

**GEOMORPHOLOGICAL, BIOPHYSICAL AND
SOCIO-ECONOMIC ATTRIBUTES OF
UMBANIUN MICRO-WATERSHED OF
MEGHALAYA**

ABSTRACT



BY

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ABSTRACT

Watershed is an area of land that drains into a common point varying in size from just a few acres of land to as large as several states. Its degradation is a common problem faced in most parts of the world due to unsustainable utilization of watershed resources as commonly observed in developing countries. These problems can only be addressed by adopting appropriate and sound watershed management/development plan which sustains and enhances watershed function.

The Umbaniun micro-watershed, having an area of 3985.62 ha, is located at latitude 25°31'49"N to 25°30'40"N and longitude 91°47'31"E to 91°51'08"E and drained by a fifth order stream in the south-western part of Meghalaya. Umbaniun River originates at an altitude of 1890m in Mawkhan village and discharges in the Umiew River at an altitude of 1582m.

Different types of land use systems are found in the Umbaniun micro-watershed where the agricultural lands occupy the major portion of the area. Agriculture is practised on the hill slopes and in the valleys without any measure taken to conserve the soil. This has caused so much degradation to the micro-watershed and they need to be looked into without delay to prevent further degradation. Thus, Umbaniun Micro-watershed has been identified for an in-depth study to suggest suitable management plans to maintain sustainability of natural resources and to ensure sustainable economy for the inhabitants of the upstream as well as the downstream regions. The objectives of the study are: 1) To study geomorphic characteristics, and biophysical status of the micro-watershed,

preparation of soil and drainage map in relation to its erodibility, 2) To study land use systems (Human settlement, Cropping systems, Forest etc) to know the gaps between existing land use systems and land capability class, 3) To study the socio-economy of inhabitants and its linkage with existing land use systems and 4) To suggest appropriate land use on the basis of land capability class to ensure sustainable economy and environmental stability.

Umbaniun micro-watershed is elongated in shape as the values of shape index calculated for Sub micro-watersheds 1, 2 and 3 are 10.43, 7.08, and 7.58 respectively. This results in low run-off (22.988 sq km-cm/sq km, 20.893 sq km-cm/sq km, 21.878 sq km-cm/sq km in Sub micro-watersheds no.1, 2 and 3 respectively) and sedimentation production rate (0.008913 ha-m/100 sq km/year, 0.006397 ha-m/100 sq km/year and 0.007158 ha-m/100 sq km/year in Sub micro-watersheds no. 1, 2 and 3 respectively).

Five categories of slope viz, nearly level to gentle slope (0° - 10°), moderate slope (11° - 20°), moderately steep slope (21° - 30°), steep slope (31° - 40°) and very steep slope ($>40^{\circ}$) (Table 4.5b) have been identified in the area. Among these, the 'nearly level to gentle slope' occupies the major portion of the area, i.e. 93.52 percent, whereas the steep slope category occupies the least area i.e. only 0.06 percent of the micro-watershed.

Dense forest cover decreased from 48.8 percent in 1977 to only 0.11 percent in 2007 in a very short period of time (i.e. in three decades) whereas the open forest cover increased from 17.2 percent in 1977 to 31.5 percent in 2007.

There has been a marked increase in agricultural land, settlement area and open forest in three decades (1977 to 2007) where, agricultural land increased by (+) 377.92 ha (575.15 ha in 1977 and 953.07 ha in 2007); settlement area increased by (+) 255.94 ha (59.29 ha in 1977 and 285.23 ha in 2007); and open forest increased by (+) 570.2 ha (687.00 ha in 1977 and 1257.20 ha in 2007). This has led to a decline in natural ecosystems like dense forest which declined by (-) 796.45 ha from 1977 (1943.21 ha) to 2007 (1146.76 ha); shrub/grass lands which declined by (-) 34.45 ha from 1977 (163.67 ha) to 2007 (129.22 ha); and water bodies declined by (-) 7.84 ha from 1977 (12.25 ha) to 2007 (4.41 ha).

The Shannon Wiener Diversity Index and Simpson's Dominance Index for trees are found to be 1.48 and 0.43 respectively, suggesting that the forests of Umbaniun microwatershed are dominated by *Pinus kesiya*, whose IVI is 192.60. The common tree associates of *Pinus kesiya* are *Alnus nepalensis*, *Aporosa dioica*, *Betula alnoides*, *Castanopsis indica*, *Myrica esculenta*, *Myrica nagi*, *Pyrus pashia*, *Quercus spicata*, *Rhododendron arboretum*, *Rhus javanica* and *Schima wallichii* with IVI values 8.51, 5.58, 11.53, 5.58, 17.35, 8.57, 8.55, 20.51, 6.77, 7.06, 7.38 respectively.

The forests harbour a diverse shrubs and herbs species with the Shannon Wiener Diversity Index of 2.76 and 2.73 respectively.

There are 30 species of shrubs belonging to 18 families in the study area, of which, species belonging to Melastomaceae, Rosaceae, Rubiaceae and Theaceae are dominants. The other shrub associates are Urticaceae, Caesalpinioideae, Elaeagnaceae, Lamiaceae, Asteraceae, Moraceae, Ericaceae, Malvaceae, Zingiberaceae, Berberidaceae, Phyllanthaceae, Chloranthaceae, Smilacaceae and Caprifoliaceae. The

ground storey of the forest represents 12 families of herbs. Poaceae alone has 8 different species and they are dominant. Other herbaceous species represent family like Asteraceae, Rubiaceae, Apiaceae, commenlinaceae, Cyperaceae, Rosaceae, Fabaceae, Lycopodiaceae, Oxalidaceae, Polygonaceae.

Agriculture, the main stay of economy of the people of Umbaniun microwatershed, is mostly permanent cultivation where the farmers grow crops both in valleys and on the hill slopes. The major cash crops grown in the microwatershed are *Solanum tuberosum*, *Brassica oleracea*, *Phaseolus vulgaris* and *Raphanus sativus*. Among them, *Brassica oleracea* is found to have the highest average income.

Umbaniun micro-watershed has 7 land capability classes, of which class I covers 49.02 per cent whereas class II, III, IV, V, VI and VII cover 8.65, 21.85, 7.02, 7.27, 2.40 and 3.79 per cent respectively. Agriculture is being practiced irrespective of the land capability classes prevailing in the micro-watershed. Growing of major crops of Umbaniun micro-watershed (*Solanum tuberosum*, *Brassica oleracea*, *Phaseolus vulgaris* and *Raphanus sativus*) involves a lot of soil tillage, weeding, etc which will lead to soil erosion and sedimentation when planted in lands having capability class III, IV, V, VI and VII. Thus it is advisable to introduce sound soil conservation measures in farming systems for example introduction of crops which require minimum soil tillage; terrace cultivation or contour bunding; tree hedge crop farming system etc.

