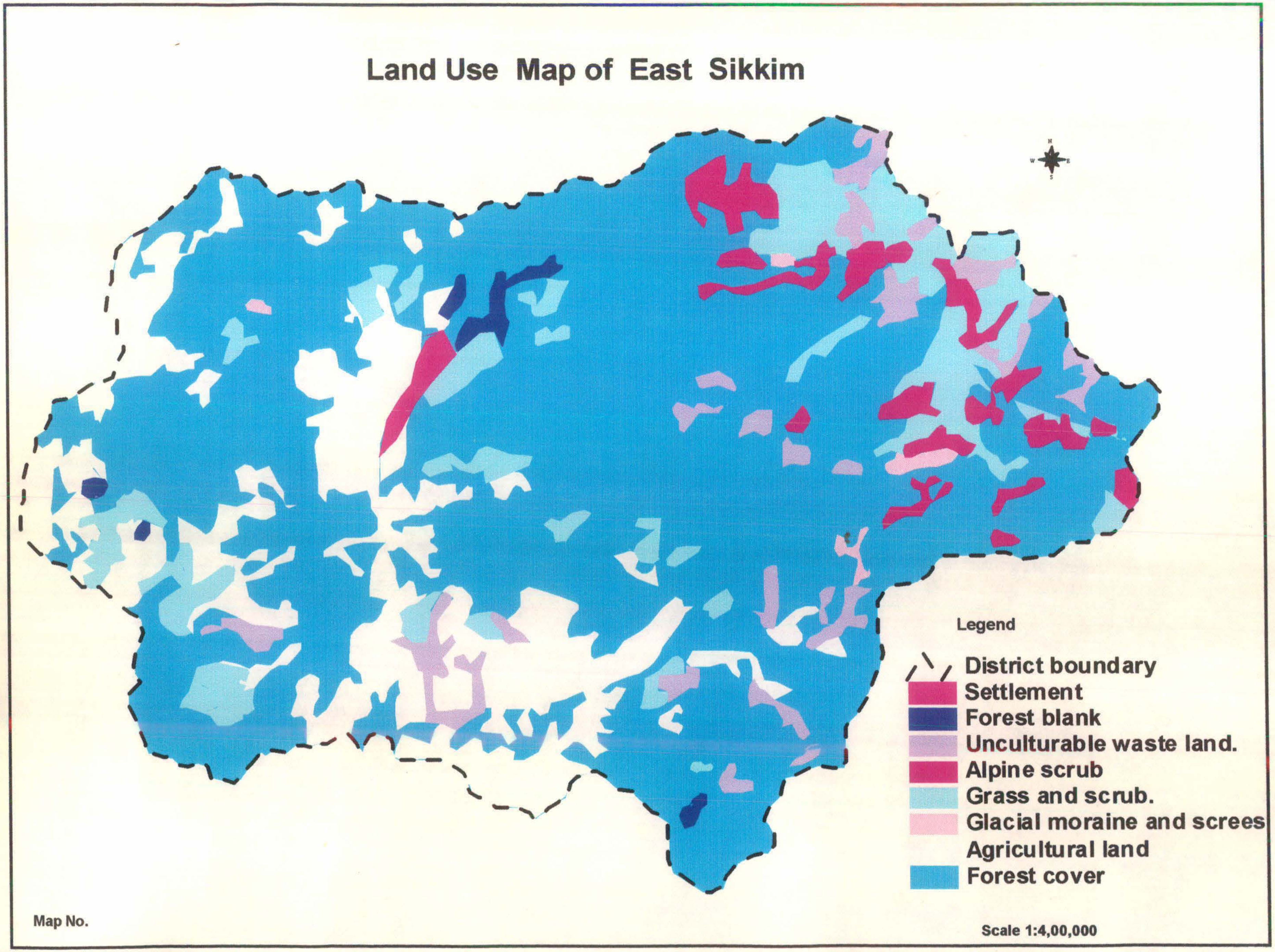
LAND USE DYNAMICS IN SIKKKIM

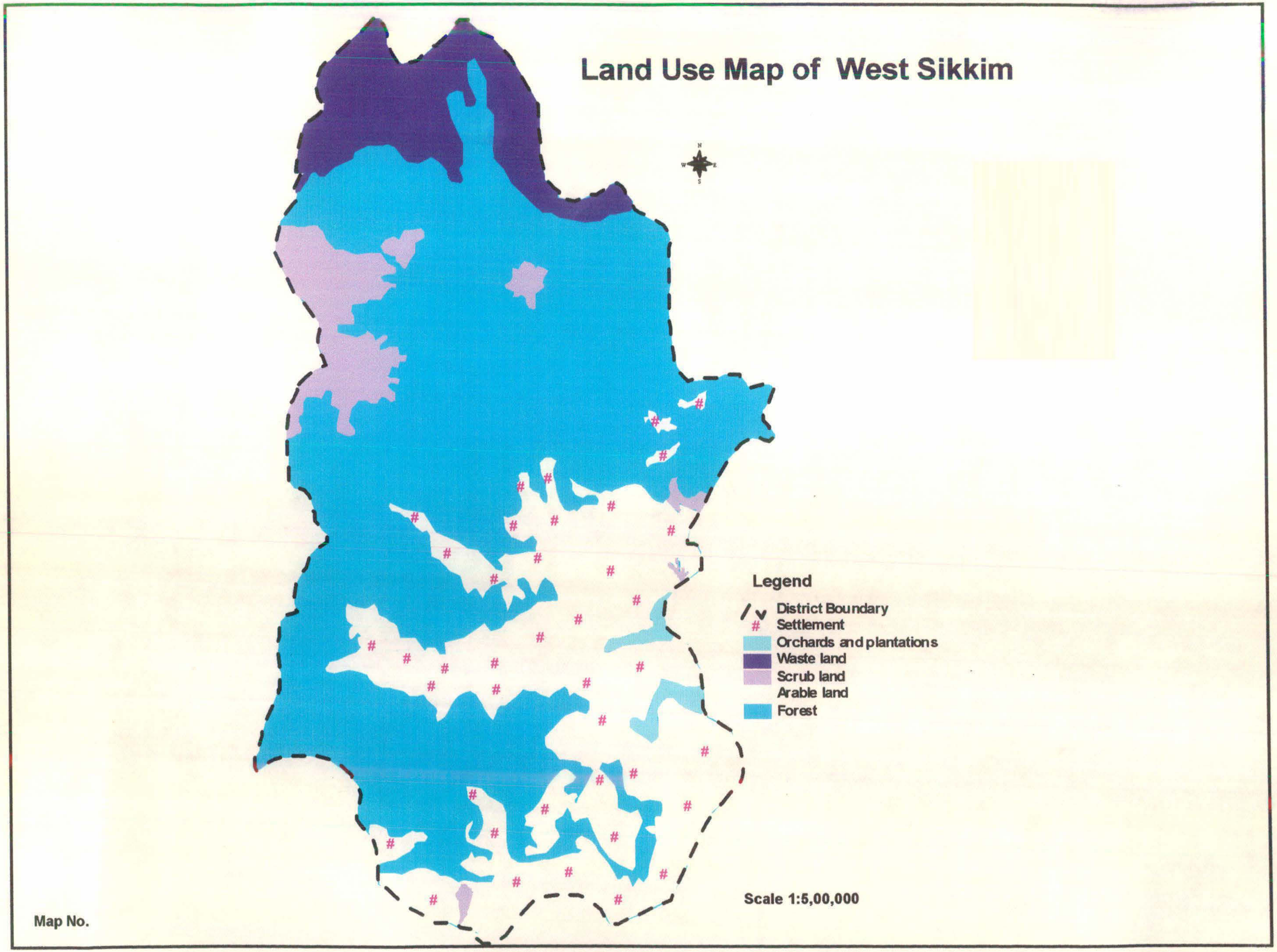
Introduction:

Land provides all types of resources for the socio economic & environmental development of a region. Hence its study is of paramount importance. Land resources fulfill our basic priority and provide the opportunity to choose resources in the best possible way. There is always a constraint in carrying capacity of the land at certain point of time and complexity arises because of stress at every turn of technological advancement and may prolong the use of the resources for a longer duration. Pattern of land allocation among various uses is the interplay of nature and quality of land resources, socio economic condition, magnitude of human and other resources, local interference and technological know how. Many factors affect the land use /land cover changes. These are economic, climate, tectonics, cropping trend, new technologies and government policies, just to mention a few. Each of these factors contributes with varying degree to change dynamics of areas. A contributory factor may be applicable in one area and not in another. It is therefore, important to determine which factor contributes significantly in a specific area before a full blown land use / land cover change study could carried out.

The study of changes in land use pattern is carried out in order to gauge the imbalance in utilization of land resources, and measures to correct


Land Use Map of West Sikkim
N
W
E
S
Legend
District Boundary
Settlement
Orchards and plantations
Waste land
Scrub land
Arable land
Forest
Scale 1:5,00,000
Map No.


Land Use Map of East Sikkim
Legend
District boundary
Settlement
Forest blank
Unculturable waste land.
Alpine scrub
Grass and scrub.
Glacial moraine and screes
Agricultural land
Forest cover
Map No.
Scale 1:4,00,000



Land Use Map of West Sikkim
N
W
E
S
Legend
District Boundary
Settlement
Orchards and plantations
Waste land
Scrub land
Arable land
Forest
Scale 1:5,00,000
Map No.

them. Such studies also help in simultaneous development of crop production, forests and pastures for livestock. Moreover, it also helps in shifting land use from a less profitable to a more profitable and sustainable one. With variation in geomorphology, soils, climate, and irrigation facilities, the diversity in land use is but obvious. With this knowledge one can be predict the availability of food and resources for the coming years. Recommendation's can also be made to policy makers for remedial measures if the result of such studies anticipates ahead problems. Land use/land cover change study is a diagnostic tool for determining sustainability. It is therefore, important that this diagnostic tool be used carefully and judiciously..

Forest cover constitutes 37 percent and forms the major land use category in the state. Because of the hilly terrain farm lands are situated between the elevations of 300-3000m, but most cultivated areas lies below 1800 m. Altitudinal factor also limit hill agriculture to a micro climatic variation. The local demarcation of the hill areas into "Lak" and "Owl" is basically done in terms of micro-climatic variations. Laks are generally the higher reaches of hills where temperature is low with a longer crop maturity period. Owl is basically the slopes nearer to the foot of valleys where temperature is high. Generally from the agricultural point of view Owls are better suited because various crops can be grown with a higher yield compared to the Lak areas. Highly acidic hill brown soil and steeply sloping lands adversely affect effective land utilization. High gradient land combined with a high rainfall in the Sikkim hills cause a heavy loss of nutrients through leaching. Because of all these factors net available land for effective cultivation becomes extremely marginal. Land use pattern shows that out of the total geographical area of 709600 hectares, the operated area account for 15.37% (109068 hectares), and the net cultivated area is only 11.66% (82749 hectares). Relatively little is known about the ecological ramifications of human-induced disturbance of forests in the state. Forests have many important biophysical roles, e.g., as store houses of biodiversity and in watershed protection. These forests also serve as a critical renewable natural resource base for subsistent people in the region. The complex and diverse nature of mountain ecosystems make generalizations difficult Any investigations at the forest stand level will: (1) improve our understanding of forest resource sustainability at local scales, (2) provide reference data for making spatial and temporal comparisons, (3) help identify key diagnostic variables for forest-use/cover change, and (4) assist in the development of standard field methods and analytical tools for establishing baseline data, monitoring changes, and developing prediction models.

