A GEOMORPHOLOGICAL AND LAND USE STUDY OF KIILE RIVER BASIN, EASTERN HIMALAYA, ARUNACHAL PRADESH

A Thesis submitted for degree of Doctor of Philosophy in Geography

Supervised
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CERTIFICATE

It is certified that Ms Tage Rupa worked under my guidance and supervision for the preparation of her thesis entitled ***"A Geomorphological and Landuse study of Kiile River Basin, Eastern Himalaya, Arunachal Pradesh".*** *Ms Rupa has fulfilled all the requirements relating to the submission of the thesis for Ph.D degree in accordance to the ordinance of Rajiv Gandhi University. To the best of my knowledge this thesis is the result of her own investigations during the prescribed period and has not been submitted for any other degree in this or any other University.*

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CONTENTS

Page No.

Acknowledgement

List of Tables

List of Figures

List of Plates

Chapter-I INTRODUCTION 1- 26

1.1 Statement of Problem

1.2 Development of Geomorphology

1.3 Landuse mapping

1.4 Role of geomorphology in land use planning and management

1.5 Objective of study

1.6 Study area

1.7 Methodology

1.8 Literature review

1.9 Data base

1.10 Organisation of work

Chapter - II PHYSICAL BACKGROUND 27 - 48

2.1 Introduction

2.2 Altitudinal zone

2.2.1 Low Altitude (< 1100m)

2.2.2 Moderately Low (1100m – 1300m)

2.2.3 Moderate (1300m – 1500m)

2.2.4 Moderately High (1500m – 1700m)

2.2.5 High (1700m – 1900m)

2.2.6 Very High (>1900m)

2.3 Geology

2.3.1 Lithology

2.3.2 Structure

2.4 Climate

2.5 Vegetation

2.6 Soil

2.7 People

Chapter – III RELIEF AND SLOPE ANALYSIS 49 - 89

3.1 Introduction

3.2 Relative Relief

3.2.1 Low Relative Relief (below 100m)

3.2.2 Moderate to moderately high relative relief (100m – 300m)

3.2.3 High to very high relative relief (300m to 400m and above)

3.2.4 Statistical Analysis

3.3 Absolute Relief

3.3.1 Distribution of absolute relief

3.3.2 Statistical Analysis

3.4 Dissection Index

3.4.1 Distribution of dissection index

3.5 Profiles

3.5.1 Serial profiles

3.5.2 Superimposed profile

3.5.3 Projected profile

3.5.4 Composite profile

3.6 Area-Height Curves

3.7 Hypsometric Analysis

3.8 Altimetric Frequency Analysis

3.9 Average Slope

3.9.1 Area of very gentle slope (below 5°)

3.9.2 Area of gentle slope (5° - 10°)

3.9.3 Area of moderate slope (10° - 15°)

3.9.4 Area of moderate steep slope (15° - 20°)

3.9.5 Area of steep slope (20° - 25°)

3.9.6 Area of very steep slope (above 25°)

3.10 Central Tendencies and Dispersions:

3.11 Slope In Percentage

3.12 Correlation between Slope and Relative Relief

3.13 Correlation between Slope and Absolute Relief

3.14 Slope Type

3.14.1 Convex

3.14.2 Concave

3.14.3 Undulating

3.14.4 Uniform/rectilinear

3.15 Regional distribution of slope types

3.16 Slope Aspect

Chapter – IV BASIN MORPHOMETRY 90 - 122

4.1 Introduction

4.2 Drainage Network

4.3 Drainage Pattern

4.3.1 Dendritic drainage pattern

4.3.2 Rectangular drainage pattern

4.3.3 Radial drainage pattern

4.3.4 Parallel drainage pattern

4.4 Basin Morphometry

4.4.1 Stream ordering

4.4.2 Bifurcation ratio

4.4.3 Law of stream numbers:

4.4.4 Length ratio and law of stream length

4.4.5 Sinousity indices

4.5 Areal aspects of the basin

4.5.1 Geometry of basin shape
4.5.2 Drainage density
4.5.3 Drainage frequency
4.5.3.1 Poor Drainage Frequency
4.5.3.2 Moderate drainage frequency
4.5.3.3 Moderately high drainage frequency
4.5.3.4 High drainage frequency
4.5.3.5 Very High drainage frequency
4.6 Longitudinal Profile
4.7 Basin Input – Output Analysis
4.7.1 Water discharge

Chapter - V GEOMORPHOLOGICAL MAPPING 123 - 141

5.1 Introduction
5.2 Geomorphic Units
5.2.1 Flat valley floor
5.2.2 Isolated hills
5.2.3 Valley floor adjoining dissected hills
5.2.4 Weathered high hills
5.2.5 High structural hills
5.2.6 Low Relief subdued hills
5.2.7 High Relief Dissected Hills
5.2.8 Low relief dissected hills
5.2.9 Steep side slope valley
5.3 Geomorphic Processes and Landform Development
5.3.1 Fluvial process
5.3.2 Colluvium
5.3.3 Weathering process
5.3.4 Lacustrine process

Chapter – VI LANDUSE ANALYSIS 142 - 178

6.1. Introduction

6.2 Existing Landuse

6.2.1 Wet Rice Cultivation

6.2.2 Bamboo and pine grooves

6.2.3 Degraded area

6.2.4 Degraded forest

6.2.5 Degraded land with dense mixed shrubs

6.2.6 Dense mixed jungle

6.2.7 Dense shrubs and scattered trees

6.2.8 Helipad

6.2.9 Shifting cultivation

6.2.10 Settlement

6.3 Land management

6.3.1 Agriculture

6.3.2 Forest

6.3.3 Settlement

6.4 Crops, Production

6.5 Geomorphology And Landuse

6.5.1 Slope And Land Use

6.5.2 Altitude and Land Use

6.5.3 Drainage type and densities and its impact on landuse

6.5.4 Soil and landuse

6.6 Soil Loss

6.7 Land Capability

Chapter – VII SUMMARY AND CONCLUSION 179 - 191

Reference 192 - 198

Appendix 199 - 200

LIST OF TABLES

Table 2.1: Altitudinal Zones
Table 2.2: Lineament
Table 2.3: Mean monthly Rainfall
Table 2.4: Mean monthly temperature
Table 2.5: Vegetation Zones
Table 2.6: Mechanical Analysis of Soil
Table 3.1: Relative Relief
Table 3.2: Statistical measurement of Relative Relief
Table 3.3: Absolute Relief
Table 3.4: Statistical measurement of Absolute Relief
Table 3.5: Dissection Index
Table 3.6: Statistical measurement of dissection index
Table 3.7: Average Slope
Table 3.8: Statistical measurement of Average slope
Table 3.9: Slope in Percent
Table 3.10: Correlation between Slope Vs Relative Relief
Table 3.11: Correlation between Slope Vs Absolute Relief
Table 3.12: Slope Type
Table 3.13: Slope Aspect
Table 4.1: Bifurcation Ratio
Table 4.2: Orderwise Number of Streams and Stream Length
Table 4.3: Mean Stream Length
Table 4.4: Channel, Hydraulic and Topographic Sinousity Indices
Table 4.5: Drainage Density
Table 4.6: Drainage Frequency
Table 4.7: River Water Discharge
Table 5.1: Geomorphic Units
Table 6.1: Land Use
Table 6.2: Land Use and Slope Categories
Table 6.3: Soil Loss from different land use
Table 6.4: Land capability classification
Table 6.5: Land Class

LIST OF MAPS AND FIGURES

1.1: Location map
2.1: Altitudinal map
2.3: Lineament map
3.1: Relative relief
3.2: Absolute relief
3.3: Dissection index
3.4: Serial Profiles
3.5: a. Superimposed
b. Projected and
c. Composite Relief Profiles
3.6: a. Hypsometric curve
b. Altimetric frequency curve
c. Area Height curve
3.7: Average slope
3.8: Slope in percentage
3.9: Slope type
3.10: Slope Aspect
4.1: Drainage network
4.2: Drainage pattern
4.3: Stream order map
4.4: Law of stream numbers
4.5: Length ratio and low of stream length
4.6: Drainage density
4.7: Drainage frequency
4.8: Longitudinal profile
4.9: Water discharge
5.1: Geomorphic units
6.1: Land use
6.2: Inside structure of House
6.3: Soil loss
6.4: Land capability map

LIST OF PLATES

1. Research scholar at GBPIHED research project experimental erosion plot construction in forest
2. Experimental erosion measurement plot in the agriculture area under GBPIHED research project
3. Experimental erosion measurement plot in the agriculture area
4. Millet grown along the bunds of Paddy fields
5. Water discharge measurement
6. Drain in the paddy field used for raring fish
7. Field made ready for the paddy nursery
8. Kitchen garden used for crop production
9. Fish fingerling grown in the agricultural field
10. Traditional and modified house types and material used
11. Millet transplantation
12. Bamboo Grooves
13. Paddy threshing
14. Paddy threshing by Nishi tribe
15. Paddy Harvesting
16. An Over view of Hapoli Town
17. Weathered Rocks
18. Soil erosion control measures adopted along the Kiile River
19. Researcher in the field observing the dip and strike of an exposure
20. Corestone in the weathered rock
21. Newly found Shivling in Ziro
22. Main canal with millet growing in the agricultural bund

23. Diversion of water from main canal to agricultural plot

24. Water is filtered before directly drained to agricultural land

25. Land utilization by Nishi (Joram)

26. Shifting land is converted into permanent vegetable garden

27. Bird eye view of Joram valley

28. Recent Deposition in the

29. Boulders as seen in the field middle course at Siro

30. Terraced wet rice agricultural fields at Joram Locality

31. Bird eye view of Apatani valley

32. Boulder deposition in the middle of agricultural field

33. Basket topography near Joram locality

34. Geomorphic units in the upper course of river

35. Quartzitic gneiss between Joram and Yachuli locality

36. Recent deposition along Kiile river near Manpolyang Locality

CHAPTER - I

INTRODUCTION

1.1 Statement of Problem

Geomorphological study deals with the dimension and scale of relief features and the processes that shape the landforms. The term geomorphology was first used in Germany by Lauman (1858). However, McGee (1888) and Powell introduced this term to the International Geological Congress in 1891. Geomorphological observations are interpreted to understand the landform history and its associated dynamics. Geomorphological study also includes the reconstruction of paleo geomorphological environment. Fennman has rightly stated geomorphology as a science that study and interpret the evidence left by erosion process. The approaches to study geomorphology have been changing with time and space. In simple words geomorphology may be explained as the study of landform evolution whether it is denudational or structural (Joshi et.al 1990). Geomorphic and hydrologic system is subjected to far reaching modification by human activities e.g. agriculture and influence the action of running water and water balance. Though, it is difficult to assess human induced soil loss but most of the investigators generally argue that cultivation has greatly increased the sediment load of rivers. The existing landuse of a particular place is always guided by the physical determinants and human endeavor. Increasing population pressure and deteriorating environmental condition is changing the capability of land. This problem is becoming more complex and intricate in the mountainous environment due to soil erosion, landslide, and deforestation and changing climatic condition. The land capability classification system is used to show the suitability of land for its optimum use. Soil scientists use to give the main emphasis on the quality of soil for its classification and management. Geographers use to associate in this scheme of classification taking into consideration the physical determinants. A proper land evaluation is necessary before making its optimal use. In this regard land capability classification scheme is one of the best technique for the evaluation, based on the physical determinants i.e. altitude, slope degree and aspect, drainage condition, erodibility and soil characteristics.

The Himalaya, youngest folded mountain is consisting ancient rocks of Pre- Cambrian to the recent deposits of Holocene period. Its landform genesis had faced many geomorphological processes during different geological epochs. Therefore, to understand the present landform processes it is important to study a geochronological sequence of the area. During Quaternary period the Himalaya has witnessed many glaciations and de-glaciations processes. A huge amount of material supply took place along the slopes, forming glacio fluvial depositional landforms. Endogenetic forces cause a great difference in basin input – output because it rejuvenates the energy involved in the processes. The episodic upliftment has caused many structural deformations forming unique depositional and constructional landforms. Anthropogenic (landuse) activities accelerate the role of the exogenetic (erosion and weathering) forces. The rivers of Himalaya are still in youthful stage and continuously at work in cutting down the irregularities in their course and lowering their channel (Wadia 1981). The drainage basin is often selected as an ideal areal unit for the analysis of landforms, processes and the impact of anthropogenic activities. The basin input – output analysis is a detailed examination of the energy input in the form of precipitation, temperature, gravity and endogenetic forces. Through evapotranspiration, river discharge and soil loss energy output takes place from an area.

1.2 Development of Geomorphology

Herodotus (485-425 B.C), a noted Greek historian described about the marine origin of Egyptian rocks. Aristotle, a Greek philosopher and natural scientist, described stream erosion and the depositional origin of the Nile River. Lucretius (99-55 B.C), described about the weathering process through which rock gets decay. Strabbo (54 B.C – 25 A.D), a noted historian, illustrated the principle of upliftment and subsidence of landforms. Seneca (3 – 65 A.D), established about the valleys eroded by stream. Avicenna (980 – 1037 A.D), described about the formation of mountains by crustal uplifts and the destruction on them by erosional process. Therefore during ancient period it was established that the mountains could be created by uplift and it is reduced by the stream/ sub- aerial erosion to lowland. Most of these ideas of the ancient scholars were lost during Dark Ages due to fall of Roman Empire. However, Arab travelers and scholars continued the observation and documentation of landforms features and processes of arid lands during the Dark Ages. In general, no significant progress was made in the theoretical development of the field due to which it failed to establish the science of geomorphology.

During the middle ages, biblical beliefs had great influence on the subject. The basic idea was that the Earth had been shaped during a very short period of time, the six days of the creation and the 40 days of flood. But not all the scientists were concern with this idea. As early as the Renaissance (the 15th and early 16th centuries) engineers such as Leonardo da Vinci (1452-1519), Agricola (1491-1555) described about the mountains as products of weathering of mass movement and Bernard Palissy (1510-90) recognized the slow rate of operation of geomorphologic processes. Therefore, during this period, the scholars were fully grasped the full implications of sub- aerial erosion in landscape development. There were few scholars who continued to recognize the power of sub- aerial erosion. Targioni – Tarzzetti (1712-1784), described that the stream erode their valleys according to rock types. Leclerc (1707-1788), described that the stream erosion is capable of reducing land to sea level. Desmarest (1725-1805), described evolution of landscape through successive stages.

These progressive views were suppressed by the Neptunist school, who believe that landforms were formed by the erosion and deposition of the rushing waters of the receding universal ocean. The school of Uniformitarianism under

James Hutton (1726-1797) developed a major opposition to the teachings of Catastrophists and Neptunists. Uniformitarianism believes that landscape is passes through a continuous cycle of uplift, erosion and uplift. Hence, there is "no vestige of a beginning, no prospect of an end" and "the present is the key to the past". According to them landform are produced by slow and continuous (uniform) actions of sub-aerial processes (e.g. running water).

During the first half of the 19th century, European scholars laid the foundation for the scientific study of landforms. Surell (1841), described on the erosion and deposition related to longitudinal profile of torrential streams. Sir Andrew Ramsay (1814-1891), presented detailed description on the marine planation. Venetz, Bernhardi, Charpentier's Brothers and Agassiz developed glaciology.

John Wesley Powell (1834-1902), a Major in American army studied detail on the Colorado river (1875) and Uinta mountain (1876) and brought the concept of base level of erosion (theoretical limit of river erosion). He described about the power of stream erosion (mountain systems could be reduced to a lowland) and considered crustal upliftment as the cause for vertical erosion. Grove Karl Gilbert (1843-1918) studied on Henry Mountains of Utah (1877), Lake Bonneville. It's him who developed the concept of dynamic equilibrium. He states that elements of a landscape rapidly adjust to the processes operating on the geology or forms within a landscape maintain their character as long as the fundamental controls do not change. C.E. Dutton (1841-1912), had geologic expeditions at Colorado Plateau and Grand Canyon Region and many other. During his study he recognized the effects of isostacy on geologic processes and also recognized that sub- aerial erosion could reduce a landscape to its base level of erosion.

William Morris Davis (1850-1934) a Harvard Professor, developed the geographical cycle of erosion as a model for the interpretation of regional landscape evolution. The cycle was depicted as a sequence by which an uplifted landmass undergoes its transformation by the processes of land sculpture ending into a low featureless plain. Walter Penck developed an alternative model in the 1920's based on the ratios between the intensity of endogenetic processes (i.e., rate of upliftment) and the magnitude of displacement of materials by exogenetic processes (the rate of erosion and removal of materials).

The quantitative analysis of landforms morphology and field measurement of geomorphic processes dominated the 1950s and 1960s. The quantitative geomorphology was influenced strongly by the works of hydraulic engineers and R.E. Horton (1945). In the continental Europe, the works of geomorphologist were concerned with climatic interpretation of landforms. It has developed a new term i.e. climatic geomorphology. Climatic geomorphology suggests that different climates have unique sets of landform assemblages and characteristics.

Applied geomorphology became prominent in the 1960's & 1970's. During these periods the subject was relied on the improved knowledge of geomorphic processes provided by hydraulic engineers working on slope stability, open channel flow, and sediment transform. More recently the applied geomorphology has played a significant role in environmental management, resource evaluation and environmental hazards highlighting the utility of the subject in the contemporary society. Consequently there is a growing evidence of laboratory culture and field work studies in geomorphology.

1.3 Landuse mapping

The land use pattern of an area is directly related with the level of techno-economic advancement and the nature and degree of civilization of its inhabitants (Whyte 1961). Utilization of land totally depends on human perception, knowledge, and understanding to fulfill their requirement. "In general land use study deals essentially with the spatial aspects of all man's activities on land and the way in which the land surface is adapted, or could be adapted to serve human needs" (Best R.H. 1968). Thus, it is essential to have a detailed and in-depth knowledge of potentials and limitation of the present land uses, so that the production can be increased and at the same time the environment, biodiversity and global climatic system can be protected.

The action of optimum land use reflects the best and most favorable ecological relationships among land use components on the one hand and man on the other. The term optimum can be defined as a point at which a given condition is the most favorable.

The pressure exerted by increasing of population, to mitigate the increasing demand, scientific land use planning and land management could provide an alternative for the sustainable development of any region (Saxena et al. 1990). There is widespread concern that human activities may be changing the climate of local circulation, resulting from changes in land use pattern (Giorgi and Mearns, 1991). Due to under utilization of potential cropland, mismanagement, faulty land use practices, increased population, land conversion, intensive fuel wood extraction and cattle grazing are found to be the major driving forces for the changes in land use during the past 10 years (Jayakumar and Arockiasamy, 2003). Land under agriculture and settlement has increased significantly at the cost of reduction of forest land and partly of barren land (Bisht and Kothyari, 2001). Information on land use/land cover provides a better understanding of the cropping patterns and spatial distribution of fallow lands, forests, grazing lands, wastelands and surface water bodies, which is vital for developmental planning (Philit and Gupta, 1990). The information on land use/land cover patterns, their spatial distribution and changes over a time scale are the prerequisite for making developmental plans (Dhinwa et al. 1992).

Land use mapping has ever since played a major role in the formulation of the land use plans in the country. For any planning activity, there is a need of updated and accessible information of the area under study (Panaguiton, 2003). Land use map will be used to investigate the importance of different land use types, how and where our land resources are used and to check what inter relationships exist between different land uses. Land use mapping can be derived from three sources i.e. cadastral map, aerial photo and satellite data. For the accurate land use map, the cadastral maps can be considered as the primary sources of data. The term cadastral is derived from the French word 'cadestre' meaning register of territorial property. The cadastral maps are drawn to register the ownership of landed property by demarcating the boundaries of fields and buildings etc. They are especially prepared by the government to realize the revenue and tax. These maps have been the result of the actual ground survey of the locality which individual parcels have its own geographic coordinates. Updated cadastre maps are needed to show the changes particularly for the efficient management of agricultural lands (Raveshti, 2003). Photographs and other images of the earth taken from the air and from space show great information about the planets landforms, vegetation and resources. Aerial and satellite images, known as remotely sensed images, permit accurate mapping of land cover and make landscape features understandable on regional, continental and even global scales. Use of satellite images has become a chief means of updating land surface. Technological advances, such as the vast amount of remote sensing data having become available from earth observation satellites, make it increasingly possible to map evaluate and monitor land cover and land use over wide areas. Space imagery and aerial photography as well become a powerful medium for mapping what's at the earth's surface.

Land resource forms the most important wealth of region. Its potentiality, proper utilization and management and its role in development is considered to be the focal point for human beings. Improper use of land can bring so many problems like land degradation, wastage, decline in productivity, acidity, etc. Utilization and management of agriculture and other land resources, according to its capability and resource region, is very much necessary because it will ensure that land resource is utilized to the best advantage in and enduring manner (Bandooni, 2004). This will ultimately improve the levels of development. So, it is believed that land resources shows reciprocal relationship between the ecological conditions and man in a particular region. For any development activities, there is a need to understand the land resources. It can be understood with the classification based on its capacity. Land capability classification is a systematic classification of land where each unit of land is classified according to what it is capable of producing and also according to the risk or damage that would result if they are mismanaged. A proper land evaluation is necessary before making its optimal use. In this regard, land capability classification scheme is one of the best tools for the evaluation based on the physical determinants i.e. altitude, slope degree and aspect, drainage condition, erodibility and soil characteristics. This classification is made primarily for agricultural purposes and it enables the farmer to use the land according to its capabilities and to treat it according to its needs. Land is arranged in various capability classes after considering a number of soil characteristics and associated land features and climate. The main soil characteristics to be taken in to account are texture, depth, permeability, salinity and alkalinity of top soil and sub-soil. The important associated soil features are slope, effect of past erosion, natural soil drainage, frequency of over flow etc. A review of land classification methods used in different countries indicates that the land capability classification system is most universally applicable with little modification (Chaudhary et al. 1962).

More than three-four hundred years ago, the world was relatively empty of people. But since the mid-seventeen century, their number had repetitively changed the social and economic structure. Shifting from subsistence type of economy to a fully fledged commercial one was accompanied by a rapid growth of population. To provide food for millions of new mouths, the farmed land was extended and improved agricultural technique was introduced. But although population has increased tenfold in the last few centuries, the total land area remained same in extend. As a result, the land surface has had to support and sustain even more people beyond its capacity.

Technological innovation and economic development have sustained growing numbers of people to live and even provide improved standards of food, material wealth from the same area of land which was available for previous less number of people. Land play a strong role for agricultural production but despite this, the technology has been intensifying its output immensely with the utilization of High Yielding Variety and fertilizers – producing more and more from the same piece of ground. As a result once, the fertile land is coming to play a diminishing role in its fertility and food production.

1.4 Role of geomorphology in land use planning and management

Geomorphology which is the science of earth forms has an important application in the investigation, evaluation and classification of land as a resource. Knowledge of land use and geomorphology is important for any planning and management activities over the surface of the earth. Land is being central to any natural resources, development planning and in the assessment and management of natural environment, geomorphological classification and analysis plays a key role in correct identification and assessment of the resources (Surendra, et.al.1991). Geomorphology is the major dominant factor in the human environment because it influences the agricultural activities as well as settlement pattern. The various agricultural systems and traditional practices of farming in different parts of the region are very largely dominated and controlled by the geomorphic forces and processes. The agricultural systems like rotation of crops, fallow system, intensity of crop land use, open and closed field systems and livestock breeding, etc. are conspicuously controlled by the geomorphology of a region (Sharma,1982). The role of various physiographic formations, soil characteristics and water conditions along with the other natural conditions like drainage, altitude, slope, climate, etc. are significant in the direction of development of any region.

The application of geomorphological knowledge in the field of land utilization particularly human habitation, agriculture, transport and communication, selection of dam sites, horticulture is of great help. It is observed that the human settlements are directly or indirectly depend on the nature of terrain, soil, topography, degree of slope, availability of drinking water, accessibility to the region and the climatic condition of the region. When we see the past historical settlements, we find that they were also been influenced by the nature of terrain, soil and climate. The climatic condition of any region is greatly influenced by the altitude. In the higher altitude, we find meager human habitation and agricultural activities. The slope gradient, aspects determine the field pattern. The field pattern refers to the size layout and alignment of the cultivated fields. On the level plain surface, the shape of the agricultural fields are rectangular and the size of the plot is also big whereas in the hilly areas the fields are terraced or used for jhum field. The terraces walls have to be parallel to the local contour, otherwise the soil and water will not be consumed, they will wash away (Enayat 1979).

Topography has a significant impact on soil formation as it determines runoff of water. Some soils are going to occur on the summit of a slope, some on the side slopes and some on the foot slope. The position of the slope determines the soil characteristics particularly its depth. In the summit the development of soil horizon is fast and it increases the depth also. In the side slopes the development of soil becomes slower because rainfall will runoff this slope position faster, there will be more soil erosion and there will be less leaching. At the bottom part of the slope, the soils will start to collect sediment from upslope which will bury the horizons and slow down their development. The hill slopes are covered by thin layer of soil which gradually decreases as the angle of slope increases. With increasing slope angle, there is and increase in the slope instability. The hills and rock plains, due to poor soil cover and severe water erosion hazard, resulting into rills and gullies are not suitable for cultivation (Gupta, 1991). High to very high slopes in the Khari river basin due to hilly terrain, the net cultivated land is low to very low. Whereas in the peneplained area where the slopes are less, the intensity of net cultivated area is very high (Kalwar and Vijay, 1995)

The physiographical condition of an area has bounded the agricultural development of various ways. The intensity of crop land use and the irrigation facilities are largely controlled by the physiography. The area which is having high drainage density due to ruggedness, the net cultivated land is very low. Whereas the areas having low drainage density in humid environment comprises very high net cultivated land.

Various sorts of land use such as agriculture or overgrazing, deforestation for the new uses, etc. degrade the top soil, which in turn reduced the soil fertility. Because of the serious nature of erosion, it affects the existing soil, especially biological characteristic that helps in the reestablishment of soil fertility. Erosion is the primary force causing soil degradation in the tropics (El Swaify et.a. 1982, 1990; Lal 1986). The soil erosion can take place due to destruction of forests, unscientific cultivation practices, heavy grazing in pasture and grasslands. Due to erosion it converts the fertile lands to barren and unproductive. Consequent loss of productivity in this area of the world is on a collision course with increasing population density and food demand. Expansion of the human population and associated intensification of human activity in the Loess Plateau, China has been accompanied by increasing soil erosion (Timothy A.Quine, et.al, 2000). The population increase will accelerate the erosion rates and the population decline will lead to a reduction in erosion. There are three major geomorphological changes which are said to have occurred in the recent decade due to the initiation of cultivation i.e. the development of the shallow gullies; the development of gully head cuts; and the landslide activity on the steep slopes. In the hilly region, there is a need for understanding the relationship between human activity and the sediment production by erosion especially impact of human activity on the slope and gully systems. Therefore there is a need for landscape analysis in response to human activity, which will show the interrelationship between land use and geomorphological processes.

Keeping in view the above said facts the Kiile river basin a part of the Lesser Himalaya made of gneiss and quartzite is selected for detailed study. This river basin appears like an intermontane valley dotted with small isolated hills and presents a typical geomorphological configuration (Joshi et.al. 2007). In this area wet rice cultivation is very popular for which a small perennial river and its tributaries provides sufficient water for irrigation. It appears ground water table is very shallow as dug well presence supports this fact. However, a detailed survey is needed to substantiate this fact.

1.5 Objective of study

The main aim of the study is to identify the geomorphological characteristics and its impact on landuse of Kiile river basin. Further the specific objectives are given as below:

- To identify the physical, the geological, topographical, climatic and soil characteristics.
- To identify the landform and associated geomorphological processes
- To identify the landuse pattern
- To assess the water discharge and soil loss
- To carry out a land capability classification of the area.

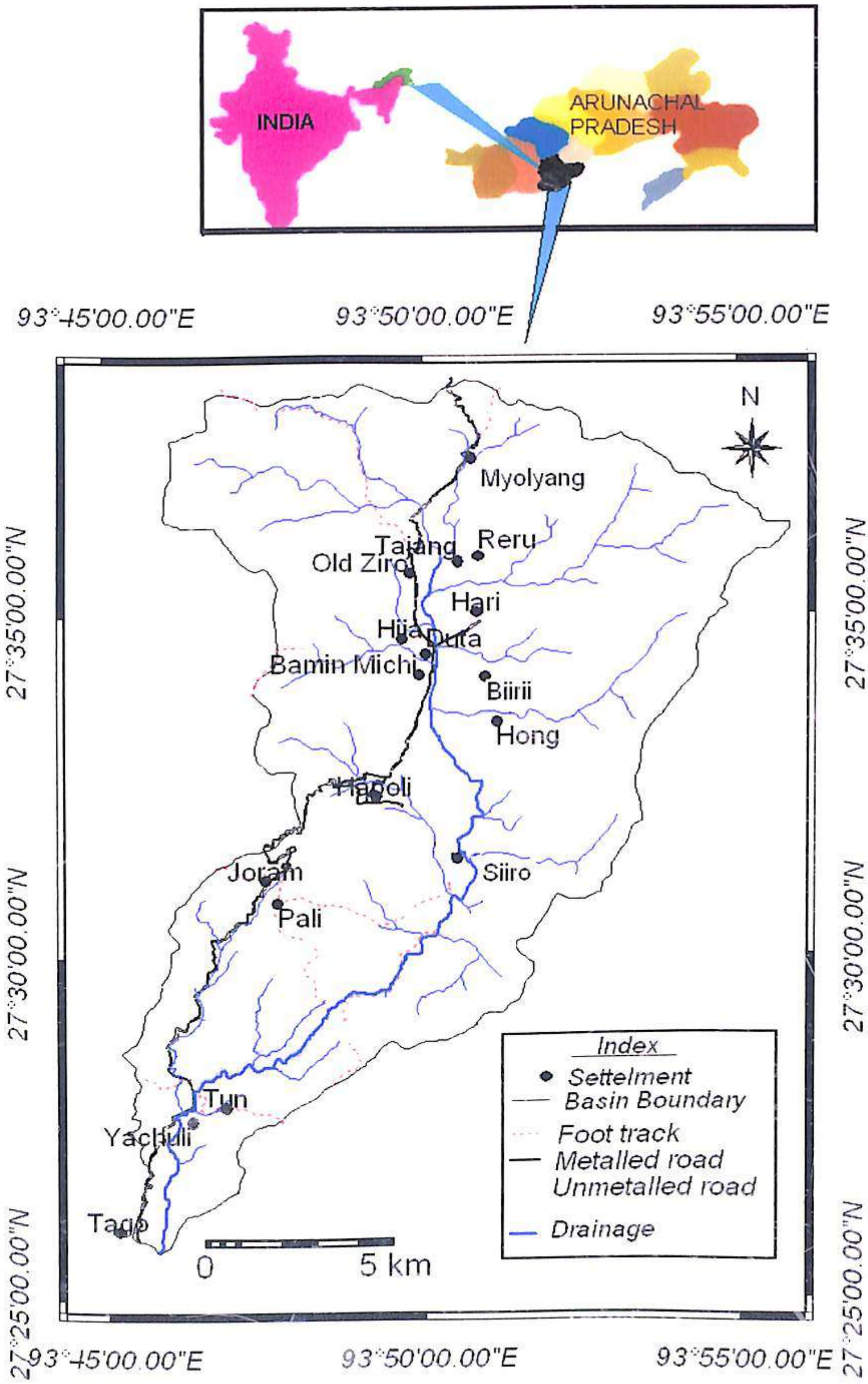

Fig. 1.1 Location Map

1.6 Study Area

The name of the river selected for the study is shown in the topgraphical map as 'Kale' however people of the area (Apatani Tribe) pronounce it as Kiile. Thus, in this study 'Kiile' name is adopted. Watershed boundaries of Kiile river (Fig. 1.1) is delineated using topographical map no. 83E/14 and 15 (1:50,000) of survey of India. It flows to the south direction for 36 kilometers before it meets the Pange river near Yachuli locality of Lower Subansiri district. The area is extending in between 27°25'52" to 27°38'37" North latitude to 93°45'30" to 93°55'50" East longitudes covering an area of about 204.062 Km^2. This area is inhabited in the upper course of the river by the Apatani Tribe. Lower part is inhabited by Nyishi tribe with scattered settlement.

1.7 Methodology

To carry out the litho – structural characteristics a geology map prepared by earlier workers (Kumar, 1997) is consulted. An intensive fieldwork is carried out to be familiar with the various rock types and their characteristics in situ. Lineament map is prepared using remote sensing data and with the help of rose diagram its direction and frequency is presented.

Altitudinal zone, relative relief, absolute relief, relief profiles, average slope, slope types and drainage analysis is carried out using the topographical maps following the morphometric approach.

Geomorphological mapping is carried out according the method suggested by ITC, Netherland, Lol et.al (1985), Tricart (1969), Hungarian Academy of Sciences (1963), Joshi and Rawat (1998) and Joshi et. al (2007). The identification and interpretation of major landforms is made during field work.

A landuse map is prepared using satellite images. Various landuse categories are identified. Identified categories and their characteristics are verified with an intensive field study. A house hold survey is conducted for the identification of various crops and their production grown by the farmers.

Data pertaining soil loss (Joshi et. al. 2006) from cultivated, barren and forest land are collected from the project of GBPIHED experimental plot sites

An attempt is also made to categorize study area into different land capability classes in the light of the earlier workers viz Joshi et.al, (1990) USDA (1960) and Jalal (1975 – 76).

1.8 Literature review

Bruijnzul, LA (1996) revealed that most results indicates that deforestation causes increased water and sediment yield.

Darst, H. et.al (2001) have discussed that identification of agricultural activities in the Venezuelan Andes at elevation in excess of 3,000m is causing severe land degradation.

Datt, D. (2001), has studied on the water discharge and sediment budget in lesser Himalaya and discussed that the cultivated catchments contribute more sediment load in comparison to moderately forested catchments.

Jose M. et. al (1995) have studied on the sediment yield under different land uses in the Spanish Pyrenees, wherein they tried to know the hydrological and geomorphic consequences of landuse changes. They described that the plot where there is dense shrub cover, the runoff is recorded lowest and vice versa. With the decreasing in the density of plant cover, soil loss and sediment yield increases.

Joshi (2007) in his book it is tried to show the interrelations of the landforms using various morphometric techniques. A detailed landslide study has been undertaken along the main Boundary thrust, which is highly fragile zone.

Using aerial photograph and satellite imageries morphotectonic observations are made in Dehradun valley.

Joshi et.al (1990) have studied on the geomorphological implication for an optimal land – use of Kotadun, Central Himalaya considering geomorphological parameters and suggested multi cropping pattern, double cropping pattern, non – agricultural uses, reserve forest for good land, medium land and poor land respectively. This study also suggested physical determinants for the land capability classification.

Kar Manik and D.C. Goswami (1997) have evaluated alternative technique for flood frequency analysis and discussed that the water level in the Kopili river normally crosses the danger level several times during the monsoon high flow season. They have also shown the high fluctuation of discharge in the said river and indicated closed correspondence between water level and discharge during monsoon months.

Lina (2000) observed water balance and soil loss under long fallow agriculture in the Venezuelan Andes and found that the runoff and soil loss were greatest at the beginning of the fallow period due to scarce ground cover.

Leopold L. et.al (1970) have described that the flowing water is responsible to carve the channel, transport the debris and degrade the landscape. The ability of flowing water to carve and transport are exerted due to effects of lithology and topography through their relation to the resisting forces.

Lu Xi Xi, et.al (2003) have observed that the significant increase of sediment load in wet seasons and decreases of water flow in dry season in the Upper Yangtze river was due to deforestation, and the inconsistency between water flow and sediment load changes was predominately due to water consumption.

Nusser, Marcus (2000) has concluded that due to general population growth, the development of the cultural landscape is characterized by the expansion of settlements and cultivated areas in all valleys.

Oyarzun, Carlos E. (1995) studied about the influence of infiltration upon overland flow and on soil erosion. He described that the variations in infiltration is related with the landuse. The undisturbed native forest soils showed the highest infiltration rates, which are likely to contribute reduction of overland flow and soil erosion losses.

Richard, M. el.al. (1996), studied on the geomorphology and forest cover controls on monsoon flooding in the Central Nepal Himalaya and they have found that it is not only deforestation which is contributing to the flood hazard rather these are geomorphic variables which exert the dominant control on peak flows.

Sing R.B. (1992) focused on land sliding as a major geomorphological process in the Himalya and identified it as a dominant contributor to the sediment load of a river. The possibility of land sliding and sediment production has been drastically increased because of increased human pressure.

Singh Savinder (1999) he described that slope cannot be only responsible for grading of river but the adjustment among volume of water, discharge velocity slope and sediment load is also an important condition.

Small R.J. (1990) described that the evolutionary drainage systems may provide valuable information about the denudational history of concern area which can be useful to attempt a reconstruction of the initial form of a river system. The initiation and development of drainage depends on the geological structure i.e. folds, faults, angles of dip and lithology.

Southwarth, Jane and Catherine Tucker (2001), have observed that the processes of population growth, increasing socio – economic inequality; and market oriented agricultural production seem likely to lead to a dominant deforestation trend in the future.

Stocking, Michael and Rebecca Clark (2001) have discussed that because of poor & costly input supplies, most small holders rely upon the intrinsic quality of the soil, and hence its productivity is the basic long term resource for future production.

Thomas, Hofer (1993) studied on Himalayan deforestation changing river discharge and increasing floods selecting four rivers of a basin i.e. the Sutlej, Beas, Chenab and Jhelum. He discussed that due to rugged relief and steeply sloppy land, the area available for agriculture is limited and confined to alluvial terraces and on the lower sections of the rivers.

Woldeamlak, B (2002) studied on the landcover dynamics of Chemoga watershed since the 1950's and described agriculture as a main type of land use, which leads to increase in runoff erosion, flooding and sedimentation. Due to little vegetation cover in the watershed area it results to extensive flooding and sedimentation problems in the down stream.

1.9 Data base

i. Survey of India topographical sheets No. 83 E/14 and 83 E/15 (1:50,000).
ii. IRS 1C, LISS III FCC (Scale 1:50,000) imageries.
iii. Rotometer and planimeter are used for the measurement of linear and areal aspects respectively.
iv. Brunton compass is used to measure the attitude of rocks.
v. GBPHIED Sponsored Research Project Peport

1.10 Organisation of work

The whole study is divided into six chapters. The first chapter deals with the Statement of the problem, study area, objectives of study, literature survey, data base, methodology and organization of work.

Second chapter deals with the Physical background i.e. altitudinal zone, lithology, structure, climate, soils, vegetation and people.

Chapter three deals with a detailed study of relative relief, absolute relief, dissection index, average slope, slope in percentage, hypsometric analysis, altimetric frequency, correlation between slope and absolute relief & correlation between slope & relative relief and slope aspect and type.

Chapter fourth includes the drainage analysis. In this chapter drainage networks, patter, stream order, bifurcation ratio, sinuosity index, law of stream numbers, length ratio and law of stream length, geometry of basin shape, drainage density, drainage frequency, longitudinal profile and river discharge are incorporated.

Fifth chapter deals division of study area into geomorphic units. Field observation on landforms, forming material and processes are discussed.

Chapter sixth includes existing land use, land management, crop and its production, land capability, geomorphology and land use and soil loss from different land use.

Final chapter presents the summary and conclusion of the whole work on geomorphology and land use.