Interestingly, land under water bodies were 0.31 percent and 0.54 percent in 1977 and 2003 respectively. The same declined to 0.11 percent in 2007. The farmers having land in the bordering area of water bodies have encroached towards and

claimed the water bodies for cultivation since increase in siltation has made the land fertile. This tendency needs to be discouraged by the village council (Dorbar shnong) or authorities through awareness programmes and measures should be taken to maintain the water level in the water body throughout the year.

The degraded land area has decreased due to rise in population and it is also noticed that such lands are put under cultivation. Degraded lands under capability class IV, V, VI and VII need much conservation measure. The same should be put under permanent tree cover. Further, top most attention of planners and concerned departments is needed to prevent the further degradation of degraded lands of class V, VI and VII.

The study also reveals that 60.3 per cent land area was under forest cover in 2007, though loss of 20.0 percent of dense forest area has been recorded in 3 decades. If dense and open forests are clubbed together then only 1 percent decline would be recorded in total forest cover. In the study area, in general, forests are owned by the individuals, clan, community, etc. It is suggested that the concerned Government Departments should provide technical knowhow to the owners to increase the growing stock of degraded forest.

The land tenure system is permanent in nature i.e. propriety right is vested with the farmers. Transfer of the right, made from one person to another, is by inheritance and in some cases it is also transferred through sale agreement. Concerned department and “durbars” should be aware of the fact that use of degraded lands without conservation measure will be a serious problem in the near future. This land (category IV to VI) should be kept under tree cover.

Introduction of conservation measures and adoption of appropriate cropping systems by individual farmers may not control the biophysical problems associated with the farming system in the study area in particular and hills in general. Thus, need is felt to establish farmers' organisations for introduction of need-based integrated micro-watershed management plan to maintain sustainability of the natural resources.

In conclusion, it can be said that the Umbaniun micro-watershed is endowed with rich natural resources. However, degradation is on the high due to negligence and lack of awareness and the land is not used as per capability class. If this continues, time will come when the micro-watershed may not sustain the livelihood of the growing population. Our planners only consider soil conservation without giving proper emphasis on the need of the farmers. In the study area even attention is not being paid to soil conservation as indicated by decreasing water bodies.

The concerned departments should involve the farmers' community in the planning and decision making process. Majority of the inhabitants of this area are khasis. The khasi society is well organized in taking care of collective and individual needs. This structure will be an effective tool in managing the land resource, provided basic infrastructure and technical knowhow is imparted in them.

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Mr. PHYLLIEWBOR NYLLA RYMBAI

A THESIS

**SUBMITTED IN FULFILMENT OF THE DEGREE OF
DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL SCIENCE**

SUPERVISOR

PROF. L. K. JHA

**DEPARTMENT OF ENVIRONMENTAL STUDIES
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DEDICATION

“THIS WORK IS DEDICATED TO MY
BELOVED PARENTS, **SHRI. J.M. NONGKHLAW** AND
MRS. MARLIN RYMBAI FOR THEIR TIRELESS WORDS
OF ENCOURAGEMENT AND PRAYERS”

NORTH-EASTERN HILL UNIVERSITY
DEPARTMENT OF ENVIRONMENTAL STUDIES
JULY, 2012

I, Phylliewbor Nylla Rymbai, hereby declare that the subject matter of this thesis entitled, "**Geomorphological, Biophysical and Socio-Economic Attributes of Umbaniun Micro-Watershed of Meghalaya**" is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.

This is being submitted to the North-Eastern Hill University, Shillong for the award of the degree of *Doctor of Philosophy in Environmental Science*.



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Taking this opportunity, I would like to apologize to the readers for the unintended shortcomings, if any, in the study. Nonetheless, I expect that this thesis would throw some light on the readers with regards to watershed management that would help in maintaining health of the environment and people, also in alleviating poverty in the society.

Shillong

Dated: 9/7/2012



Phylliewbor Nylla Rymbai

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INTRODUCTION

1.1 Watershed Management

A watershed is the area of land that drains into a common point. It is a nature's boundary for water. It includes all the land that drains to a single stream, river lake or body of water. Watersheds may be as small as just a few acres, or as large as several states.

Watershed degradation is a common problem faced in most parts of the world. The major cause is unsustainable utilization of watershed resources, which is commonly observed in developing countries. These problems can only be addressed by the appropriate policy, strategy and sound watershed development plan which sustains and enhances watershed function. Watershed management is the process of creating and implementing plans, programs, and projects to sustain and enhance watershed functions that affect the plant, animal, and human communities within a watershed boundary. It also implies the judicious use of all the resources i.e. land, water, vegetation in an area of a watershed for providing an answer to alleviate droughts, floods, prevent soil erosion, improve water availability and increase production of food, fodder, fuel and fibre on sustainable basis to achieve the maximum production with minimum hazard to the natural resources and for the well being of the people of the present and future generation. The watershed management concept recognizes the inter-relationships among the linkages between uplands and low lands, land use, geomorphology, slope and soil. . It is characterised by a variety of

possible interrelationships between productivity and conservation of natural resources for poverty alleviation (Chauhan, 2010). Soil and water conservation are the key issues in watershed management (Vittala *et al.* 2008).

Watershed management encompasses the simultaneous consideration of hydrological, pedological, and biological resources, which necessitates the need for sound approaches for making better use of analytical tools to address spatial and temporal variability. The cumulative impacts of human activities threaten the ecological, economic and aesthetic integrity of many drainage systems and the strategies to mitigate these impacts, have explicit spatial dimensions (Morgan and Nyborg, 1996). Watershed approaches in resource planning required timely and accurate spatial and temporal data on biophysical, geophysical and socioeconomic aspects. In this regard GIS holds great promise with a provision to handle spatial and temporal data and an aid for an integrative planning tool for watershed management (Ramachandra and Kumar, 2004).

Watersheds should be regarded as a business model-policy for Public and Private-Partnerships, which need to be owned and managed by the people. The rural population should have a strong commitment and therefore, need incentives and tangible economic benefits from the investments in the watershed. Such benefits cannot be created through non-participatory top down projects (Wani *et al.* 2009).

Spatial and temporal attributes of watersheds and the associated market failures that accelerate degradation of agricultural and environmental resources require innovative institutional arrangements for co-ordinating, use and management of resources. Effective collective action allows small farm holders to jointly invest in management practices that provide collective benefits in terms of sustainable

economic gains. Integrated watershed management (IWM) has been promoted in many countries as a suitable strategy for improving productivity and sustainable intensification of agriculture. The Government of India has accepted integrated watershed management as a key strategy for improving productivity and livelihoods in the rain-fed drought-prone regions (Shiferaw *et al.* 2005). It goes beyond conservation technologies and emphasizes the importance of human dimension and the need to integrate technological tools with broad-ranging social, political, and economic changes. Instead of focussing exclusively on biophysical processes that improve resources conditions, IWM includes multiple crop and livestock-based income strategies that support and diversify livelihood opportunities for the poor, and create synergies between targeted technologies, policies, and institutions for sustainable uses of resources and to maintain the sustainability of the productivity as well as income, through desired market access (Kerr, 2001; Reddy *et al.* 2004; Shiferaw *et al.* 2008)

Participatory watershed management has emerged as a potential concept which harmonizes the judicious and sustainable use of the resource trinity- land, water and biomass, for their long term sustainability, optimal productivity and environmental balance which form the prime requisite of economy. The concept of integrated and participatory watershed management has emerged as the corner stone of rural development in the dry semi-arid and other rain-fed regions of the world. Most watershed projects in India implemented with the twin objectives of soil and water conservation and enhancing the livelihoods of the rural poor. It has also been widely accepted as a sound development paradigm by the local self Governments and donor agencies for uplift of the rural masses in eco-fragile zones (Rao, 2005).