The land use pattern of the Sikkim state during the period 1977- 78 to 1997- 98 is presented in the Table 1

As a result of land use changes net sown area has increased from 61100 hectares in1977 78 to 95000 hectares In 1990 91. From table 4.1 it becomes clear that there is a sharp increase in the percentage of culturable waste land In proportion to total geographical area. It increased from 1100 hectares in 1977 -78 to 11500 hectares In 1980 - 81 and it shows a very steep decline to 0.40 percent In 1990 -91 from the earlier for which data is available. 1.62 percent in 1980- 81. There was substantial increase in area and culturable land in the initial decades. But the area under this category shows a sharp decline during the period 1985 86 to 1990- 91. During the year 1977- 78 the total area under area and uculturable land shared a percentage of 29.45 % of the total geographical area of the state, which gradually declined to 13.669 percent of the total geographical area by 1990-91.

The area under forest cover showed a gradual decline over the studied period. The total forest cover of the state in 1977- 78 was 37.37 percent which gradually declined to 36.95 percent by 1980- 81, followed by 36.21 percent for the year 1990- 91.

The land use trend reflects that there is a gradual increase in the area under land put to non agricultural uses which implies that the there is gradual process of developmental activities in action in the state over this period of study. The area under non agricultural uses was 9.86 percent during the period 1977- 78. In the year 1980 -81 there was a decline in the area under non-agricultural uses which. It was 6.93 percent in 1980- 81 which further increased to 13.66 percent during 1985 -86.

Area under permanent pastures and grazing showed a negative trend for the period of study, which implies that this areas has been put to other category of land use, especially agricultural uses. The area under permanent pastures and grazing land was 14.44 percent during 1977- 78, which declined to 9.72 percent during the year 1990- 91. The area under trees, miscellaneous tree crops and grooves are included in the net sown area which was 5.91 percent 1977- 78 sharply declining to 0.56 percent during 1980 -81, which increased to 0.70 percent during 1985 86.

Marginally land use pattern shows that there was a sharp decline land cover put to fallow land category in 1980-81. The fallow land occupied a total area of 14000 hectares which accounted for 1.97 percent of the total geographical area during 1977-78, which declined to 0.18 percent during 1990- 91.

4.2 VARIATIONS IN DIFFERENT LAND USE PATTERN

Coefficient of variation was worked out to examine the extent of overall variation in different land use categories over the period. Coefficient of variation has been calculated to examine the actual amount of increase or decrease in the area put to different land use categories. Table4.2 provides the result of the analysis. The C.V. has been calculated by using the following formula:

C.V. = S.D* 100/x

Where x is mean

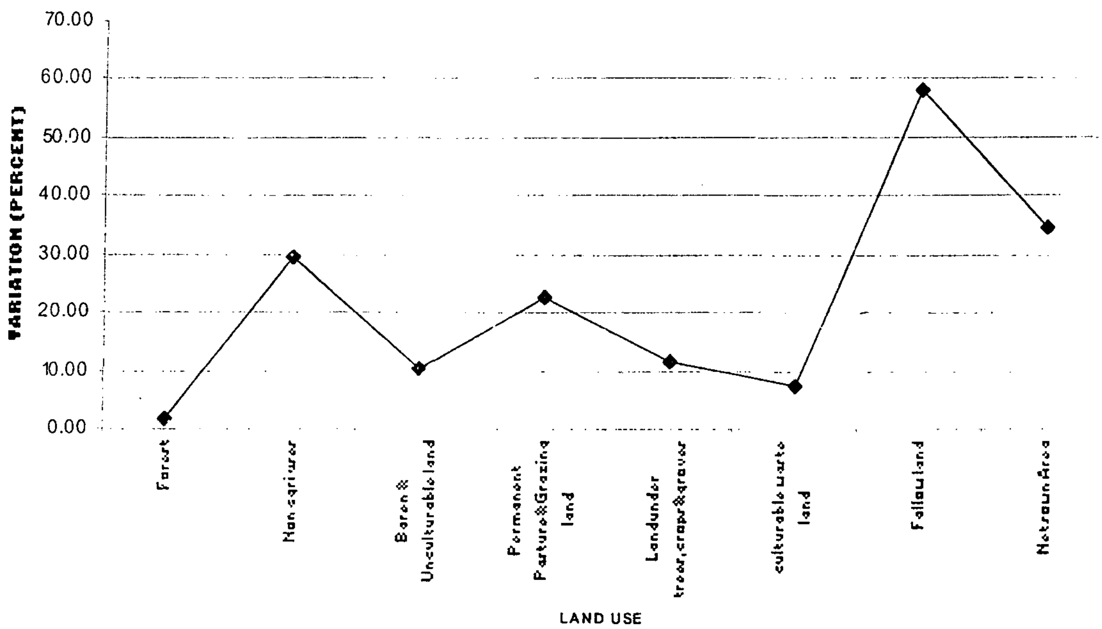


Fig 4.2 Variation In land Use

Analysis of the data shows that land under fallow show the highest degree of variation, being 57.88 percent of variation followed by area under net sown (34.52) non-agricultural uses (29.632%); permanent pastures and other grazing land (22.528 %); area under barren

4.2 VARIATIONS IN DIFFERENT LAND USE PATTERN

Coefficient of variation was worked out to examine the extent of overall variation in different land use categories over the period. Coefficient of variation has been calculated to examine the actual amount of increase or decrease in the area put to different land use categories. Table4.2 provides the result of the analysis. The C.V. has been calculated by using the following formula:

C.V. = S.D* 100/x

Where x is mean

Analysis of the data shows that land under culturable waste show the highest degree of variation, being 143.38 percent of variation followed by land under trees crops and grooves which is 133.37 percent; fallow land (132.51%); area under agricultural uses (29.632%); permanent pastures and other grazing land (22.528 %); net sown area (17.328 %); area land (10.360 %) and forest area showed a minimum variation of 1.558 percent. The trend depicts that the area under culturable waste land exhibited the highest degree of dynamism. The lowest rate of variation was recorded for the forest area which implies that the change in the forest covers was almost constant over the period of study. Similar trends of less variation were noticed In the case of area land, unculturable waste. The high degree of variation was noticed In the land under trees crops & grooves which resulted In the dynamic changes of land use pattern.

4.3 COMPOUND GROWTH RATE OF DIFFERENT LAND USE CATEGORIES

The compound growth rate of different land use categories has been to analyze the growth rate of various land use categories; C.G.R has been calculated for all the periods. The CGR has been calculated by using the following formula

$$CGR = (b-1)^{*}\ 100$$

Where b=regression on t

T=time

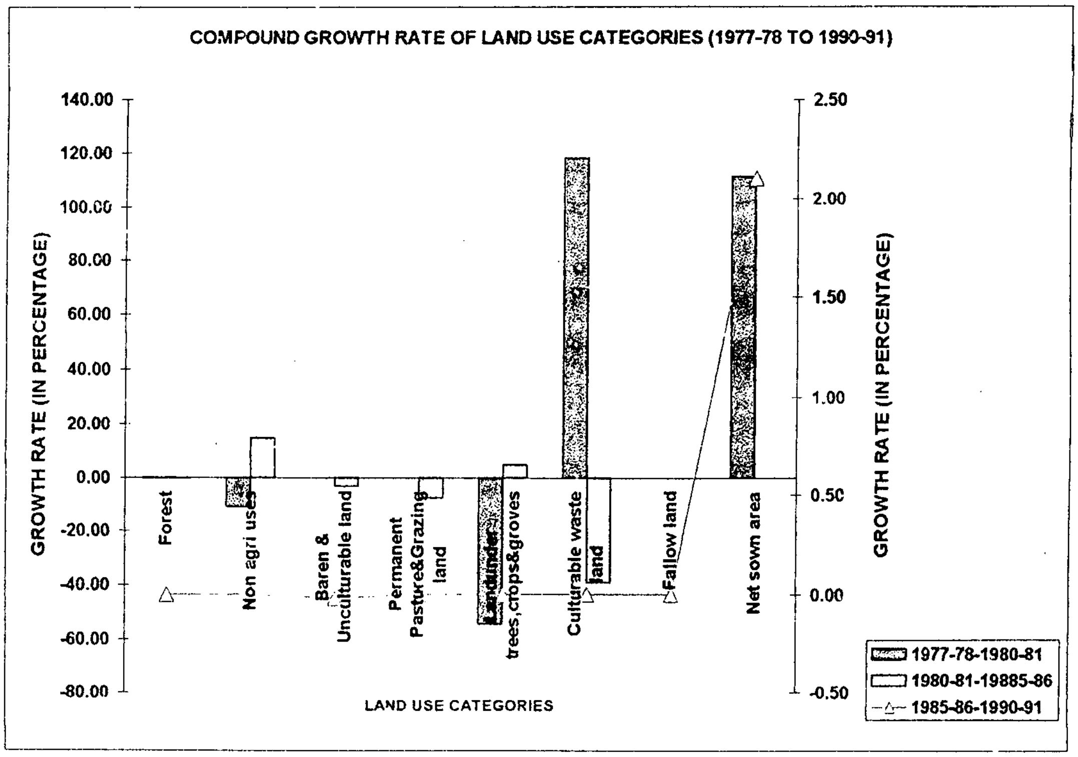


Fig 4.3

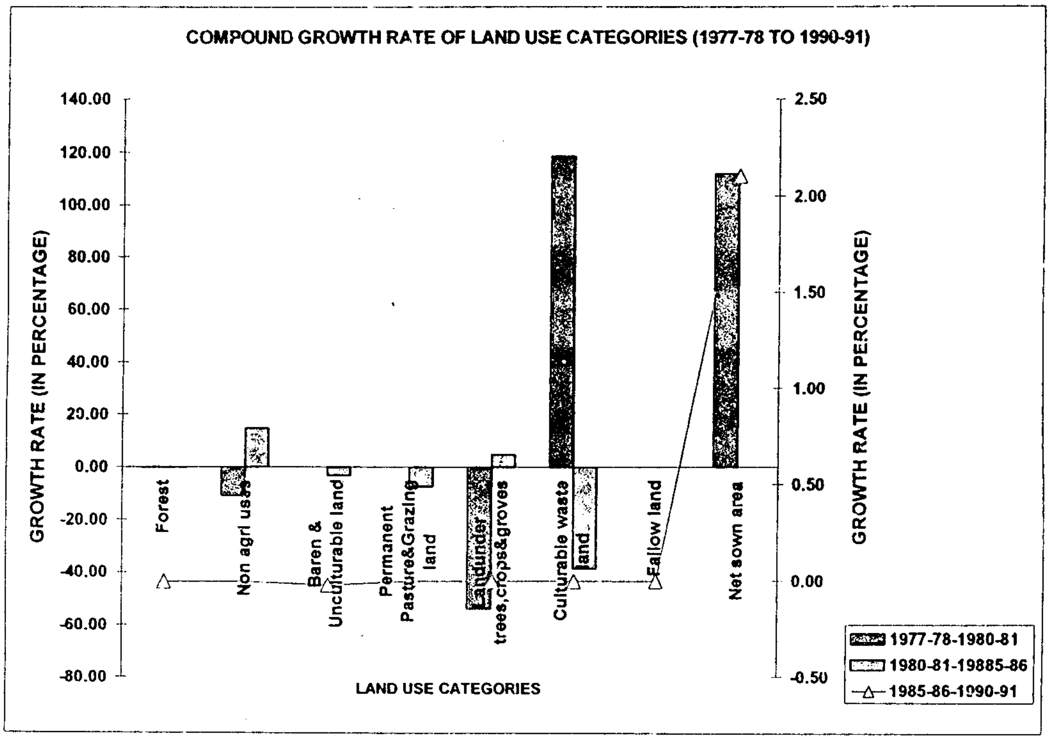


Fig 4.3

4.4 ELEMENTS OF LAND USE CATEGORIES

To analyze the relationship among various elements of land use, a correlation matrix has been computed. The correlation has been calculated by using following formula:

$R = \Sigma X \times \Sigma Y \div \sqrt{\Sigma XY} / \sqrt{\Sigma X} \times \sqrt{\Sigma Y} / N$

where n =Number of variables

The correlation matrix is given in table no 4.4

1. The analysis reveals that the proportion of area under forest is positively correlated with fallow land and uncultivable land, permanent pastures and other grazing land, land under miscellaneous tree crops and grooves, culturable waste

grooves and fallow land. Proportion of net sown area and proportion of wasteland are positively correlated but insignificant, which means it is chance just a chance factor, which may not hold good In case of large number of observations.