CHAPTER II
PHYSICAL BACKGROUND

2.1 Introduction

A scientific study on the geomorphology of a particular region needs a proper knowledge of its physical characteristic. The information on the physical background of any region includes geological setting, altitudinal variation, climatic condition, vegetation, soil and people. The morphology of the Kiile river basin has been largely determined by its rocks, structure and processes. Therefore, the physical background of the study discussed as the following forms an important part.

2.2 Altitudinal Zone

The altitude of the study area ranges from 740m to 2684m. The height of the basin increases towards the northern direction. The altitudinal zone map (fig 2.1) is prepared by taking the contour interval of 200m. The contours near the confluence are closely spaces which shows steep slope. Towards the north direction after crossing the confluence, the contours become wide with zigzag pattern. The contours are spaced widely in the Joram and Ziro valley. The highest altitude i.e. 2684m is found at the source of Siya river, one of the tributary

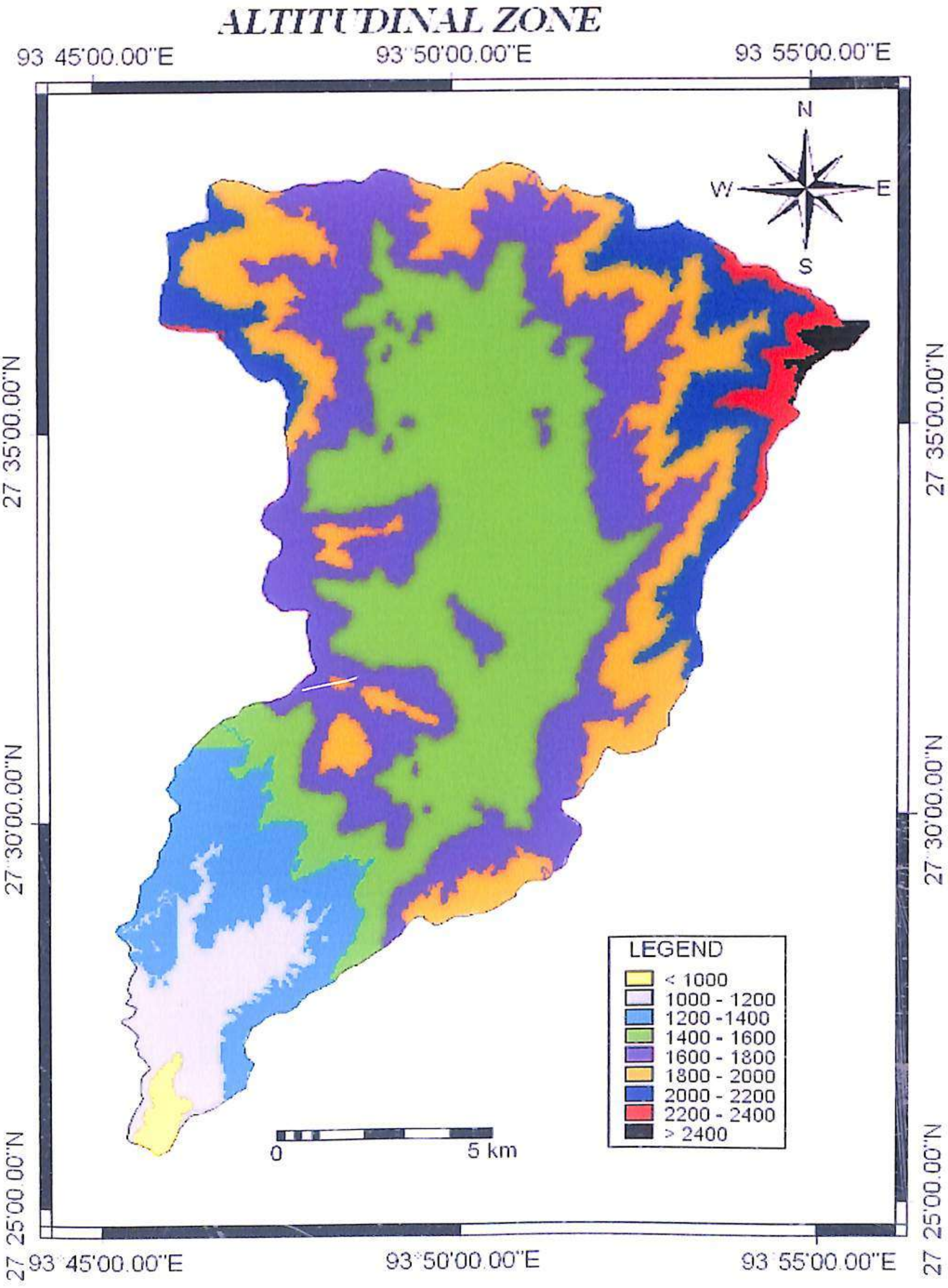

Fig. 2.1 Altitudinal zone map

of Kiile. At the mouth near confluence of Kiile and Pange river, the height is 740m. The altitudinal range of the study area is divided into six groups (Table 2.1).

Table 2.1
Kiile River Basin: Altitudinal zones

Altitudinal categories (in meters)	Area (in km²)	Area (in %)	Cumulative area (in km²)	Cumulative area (in %)
Below 1100	3.79	1.85	3.79	1.85
1100 – 1300	19.21	9.41	23	11.26
1300 – 1500	11.71	5.47	34.71	16.73
1500 – 1700	96.47	47.28	131.18	64.01
1700 – 1900	36.01	17.64	167.19	81.65
Above 1900	36.87	18.11	204.062	100
Total	204.062	100	204.062	100

2.2.1 Low Altitude (<1100m)

Under this category, area is concentrating near the mouth of Kale river basin. This comprises an area of 3.79 km² which is 1.85% of the total study area. In this category contours are very close and slope is very steep. Rocks are dipping 68° - 75° which reflects the geological control on topographic slope.

2.2.2 Moderately Low (1100m – 1300m)

This altitudinal category covers about 19.21 km² or 9.41 % of the total basin area. Under this category, plain area of Yachuli locality and very small hillocks are covered.

2.2.3 Moderate (1300m – 1500m)

This category covers an area of 11.71 km² or 5.74% of the basin area. This category includes numerous hillocks and a small valley known as Joram

2.2.4 Moderately High (1500m – 1700m

This category covers the maximum area of 96.468 km^2 or 47.28% of the total basin area. The flat valley and foothill parts are under this category. The contour line of 1540m runs around this flat valley. Extensive valley which is surrounded by the hills is completely devoted for the paddy cultivation. Unconsolidated sands, clay, loam are deposited along the main river.

2.2.5 High (1700m – 1900m

This category includes the adjoining hills around the valley. It covers 36.01 km^2 or 17.64% of the total basin area.

2.2.6 Very High (>1900m)

Under this category, the area comprising 36.87 km^2 or 18.11% of the total area. This includes the higher reaches of water divides.

2.3 Geology

Litho structural set up of the study area falls under the Lesser Himalayan part. Kiile river basin is crossed by a road passing through Kimin locality in the south and Taliha-Nacho in the north. Lesser Himalayan rocks are separated in the south from Siwaliks at Lichi locality and in north from Great Himalaya at Taliha locality by Main Boundary Thrust (MBT) and Main Central Thrust (MCT) respectively. A brief description of lithology and given as below:

2.3.1 Lithology

Lesser Himalayan rocks are named as Bomdila Group which is further subdivided as Khetabari, Tenga and Chilliepam. Khetabari formation comprises sericite-quartz, phyllite, schist, quaratzite graphitic phyllite with bands of marble and calc-silicates. These rocks are exposed around the village Khetabari along the Kimin-Ziro road. Tenga formation exposed in between Bame and Along comprising vesicular and amygdaloidal volcanics. Thin beds of marble, sericite quartzite and dark grey phyllites has been observed as interbedded with the volcanics. In Jameri area it includes quartzite with thin bands of phyllites. Lower part of Chilliepam Formation contains basal oligomictic conglomerate followed by quartzite with thin bands of dolomite, black phyllite and dolomite. Upper member includes carbonate with phyllite. Dirang Formation unconformably overlying the Bomdila group in south and truncated in north by the MCT. It includes garnet-muscovite-biotite schist, flaggy and platy garnet-quartzite, intrusive biotite augen gneiss, schist and quartzite. Gondwana rocks are found to be unconformably lying over Bomdila Group along south. It is divided into Miri, Bichom, Bhareli and Abor-volcanic formation. Miri includes conglomerate, sandstone/quartzite purple shale and diamictite. Bichom is having diamictite. Bhareli formation comprises dark grey feldspathic sandstone and grey to black carbonaceous shale with lenticular coal beds. Abor comprises basalt andesites, acidic ruffs, and lapillis.

Kiile river basin comprises gneiss, schist, phyllites and quartzite. Quaternary deposit includes pebble, boulder, sand and clay underlain by the lesser Himalayan deposits.

2.3.2 Structure

Lineament is a mapable simple or composite linear feature of the surface which parts are aligned in a straight or slightly curved and differ distinctly from the pattern of the adjacent features. It reflects a subsurface phenomenon (Bharktya, and Gupta, 1982). The linear features, which were distinct, have been picked up and directions were measured for the preparation of rose diagram (Fig.2.2). All lineaments are traced as seen in IRS 1C, LISS III FCC data. Each of identified lineaments is labeled by their direction. Number of lineaments is counted falling under the six group direction (0° - 360°) at the interval of 30°. Maximum lineaments (34%) are found extending in 30°- 60° to 210°- 240° direction group.

General trend of lineaments indicates two patterns:

i. Parallel to Major structural trend of the Himalaya i.e. extension of Main Boundary Thrust (MBT) and Main Central thrust (MCT).

ii. Across the Major structural trend.

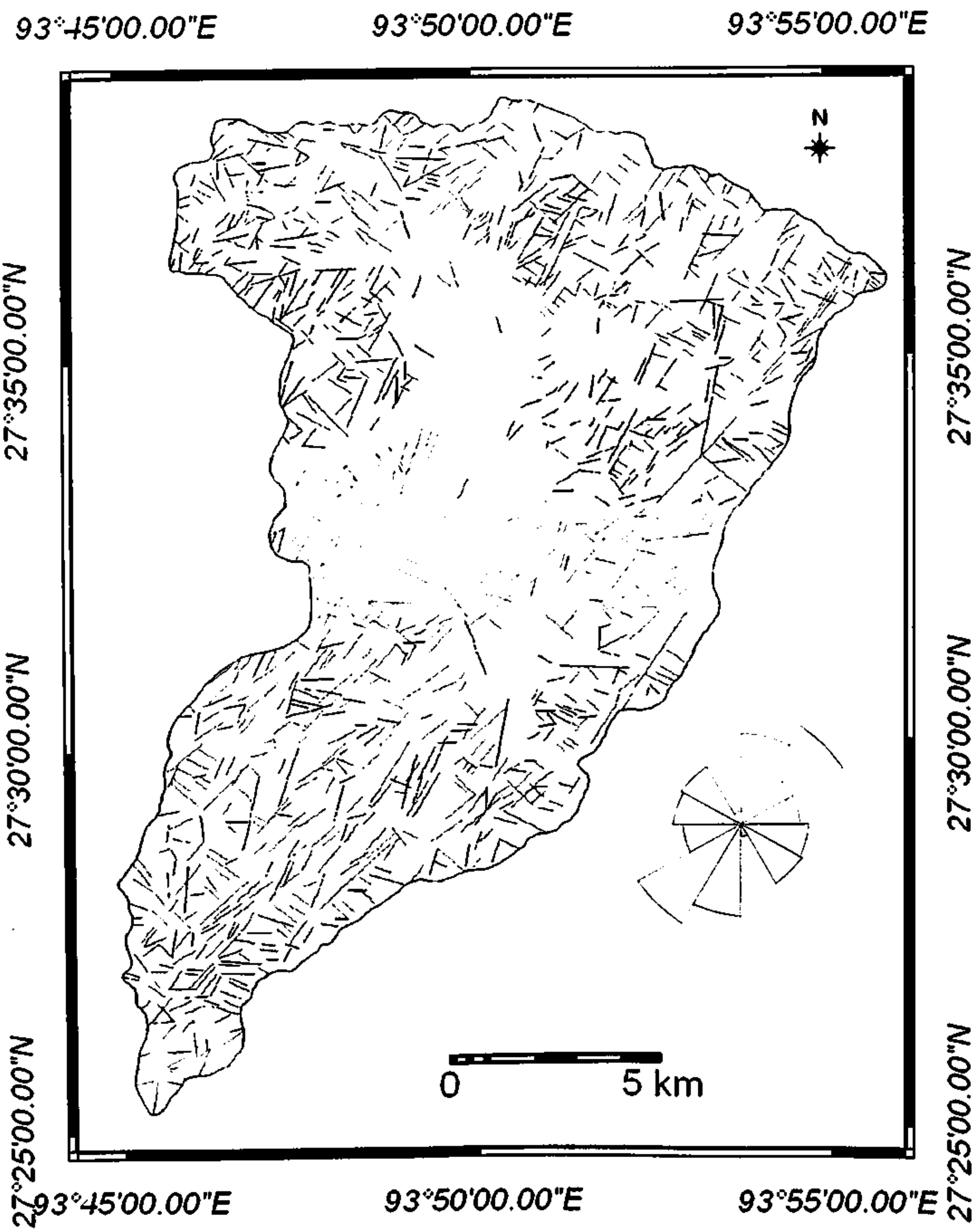

Fig. 2.2 Lineament map with rose diagram

Table 2.2

Kiile River Basin: Lineament

Direction (In Degree)	Frequency
0 - 30 to 180 - 210	250
30 - 60 to 210 - 240	311
60 - 90 to 240 - 270	154
90 - 120 to 270 - 300	182
120 - 150 to 300 - 330	186
150 - 180 to 330 - 360	38
Total	1121

2.4 Climate

Climate is the main characteristic condition of the atmosphere near the earth's surface at a given place or over a given region. Climate is one of the important factor in modifying the topography of a region. Climate directly through its elements and indirectly through vegetation influences the geomorphic processes which in turn account for the shaping of lesser topographical forms (Sinha, 1968).

Each climatic type produces its own characteristic assemblages of landform and set of geomorphic processes which shape them. Changes in the climatic condition, influences entire geomorphic processes of a region viz, a fluvial cycle of erosion passing through mature stage, use to change into a new cycle of erosion in case of sudden climatic change, either by extreme cold or dry condition, resulting in the formation of polygenetic landforms

Climate affects indirectly the amount and type of vegetal cover and directly the amount and kind of precipitation, evaporation, daily range of temperature and wind velocities and direction of any region. However, it is difficult to find out the impact of vegetation on climatic variation or vice – versa.

In general in Arunachal Pradesh climatic conditions are governed by the Himalayan mountain system and the altitudinal differences. In the Kale river basin, the weather and climatic condition is quite unique from the rest of the Arunachal Pradesh. Study area which is an intermontane valley, shows a very unique type of weather condition in comparison with its neighboring areas. The upper part experiences below 0° temperature in winter whereas in the lower stream, the weather became little bit warmer. The variation in the weather condition of study area is controlled by the topographical variation. Due to rapid population growth during the past two decades, the development of the cultural landscape is characterized by the expansion of settlements and cultivated areas which might have its bearing on climatic conditions. The climatic data of the basin for the last 1 and half decades, it is observed indicates increase in temperature as well as rainfall.

The basin presents a humid sub – tropical to temperate type of climatic condition, due to which it gets sufficient amount of rainfall in summer season. The weather condition vary from place to place in the study area due to its variation in topography.

According to Koppen's (1954) classification, the area falls into 'Cwa' type of climate. Its connotations are as under:

C stands for Humid climate

w for dry season in winter and ten times precipitation in a summer month

a with warmest month is over 22 °C; at least 4 months over 10 °C.

The basin has been divided into four major seasons on the basis of variation in temperature, pressure and humidity condition. The dividing lines between the two varied seasons are purely hypothetical, since a month can be evolved into the other season at different times.

1. Winter Season (December, January and February)
2. Pre – monsoon (March, April and May)
3. Monsoon season (June, July, August and September)
4. Retreating monsoon (October and November)

Rainfall data for the period of 1986 to 2006 and temperature data for the period of 2003 - 2006 are collected from the Meteorological station situated at Ziro. The mean monthly average rainfall for the period under observation is presented in table 2.3. Rainfall varies from year to year over the region. Highest total rainfall i.e. 2349.03 cm is observed in the year 1991, and the lowest during 2003, when it was just 681.5 cm. The year 1996 recorded no rainfall for consecutively 3 months i.e. October, November and December. During the year

1988, 1990 and 2005 no any rainfall was recorded in the month of December. Highest rainfall was recorded on May 1991, when it was 447.3 cm.

Table 2.3

Kiile River Basin: Mean Monthly Rainfall, Ziro (1986 – 2006)

MONTH	RAINFALL (in Cm)
January	30.66
February	61.14
March	68.82
April	103.1
May	126.45
June	181.02
July	194.55
August	149.73
September	124.76
October	86.85
November	34.47
December	18.25

Source: Soil and Conservation office, Ziro, Lower Subansiri district

The Soil Conservation Department recorded 26 rainy days with just 120.4 cm rainfall on May 2005. The south – west monsoon covers about 66 percent of the total annual rainfall. Out of total rainfall 2349.03 cm in 1991, about 1925 cm (82%) of rainfall occurred only during monsoon season. But the next year i.e. 1992, out of total rainfall i.e.1107.57 cm only 641.7 cm or 58% of rainfall occurred during monsoon. After observing the rainfall data for the last 20 years, it is clearly visible that the total amount of rainfall has decreased tremendously. The total amount of rainfall was 921.4 cm, 776.21 cm and 735.88 cm in the year 1986, 1996 and 2006 respectively. During these years out of total rainfall about 635.1

cm or 69%, 600.1 or 77% and 536.28 cm or 72.8% of rainfall respectively occurred during monsoon season.

Table 2.4

Kiile River Basin: Mean Monthly Temperature (2003 – 2006)

MONTH	Temperature (^oC)	
	Max	Min
January	13.8	4.15
February	16.67	8.77
March	17.97	10.92
April	18.4	13.32
May	21.55	15.97
June	23.32	18.52
July	23.57	19
August	23.9	19.4
September	22.75	14.52
October	19.67	12.57
November	16.7	10.2
December	16.15	8.5

Source: Soil and Conservation office, Ziro, Lower Subansiri district

2.5 Vegetation

Climate, soil type, topography, and elvation are the main factors that determine the type of forest. Forests are classified according to their nature and composition, the type of climate in which they thrive, and its relationship with the surrounding environment.

Champion (1936) and Rautela (1962) have classified the vegetation of the Himalaya on the basis of its altitude. They have classified climatic zones as below: i) Sub – Tropical (less than 1200 m),

ii) Temperate (1200m – 1800m), and

iii) Sub – Alpine (above 1800)

According to Champion & Seth's (1968), forest types of the Himalaya may be divided into following types:

i) Tropical wet evergreen forest

ii) Sub tropical dry evergreen forest

iii) Montane wet temperate forest

iv) Tropical dry decidous

v) Himalayan moist temperate forest

vi) Himalayan dry temperate forest

vii) Tropical moist decidous forest

viii) Sub tropical pine forest

ix) Sub – alpine & alpine forests

Based on Champion and Rautela, the study area has been divided into three vegetation zones based on their altitudinal extension as below:

Table 2.5

Kiile River Basin: Vegetation Type

Vegetation Type	Height categories	Area (Km²)	Area (%)
Sub – Tropical	Below 1200	13.93	6.82
Temperate	1200 – 1800	130.1	63.71
Sub – Alpine	Above 1800	60.13	29.47

Table 2.5 indicates that about 6.82 % and 63.71 % of the study area lies under sub – tropical and temperate forest respectively. The remaining 29.47 % of area lies under sub – alpine vegetation.

Upper part of the study area is inhabited by Apatani tribe. As the Apatanis do not practice jhum or shifting cultivation, the mountains and hills surrounding the valley have not been deprived of the beautiful forest as compare to the other areas of lower basin (Joram, Yachuli) where the shifting cultivation is actively in practice. But few patches of degraded pine forest due to natural fire can be seen near Siibe (Hapoli) and Siiro villages in the upper part of the study area. The forest fire took place due to flowering of pine trees.

As the valley enjoys temperate climate, the main species found in these forest are Abies densa, Quercus spp., Michilus vilosa, Schima wallichii, Cinnamomum cecidephne, Prunus cornata, Taxus baccata, Cephalotaxus, etc. in the top storey under which Acer spp., Rhododendron, Pieris ovalifolia, Gaultheria, Rubus niveus, Prinsepia utilis, Indigofera spp., ferns, orchids, medicinal plants, etc. are present. Besides, the above mention broadleaved species like the conifers, Abies densa, Pinus wallichiana etc. are also available. The blue pine (Pinus Wallichiana) is found comparatively in narrow belt at the lower slopes around the periphery of the cultivated land. Apatanis are believed to be a mastery over the afforestation technique. Besides bamboo and pine plantation, they also plant trees like Alnus nepalensis (RIME), Prunus spp.

(PIITA), Pyrus (PECHA), Prunus nepalensis (SEMBO) etc. with the bamboo and pine groove for various domestic purposes viz. Firewood, building materials, furniture, and variety of craft items etc.

2.6 Soil

Soil is natural three dimensional bodies used for many purposes, the most important of which is to produce food and fiber for humankind (USDA, Soil Conservation Services). Soil is the product of physical, chemical and bio – chemical processes which are acting over the earth surface within distinct topographical and climatic condition. Pedologist carry out detailed study about the morphology and distribution of soils in the places where they have formed. Soil formation are influence by climate (temperature & precipitation), living organism (vegetation & human beings), parent material (texture & structure and chemical & mineralogical composition), topography and time. Soil is a dynamic creation of the natural environment, reflecting changes in the character of its soil forming elements.

Dokuchev, a Russian Pedologist has given prior importance on the effect of climate on soil formation. The climatic type of the study area is humid climate. The amount of rainfall is very high. Observations shows except a few months, the region receives rainfall through out the year. Besides this, during summer, the

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According to soil map of India, the study area falls within mountain soil. But in true sense varieties of soil type can be observed. So, in order to describe the chemical properties of soils, information is collected from the GBPI sponsored research project in the department of Geography.

The pH of the study area ranges from 4.03 to 6.29 with strong acidic (4 or even less to 5.5) and moderately acidic (5.5 to 6.5). The highest pH value (6.29) has been recorded from agricultural field at Yachuli. The reason for this value may be due to the nearness of agricultural field with the pine groves. The lowest pH value (4.03) has been recorded from dry agricultural field, near Helipad, Old Ziro.

Soils from different parent materials show variation in depth, colour, texture, structure, consistency, development of diagnostic sub – surface horizons and morphological properties of the soils (Tamgadge and Ghosh, 1991). Near Kaiyan North west of basin, along the road side, alternate quartzitic gneiss and crystalline rocks are found. The rocks are highly weathered after few meters and forming saffron soil color. The pH value of the soil collected from this unit is 4.4 which are strongly acidic. Weathered schist and gneiss alternate beddings are seen along the road cutting of Jatputu, Yazali which is overburden with the weathered material having saffron soil colour with the thickness of more than 1 meter. The pH value near this point is 4.84 which show highly acidic. The parent rock i.e. Quartzitic Gneiss found in the surrounding of the valley floor provides grayish colour and clayey texture of soil. Whereas the valley adjoining hills have mostly the saffron color of soil.

The influence of topography on the soil formation cannot be overlooked. Rivers debouching from the surrounding uplands deposits fine eroded soil particles in the low lying areas, which makes the valley more fertile than its surroundings. The Kiile river basin gives a quite variation of relief features. Based on the topography the soil profile also varies. In the study area, the valley depression like Ziro valley, Joram valley and Yachuli valley shows a deep, dark soil color whereas the soil in the hillslope as well as isolated hills are shallow, unweathered.

The living organism, both human and plant plays a significant role in soil development. The plant cover reduces the soil erosion and adds the organic residue or humus and also provides a developed soil profiles. The region which is covered with pine trees is more acidic than others. So, based on the type or vegetation cover, one can delimit the soil type and profile. In the upper stream which is inhabitant by Apatanis are mostly covered with thick vegetation, whereas in the lower stream due to shifting cultivation practice by Nishi tribe, almost all the hills have become barren or covered with grasses. This anthropogenic activity can influence the soil profile development. Due to varied vegetation cover, humus content in the upper stream is thicker than the lower stream. The removal of natural vegetation by cutting trees or by cultivating the soil abruptly modifies the soil – forming factors. During the field study sharp variation in soil characteristics are found in the areas of settled & Jhum cultivation.

Srivastava (2002) has grouped the soil characteristics of study area as Michao series, Hari series, Joram top series, Joram medium hill series, Joram series and Yachuli series. A brief description of each series is as below:

Michao Series is comprised of very deep layer and is moderately well – drained. Its color is dark brown to dark yellowish brown soils which occurs on 30 to 50 % slopes. The surface texture is loamy sand with loam to clay loam sub – soils. The soils are moderately eroded and under forest. It includes the watershed areas.

Hari series soil is deep and moderately well drained and occurs on 1 – 3% and 3 – 8% slopes or flat surface. The color ranges from very dark grayish brown to very dark brown soils. The surface texture is loam with loam sub – soils. The soils are moderately eroded and are under agricultural practice. This series cover the vast flat valley in the upper stream.

Joram top series is excessively drained which is comprised of very deep layer. It varies from dark grayish brown to dark yellowish brown in color and occurs upon the slope group of 30 – 50%. The surface texture is loamy sand with

Table 2.6
Kiile River Basin: Mechanical Analysis of Soil

Soil Series	Depth (include)	Soil Category			Textural (Class)
		Sand %	Silt %	Clay %	
Michao	0 – 20	66.6	22.4	11.4	Loamy sand
	20 – 39	66.2	17.4	20.4	Loamy
	39 – 70	56.2	16.4	27.4	Clay loam
	70 – 122	59.9	158	24.3	Clay loam
	>122	62.2	16.4	21.4	Loamy
Hari	0 – 15	79.4	14.5	6.1	Loamy sand
	15 – 33	78.4	12.5	9.1	Loamy sand
	33 – 60	89.4	5.5	5.1	Loamy sand
	60 – 90	84.4	8.5	7.1	Loamy sand
Joram top	0 – 9	70.9	17.8	11.3	Loamy sand
	9 – 24	64.9	16.8	18.3	Loamy
	24 – 74	60.9	19.4	19.7	Loamy
	74 – 120	60.9	18.4	20.7	Loamy
Joram Medium Hill	0 – 13	76.9	15.8	7.3	Loamy sand
	13 – 29	77.9	11.8	10.3	Loamy sand
	29 – 50	73.9	13.8	12.3	Loamy
	50 – 84	69.9	23.8	6.3	Loamy sand
	84 – 152	68.9	16.8	14.3	Loamy
Joram	0 – 15	69.9	18.4	11.7	Loamy sand
	15 – 23	62.9	16.4	20.7	Loamy
	23 – 75	58.9	13.4	27.7	Clay loam
	75 – 93	56.9	15.4	27.7	Clay loam
Yachuli	0 – 19	69.2	15.4	15.4	Loamy
	19 -42	66.2	16.4	17.4	Loamy
	42 – 75	63.2	13.4	23.4	Loamy
	75 – 107	60.2	9.4	30.4	Clay loam
	107 – 150	56.2	9.4	34.4	Clay
	150 – 185	59.2	11.4	29.4	Clay loam

Source: The Directorate of Soil Survey and landuse, Naharlagun loam as its sub – soils. The areas are severely eroded due to jhum cultivation. Only few patches are covered with sparse vegetation mostly of bamboos and pine.

Joram medium hill series also comprises very deep and well drained. The color varies from dark brown to very dark grayish brown to dark yellowish brown soils which is occurring in the slope group of 15 – 30%. The surface texture is loamy sand with loam as sub – soil. As the soil is under shifting cultivation, soil is moderately eroded due to gentle slope.

Joram series are occurring in the slope category between 8 – 15%. The soil is deep and well drained. The color of the soil varies from black to very dark grayish brown to dark yellowish brown to yellowish brown soils. The surface texture is loam with clay loam sub – soils. Some of the soils are under shifting whereas maximum portion of the series are under permanent paddy cultivation.

Yachuli series is very deep and well – drained which occurs on 15 – 30% slopes. Its colour varies from very dark grayish brown to dark brown to yellowish red to red soils. The surface texture is loam to clay sub – soils.

2.7 People

The study area is inhabitant by two major tribes of Arunachal Pradesh i.e. Nishi and Apatani. The northern and southern portion of the basin have occupied by Apatani's and Nishi's respectively. Both the groups belong to Tibeto – Mongoloid stock and their language belongs to Tibeto – Burman family. They trace themselves from one legendary ancestor, ABOTANI. It is believed that both the groups have migrated from northern part of the present settlement, beyond Khru & Kiime river. It was revealed by the findings of three Neolithic belts at Parsiparlo and Raga circle (north, north – west of the basin) and also by the historical remains at Talle Valley (in case of Apatani) by the Archeological findings.

Besides being originated from same family, these two groups of people vary from each other not only based on its social structure but also in the field of culture, economy and political structure. The Apatani's are settled in a flat valley in the upper basin. They live in compact villages, where the houses are constructed at the gap of 1 meter. Most of the villages are either located in the isolated hill or in the adjoining hills. They are expert in wet rice cultivation and with paddy they also grow millet and fish in abundance side by side in the paddy field. Therefore, they have a stable agricultural economy and make them self sufficient by their product. Whereas, the Nishi's villages are rarely found in clusters. Even the houses are built far from each other. Due to lack of sufficient suitable land for wet rice cultivation, they are entirely depending on slash and burn cultivation which is popularly called as Jhum cultivation. It was observed during field investigation that they are carefully utilising the limited plain land in form of narrow valley. They use these valleys for wet rice cultivation. The way of their practicing shows that they have also learnt from their Apatani neighbor. Besides agriculture, they are also fond of hunting and fishing, in which they are perhaps more expert than any other neighboring tribes. According to 2001 census, the total population of Ziro circle is 24,703 (male – 12,478 and female – 12,225). Out of total population 12, 319 are rural population and 12, 384 are urban population, which shows balance distribution of population in town and villages. The Yachuli circle have the total population of 14, 116 (malw – 7391 and female – 6725). The sex ratio of Ziro circle and Yachuli circle is 980 and 910 respectively. The sex ratio at Ziro circle during 1991 was 1025 female/1000 male but it has decreased during 2001 census with 979.72 female/1000 male.

CHAPTER - III

RELIEF AND SLOPE ANALYSIS

3.1 Introduction

Landform, considered to be dynamic in nature which shape is being changed either by endogenic or exogenic processes. The variation in shape and size of landforms use to be responsible for the differences in elevation which forms relief features and other geomorphological attributes (absolute relief, relative relief, dissection index, slope). Relief has been a measuring scale of unconformity of landforms in the vertical direction in relation to their horizontal distance for a long time (Pande, 1990).

Study of relief features reveals the present & past climatic and litho-structural setup of the area. Qualitative approach to explain the characteristics of relief features and their distribution emphasizes the detailed study of forming material and processes involved. Morphometric approach based on contours appears relatively easier to carry out the study of relief of the area. In this study an attempt is made to study relief characteristics with the help of relative and absolute relief, dissection index, profiles and hypsometric curve.

3.2 Relative Relief

Relative relief represents the difference in elevation between the highest and the lowest points falling in a unit area. The term relative relief is also called in a various other names i.e. 'local relief' or 'amplitude of relief' etc. Though the concept of relative relief was first introduced by Portsch in 1911, but its first scientific study was presented by Smith (1935). After its scientific presentation, there has been frequent application of relative relief, especially in showing the relationship of landform and land use.

Relative relief of the study area has been determined following Smith's method (1935). Study area is divided into the grids of 1km². In each grids the value of minimum and maximum height difference is placed. Relative relief is ranging from level to 498m. This range is further divided into five classes, viz.

i. Low (<100)
ii. Moderate (100 – 200)
iii. Moderately high (200 – 300)
iv. High (300 – 400)
v. Very high (>400)

The distribution pattern of relative relief shown in fig. 3.1 reveals that the areas of high relative relief correspond to the areas of high absolute relief. About 66.42 percent of the basin area lies in the moderate to moderately high relative

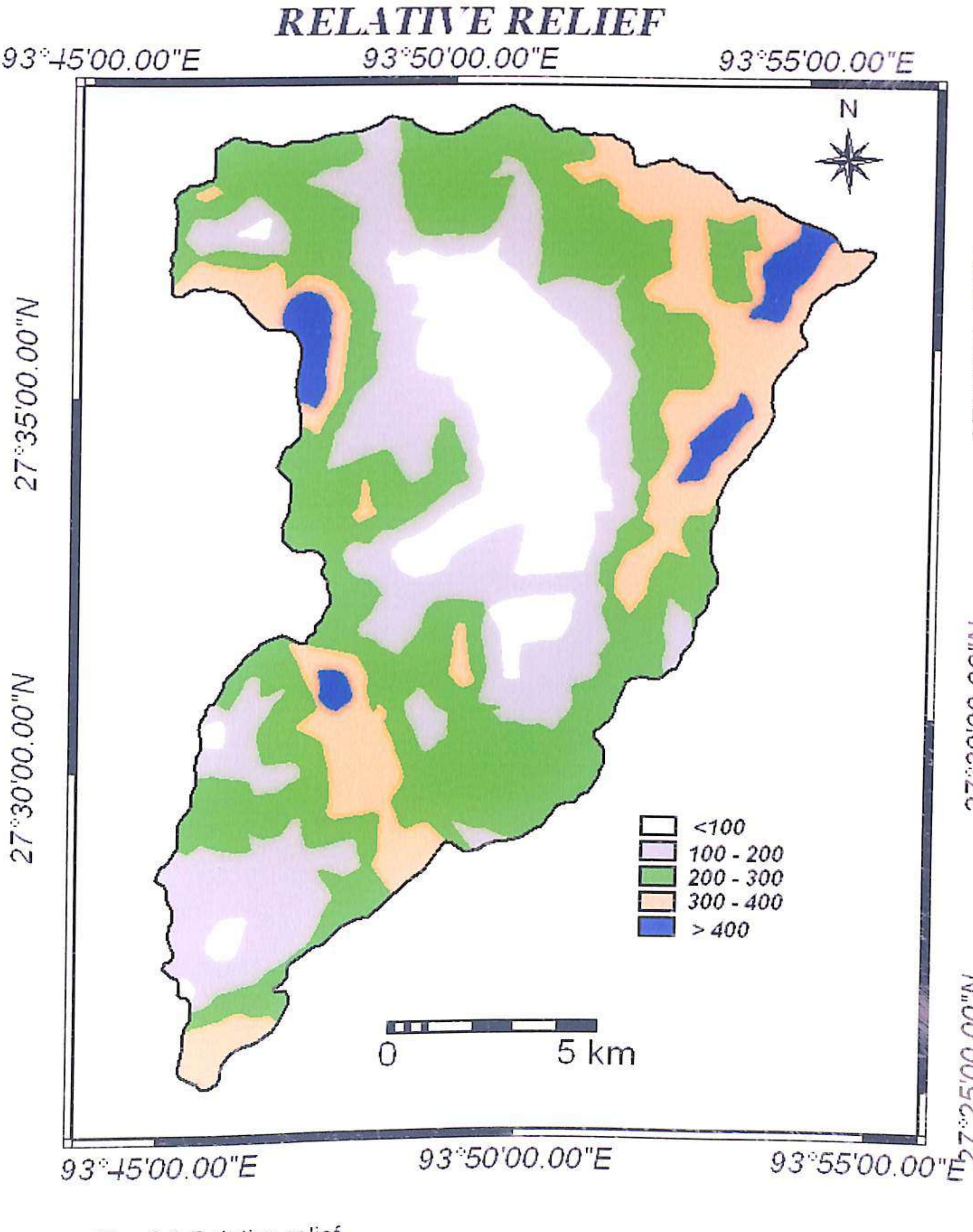


Fig. 3.1 Relative relief

relief category (Table 3.1). High to very high relative relief comprises about 19.43 percent of the basin area. Low relative relief, which is associated with the flat valley accounts about 14.15 percent of the basin area.

Table 3.1

Kiile River Basin: Relative relief

Relative relief category (m)	Ares in Km^2	Area in %	Cumulative area in %	Major categories of relative relief
<100	28.87	14.15	14.15	Low
100 – 200 200 – 300	55.90 79.65	27.39 39.03	41.54 80.57	Medium
300 – 400 >400	33.85 5.79	16.59 2.84	97.16 100	High
Total	204.062			

3.2.1 Low Relative Relief (Below 100m)

The lowest relative relief region occupies the northern and central sections of the basin covering an area of 28.87 km^2 or 14.15 percent of the total basin area. Low relief areas are found in the central part of northern basin distinctly marked as the main settlement zone of the Apatanis and Nishis.

3.2.2 Moderate to moderately high relative relief (100 – 300m)

The next important relative relief region is between 100m and 300m which cover maximum part of the basin area comprising an area of 135.55 km^2 (66.42%). It encircled the flat valley in the north and Joram and Yachuli localities in the south.

3.2.3 High to very high relative relief (300m to 400m and above)

The surface having relative relief ranging from 300m to 400m and above, covers 39.64 km^2 (19.43%) of the total basin area. It is found in the north eastern, western and southern part of the study area. The high relief region which covers only 5.79 km^2 or 2.84 % of the basin area lies in the extreme north east and western part.

3.2.4 Statistical Analysis

The statistical analysis is done for the relative relief which includes the central tendency i.e. mean, median and mode and other dispersion i.e. standard deviation, kurtosis, skewness, range, maximum and minimum. The table 3.2 shows the result of the analysis. The mean value of relative relief is 227.79 m for the study basin. The median and mode i.e. 220 indicates the central category of relative relief. The median or mid value divide whole the basin into two equal parts. But the measure of central tendency is not capable of specifying the distribution sufficiently because it does not take into consideration the internal variations between the data. Therefore the measure of dispersion is important to measure the internal variability of the values of the variable. Dispersion includes standard deviation, kurtosis, range, etc.