The world is rapidly converting forest, wetlands and other critical habitats into agricultural land to meet growing demands and diverting major rivers to produce food. Ninety nine per cent of watershed development projects are based on conventional approaches considering only physical planning without attention to socio-economic or ecological conditions of the watersheds. Governments and NGOs have realized that protection of watersheds cannot be achieved without the participation of local people. Therefore, people's participation is essential for the successful and sustainable watershed management. Inadequate monitoring and impact assessment of watershed programmes is a major concern (www.decwatch.org/?q=node/170).

1.2 Watershed Approach for Conservation and Development

A repeatedly raised question by policymakers and planners is why a watershed should be considered a natural resource conservation and development planning unit. It is apparent that a watershed can include the notions of both bio-physical and socio-economic unit comprising all natural resources, people and their socio-economic activities within the confines of a drainage divide. Watersheds vary in size. They may be as small as watersheds of rivulets or as large as watersheds of major rivers.

A watershed is physically distinguished into lowland and upland or, in conventional terms, upstream and downstream. These two physical entities are integrated through a number of bio-physical and socio-economic linkages. Rivers originating in uplands provide water for drinking purposes as well as for the pursuit of economic activities in the entire watershed. Thus, any change in the volume of water caused by human activities leads to chain reactions in both upstream and downstream areas. Increased surface run-off caused by upland degradation raises the volume of

water in rivers and streams, and accelerates the erosion of soil that is deposited in reservoirs, riverbeds and canals. As a consequence, in the upstream and the downstream areas major issues include dwindling land productivity and the flooding respectively. Some agricultural lands, however, in lowlands benefit from flooding, as through in this process, nutrients are deposited in the rich silt. Siltation of reservoirs constructed for hydroelectricity generation and irrigation impairs the amounts of energy and irrigation water provided by these structures and eventually curtails both agricultural and non-agricultural economic activities mainly in the downstream region. Agricultural activities in the upstream area may not be much affected by such change, as most of these activities take place on hill slopes with rain-fed cultivation system. Reduced volumes of water in rivers caused by the development of irrigation schemes in the upstream area also generate a chain of negative effects particularly in the downstream.

Upland-lowland linkages in watersheds are not limited to the flow of water and silt. Apart from being in the same physical contiguous system, the upstream area of a watershed is socially and economically well linked with the downstream area. Even in remote watersheds, uplands and lowlands are inter-linked through foot-trails, which normally follow the river courses, and through these trails the two-way flow of goods, commodities and people takes place. The uplands are sources of several kinds of forest products, fruits and livestock products for people living in the lowlands. In an ideal situation, lowlands provide food crops and manufactured goods as well as offer job opportunities to upland people. In small watersheds, strong social ties, facilitated by kinship, are found between upland and lowland settlers. Such attachment is reinforced by ownership of paddy lands, for example, in the valley floor

by upland settlers and the practice of grazing livestock in upland forests by lowland settlers especially during lean periods of fodder and forage shortages.

In view of upland-lowland linkages and watershed-wide reactions during changes accompanying development, the watershed is an ideal planning unit. The specific advantages of a watershed approach to conservation and development are the following:

1. Conservation and development activities in upland and lowland can be planned and implemented in a well-coordinated way, so that the entire watershed benefits from the activities.
2. The above facilitates cost-effective implementation of conservation and development activities.
3. Both upland and lowland settlers are the primary beneficiaries of watershed resources. Thus, in principle, both groups should have an interest in watershed management, provided costs and benefits are well understood and the planning and management system is participatory.
4. The cost of watershed degradation is internalized to a considerable extent, as both upstream and downstream environmental costs are taken into account. This contributes to justify the implementation of watershed management programs. (<http://www.eolss.net/Sample-Chapters/C14/E1-18-04-05.pdf>).

1.3 Major Issues in Watershed Management

Watersheds bear significant importance from ecological, aesthetic and socio-economic perspectives. The watersheds are home to millions of people, a substantial proportion of whom are indigenous ethnic minorities eking out their livelihoods by

utilizing natural resources available there. The specific issues being confronted in regard to watershed management are as follows (Thapa, 1996):

1. How to control or even reverse the process of forest and rangeland degradation?
2. How to reduce the rate of soil erosion in agricultural land to a minimum possible limit?
3. What should be done to improve the soil fertility, so as to increase crop yield on a sustainable basis?
4. How to enable watershed settlers to improve their quality of life without inflicting damage on natural resources?

1.4 Watershed Management in India

Watershed development is the focus of poverty alleviation programmes in rural India. Watershed projects aim to solve problems of externalities, but they also create their own externalities, which cause uneven distribution of costs and benefits that undermine project objectives and harm the poor (Shiferaw and Rao, 2006; Kerr *et al.* 2007). In India, watershed projects are located mainly in semi-arid areas with rain-fed agriculture, dense population, and small farms predominantly less than two hectares. Complex livelihood strategies draw on multiple income sources including agriculture, livestock, and labour, including seasonal migration. Where rainfall is less assured, rain-fed agriculture is unproductive and watershed projects focus on harnessing water resources for maximum agricultural productivity.

Typical watersheds in undulating areas of semi-arid India contain good quality agricultural land in lower watersheds, owned by better off people. Lands may be irrigated or with irrigation potential, and tend to be flatter than in the upper watersheds. Upper watersheds often contain small farms on poorer soil and

uncultivated common lands that may be degraded due to overgrazing and harvesting (Kerr *et al.* 2007). Watershed projects in general aim to combat the downstream external effects of the upper watershed degradation.

Watershed projects in India begin with soil conservation and revegetation in uncultivated upper catchments, and water harvesting structures for irrigation. During revegetation, which typically lasts three years (longer in dryer areas), protecting young plants against cutting and grazing is important. Allowing vegetation to establish will reduce erosion and help transform the landscape from a perennially degraded, low productivity state to a lush pasture (Kerr *et al.* 2007).