5 Culturable waste land positively correlate with the fallow land, forest area, uncultivable waste land, land under permanent pastures, other grazing land and net sown areas. Though the area under culturable waste and net sown areas are positively correlated, yet both these relationship are insignificant, indicating their relationship are chance factors only.

6. Study reveals that the area under fallow land is positively correlated with forest Area, uncultivable land, land under permanent pastures, other grazing ground and culturable wasteland. Striking feature is that it shows a high positive correlation among the variables.

7. The land put to miscellaneous tree crops and grooves show positive relationship with the forest area, uncultivable land, land under permanent pastures, other grazing land and fallow land. The land put to miscellaneous tree crops and grooves show high degree of correlation with fallow land (1.000) but negative correlation with net sown area, culturable waste land and area under non agricultural uses

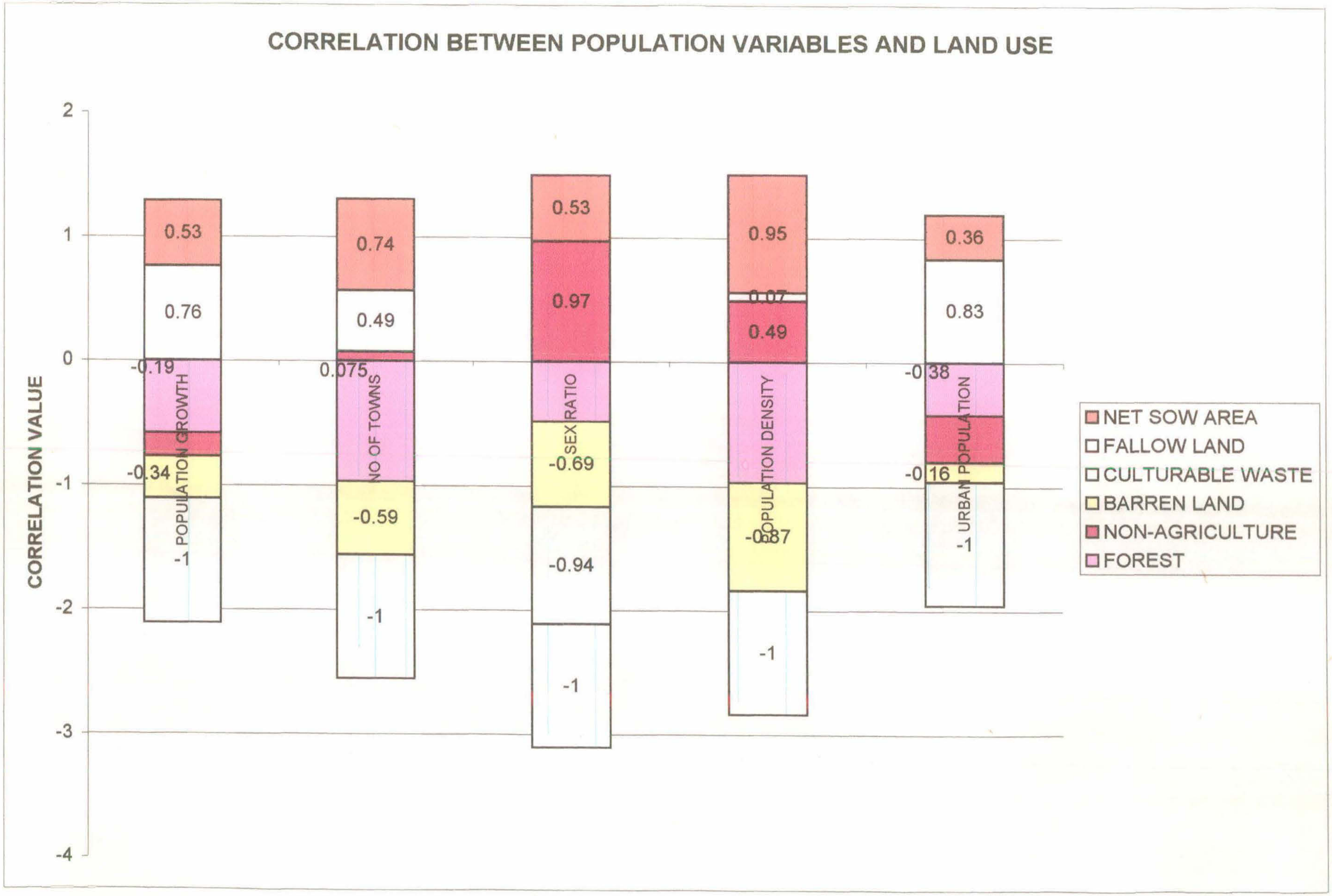
8. Proportion of area under permanent pastures and other grazing land is positively correlated with forest area, uncultivable land, miscellaneous tree crops, grooves, culturable waste land and fallow land, and negatively correlated with area under non agricultural uses and net sown area.

9. The most striking feature of the analysis is that all the elements of different land use categories except net sown area and land under non agricultural uses show highly positive correlation with fallow land.

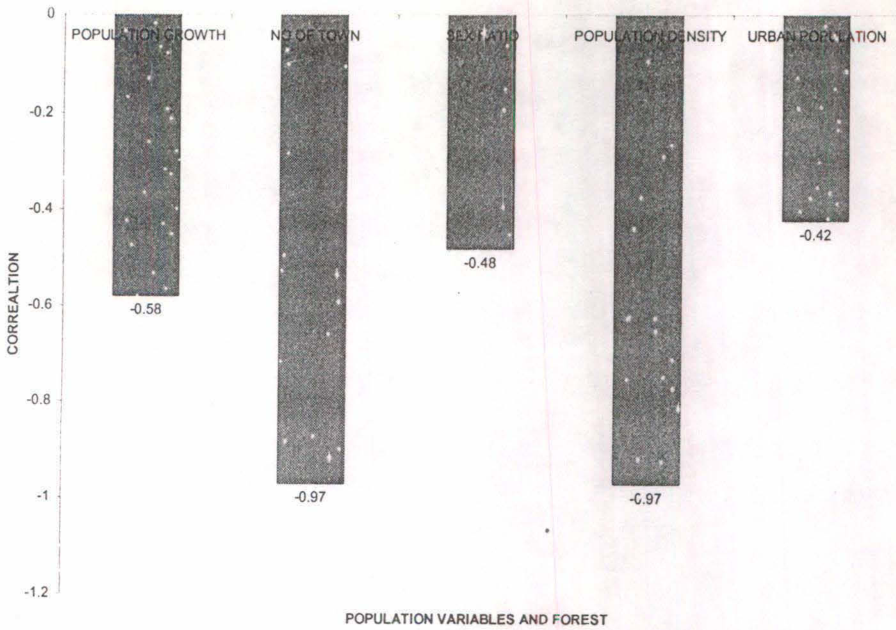
4,5 LAND USE AND POPULATION VARIABLES

Human population growth changed in character and form in the twentieth century. The unprecedented rate of population growth has sparked alarm about its impact on the global environment and future prospects for human societies. All human activities since time immemorial have disturbed the virgin nature. Thus it is not surprising that the high rates of economic and industrial development that accompanied population growth in the twentieth century has resulted in the depletion of natural resources and degradation of the land, air, biotic, and water resources in many regions on the globe. In general, farmers must either expand the area of land under cultivation or intensify agricultural practices to meet demand. Because the conversion of land from its natural state to human use is the most permanent and often irreversible effect that humans can have on the natural landscape, a critical aspect of these debates may be the relation of growing population numbers and changes in land use. Beyond agriculture, other drivers of land use change include industrialization and urbanization, which may further degrade natural resources and the environment.. Population is the major cause of land use changes over the time period. It becomes necessary to analyze the effect of population variables on land use pattern of the study area as. The relationship between different elements of land use and population variables are derive with the help of correlation co-efficient technique. The lists of variables used for analysis are as follows:

Land use elements



CORRELATION BETWEEN POPULATION VARIABLES AND LAND USE
CORRELATION VALUE
2
1
0
-1
-2
-3
-4
0.53
0.76
-0.19
-0.34
-1
POPULATION GROWTH
0.74
0.49
0.075
-0.59
-1
NO OF TOWNS
0.53
0.97
-0.69
-0.94
-1
SEX RATIO
0.95
0.07
0.49
-0.87
-1
POPULATION DENSITY
0.36
0.83
-0.38
-0.16
-1
URBAN POPULATION
NET SOW AREA
FALLOW LAND
CULTURABLE WASTE
BARREN LAND
NON-AGRICULTURE
FOREST



Population variables and forest cover: Proportion of forest cover is negatively correlated with all the variables, indicating that higher the proportion of population variables, lower will be the forest cover. Growth of all population variables leads to large scale forest clearance for various human activities. Among the population variables, density of population shows the highest degree of negative correlation (0.972) and urban population the least (0.380)

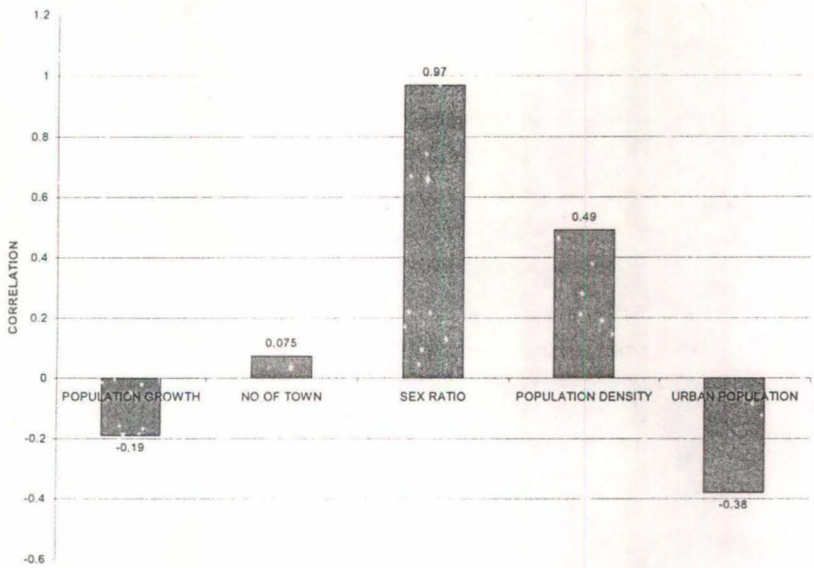


Fig No 4. Population variables and area under non-agriculture uses:

Population variables and area under non-agriculture uses: Study reveals that the proportion of agriculture is positively correlated with town, sex ratio, density, but negatively correlated with population growth and urban population. With the growing population, the demand for land resources has leads to construction of buildings, roads and railways, which ultimately results in reduction in non-agriculture use. Although proportion of area under town and density of population is positively correlated with area under non agricultural uses, but is insignificant which means the relationship a chance factor only

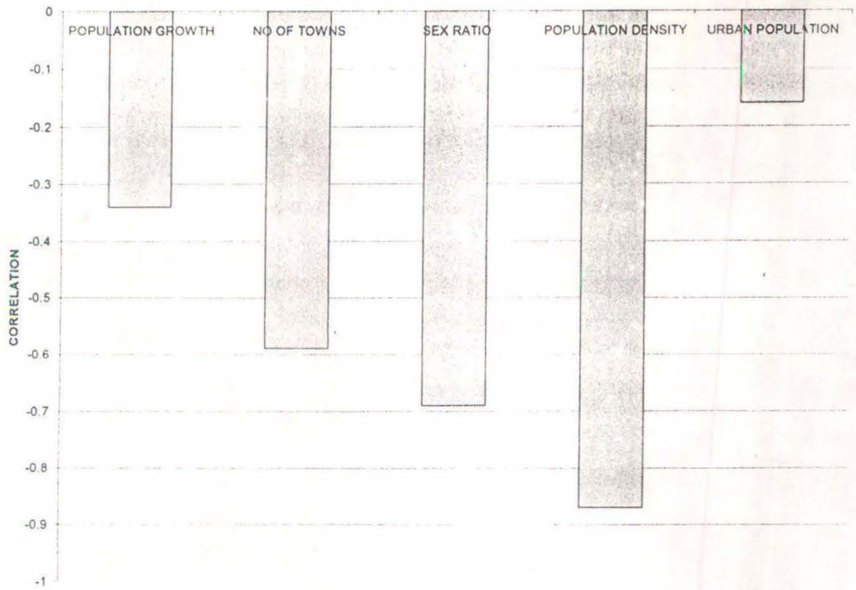


Fig No. 4.7 Population Variables And Barren Land

Population variables and barren land Proportion of area under barren land is negatively correlated with all the population variables, meaning that higher the proportion of barren land, lower is the proportion of population variables. Among the population variables density of population indicates highest negative correlation followed by sex ratio, total no of towns, population growth and urban population.

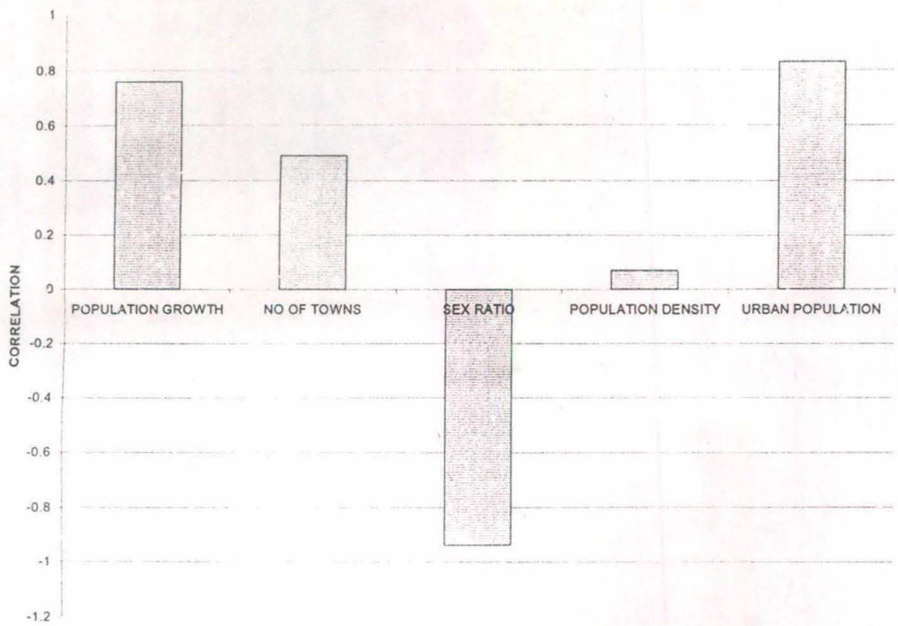


Fig No 4. Population variables and culturable waste:

Population variables and culturable waste: The proportion of culturable waste is negatively correlated with sex ratio, but positively correlated with population growth,, town, density of population, and urban population. The reason may be that, the increase in population pressure on land and growing demand for food in recent years has lead to exploitation of more culturable wasteland for agricultural purposes.

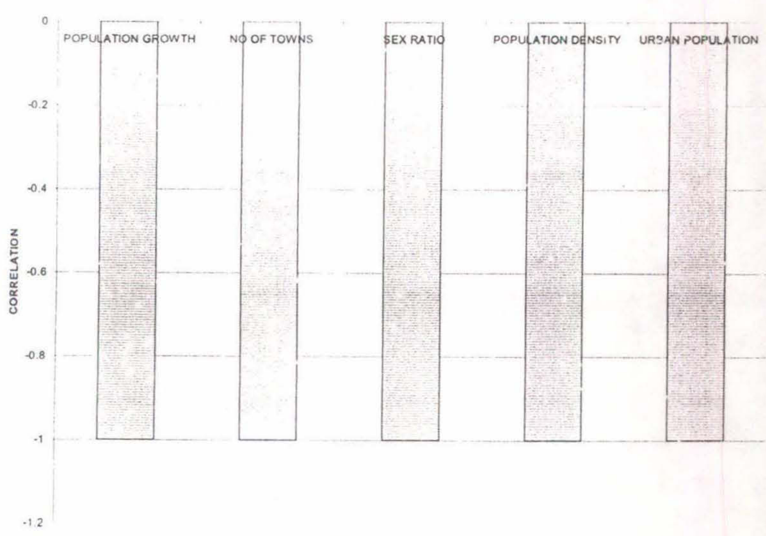


Fig No 4. Population variables and fallow land:

Population variables and fallow land: Proportion of fallow land is negatively correlated with all the population variables, indicating higher the proportion of population variables, lower will be the proportion of fallow land, since the growth of population leads to higher utilization of land resources.

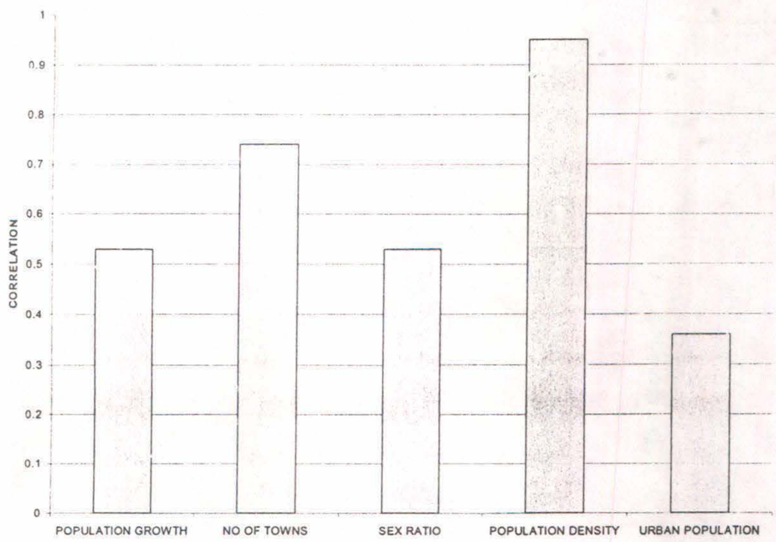


Fig No 4. Population variables net sow area

Population variables net sow area Study reveals that proportion of net sown area is positively correlated with all the population variables. Although urban population and area under net sown categories are positively correlated, but insignificant, meaning the relation ship as chance factor only. It may not show the same relation ship if larger observation are taken into account

CONCLUSION: Land is the most important resource of a region especially in a hilly state like Sikkim. With the population pressure in the state there has been significant changes in land use pattern over the decades. Forest constitutes the major land use category of Sikkim, but the total area under forest is steady decreasing over the period of study and the proportion of the non agricultural has increased from 1977-78 to 1990-91. Increasing pressure on agricultural area may be the cause for the reduction of forest cover during the study period. The relationship between population and land resource has been analyzed by correlation technique

CHAPTER V

LAND USE PLANNING FOR SUSTAINABLE DEVELOPMENT

Land use planning is the systematic assessment of physical, social and economic factors in such a way so as to encourage and assist land users in selecting options that increase their productivity with sustainability and meet the needs of society (FAO, 1993).The environment of which land is a vital component, acts as a highly sensitive system to provide the means of sustainability to all forms of life. The Agenda 21 of Chapter 10 of the United Nations Conference on Environment and Development (UNCED), held at Rio de Janeiro in 1992, focused attention on planning and management of land resources, to make management economically and environmentally sustainable and socio-economically acceptable. Soil and land degradation are perhaps more important and less spectacular but widespread

Planning is considered as an attempt, on the basis of available knowledge and insight, to lead the course of events in some desired direction. From the beginning of last century, natural resource inventories (*e.g.*, soil surveys, forest inventories, vegetation mapping,

wildlife resources, agro climatic mapping, present land use surveys) have provided the basic information for land use planning. Land use-planning aims at improving sustainable use and management of resources. This would imply that those who use and manage the resources are the key players in the planning process. Thus planning for sustainable land management can only be relevant and successful when all stakeholders are involved—