Table 3.2

Kiile River Basin: Statistical Measurement of Relative Relief

Mean	227.79
Median	220
Mode	220
Standard deviation	112.33
Skewness	0.128
Kurtosis	-0.285
Range	580
Minimum	0
Maximum	580

3.3 Absolute Relief

Absolute relief shows the elevation of any area above mean sea level. For the precise description of specific relief and for getting the direct or indirect evidences of the genesis and evolution of certain landform, absolute altitude is an important tool (Satpathi, 1981). The absolute relief map has been prepared by dividing the study area into grids of 1 km^2 and then the maximum height of each square is noted with the help of contours and spot heights for each grid. These values range from 1100 m (at Tago hydel) to 2684m (at the north eastern extreme). Absolute relief is further categorized into six groups at an interval of 200 m (Table 3.3, figure 3.2)

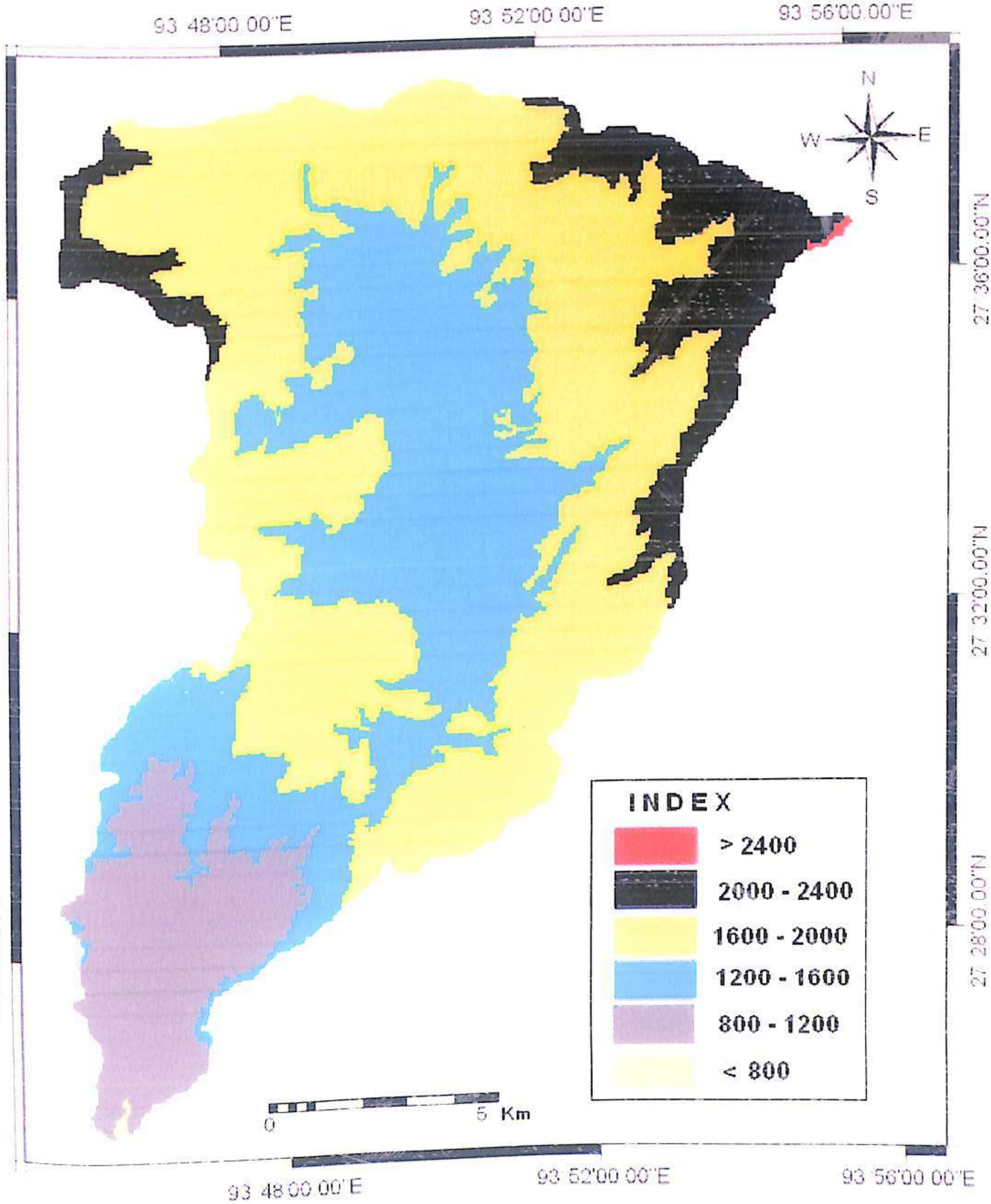


Fig. 3.2 Absolute relief

Table 3.3
Kiile River Basin: Absolute relief

Absolute relief (m)	Total area (sq km)	Area (in %)	Cumulative area (in %)	Major categories
Below 1200	5.997	2.94	2.94	Low
1200 – 1400	15.465	7.58	10.52	Moderate Low
1400 – 1600	16.75	8.21	18.73	Moderate
1600 – 1800	64.675	31.69	50.42	Moderate high
1800 – 2000	61.85	30.31	80.73	High
Above 2000	39.325	19.27	100	Very High
Total	204.062			

3.3.1 Distribution of Absolute Relief

The lowest absolute relief category i.e. below 1200 m covers most of the southern part of the basin. It covers an area of 5.997 km² (2.94 %) of the total study area. Villages like Tago and Yachuli, are situated within this group.

The absolute relief class having the height range of 1200 – 1400m covers 15.46 km² (7.58 %) of the basin area. It covers maximum area in the southern part of basin. Parts of Mai and Yachuli and Tun villages are falling under this category.

The next important higher category lies with a height range of 1400 – 1600m, covers 16.75 km² (8.21%) of the basin area. It includes upper part of Mai and Joram localities.

The area of absolute relief having the height range of 1600 – 1800 and 1800 –2000m has the largest extension in the Kale basin. It covers 64.67 km² or

31.69 percent and 61.85 km² or 30.31 percent respectively. It covers areas in the surrounding of the flat valley and also some of the part in the lower course of the river.

The highest altitude i.e. above 2000m with 39.32 km² (9.27%) of the total basin area is associated with dense mixed forest having least human habitation.

3.3.2 Statistical Analysis

The statistical analysis of absolute relief of Kiile river basin is shown in table no 3.4. The mean value is 1802.62 m which falls under the largest basin area extention. The median and mode is 1820m and 1880m respectively.

Table 3.4

Kiile River Basin: Statistical Measurement of absolute relief

Mean	1802.62
Median	1820
Mode	1880
Standard deviation	320.92
Skewness	0.02
Kurtosis	-0.025
Range	1584
Minimum	1100
Maximum	2684

3.4 Dissection Index

The dissection index is an important morphometric indicator in understanding the nature and magnitude of dissection pattern of landscape. It is expressed as the ratio between relative relief and absolute relief. Dov Nir (1957) states that dissection index may be considered as a criterion of relief energy. Equal relative altitudes are not always of equal importance, since their absolute altitudes may differ. The picture gained from relative altitudes only is static, for it fails to take into account the vertical distance from the erosion base, i.e. the dynamic potential of the area studied. On this basis, Dov Nir presented the calculation of dissection index by taking in account the dynamic potential state of the area i.e. the ratio between relative relief and absolute relief. He expresses the formula for obtaining the dissection index as:

Dissection Index (DI) = Relative Relief (Rr)/Absolute Relief (Ar)

The dissection index determines the stage of cycle of erosion, as it provides base for the estimation of the vertical balance of erosion in an area. Thus, it shows the degree of dissection. The values of dissection index vary in between 0 (complete absence of dissection) to 1 (vertical cliff at sea level).

The computation of dissection index is done through grid method, wherein the study area is divided into grids of 2cm which represent $1km^2$ and the ratio is

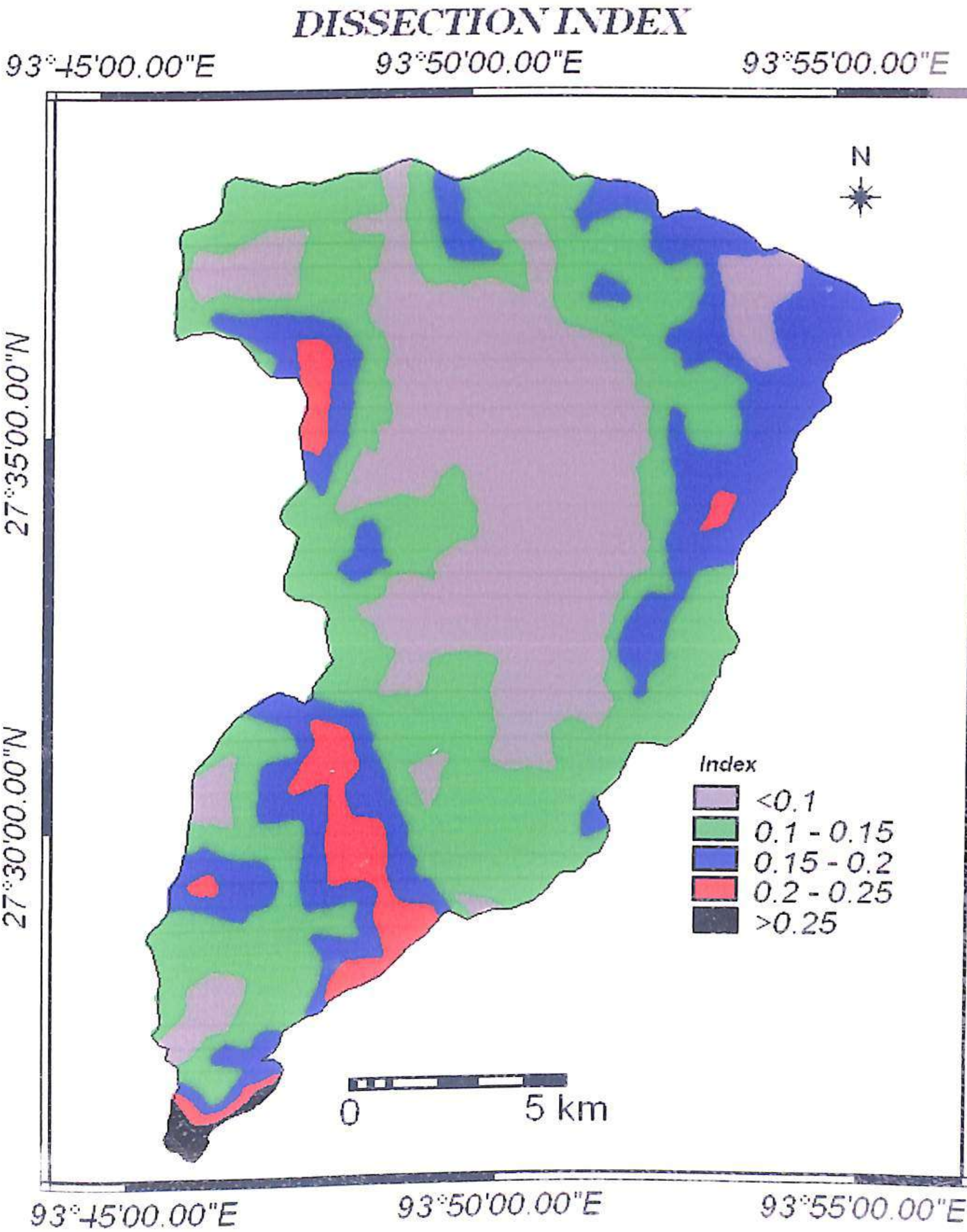


Fig. 3.3 Dissection Index

calculated for each individual grid. After the computation of values for each groups, isopleths are drawn at suitable class interval (fig 3.3).

The calculated dissection index of Kiile river basin varies from 0 to .345 showing five different ranks of index:

1. Very low dissection index (Below 0.10)
2. Low dissection index (0.10 – 0.15)
3. Moderate dissection index (0.15 – 0.20)
4. High dissection index (0.20 – 0.25)
5. Very high dissection index (Above 0.25)

3.4.1 Distribution of Dissection Index

Table 3.5 shows the distribution of dissection index in the study area signifies that low to very low group of the dissection index covers maximum area i.e. 152.882 km^2 (74.92%) while the area coverage decreases with the increase in dissection index i.e. moderate to high and very high expresses 49.88 km^2 (24.44%) and 1.3 (0.64%) respectively.

The area of very low dissection index covers 62.865 km^2 (30.81%) of the total basin area. It occurs mostly in the central part of the basin except a few patches in the southern part covering the Ziro, Joram and Yachuli localities.

Table 3.5

Kiile River Basin: Dissection index

Dissection index category	Area (in km^2)	Area (in %)	Cumulative area (in %)	Major Categories
Below 0.10	62.865	30.81	30.81	Very low
0.10 - 0.15	90.017	44.11	74.92	Low
0.15 – 0.20	40.365	19.78	94.7	Moderate
0.20 – 0.25	9.515	4.66	99.36	High
Above 0.25	1.3	0.64	100	Very high
Total	204.062			

The low dissection index covers maximum part of the basin which measure 90.017 km^2 or 44.11 percent of the basin area.

Moderate dissection index accounts for 40.365 km^2 or 19.78 percent of the basin area. It occurs in small patches in the basin except a single large area in the north eastern extreme which covers about 20.725 km^2.

High dissection index is associated with the rugged and broken hilly terrains forming divides and the steeply sloping areas of the region. It measures 9.515 km^2 or 4.66 percent of the basin area.

Very high dissection index accounts only 1.3 km^2 or 0.64 percent of the basin area. It only occurs near the mouth.

The mean of dissection index is 0.1237 which implies low dissection index. The median, mode and standard deviation are 0.1260, 0.10 and 0.0059 respectively. The statistical analysis values are shown in table 3.6.

Table 3.6

Kiile River Basin: Statistical Measurement of Dissection Index

Mean	0.1237
Median	0.126
Mode	0.1
Standard deviation	0.0059
Skewness	0.402
Kurtosis	1.129
Range	0.36
Minimum	0
Maximum	0.36

3.5 Profiles

Preparation of the profiles of an area is considered the easiest way of showing different landform is the profile drawing. In comparison to contour map, profiles are the appropriate source for the interpretation and identification of relief and landforms. Cross profile of the region, can give a considerable knowledge of the form, stage of erosion, breaks in the slope, etc. The contour lines at a suitable interval on topographical maps provide the prime information for the construction of profiles. From the topographical map, seven numbers of parallel lines have been drawn at six centimeters interval along east to west. Then a series of profiles have been drawn. All are arranged in one column representing a series from one end of the map to the other. This way Kale river basin has been divided into seven parts and serial profiles have been drawn across the river.

3.5.1 Serial Profiles

Seven serial profiles are drawn along AB, BC, CD, EF, FG, GH, and IJ lines (Fig.3-4) . The serial profiles show summit point, river valley, etc. The height of the profiles is more towards the eastern part of the basin. The presence of ruggedness in the profiles towards the periphery of the basin shows active erosional processes. The profile in the middle course of the river in the northern side is flat which is showing the flat valley. Isolated summit within the flat profile depicts the presence of isolated hillock within the flat valley.

3.5.2 Superimposed Profile

After tracing all the profiles of the series are traced on a single frame, which is known as superimposition of profiles one over another. The superimposed profiles show different stages of erosional surfaces and also depict the surfaces of different slopes. This type of drawing of profiles reflects the true view of landform from a particular direction. Fig 3.5 reveals that the northern part is mountainous region consisting a flat valley. The southern part reveals low undulating relief.

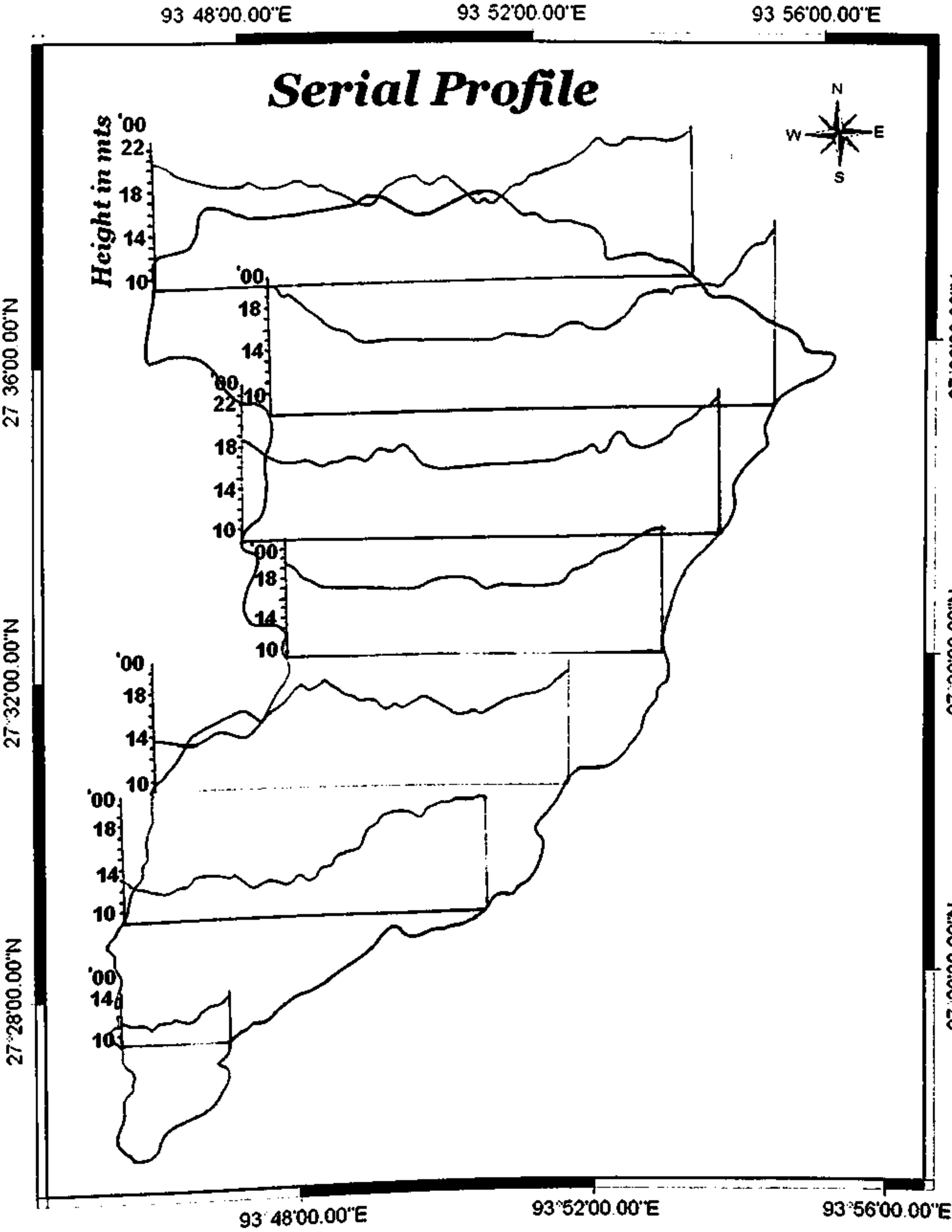


Fig 3.4 Serial profiles

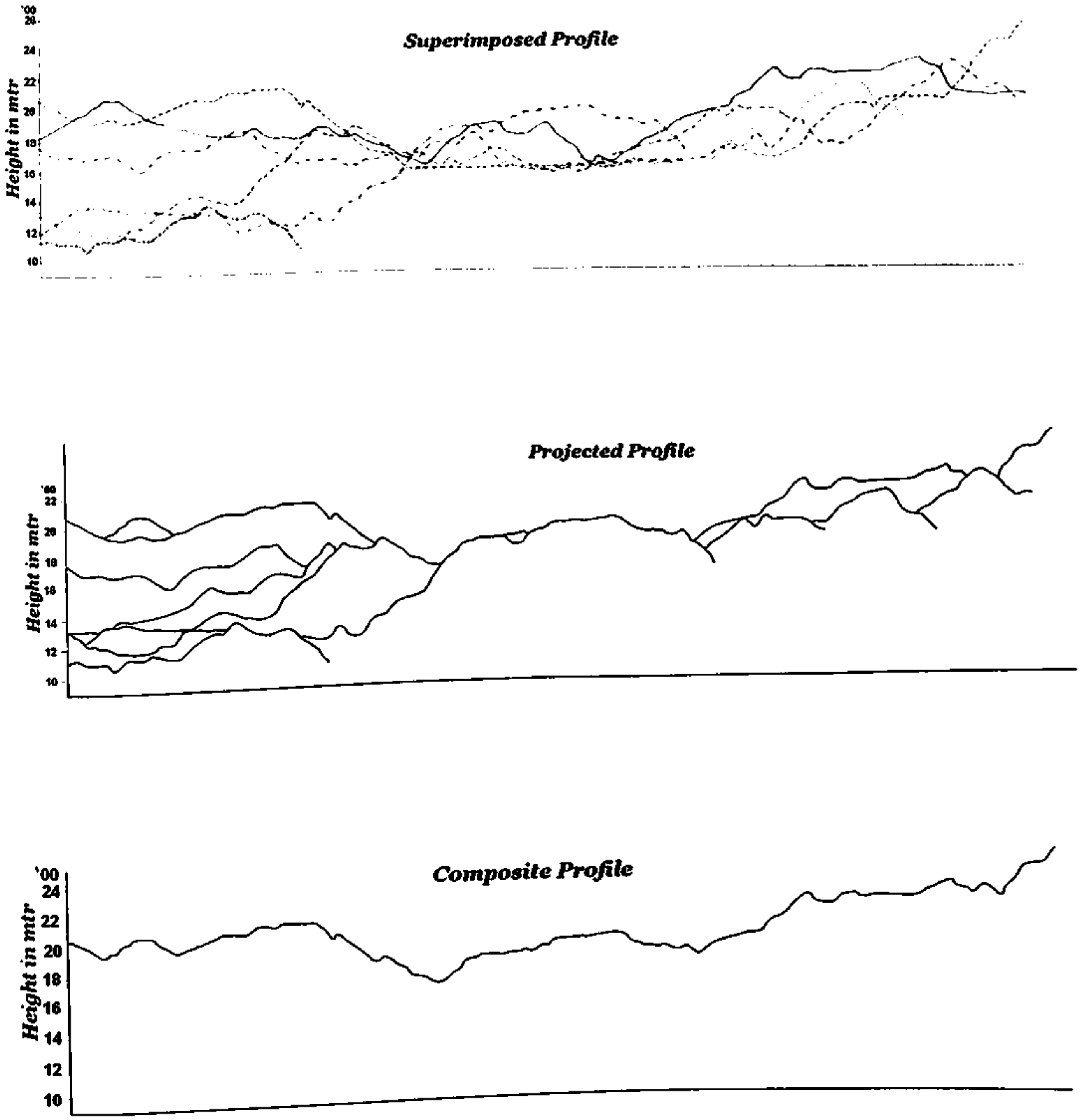


Fig. 3.5 a. Superimposed profile b. Projected profile c. Composite profile

3.5.3 Projected Profile

In case of projected profile, the relief profiles are plotted within a single frame and the profiles which come below the succeeding profile is left untraced. Therefore, the projected profile (fig 3.5) gives a panoramic effect, with a distant skyline, showing the summit details.

3.5.4 Composite Profile

The composite profile can represent the surface of any area of relief which shows surface ruggedness and the general skyline of the landscape.

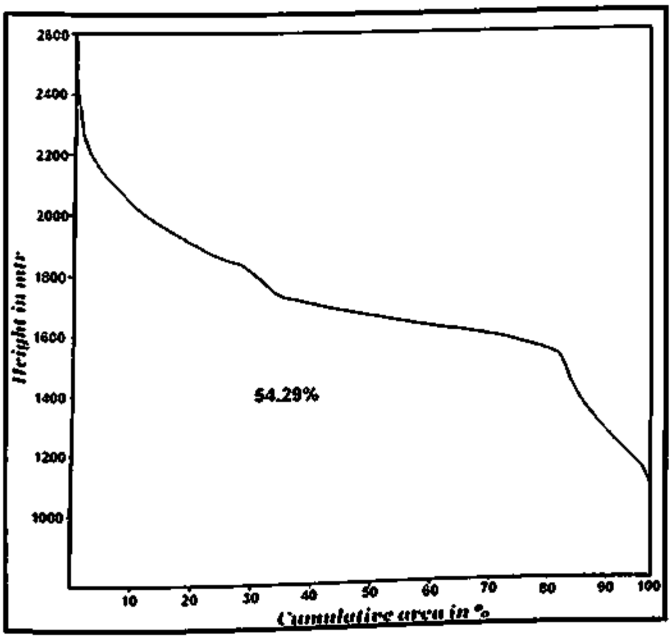
3.6 Area-height curves

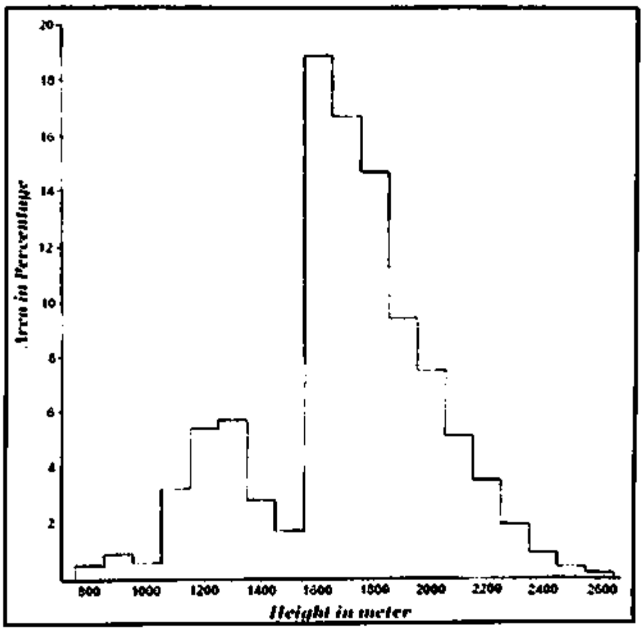
The area height curve shows the actual area of land between two successive contours. To prepare this curve for the Kiile river basin, calculated percentage of the area has been plotted against the height. The area coverage in between 1600m to 1700m is minimum. In the margin of this category, degradational activities are observed very active due to the gravity affect.

3.7 Hypsometric Analysis

Hypsometry refers the distribution of elevation as a function of area occupied by each contour interval within a geomorphic unit. Hypsometry is often used to characterize landscape morphology, traditionally in the context of the degree of fluvial dissection (Brodlehurst, Kelin, 2004). This process determines the fraction of a surface bounded by specific elevations. Hypsometric analysis is the study of the distribution of horizontal cross – sectional area of a landmass with respect to elevation (Strahler, 1952). The hypsometric analysis has been used to differentiate between erosional landmass at different stages during their evolution (Strahler, 1952). Area height curves, hypsometric curves and percentage hypsometric curves are generally used to show the relationship between elevation and area of the geomorphic unit. The basic data which required for its preparation are area between successive contours and their respective heights (fig 3.6).

The hypsometric curve, the distribution of area with elevation, provides a quantitative means for characterising the planimetric and topographic structure of a catchment (Luo, 1998). The hypsometric curve therefore provides a method for analysing the geomorphic form of catchments and landforms by characterising the distribution of elevation within a catchment (Willgoose and Hancock, 1998). The shape of the hypsometric curve shows the age of the particular catchment. Strahler in 1957 and 1964 recognised three distinct





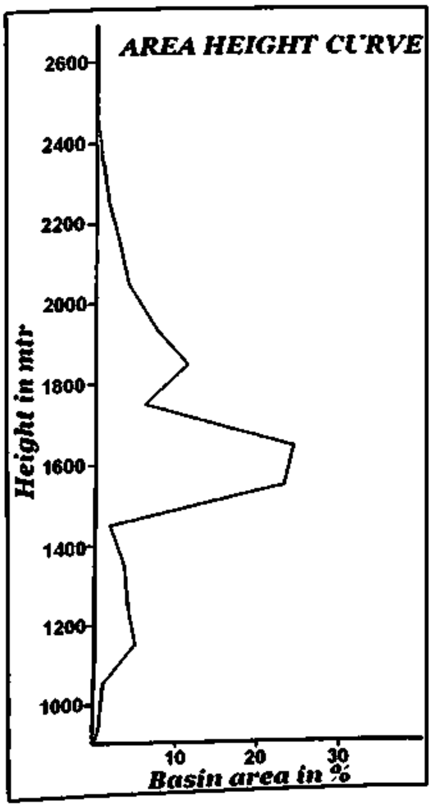


Fig. 3.6 a. Hypsometric curve b. Altimetric frequency curve

c. Area height curve

developmental stages that can be identified using the hypsometric curve including young, mature and monadnock. The hypsometric integral, the area under the curve itself, also provides a measure of dissection of a landscape. The hypsometric curve is therefore an important tool for the analysing of landform evolution over the geologic time scales.

The values of the area are plotted as ratios of the total area of the basin against the corresponding heights of the contours. The hypsometric curve of Kiile river shows that the highest peaks (above 2000m or more) comprise a very small portion of the total basin area. The area between 2600 m to 2000m height covers the main basin of the Kiile river, form some what plain land and receive masses removed by erosion while the land below 1500m shows a high gradient with high erosional surfaces.

The percentage hypsometric curve is prepared using two ratios of relative height (h/H, where 'h' denotes height between two successive contours and H indicates total height) versus relative area (a/A, where 'a' denotes area between two successive contours and A indicates total basin area). This provides useful information to recognize the stages of cycle of erosion in a drainage basin. By dividing the height of a given point (h) by the total relief (H), the relative height of any point is simply a number between 0.0 and 1.0. Height, 'a' is divided by the total area of the basin (A) which gives a value between 0.0 and 1.0. When the values are plotted on an x & y coordinates, the relative values of h/H and a/A form the hypsometric curve. The x and y values are dimensionless, representing proportions of the total area and height. The areas below the curve signify as the hypsometric integral, which provides a measure of dissection of a landscape. The differentiation of the curves shows the lithological and structural differences.

The Kiile river basin which is consisting of gneiss-quartzite as base material is approaching to attain mature stage of cycle of erosion with hypsometric integral of 54.29%.

3.8 Altimetric Frequency Analysis

The altimetric frequency analysis is valuable for the geomorphological studies especially for the recognition and correlation of erosional surfaces. This analysis is done by computing the frequency of occurrence of heights above sea level. The altimetric frequency histogram of Kiile river basin gives clear picture of the relative position and percentage of different land surfaces of the basin. From the histogram, it is seen that the area between 1600m and 1800m covers 50.3 percentage of the total basin area. The area between 800m and 1000m contour interval has only 2 percent and covered with the low hills near the mouth of a river. The region having the contour interval of 2400m and 2600m are of limited extends covering a small area of the basin i.e. 1.5 percent. These portions are confined to the northern and north eastern parts of the basin area.

3.9 Average Slope

The study of slope is one of the most significant aspects of geomorphology. There is no any doubt to say that geomorphology is primarily a study of slopes. The slope is one of the main properties of landforms which affect the human activities like agriculture, transport, human settlements, etc. Slope is the product of both endogenetic and exogenetic processes. Based on this two processes, the slope can be either endogenetic or exogenetic slope. The slopes which are originated from the upliftment folding, faulting, etc., are endogenetic slopes because they are directly related with the geological structure whereas exogenetic slopes are those slopes which are formed by the action of external atmospheric processes such as weathering, erosion, mass wasting, etc., it may be either aggradational or degradational.

There are several techniques for the construction of average slopes. A method of average slope determination was used as long ago as 1890 by S. Finsterwalder and by K. Peucker. Later on studies have been made by J. Tricart and J. Muslin (1951), C.K.Wentworth (1930), G.H.Smith(1935), Raiz and Henry (1937), A.H.Robinson (1948), A.N.Strahler (1956), J.I.Clarke and K.Orrell (1958), R.J.Eyles (1965), etc.

In the present study of the Kiile basin, the average slope is determined with the method as suggested by C.K.Wentworth (1930). Modified (Joshi et. al

1989) constant value is applied in this formula as topographical maps used are in metric system:

$$\text{Slope angel} = \tan\emptyset = \frac{N \times I}{636.6}$$

Where N = Average number of contour crossing

I = Contour Interval

tanØ = Average slope angle

636.6 = Constant value

To apply this method study area is divided into grids of one square kilometer. Contour crossing at 20m interval in each grid is counted. Using the calculated average value of contour crossing in the above formula, the average slope is worked out. The average slope of the study area ranges in between level to 29°. Altogether calculated average slope is categorized in six groups. Table 3.7 indicates the six categories of slope with their area coverage and remarks.

Table 3.7
Kiile River Basin: Average slope

Slope (in degree)	**Area in Km²**	**Area in %**	**Cumulative area in Km²**	**Major slope categories**
Below 5	5.162	2.53	5.162	Very Gentle slope
5 – 10	17.75	8.71	22.912	Gentle slope
10 – 15	28.5	13.97	51.412	Moderate slope
15 – 20	71.55	35.06	122.962	Moderate steep slope
20 – 25	72	35.28	194.962	Steep slope
Above 25	9.1	4.46	204.062	Very steep slope
Total	204.062	100		

Fig. 3.7 indicates the spatial distribution of average slope in the study area. The various categories shown in the map is described as below:

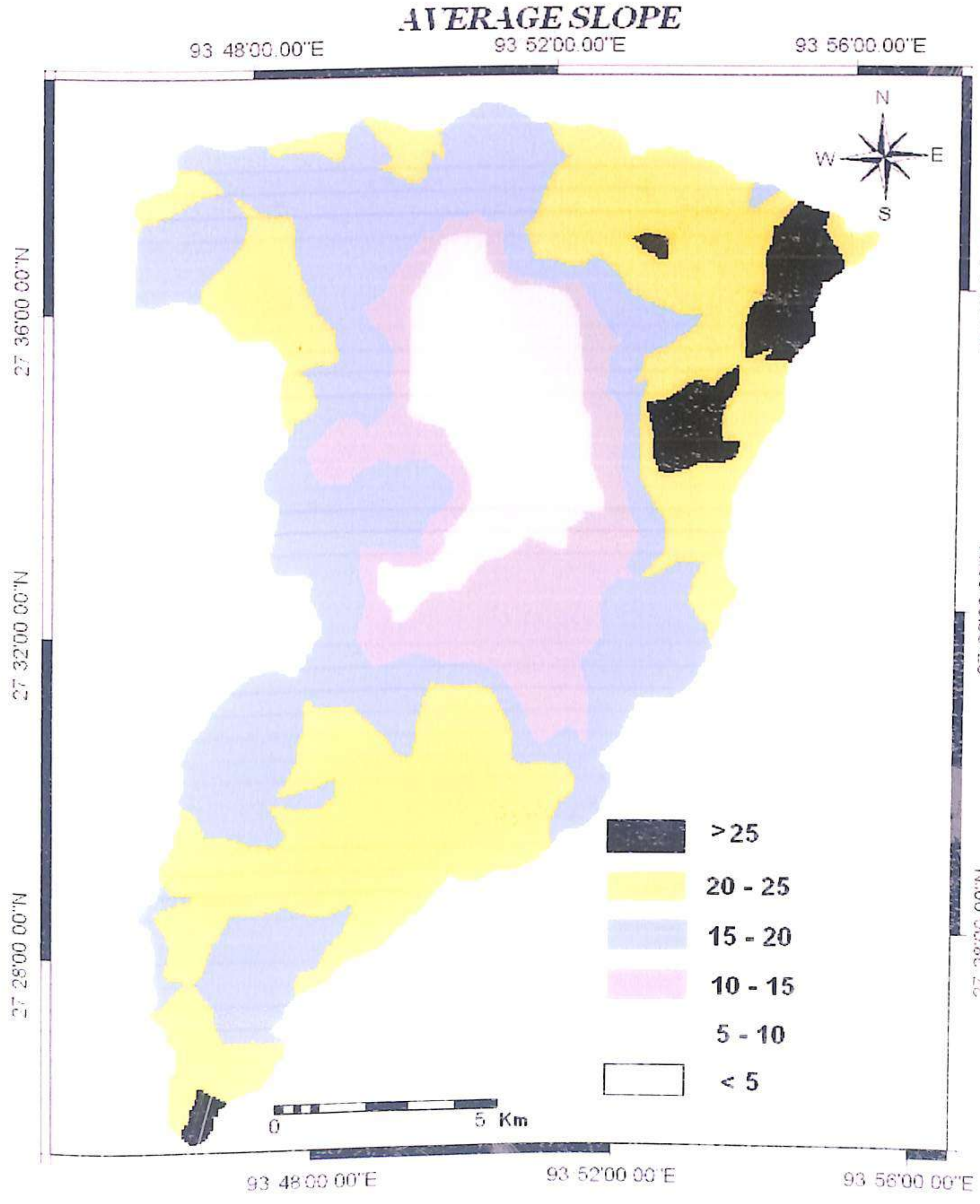


Fig 3.7 Average Slope

3.9.1 Area of Very Gentle slope (Below 5°)

It is characterize by the flat valley, which shows suitable areas for the agricultural purposes. It occupies 5.165 Km^2 (2.53%) of the total basin area. Gentle slope occurs only in the central portion in Northern part of the basin.

3.9.2 Area of Gentle slope (5° - 10°)

The area of gentle slope covers 17.75 Km^2 (8.71%) of the total basin area. This slope type occurs in the central portion of northern basin. Maximum of the agricultural field are within this slope category. This area is also characterized by few river terraces which are observed along the rivers.

3.9.3 Area of Moderate slope (10° - 15°)

The area of moderate slope is accounting for 28.5 Km^2 (13.97%) of the basin area. This slope category is associated with the upper valley slopes, which are visible mostly in the periphery of gentle slope in the northern basin and few patches in the extreme north western, south eastern and south western position.

3.9.4 Area of Moderate steep slope (15° - 20°)

Moderately steep slope is associated with the mountainous uplands, crests of the ranges, and intermediate parts of the mountain ranges, accounts for an area of 71.55 Km^2 (35.06%) of the basin area.

3.9.5 Area of Steep slope (20° - 25°)

Steep slopes covers an area of about 72 km^2 (35.28%) of the total area of the basin. The steep slopes occur mostly in the upper part of the basin both in the eastern and western watershed and also few patches in the northern part.

3.9.6 Area of Very Steep slope (Above 25°)

The area of very steep slope covers about 9.1 Km^2 (4.46%) of the study area. This category occurs in the primary and secondary divides of the basin. Big patch of very steep slopes occurs in the north eastern side of the basin. Small patch of steep slopes are also noted near the mouth of the river.

3.10 Central Tendencies and Dispersions

The average slope in Kiile river basin ranges from 0° to 29.5°. The mean, median and mode of the average slope shows 18.30, 19.50 and 21 respectively.

The measures of location or central tendencies tells about the general level of magnitude of the distribution.

As the values vary greatly in their qualitative as well as quantitative nature, the distribution which is to be analysed in various respects, needs such a value which can be taken as the base for the measurements. Whereas measures of deviation or variability tells about the distances of the variates from the central value or mean value. Dispersion includes the deviation, Skewness and Kurtosis. Table 3.8 shows the values of statistical measurement.

Table 3.8

Kiile River Basin: Statistical Measurement of Average Slope

Mean	18.3
Median	19.5
Mode	21
Standard deviation	5.82
Skewness	-0.832
Kurtosis	0.337
Range	29.5
Minimum	0
Maximum	29.5

3.11 Slope In Percentage

The National Remote Sensing Agency (NRSA), Hydrabad have developed a new way to identify the slope characteristics on an area by following the guidelines of All India Soil and Land use Survey (AIS & LUS). This technique is the direct way to find out the slope categories. Even the minor slope variation can be depicted. Because of all these advantages, this technique have got wide acceptance in different fields, may be a geomorphologist, hydrologist etc. Survey of India toposheets with 1:50000 scales are used for the calculation of slope in percent.

The slope in percentage depends on the comparisons of vertical distance (VD) to horizontal distance (HD). The vertical drop can be estimated from the contour intervals. The horizontal distance between the contours can be measured by multiplying the map distance with the scale of the map.