In early watershed projects, the benefits of rehabilitating landscapes were assumed to be neutral with respect to different types of land users and levels of affluence and poverty (Anon., 1990 a; Anon., 1990b). Regenerating uncultivated lands would make fuel and fodder abundant rather than scarce, and expanding irrigation and raising agricultural productivity would stimulate demand for labour and thus raise incomes for all. As with the green revolution (Leaf, 1983), rising incomes would then trigger other economic activity and transform entire village economies. This scenario has in fact played out in several famous watershed villages including Sukhomajri in Haryana and Ralegaon Sidhi, Hivrebazar and Pimplegaon Wagha in Maharashtra (Chopra *et al.* 1990; Farrington and Lobo, 1997; Kerr *et al.* 2002).

This optimistic expectation of favourable outcomes helps to explain the seeming unconcern that watershed development could impose hardships on the landless and undermine popular support for required collective action. In fact, authorities have long promoted the watershed approach for poverty alleviation (Anon., 1990a, 1994, 2000). Early projects did not concentrate on building

mechanisms to protect uncultivated common lands during regeneration (Anon., 1990b), as its benefits were assumed to be self-evident and uncontroversial. By the early 1990s, however it became clear that the lag between investments and benefits, and the access to productive resources for people dependent on common lands, meant that such people disproportionately bore the costs of watershed development. They could not be expected to support watershed development and even had an incentive to undermine it. This is a second type of watershed externality that projects must address.

In north eastern states of India management of land resources and its vegetation on sustainable basis has been taken up since last two to three decades. The projects could not create desired impact due to poor participation of the inhabitants of watersheds and non adoption of integrated approach. The watershed projects of north eastern India has been critically examined by Sarma and Sarma, 2011; Singh *et al.* 2006; Barik and Darlong, 2008.

1.5 Statement of the Problem

In the State of Meghalaya, the Umbaniun Micro-watershed is being exploited for various developmental activities like agriculture, sand quarries, timber and fire wood extraction, fodder collection, etc and this has brought about an ecological imbalance in the microwatershed putting a threat to both ecosystem and economy of the inhabitants both in the upstream as well as the downstream regions. Thus, the Umbaniun Micro-watershed has been identified for in-depth study to suggest suitable management plans to maintain sustainability of natural resources and to ensure sustainable economy for the inhabitants of the upstream as well as the downstream regions. The objectives of the study are:

- To study geomorphic characteristics, and biophysical status of the micro-watershed. Preparation of soil and drainage map in relation to its erodibility.
- To study land use systems (Human settlement, Cropping systems, Forests etc) to know the gaps between existing land use systems and land capability class.
- To study the socio-economy of inhabitants and its linkage with existing land use systems.
- To suggest appropriate land use on the basis of land capability class to ensure sustainable economy and environmental stability.

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REVIEW OF LITERATURE

2.1 Drainage Basins, the Units for Resource Management

Drainage basins are the fundamental units for the management of land and water resources (Moore *et al.* 1994). They have been identified as planning units for administrative purpose to conserve the precious natural resources (Anon, 1985; 1987; Honore, 1999; Khan, 1999). The concept of watershed management recognises the inter-relationships between land use, soil and water and the linkage between uplands and downstream areas (Tideman, 1996).

2.2 Geomorphology and its Analysis Using GIS and Remote Sensing

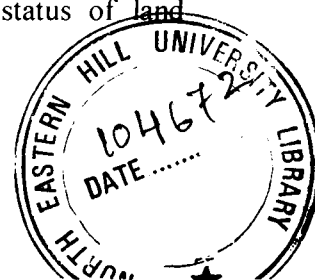
The term morphometry is used in several disciplines to mean the measurement and analysis of form characteristics; however in geomorphology it is applied to numerical analysis of landform, which may be more appropriately termed geomorphometry (Gardiner, 1982). Geomorphology is associated with topographic landforms, which in turn are related to surface runoff and infiltration. Geomorphologic studies involve the identification and characterization of the fundamental units of landscape. Geomorphologic processes are generally complex and reflect inter-relationship among the variables such as climate, geology, soils and vegetation (Buol *et al.* 1973).

A major emphasis in geomorphology over the past six decades has been on the development of quantitative physiographic methods to describe the evolution and behaviour of surface-drainage networks (Horton, 1945; Leopold and Maddock, 1953;

Leopold and Wolman, 1957; Abrahams, 1984). These parameters have been used in various studies of geomorphology and surface-water hydrology, such as flood characteristics, sediment yield, and evolution of basin morphology (Jolly, 1982; Ogunkoya *et al.* 1984; Aryadike and Phil-Eze, 1989; Jensen, 1991; Breinlinger *et al.* 1993).

The underlying lithology, slope and the type of existing drainage pattern influence the genesis and processes of different geomorphic units (Singh *et al.*, 2010; Sarmah *et al.* 2012). The geomorphic units distinctly separated each other by topographic change in slope segments similar to the morphological mapping techniques (King, 1962; Savigear, 1965; Dalrymple *et al.* 1968)

Detailed geomorphological mapping is one of the principle means of studying the morphology, genesis, distribution and age of forms, which in turn helps to interpret the geomorphic history of any evolved landscape. The detailed analysis of landforms is an important aspect of any environmental or resource analysis and planning (Blarzcynski, 1997; Prakasam and Biplab, 2011). Geomorphologic survey is primarily concerned with the classification and mapping of relief forms through differentiation of morphographic patterns with respect to their genesis and processes (Reddy *et al.* 2002). The synoptic coverage and high precision of remotely sensed data coupled with marked cost effectiveness and time efficiency in data acquisition and analysis procedures have made geomorphologic mapping an extremely effective tool for management of natural resources and environment (Srinivasan, 1988; Reddy *et al.* 2002; Prakasam and Biplab, 2011). The remote sensing data and GIS based detailed geomorphologic and degraded lands analysis ensure better understanding of landform-eroded lands relationship and distribution to assess the status of land



degradation at micro geomorphic unit for reclamation, geo-environmental planning and management (Shanwad, 2006). Similar study also helps in the areas of natural resource management, environmental planning and management, watershed management and hazards monitoring and mitigation (Reddy *et al.* 2002).

In India Joglekar (1965) and Varsheney (1975) have suggested a number of enveloping curves for the prediction of sediment yield for different catchment areas. Correlation studies conducted by Jose and Das (1982) reveals that area alone does not have any significant association with sediment production rate (SPR) and hence there is scope for multivariate analysis using climatic and physiographic parameters. Statistical models on a spatially distributed basis have been developed by Mishra and Satyanarayan (1991) and Bundela *et al.* (1995) for small watersheds in river Damodar in east India.

The description of drainage basin characteristics and stream channel networks has evolved from a qualitative study to a quantitative analysis in recent years (Branson *et al.* 1972). Horton (1945) was the pioneer of these systematic studies, and more recently, Strahler (1954) and his students have expanded on Horton's work (Fuller and Fish, 1978). These quantitative variables have been the basis for inter-basin comparisons and evaluation of hydro-graphic responses.