Fog No.5.3 Major Land Use System (KL Beek, KD Bie And P. Driessen

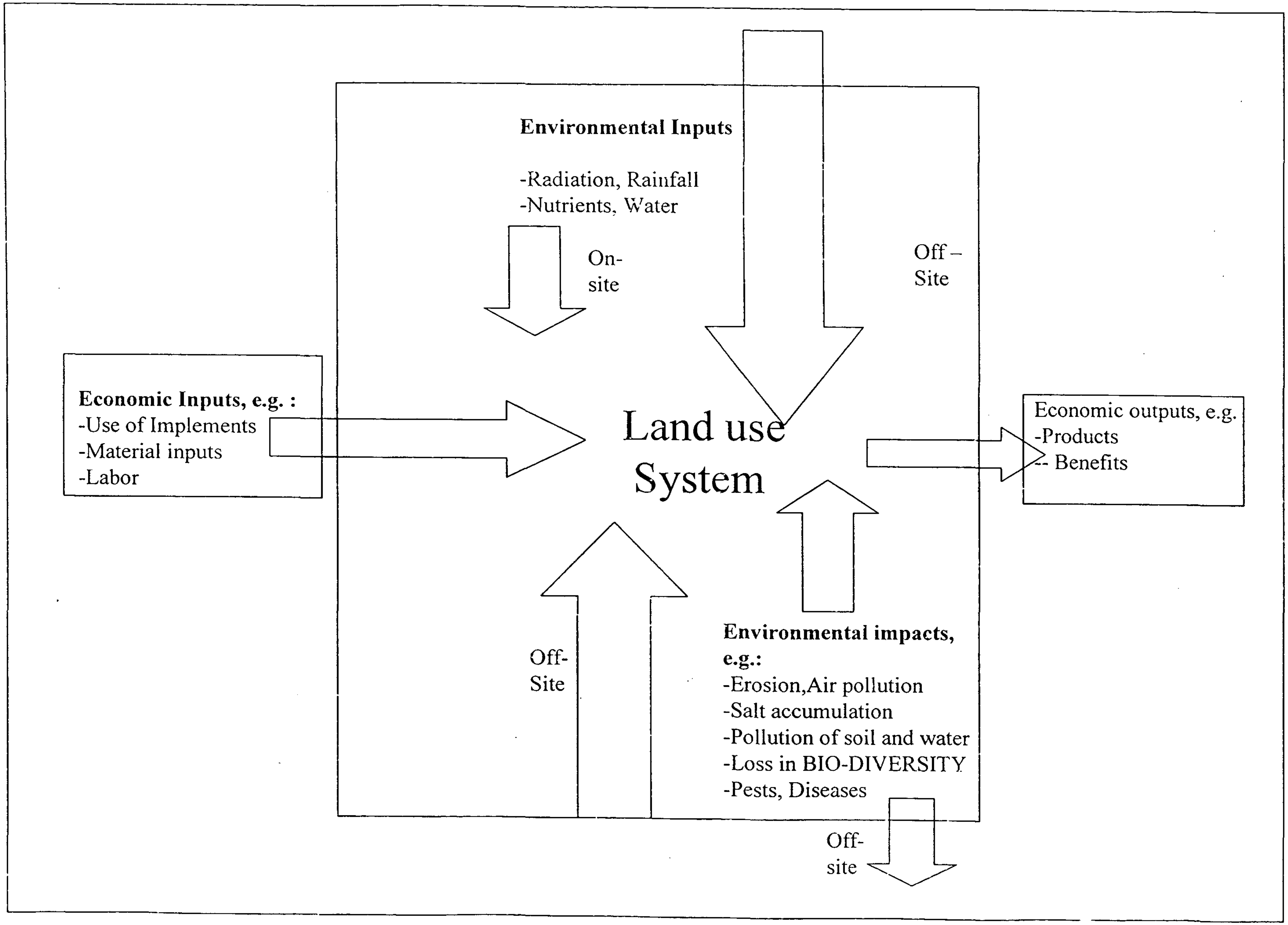


Fig No. 5.1 Elemets Of A Land Use System With Attributes That Influence The Holder 's Decision(Adapted From De Bie et al, 1996)

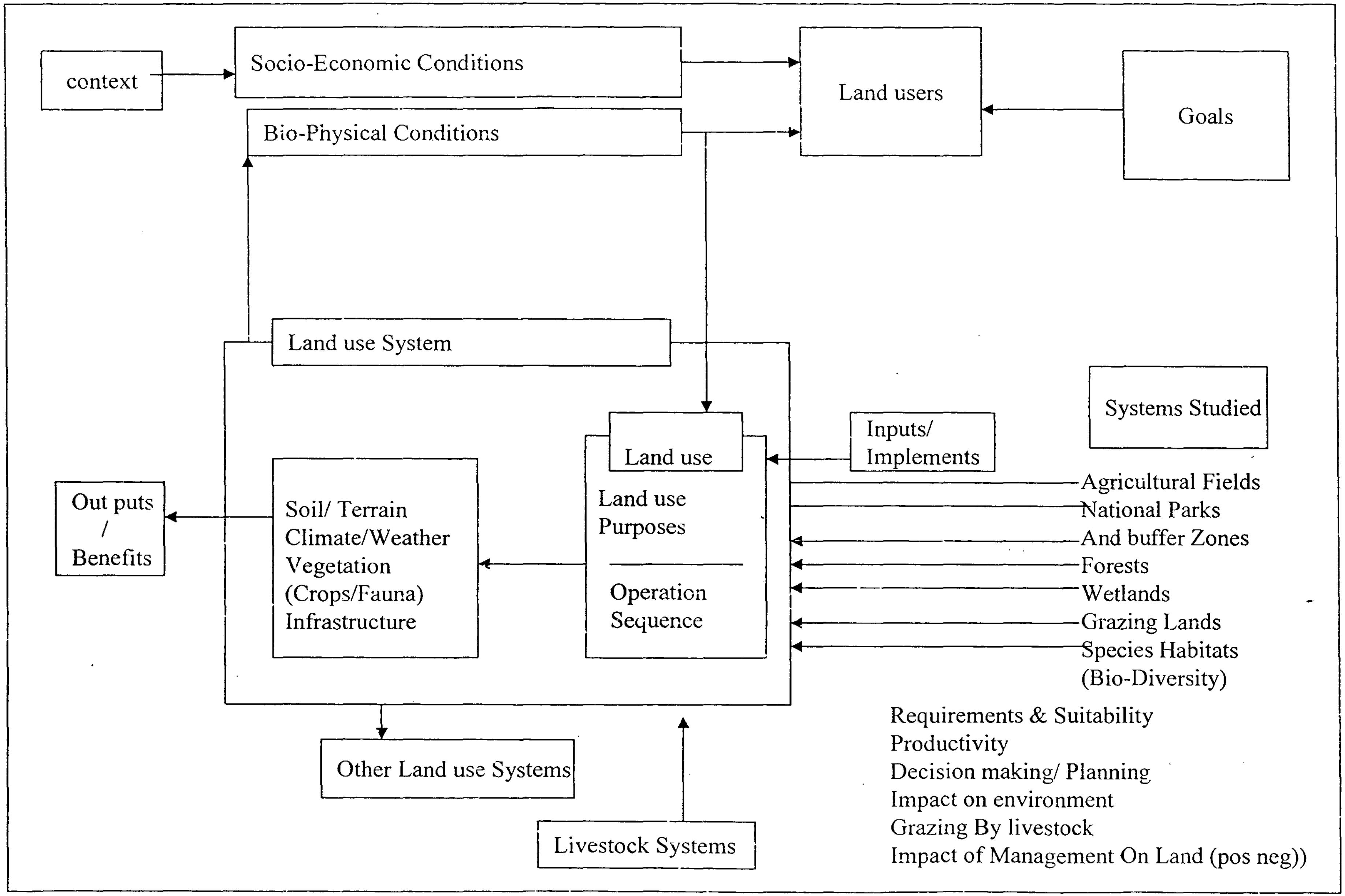
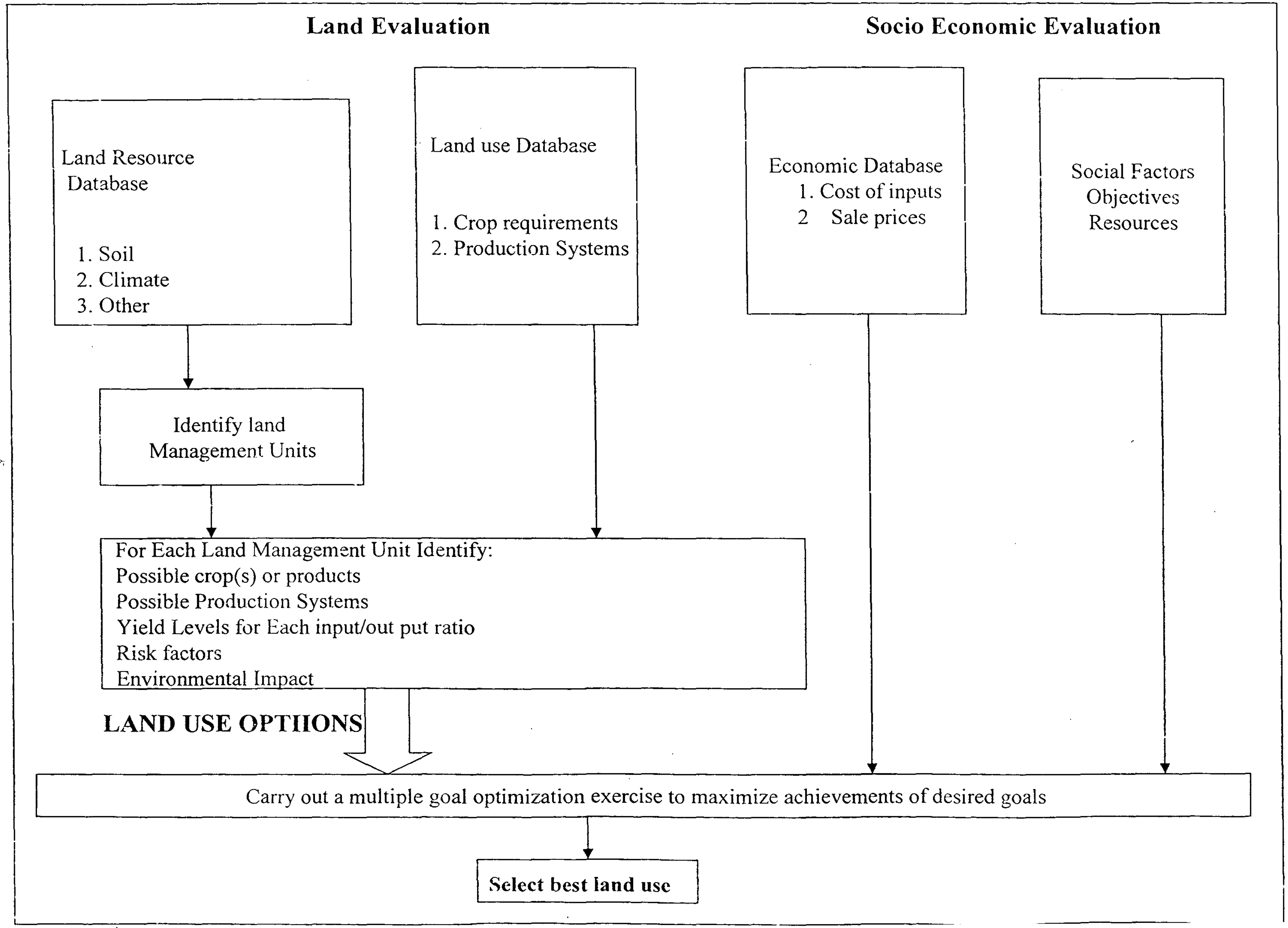


Fig.No 5.2 Decision Support System For Land Use Planning (F A O,1995)



hence the development and/or use of more participatory approaches to land use planning Improved use and management of resources incorporated by identifying land use problems, conflicts over use, exploitation and under utilization. Better management through solving conflicts and reaching agreements between different user groups is one possible solution to resource use planning. Different planning methods for sustainable land use have been applied for planning sustainable land management.