The slope in percent can be expressed as :

Slope in percent = $\frac{\text{Contour interval x 100}}{\text{Horizontal distance between contours converted to map scale}}$

To illustrate this, if the contour spacing is 2cm, that means the horizontal distance will be 2 cm x 50,000 = 100000 cm or 1000 m and vertical drop is 10 m. Thus the percentage of slope can be written as –

$$\frac{20 \times 100}{1000 \text{ m}}$$

$$= 2 \%$$

Closed spaced contours on the toposheet map have higher percentage i.e. .05 cm or .1 cm have 80 % and 40 % respectively. Whereas sparse contour spacing have lower slope percentage i.e. 1.9 cm or 2 cm have 2.1 % or 2 %

respectively. Thus, wherever the density of contours on the map is high, it will represent higher slope percentage and vice versa. By following the procedure, the Kiile river basin has been divided into different zones of percent slope. With the help of planimeter the area of each category is identified.

Table 3.9
Kiile River Basin: Areal distribution of slope in percent

Slope (%)	Area (Km^2)	Area in %	Cumulative area (Km^2)	Cumulative area in %	Remarks
Above 40	9.925	4.864	9.925	4.864	Very steep
30 – 40	142.56	69.84	152.451	74.704	Moderately steep to steep
10 – 30	9.455	4.63	161.906	79.334	Strongly sloping
5 – 10	2.092	1.02	163.998	80.354	Moderately sloping
3 – 5	2.162	1.06	166.16	81.414	Gentle sloping
1 – 3	1.646	0.81	167.806	82.224	Very gentle sloping
Below 1	36.256	17.77	204.062	100	Nearly level
Total	204.06 2	100			

The slope in percent of Kiile river basin varies in between 0 to 40%. The 40% slope signifies very steep slopes. The area under nearly level slope i.e. below 1 is 36.256 km^2 (17.77%) of the total basin area. The very gentle sloping group, i.e. 1 – 3% slope, is only 1.646 km^2 or 0.81% of the total area. The slope group of 30 – 40% covers the maximum area of 142.526 km^2 (69.84%) of the total basin area and it is under moderately steep to steep sloping group. The very steep slopes i.e. above 40% slope covers 9.925 km^2 (4.864%).

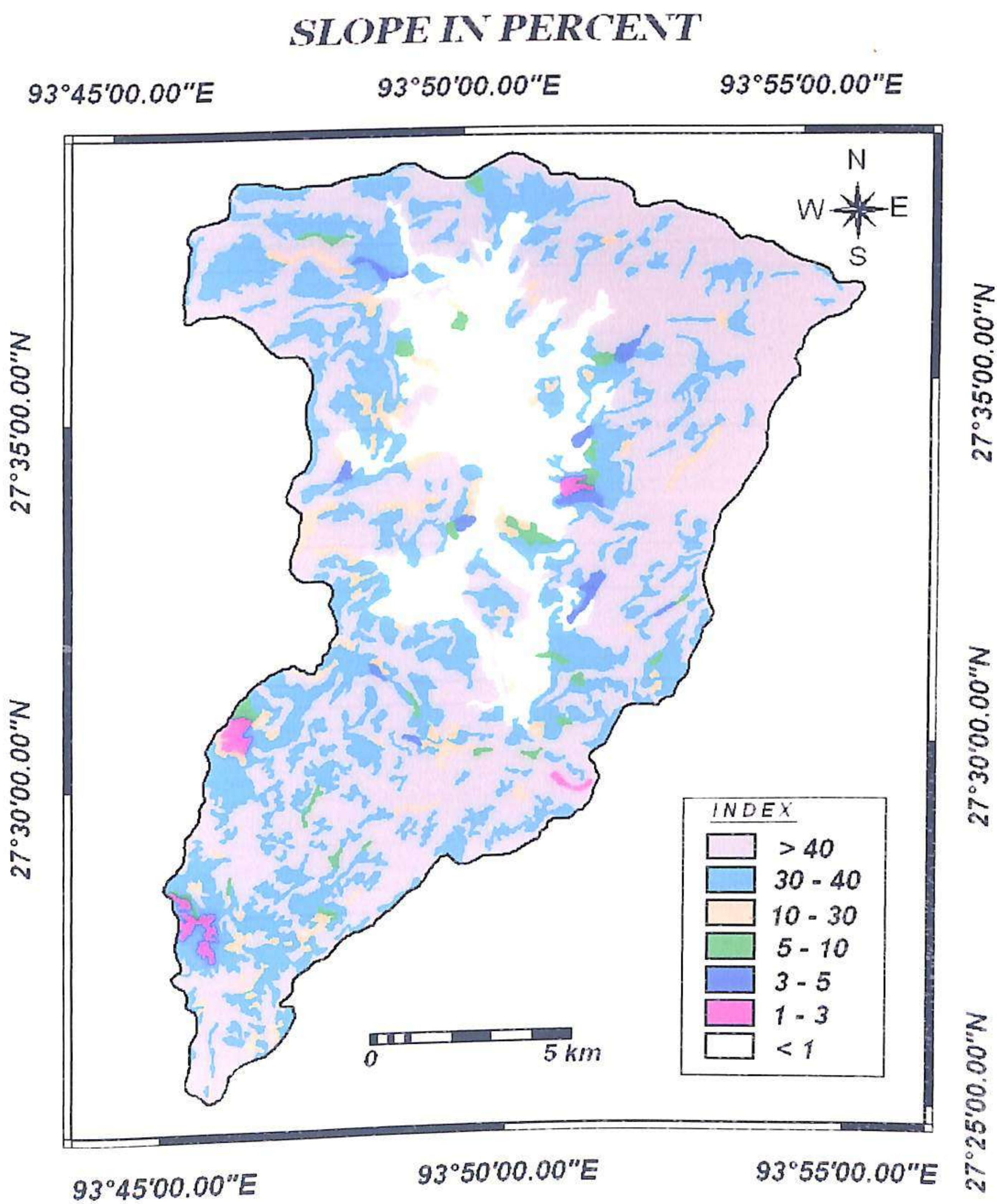


Fig. 3.8 Slope in percentage

The fig 3.8 shows the spatial distribution of slope in percent. The main advantage of this method of slope determination is that, it helps to identify the slope variation even in a micro level. The majority of slope falls under the group 30 – 40% slope, which is distributed throughout the basin. Some patches under these slopes can be also observed in some of the isolated hillocks. When the average slope of the study basin by C.K.Wenthworth's method and the slope in percent were compared, some similarities on moderately steep to steep slopes and nearly level cover similar region. Except 30 – 40% and below 1% slope category, all the other groups are distributed in a scattered manner. The Ziro valley falls under nearly level sloping group i.e. below 1%.

3.12 Correlation between Slope & Relative Relief

In table 3.10 are shown the distributional characteristics of two variables, viz., Relative relief and slope with respect to each other in the study area. The distribution shows that the area decreases with the increasing slope. The distribution is not having a particular trend. Therefore, by using Karl Pearson's coefficient of correlation a value of 0.090 is calculated which shows positive correlation. Under the group 0 – 100m relative relief, slope ranges in between 0° - 24.9° covers an area of 29.349 Km^2 which is 14.38% of the total area.. The slope group i.e. 0° - 5°, 5° - 10°, 10° - 15°, 15° -20°, 20°- 25° comprises an area of 18.8%, 50.63%, 26.06%, 4.04% and 0.47% respectively. Maximum part of this group is under 5° - 10° slope category which covers maximum area in the upper course.

Table 3.10

Kiile River Basin: Slope vs Relative Relief

Slope/ Relative Relief	0 – 5°	5° – 10°	10° – 15°	15° – 20°	20° – 25°	25° – 29.5°	Total
0 – 100	5.512	14.861	7.651	1.186	0.139	-	**29.349**
100 – 200	0.302	3.953	18.929	23.604	8.883	-	**55.671**
200 – 300	-	-	2.441	40.542	31.068	1.767	**75.818**
300 – 400	-	-	-	5.487	25.372	5.9	**36.759**
400 – 500	-	-	-	0.349	3.651	2.465	**6.465**
Total	**5.814**	**18.814**	**29.021**	**71.168**	**69.113**	**10.132**	**204.062**

Under the 100m – 200m relative relief, slope ranges *in* between 0° - 24.9° covering an area of 55.671 Km² which is 27.28% of the total basin area. The table shows that with the increasing of slope, the area also increases. The slope group i.e. 0° - 5°, 5° - 10°, 10° - 15°, 15° - 20° and 20° - 25° consist of 0.54%, 7.10%, 34%, 42.40% and 15.95% respectively. About 76.4% areas are under 10° - 20° slope category.

The 200m – 300m of relative relief, covers and area of 75.818 Km² or 37.15% of the total basin area. In this group, slope categories varies from 10° - 15°, 15° -20°, 20°- 25° and above 25° consisting 3.22%, 53.47%, 40.98% & 2.33% respectively. This category covers the maximum area.

Under the group 300m – 400m, relative height slope ranges in between 15° to 29.5° covers an area of 36.759 Km² or 18.01% of the total area. The slope groups are 15° -20°, 20°- 25° and above 25° with 14.92%, 69.02% and 16.05% respectively.

Relative relief under the group 400m – 500m height consist of an area of only 6.465 Km² or 3.17% of the total basin area. This is the group of lowest area cover. Slope groups are 15° -20°, 20°- 25° and above 25° consisting 5.4%, 56.47% and 38.13% of the total area respectively.

3.13 Correlation between Slope and Absolute Relief

Table 3.11 reveals that with an increasing in absolute relief, slope also increases suddenly and when slope inclination is very high, absolute relief also reach very high. The coefficient of correlation between slope and absolute relief is -0.11 which shows negative correlation. Where slope is above 25°, absolute relief is 1600m – 2684m and where slope is 0° - 5°, absolute relief is also 1400m – 1800m. So, it is very clear that the slope rises along with the rise in altitude.

Table 3.11

Kiile River Basin: Slope vs Absolute Relief

Absolute Relief Slope	**Below 1200**	**1200 – 1400**	**1400 – 1600**	**1600 – 1800**	**1800 - 2000**	**Above 2000**	**Total**
Below 5°			2.961	4.447			**7.408**
5° - 10°			2.208	15.622			**17.83**
10° - 15°		0.225	1.2	26.247	1.425	0.9	**29.997**
15° - 20°	0.875	7.722	4.547	11.272	40.287	6.122	**70.825**
20° - 25°	3.572	7.247	5.825	9.222	15.247	28.192	**69.305**
25° - 29.5°	0.75			0.875	2.225	4.847	**8.697**
Total	**5.197**	**15.194**	**16.741**	**67.685**	**59.184**	**40.061**	**204.062**

Under the group 0 – 1200m absolute relief, slope ranges in between 15° - 29.5° covers an area of 5.197 Km² which is only 2.55 % of the total basin area. The slope group i.e., 15° - 20°, 20° - 25° and above 25°, comprises an area of 16.84 %, 68.73 % and 14.43% respectively. Maximum part of this class is under the slope category of 20° - 25°.

The absolute relief group i.e. 1200m – 1400m, falls under the slope category in between 10° - 24.9° covers a total area of 15.194 or 7.44%. The slope group i.e. 10° - 15°, 15° - 20° and 20° - 25° comprises an area of 1.48%, 50.82% and 47.69% respectively. About 98.52% areas are under 15° - 25° slope group.

The 1400m – 1600m absolute relief, covers an area of 16.741 Km² which is 8.2% of the total basin area. The slope category in this group ranges from 0° - 5°, 5° - 10°, 10° - 15°, 15° - 20° and 20° - 25° consisting an area of 17.69 %, 13.19 %, 7.17 %, 27.16 % and 34.79 % respectively. It shows that as the slope angle increases the area also increases.

Under the group 1600m – 1800m, covers the maximum area of 67.685 Km² or 33.17 % of the total basin area. The slope category in this absolute relief group ranges from 0° - 29.5°. In this group slope categories ranges from 0° - 5°, 5° - 10°, 10° - 15°, 15° - 20°, 20° - 25°, 25° - 29.5° consisting 6.57 %, 23.08 %, 38.78 %, 16.65 %, 13.62 % and 1.29 % of the area respectively.

Absolute relief under the group 1800m – 2000m consists of an area of 59.184 Km^2 or 29 % of the total basin area. This category is the second highest under area covered. Slope groups are 10° - 15°, 15° - 20°, 20° - 25° and 25° - 29.5° covers an area of 2.49 %, 68.07 %, 25.76 % and 3.76 % respectively. The slope group 15° - 25° inclination covers the maximum area of 55.534 Km or 93.83%.

The absolute relief under the group 2000m – 2684 m height consist of an area of 40.061 Km^2 or 19.63 % of the total basin area. The slope groups under this category are 10° - 15°, 15° - 20°, 20° - 25° and above 25° consisting an area of 2.2 %, 15.28 %, 70.37 % and 12.1 % respectively.

3.14 Slope Type

Slope is defined as the surface inclination between hilltop and valley bottom. Identification of slope is very significant in the geomorphic study. Slope type is not same through out the earth surface. There are various factors which are responsible for the determination of slope type of any region. Slopes are mainly controlled by the geological setting, lithology, climatic condition, vegetal cover, drainage characteristics, relief and denudational processes (weathering and mass wasting).

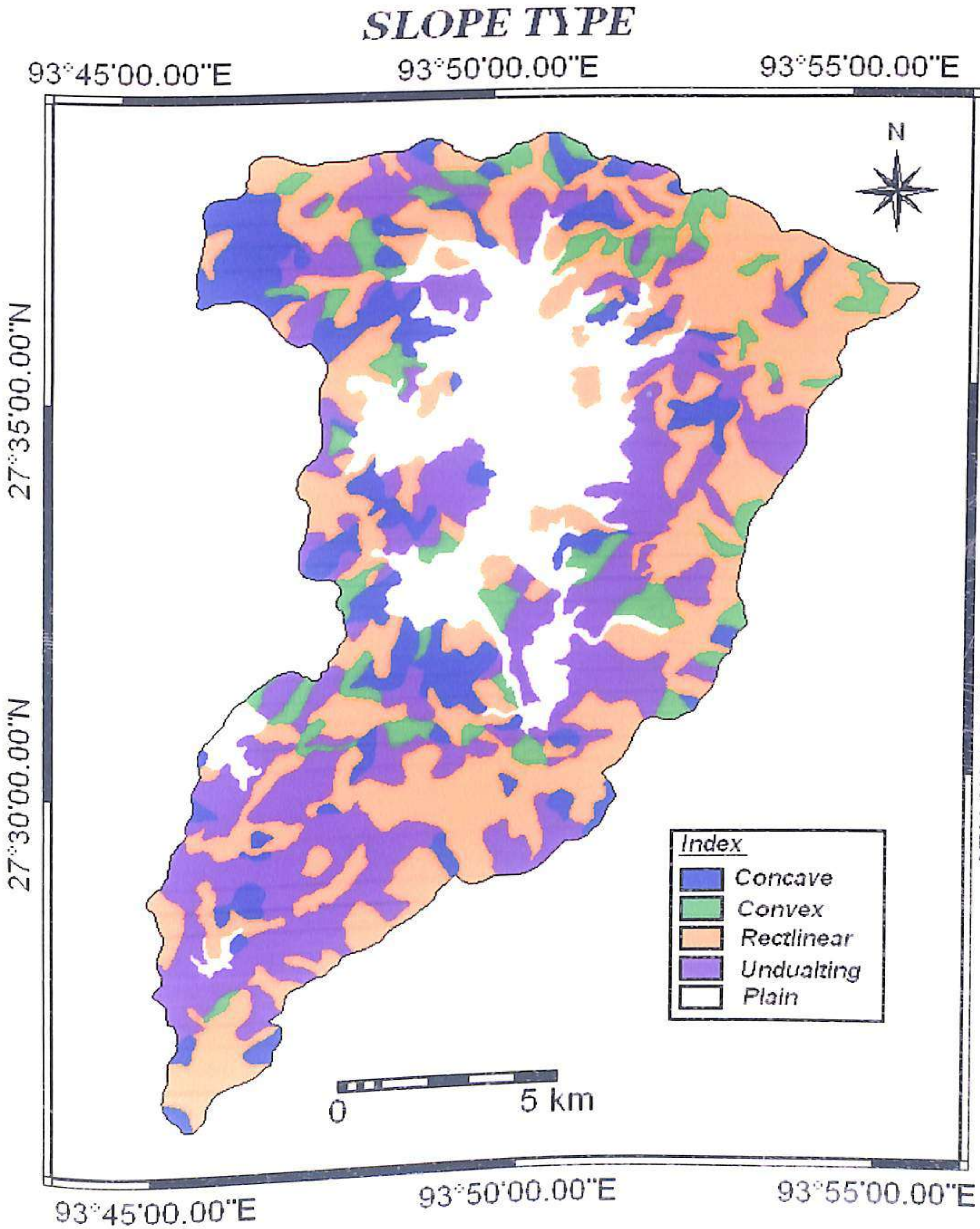


Fig. 3.9 Slope type

For the identification of slope, the topographical map (1:50,000) has been used. The irregularities of slope in the contour map are clearly visible. The space between two contours and their pattern are considered for the slope type identification. Following are the main types of slope identified:

3.14.1 Convex

Convex slope also called as waxing slope is found at the hill crest (hill top). In the topographical map, convex slope indicates, when the space between contour decreases towards the main channel from watershed boundaries. The reason for the formation of this slope type is due to lithological characteristics and due to lateral erosion carried out by the river channel.

3.14.2 Concave

When the contours are close together at the hill top and become widen downwards is identified as a concave slope. This slope type is also called as valley floor basement slope. The concavity in the base of the valley is mainly due to active denudational process like rainwash, rill and gully erosion.

3.14.3 Undulating

When the area is having undulating slope, it is represented in the topographical sheet with variable contour spacing. The main reason for this variation is due to presence of alternate rocks like resistant and weak rocks.

3.14.4 Uniform/Rectilinear

This slope type is also term as the constant or regular slope because of uniform slope angle. In the topographical sheet, the contours are represented with uniform or regular spacing. Uniform slope reflect homogenous rock type.

3.15 Regional distribution of slope types

The areal extension slope types show variable terrain characteristics. Almost all types of slopes are identified within the study area. Concave slope is dominating along the watershed boundary. In the north western tip, a large patch of concave slope can be observed. Table 3.12 reveals the areal coverage by each slope type. The given table reflects that maximum slope type of the basin is rectilinear i.e. 35.68% of the total basin area.

Table 3.12
Kiile river basin: Slope type

Slope type	Area (Km^2)	Area (%)
Concave	23.574	11.55
Convex	15.446	7.57
Rectilinear	72.804	35.68
Undulating	55.294	27.10
Plain	36.944	18.10
Total	**204.062**	**100**

3.16 Slope Aspect

The slope aspect refers to the direction to which a mountain slope is facing. The aspect of a slope can provide a significant influence on its local climate directly and geomorphic processes indirectly. The slope direction found in the study area are north, north-east, north- west, west, south- west, south, south – east and east. In the study area, maximum of slope is facing towards the north – west (62.56 Km^2 or 30.65)), it occurs mostly in the eastern side of the watershed boundary. Table 3.13 shows the spatial distribution of slope aspect of the Kiile basin. Maximum of slope is facing in the western side.

Table 3.13

Kiile river basin: Slope Aspect

Slope aspect	Area in km^2	Area in %
South - west	56	27.44
South - east	48.89	23.96
North - east	36.61	17.94
North - west	62.56	30.66
Total	**204.062**	**100**

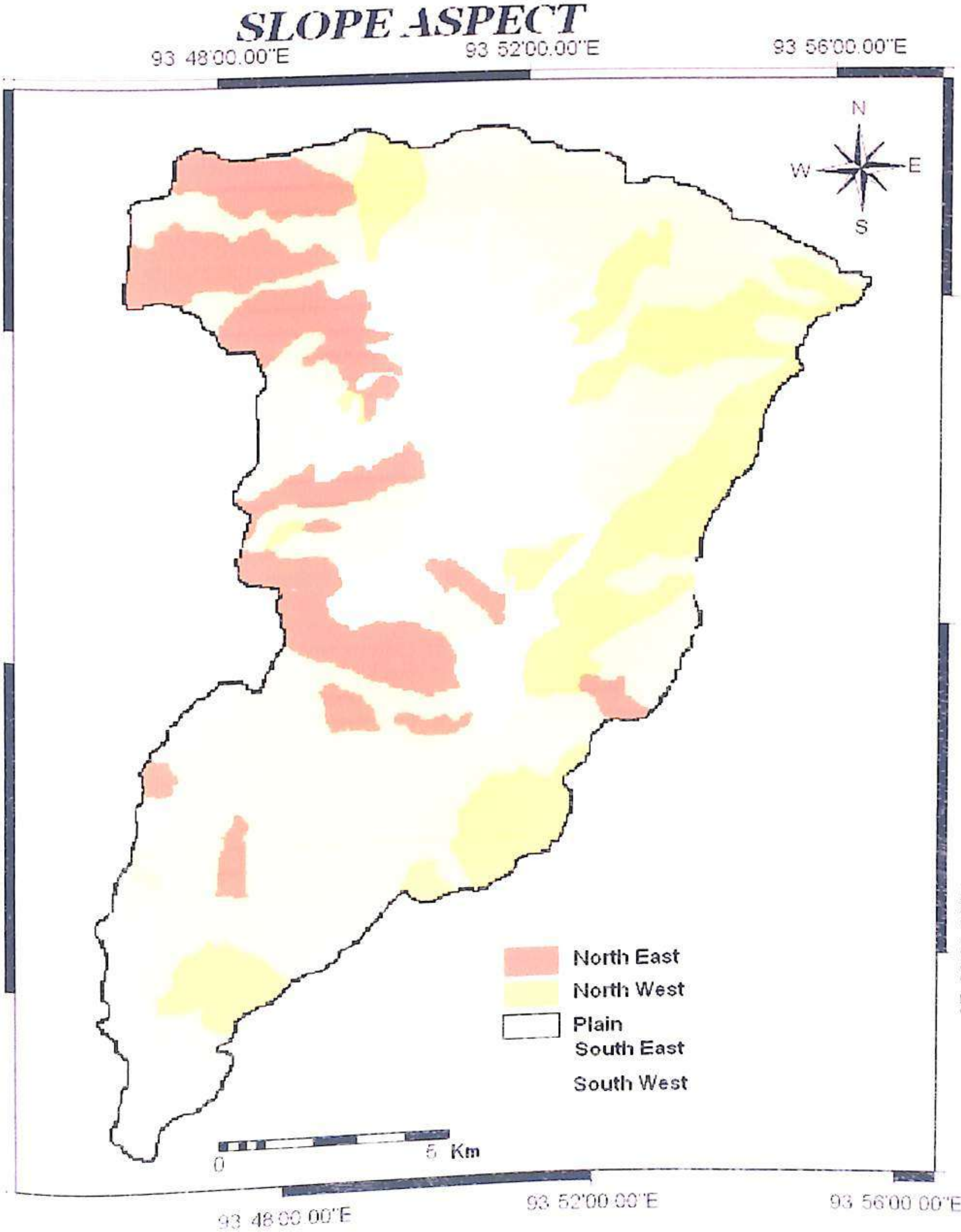


Fig. 3.10 Slope Aspect

CHAPTER IV

BASIN MORPHOMETRY

4.1 Introduction

'Measurement of the shape, or geometry, of any natural form – be it plant, animal or relief features are termed as morphometry' (A.N.Strahler, 1969). But in geomorphology, the term morphometry may be defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of its landform (Clarke, 1966). In this study the main features examined are the area, altitude, volume, slope, profile and texture of the land as well as the varied characteristics of drainage and its basin. Although morphometric analysis was carried out in the second quarter of the 20th century, only recently it has received a great attention. Without citing the name of R.E.Horton, it would be incomplete if one talk of morphometric methods. The year 1945, which is a landmark in the growth and development of geomorphology when R.E.Horton an American engineer realized the need and importance of morphometric technique in the field of basin geomorphology. After Horton many significant contributions have been made by scientists from time to time viz. J.I.Clarke & K.Orrell (1958), M.A.Melton (1957, 1958, 1959), S.A.Schumn (1956, 1963), H.W.Anderson (1957), M.Morisawa (1959), R.J. Chorley (1957, 1962, 1966, 1969, 1972), L.B.Leopold & W.B.Langbein (1962), B.R.Boyce & W.A.V.Clark (1964), C.A.M.King (1966), K.J. Gregory (1968), V.C. Miller (1953) and L.E.Milton (1966).

The quantitative revolution in geography, labeled as such by Burton (1963), was largely concerned with the application of statistical methodology to geographical systems of interest. A quantitative approach has been applied for the present work. But qualitative assessment has also been included at various areas to incorporate quantitative technique. After the detailed quantitative assessment of the study area, it is correlated with the collected qualitative information. The associated qualitative technique involves field measurement e.g. river water quality, land use, forming material, verbal description, etc. Therefore this technique involves detailed field work and mapping by applying the statistical and mathematical methodology.

Recent emphasis is on quantitative geomorphology of drainage basins by various morphometric techniques and measures to establish the interrelationship of basin parameters. Studies of Gupta, Arijit and Chakraborti, S.C. (1965); Ghosh, Bimal Pandey, Singh and Gheesa Lal (1967); Dharma, Vijay (1968); Singh, R.P and Kumar, A. (1969); Singh, Labh (1970 & 1971); Kharkwal, S.C. (1970 & 1971), Pal, S.K. (1972), Verma, V.K. and Tandon, S.K. (1971 & 1974); Agrawal, Meera (1972); Sidhu, G.S. and Pandey, I.C. (1974), Anil Kumar (1973 – 1975), Sharma, H.S. and Padmaja, G. (1977; 1978); Srivastava, Renu (1978), Singh, Savindra (1978 & 1980), Subramanyam, V. (1976); Singh, R.L. (1967) are worth mentioning on basin morphometry.

The present study is an attempt to find out the geomorphic characteristics of the Kiile River basin, with the help of different morphometric parameters or attributes, viz., stream order, numbers, lengths, bifurcation ratio, stream length ratio, drainage density, stream frequency, etc.

The basin morphometry includes the consideration of linear, areal and relief aspects. The linear aspect deals with the heirchical orders of stream numbers and lengths of stream segments, bifurcation ratio, length of overland flow, sinuosity indices, etc. All these attributes depend on the relief, lithology, climatic variation, forest cover, nature of regolith, etc.

Drainage basin is one of the most fundamental geomorphic units which reflects its own characteristics and stages of development. The drainage area may be defined as the area which contributes water to a particular channel or set of channels (Leopold et.el 1964). The work of running water in the form of surface runoff is the most important and active agent of all the exogenetic processes, which is continuously shaping the landform. In the publication of 'Mediterranean Quarternary River Environments' edited by Levin Maclin and Woodward (1995), has drawn attention to the importance of river systems in changing the landscapes of a region that is highly responsive to changes in climate, vegetation and human activities. Drainage basin gives a very significant unit on the earth's surface within which basic climate quantities can be measured and different characteristics of landforms can be observed. It is a system within which a balance is present in between the inflow and outflow of moisture as well as energy.

4.2 Drainage Network

The Kiile river (4.1) is originating at an elevation of 2684m and is feeded by numbers of tributaries and sub – tributaries. It comprises of sixth order basin with 876, 198, 55, 18, 3 and 1 first, second, third, fourth, fifth and sixth order streams respectively.

The river at its source in north eastern part is known as Siya river and is flowing towards the west. When it reaches to flat valley, joined by some more tributaries as Siya nala, Sehke nala, Sikhe nala and Tajang nala. In the lower stream it is joined by the tributaries like Niyalisi nala, Njuth nala, Pail nala, Sul nala. And finally it joins with Pange near the Tago hydel micro hydel project.

4.3 Drainage Pattern

Drainage pattern refers to the particular plan or design that emerges on a drainage map due to assemblage of drainage channels from all the sides of a

DRAINAGE MAP

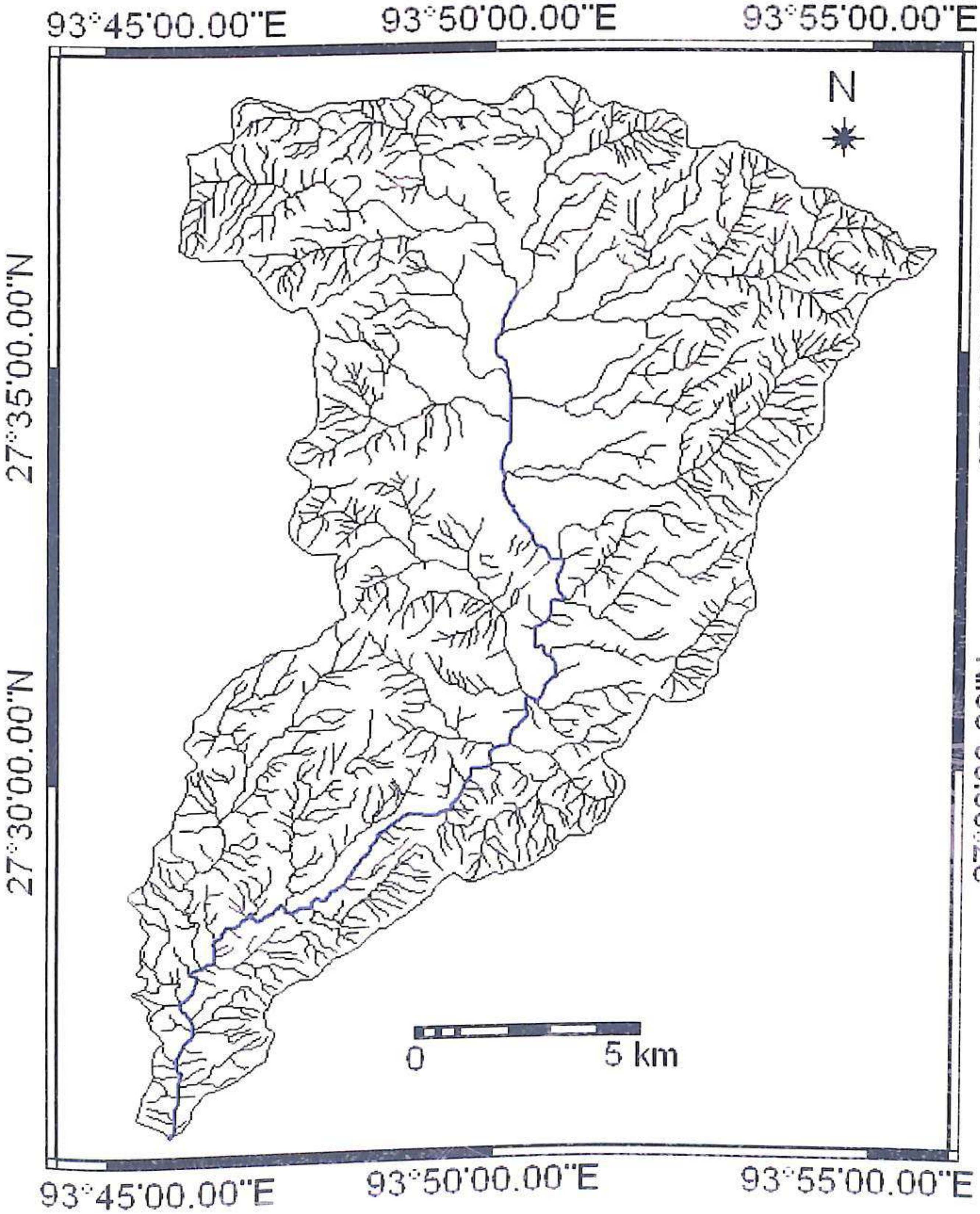


Fig. 4.1 Drainage network

basin. The design and pattern of drainage is influenced by the types of rocks and their structure, initial slope, geology, vegetal cover, anthropogenic activity, and climatic condition, etc. If there is an area of homogenous lithologies, horizontal or very gently dipping strata, flat and rolling extensive topographic surface having extremely low relief is associated with dendritic type of drainage pattern. As drainage patterns are highly influenced by so many factors, they can be extremely helpful in the interpretation of geomorphic features especially to an understanding of structural and lithologic control of landform evaluation.

For the purpose of the identification of drainage pattern, detailed drainage channels were traced out from the 1:50,000 topographical sheet nos. 83E/14, 15. The following drainage patterns (fig 4.2) have been identified in the Kiile river basin.

i. Dendritic pattern
ii. Radial/centrifugal patterns
iii. Rectangular pattern
iv. Parallel drainage pattern

4.3.1 Dendritic Drainage Pattern

The most common pattern which is observed in the study area is the dendritic pattern. The only guiding factor for this pattern is the initial slope of the land and it has a little adjustment with the underlying structures. Generally this type of drainage pattern develops over the area which is having uniform resistance and found nearly on horizontal sedimentary rocks. Dendritic pattern is one of the dominant patterns in the Himalayan ranges.

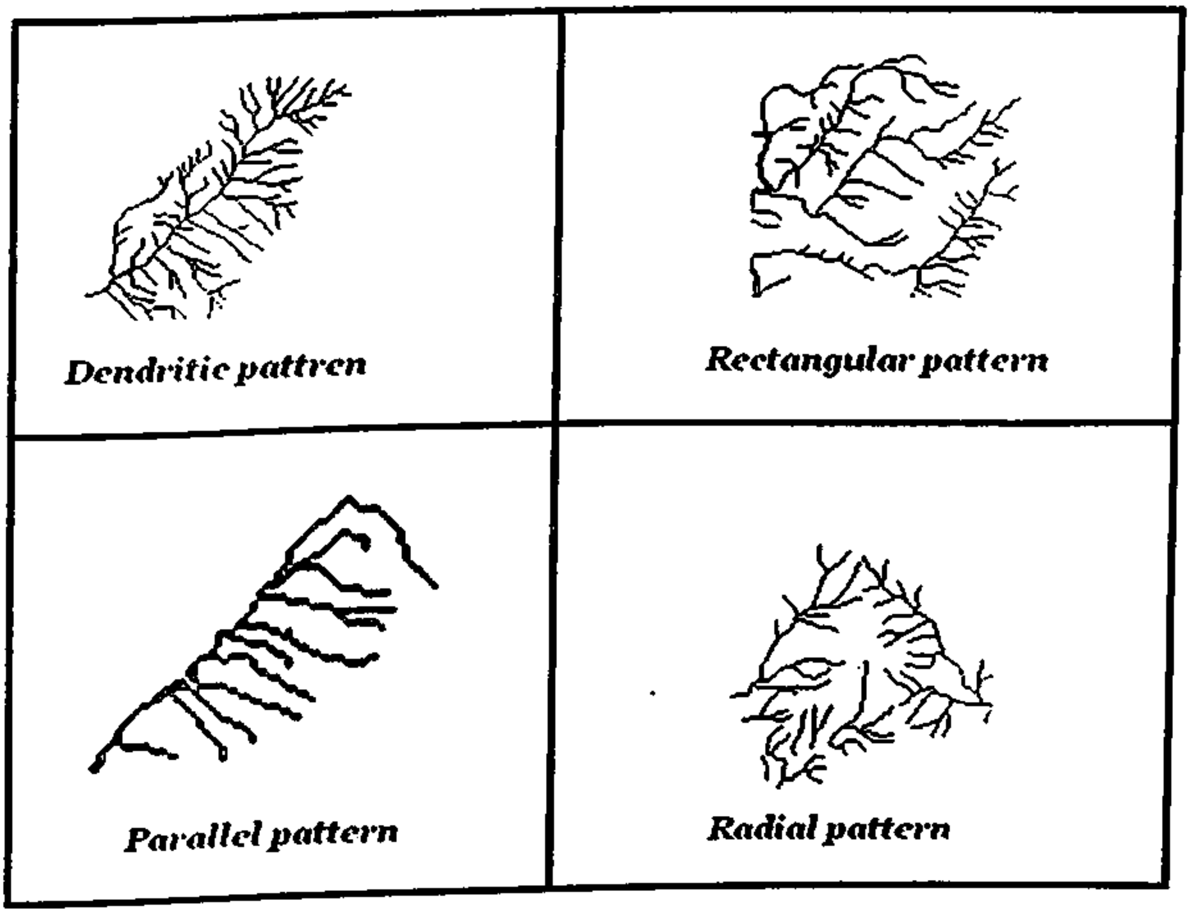


Fig. 4.2 Drainage pattern

This type of pattern may be noticed in all the corners of the study area. The present form/shape of drainage pattern might have been influenced by erosional processes and topography of the area.

4.3.2 Rectangular Drainage Pattern

In rectangular pattern, both the tributaries and master stream join almost at right angle which determines the lines of weaknesses (e.g. faults, fractures and joints) of rock. This type of pattern is observed in those regions where the rock joints form rectangular pattern. The rocks are easily weathered and eroded along the weaker lines and thus surface runoff forms numerous rills, gullies and finally river along these weaker planes

In the present study of Kiile river basin, the rectangular drainage pattern is noticed in the eastern and north eastern part, where the area is occupied with hard gneiss rocks. The rock structure of this region shows the presence of jointed and fractured nature.

4.3.3 Radial Drainage Pattern

Radial drainage pattern, which is also known as centrifugal pattern, is formed in those areas where the highland is surrounded by lower elevations. This type of pattern found in the area covers a small area. The radial stream pattern is observed in the central part of the study area.

4.3.4 Parallel Drainage Pattern

The parallel drainage pattern comprises numerous rivers which are parallel to each other and follow the regional slope. This type of pattern developed in the uniform sloping and dipping rock beds. In the study area, this pattern can be observed in the upper course in the north and in the lower course near Mai locality. In the both places where parallel drainage pattern is found presence of lineaments indicate the influence of structure.

With the study of the drainage pattern, in the Kiile river basin, it can be stated that the landform development of the study area is a result of long continous changes by exogenetic and endogenetic forces.

4.4 BASIN MORPHOMETRY

The drainage basin, having its own characteristics and stages of development is one of the most fundamental geomorphic unit. Therefore, the measurement an mathematical analysis about the basins shape & dimension is important for geomorphological study. The morphometric analysis helps to disclose about the present processes which have externally or internally adjusted within the basin.