One of the easiest physical hydrologic characteristics to measure is the areal extent of a particular watershed. The size or area of a drainage basin is an important consideration in that the total volume of water is directly related to the size of the basin. Generally, large watersheds have greater runoff than small watersheds (Anderson, 1957). However, the runoff per unit of area decreases as the area of the watershed increases (Schumm and Hadley, 1961; Wolman and Gerson, 1978; Molnar

and Ramirez, 2001). Another important consideration is the effect of watershed area on peak flows. As is the case with total water yields, higher peak flows are usually associated with larger areas. However, when such outputs are expressed in terms of flow per unit watershed area, it is the smaller watersheds that characteristically have the greatest rates of flow (Avery, 1975).

The outline form or shape of a watershed strongly influences its hydro-graphic patterns (Fuller, 1976). Although watershed shape is difficult to quantify, several different indices comparing the configurations of different watersheds have been proposed. Two of these methods quantitatively express the compactness or degree of circularity of a basin's form.

a. When a watershed is a perfect circle it will have an index of 1. The closer a shape index is to 1, the greater the likelihood that precipitation will be quickly concentrated in the main channel, resulting in peak flows (Avery, 1975).

b. Miller's Circularity Ratio (Miller *et al.* 1964) expresses the departure from circularity of a watershed. In this instance, a perfect circle would have a circularity ratio of 1 and all others would have a ratio of less than 1 (Chorley, 1969; Branson *et al.* 1972).

Both of these shape coefficients express quantitatively that circular watersheds have high runoff and low sediment yields. This relationship can be explained by the fact that circular watersheds concentrate water faster and runoff travels shorter distances, allowing for less evaporation and less opportunity for channel storage. However, long narrow watersheds tend to have steep slopes with consequently higher overland velocities and sediment transport capacities (Branson *et al.* 1972; Fuller, 1976).

The pattern or arrangement of natural streams in a watershed is another important physical characteristic for two reasons. First, they provide evidence of the efficiency of the drainage system and therefore its hydrologic pattern; second, as Horton (1933) points out, "It is an excellent indicator of soil permeability."

Three such indices are useful in determining the pattern of natural streams. Drainage density (Branson *et al.* 1972) is an expression of the closeness of spacing of stream channels in a watershed. In general, low drainage densities are indicative of regions of highly permeable sub-soils, dense vegetative cover, and low relief (Avery, 1975). Schumm and Hadley (1961) indicate that when drainage density is plotted against mean annual runoff, the results suggest that drainage density, if not dependent simply on runoff, is at least dependent upon the same variables that influence runoff.

A second index is a quantitative approach to classifying streams (stream ordering) in a basin. This classification is a systematic ordering of the branches of a stream network and it was first proposed by Horton (1945) then revised by Strahler (1952, 1957) and Shreve (1967). According to Gregory and Walling (1973), the Strahler (1964) modification of Horton's method (1945), which essentially designates all fingertip tributaries as first order, two first order streams produce a second, two second order streams produce a third order and so on, has been used most extensively.

The third index is a qualitative classification of the overall drainage pattern. These classification systems have been described by many researchers (Gregory and Walling, 1973; Avery, 1968; Small, 1970; and Leuder, 1959).

Slope and elevation are also important hydrologic characteristics. The slope of a watershed channel, expressed in the number of feet of elevation drop per mile of stream channel, greatly influences the velocity and therefore the erosion potential of

stream flow. Slope is also related to infiltration, evapotranspiration, soil moisture, and groundwater contribution to stream flow. The variations in elevation of a watershed are important factors with respect to temperature and precipitation patterns, especially in mountainous topography (Avery, 1975; Fuller, 1976).

Each of these hydrologic characteristics in its own way influences the hydro-graphic pattern of a watershed. Therefore, a comparison of each of these characteristics for each watershed can provide a quantitative basis for inter-basin similarity analysis (Fuller and Fish, 1978).

Land morphometry represents the topographic expression of land by way of area, slope, shape, length etc. These parameters affect catchment stream-flow pattern through their influence on concentration time (Gregory and Walling, 1973). The significance of these parameters was pointed out by Morisawa (1967), when she expressed catchment stream-flow pattern as a general function of geomorphology of a watershed. This assertion still stand valid; as various studies have also observed that geomorphic characteristics of a river basin play a key role in controlling the basin hydrology (Adejuwon *et al.* 1983; Ogunkoya *et al.* 1984; Pitlick, 1994; Ifabiyi, 2004).

2.3 Watershed Prioritization

Watershed prioritization is the ranking of different sub watersheds of a watershed according to the order in which they have to be taken for treatment and soil conservation measures. Prioritized watersheds based on the sediment production rate for adopting suitable soil conservation measures (Suresh *et al.* 2004; Khare *et al.* 2007). Information derived from remote sensing data is being widely used in watershed prioritization. Erosion hazard assessment and prioritization based on morphometric parameters like relief ratio, drainage density, drainage texture and

bifurcation ratio have been studied by Chaudhary and Sharma, 1998; Biswas *et al.* 1999; Londhe *et al.* 2010 and Sethupathi *et al.* 2011.

Several methods such as Sediment Yield Index (SYI) method proposed by Bali and Karale (1977) and Universal Soil Loss Equation (USLE) given by Wischmeier and Smith (1978) are extensively used in the prioritization of watersheds. Several researchers have adopted these techniques depending upon the purpose and the information availability (Suresh *et al.* 2004).

The rapid advancement in remote sensing technology and continuous inflow of satellite data has given input and realization for periodic updating of the priority status of sub watersheds.

2.4 Run-off and Sediment Production Rate

For assessing erosion, several empirical models based on the geomorphologic parameters were developed in the past for quantifying the sediment yield (Linsley *et al.* 1982; Misra *et al.* 1984; Jose and Das, 1982). Garde and Kothari (1987) developed an empirical relationship involving catchment area, catchment slope, drainage density, vegetation cover factor and annual precipitation for average annual sediment yield estimation using a data of 50 catchments located in the plain region of India.

Increasingly, linear, areal, and relief relationships evolved beyond basic analysis and have been refined to predict geomorphic processes. For example, they have been used to predict flood peaks, assess sediment yield, and estimate erosion rates (Jolly, 1982; Jensen, 1991; Breinlinger *et al.* 1993; Glennon, 2001).

Remote sensing data provides accurate, timely and real-time information on various aspects such as size and shape of the watershed, land use/cover, physiography,

soil distribution, drainage characteristics, etc (Shanwad, 2006). It also assists in identification of existing or potential erosion-prone areas and provides inputs to many of the soil erosion, sediment yield and runoff models. Satellite imagery has been widely used in the fields of agriculture, forestry, watershed management, hydrologic modeling etc. (Still and Smith, 1985; Pande and Saha 1994; Sudhakar *et al.* 1994; Jose *et al.* 1994; Saxena *et al.* 2000; Daniel *et al.* 2010). Remote sensing data can permit hydrologists to derive the curve number as percentage basis from the Soil Conservation Service (SCS) table which is used for computation of runoff by applying digital land use/land cover information obtained from the IRS satellite (Ragan and Jackson, 1980; Tiwari *et al.* 1991). In Northeastern states of India, run-off and sedimentation rate have been studied by many researchers (Kothyari, 1996; Starkel *et al.* 2002; Sharma, 2004; Singh *et al.* 2010; Singh *et al.* 2011).