Planning decisions may not always be scientific because of conflicts among sectoral interests, government policies and the priorities of landowners. Therefore, planning directives for implementation should be based on compromisation among several interests without risking the principles of land capability, sustainability and environmental security for agriculture, forests, horticulture, grasslands, urban development, mining, infrastructure facilities, recreation and others. Suitable planning of land use with reference to the nature of land and needs of the community would provide maximum returns of optimum land resources. Land use systems require constant monitoring and adaptation to maintain food security, minimize deforestation, conservation of biological diversity, reduction of green house gas emissions, protection of environments and enhancement of health and safety of human occupation to the changing social, economic and natural environments.

Land evaluation is only a part of the process of land use planning. Its precise role varies in different circumstances. In the present context it is sufficient to represent the land use planning process by following the generalized sequence of activities and decisions:

i). Recognition of a need for change;

ii). Identification of aims;

iii). Formulation of proposals, involving alternative forms of land use, and recognition of their main requirements;

iv). Recognition and delineation of the different types of land present in the area;

v). Comparison and evaluation of each type of land for the different uses;

vi). Selection of a preferred use for each type of land;

vii). Project design, or other detailed analysis of a selected set of alternatives for distinct for distinct parts of the area. This, in certain cases, may take the form of a feasibility study.

viii). Decision to implement;

ix). Implementation;

Land use planning normally places more emphasis on the process than on the outcome of a blueprint plan. This requires a thorough understanding of the land/resource users (stakeholders) and an understanding of the decision- making processes in resource use. This focus on users implies that user's needs, user's priorities, their constraints and possibilities need to be considered in planning. The collective efforts of those immediately responsible for managing resources. Improved use and management of resources involves

i) Identifying land/resource use issues; conflicts over use,

ii) Exploitation and underutilization; and finding appropriate "solutions". Possible solutions include:

iii) Better management through solving conflicts and reaching agreement with different user groups

iv) Introducing new technologies.

The concept of sustainable land management is being increasingly applied in land management decisions. Land provides an environment for agricultural production, but it is also an essential condition for improved environmental management (source/sink functions for greenhouse gases, recycling nutrients, ameliorating and filtering pollutants, transmitting and purifying water as part of the hydrologic cycle, etc).(reference) The sustainable land utilization of hills involves the management and conservation of natural resources (land, water and forest) to maintain the quality of environments for favour of the present and future households and community's needs.

The concept of sustainable land management (SLM) grew out of a workshop in Chiang Rai,, Thailand, 1991(Julian Dumanski, ITC Journal 1997-3/4). The definition of sustainable land management calls for integrating technologies, policies and activities in the rural sector, particularly agriculture, in such a way as to enhance economic performance while maintaining the quality and environmental functions of the natural resource base. Five criteria, called the pillars of SLM, were identified: productivity, security, protection, viability and acceptability.

Sustainable land management (SLM) will not be achieved on the basis of technologic and scientific advances alone; changes in institutional and economic structures will also have to be part of the solution. For example, soil conservation technologies and programmes, which were originally designed for rehabilitating degraded areas, must move more into programmes of preventative maintenance;

i) Reduce the level of production risk

ii) Protect the potential of natural resources and prevent degradation of soil and water quality

iii) Be economically viable

iv) Be socially acceptable."

planning of area development can be best achieved on a natural drainage unit called 'watersheds' with a view to develop resources in such a manner so as to get maximum benefits to the people by maintaining ecological balance through continued long-term efforts and commitments; for example maintenance of infra-structure, protection and judicious use of land, water and forest resources to meet the continued demands, etc. Implementation of the land use planning at catchments for the hilly terrain of Sikkim should be based on following objectives:

a) Steep lands under watershed programmes with appropriate soil and water conservation practices have should be taken into consideration for the economy and environmental risks.

b) The preservation of natural ecosystems, scenic areas and wildlife habitat represent another dimension of watershed projects. The preservation of ecosystems, particularly those with threatened species, could be in the interest of ecology and society as a whole. In such instances, the importance of an ecosystem may not readily be evaluated on the basis of economics, but the expected benefits should be explicitly described in the appraisal. High quality water is usually associated with forested watershed that should be well managed, having sparse human populations, few grazing animals and least soil erosion. According to established practice, climate, soil, land form, hydrology etc. of an area, the human intervention should be restricted to the choice of a crop, a livestock or a forest type.

ECOLOGICAL MANAGEMENT OF LAND RESOURCES

The developmental activities in Sikkim have started off, but unfortunately, the impacts have been negative which further stressed the land resource of the state. A pragmatic programme for the land management and land use planning, which should lead to a workable land use policy in Sikkim involves the following.

5.1AGRICULTURE

Agriculture should incorporate the concept of watershed development programme based on catchments and micro planning at the lower levels for formulating cropping plans, taking physical parameters into consideration particularly for varied soil and different climatic condition. Agriculture is the mainstay of the economy for the state, and only sustainable agriculture is likely to provide the long-term benefits required to achieve development and poverty alleviation. Proper planning and management of the available resources is necessary to ensure maintenance of their production potential, quality and diversity. Sustainable land management, if properly designed and implemented, will ensure that agriculture becomes part of the environmental solution, rather than remaining an environmental problem. Indicators of land quality are needed to guide us along the way. Agricultural intensification is often necessary to achieve more sustainable systems. This means matching land uses to the constraints of local environments, planning production within biologic potentials, and carefully limiting the use of fertilizers, pesticides and other inputs in order to ensure they do not exceed the capacity of the environment to absorb and filter any excess. It requires a policy environment where local decision makers, including farmers, reap the benefits of good land use decisions but are held responsible for inappropriate land uses.

1) Implementation of intensive and improved cultivation practices so that productivity per unit area increases, particularly in the higher hills.

2) Introduction of advanced agricultural practices and scientific management of land and water resources of the state and adoption of watershed management development programme.

3) Intensify agriculture research and management programmes.

In view of the ecological and reclamation of degraded land, water and soil resources of the state, effort should be directed in bringing barren and degraded lands under forest cover, steeper slopes should be brought under perennial shrubs and trees and waste land should be developed in scientific manner.

5.2 HORTICULTURE

The wide range of agro-climatic variation in Sikkim, from sub-tropical to alpine, provides a good scope for growing large number of fruits like mandarin (orange), guava, mango, banana, avocado, peach, plum, pear, apple etc. All kinds of vegetables and flowers like orchid, gladiolus, ornamental and house plants have good potential for growth. The land which is not suitable for seasonal crops remains barren and unproductive Horticultural development can be developed on the degraded and denuded areas, which may help in controlling the soil erosion and conserving water. Horticulture should be given high priority, and encourage proper land use, especially on the steep slopes where agriculture is discouraged. This can be achieved through:

1 Increasing the area under to horticulture by laying emphasis on fruits, vegetables, spices etc

2 Increasing productivity per unit area in existing horticultural land by proper management and marketing facilities.

3. Increasing infrastructural facilities and strengthening the training and research programmes.

4. Mixed land use system comprising agriculture and horticulture.

5 .Government involvement on large scales.

5.3 LIVESTOCK BASED FARMING SYSTEM

The climate and topography of the areas favors the development of livestock farming. Livestock faming can be developed in the steep slopes with minimum soil depth This type of land use is expected to retain greater percentage of moisture and restrict soil erosion. Livestock farming has potential for substantial income growth from animal products. These animals also provide manure to meet the plant nutrient requirement. The objective of livestock farming is to increase productivity per unit. This can be achieved through the following measures

1. Increasing quality and quantity of fodder resource for the livestocks.
2. Cattle raising according to the carrying capacity of the land
3. Cross breeding programmes for healthy livestock population and production.
4. Training programmes on livestock product and its marketing
5 Credit facilities for the marginal farmers

5.4 FORESTRY

Forests, hydrologically and from erosion control point of view, provide more protection due to closed system as long as they are maintained as forestlands. Even after cutting of trees, re-growth of vegetation quickly restores any hydrological or erosion impacts to pre-harvest level, at least in the more humid zone. Open/degraded forestland + forest blank + scrubs in reserve forest and alpine scrub occupy 38% of the geographical area ($2709 km^2$) (Anonymous, 1996 *Sikkim State Annual Plan* 1996-97. Planning and Development Department Government of Sikkim, Gangtok.). In order to restore these are as an integrated approach is needed through. In the initial stage, severely eroded lands require complete forest cover of local origin, coupled with protection from grazing. The local perennial tall tufted grass species amliso (*Thysanolaena agrostis*) can reclaim and protect the degraded land, terrace risers, water ways, land between trees, and vulnerable points and provides fodder to animals in winter along with spikes for brooms.

Appropriate agro-forestry system has the potential to check soil erosion, maintain soil organic matters and physical characteristics, augment nitrogen buildup through nitrogen fixing trees and promote efficient nutrient cycling. In Sikkim, agro-forestry is an integral part of the farming system, where trees are integrated extensively with crop and livestock production. Large cardamom with shade trees on hill slopes, other wise unsuitable for any other crop production, is ecologically sustainable. The combination of trees, grasses, herbs and shrubs along with large cardamom plantation arrest the flow of water, reduce the risk of soil erosion and water related hazards. Besides this, fodder trees are extensively grown around the settlement, roadsides, on field bunds and small patches of land. Bamboo thickets along the drainage channels on steep slope, grasses on terrace risers and on marginal land stabilize the soil against degradation and land productive. The multistory homestead gardening and mandarin (*Citrus reticulata* Blanco) based cropping system possess the inherent capacity to arrest land denudation. All the existing systems optimize the positive interaction among components (trees/shrubs and crops/animals) to obtain a more diversified and/or more sustainable production from the available resources and physical environments that is possible under socio-economic conditions. The varieties of climate due to altitude further provides ample scope for growing a variety of agricultural crops, multipurpose tree species and fruits of tropical to temperate climates in Sikkim for the effective utilization of land under agro-forestry for its sustainability.

The major thrust of the objective of forestry programme should as follows

1. Ensure ecological security, environmental conservation and resource base.

2. Afforestation programmes with emphasis on multistoried forests.

Upgrade the grasslands. Cultivation of grass, fodder and fuel wood in fallow and agricultural waste and specially in marginal unproductive lands

Improvement of road and transport system for better utilization of high altitude coniferous forest of west Sikkim.

Development of pastures for grazing purpose.

Encouraging plant soil binding species like Agave to control land slides and erosion

Regeneration of degraded and denuded lands by afforestation programmes.

Provision of fuel, fodder and timber needs for the population.

5.5 SOIL EROSION AND PROTECTION:

Soil erosion is a disastrous phenomenon in the hilly areas. The most serious effect of soil erosion results into loss of most fertile top soil and exposure of infertile acid subsoil, decrease of plant available water capacity, degradation of soil structure, non uniform removal of soil surface and ultimately decrease of economic return on production. Soil conservation not only includes control of erosion, but also recognizes equally the importance of soil fertility maintenance.

Thus adoption of appropriate soil and water conservation measures is considered to be the only way to control soil erosion and to improve the degrading environment. Initially water conservation programmes were confined to the improvement of agricultural lands and contour bunding was the principal activity. In the last few decades the water shed based farming system with mechanical soil conservation method like contour trenches, bench terracing of slopes, contour bunds and runoff harvesting, grass waterway retain maximum rainwater within the scope of slope, safely disposing off the excess runoff to the piedmont with non erosive velocity. Providing of vegetative cover through fuel- fodder plantation is one of the most effective ways of soil and water conservation of non agricultural lands.