4.4.1 Stream Ordering

Stream ordering refers to the determination of the hierarchical position of a stream within a drainage basin. Stream order is measure of the position of a stream in the hierarchy of tributaries (Leopold, et.al, 1964). The present study is carried out in light of the work of Strahlers, Ronald L.Shreve and Horton. According to Strahler, the first order streams are those which have no tributaries. When two first order streams join they form second order stream. With the union of two second order streams comes into existence, a third order stream form and so on. The master channel is the last series in the stream ordering. The Shreve's method (1969) accounts for all links in the network. As with the Strahler method, all exterior links are assigned an order of 1. For all interior links in the Shreve method's, however, the orders are additive. For example, the intersection of two first order links creates a second order link, the intersection of a first and second order link creates a third order link and the intersection of a second and third order creates a fifth order link. Because the orders are additive, the numbers from the Shreve method are sometimes referred to as magnitudes instead of orders. The magnitude of a link in the Shreve method is the number of upstream links. According to Horton's technique, ordering of streams begins from the finger – tip tributaries, having no any their own feeders. These tributaries are considered as first order. When two streams of first order join together, they form 2nd order stream in the junction. Likewise, when two 2nd order meet 3rd order

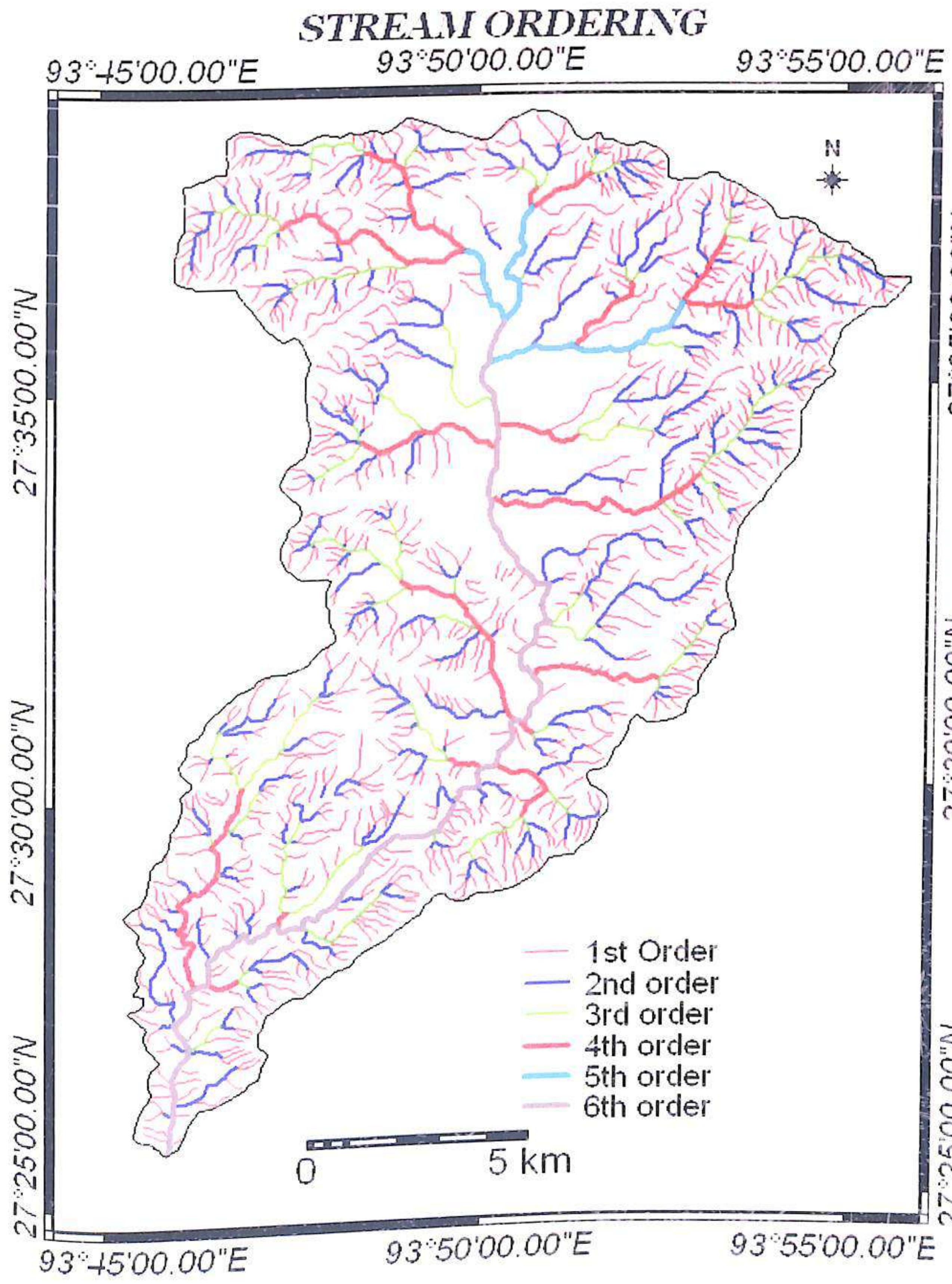


Fig. Stream order

stream form and this process continues will the trunk stream reaches the highest order.

In the present study, the streams of the Kiile river basin have been ranked as sixth order stream according to Strahlers ordering system.

4.4.2 Bifurcation ratio

R.E. Horton introduced the term "bifurcation ratio" to express the ratio between the total numbers of streams of one order to that of the next higher order in a drainage basin. The bifurcation ratio reveals the degree of integration between streams of various orders in a given drainage basin. The bifurcation ratio is calculated by using the following equation –

$$Rb = N\mu / N\mu + 1$$

Where $N\mu$ = number of streams of a given order

$N\mu + 1$ = number of streams of the next higher order

According the Horton (1945) & Strahler (1957), the bifurcation ratio's ranges from 3.0 to 5.0 for that drainage basin where the geological structure do not twist out the drainage pattern. The bifurcation ration of Kiile river basin ranges from 3.0 to 6.0, with an average value of 4. The higher values of the ratio indicated that there is low degree of drainage integration. Bifurcation ratio which is a dimensionless property of drainage basin is usually controlled by the lithological characteristics, topographical configuration, basin shapes & areas, vegetal cover, climatic condition, etc. If there is uniform lithology, surface configuration, climatic condition, etc, then it is expected similar values of bifurcation ratio. High bifurcation ratio is due to wide variations between the number of stream segments of lower & higher stream order.

Table 4.1

Kiile River Basin: Bifurcation ratio

Stream Order (μ)	Number of Streams (Nμ)	Bifurcation ratio (Nμ +1)
1	876	4.4
2	198	3.6
3	55	3.0
4	18	6
5	3	3
6	1	
Average		4

.4.4.3 Law of Stream numbers

The law of stream numbers (fig 4.4) states that the number of streams of different orders in a given drainage basin. Horton showed that stream order is related to number of streams, channel length and drainage area by simple geometric relationships; that is stream order plots against there variables as straight lines on semi logarithmic paper. Table 13 shows the morphometric

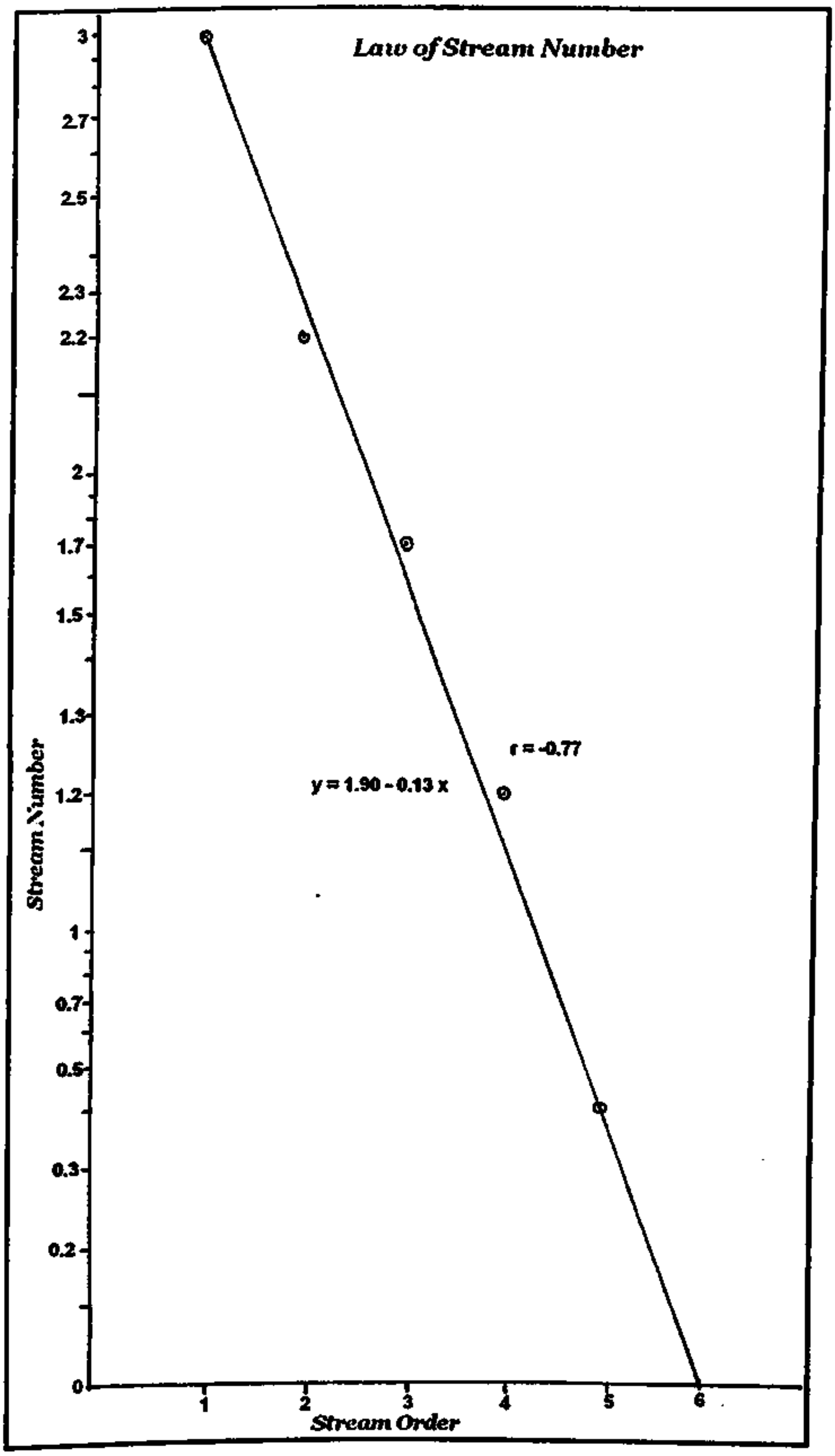


Fig 4.4 Law of stream number

components of the drainage network, such as stream number, stream length, etc. The number of first order is 876 with 253.5 Km of total length. There are 198 second order streams with 113 Km of stream length. With the increasing of stream order, the number of stream decreases.

The regression line drawn on the basis of number of stream and stream order of Kiile river basin is plotted on semi – log graph. The graph validated the Horton's law of stream number as the coefficient of correlation is (–0.778). The coefficient of correlation between stream number and stream length is 0.981, which shows a significant correlation.

Table 4.2

Kiile River Basin: Orderwise number of streams and stream length

Stream Order	Number of Streams	Stream length (Km)
1	876	253.5
2	198	113
3	55	54
4	18	40.5
5	3	9.5
6	1	25.5

4.4.4 Length ratio and law of stream length

According to R.E. Horton, 'length ratio' is the ratio of average length of streams of a given order to that of streams of the next lower order. The length ratio should range between 2 and 3. The law of stream lengths states that "the mean lengths of stream segments of each of the successive orders of a basin tend to approximate a direct geometric sequence in which the first term is the

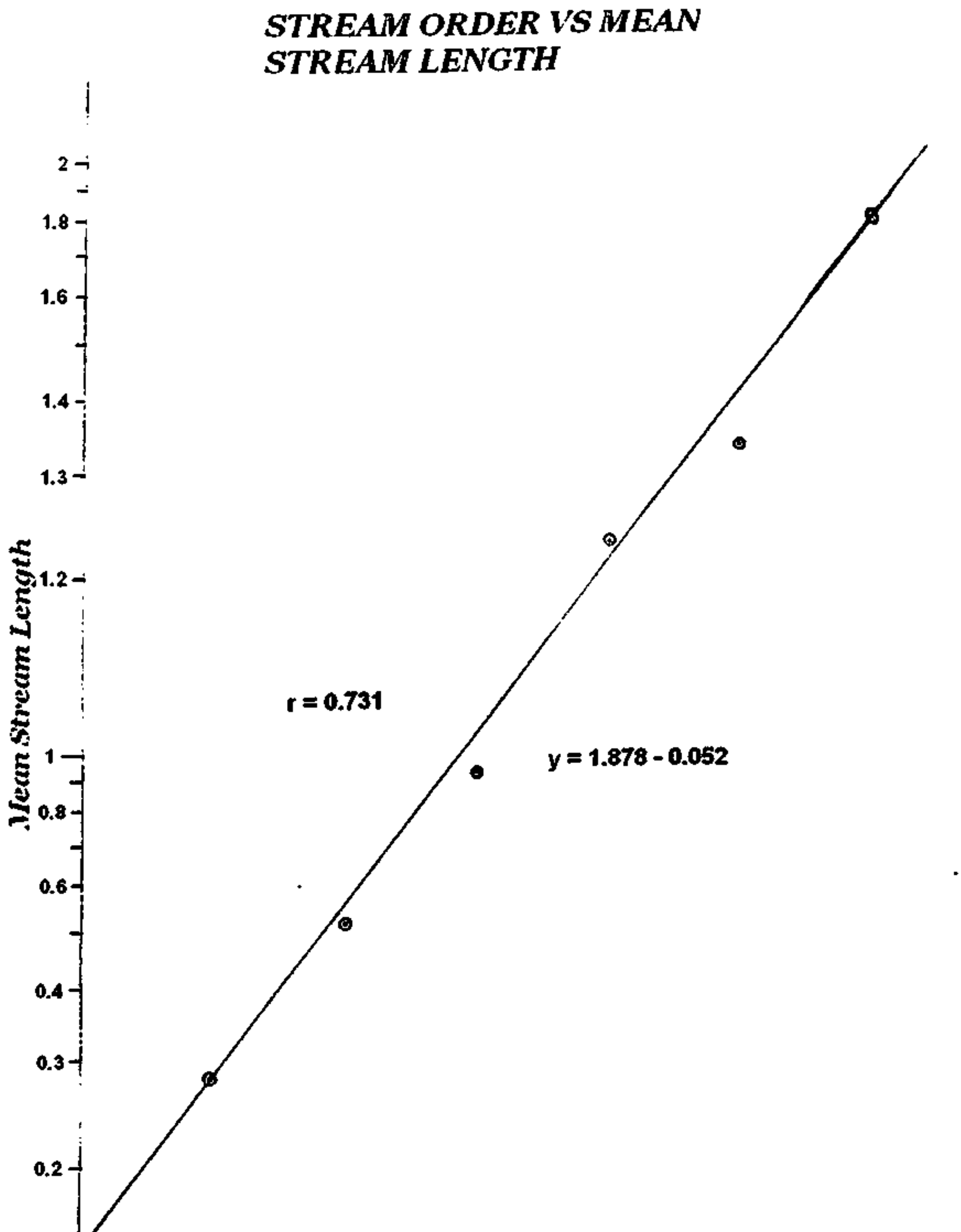


Fig. 4.4 Length ratio and law of stream length

average length of segments of the first orders (Horton, 1940). The stream length ratio is calculated by using the following formula:

$$R_L = L\mu / L\mu - 1$$

When $L\mu = L\mu / N\mu$, $L\mu - 1 = L / N\mu - 1$

Where 'R_L' is the stream length ratio, $L\mu$ is the mean stream length of a given order. $N\mu$ is the number of stream segments of a given order.

Table 4.3

Kiile River Basin: Mean Stream length

Stream Order	Mean stream length (Km)	Stream length ratio
1	0.579	-
2	1.141	1.97
3	1.964	1.72
4	4.5	2.29
5	6.333	1.41
6	51	8.05

It is noted from the above table that the mean stream length increases with the increase of basin order so there is a positive relationship in between mean stream length and basin order.

The stream length ratio of Kiile river basin ranges from 1.41 to 8.05. The length ratio is not increasing uniformly. The lowest stream length ratio is in case of ratio between fourth & fifth order stream i.e. 1.41. In case of 3rd order stream also the length ratio is lower than the second order basin. The highest stream length is in between the fifth & sixth order stream i.e. 8.05.

4.4.5 Sinousity Indices

Sinousity index measures the deviation of observed drainage path from their expected path. The river channel form as a straight line during its initial formation e.g. rills, but in real picture, no any river shows sinnous path. Their formation depends on the geological structure, dip angels, slope, climate, vegetation, absolute and relative reliefs, etc. Thus, sinuosity of a stream devotes the degree of deviation of its actual path from expected theoretical straight path. The study of sinuosity index helps in studying the effect of terrain characteristics on the river course and vice – versa.

The sinuosity value varies from a value of unity i.e. 1 to 4 or more; rivers having a sinuosity of less than 1.5 are called straight or sinous and those rivers which are having a sinuosity index of 1.5 or more than 1.5 are called meandering (Leopold, Wolman and Miller, 1969, p.281)

J.E. Miller (1968), proposed sinuosity index in terms of hydraulic and topographic sinuosity, which is the measured of ratio between the channel length (CL), valley length (VL) and air distance from source to mouth of the river (AL). The hydrological and topographical sinuosity are sued as an important morphometric tools in identifying the factors responsible for sinuosity of a river and also in the determination of the stage of basin development. During the youth stage, the topographic sinuosity index (TSI) or (>60%) dominates over hydraulic sinuosity index, but the hydraulic sinuosity (HIS), becomes more dominant in the late mature and old stage (>60%).

Calculation of various types of sinuosity indeces are find out on the basis of following formula.

1. Channel Index (CI) = CL/AL
2. Valley Index (VI) = VL/CL
3. Standard Sinousity Index (SSI) = CI/VI
4. Hydrological Sinousity Index (HIS) = % equivalent of CI – VI/CI – 1
5. Topographic Sinousity Index (TSI) = % equivalent of VI – 1/CI – 1
6. Channel Sinousity Index (CSI) = CL/VL

Table 4.4

Kiile River Basin: Channel, Hydraulic and Topographic Sinousity Indices

Basin	CL (Km)	VL(Km)	AL (Km)	CI	VI	CSI	HSI	TSI	SSI
Kiile river basin	62	61	47.5	1.3	1.28	1.02	6.7	93.3	1.01

Above table shows the channel index (CI), valley index (CI), channel sinuosity index (CSI), hydraulic sinuosity index (HIS), topographic sinuosity index (TSI) and standard sinuosity index (SSI) for the Kiile river basin. The sinuosity index of the Kiile river basin is 1.01, which shows that the channel is in straight course. The table also reveals that the topographical sinuosity indices (TSI) is high (93.3%) and hydraulic sinuosity indices (HIS) is low (6.7). So, it indicates that the basin is in its youthful stage.

4.5 Areal Aspects of the Basin

The basin area study is an important morphometric attribute as it relates to the spatial distribution of number of significant variables viz. geometry of basin shape, drainage density, drainage frequency, slopes, relative relief, absolute relief, dissection index, etc,

4.5.1 Geometry of Basin shape

The shape of a drainage basin, occupies a very significant place among the areal aspects of the basin. Basin shape is dependent on the size of the basin and length of the main channel and also basin perimeter which is again control by the other variables such as absolute reliefs, slopes, internal structure, lithological characteristics, etc. The shape of the basin can affect the characteristic of stream discharge in a basin. If the basin is of pear shape, it can contribute more discharge then the elongated one. Many attempts have been made by different earth – scientists to establish a definite geometric shape of the drainage basin, i.e. Form factor (Horton, 1932), Elipticity index (Stoddarts, 1965), Circularity Index (V.C. Miller, 1953), Elongation ratio (Schumm, 1956) and Lemniscate method (Chorley et.al 1957). On the basis of which 3 sub – categories of basin shape can be recognized i.e. circular, elongated, etc.

Horton's form factor (F) 1932, is the ratio in between area of the basin and square of basin length. It is expressed as

$$F = A / L^2$$

Where F = form factor indicating elongation of the basin shape

A = basin area

L = basin length

The value of form factor (F) ranges from 0 to 1. Thus, higher the value of F, the more circular the shape of the basin and vice – versa.

The form factor of Kiile river basin is 0.33, which shows that the basin is having an elongated shape.

4.5.2 Drainage Density

The drainage density was first introduced by Horton (1945), who defined it as the ratio of total length of all stream segments in a given drainage basin with the total basin area. Drainage density (Dd), defined by

$$Dd = \sum L / Ad$$

Where $\sum L$ is the total length in a basin of area Ad.

It is regarded as a significant areal measure of basin because it expresses the degree of basin dissection by surface streams and also links it with the underlying structure (Knighton, 1984). The drainage density varies over the space. It is mainly control by the lithological characteristics, weaker zones,

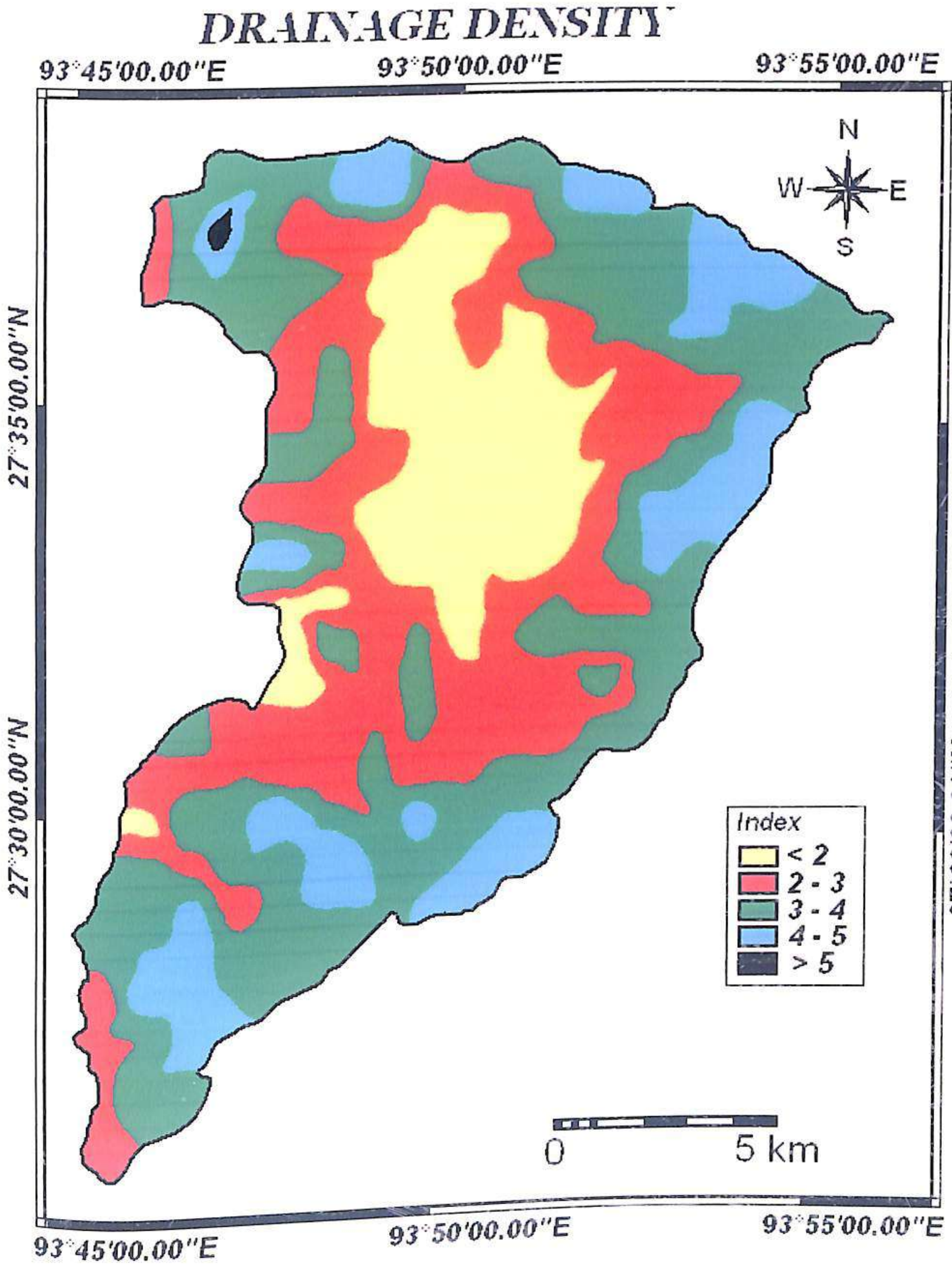


Fig. 4.6 Drainage density

varying climatic condition, vegetational, adaphic and topographical influence. If the lithology of a said basin is hard, then there is less expectation of stream length and vice – versa.

For the drainage density, the study area is divided into grids of 2cm which represent 1km² each. Among the 207 grids, the drainage density varies from 0.125 km/ km² to 5km/ km². The drainage density (fig 4.6) in general reflects the geomorphic environment in the basin. Lithology, natural vegetation coverage and climatic variation also affect the drainage density. All the 207 grids are classified into five classes (Table 4.5). Moderate high drainage density i.e. 3 – 4 km/ km² have the highest frequency of 73 grids. Very low drainage density group i.e. 0.125 – 1 km/ km² have minimum grids of 5. The mean of drainage density is 2.91 km/ km².

Table 4.5

Kiile River Basin: Drainage density

Drainage density km/ km²	Frequency	Density classes
0.125 – 1	5	Low
1 – 2	28	Moderately low
2 – 3	59	Moderate
3 – 4	73	Moderately high
4 – 5	42	High
Total	207	

4.5.3 Drainage Frequency

The stream or drainage frequency of a basin is defined as the ratio between the total numbers of stream segments with the total basin area (Horton, 1932). It is expressed by using the following formula:

$$F = \sum N\mu / A\mu$$

Where F= Stream frequency

$\sum N\mu$ = Total number of all stream segments

$A\mu$ = Total basin area

The drainage frequency in the Kale river basin is obtained by counting the number of streams segments in square grids with an area of 1km², varies from 1 stream/ km² to 14 streams/ km² (fig 4.7).Thus, the drainage frequency is categorized into five groups (Table 4.6).

Table 4.6

Kiile River Basin: Drainage Frequency

Drainage frequency (no./ km²)	**Area (km²)**	**Area (%)**	**Categories**
Less than 3	18.30	8.97	Poor
3 – 6	38.48	18.86	Moderate
6 – 9	68.24	33.44	Moderately high
9 – 12	66.30	32.49	High
Above 12	12.74	6.24	Very high
Total	204.062		

DRAINAGE FREQUENCY

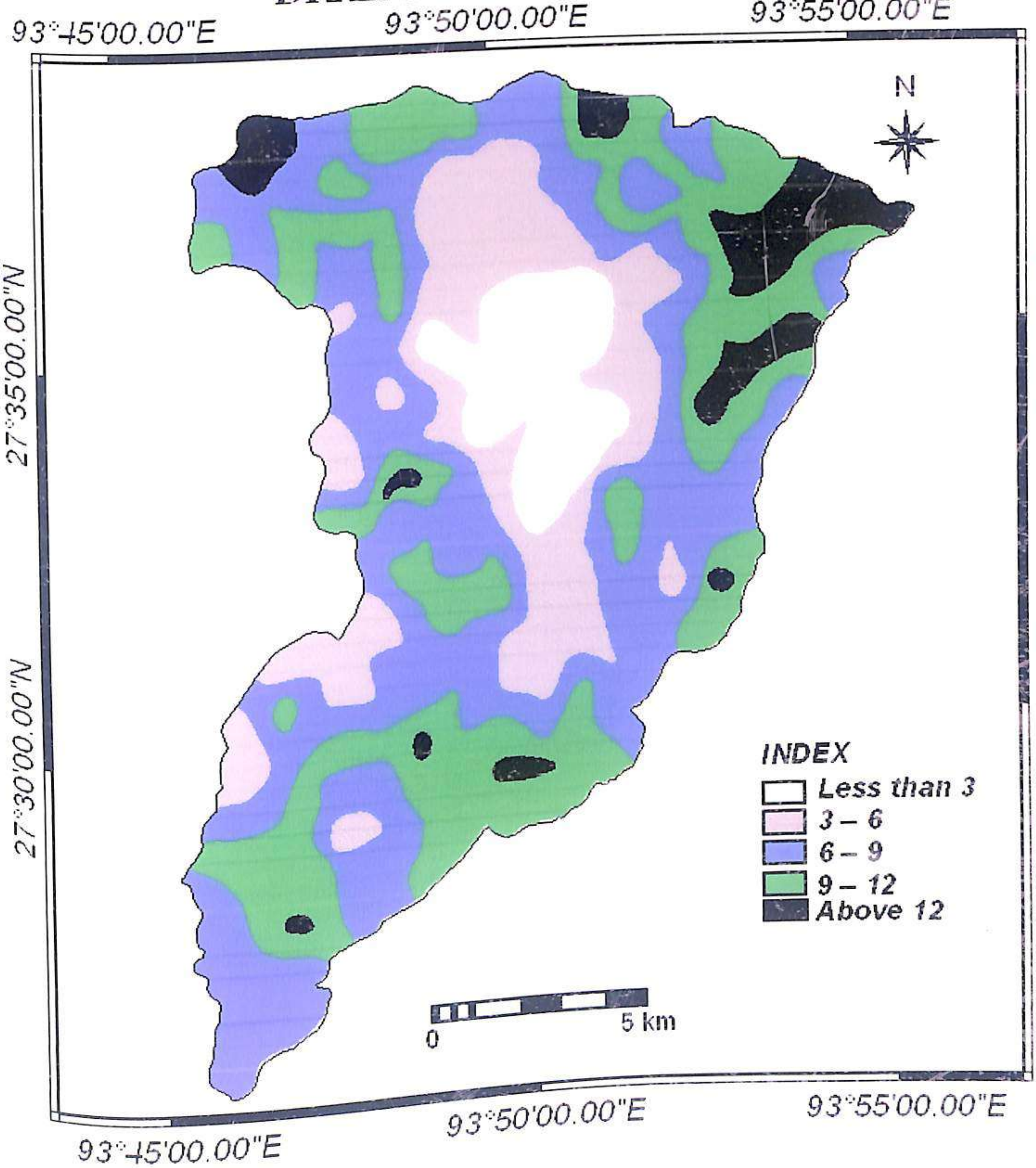


Fig. 4.7 Drainage Frequency

Table 4.6 shows the distributional pattern of drainage frequency in the study basin. About 65.93% of the study area has moderately high to high drainage frequency. Only 6.24% and 8.97 are under very high and low drainage frequency respectively.

4.5.3.1 Poor Drainage Frequency (Below 3/ km²)

The areas below 3 streams/ km² lies in the central portion of the basin in upper course. It covers about 18.30 km² or 8.97% of the total basin area. Though it covers only a small area in the basin, but this low frequency covers a verysignificant area. This category only occurs on the flat valley area, which is composing of very fertile soil.

4.5.3.2 Moderate drainage frequency (3/ km² - 6/ km²)

Moderate drainage frequency covers about 38.48 km² or 18.86% of the total study area. Maximum of area occurs in the plain and foot hill areas of upper course bordering the areas of low drainage frequency. It also covers the Joram valley and few pockets in the western part of river divide.

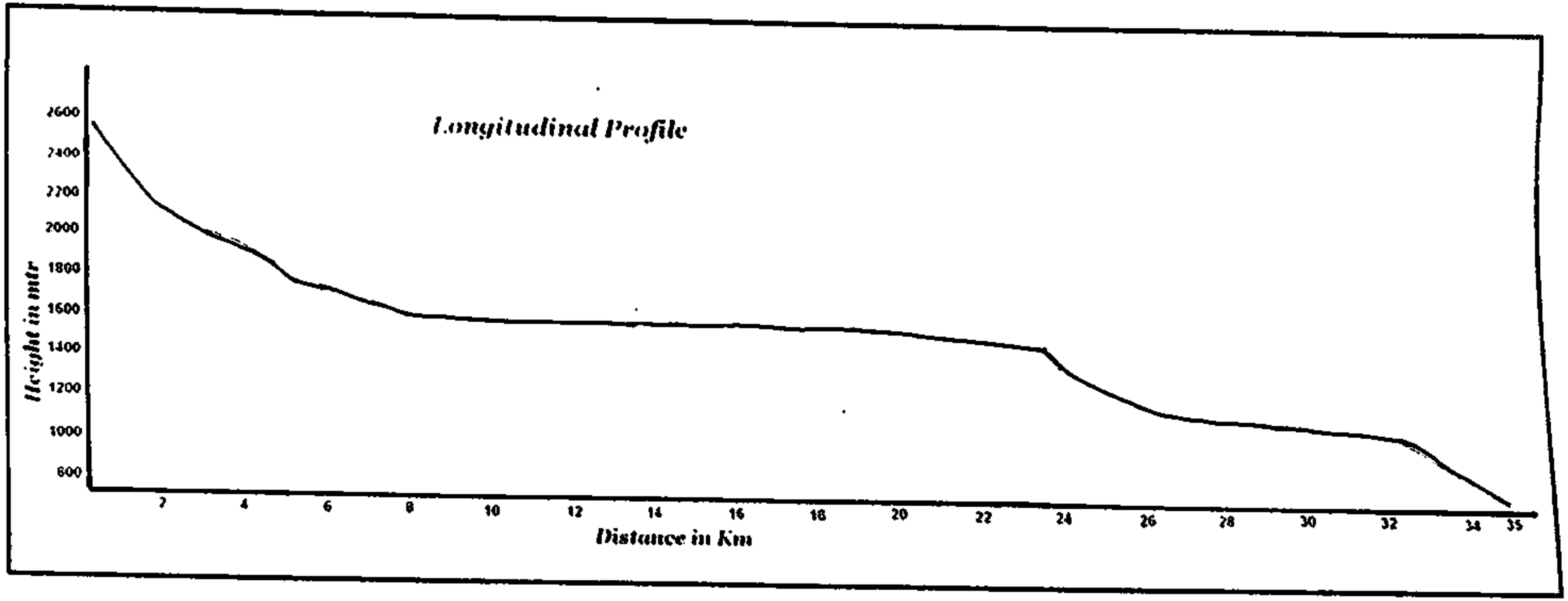


Fig. 4.8 Longitudinal Profile

4.6 Longitudinal Profile

The longitudinal profile (fig 4.8) of a river express the outline of the shape of a river valley from source to mouth. The river profile directly shows the stage of the terrain. Therefore, the specific type of river profile is considered as an outcome of the stage of terrain and an indication to the stage of the cycle of erosion. The longitudinal profiles with some knick points show some tectonic disturbances like upliftment or rejuvenation in river life. The profiles with high gradient and steep curve shows the youthful stage of terrain whereas the long profiles with smooth curve represent the old stage of the terrain. However, the longitudinal profile gives the graphical representation of distance versus elevation of river.

The Kiile river covers 35 km, which runs through the heart of the Ziro valley and Yachuli. The longitudinal profile of Kiile river reflects two abrupt break in slope or knick points. Longitudinal profile shows there is impact of endogenetic and exogenetic processes. From source to valley (1560m -2640m), river is flowing along its channel forming concave and rectilinear slope. During this course at two places, knick points are seen concave slope part is showing erosion by river. Knick point or break in slopes indicating sudden change in erosional and depositional processes. In between two knick points slope is rectilinear. Low degree of rectilinear slope may be because of loose depositional matter whereas high degree of rectilinear slope may be controlled by sub-surface structure covered with very low amount of depositional structure.

In the valley, from 1560m to 1440m height, river flows with almost level surface of channel. It is formed by depositional matter where structural influence can be determined based on the multilevel river terraces and fan cut terraces.

Another segment towards source in between 1440m to 1050m is also forming concave slope. This segment is having four points of break in slope. In between first and second point, a sharp vertical drop of altitude is found. Probably, this area is formed due to faulting. This shows thin cover of soil. Between second and third point, the drop becomes gentle which may be consisting coarse deposits. The third point between 1160m to 1050m shows a more gentler drop, which is covered with medium to coarse depositional material.

In between 1050m to mouth of the river, rectilinear slope in the channel is observed. The break in slope at 1050m is also reflecting the presence of sub – surface structural change either in the form of faulting or lithological change.

4.7 Basin Input – Output Analysis

"A geomorphic 'system' is an integrated complex of landform which operates together according to some discernible pattern (e.g. a drainage basin);

energy and matter input into the system giving rise to a predictable system response in terms of internal organization and resulting energy and matter input (Chorley, R.J. 1967)".

River flow is one of the most influence forces which is operating over the earth's surface both in terms of the total energy expended and the total amount of debris transported (Knighton, David, 1984). In due course of time, rivers have develop and continue to develop numbers of river network. Therefore rivers have well define boundaries and can be regarded as an open systems in which energy and matter are exchanged with an external environment. The geological structure, climatic condition, land use and basin topography determines the nature and character of river system like the amount of water discharge, and the sediment load carried by them. Bruijnzul (1996) reveals that the deforestation causes increased water and sediment yield. The great reductions of forest land cover for commercial purpose are expected to lead to increasing water discharge and sediment loads. It shows that the hydrological system responds to land use changes and human activity.

4.7.1 Water Discharge

The total amount of water being wasted from a particular point of river is called as water discharge. The amount of water discharge change with the changing nature of human activity, land use and climatic condition. Therefore,

Table 4.7

River water discharge

OBSERVATION PERIOD	DISCHARGE (Cumec)		RAINFALL (cm)	
	2005 – 2006	2006 - 2007	2005 - 2006	2006 – 2007
MAY – JUN	206.3	107.66	278.5	303.6
JUN – JUL	204.69	174.79	285.4	273.7
JUL- AUG	207.02	178.15	350.2	477.92
AUG – SEP	165.75	92.94	122	248.87
SEP – OCT	131.37	101.88	120.5	89.81
OCT – NOV	111.22	57.80	163	38.1
NOV – DEC	34.95	58.97	43.9	86.7
DEC 05 – JAN	42.71	51.19	9	39.8
JAN – FEB	44.76	59.58	23.3	169.5
FEB – MAR	49.63	72.57	88.7	123.5
MAR – APR	55.83	100.12	212	212
APR – MAY	92.31	84.30	220.1	408
TOTAL	**1346.54**	**1139.96**	**1916.6**	**2471.5**

Source: G.B.Pant Institute of Himalayan Environment Development projects

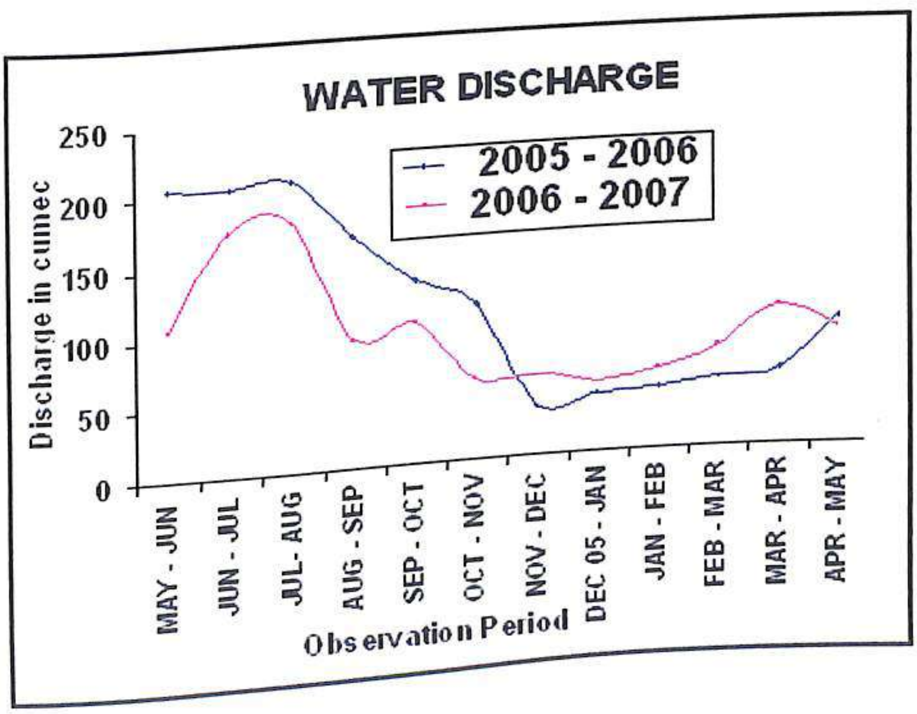


Fig. 4.9 Water discharge

analysis of seasonal water discharge data indicates significant changes in the whole basin. The amount of water discharge by the world rivers to the present day oceans is estimated to be between 32 and 37 x 103 km^3yr^{-1} (Chakrapani, G.J. 2005).