2.5 Normalized Difference Vegetation Index (NDVI)

The most commonly used vegetation index is the NDVI which is based on the difference between the maximum absorption of radiation in infrared radiation (R) as a result of chlorophyll pigments and the maximum reflectance in near infrared radiation (NIR) spectral region as a result of leaf cellular structure (Tucker, 1979). Tucker and Choudhury (1987) found that NDVI could be used as a response variable to identify and quantify drought disturbance in semiarid and arid lands, with low values corresponding to stressed vegetation. It has been used in monitoring desertification (Tucker *et al.* 1991), land-use change (Anon., 1997; Panhalkar and Pawar, 2011) and the effects of global warming in high latitudes (Myneni *et al.* 1997).

More recently, Ji and Peters (2003) found that NDVI is an effective indicator of vegetation response to drought in the Great Plains of United States, based on the relationships between NDVI and a meteorologically based drought index.

Tisdell and Roy, 1997; Talukdar *et al.* 2004; Sharma and Sharma, 2009; Sharma and Sharma, 2010; Sarmah *et al.* 2011 and many more have studied land use changes in north-eastern states of India.

2.6 Phytosociology

The northeast region of India is considered as one of the richest biodiversity centres of the Indian continent. According to Takhtajan (1988), it is the centre of origin of angiosperms. Meghalaya, a constituent of Indo-Burma biodiversity hot spot, harbours 3128 species of angiosperms which include 1237 endemic species and 53 threatened plant species (Khan *et al.* 1997). The biodiversity of primary forests of Meghalaya has been studied by workers like Upadhaya (2002), Jamir and Pandey (2003) and Tripathi *et al.* (2006). Almost all types of world's natural forests have been commercially logged to cope with the demand of forest products and land for agriculture (Uma Shaankar *et al.* 1998). Millions of hectares of natural forests have been degraded by logging (Putz *et al.* 2001) and for agricultural uses (Lenne & Wood, 1999). It is generally considered that human exploitation causes major changes in the biodiversity of these forests, even though research on this subject has been limited and results often controversial (Turner, 1996). Some studies reveal conspicuous reduced species richness in secondary rain forests (Parthasarathy, 1999), even in over 100 years old regrowth stands (Turner *et al.* 1997), while other studies have reported increase in species richness in secondary forests (Kappelle *et al.* 1995). The disturbances of ecosystems results in loss of species and reduce its resilience to stress.

Arunachalam and Arunachalam (2005) were of the opinion that diversity of plant species may affect the functional processes in a disturbed ecosystem. Tynsong and Tiwari (2011) reported that the conversion of natural forests in Meghalaya to arecanut agroforests have impacted the density and basal area of woody species.

2.7 Agriculture and Socio-economy

Agriculture is the main occupation of the people of Meghalaya. Jeeva *et al.* 2006 reported that about 83% of the total population of state depends on agriculture for their livelihood. However, agricultural land is accounted as only 48% of the total geographical area of the state. The state offers scope for cultivation of a wide variety of agricultural crops because of highly diversified topography, altitude and climatic conditions. Terrace cultivation is predominant in the state, bringing land under permanent cultivation in later case (Anon, 1998). The ethnic communities of Meghalaya follow two major types of agricultural practices such as shifting cultivation or slash and burn agriculture, and terrace or bun cultivation. Shifting cultivation is practised in and around forests, and terrace cropping is practised in valleys and foothills, and inside plantation forest (Jeeva *et al.* 2006).

Meghalaya produces a variety of agricultural crops such as food grains, commercial crops, horticultural crops, etc (Munda, 2002; Singh, 2002, Singh and Saxena, 2002; Gupta, 2002). Of the total agricultural land in Meghalaya, 62% is used for food grains, 25% for cash crops, 9% for horticultural crops and the rest 4% is used for raising miscellaneous crops (Bhakta, 1995).

The State's population is 2, 318, 822 persons as per 2001 Census as against 17, 74, 778 in 1991 showing a decadal growth rate of 30.65%. Nearly 80.4% of the population resides in the rural areas. The population is predominantly tribal which

constitutes nearly 86% of the State's population. The sex ratio is 972 in 2001 Census for the State. The State's average density is 103 persons per square kilometer with East Khasi Hills district having a population density of 240 persons per sq.km followed by West Garo Hills with 139 persons per sq.km.

According to 2001 Census the literacy level in the State is 62.6%, which is below the national average of 65.4% (nnurm.nic.in/wp-content/uploads/2010/12/Shillong_Chapter2.pdf).

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STUDY AREA AND METHODOLOGY

3.1 STUDY AREA

3.1.1 Meghalaya

3.1.1.1 Location

Meghalaya is a hilly strip, about 300 km long (east-west) and 100 km wide, with a total geographical area of about 22,429 km² in the eastern part of the nation. The state is bounded by Assam and Bangladesh on the north and south respectively. The State of Meghalaya is located at 25°47'N to 26°10'N latitude and 89°45' to 92°47'E longitudes. About one third of the geographical area of the state is covered by forests. The forests are rich in biological diversity.

Meghalaya is predominantly an agrarian economy. The important crops of the state are potato, rice, maize, pineapple, banana etc.

3.1.1.2 Climate

Meghalaya is the wettest place on earth, with an average annual rainfall about 205 cm. The western part of the Meghalaya's plateau (the Garo Hills Region) is located at lower elevations with an altitude ranging from 450 m to 1412 m. The altitude ranges from 450 m to 1412 m. This region experiences high temperatures for most of the seasons. The Shillong area, with the highest elevations, experiences generally low temperatures. The maximum temperature in this region rarely goes beyond 28 °C.

3.1.1.3 Physiography and Relief

The plateau is standing as a watershed between the Surma Valley of Bangladesh on the South and the Brahmaputra Valley on the North. Several rivers and a network of their tributaries and lateral streams dissect the plateau. The State can, broadly, be divided into three physiographic zones (i) the Central Plateau Region between 900-2000m elevation: (ii) Sub-montane region in continuation with the Central Plateau below 900m which gradually merges with the plains in the West and North and (iii) Border region which stretches south-wards abruptly from the Central Plateau to the plains in Bangladesh (http://megsoil.nic.in/basic_inf.htm 4/05/2012).

3.1.1.4 Geology

Geologically the Meghalaya plateau comprises of rocks from the oldest Precambrian gneissic complex to the Recent alluvium formations. The stratigraphic sequence is as follows.