5.5 (a) SOIL CONSERVATION MEASURES

The watershed based farming system should be coupled with mechanical soil conservation measures like contour trenches, contour bunds, bench terraces, half moon terrace, grassed water way and so on to retain maximum rain water within slope, safely disposing off the excess runoff to the piedmont with non erosive velocity (Patiram, R.K.Avasthe, 2003) suggested the following measures for soil conservation

5.5 (b) CONTOUR TRENCHES

These are trenches excavated along the contour to break the slope length for reducing the velocity of surface runoff. Water is retained in the trenches and helps in conserving the moisture. The size of trenches depend upon the soil depth, and its cross section may vary from 100 sq cm to 2500 sq cm. These are designed according to the rainfall amount to be retained per unit area.

5.5 (c) CONTOUR BUNDS

These are small embankments or bunds constructed across the slope to decrease the slope length, which reduces soil erosion and diverts the excess runoff to the designed outlet. The eroded soil is retained within the bund interspaces, which get leveled up in the course of few years to form bench terrace. These bunds on steep slopes are created by way of excavated parabolic channels on contour and keeping the dugout soil in the form of a bund at the lower edge of the channel

5.5 (d) BENCH TERRACES

Bench terraces are series of flat beds constructed across the hill slope, separated at regular intervals in a step like formation. Manual labor as well as bulldozer can be engaged to form bench terraces. Bench terraces with inward slopes are adopted in high rainfall areas. The alignment of bench terraces on slopes should be made to obtain convenient, width making deviations wherever necessary for depressions. These measures are normally adopted where soil depth is more than 1 meters. Terracing of the entire hill slope is not necessary since trees and horticultural crops can be raised without terraces. Only the lower portion of the hills needs to be terraced for agricultural crops. The terrace risers can be utilized for growing perennial fodder grasses and legumes, which not only help in conservation but also provide enough fodder.

5.5 (e) VEGETATIVE BUNDS

Barrier hedges substantially reduce runoff and increases infiltration. Some of runoff may cross the barrier, while the entrained soil will be partly filtered out and deposited. Pineapple plantation has been successfully used as vegetative bunds in the hills.

5.5 (f) RUNOFF COLLECTION, STORAGE AND RECYCLING

Runoff is a natural process of hydrological cycle. Runoff can not be eliminated but can only be minimized. The runoff must be stored in the catchments area to reduce the flurry of flash floods. Runoff recharges the ground water. The runoff water collected can be used either as pre sowing irrigation or life saving irrigation.

5.6 LAND DEGRADATION

Degraded lands include those lands where condition has deteriorated to such an extent that it can not be put to any productive use as such, except current fallows due to various constraints. Degraded lands of Sikkim mainly have resulted due to over exploitation of forest for fuel, timber and fodder, improper land use practices and infrastructure development. Theng (1991) in his review essay addressed three soil related issues: forest resources and deforestation; degradation of soil resources and soil management as integral parts of sustainable land management. Soil erosion is one of the major causes of soil degradation on steep slopes land devoid of vegetative cover and often subjected to landslides or landslips during rainy season (May to September). Before restoration of degraded lands, the stabilization of landscape against erosion or slope failure is essential. It can be done through the grading of slopes before surface treatment and re-vegetation or cut-off-ditches with a variety of terraces. With an effective vegetation cover, the establishment of plants may control gradients without supplemental mechanical measures in protecting the landscape against water erosion. Catastrophic events (such as land slides) cannot be altogether prevented, but management action can be implemented to reduce the frequency of events by preventing human occupation, economic development therein, and planting of deep-rooted trees and/or shrubs on steep slopes.

Soil degradation by erosion is often non-reversible, particularly where a top fertile soil is replaced by a compact acid sub-soil, through adverse changes in physical, chemical and biological properties. The rate of soil degradation by different processes is generally increased by unsuitable methods of soil and crop management. Consequently, soil degradation sets in resulting in widespread occurrence of sheet and gully erosion.

5.6 (a) RESTORATION OF LAND DEGRADATION

Understanding the processes, factors and causes of land degradation is a basic prerequisite towards successful restoration of the productivity of degraded lands. Knowing the stage of soil degradation is an important step to restore the soil quality and its productivity by preventing soil erosion, promoting high biological activity, increasing soil organic matter content and increasing rooting depth of plants. There are two approaches that have been used to reclaim degraded soils and intensify agricultural production from areas already under cultivation.

1. Engineering approaches
2. Ecological approaches

5.6 (b) ENGINEERING APPROACHES

Engineering approaches are used in cases of extreme degradation, where other approaches are not possible or slow. Contour ridges, check dams and bench terraces involve high cost of construction and maintenance, which poor farmers cannot afford to invest. Ecological measures are more effective when used in combination with engineering techniques. By adopting terracing and protected waterways, the steep slope could be cultivated safely and profitably. Any small damages in terraces should be immediately repaired before it becomes worse. Many terrace areas have failed not because of design or construction, but owing to negligence in protection and maintenance. The terrace risers can be planted with local grasses to protect the soil loss and produce forage for cattle. The terrace outlets are well protected either "sod-forming" grasses or using a piece of rock or brick to form a check. Ford culverts and bridges are needed in large numbers for crossing small streams, sediment, debris etc. to remove the water before it has a chance to stabilize and cause erosion. Slope stabilization includes re-vegetation and other bio-engineering measures to control surface erosion on road cut and fill slope, waste and borrow areas. During construction of road, to avoid mass movement of soil, the best way is to place the culverts to the natural stream channel as closely as possible.

5.6 (c) ECOLOGICAL APPROACHES

The ecological approaches involve the manipulation of inherent soil processes to check the soil degradation. Practical method of controlling water erosion require that a cover be maintained over the soil at all times to break the erosive force of the rain. Farmers, foresters and pastoralists who use land for production and sustained output of plant materials year after year depends on maintaining the quality and quantity of soil as a rooting medium and supporting the dynamics of the biological self renewed capacity of soil (Shaxson 1981). The objective of conservation is to work out how to satisfy people's aesthetic and physical needs from the land without harming or destroying its capacity to go on satisfying those needs in the future (Shaxson *et al.*, 1989). The ecological approaches to restore land degradation includes following objectives:

1 To stabilize slopes and control of sedimentation in the stream,

2 To establish dense and diverse vegetative cover to provide ecological stability to the site and act as soil amendments,

3 To ensure nutrient cycling and enrichment of soil,

4 To fulfill fuel, fodder and other requirements of local people, and

5 To enhance the ameliorative value of the site.

The main ecological approaches are described in brief for the sustainability of land.

5.7 WATERSHED MANAGEMENT

Integrated watershed is being widely used as an important indicator for checking soil erosion, rejuvenating degraded land, increasing food and fodder production. The strategy of integrated watershed management programme envisages ecological and optimal utilization of resources in scientific way. Watershed is a natural drainage unit, where all the ecological process are inherently linked to both biotic and abiotic. Watershed should form the basis for land use planning. The strategy is to rejuvenate the ecology by optimal utilization of resources in scientific way. The management programmes should include the following approach:

1. Watershed based farming system

2 To minimize soil erosion and surface runoff

3. Participation of the peoples and their productive efforts through training programmes

CONCLUSION: Land is the most important and non renewable resource. Land provides not only an environment for agricultural production, but it is also an essential condition for improved environmental management. Planning is considered as an attempt, on the basis of available knowledge and insight, to lead the course of events in some desired direction, and its scientific management is of paramount important for land use planners. Land use incorporates physical, socio-economic, legal and institutional component, making it as a useful tool for addressing the land issues and its management. Different criteria can be adopted for sustainable management of land resources based on Land Capability Classification, Integrated Watershed management etc.

SUMMARY AND CONCLUSION

In the Preset study an attempt has bee made to study the various aspects of Land use changes in Sikkim. Sikkim is located on the Eastern Himalayas between the Chinese occupied Tibet. It lies between lat. 27° 04' and 28° 07' N and long 88° 00' and 88° 55' E.. It covers a geographic area of 7096 sq.kms with a north south extension of 112 kms and east-west extension of 64 kms. It is bounded in the north and northeast by west Tibetan plateau and in the west by Nepal. In the east it is bounded by Bhutan and the Chumbi valley of Chinese occupied Tibet and in the southeast by Bhutan. The southern boundary is about 45 kms. Sikkim has four political division: North, East, South and West. The North district with an area of 4226 sq kms is the largest and the South with an area of 750 sq kms is the smallest district. The West district has an area of 1166 sq kms and East district has an area of 954 sq kms.

Land use study carries a great importance because it provide a picture of intensively used, under used and unused land resources of a region and helps in proper planning and management of land resources Land use pattern is dynamic in nature. It changes with time to meet the various demand y society which may be governed by changes in composition, size or requirement of the society or due to technological changes. There has been phenomenal increase in Sikkim's population since independence.. In this direction developmental planning has been sought for the state. The conclusion derived from the present study has been summed up in the following text systematically as per chapter scheme, followed in the present study.

The first chapter of the study deals with the introduction, Objectives, Database and methodology and chapter scheme and review of available literature on related topic. Going through the available literature, it is clear that there is dearth of research dealing with the problem of Sikkim in a integrated manner. No study has been carried out so far which focus on the impact of land use change on environment in Sikkim

In the second chapter a brief description on the studied area has dealt. The chapter descries about the location, physiography, drainage, geology & minerals resources, soil, climate vegetation & population.

The third chapter deals with land use changes and its implication on environment in which various aspects of causes of Land use changes and its implications on environment has been analyzed.

In the Fourth chapter, the Land use pattern of the state has been analyzed. The analysis of Land use change cover in Sikkim reflects various distinguishable characteristics.

As the result of these changes the net sown area has increased from 61100 hectares in1977-78 to 95000 hectares in 1990-91. It is clear that there is sharp increase in the percentage of culturable waste land in proportion to the total geographical area. It increased from 1100 hectares in 1977 - 78 to 11500 hectares in 1980 81 but showed a very steep decline to 0.40 percent in 1990 -91 from 1.62 percent in 1980-81. There was substantial increase in area and culturable land in the initial decades. But the area under this category showed a sharp decline during the period 1985-86 and 1990- 91. In the year 1977-78 the total area under area and uculturable land shared a percentage of 29.453 of the total geographical area of the state, which gradually declined to 13.669 percent of the total geographical area during 1990-91.

The area under forest cover showed a gradual decline over the studied period. The total forest cover of the state in 1977- 78 was 37.373 percent which gradually declined to 36.956 percent in the year 1980- 81 followed by 36.217 percent in the year 1990-91.

The land use trend reflects that there was gradual increase in the area under land put to non-agricultural uses which implies that the there is gradual process of developmental activities being carried out in the state over the period of study. The area under non-agricultural uses was 9.864 percent during the period 1977-78. In the year 1980-81 there was decline in the area under non-agricultural uses which was 6.933 percent in 1980-81. This sharply increased to 13.66 percent during 1985-86.