The two year data (2005 - 2006 and 2006 – 2007) on water discharge was collected from G.B.Pant Institute of Himalayan Environment Development projects. Table 4.7 reflects the monthly discharge of Kiile river from the year 2005to 2007. Maximum amount of discharge i.e. 207.02 cumec and 178.15 cumec were observed during the month of July to August. The table shows that the total amount of water discharge has decreased from 1346.54cumec (2005 – 2006) to 1139.96cumec (2006 – 2007). Decreasing in water discharge may be due to less amount of rainfall during that particular year or may be because of afforestation in the upper ridge.

CHAPTER - V

GEOMORPHOLOGICAL MAPPING

5.1 Introduction

Geomorphological mapping involves the recording of surface form, near – surface materials and evidence of surface processes. For a geomorphologist, mapping is an essential tool for the interpretation of existing landforms. Geomorphological mapping involves the identification and characterization of the fundamental units of the landscape. Geomorphic unit is defined as an individual and genetically homogeneous landform produced by a definite constructional or destructional geomorphic process (Fairbridge, 1968). Accurate geomorphological maps can provide valuable information not only regarding ground condition but also the underground configuration. Geomorphological maps are more interpretative than any other maps like topographic, land use, land type (soil, vegetation), etc. Therefore, it is important to give due consideration about the geomorphological information of an area before the work as it is an essential base for the integrated survey and mapping. The first conception of a detail geomorphological map was presented in the year 1914 by S. Passarge in the form of a Morphological Atlas. According to Gehne (1912) a geomorphological map should inform about morphographic features, structure of the sub – stratum and morphology or forms of the relief and their origin. But only after World War II, detailed geomorphological maps on the basis of a systematic mapping of landforms began. Gellert (1982), define that geomorphic mappings includes delimitation, characterization and cartographic representation of general units of various rank & size orders. Anon (1982) divided geomorphological mapping into four broad components i.e. morphological (shape), morphographical (type), morphogenetic (origin) and morphochronology (age). Hironi (1987) has presented geomorphic regions of Sawai Modhopur district by taking into consideration of its geological history and structure, lithological variations, slope, form of ground, quantitative properties of streams and surface morphology. Ibeyaima Devi (2000) prepared the geomorphic map of Iril basin, Manipur on the basis of relative relief, intensity of relief, dissection index, drainage density, texture of dissection, etc. Singh, Surendra, et.al. (1991) have delineated Rajasthan into different geomorphological units based on landform evolution, climatic variability, different morphological properties and associated hazards.

In the mountainous region especially Himalayan belt which is very fragile, the proper geomorphological mapping and terrain classification will provide a perfect base for hill development planning and economic development of the region. A basin as a part of active tectonic zone and inhabited with high population density (Ziro), need a careful mapping based on its geomorphological features for land, water management, etc.

This investigation is based on the four phases of research as suggested by Panizza et.al. (1980, 87) i.e.

i. bibliographical research,

ii. detail interpretation of Remote Sensing Data,

iii. field Survey and

iv. final Synthesis.

Geomorphic unit are identified as delineated by Joshi et.al (2007) for upper course of the river basin (fig 5.1). However, for lower river basin five more geomorphic units are identified using remote sensing data which is supported by intensive field work. Final research findings are derived from comparison of data obtained in the various phases as mentioned above. While dividing area into different geomorphic units and describing its characteristics detailed geomorphological analysis has been carried out based on their genesis and processes in association with image characteristics. The drainage parameters were also analysed to assess their influence on the genesis of geomorphic units, characteristics and their processes

The IRS 1C, LISS-III FCC (scale 1:50,000) satellite data of October 2000 pertaining to the study area was collected and the Survey of India topographical sheets at 1:50000 scale were used. Field observation was carried out for field verification. Visual interpretation of the satellite data was carried out for analyzing the lithological, drainage characteristics. Visual interpretation techniques have been followed in delineation of geomorphic units based on the tone, texture, shape, drainage pattern, colour and differential erosion characteristics in the image. After the demarcation of tentative geomorphic units based on visual interpretation, intensive field checks have been carried out in the study area by taking river and road traverse to verify the boundaries and properties of the delineated geomorphic units. The boundaries of the geological units have been modified based on the information gathered during field truth verification as well as image characteristics. Ground truth is an important part of mapping process. Even small scale important features can be missed out and larger scale features can be misinterpreted.

Wide valley in the upper part of the Kale river with recent deposit indicates about its lacustrine origin. Small River flowing along the slope to the valley might have developed the intermingled fan shape landforms during Pleistocene period now appearing as plain area after the drying of lake/marshy area. Along the down stream of valley the thick deposition is seen in the horizontal strata consisting dark clay material to sandy deposition with small pebbles. Very huge, smooth and angular boulders of gneiss are observed. Some workers (G. Kumar) correlated it with the deposit of Pleistocene glaciations. Basement of the recent deposition is made of gneiss. Typically deep weathered gneiss in the upper reaches flow with water along the slopes and finally deposited in the low lying areas of the valley. This region falls under Lesser Himalayan part which is younger in age provides some confusion about the stratigraphy of the region.

After weathering quartz crystals can be seen in small size whereas remaining material appears as fine material) Therefore, soil cover of the area is clayey with quartz concretion. In this area forms a rampart left as the basement rock of Tethys Sea at the time of structural deformation of the Himalayan origin. When water falls over the weathered material small pieces (concretion) of quartz moves along the slope to foothill part whereas remaining fine material reaches to valley area. The lower course of the area show different picture. It was difficult to demarcate the watershed boundary due to many subdued isolated hills. From a bird eye view, it looks like an inselbergs. Within the narrow valleys which are used for wet rice cultivation, big boulders of not less than 1 meter are seen.

5.2 Geomorphic units

Geomorphic units are identified in light of the earlier work carried out by K.S. Lol et.al. (1985), J. Tricart (1969) , Paniza, Joshi & Rawat (2000) and Joshi et.al. (2007). A detailed fieldwork is carried out to identify rock types, landform, and forming processes. On the basis of altitude, dissection pattern, landform and weathering processes study area is divided into different geomorphic units which description is given as below:

5.2.1 Flat Valley Floor

From a distance though valley surface appears almost plain, but presence of small hillocks and river creates undulations. The contour internal available for the area is 20m. Therefore undulation within two contours of 20m interval could not be shown. In general relative relief is ranging from 1540m to 1620m. Average slope found to be ranging from level to 17°. This variation in slope is because of minimum height of channel and peak height of small hillocks. Otherwise, valley floor area is almost plain. This area is under intensive wet rice cultivation and maximum settlement of the area falls under this group. As this area is having almost plain surface dissected by the main river and its tributaries is delimited and named as flat valley floor. It covers about 24.191 Km² or 11.85% of the total area. Altitude of this unit is ranging from 1540m to 1600m above mean sea level.

Table 5.1

Kiile River Basin: Geomorphic units

Geomorphic units	**Area in Km²**	**Area in %**
Flat valley floor	24.191	11.85
Isolated hills	7.04	3.45
Adjoining valley floor	43.111	21.13
Weathered high hills	77.830	38.14
High relief structural hills	22.7	11.12
High relief dissected hills	4.45	2.18
Low relief subdued hills	12.62	6.18
Low relief dissected hills	10.25	5.02
Steep side slope valley	1.87	0.92
Total	**204.062**	**100**

The forming material is unconsolidated clay, sand and pebbles which are seen along the sides of rivers. Two to three levels of terraces with very low width are observed. The terrace forming material comprises elongated, semi rounded

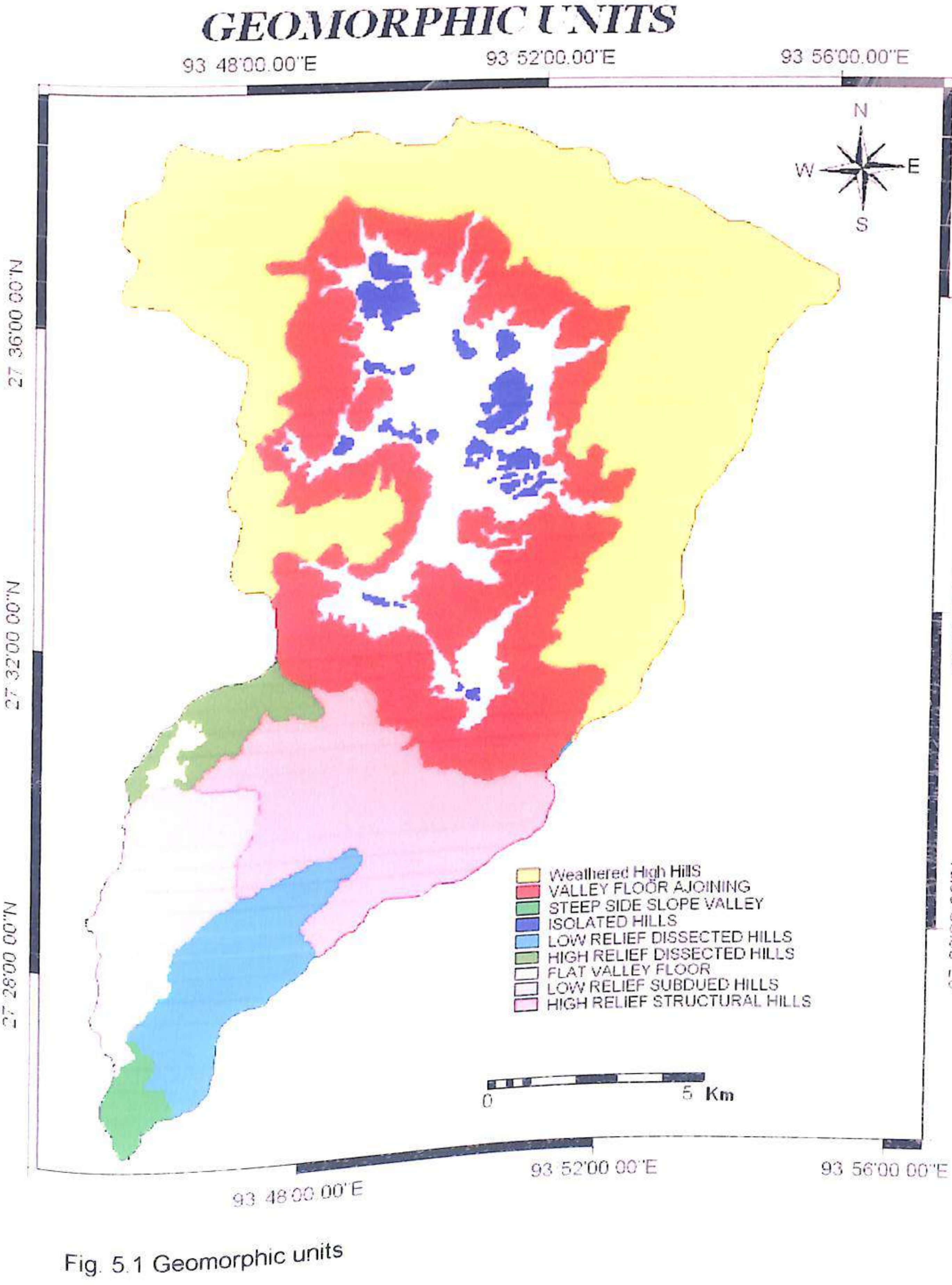


Fig. 5.1 Geomorphic units

gneiss and quartzitic pebbles. Pebbles size is ranging in between few cm to 1 ft. It is important to notice that small and big size pebbles are agglomerated together in sandy matrix which reflects very poor sorting. About 6 ft thick peaty soil layer is found along the river Siya (Hari village) whereas, just few meter ahead the river terraces towards the source of river are seen. Peaty soil layer is not having any correlation with the river terraces comprising big boulders. This observation indicates the involvement of glacio-fluvial process in its origin. At present both side of the river agricultural fields are present which soil type is not matching with this peat/bog layer. River terraces are indicating the reverine nature with turbulent flow. Peaty soil formation might have been in the stagnant water/marshy land. At the margin of valley floor, rivers coming down to plain area might have formed alluvial fan which are further eroded by the changing course of river appear as fun cut terraces. At present due to intensive agriculture, terraces are converted into agricultural fields. However, remnants of alluvial fan deposit present the clue of the existence of the alluvial processes. A pile of blocky elongated bounders made of quartzitic gneiss is observed at a few meters ahead to the Hr. Sec School. The height and width of these boulders are a few centimeter to 10 feet and 6 to 8 ft respectively. The size & roundness of boulders poses a vexed question about the processes responsible in its evolution. River side cuttings are indicating a 3meter thick layer of dark brown clay overlain and underlain by sand layers. There are many localities where this dark brown material appears like peat/bog soil. There might have been period when water was stagnant in the form lake in which organic material was deposited. However, in some places presence of coarse sand with quartz fragments and cross bedding reveals its association with reverine processes. In this unit water level in dug well is found almost parallel to the surface level. Therefore any low lying area in the valley appears like marshy land which indicates the presence of a huge amount of sub - surface water.

In the lower course of river, channel becomes very narrow before which in the river bed huge boulders are seen. Along the right bank recent deposit about 1½ meter height from the river bed is seen. The uppermost layer is consisting wooden log embedded in black soil. After observing the condition of tree trunk, it appears that the upper deposition is of recent one. Lower layer is formed of the pebble and sand deposition. Pebble size ranging from few mm to 7cm. The deposition of this layer is very much thicker than the upper layer. Clay lenses are also seen in the lowermost layer. Though it is difficult to come to the conclusion regarding the causes of its evolution with a limited field study carried out. However, the recent deposition characteristic hints involvement of lacustrine deposit affected by glacio- fluvial processes.

Apart from the main valley, there are two wide depressions are seen in the middle west and south of the study area. Forming material is almost same though soil texture is coarse than the Ziro area. Boulders as seen in Ziro area are not found in Yachuli area. However, a few boulders are seen scattered over area.

In both places i.e., Joram and Yachuli are also under intensive wet rice cultivation. Altitude of this area is ranging in between 1200m to 1300m.

In comparison with Ziro valley, these two (Joram and Yachuli) depressions are very small and locationally situated in low altitude. The resemblance of landforms may be because of same geological and climatic conditions involved.

5.2.2 Isolated Hills

Within flat valley floor area there are number of small and big hillocks are present. Isolated hills covers about 7.04 Km^2 or3.45% of the basin area. From a distance view these hillocks appear as islands. Small hillocks are surrounded by agricultural fields. There are made of gneiss, rocks overlain by weathered material and small semi angular pebbles embedded in soil. Large hillocks are used for settlement, pine-bamboo grooves and rain fed agricultural. In some areas these are covered by huge boulders (some appears with smooth edges, whereas some are angular). At the margin alluvial deposit of alternate sands, silt and pebbles is seen. This forming material indicates there might have been deposition and later on receding stagnant water isolated the area. From the surface the height of these hillocks extends up to 120 meter. These described two levels of isolated hills indicate that these are remnants of older relief of the area. Later on during recent past (Pliestocene) sedimentary deposit covered these hillocks. At present smaller hillocks are having less over burden than the high elevated hillocks.

Huge crystalline boulders which width varies from 6 feet to 11 feet embedded in Yellowish soil with quartz crystals. At Hari village boulders are seen in situ on the hard gneiss (crystalline) rock exposure. Overall observation made during field work indicates all huge boulders are concentrating either within or at the margin of this unit.

Five meter thick loose conglomeratic deposit made of semi- angular weathered quartzite pebbles (pebble size ranging from 1½ ft to few cm) in this unit. There is no sign of reverine deposit as pebbles are not well sorted and elongated. This deposit is not having cementing material as used to be in case of conglomeratic deposit. In another locality within this unit crystalline boulders (11ft length & 6ft to 11ft height) are seen in half circular shape with flat bottom.

5.2.3 Valley Floor Adjoining Dissected Hills

Near Blue Pine Hotel hard micaceous gneiss is observed with very high amount of quartz and mica flakes. However, mica flaks and quartz amount vary in its surrounding. In the same area highly weathered quartzitic gneiss is also seen having an appearance of loose sandstone.

On the way to Hiija from Kaiyang weathered quartzite is overlain by a soil which is fine sandy in nature whereas gneiss (crystalline) overlain by grey dark soil with small quartz crystals. On the way along the road side, alternate quartzitic gneiss and crystalline rocks are found. Crystalline rocks are highly weathered. Near Tajang village highly weathered gneiss exposures of the height about 5m is overlain by a small clay layer. This loose weathered material forms small quartz crystals with dark gray soil. Near St. Claret College along the slope huge boulders (2-3m.) of gneiss are seen. These boulders are not weathered and appear very hard. Though same kind of gneiss is highly weathered and easily can be smashed at Tajang village. These boulders are not showing any sign of water transportation and appear gravity fall/slide of corestone which is confirmed while taking traverse along ring road (source place).

In the North-east of Hari village along hills fan shape landform having pebbles (semi- rounded made of quartzitic gneiss) appears to be made of fluvial action whereas at the right side deposit consists concretion of weathered gneiss, fine pebbles of 3cm and angular pebbles of quartz are seen. After crossing bridge on Kale along Manpolyang road a 3m thick deposit is seen. It is made of concretion and the fresh clay boulders in which cross beddings are present.

River flowing along the hills have dissected this area which is clearly visible in the satellite images. It covers about 43.111 Km^2 or 21.13% of the total basin area. This unit is made of weathered micacious and quartzitic gneiss.

Rocks are having eroded joints filled with quartz matter. In some parts low lying areas along the slope consisting yellow brownish soil. Boulders size is increasing from high hill to low lying area. There are river terraces and alluvial fan at the margin of this unit comprising well sorted alluvial deposit. In the western part of this unit apart from gneiss, quartzitic rocks are also seen with a vertical to near vertical dip in the south east direction.

During field work though it was confusing to differentiate joints and foliation plane. But repetition of observation of strike & dip attitude indicate north – west to south – east dipping towards east. This trend indicates the dip direction of rock towards valley floor.

While traveling across the geomorphic unit at the foothill depositional material (gravity and water influence) whereas in the upper part bed rocks with thin regolith may be seen. In simple words one can address this whole a fan like deposit is alluvial fan material. Field observations indicate fan material. Field observations indicate the huge boulders along the slope may be sliding of corestone made of the weathering of bed rocks affected by glacio – fluvial action.

5.2.4 Weathered High Hills

Weathered high hills cover the maximum area of 77.830 Km² or 38.14%. Quartzitic gneiss found in this unit is having well foliated plane with NW to SE strike line. Rocks are dipping in NE direction with 50° inclination. This type of rock exposures are frequently observed in this part. However, attitude of foliation plane vary from place to place. This unit is made of weathered micaceous and quartzitic gneiss. The rocks are having well defined foliation plane dipping vertical to near vertical in the south east direction along the watershed boundary and appears as a systematic piles of slabs. Recently, huge elongated boulders of gneiss in this unit are reported a Shiv Ling'. Quartz filled weaker plane joints running around the boulder has been referred as garland. Spherical weathered area in the boulder is considered as an eye of Lord Ganesha. On the way from newly identified Shiv Ling to Hapoli fine grain quartzitic gneiss (without weathering) with slaty structure is seen. Thickness of bed ranges from ½ ft to few inches.

In the eastern part of the area weathered crystalline rocks are visible. Weathering depth is observed upto 10m. Crystalline boulders are seen embedded in weathered material. It appears these are corestones and sliding along the slope towards downhill due to gravity. While following Ziro – Raga road from its northern boundary, weathered crystalline rocks area are being used as sand and quartzitic gneiss beds are being used for concrete material. Over all observation suggest that there is difference in the eastern and western part of the area regarding its lithological characteristics and weathering intensity.

Slopes are covered with weathered material. In the north, north-west part gneiss is weathered up to 3 meter depth. However, area consisting quartzitic gneiss is relatively less weathered. Since this unit is covering watershed boundary, a huge weathered material is supplied by gravity and water action towards valley. Summits of hills appear as subdued. The very deep weathering of rocks appears misfit because Himalayan rocks are not as older as Peninsular regions deep weathering. So, this is the matter of a unique kind of finding. Had it been the part of older rocks of Tethys basement there would have been possibility of similarity in weathering with Peninsular rocks. This kind of weathering has been observed in the Precambrian gneiss in Shillong town where people are using it as sand after sieving for building construction.

5.2.5 High Structural Hills

In the satellite image the area not showing much dissection and consisting flat irons (triangular facets). On the basis of the presence of flat irons, it appears that topography is controlled by sub surface structure. Therefore it is named as high relief structural hills. During the field work, rocks are identified as hard unweathered quartzitic gneiss.

5.2.6 Low Relief Subdued Hills

In the satellite image a combination of small hills separated by small valleys are spreaded over within an altitude of about 1100 to 1200 mtr. In the toposheet rounded contours separated by small streams are observed in between Tago and Yachuli locality. From the distance view it appears like basket topography. Weathered schist and gneiss alternate beddings are seen along the road cuttings, overburden area is having the safron soil color with the thickness of more than 1 mtr. These hills were being used for shifting cultivation and now are covered with dense shrubs with scattered trees. The narrow valleys between the hills are converted for the paddy cultivation.

5.2.7 High Relief Dissected Hills

An area having high dissected pattern observed in between Joram top to Joram plain. It may be because of abrupt decrease in altitude and slope. From Joram top to the plain, the altitude is dropping from 1800 to 1300 mtr within a short distance. This area is made of weathered crystalline rocks. This high dissection may be because of high gradient and loose rocks.

5.2.8 Low Relief Dissected Hills

This area is delineated in between 1200 to 1300 mtr. This unit is delineated in the south by low relief subdued hills and in the north by high relief dissected hills. This area is being used extensively for the Jhum cultivation.

5.2.9 Steep Side Slope Valley

An area near confluence of Kale and Pange River is found to be narrow valley with steep side slope. Slopes are covered with regolith material consisting quartzitic boulders and sandy soil. Sub-surface rocks are dipping vertical to near vertical with high joint frequency. Topographic slopes also very high as a result during heavy rainfall exposed rocks are sliding down along the slopes. A recent landslide is observed with a large volume of debris material embedding the building constructed for Tago Hydel Project. The northern boundary of this geomorphic unit might had been delimited by a fault as sub – surface rocks are having very steep slopes (75° dip) whereas topographic slope is lower and covered with regolith.

5.3 Geomorphic processes and landform development

Each geomorphic process develops its own assemblage of landform. During field work different landforms were observed, which reflects the prints either by the present processes or by the recent past process. Therefore, following geomorphic processes and their associated landforms are discussed below:

5.3.1 Fluvial process

Fluvial processes are those which are associated with the flowing water. This process plays an important role in the denudation of land surface and the transportation of rock fragments from higher region to lower region. Sediments which are eroded in one region are transported and deposited in another. Two levels of river terraces were observed near Siya river. The terraces now are converted into intensive cultivation. The alignments of cobbles deposition are in elongated manner.

5.3.2 Colluvium

Colluvium is the name of loose bodies of sediment that have been deposited at the bottom of a low gradient slope by gravity. The materials are eroded and collected at the base of mountains or foothills, with little or no sorting. An alluvial fan having small concretion of weathered gneiss and fine pebbles of quartz are seen behind the isolated hill (Hari village). Regoliths with boulder deposits are also observed at the margin of valley floor and adjoining hill. Regolith thickness represents the balance between weathering and erosion.

5.3.2 Weathering process

Weathering is the decomposition and disintegration of rocks through the direct impact of earth's atmosphere. The rate of weathering process is controled by the parent material, climatic element, biological factor, etc. The weathering process in the present study seems very high. About 3m thick body of weathered material is seen near Tajang village. In the northern ridge, a relict mass of unaltered bedrock are observed which reflect as the result of subsurface weathering.

5.3.4 Lacustrine process

The sediments which are carried by the rivers and deposited in the lake are called as lacustrine deposits. Lake sediments can vary greatly in density and consistency. The genesis of the sediment, the processes by which the material is transported to the lake, its pathway through the water body, and the digenetic processes acting upon it as it is incorporated into the lake bed are all significant factors (Last, William M. et al, 2002). While field work several sediment deposition consisting the mixture of sand, silt, clay and gravels are recorded. The depositional patterns of sediments interpret the paleoenvironmental condition which existed at that place.

CHAPTER - VI

LANDUSE ANALYSIS

6.1 Introduction

'Land' as a main resource forms the base for various developmental activities on the terrestrial ecosystem. The land available for cultivation, construction, its quality, moisture capacity, etc. are the main controlling factors to call a 'land' efficient. Land has been a precious gift of God to human beings. With the increasing in our understanding, we have changed the face of the land. The population pressure and socio – economic policies have changed the land through deforestation for settlement and extension of agricultural land. The changes have profound effect on the human kind. Great reduction in forest cover has caused soil erosion and sediment transport potentiality. The reduction in the forest cover, changes, especially in the sensitive Himalayan belt should be discouraged, as it will bring more hazards to the dwellers. Any kind of changes in the land cover can affect the global system. Some of the scholars believe agriculture as a main cause of current global climate change. Land use, land cover shows the expression of human activities and their intelligence. The term 'land use' seems to be self explanatory. When a virgin plot of land is used for some fruitful result, it deals with land use. The land use pattern of an area is directly related with the level of techno – economic advancement, nature and degree of civilization of its inhabitants (Whyte, 1961).

6.2 Existing Landuse

Land use categories have been delineated using satellite imagery and topographical map (fig 6.1). To have a ground truth verification, intensive field study was carried out. The existing land use maps provides a picture of current development pattern and also serve as a basis for developing land use plans. The land use may be for agriculture or for settlement is primarily depends on the nature of landform configuration. In this study an attempt is made to analyze the impact of geomorphic factors on land use. In general man does not control the nature rather nature controls his activity. Man cannot practice the wet rice cultivation in a very steep slope. To prepare a land for wet rice cultivation he needs a plain land with clayey loamy type of soil. Man cannot perform irrigation without having any natural source nearby the agricultural field.

Landuse is a dynamic process and keep on changing with time. Thus, for classification, adequate survey of the existing land use is necessary. Through proper landuse monitoring one can measure its capabilities which use to be helpful for land management and planning.

The existing landuse of the study area shows a contrast picture in the upper and lower part of the river. The upper course of river with flat valley is inhabitant by Apatanis. This area is under wet rice cultivation. Surrounding hills and isolated hills are either used for the rain fed agricultural field or for settlement or as a pine and bamboo grooves. Recently some changes in the landuse pattern can be observed in the upper part of basin. Due to high growth of land more agricultural land in the flat area is being used for the residential and commercial purpose. Thus, the area under agriculture is decreasing. Though, presently this problem may not be visible by the present generation, but this can result huge scarcity of food to the dwellers in future. In the part of the study area, Slash and burn or jhum agriculture is being practiced. However, in places where flat area is available wet rice cultivation is also being practiced. Majority of area is found to be with degraded forest due to jhum practice. Their staple food is rice. Maize and millets also used as supplementary food. Total area for cultivation in the upper part is almost flat and very fertile.

Table 6.1

Kiile River Basin: Land use

Sl.no	Major Land use	Area in Km²	Area in Percentage
1	Wet rice cultivation	25.051	12.276
2	Bamboo & Pine groove	28.851	14.138
3	Forest Degraded Area	2.05	0.99
4	Barren land	5.65	2.73
5	Degraded land with dense mixed shrubs	8.48	4.10
6	Dense mixed jungle	102.329	50.146
7	Dense shrubs and scattered trees	10.98	5.30
8	Helipad	0.58	0.28
9	Shifting cultivation	16.23	7.84
10	Settlement	3.86	1.86

The present study has been grouped into ten land use categories (Table 6.2).

The distributional pattern of land use shows quite a variation in the basin. The characteristics found during study are summarized as below:

1. The Shifting cultivation is concentrated in the lower part of the study area, because of which forest cover is degraded. At present area is under dense mixed shrubs and scattered trees.
2. The forest land is more in the watershed divides because the slopes are very steep near the divide due to which it cannot be considered ideal either for the settlement or for agriculture.
3. In the upper part of river, inhabited by Apatani tribe, a few patches of degraded hill can be seen near Siiro and Siibe. Forest of this area is degraded not because of shifting cultivation but because of forest fire.
4. The net sown area is confined to the fertile valley area in the upper, south – west (Joram) and near the mouth of the river (Yachuli) due to good flat land and good soil cover.
5. Bamboo with pine groves tells a successful story of Apatanis land management. Due to their utility, it is grown near to the settlement. Even the neighboring tribes have learned to cultivate bamboo in their surrounding. The landuse of the study area shows that all major and minor plain areas are intensively used for the crop production. Therefore the settlements are concentrated in the periphery of agricultural land.

6. By seeing the scarcity of food due to growing population, even narrow valleys between hills are converted for wet rice cultivation. This can be seen in the area nearby Joram and Yachuli localities.

The detailed mapping and analysis of the existing landuse has been attempted by using topographical map and satellite imagery of the study area.

6.2.1 Wet Rice Cultivation

The wet rice cultivation is practiced in the small terraces all around the flat valley land in and around Ziro and Hapoli locality in the upper course of Kiile river. Some patches of flat area also available under wet rice cultivation near Joram and Yachuli localities in the middle part of the study area. The cropping pattern is found to be influenced by the topography of the region. The soils in the valley floor are very fertile due to deposition of the nutrient washed out from the surrounding hill slope. This is the reason without using fertilizer, area is maintaining its fertility. The identified categories show that about 25.051 Km^2 (12.28%) of the total area is under wet rice cultivation. The land use map of the study area reveals that maximum area under wet rice cultivation is concentrated in the central part of upper course of the river. The reason for its maximum

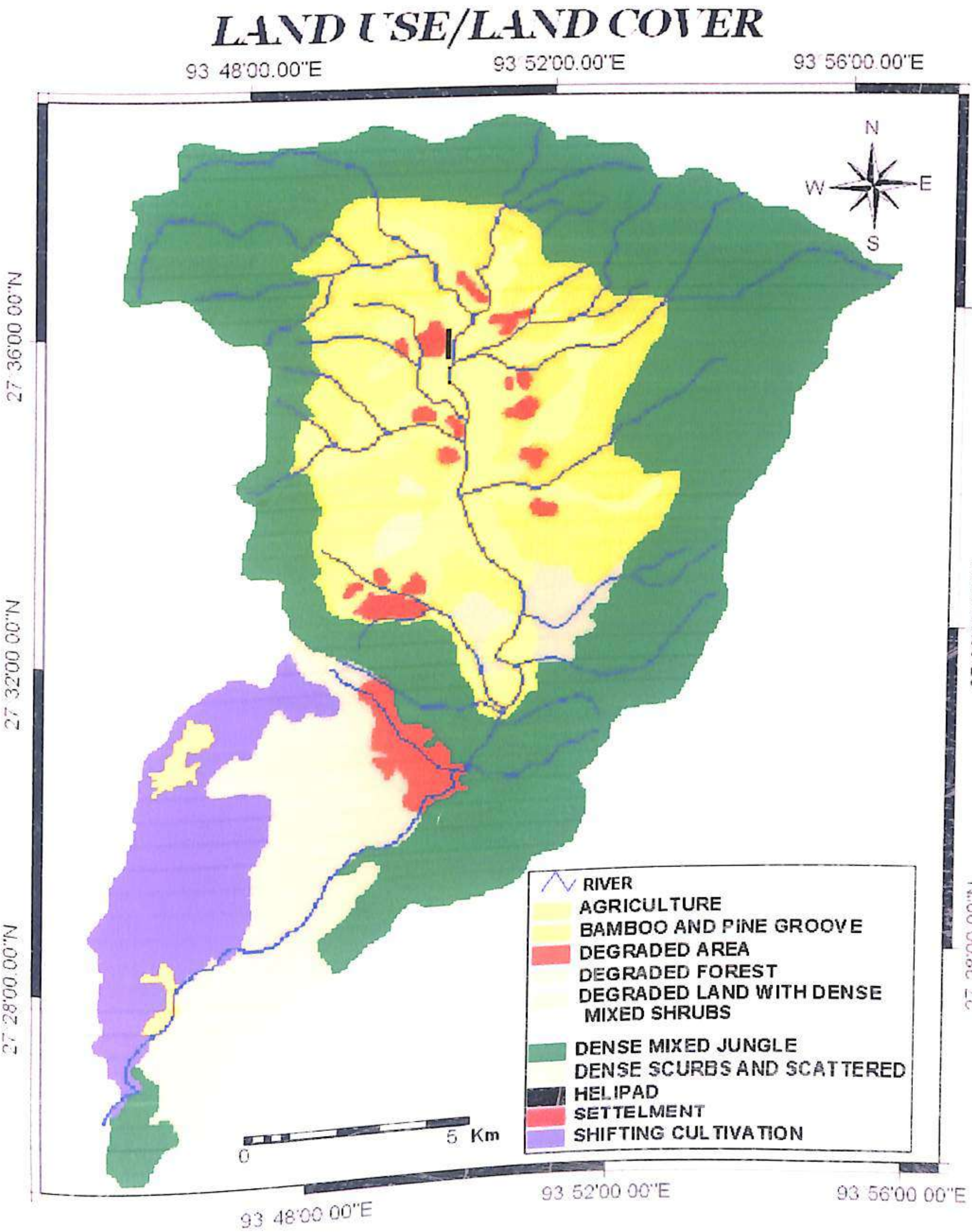


Fig. 6.1 Land use/land cover map

concentration is due to presence of flat land, fertile soil and perennial source of water. Therefore, the valley has been appropriately called "the rice bowl" of the Apatanis. The presence of water throughout the year in the paddy fields shows that the water table is near to the surface. It is verified with the existence of village well (Sukung) in the adjoining areas of paddy fields. Fish culture practiced since 5 decades along with the paddy cultivation by the Apatanis, provides subsidiary source of income to the farmers.

6.2.2 Bamboo and Pine Grooves

Maximum of bamboo and pine grooves are located in the Apatani valley. It is planted in the isolated hillocks and the adjoining hills. The area under this land use is more than wet rice cultivation. The land use category table shows that 28.851 Km² or 14.14% of the total area are under this land use. The bamboo and pine grooves are well maintained by the Apatani people. Now a days, the bamboo & pine plantation are also taken up in the Nyishi villages located in the middle and lower parts of the study area.

6.2.3 Degraded Forest Area

Small patch of degraded area can be seen in the middle part of basin. It covers 2.05 Km² or 0.99% of the total basin area. The area is degraded due to shifting cultivation and left as fallow land. The term fallow is applied to the land which is not under cultivation but has been used for agriculture in the past.

6.2.4 Barren Land

These are the areas which have been degraded due to forest fire. It covers about 5.65 Km² or 2.73% of the total basin area. It is located in the adjoining hills near Siibe in the western part and in the isolated hill near Siiro in the upper part of the river course. Few numbers of left out pine trees with sparse grasses can be seen in both the patches.

6.2.5 Degraded Land with Dense Mixed Shrubs

This land use category covers about 8.48 Km² or 4.1% of the total area. It covers large extension of area near Yachuli and Mai locality. Forest cover of this area is degraded due to the practice of shifting cultivation and left as a fallow land. The climatic condition is so favourable for the formation of soil, due to which the top soil is having high humus content, which is again enhanced by the presence of dense mixed shrubs in it.

6.2.6 Dense Mixed Jungle

This land use category covers the half of the whole basin area i.e. 102.33 Km² (50.146%). It covers the upper reaches of the area along its water divides.

6.2.7 Dense Shrubs and Scattered Trees

This category is another fallow land where the shrubs are seen with some scattered trees. Presence of shrubs with trees shows that this area is under fallow for a very long period. It covers about 10.98 Km² or 5.3% of the total basin area. Parts of Mai and Joram localities are under this category.

6.2.8 Helipad

An airdrome of about 1.5 km distance is present at Old Ziro which covers about 0.58 Km² or 0.28% of the total area. This airdrome is located in the middle of the valley.

6.2.9 Shifting Cultivation

Maximum agriculture area in the lower basin is under shifting cultivation, except a few patches of flat valley at Joram and Yachuli, where wet rice cultivation is carried out. With the increase in population, the jhum cycle is becoming shorter; therefore enough natural fertility of soil is not maintained. Due to frequent use of the hill slopes, it has evoked top soil erosion, which results infertile land. The extensive forest areas in the lower part were encroached upon to increase agricultural productivity. The available natural resources are now being started to deplete and if it is not checked, will lead to a number of serious consequences.

6.2.10 Settlement

The location of settlements is an expression of the geographical factors favorable at a particular spot on the landscape. The settlement covers just a little portion of the basin i.e. only 3.86 Km^2 or 1.86%. The Apatanis considered flat valley to be used only for agriculture. Elevated land which is found to be not favorable for wet rice cultivation used for settlement purpose. Due to the increase new settlements have emerged in the periphery of the valley. The settlement pattern of Nyishi gives a different picture. The houses are scattered in the hill slopes, except in the Joram and Yachuli, where the settlements are compact.

6.3 Land Management

A sustainable development of land resource can be carried out only after a proper assessment of its capability. The land being the central theme to any natural resources needs to be managed properly so that it can be used for a longer duration. Land resource should be used in a most beneficial way to conserve it for which a careful planning and management is needed (Shah 1996). An assessment of the land resource is essential to understand the agricultural potential for the planning of a region (Chauhan, 1996). In general land management may be defined as an act or manner of its utilization in a judicious way. The scientific management of land resource is essential for sustainable agricultural development and environment preservation (Singh, 1996). In the tribal society, the land management is relied on their traditional knowledge.

The land management practiced by Apatani tribe (Rupa and Joshi, 2004- 2005) is a brilliant indigenous technique which is not comparable with any other tribe of Arunachal Pradesh. Haimendorf (1962, 80) observed there is a fundamental and striking differences between the Apatanis and all their neighbors. None of the people of Himalayas, east of Bhutan resembled the Apatanis to any extent, nor can any other tribe boast of a similar mastery of nature'. Bamboo based industrial activities and brilliant method of agricultural system are synchronized with the favorable climatic conditions and fertility of soil has made their economy self sufficient (Kani 1993).

As no any trace can be made on the idea of landuse practices by the Apatani due to unavailable of any written literature or any archaeological evidences, therefore it is very difficult to say about its origin. As per oral literature, it is believed that Apatanis have migrated from Tang Tsangpo valley, Tibet via river routes of Kuru, Kamala and Subansiri. So, the Apatanis might have acquired this knowledge from their ancestor before coming to this place. Apatanis consider land most precious. So, even an inch of land is not left unutilized.

Apatanis have a good knowledge of forest, land and water management. The management of land starts with the preparation and maintenance of agricultural land. The traditional system of terraced wet rice cultivation, irrigation, settlement, plant grooves, etc. by the Apatanis was developed over many generations. Though shifting cultivation is the pre dominant land use system in the lower course of basin by the Nishis, but they have also developed sedentary form of wet rice cultivation throughout the valleys in the area. The people found this practice as complementary system to jhum cultivation. As the agricultural system is restricted by the topography, wherever terrain permits, flat land is converted into agricultural land. Around the flat valley land, small terraces are also extended towards foothills. For preparation of agricultural land weeds or the grasses are cleared during the month of January to February. Tillage of agricultural land starts in the month of April and last till the end of May. With the help of spade, the earth is dig into big blocks, which is then filled up with water for about 6 – 7 weeks. This is followed by the second time digging, to break the large blocks into small fragments. The plots are left for some days filled with water so that the weeds can be decayed completely. The preparation needed for the paddy field varies based on the land characteristics. Some land where the irrigation is a problem needs more care than the plot near the source of the river.