1. Cretaceous –Tertiary sediments
2. The Sylhet trap
3. Lower Gondwana rocks
4. Shillong Group of rocks
5. Precambrian gneissic complex (Basement gneiss)

The Precambrian gneissic complex comprising para and orthogneisses, migmatites and the Shillong Group of rocks comprising mainly quartzites. They are exposed in the central, eastern and northern parts of the Meghalaya plateau. They are intruded by basic and ultrabasic intrusives and late tectonic granite plutons (Fig 3.1.1.4).

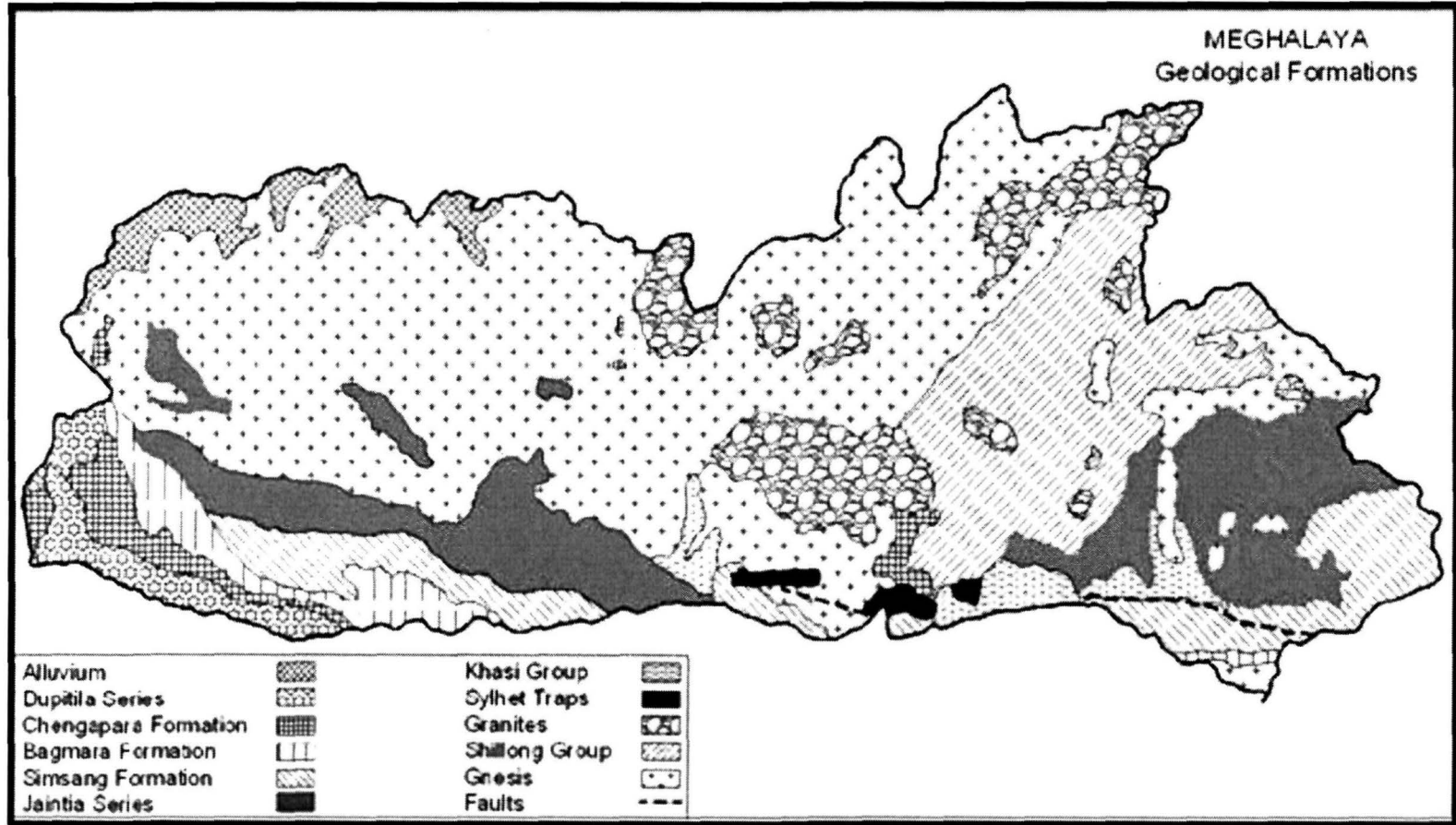


Fig 3.1.1.4: Geology of Meghalaya (Source: <http://www2.wii.gov.in/envis/hoolockgibbon/meghalaya.htm>)

The lower Gondwana rocks of Permo-Carboniferous age are recognized at the western part of the Garo Hills and consists of pebble bed, sandstone, and carbonaceous shale. The Sylhet trap of middle Jurassic age comprising mainly of basalt, rhyolites, and acid tuffs. The acid tuffs are exposed in a narrow E-W strip along the southern border of Khasi Hills.

The Cretaceous – Tertiary sediments occupying southern part of the Meghalaya plateau comprises of the Khasi Group (arenaceous facies), the Jaintia Group (calcareous facies) and the youngest formation the Garo Group which is represented as Simsang, Bagmara and Chengapara formations.

Besides these the Dupi Tilla group of mid-Pliocene age occurs in the western part of Garo Hills and towards south of Khasi Hills. Isolated patches of older Alluvium overlie the Tertiary rocks along the southern and western borders of the State. The recent Alluvium formation is mostly found in the river valleys of Garo & Khasi Hills Districts (<http://megdmg.gov.in/features.html> 4/04/2012).

3.1.1.5 Soil Types

The soils of the hills are derived from gneissic complex parent materials; they are dark brown to dark reddish-brown in colour, varying in depth from 50-200 cm. The texture of soils varies from loamy to fine loamy. The soils of the alluvial plains adjacent to the northwest and southern plateau are very deep, dark brown to reddish-brown in colour and sandy-loam to silt-clay in texture.

Meghalaya soils are rich in organic carbon, which is a measure of nitrogen supplying potential of the soil, deficient in available phosphorous and medium to low in available potassium. The reaction of the soils varies from acidic (pH 5.0 to 6.0) to

strongly acidic (pH 4.5 to 5.0). Most of the soils occurring on higher altitudes under high rainfall belt are strongly acidic due to intense leaching. Base saturation of these soils is less than 35 per cent. These soils are not suitable for intensive crop production (Anon., 2006). Four soils fertility classes, namely, High Low Medium (HLM), High Medium Medium (HMM), Medium Medium Low (MML), Medium Low Medium (MLM) have been established from the soil test data compiled in the soil Testing Laboratory of the State of Meghalaya (Anon., 2006; http://www.advanceagriculturalpractice.in/w/index.php/Farming_in_Meghalaya 5/05/2012).