Area under permanent pastures and grazing ground showed a negative trend during the period of study, which implies that this area has been put to other categories of land use especially these areas has been put to agricultural uses. The area under permanent pastures and grazing land was 14.444 percent in the year 1977-78 which declined to 9.723 percent during the year 1990-91. The area under trees miscellaneous trees crops and grooves at included in the net sown area was 5.918 percent during the period of 1977-78. This sharply declined to 0.563 percent during the year 1980 81, but increased marginally to 0.704 percent during the year 1985-86

The land use pattern showed that there was sharp decline in the area during 1980-81 under land put to fallow land. The fallow land occupied a total area of 14000 hectares which accounted for 1.972 percent of the total geographical area during 1977-78.This declined to 0.183 percent during the period 1990-91.

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Table. No. 2.1 Physiographic Unit Of Sikkim

Physiographical unit	Area (In percentage)
1. Summit and ridge	4.50
2. Escarpments	5.76
3. Very steeply sloping (70%)	19.02
4. Steeply sloping (33-50%)	33.49
5. Moderately steep sloping (15-30%)	2.21
6. Valleys	1.22
7. Cliff and precipitous slope	12.20
8. Glacial drifts/moraines/boulders	3.59
9. Perpetual snow	14.01

Source: Patiram; R.K.Avasthe And S.B.S.Bhudaria; Sustainable land use planning for the Sikkim Himalayas perspective and options, Himalayan Ecology 11(2)

Table No: 2.2 Average Monthly Suspended Silt Load In Teesta

Months	Chungthang (ham)	Dikchu (ham)
January	0.19	0.49
February	0.12	0.48
March	0.34	1.50
April	0.85	11.82
May	4.06	36.67
June	20.32	92.38
July	24.04	148.35
August	15.72	132.26
September	8.41	61.43
October	2.06	10.00
November	0.73	1.54
December	2.24	1.18

Source: Patiram; R.K.Avasthe And S.B.S.Bhudaria; Sustainable land use planning for the Sikkim Himalayas perspective and options, Himalayan Ecology 11(2)

Table No: 2.5 District-wise forest covers (1999)

Area (sq kms)

District	Geographical area	Dense Forest	Open Forest	Scrub	Total
North District	4,226	847	332	267	1179
South District	750	421	129	16	550
East District	954	501	115	68	616
West District	1,166	594	179	35	773
Total					3118

Source N.R.S.A

Table No: 3.1 Population of Sikkim

YEAR	POPULATION	DECENIAL VARIATION	DECENIAL VARIATION (%)	DENSITY
1901	59014	Nil	Nil	8
1911	87920	28906	48.89	12
1921	81721	6199	7.05	12
1931	109808	28087	34.37	15
1941	121520	11712	10.67	17
1951	137925	16205	13.34	19
1961	162189	24464	17.76	23
1971	209843	47654	29.38	30
1981	316385	106542	50.77	45
1991	406457	90072	28.47	57

Source: Census Of India, Various issues

TABLE 3.2 : Total Cultivated Area

(000 Hectares)

Year	Net Cultivated Area	Gross Cultivated Area
1977 78	61	65
1978 79	61	65
1980 81	86	91
1982 83	76	103
1994 95	95	127
1995 96	95	142
1999 2000	95	121

Source Fertilizer Statistics Of India, Various Issues

Table No: 3.3 Total Deforestation in Sikkim (in hectare)

Year	Total Geographical area	Forest cover	Variation	Percentage
1977-78	709600	265200	Nil	37.37
1980-81	709600	262200	3000	36.95
1985-86	709600	257000	5200	36.21
1998-99	709600	Nil	Nil	Nil

Source Agricultural Statistics, Various issues

Table3.4 Pastures land of Sikkim

Year	Pastures	Variation
1977-78	102500	nil
1980-81	102400	100
1996-97	69000	33400

Source: Agricultural Statistics

Table 4.1Land Use Pattern of Sikkim (1977- 78 to 1997- 98)

Land use categories	1977-78	1980-81	1985-86	1990-91
Geographical area	709600	709600	709600	709600
Forests	265200	262200	257000	257000
Non agricultural uses	70000	49200	97000	97000
Barren and unculturable waste land	209000	204800	173200	173000
Permanent pastures and Grazing land	102500	102400	69000	69000
Misc tree, crops & groves not included in net sown area	42000	102400	5000	5000
Culturable waste land	1100	11500	1000	1000
Fallow land	14000	N/A	1300	1300
Net sown area	61100	85600	85600	95000

Fig. No.Agricultural Statistics, Various Issues

Table No. 4.2 Variation in Different Land Use Pattern

FOREST AREA	-1.31	-1.983	nil
NON AGRICULTURAL USES	-29.7143	97.154	nil
BARREN LAND	-2.01	-15.43	-0.115
PASTURES & PERMANENT GRAZING LAND	-2.01	-15.43	-0.115
TREES, CROPS & GROOVES	-90.476	25	0
CULTURABLE WASTE LAND	945.455	-91.304	0
FALLOW LAND	945.455	-91.304	0
NET SOWN AREA	40.098	0	10.981

Table No: 4.3 Compound Growth Rate Of Land Use Categories

Land use categories	1977-78 TO 1980-81	1980-81 TO 1985-86	1985-86 To 1990-91
Forest area	-0.0378	-0.399	Nil
Non Agricultural uses	-11.809	14.541	Nil
Barren land	-0.674	-3.296	-0.023
Permanent land under Pastures & Grazing land	-0.032	-7.591	Nil
Culturable waste land	-54.332	4.563	Nil
Fallow land	118.659	-38.643	Nil
Net sown area	111.895	0	2.105

Table No: 4.5 Population Variables And Forest

POPULATION GROWTH	-0.58
NO OF TOWN	-0.97
SEX RATIO	-0.48
POPULATION DENSITY	-0.97
URBAN POPULATION	-0.42

Table 4.6: Population Variables And Non-Agriculture

POPULATION GROWTH	-0.19
NO OF TOWN	0.075
SEX RATIO	0.97
POPULATION DENSITY	0.49
URBAN POPULATION	-0.38

Tabl4.7: Population Variables And Barren Land

POPULATION GROWTH	-0.34
NO OF TOWNS	-0.59
SEX RATIO	-0.69
POPULATION DENSITY	-0.87
URBAN POPULATION	-0.16

TABLE4.8: Population Variables And Culturable Waste

POPULATION GROWTH	0.76
NO OF TOWNS	0.49
SEX RATIO	-0.94
POPULATION DENSITY	0.07
URBAN POPULATION	0.83

Table4.9: Population Variables And Fallow Land

POPULATION GROWTH	-1
NO OF TOWNS	-1
SEX RATIO	-1
POPULATION DENSITY	-1
URBAN POPULATION	-1

Table 4.10 Population Variables And Net Sown Area

POPULATION GROWTH	0.53
NO OF TOWNS	0.74
SEX RATIO	0.53
POPULATION DENSITY	0.95

Correlations

		Forest Area	Non-agri.	Bbarren	Pasture	Trees,Crops	Waste Land	Fallow Land	NS Area
Forest Area	Pearson Correlation	1.000	-.777	.976*	.954*	.781	.313	1.000**	-.851
	Sig. (2-tailed)	.	.223	.024	.046	.219	.687	.000	.149
	Sum of Squares and Cross-products	49390000	-2.2E+08	2.3E+08	2.2E+08	177600000	19910000.0	69426666.7	-1.5E+08
	Covariance	16463333	-7.3E+07	7.8E+07	7.5E+07	59200000.0	6636666.67	34713333.3	-5.0E+07
	N	4	4	4	4	4	4	3	4
Non-agri.	Pearson Correlation	-.777	1.000	-.895	-.930	-.214	-.841	-1.000**	.375
	Sig. (2-tailed)	.223	.	.105	.070	.786	.159	.000	.625
	Sum of Squares and Cross-products	-2.19E+08	1.6E+09	-1.2E+09	-1.2E+09	-278000000	-306380000	-228600000	3.8E+08
	Covariance	-73126667	5.4E+08	-4.1E+08	-4.2E+08	-92666666.7	-102126667	-114300000	1.3E+08
	N	4	4	4	4	4	4	3	4
Bbarren	Pearson Correlation	.976*	-.895	1.000	.996**	.627	.511	1.000**	-.733
	Sig. (2-tailed)	.024	.105	.	.004	.373	.489	.003	.267
	Sum of Squares and Cross-products	232760000	-1.2E+09	1.2E+09	1.1E+09	688200000	157300000	303953333	-6.3E+08
	Covariance	77586667	-4.1E+08	3.8E+08	3.8E+08	229400000	52433333.3	151976667	-2.1E+08
	N	4	4	4	4	4	4	3	4
Pasture	Pearson Correlation	.954*	-.930	.996**	1.000	.558	.583	1.000**	-.676
	Sig. (2-tailed)	.046	.070	.004	.	.442	.417	.000	.324
	Sum of Squares and Cross-products	224265000	-1.2E+09	1.1E+09	1.1E+09	604000000	176765000	283633333	-5.7E+08
	Covariance	74755000	-4.2E+08	3.8E+08	3.7E+08	201333333	58921666.7	141816667	-1.9E+08
	N	4	4	4	4	4	4	3	4
Trees,Crops	Pearson Correlation	.781	-.214	.627	.558	1.000	-.349	1.000**	-.948
	Sig. (2-tailed)	.219	.786	.373	.442	.	.651	.000	.052
	Sum of Squares and Cross-products	177600000	-2.8E+08	6.9E+08	6.0E+08	1046000000	-102200000	313266667	-7.7E+08
	Covariance	59200000	-9.3E+07	2.3E+08	2.0E+08	348666667	-34066667	156633333	-2.6E+08
	N	4	4	4	4	4	4	3	4
Waste Land	Pearson Correlation	.313	-.841	.511	.583	-.349	1.000	1.000**	.165
	Sig. (2-tailed)	.687	.159	.489	.417	.651	.	.000	.835
	Sum of Squares and Cross-products	19910000	-3.1E+08	1.6E+08	1.8E+08	-102200000	82170000.0	846666.667	3.8E+07
	Covariance	6636666.7	-1.0E+08	5.2E+07	5.9E+07	-34066666.7	27390000.0	423333.333	1.3E+07
	N	4	4	4	4	4	4	3	4
Fallow Land	Pearson Correlation	1.000**	-1.000**	1.000**	1.000**	1.000**	1.000**	1.000	-.963
	Sig. (2-tailed)	.000	.000	.003	.000	.000	.000	.	.173
	Sum of Squares and Cross-products	69426667	-2.3E+08	3.0E+08	2.8E+08	313266667	846666.667	107526667	-2.5E+08
	Covariance	34713333	-1.1E+08	1.5E+08	1.4E+08	156633333	423333.333	53763333.3	-1.2E+08
	N	3	3	3	3	3	3	3	3
NS Area	Pearson Correlation	-.851	.375	-.733	-.676	-.948	.165	-.963	1.000
	Sig. (2-tailed)	.149	.625	.267	.324	.052	.835	.173	.
	Sum of Squares and Cross-products	-1.50E+08	3.8E+08	-6.3E+08	-5.7E+08	-770600000	37565000.0	-247226667	6.3E+08
	Covariance	-50105000	1.3E+08	-2.1E+08	-1.9E+08	-256866667	12521666.7	-123613333	2.1E+08
	N	4	4	4	4	4	4	3	4

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).