The agricultural plot size ranges from 235m² to 2740m² in the sloppy and flat valley respectively. In between the terraces, bunds or dykes are constructed which are supported by the bamboo and wooden planks. The width and height of the bund ranges between 0.6m – 1.4m and 0.2m – 0.6m respectively. The bunds in the Apatani paddy field are constructed very strong, as the finger millet are transplanted over this. Sometime paddy also transplanted in place of millet in the bunds. After the bunds are prepared leveling of the agricultural plot is done properly, so that the water may not be concentrated only in some portion. Before the leveling process the plot is filled up with water for the full saturation of the soil. After full saturation when the soil becomes loose, it is easy to break and leveled it. At the start of cropping season, fish fingerlings are broadcasted in the rice fields. Typical fish channels (*Hete*) in rice fields are prepared. About 200kg – 250kg of fish is produced from per hectare. The average weight of a fish is attained in between 130 to 400 gram. Rearing of fish adds subsidiary source of income for the farmers.

The canal network for irrigation has been developed applying indigenous knowledge in such a way that not a single agricultural plot is left without water. Main agricultural area is concentrated in the almost flat portion of Ziro and its surroundings. In this area only a single crop, i.e. paddy is produced. Besides, paddy some other crops are cultivated along the hill slopes and slightly elevated areas of the flat land.

The land management by both the tribes within the basin shows a strong application of indigenous knowledge. However, the impact of modern infrastructural development cannot be ignored in their day to day activities. In landuse planning and management they still prefer their traditional technique. A brief description of each of the identified categories is given below:

6.3.1 Agriculture -

Distance from settlement, plain area and availability of water for irrigation are the main criteria for the selection of agricultural site. The land nearby the residential place is used as kitchen garden, where the fertility of the soil remains high due to continuous application of domestic manures. The land where water is available for irrigation is converted into wet rice agricultural field. The slopes of the adjacent hills in the vicinity of the wet rice-fields are used for rain fed agriculture.

Water supply in the catchment area is very high because of the prevailing good amount of rainfall and forest cover in the surrounding hills, as a result of which water for irrigation is maintained and regulated easily. All the small rivulets present nearby field are connected with a main canal, from which with a wooden or bamboo tube water is received by the individual farmer. The entire agricultural plots have inlet and outlet system of water. The terraced plot can be flooded or drained off with water by opening and blocking the inlets and outlets as and when required. Careful consideration is made while the construction of outlet either from wooden plank or from bamboo stem. Based on the water requirement by the upper plot, the height of outlet is decided. The outlets (Siikhho) are prepared from pine wood or bamboo stem. The outlets from wooden plank are especially used during the flooding time. Through the outlet excess water is drained which protect the bund to be damaged. When the paddy is in early stage, it need more water so outlets are blocked either with soil or with weeds. Before the weeding in the field all the water except water in the *Hete* (channel within the paddy plot especially prepared for the fish rearing) are drained out. A cylindrical pipe made of pine tree trunk (*Hete Hubu*) is inserted in the bund in continuation with the fish channel. Bamboo tube is also used to move excess water from one field to another. In the upper plot, net made from bamboo split are used to obstruct the free movement of fish to lower plot. Wooden sticks are used in the water outlet to control erosion.

In the wet rice field, rotten stubbles act as fertilizer. After harvesting the left over like straw are burned to ash and it naturally fertilized the agricultural field. Besides all these, the organic waste i.e. pig and poultry droppings from the village are also used for sustaining the soil fertility. Fields are drained off, cleaned and dug with hoes and spades. Prepared fields are kept under knee deep water till soil is saturated. It is puddled by both men and women with a depth upto two feet. So, in this way soil is churned to a smooth paste and becomes ready for transplantation. Rain fed agriculture area along the slope is tilled with hoes and spades and the lump of earth are broken up by hand or Palii (curved agricultural tool with iron edge). Nurseries are developed in the land nearby the villages for the growth of paddy saplings. In the case of immediate necessity, seeds are sprouted for the faster growth before broadcasting.

Transplantation begins in the middle of April till May. Before the transplantation, agricultural fields are manured using ash, nitesoil, fermented residue of rice beer. The womenfolk lift the seedlings from the nurseries, tie them into bundles and carry in basket to the field for transplantation.

Healthy plants with good production are selected for seed. Earlier seeds were stored in earthen pot covering its mouth with a piece of stone slab. Some are still using the earthen pots. The skull of matured gourd, a container locally called Pinta is also used. Nowadays most of them are using tin container available in the market.

Except paddy other crops are sown in the rain fed land, where domestic manures like husk, excreta of poultry, ash, etc., are used to sustain the soil fertility. The dry fields where millet saplings are grown need a great care. In the field dry maize plants and rice husk are burn to ash for increasing the fertility of soil. After one week it is mixed with soil and then the seeds are sown.

The millet transplantation also takes place simultaneously with the paddy transplantation. Seedlings are lifted from the nursery (which are grown in dry agricultural land) and with the help of *Damii* (long wooden spike for making hole in the soil for planting millet sapling) transplanted on the bunds of paddy field. Some seedlings are left to grow in dry field.

Fields are weeded three or four times till the crop is ready for harvesting. The harvesting season begins from October and continues till early November. All family members give their great concerted effort for two or three weeks. The harvesting technique of Apatani's is different from others. Women cut the stalks with iron sickles, tie it into sheaves and beat against wooden board, which is attached in a large basket. The paddy seeds slides into the basket (Giida Patta) as soon as it is full, the seeds are use to be vacated into a mat. Later on it is carried to the granary. The paddy is spreaded on the floor of granaries (which is raised about 2 to 6 feet from the ground). Except trapping and covering the holes, there is no other precaution to protect against mice and rats. The procedure of the selection and storage of millet is same as paddy. But the other crop seeds e.g. maize, chili, cucumber, green leafy vegetables, etc., are kept on the hearth rack.

6.3.2 Forest

The careful farming of bamboo and pine is considered as one of the unique characteristic of Apatani's land use. Therefore, bamboo and pine groves hold a significant part of their landuse. Until and unless one holds at least one small bamboo grove, he cannot be considered as economically independent. Varieties of wild bamboo are available in the hills surrounding the valley which are suitable only for making basket but not for house construction. Moreover, transport of these bamboos from the distant hills is also a difficult task. So, people cultivate medium sized straight- stemmed bamboo in close proximity to their villages. Bamboos are planted by spacing the roots at two or three feet intervals. Only one to two stems are allowed to grow from each root. After its plantation, the grove retains regeneration capacity for many years. When the groves become over crowded, it is lifted and planted in the empty space. The bamboo groves are equally cared like the agricultural farm. They believe that this type of bamboo was brought by their forefathers with them while migrating to this place.

Pine is considered as one of the most characteristic tree of the people. It does not occur in neighboring areas having similar altitude. So, it is believed that this plant was brought somewhere from north during migration. This is a splendid tree used for timber and firewood purpose. It is grown in the lower slopes of nearby settlement. Most of the bamboo groves are also having scattered pine trees. When pine trees attain a great height, bamboo do not flourish in the shade of their wide canopy. The pine, sometimes interspersed with few other tree species, is used as building material. The pine and bamboo grove is fenced to protect against wandering cattle. The way they manage pine and bamboo groves in the area shows their skill in forestry.

Besides bamboo and pine, there are number of fruit trees like small cherry, peach, small pear and greenish, bitter apple which are planted in groves, gardens, paths and lanes, burial ground and close to houses. Large numbers of evergreen as well as deciduous species like Hollock, Jutuli, Tita Sopa, Hillika, Dhuna, Borpat, Nahal, Udal, Gonsari, Makrisal, Bogipoma, Khokan, etc. are found in the area. The proportions of evergreen species are more than that of the deciduous species mainly due to favorable climatic conditions in the area.

6.3.3 Settlement

People of the area are seriously concerned with their environment as their main economy is agriculture. So flat areas are kept only for agriculture and the slightly elevated areas in the vicinity of flat land are used as settlement. Because of high density of population, houses are constructed very closely, mainly built of wooden piles and bamboo. Earlier houses were thatched with rice straw but now tin sheet are being used for the purpose. As land is limited to accommodate the growing needs, houses are standing wall to wall with narrow streets. The *Lapang* (an open assembly platform), is a unique feature for all villages. It is raised about 5 or 6 feet from ground, which is made of wooden planks. Lapang is used for the socio- religious rituals like the sacrifice of animals (mithuns or cows) during festivals (SUBU, MURUNG and MYOKO) and for public gathering to discuss important matter.

Houses have been constructed so systematically that every part of it holds some kind of special purpose. The traditional houses are standing on high pillars and wooden stairs, with open verandahs. From front verandah (fig.2) one can enter to the porch, which is made for keeping fowl, agricultural implement, winnowing fan, heavy wooden mortars. The porch is connected with the main room with an opening door. There are two-fire places or hearths, based on which inside the house space is divided into two parts known as Ago Empung and Ura Empung. Front fireplace of Ago Empung is considered as a common place as it is used for the entertainment of guest, cooking, washing, etc. There are certain restrictions in this part of the house like sitting position, cooking place and walking. Guest can only sit in the front side of the first fireplace while entering from the front door, whereas the place on the right side of the first hearth is only for the host especially the head of the family. Cooking activities cannot be done from the either side or front side of the first hearth. The female has to pass by the right side of the hearth. Ura Empung or second fireplace is used for keeping the containers of rice, cloths, beads, and other household utensils like baskets, big beer jar, strainer, etc. For the performance of all rituals, only the inside hearth is

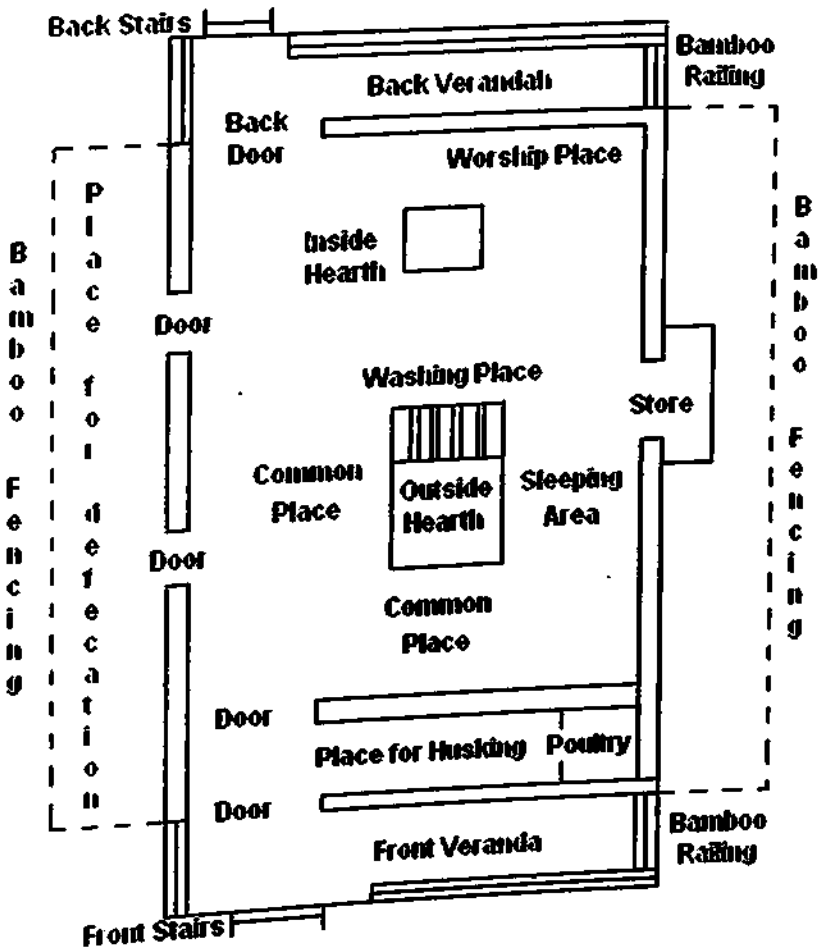


Fig. 6.2 Inside structure of House

used because the outside hearth is used for common purpose to cater day to day needs. So, for the performance of rituals, it is not considered to be clean. Another reason for having second hearth is when a son gets married, parents have to shift to the second hearth. Back door of the house leads to back verandah. In comparison with front verandah, this is usually larger in size. It is used for weaving and spinning purpose. After entering the front door, there is a narrow shelf on either side (depends on the position of the door) which is protected by the under side of a projected roof and accessible by a small door in both outside and inside of the main room. This is the place for a sanitary arrangement or a place for defecation. Below it there is a fenced enclosed area where pigs are kept, because the pigs can dispose off the human excrement and any kitchen waste very quickly.

6.4 Crops and Production

In general paddy among Apatani is locally known as emo. However, the paddy is divided into three main categories i.e. emo (Arey and Hati), pyaping (hari pyaping, gi pyaping, pyaping pyapu, tiipe pyaping, pyaping pyatii, mishang pyaping) and pyare mipya. Besides these three main local seeds, there are some more varieties brought from Assam plain including Lie, Halyang and Mota. Besides paddy as a main stable food, many other crops are being produced by the dwellers in the basin. Millets are grown both in the rain fed agricultural land and in the bunds of the wet rice fields. Different varieties of crops are produced within the basin. The production of crops varies depending on the socio-ecological condition in which it is practiced. An agricultural plot located near the source of main channel in the valley produces 500 gram of paddy/m². But the production decreases with the increase in distance from the main channel in valley.

6.5 Geomorphology and Land use

The study of geomorphology has an important application in the field of identification, evaluation and classification of land as a resource. The geomorphic features have a direct bearing on the type and distribution of land use. The hills and mountainous region due to its physical limitations such as high steep slope and deep to very deep gullies are discarded for any agricultural practices. Therefore, it controls the utilization of land for different purposes. Any modification in the landform by the geomorphic process can change the face of the existing land use.

6.5.1 Slope and land use

Slope has its direct bearing on agriculture as it influences soil, drainage, climate and water table. The thickness of soil cover varies with the change in slope; it is relatively thicker in the valleys and depression, due to the deposition of detritus washed down from the uplands.

In the study area, the slope ranging between level to 10° are found to be the most suitable for cultivation as well as for settlement. Under this category, the areas are gentle to very gentle and are used especially for the permanent paddy cultivation. As the slope angle increases, the slope become unstable, due to which mostly the steep slopes are not utilized either for permanent agriculture or for settlement. Therefore, it is very important to understand the relationship between slope and landuse categories. The slope near the mouth of river valley is very steep; due to which, this area is not utilized for the shifting cultivation and are remain under dense mixed forest. In the lower course the slope under the range of 20° - 25°, appears as subdued hills is under shifting cultivation. Table 6.3 clearly shows the relationship of slope and various landuse categories.

Table 6.2

Kiile River Basin: Land use and slope categories

Slope categories	Level	Land use categories
Below 5°	Very gentle slope with flat valley	Helipad, Wet rice cultivation (WRC), settlement
5° - 10°	Gentle slope	Pine & bamboo grooves, settlement, terrace cultivation, rain fed agriculture
10° - 15°	Adjoining valley floor with moderate slope	Degraded forest, rain fed agriculture, Pine & bamboo grooves, settlement
15° - 20°	Moderate steep slopes	Pine & bamboo grooves, degraded area, dense mixed jungle, shifting cultivation, dense shrub and scattered trees
20° - 25°	Steep slopes	Dense forest, dense shrubs & scattered trees, shifting cultivation, degraded land with dense mixed shrubs
Above 25°	Very steep slopes	Dense forest

The average slope of study area shows the uneven distribution of slope through the entire area. Based on its varied slope characteristics, different landuse categories are found.

6.5.2 Altitude and land use

Altitude has a direct and indirect impact on landuse. It determines soil formation, runoff of water, denudational process, vegetation cover, which affects land use. The temperature under normal conditions decreases with altitude. Thus, the summit area of a mountain is always cooler than its base. Therefore, the decreasing in temperature directly affects the human activities.

The altitude of the study area ranges from 740m to 2648m above mean sea level. As altitude increases, the landuse changes. Agriculture is mainly concentrating in the lower altitude. The settlement are existing just above the agricultural field which is followed by pine and bamboo plantation. Finally, the uppermost range is found to be covered by forest. Maximum part of the shifting cultivation is practiced in between the altitude of 740m to 1200m. Cold temperature during winter season limits the crop rotation in the valley.

6.5.3 Drainage network and landuse

The direction, number and nature of streams in a given region depend on the nature of slope, structural control, lithological characteristics, tectonic factors, climatic condition, vegetal characteristics etc. Based on all these factors, different drainage patterns can be seen through out the earth surface. In the study area, dendritic pattern is very common. Through out the study area irregular branching of tributary from many directions can be observed. These irregular branching affect the landuse of the region. The density of the river is higher wherever there are numerous irregular branching of streams. The density of basin ranges from 0.25 km/km² to 5 km/ km². Whole the flat valley in the upper part is under the lowest drainage density category. Therefore this portion is economically very important. The highest drainage density is observed mainly in the water divide and few patches are also identified near Yachuli and Mai locality. The regions of very high density are not found to be good for the agriculture and settlement purposes.

6.5.4 Soil and landuse

All soil types are the aggregates of different minerals or broken remnants of the parent rocks passed through different geomorphological processes. A soil usually includes common sands, clays, peat and other materials. In Kiile river basin, except the flat valleys, the majority of soils are mountain soil. In the steep slopes, soils are generally shallow and have a thin surface horizon with medium to coarse texture. Whereas the valley soils are developed from the colluvium brought down from the surrounding hills. A soil of the valley bottom comprises alluvium, brought and deposited by rivers in the process of aggradation. Therefore, the valley soils are very fertile, due to which paddy cultivation is concentrated under this soil category. But the valley soil of Apatani valley is quite better in comparison with Joram and Yachuli valley. This may be because the natural nutrient is continuously provided by the forest cover in the periphery of flat Apatani valley. But in the rest of two areas, surrounded hills are degraded due to shifting cultivation which hampers the flow of rich nutrient to the fields situated in the valley.

6.6 Soil Loss

Man's activity in the changing natural cover has been the main reason behind the soil loss. The problem of soil loss is due to prevalence shifting cultivation, faulty land use, improper land tenure system and lack of awareness. Such intervention against the natural limitation can have severe consequences in agriculture due to loss of top fertile soil. In the Brahmaputra river with annual runoff of 537.2 km², more than 660 m^3Km^{-1} of silt load is brought by the northern tributaries and about 100 m^3 Km^{-1} by the southern tributaries. Due to high rainfall (2470mm, annually), the annual soil loss due to erosion is 455.9 million tones, carrying with it about 976 thousand tones of nutrient load (Sharma, U.C). Due to continues huge loss of soil from the hills and silting in river beds, causes floods in the lower stream during peak monsoon period.

Different land use/land cover results varied amount of soil loss. Therefore, for the estimation of soil loss from the study area, 12 experimental plots were installed, 4 each in different environment i.e. forest cover, barren land and agricultural land. Initially, only three experimental plots were established and observations were made during May 2004 – May 2005. In May 2005 nine more replicated erosion plots under GBPIHED project were established in each of the three land use categories. Erosion plots having a dimension of 3mx5m are established in each land use categories along the 40% slope. The results for the first month of the study were rejected to avoid the effects of the changes resulting from construction of the plots. Overland flow and soil loss is being estimated from 12 experimental plots under different land use i.e. agriculture, forest and barren from May 2004. These plots are fenced with aluminum sheets of 1feet (5inches are inserted in soil and remaining 7 inches exposed in the air) from all the sides to prevent penetration of water from the adjacent areas. Rain gauge is installed close to the plots to estimate daily rainfall amount. From each plot through a pipe overland flow is allowed to be collected in a container. The deposited overland flow in the container is filtered taking sample of one liter (in case overland is below one liter whole amount is taken as sample) water and the material is sorted out. After the completion of filtration, the filter paper with soil is kept for oven dry and the weight of same is measured by balance.

Total annual average soil loss from agriculture, barren and forest plots is 0.283473 t $ha^{-1}yr^{-1}$, 0.1888 t $ha^{-1}yr^{-1}$ and 0.120044 t $ha^{-1}yr^{-1}$ respectively. In agricultural plots during 16th June to 15th July and 16th July to 15th August, soil loss is recorded highest in three years with 0.10434 t $ha^{-1}yr^{-1}$ and 0.11567 t $ha^{-1}yr^{-1}$ respectivley. The reason for this much of soil loss may be because of disturbances in the plot for tillage and seed showing. Even the rainfall during this

Table 6.3

Kiile River Basin: Soil loss from different land use

Observation period	**SOIL LOSS t ha^{-1}yr^{-1} (2004 – 2007)**		
Months	**Barren**	**Agriculture**	**Forest**
May – Jun	0.03332	0.02475	0.00474
Jun – Jul	0.00487	0.10434	0.01621
Jul – Aug	0.07617	0.11567	0.06382
Aug – Sep	0.04292	0.00622	0.00214
Sep – Oct	0.00339	0.00284	0.00013
Oct – Nov	0.00006	0.00136	0.00017
Nov – Dec	0	0	0
Dec – Jan	0.003	0	0
Jan – Feb	0	0.00043	0.00005
Feb – Mar	0.00144	0.00349	0.00017
Mar – Apr	0.00190	0.00594	0.00251
Apr – May	0.00463	0.01843	0.03011
Total	**0.1888**	**0.283473**	**0.120044**

Source: GBPIHED Project report and self observation

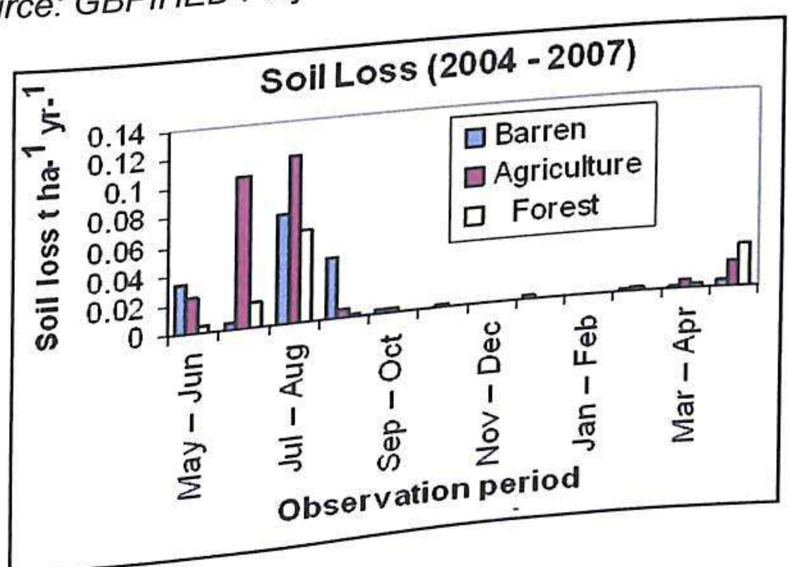


Fig. 6.3 Soil loss

period was recoded highest i.e. 285.5 cm and 350.2 cm respectively. The soil loss during the winter months is negligible due to no rainfall or scanty rainfall. Out of three land use categories, forest cover recorded the lowest soil loss (0.120044 t ha^{-1}yr^{-1}) and highest in agriculture plot 0.283473 t ha^{-1}yr^{-1} due to no any vegetation coverage.

The three years data reflects that the soil loss and overland flow is very low in the forest cover. The reason for less soil loss in forest cover may be due to thick layer of pine litter which protects the soil to expose directly. Whereas, the agricultural plot which is continuously being disturbed by the human for tilling, seedling and harvesting are recorded the highest soil loss in all three observation years.

6.7 Land Capability

The land capability classification (fig.6.4), classify and map land according to its ability & suitability to support a range of crops on a long term sustainable basis. Land is grouped according to their limitations for food crops, its productivity, their risk of damage if used for crops, and the way they respond to management. In this method, land is placed in each type of land in a land class.

Land may be classified according to its present land use, its suitability for a specific crop under the existing forms of management, its capability for producing crops or combinations of crops under optimum management, or its suitability for non-agricultural types of land use (USDA). Therefore good knowledge of the land capability and its suitability combined with good information of soil characteristics & its management can give a fruitful result in production and sustainable agriculture. The USDA classified land capability into eight categories by using the USDA soil survey map with other parameters i.e. evidence erosion, slope (%), soil depth (cm), surface stoniness, soil stoniness, soil drainage, soil texture, rock outcrops, available water capacity, organic matter (%), carbonate (%) and pH. A new land suitability classification has been also developed by FAO (1983) based on the survey of the physical attributes of the land (soils, climate, vegetation, topography, hydrology, etc.). For the present study, the land capability classification was prepared by taking the parameters such as, slope, existing landuse, altitude, geomorphic units, and nearness to settlement.

Five parameters were considered for the study of evaluation and their quantification are shown for the tentative classes in table 6.4. Different parameters give information about topographical characteristics i.e. slope, altitude, geomorphic unit, and the man influence characteristics i.e. nearness to settlement and existing land use.

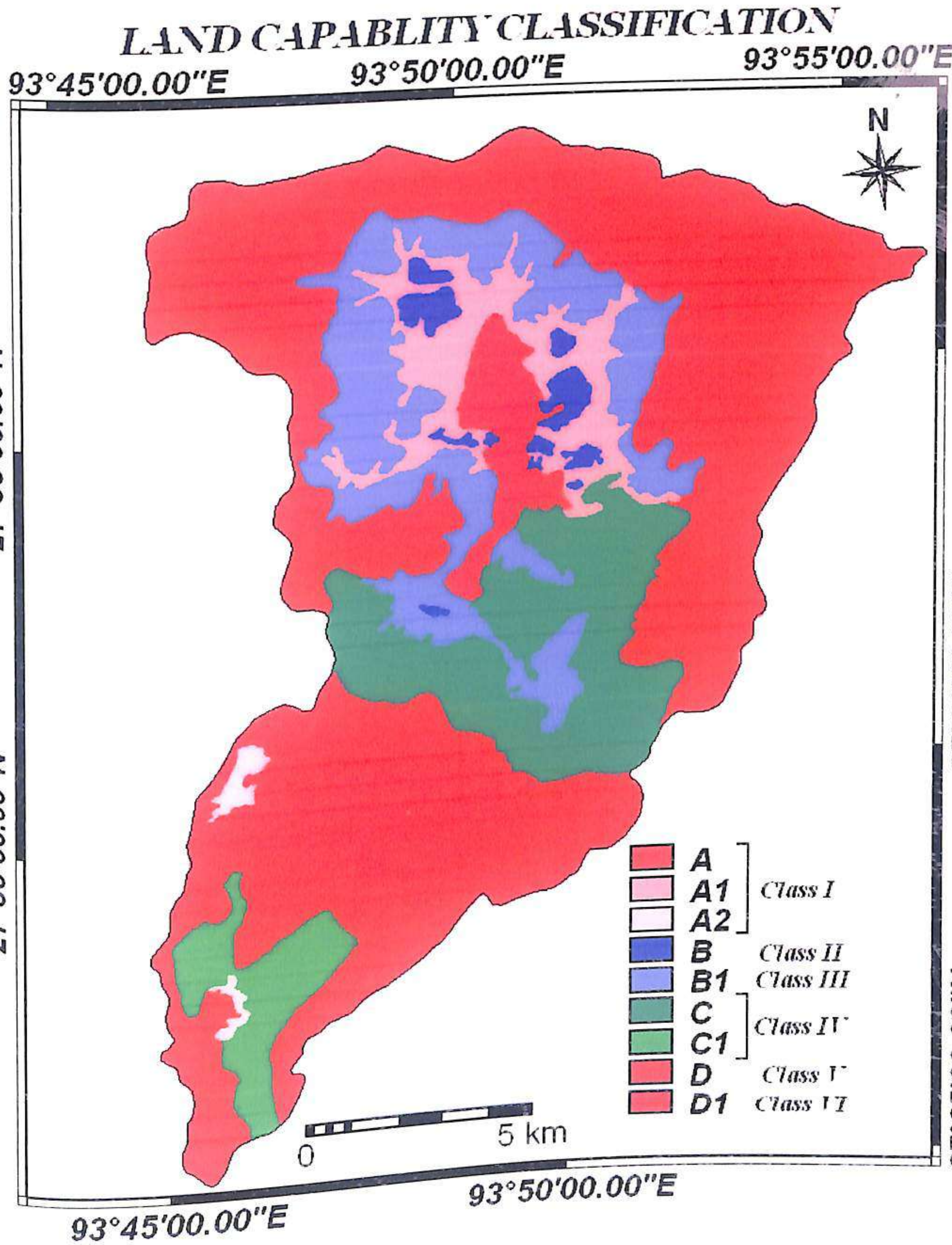


Fig. 6.4 Land capability classification

Table: 6.4

Kiile River Basin: Parameters used for Land Capability Classification

VARIABLES					
CLASS	Slope (%)	Altitude (m)	Geomorphic unit	Nearness to settlement (km)	Existing landuse
A	<1	1540 – 1600	Flat valley	0 - .3	Wet rice cultivation, settlement
A1	1 – 8	1540 – 1600	Flat valley	-	Terrace cultivation, settlement
A2	6.7 – 20	1100 – 1300	Flat valley	2.6 – 3.2	Wet rice cultivation
B	13.3 – 40	1600 – 1720	Isolated hill	1.6 – 4	Bamboo and pine grooves
B1	10 – 80	1600 – 1800	Adjoining valley floor	2 – 5.4	Pine and bamboo, rain fed agriculture
C	8 – 80	1600 – 1900	Adjoining valley flôor	1.4 – 15.2	Bamboo & pine grooves
C1	13.3 – 80	1100 – 1200	Low relief subdued hill	16 – 18	Shifting agriculture, degraded land with dense mixed shrubs
D	10 – 80	1800 – 2648	Weathered high hills	2.4 – 12.6	Dense mixed jungle
D1	10 - 80	1200 - 1900	High relief dissected hill, low relief subdued hill	6.4 – 8	Dense shrubs & scattered trees, degraded area, dense mixed jungle, shifting cultivation

Based on the prescribed information, the units that have the same degree of limitations are kept under one class. Following six land capability classes are prepared:

Table 6.5

Kiile River Basin: Land Class

Land Class	Land units	Area (km²)	Area (%)
Class I	A, A1,A2	20.77	10.18
Class II	B	3.46	1.69
Class III	B1	28.14	13.79
Class IV	C, C1	33.46	16.39
Class V	D1	72.05	35.31
Class VI	D	46.19	22.63

Class I

Land under Class I is the highest land category having high capability with slight limitations that restrict their use. This class includes three land units A, A1 and A2 which covers an area of 20.77 km^2 or 10.18% of the total basin area. The slope varies from less than 1% - 8% (upper valley) to 6.7% - 20% (lower valley), which reflects very level to level land. The altitudinal extension is from 1540m – 1600m & 1100m – 1300m in upper & lower valley respectively. Presently both the valleys are under intensive cultivation. Maximum of the settlements are situated within 0.3 km from the valley land, except in some areas where the settlements are located between 2.6 – 3.2 km.

Class II

All the isolated hills are included under this land category. This class covers the minimum area (3.46 km^2 or 1.69%) within the basin. They have some hazards and limitation due to slope (13.3% - 40%). The slope also varies based on the areal extension. The hills which are large have higher slope in compare with the smaller. Presently this category is under bamboo & pine grooves and even rain fed cultivation land use. The settlement is situated 1.6 – 4km from this land class.

Class III

The valley floor adjoining parts are under this class. About 28.14 km^2 or 13.49% of the basin area is under this class. This category limits the choice of crops or it will require moderate conservation practices for crop production. The slope is moderate to high between 10 – 80%, due to which the terracing can be difficult. Some of the settlements are located close to this class (2km) but few are situated at the distance of 5.4km. The land is under the pine & bamboo grooves but gentler slope are converted for rain fed agriculture. This land is situated at an altitude of 1600m – 1800m above mean sea level.

Class IV

Category IV includes some part of higher part of adjoining valley floor and low relative subdued hills in the upper and lower course respectively. This class includes two land units C and C1 covering an area of 33.46 km^2 or 16.39% of the total basin area. The slope ranges from 8 – 80% which is moderately steep to steep slope. The altitude ranges from 1600m – 1900m (upper course) and 1100 – 1200m (lower course). Pine & bamboo plantation cover the adjoining valley floor whereas the lower part is under shifting cultivation and some are degraded land with dense mixed shrubs. The land are sloping with poor soil characteristics, therefore careful management of soil is require.

Class V

High relief dissected hill and low relief subdued hills geomorphic units are under this category. This class covers the maximum area of 72.05 km^2 or 35.31% of the total area. The steep slope (10% - 80%) limits to make the land suitable for cultivation. Presently majority lands are under dense shrubs with scattered trees, degraded area and also few patches of shifting cultivation. Its altitudinal extension ranges from 1200m – 1900m. The settlement zone is situated at the distance of 6.4 – 8km.

Class VI

The weathered high hill which is extended at an altitude between 1800m–2648m are categorized under this class. This class covers total area of 46.19 km^2 or 22.63% within the basin. In this class the soils have severe limitations due to steep slopes, erosion, and thin soil cover, therefore this class is not suited for cultivation. Presently, this land is under dense mixed jungle. Except a few hamlet of settlement which is situated with the distance of 2.4 km, the entire settlement zones are far distant.

The above descriptions of the land classes tell that the land capability decreases towards the higher lands. In the upper ridges, the quality of the land is very poor due to decreasing in the thickness of soil cover. Whereas the capability of land is high in the valley floor due to thick soil cover, good irrigation facilities, nearness to the settlement and road.

A GEOMORPHOLOGICAL AND LAND USE STUDY OF KIILE RIVER BASIN, EASTERN HIMALAYA, ARUNACHAL PRADESH

A Thesis submitted for degree of Doctor of Philosophy in Geography

Supervised
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CHAPTER VII

SUMMARY AND CONCLUSION

In simple words geomorphology may be explained as a science which deals with the identification, mapping and genesis of landforms. In the Himalayan region, geomorphology plays a vital role in land use, management and planning. Growing population is exerting pressure on land resources as a result land degradational processes leads to soil erosion, landslide and decreasing water discharge of rivers. Therefore, it is very significant to have a proper land evaluation before planning for land resource utilization.

In the Himalayan region, high relief variation, high amount of monsoonal rainfall, highly fragile rocks and unstable structural formation draw attention for a proper database generation. A systematic geomorphological techniques to carry out study took a long span of time to emerge geomorphology as a discipline. In this study an attempt is made to observe geomorphological and land use characteristics of the area. A Kiile river basin is selected to carry out this work. The study area is extending in between 227°25'52" to 27°38'37" North latitude to 93°45'30" to 93°55'50" East longitudes covering an area of about 204.062 Km².

Morphometric approach is adopted to carry out relief, slope and drainage characteristics. Land use mapping and geomorphological mapping is done using remote sensing data and field observations. An attempt is also made to identify present trend in water discharge of a river and soil loss based on secondary data as well as field observations. Along the whole region in Central, Western, Nepal, Darjeeling and Sikkim Himalaya lot of work is carried out on this theme except in Arunachal Himalaya. The survey of India topographical map (83 E/14,15), GBPIHED project report and remote sensing data (IRS IC, LISS III FCC) with field verification are used as data base for the present work.

Geologically this area falls under the Lesser Himalayan part. It consists meta – sedimentary and metamorphic rock i.e. gneiss, schist, phyllite, quartzite and crystalline rocks. Quarternery deposit is found in this upper river course appear to be lacustrine origin. Altitude is ranging from 740m to 2684m. In the upper course a wide valley with an altitude ranging from 1540m to 1600m cover a very significant area in the basin. In the lower course two more small valleys are present which are surrounded by the basket type (small hillocks) of topography. Lineaments reflect a subsurface phenomenon thus all linear features, which were distinct, are picked up and directions were measured and divided into six groups at the interval of 30°. Maximum lineaments (34%) are extending in 30°- 60° to 210°- 240° direction. General trend of lineaments aligns to Major structure of the Himalaya i.e. extension of Main Boundary Thrust (MBT) and Main Central thrust (MCT).

The upper part of study area which is an intermontane valley, shows a very unique type of weather condition in comparison with its neighboring areas.

The upper part experiences below 0° temperature in winter whereas in the lower stream, the weather became little bit warmer. The variation in the weather condition of study area is controlled by the topographical variation. The basin presents a humid sub – tropical to temperate type of climatic condition, due to which it gets sufficient amount of rainfall in summer season. Rainfall data for the period of 1986 to 2006 and temperature data for the period of 2003 - 2006 are collected from the Meteorological station situated at Ziro. Highest total rainfall (2349.03 cm) is observed in 1991. The lowest rainfall (681.5 cm) is found in 2003. The highest maximum mean temperature of 23.57 °C is recorded during the month of July. The lowest temperature is found to be droped upto 0° in the month of January. Based on Champion and Rautela, the study area has been divided into three vegetation zones. The division indicates that about 6.82 % and 63.71 % of the study area lies under sub – tropical and temperate forest respectively. The remaining 29.47 % of area lies under sub – alpine vegetation. Besides bamboo and pine plantation, people also plant trees like Alnus nepalensis (RIME), Prunus spp. (PIITA), Pyrus (PECHA), Prunus nepalensis (SEMBO) etc. In order to describe the chemical properties of soils, information is collected from the GBPIHED sponsored research project in the department of Geography. These observations indicate that the pH of the study area ranges from 4 to 6.5. The highest pH value (6.29) has been recorded from agricultural field at Yachuli. The lowest pH value (4.03) has been recorded from dry agricultural field, near Helipad, Old Ziro. The study area is inhabited by two major tribes of Arunachal Pradesh i.e. Nishi and Apatani. The northern or the upper course of the river is occupied by Apatani's. The lower course is inhabited by the Nishi's. Both the groups belong to Tibeto – Mongoloid stock and their language belongs to Tibeto – Burman family.

The morphometric approach has been applied to carry out the study of relief of the area. In this study an attempt is made to study relief characteristics with the help of relative & absolute relief, dissection index, profiles and hypsometric curve. The relative relief is ranging from level to 498m. About 66.42 percent of the basin area lies in the moderate to moderately high relative relief category. High to very high relative relief characterizes about 19.43 percent of the basin area. Low relative relief found in the flat valley accounts 14.15 percent of the basin area. The absolute relief ranges from 1100 m (at Tago hydel) to 2684m (at the north eastern boundary of the area). The dissection index varies from 0 to .345. Low to very low group of the dissection index covers maximum area (74.92% or 152.882 km^2) while the area coverage decreases with the increase of dissection index. The profiles are drawn from east to west of the basin to observe the variation in the height. The serial profiles are drawn to show the summit point, river valley, etc. The eastern part of the basin is showing higher altitude along the profile lines. The ruggedness in the profiles towards the periphery of the basin shows active erosional processes whereas towards valley aggradation may be higher. The area – height percentage indicates that the area between 1500m to 1800m experiences erosional activities. The altimetric frequency histogram of Kiile river basin gives a clear picture of the relative position and percentage of different land surfaces of the basin. The highest percentage of the total area (50.3%) seen between the height of 1600m and 1800m. The lowest area (1.5%) is observed in between the contour interval of 2400m and 2600m.

Average slope is ranging between 0° to 29.5°. Study area is divided into six average slope categories. Maximum slope of 35.28 percent is characterized by slope values of 20° to 25°. The steep slopes occur mostly in the upper part of the watershed boundary. The minimum area of only 2.53% is under very gentle slope (Below 5°) which occurs in the central portion in northern part of the basin. The mean, median and mode of the average slope are 18.30, 19.50 and 21 respectively. The slope in percent of Kiile river basin varies in between 0 to 40%. The maximum area (142.526 km² or 69.84%) falls under the slope group of 30% – 40% which is distributed throughout the basin. The very gentle slope group (1% – 3%) is covering only 1.646 km² or 0.81% of the total area. The Ziro valley falls under nearly level sloping group i.e. below 1%. Except 30 – 40% and below 1% slope category, all are distributed in a scattered manner. The slope and absolute relief reveals that with the increase in absolute relief, slope also increases. Study area also divided into convex, concave, rectilinear and undulating slope types.

The basin morphometry is carried out with the help of different morphometric parameters or attributes, viz., stream order, number, length, bifurcation ratio, stream length ratio, drainage density, stream frequency, etc.

The Kiile river is originating at an elevation of 2684m and is feeded by numbers of tributaries and sub – tributaries. The various drainage patterns identified are dendritic, radial/centrifugal, rectangular and parallel. The Dendritic pattern is commonly observed throughout the study area. The radial stream pattern is observed in the central part of the study area. The rectangular drainage pattern is noticed in the eastern and north eastern part. According to Strahlers stream ordering system the Kiile river has been ranked as sixth order stream. It comprises of sixth order basin with 876, 198, 55, 18, 3 and 1 first, second, third, fourth, fifth and sixth order streams respectively.

The bifurcation ration of Kiile river basin ranges from 3.0 to 6.0. The stream length of 1st, 2nd, 3rd, 4th, 5th and 6th order river is 253.5 km, 113 km, 54 km, 40.5 km 9.5 km and 25.5 km respectively. In general the stream length decreases with an increase in order, but in the present study, the stream length is more in 6th order (25.5 km) than in the 5th order (9.5 km). The coefficient of correlation between the stream order and stream number is -0.778. It is noted that the mean stream length increases with the increase of drainage order so there is a positive relationship in between mean stream length and drainage order. The stream length ratio of Kiile river basin ranges from 1.41 to 8.05. The sinuosity index is 1.01, which shows that the channel is in straight course. The topographical sinuosity indices (TSI) is high (93.3%) and hydraulic sinuosity indices (HIS) is low (6.7). So, it indicates that the basin is in its youthful stage. The geometry of basin shape is identified by calculating the form factor as suggested by Horton. The form factor of Kiile river basin is 0.33, which shows that the basin is having an elongated shape. The drainage density of study area varies from 0.125 km/ km² to 5km/ km². The drainage frequency ranges from 1 stream/ km² to 14 streams/ km². The highest percentage of area in under the frequency of 6 – 9 streams/ km². The Kiile river with a length of 35 km from source to mouth runs through the heart of the Ziro and Yachuli area. The longitudinal profile of Kiile river reflects two abrupt break in slope. Knick point or break in slopes indicating sudden change in erosional and depositional processes due to the impact of endogenetic and exogenetic processes. The basin output analysis is carried out through water discharge and evaporation. The two year data on water discharge reflects that the maximum amount of discharge i.e. 207.02 cumec and 178.15 cumec were observed during the month of July to August. The total amount of water discharge has decreased from 1346.54 cumec (2005 – 2006) to 1139.96cumec (2006 – 2007).

A geomorphological study is carried out using satellite imageries and detailed field work. Study are is divided into nine geomorphic units on the basis of altitude, dissection pattern, landforms and weathering processes. In general study area is divided into three groups. First group, i.e. upper course is consisting four geomorphic units viz. Flat valley floor, Isolated hills, Adjoining valley floor and Weathered high hills. Second group of geomorphic unit falls in the middle and lower middle course of river where relief, structure and dissection pattern is responsible for geomorphological variation. In the lower most course of river at the mouth, forms a separate geomorphic unit dominantly influenced by slope.

After classification of the area into various geomorphic units an intensive field work is conducted and various geomorphological processes and forming material is identified. Geomorphological processes are mainly associated with weathering, fluvial and colluvial processes. In the upper reaches of study area, weathering is very common. In the valley area depositional processes are seen in the form of narrow alluvial plain and 3 levels of river terraces along the rivers. In the valley adjoining area, colluvium processes are responsible for the boulders and alluvial fan deposition.

The growing population pressure and changing socio – economic practices have changed the land through deforestation for settlement and extension of agricultural land. The landuse changes in the hills have caused soil erosion and sediment transport potentiality. Land use categories have been delineated using satellite imagery and topographical map. Intensive field study was carried out to identify the various landuse categories delineated through satellite imageries. The main land use categories identified are area under wet rice cultivation, Bamboo & Pine groove, Forest Degraded Area, Barren land, Degraded land with dense mixed shrubs, Dense mixed jungle, Dense shrubs and scattered trees, Helipad, Shifting cultivation, and Settlement.

The existing landuse vary from place to place because of its topography. In the upper course of the river area is under intensive use, due to availability of valley plain with ample water resource. This area is inhabited by Apatani tribe which is considered traditionally very good land managers. Surrounding hills and isolated hills in the valley area are used for the rain fed agriculture, settlement as well as pine and bamboo grooves. Now days agricultural lands in the flat area is also being used for the residential and for commercial purpose. The Nyishi who inhabit in the middle & lower part of study area are practicing "Slash and burn" or "jhum" agriculture system. However, plain area (Joram and Yachuli localities) is also being used for wet rice cultivation. Main crops grown in the Jhum fields are paddy, maize and millets.

Area for cultivation in the upper part of the river is concentrating in the valley area which is very fertile. Land holding among the all families is not equally distributed. The wet rice cultivation is practiced in the small terraces all around the flat valley land in and around Ziro and Hapoli locality in the upper course of Kiile river. An agricultural plot located near the source of main channel in the valley produces about 500 gram of paddy/m². But the production decreases with the increase in distance from the main channel in valley. Some patches of flat area also available under wet rice cultivation near Joram and Yachuli localities in the middle part of the study area. Maximum of bamboo and pine grooves are located in the upper course of the river. Now a days, the bamboo & pine plantation are also taken up by the Nyishi tribe located in middle and lower parts of the study area. Forest degradation use to take place due to jhum cultivation. After cultivation for one year land is left as fallow land. Due to forest fire in the upper reaches about an area of 5.65 Km^2 is found to be barren. Few numbers of left out pine trees with sparse grasses can be seen in this area. An airdrome of about 1.5 km distance is present at Old Ziro which covers about 0.58 Km^2 or 0.28% of the total area. This airdrome is located in the middle of the valley. Maximum area in the lower part of the study area is under shifting cultivation. With the increase in population, the jhum cycle is becoming shorter. Due to frequent use of the hill slopes, it has evoked top soil erosion, which results infertile land.

The Apatanis considered flat valley to be used only for agricultural purpose. Slightly elevated land in the surrounding of wet rice cultivation is used for settlement purpose. The settlement pattern of Nyishi is scattered in the hill slopes. However, in the Joram and Yachuli area, settlements are compact. An area of 3.86 Km^2 is found under settlement in the Ziro – Hapoli localities.

The land management by both the tribes within the basin shows a strong application of indigenous knowledge. However, the impact of modern infrastructural development cannot be ignored in their day to day activities. In landuse planning and management they still prefer their traditional technique. Distance from settlement, plain area and availability of water for irrigation are the main criteria for the selection of agricultural site. The land nearby the residential place is used as kitchen garden, where the fertility of the soil remains high due to continuous application of domestic manures. The land where water is available for irrigation is converted into wet rice agricultural field. The slopes of the adjacent hills in the vicinity of the wet rice-fields are used for rain fed agriculture. Apatani tribe use to develop a planted forest of pine and bamboo. Therefore, bamboo and pine groves hold a significant part of the land among them. Until and unless one holds a property of at least one small bamboo grove, he cannot be considered as economically independent. Besides bamboo and pine, there are number of fruit trees like small cherry, peach, small pear and greenish, bitter apple which are also planted in groves, gardens, paths and lanes, burial ground and close to houses. Large numbers of evergreen as well as deciduous species like Hollock, Jutuli, Tita Sopa, Hillika, Dhuna, Borpat, Nahal, Udal, Gonsari, Makrisal, Bogipoma, Khokan, etc. are found in the area.

Settlement in the Apatani area is managed in the slightly elevated areas in the vicinity of flat land and flat areas are kept only for agriculture. Because of high density of population, houses are constructed very closely, mainly built of wooden piles and bamboo. Earlier houses were thatched with rice straw but now tin sheet are being used. Settlement in Nyishi area is scattered and different from the apatani tribe.

Geomorphology has an important application in the field of identification, evaluation and classification of land as a resource. The geomorphic features of the landforms have a direct bearing on the type and distribution of land use. The hills and mountainous region due to its physical limitations such as high steep slope and deep to very deep gullies are discarded for any agricultural practices or for other utilization. For the proper evaluation and management of land resources information regarding the geomorphic units and the associated processes of an area is very important. The geomorphic processes can shape and modify the existing landform. Therefore, it controls the utilization of land for a particular purpose. Slope has its direct bearing on agriculture as it influences soil, drainage, climate and water table. The thickness of soil cover varies with the change in slope. It is relatively thicker in the valleys and depression, due to the deposition of detritus washed down from the uplands. In the lower course of the study area where slope is in between 20° - 25 found under shifting cultivation. The average slope of study area shows the uneven distribution of slope through the entire area. Based on its varied slope characteristics, different landuse categories are found.

Water availability has played a very important role to determine the use of land in the study area. The perennial river courses are providing water throughout the year in the valley areas. In Ziro-Hapoli, Joram and Yachuli localities soil is found to be very fertile and being used for the production of paddy. Remaining area is forming mountainous soils which is relatively less fertile.

The changing natural cover has been the main reason behind the soil loss. The practice of shifting cultivation, faulty land use, improper land tenure system and lack of awareness can have severe consequences in agriculture due to loss of top fertile soil. Total annual average soil loss from agriculture, barren and forest plots is 0.283473 t $ha^{-1}yr^{-1}$, 0.1888 t $ha^{-1}yr^{-1}$ and 0.120044 t $ha^{-1}yr^{-1}$ respectively. An attempt has also been made to classify and map land according to its ability & suitability to support a range of crops on a long term sustainable basis. It is carried out considering the slope, soil, altitude, geomorphic processes and nearness of settlement. Whole study area is classified into six major classes.

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Appendices:

Appendix –I

Itms	**Symbol**	**Formula**
1. Dissection Index	: DI	Relative Relief/Absolute Relief
2. Relative Relief	: Rr	
3. Absolute Relief	: Ar	
4. Relative height	: h/H	
5. Relative area	: a/A	
6. Slope in angle	: tanØ	$\frac{N \times I}{636.6}$
7. Bifurcation ratio	: Rb	Stream Number of order 'u' /Stream number of the next higher
8. Stream length ratio	: RL	Total mean stream length of order u'/mean length of the next lower order
9. Mean stream length	: Lμ	
10. Number of stream segments	: Nμ	
11. Channel length	: CL	
12. Valley length	: VL	
13. Air distance from source to mouth of the river	: AL	
14. Topographic sinuosity index	: TSI	% equivalent of Valley indexI–1/Channel index – 1
15. Hydraulic sinuosity index	: HIS	% equivalent of Channel index–Valley index/Channel index – 1
16. Channel Index	: CI	Channel length/Air distance
17. Valley Index	: VI	Valley length/Channel length
18. Standard Sinousity Index	: SSI	Channel index/Valley Index
19. Channel Sinousity Index	: CSI	Channel length/Valley length
20. Form Factor of the Basin	: Rf	Area of the basin/Length of the basin
21. Basin area	: A	
22. Basin length	: L	
23. Drainage density	: Dd	Total stream length of the basin / Area of the basin
24. Stream frequency	: F	Total number of stream segments / Basin area

Appendix –II

Local terminology

1. Siikhho	: Outlet from the paddy field, made of pine wood
2. Hete	: Channel within the paddy plot especially prepared for the fish rearing
3. Hete Hubu	: Cylindrical pipe made of pine tree trunk
4. Palii	: Curved agricultural tool with iron edge
5. Hiitah	: A flat wooden tool used for leveling of prepared agricultural field
6. Damii	: Long wooden spike for making hole in the soil for planting millet sapling
7. Lapang	: An open assembly platform
8. Subu, Murung and Myoko	: Festival
9. Ago Empung	: Front fire place consider as common place
10. Ura Empung	: Inside fire place
11. Pinta	: Skull of matured gourd use as a container
12. Giida Patta	.: Rice basket

Plate No.1: Research scholar at CBPIHED research project experimental erosion plot construction in forest

Plate No- 2 Experimental erosion measurement plot in the agriculture area under GBPIHED research project

Plate – 3 Experimental erosion measurement plot in the agriculture area

Plate No. 4: Millet grown along the bunds of Paddy fields

Plate No. 5: Water discharge measurement

Plate No. 6: Drain in the paddy field used for raring fish

Plate No. 7: Field made ready for the paddy nursery

Plate No. 8: Kitchen garden used for crop production

Plate No. 9. Fish fingerling grown in the agricultural field

Plate No. 10: Traditional and modified house types and material used

Plate No.11: Millet transplantation

Plate No. 12: Bamboo Grooves

Plate No. 13: Paddy threshing

Plate No. 14: Paddy threshing by Nishi tribe

Plate No. 15: Paddy Harvesting

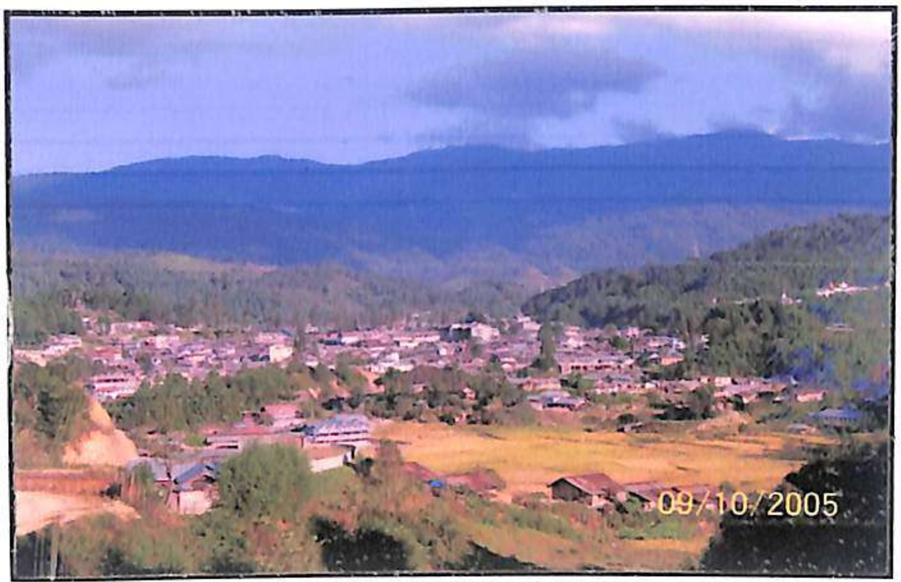

Plate No. 16: An Over view of Hapoli Town

Plate No. 17: Weathered Rocks

Plate No.18: Soil erosion control measures adopted along the Kiile River

Plate No. 19: Researcher in the field observing the dip and strike of an exposure

Plate No. 20: Corestone in the weathered rock

Plate No.21: Newly found Shivling in Ziro

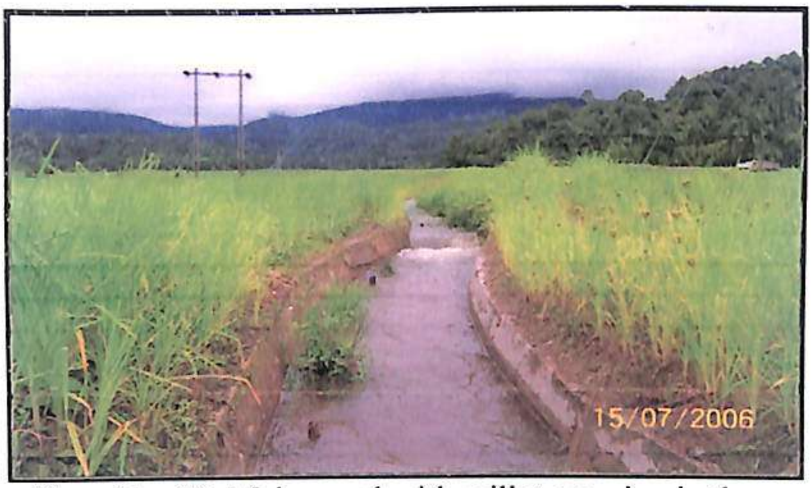

Plate No. 22: Main canal with millet growing in the agricultural bund

Plate No. 23: Diversion of water from main canal to agricultural plot

Plate No. 24: Water is filtered before directly drained to agricultural land

Plate No.25: Land utilization by Nishi (Joram)

Plate No. 26: Shifting land is converted into permanent vegetable garden

Plate No 27: Bird eye view of Joram valley

Plate No 28. Recent Deposition in the middle course at Siro

Plate No.29: Boulders as seen in the field

Plate No.30 :Terraced wet rice agricultural fields at Joram Locality

Plate No.31: Bird eye view of Apatani valley

Plate No. 32: Boulder deposition in the middle of agricultural field

Plate No.33 Basket topography near Joram locality

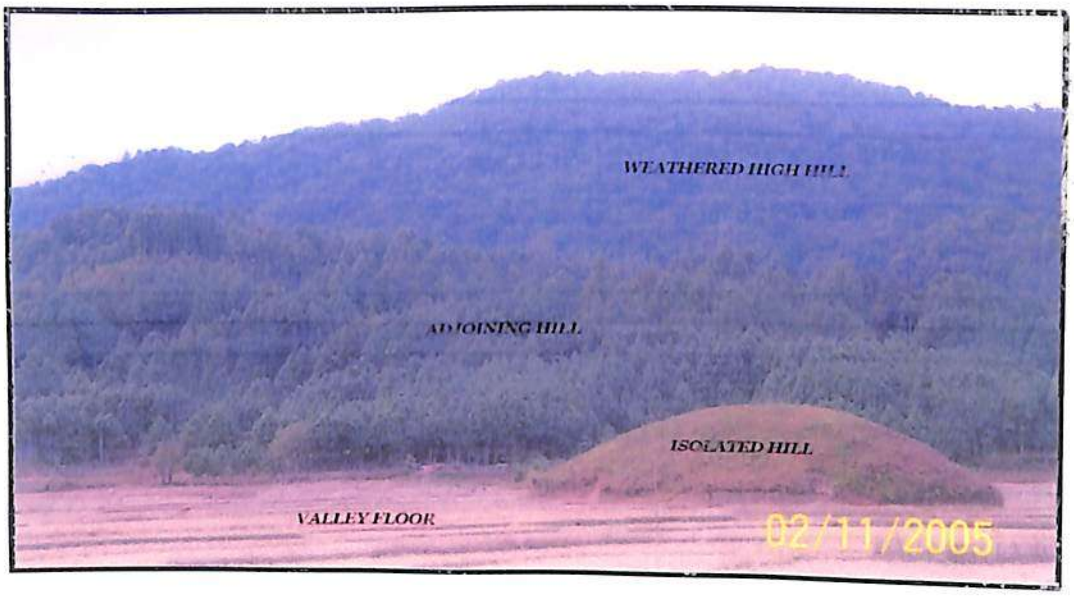

Plate No.34: Geomorphic units in the upper course of river

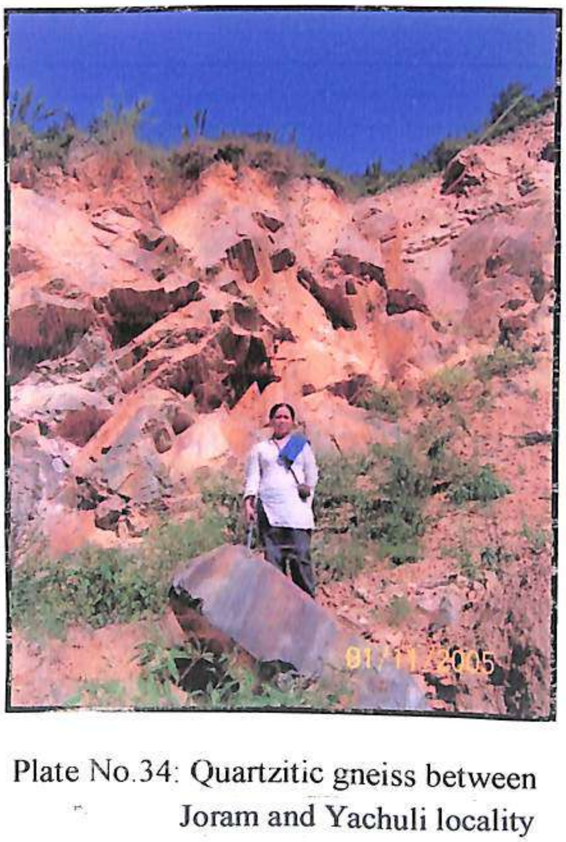

Plate No.34: Quartzitic gneiss between Joram and Yachuli locality

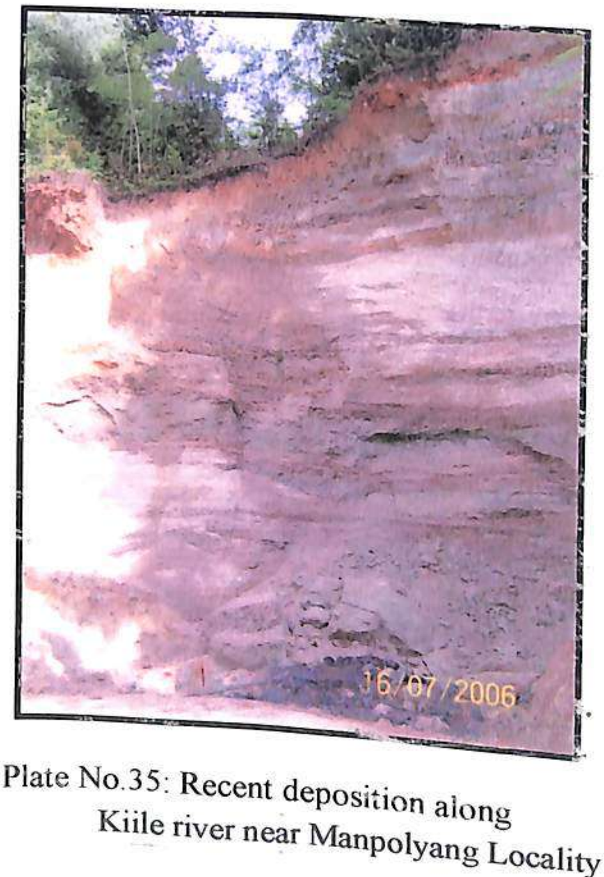

Plate No.35: Recent deposition along Kiile river near Manpolyang Locality

A GEOMORPHOLOGICAL AND LAND USE STUDY OF KIILE RIVER BASIN, EASTERN HIMALAYA, ARUNACHAL PRADESH

A Thesis submitted for degree of Doctor of Philosophy in Geography

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CHAPTER VII

SUMMARY AND CONCLUSION

In simple words geomorphology may be explained as a science which deals with the identification, mapping and genesis of landforms. In the Himalayan region, geomorphology plays a vital role in land use, management and planning. Growing population is exerting pressure on land resources as a result land degradational processes leads to soil erosion, landslide and decreasing water discharge of rivers. Therefore, it is very significant to have a proper land evaluation before planning for land resource utilization.

In the Himalayan region, high relief variation, high amount of monsoonal rainfall, highly fragile rocks and unstable structural formation draw attention for a proper database generation. A systematic geomorphological techniques to carry out study took a long span of time to emerge geomorphology as a discipline. In this study an attempt is made to observe geomorphological and land use characteristics of the area. A Kiile river basin is selected to carry out this work. The study area is extending in between 227°25'52" to 27°38'37" North latitude to 93°45'30" to 93°55'50" East longitudes covering an area of about 204.062 Km².

Morphometric approach is adopted to carry out relief, slope and drainage characteristics. Land use mapping and geomorphological mapping is done using remote sensing data and field observations. An attempt is also made to identify present trend in water discharge of a river and soil loss based on secondary data as well as field observations. Along the whole region in Central, Western, Nepal, Darjeeling and Sikkim Himalaya lot of work is carried out on this theme except in Arunachal Himalaya. The survey of India topographical map (83 E/14,15), GBPIHED project report and remote sensing data (IRS IC, LISS III FCC) with field verification are used as data base for the present work.

Geologically this area falls under the Lesser Himalayan part. It consists meta – sedimentary and metamorphic rock i.e. gneiss, schist, phyllite, quartzite and crystalline rocks. Quarternery deposit is found in this upper river course appear to be lacustrine origin. Altitude is ranging from 740m to 2684m. In the upper course a wide valley with an altitude ranging from 1540m to 1600m cover a very significant area in the basin. In the lower course two more small valleys are present which are surrounded by the basket type (small hillocks) of topography. Lineaments reflect a subsurface phenomenon thus all linear features, which were distinct, are picked up and directions were measured and divided into six groups at the interval of 30°. Maximum lineaments (34%) are extending in 30°- 60° to 210°- 240° direction. General trend of lineaments aligns to Major structure of the Himalaya i.e. extension of Main Boundary Thrust (MBT) and Main Central thrust (MCT).

The upper part of study area which is an intermontane valley, shows a very unique type of weather condition in comparison with its neighboring areas.

The upper part experiences below 0° temperature in winter whereas in the lower stream, the weather became little bit warmer. The variation in the weather condition of study area is controlled by the topographical variation. The basin presents a humid sub – tropical to temperate type of climatic condition, due to which it gets sufficient amount of rainfall in summer season. Rainfall data for the period of 1986 to 2006 and temperature data for the period of 2003 - 2006 are collected from the Meteorological station situated at Ziro. Highest total rainfall (2349.03 cm) is observed in 1991. The lowest rainfall (681.5 cm) is found in 2003. The highest maximum mean temperature of 23.57 °C is recorded during the month of July. The lowest temperature is found to be droped upto 0° in the month of January. Based on Champion and Rautela, the study area has been divided into three vegetation zones. The division indicates that about 6.82 % and 63.71 % of the study area lies under sub – tropical and temperate forest respectively. The remaining 29.47 % of area lies under sub – alpine vegetation. Besides bamboo and pine plantation, people also plant trees like Alnus nepalensis (RIME), Prunus spp. (PIITA), Pyrus (PECHA), Prunus nepalensis (SEMBO) etc. In order to describe the chemical properties of soils, information is collected from the GBPIHED sponsored research project in the department of Geography. These observations indicate that the pH of the study area ranges from 4 to 6.5. The highest pH value (6.29) has been recorded from agricultural field at Yachuli. The lowest pH value (4.03) has been recorded from dry agricultural field, near Helipad, Old Ziro. The study area is inhabited by two major tribes of Arunachal Pradesh i.e. Nishi and Apatani. The northern or the upper course of the river is occupied by Apatani's. The lower course is inhabited by the Nishi's. Both the groups belong to Tibeto – Mongoloid stock and their language belongs to Tibeto – Burman family.

The morphometric approach has been applied to carry out the study of relief of the area. In this study an attempt is made to study relief characteristics with the help of relative & absolute relief, dissection index, profiles and hypsometric curve. The relative relief is ranging from level to 498m. About 66.42 percent of the basin area lies in the moderate to moderately high relative relief category. High to very high relative relief characterizes about 19.43 percent of the basin area. Low relative relief found in the flat valley accounts 14.15 percent of the basin area. The absolute relief ranges from 1100 m (at Tago hydel) to 2684m (at the north eastern boundary of the area). The dissection index varies from 0 to .345. Low to very low group of the dissection index covers maximum area (74.92% or 152.882 km^2) while the area coverage decreases with the increase of dissection index. The profiles are drawn from east to west of the basin to observe the variation in the height. The serial profiles are drawn to show the summit point, river valley, etc. The eastern part of the basin is showing higher altitude along the profile lines. The ruggedness in the profiles towards the periphery of the basin shows active erosional processes whereas towards valley aggradation may be higher. The area – height percentage indicates that the area between 1500m to 1800m experiences erosional activities. The altimetric frequency histogram of Kiile river basin gives a clear picture of the relative position and percentage of different land surfaces of the basin. The highest percentage of the total area (50.3%) seen between the height of 1600m and 1800m. The lowest area (1.5%) is observed in between the contour interval of 2400m and 2600m.

Average slope is ranging between 0° to 29.5°. Study area is divided into six average slope categories. Maximum slope of 35.28 percent is characterized by slope values of 20° to 25°. The steep slopes occur mostly in the upper part of the watershed boundary. The minimum area of only 2.53% is under very gentle slope (Below 5°) which occurs in the central portion in northern part of the basin. The mean, median and mode of the average slope are 18.30, 19.50 and 21 respectively. The slope in percent of Kiile river basin varies in between 0 to 40%. The maximum area (142.526 km² or 69.84%) falls under the slope group of 30% – 40% which is distributed throughout the basin. The very gentle slope group (1% – 3%) is covering only 1.646 km² or 0.81% of the total area. The Ziro valley falls under nearly level sloping group i.e. below 1%. Except 30 – 40% and below 1% slope category, all are distributed in a scattered manner. The slope and absolute relief reveals that with the increase in absolute relief, slope also increases. Study area also divided into convex, concave, rectilinear and undulating slope types.

The basin morphometry is carried out with the help of different morphometric parameters or attributes, viz., stream order, number, length, bifurcation ratio, stream length ratio, drainage density, stream frequency, etc.

The Kiile river is originating at an elevation of 2684m and is feeded by numbers of tributaries and sub – tributaries. The various drainage patterns identified are dendritic, radial/centrifugal, rectangular and parallel. The Dendritic pattern is commonly observed throughout the study area. The radial stream pattern is observed in the central part of the study area. The rectangular drainage pattern is noticed in the eastern and north eastern part. According to Strahlers stream ordering system the Kiile river has been ranked as sixth order stream. It comprises of sixth order basin with 876, 198, 55, 18, 3 and 1 first, second, third, fourth, fifth and sixth order streams respectively.

The bifurcation ration of Kiile river basin ranges from 3.0 to 6.0. The stream length of 1st, 2nd, 3rd, 4th, 5th and 6th order river is 253.5 km, 113 km, 54 km, 40.5 km 9.5 km and 25.5 km respectively. In general the stream length decreases with an increase in order, but in the present study, the stream length is more in 6th order (25.5 km) than in the 5th order (9.5 km). The coefficient of correlation between the stream order and stream number is -0.778. It is noted that the mean stream length increases with the increase of drainage order so there is a positive relationship in between mean stream length and drainage order. The stream length ratio of Kiile river basin ranges from 1.41 to 8.05. The sinuosity index is 1.01, which shows that the channel is in straight course. The topographical sinuosity indices (TSI) is high (93.3%) and hydraulic sinuosity indices (HIS) is low (6.7). So, it indicates that the basin is in its youthful stage. The geometry of basin shape is identified by calculating the form factor as suggested by Horton. The form factor of Kiile river basin is 0.33, which shows that the basin is having an elongated shape. The drainage density of study area varies from 0.125 km/ km² to 5km/ km². The drainage frequency ranges from 1 stream/ km² to 14 streams/ km². The highest percentage of area in under the frequency of 6 – 9 streams/ km². The Kiile river with a length of 35 km from source to mouth runs through the heart of the Ziro and Yachuli area. The longitudinal profile of Kiile river reflects two abrupt break in slope. Knick point or break in slopes indicating sudden change in erosional and depositional processes due to the impact of endogenetic and exogenetic processes. The basin output analysis is carried out through water discharge and evaporation. The two year data on water discharge reflects that the maximum amount of discharge i.e. 207.02 cumec and 178.15 cumec were observed during the month of July to August. The total amount of water discharge has decreased from 1346.54 cumec (2005 – 2006) to 1139.96cumec (2006 – 2007).

A geomorphological study is carried out using satellite imageries and detailed field work. Study are is divided into nine geomorphic units on the basis of altitude, dissection pattern, landforms and weathering processes. In general study area is divided into three groups. First group, i.e. upper course is consisting four geomorphic units viz. Flat valley floor, Isolated hills, Adjoining valley floor and Weathered high hills. Second group of geomorphic unit falls in the middle and lower middle course of river where relief, structure and dissection pattern is responsible for geomorphological variation. In the lower most course of river at the mouth, forms a separate geomorphic unit dominantly influenced by slope.

After classification of the area into various geomorphic units an intensive field work is conducted and various geomorphological processes and forming material is identified. Geomorphological processes are mainly associated with weathering, fluvial and colluvial processes. In the upper reaches of study area, weathering is very common. In the valley area depositional processes are seen in the form of narrow alluvial plain and 3 levels of river terraces along the rivers. In the valley adjoining area, colluvium processes are responsible for the boulders and alluvial fan deposition.

The growing population pressure and changing socio – economic practices have changed the land through deforestation for settlement and extension of agricultural land. The landuse changes in the hills have caused soil erosion and sediment transport potentiality. Land use categories have been delineated using satellite imagery and topographical map. Intensive field study was carried out to identify the various landuse categories delineated through satellite imageries. The main land use categories identified are area under wet rice cultivation, Bamboo & Pine groove, Forest Degraded Area, Barren land, Degraded land with dense mixed shrubs, Dense mixed jungle, Dense shrubs and scattered trees, Helipad, Shifting cultivation, and Settlement.

The existing landuse vary from place to place because of its topography. In the upper course of the river area is under intensive use, due to availability of valley plain with ample water resource. This area is inhabited by Apatani tribe which is considered traditionally very good land managers. Surrounding hills and isolated hills in the valley area are used for the rain fed agriculture, settlement as well as pine and bamboo grooves. Now days agricultural lands in the flat area is also being used for the residential and for commercial purpose. The Nyishi who inhabit in the middle & lower part of study area are practicing "Slash and burn" or "jhum" agriculture system. However, plain area (Joram and Yachuli localities) is also being used for wet rice cultivation. Main crops grown in the Jhum fields are paddy, maize and millets.

Area for cultivation in the upper part of the river is concentrating in the valley area which is very fertile. Land holding among the all families is not equally distributed. The wet rice cultivation is practiced in the small terraces all around the flat valley land in and around Ziro and Hapoli locality in the upper course of Kiile river. An agricultural plot located near the source of main channel in the valley produces about 500 gram of paddy/m². But the production decreases with the increase in distance from the main channel in valley. Some patches of flat area also available under wet rice cultivation near Joram and Yachuli localities in the middle part of the study area. Maximum of bamboo and pine grooves are located in the upper course of the river. Now a days, the bamboo & pine plantation are also taken up by the Nyishi tribe located in middle and lower parts of the study area. Forest degradation use to take place due to jhum cultivation. After cultivation for one year land is left as fallow land. Due to forest fire in the upper reaches about an area of 5.65 Km^2 is found to be barren. Few numbers of left out pine trees with sparse grasses can be seen in this area. An airdrome of about 1.5 km distance is present at Old Ziro which covers about 0.58 Km^2 or 0.28% of the total area. This airdrome is located in the middle of the valley. Maximum area in the lower part of the study area is under shifting cultivation. With the increase in population, the jhum cycle is becoming shorter. Due to frequent use of the hill slopes, it has evoked top soil erosion, which results infertile land.

The Apatanis considered flat valley to be used only for agricultural purpose. Slightly elevated land in the surrounding of wet rice cultivation is used for settlement purpose. The settlement pattern of Nyishi is scattered in the hill slopes. However, in the Joram and Yachuli area, settlements are compact. An area of 3.86 Km^2 is found under settlement in the Ziro – Hapoli localities.

The land management by both the tribes within the basin shows a strong application of indigenous knowledge. However, the impact of modern infrastructural development cannot be ignored in their day to day activities. In landuse planning and management they still prefer their traditional technique. Distance from settlement, plain area and availability of water for irrigation are the main criteria for the selection of agricultural site. The land nearby the residential place is used as kitchen garden, where the fertility of the soil remains high due to continuous application of domestic manures. The land where water is available for irrigation is converted into wet rice agricultural field. The slopes of the adjacent hills in the vicinity of the wet rice-fields are used for rain fed agriculture. Apatani tribe use to develop a planted forest of pine and bamboo. Therefore, bamboo and pine groves hold a significant part of the land among them. Until and unless one holds a property of at least one small bamboo grove, he cannot be considered as economically independent. Besides bamboo and pine, there are number of fruit trees like small cherry, peach, small pear and greenish, bitter apple which are also planted in groves, gardens, paths and lanes, burial ground and close to houses. Large numbers of evergreen as well as deciduous species like Hollock, Jutuli, Tita Sopa, Hillika, Dhuna, Borpat, Nahal, Udal, Gonsari, Makrisal, Bogipoma, Khokan, etc. are found in the area.

Settlement in the Apatani area is managed in the slightly elevated areas in the vicinity of flat land and flat areas are kept only for agriculture. Because of high density of population, houses are constructed very closely, mainly built of wooden piles and bamboo. Earlier houses were thatched with rice straw but now tin sheet are being used. Settlement in Nyishi area is scattered and different from the apatani tribe.

Geomorphology has an important application in the field of identification, evaluation and classification of land as a resource. The geomorphic features of the landforms have a direct bearing on the type and distribution of land use. The hills and mountainous region due to its physical limitations such as high steep slope and deep to very deep gullies are discarded for any agricultural practices or for other utilization. For the proper evaluation and management of land resources information regarding the geomorphic units and the associated processes of an area is very important. The geomorphic processes can shape and modify the existing landform. Therefore, it controls the utilization of land for a particular purpose. Slope has its direct bearing on agriculture as it influences soil, drainage, climate and water table. The thickness of soil cover varies with the change in slope. It is relatively thicker in the valleys and depression, due to the deposition of detritus washed down from the uplands. In the lower course of the study area where slope is in between 20° - 25 found under shifting cultivation. The average slope of study area shows the uneven distribution of slope through the entire area. Based on its varied slope characteristics, different landuse categories are found.

Water availability has played a very important role to determine the use of land in the study area. The perennial river courses are providing water throughout the year in the valley areas. In Ziro-Hapoli, Joram and Yachuli localities soil is found to be very fertile and being used for the production of paddy. Remaining area is forming mountainous soils which is relatively less fertile.

The changing natural cover has been the main reason behind the soil loss. The practice of shifting cultivation, faulty land use, improper land tenure system and lack of awareness can have severe consequences in agriculture due to loss of top fertile soil. Total annual average soil loss from agriculture, barren and forest plots is 0.283473 t $ha^{-1}yr^{-1}$, 0.1888 t $ha^{-1}yr^{-1}$ and 0.120044 t $ha^{-1}yr^{-1}$ respectively. An attempt has also been made to classify and map land according to its ability & suitability to support a range of crops on a long term sustainable basis. It is carried out considering the slope, soil, altitude, geomorphic processes and nearness of settlement. Whole study area is classified into six major classes.