Regarding micronutrient status, it has been observed that almost all the acid soils of the north-eastern region of the country are deficient in available Boron (B) and Molybdenum (Mo). Acid soils of Meghalaya are also low in available B and Mo. Total Zinc, Copper and Manganese contents of these soils vary from 10.00 to 17.25, 17.00 to 71.00 and 110 to 770 ppm (parts per million), respectively and DIPA (Diethylene Triamine Penta Acetic Acid) extractable zinc, copper and manganese contents of these soils ranges from 0.72 to 3.20, 0.6 to 2.8 and 3.0 to 162.0 ppm respectively. It is estimated that about 40 per cent of the soils of the state contain micronutrients below the critical level (Anon., 2006)

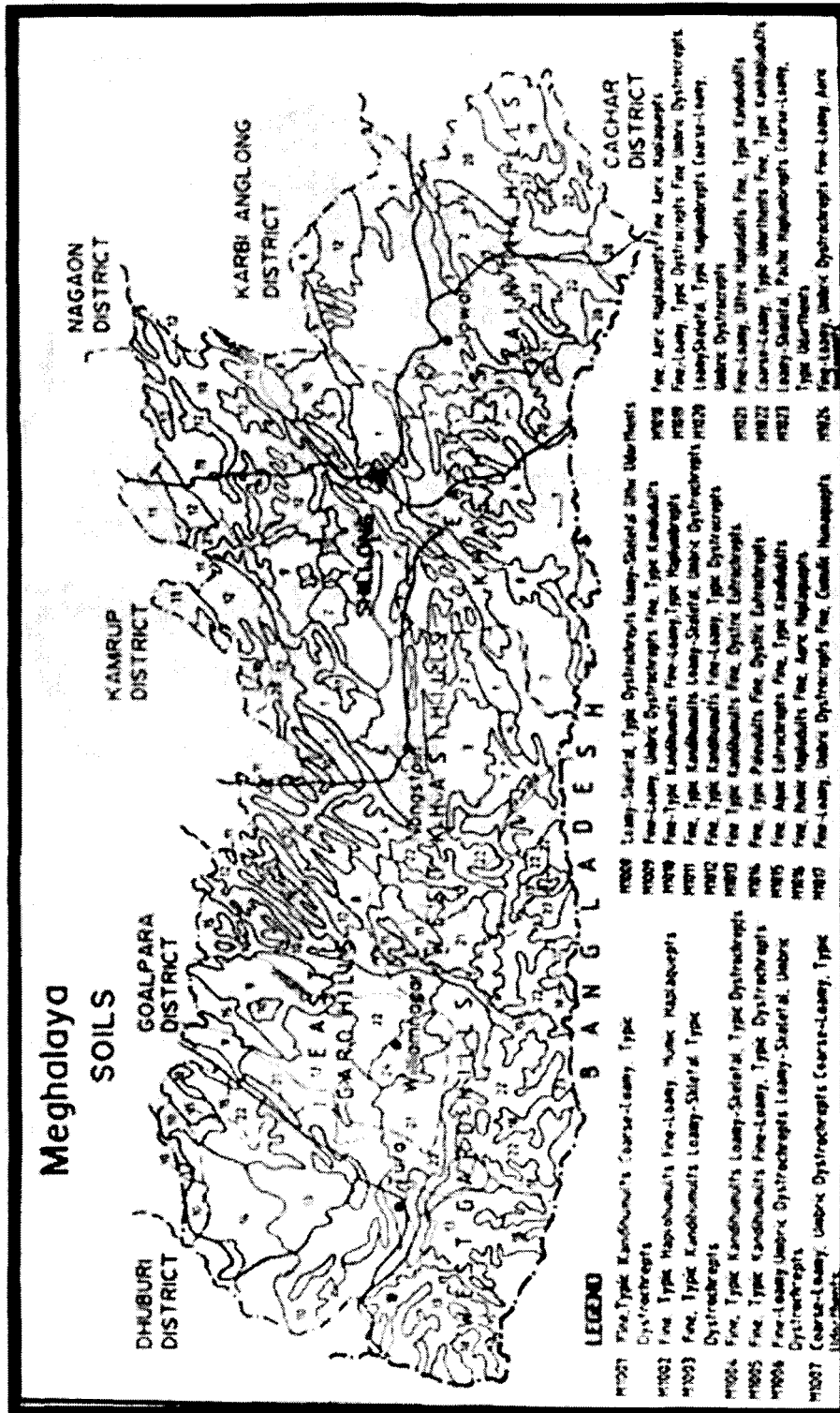


Fig: 3.1.1.5:- Soil types of Meghalaya (Source: Soil and Water Conservation Department, Government of Meghalaya)

3.1.1.6 Drainage Network

The drainage system of Meghalaya is greatly determined by its geological structure and the physiographic features. The rivers flow down towards the plains of Bangladesh in the south and the Brahmaputra valley in the north Tura range from the watersheds of Garo Hills and the central uplands in Khasi and Jaintia Hills. The important rivers in the Garo Hills (of the northern group from west to east) are the Kalu (navigable), Ringgi, Didak, Didram, Krishnai (navigable) and Dudhnai. Sanda, Bandra, Bhogai, Dareng, Nitai and Simsang are the important rivers of the southern group. Among the rivers of Garo Hills, the Simsang is the longest and is navigable for a distance of about 30 km.

The main rivers of the northern groups (Khri, Digaru, Umtrew, Umiew and Myngot) form the boundary of the plateau very irregular. The south bound rives give rise to deep valleys on the faulted surface of the hills as they leave Meghalaya to enter Bangladesh plains (http://www2.wii.gov.in/envis/hoolock_gibbon/meghalaya.htm 28/March/2009).

3.1.1.7 Forest

The forests of Meghalaya can be broadly grouped into tropical, subtropical and temperate types. The vegetation of the State of Meghalaya has been classified into tropical evergreen, tropical semi-evergreen, tropical moist deciduous, subtropical broad leaved, subtropical pine and temperate forest types, grasslands and savannas as shown in Fig 3.1.1.7 (Anon., 2001).

3.1.1.7.1 Tropical forest

These forests occur up to an elevation of 1,200 m where average annual rainfall ranges between 100 and 250 cm. They may be evergreen, semi-evergreen, and moist deciduous depending on the annual rainfall. Tropical evergreen forests occur in high rainfall as well as near catchments areas. They are rich in species diversity. The tropical semi-evergreen forests occupy the north-eastern and northern slopes of the state, typically up to elevation of 1,200 m, where annual rainfall is relatively less. The tropical moist deciduous forests occur at lower elevations where annual rainfall is below 150 cm. The typical natural deciduous forests do not occur in Meghalaya. These are sub-climax or man-made forests, characterized by seasonal leaf shedding and profuse flowering of the trees. Occurrences of fire are common in these forests. The trees of the deciduous canopy are lofty with straight bole and spreading crown.

3.1.1.7.2 Subtropical and Temperate Forest

The Subtropical and Temperate forests occur at 1,500 m and above, mostly along the southern slope of the Khasi and Jaintia Hills. The annual rainfall in these areas ranges from 200-500 cm with a severe winter during November to March. Ground frost is common during December and January. Subtropical Pine forests have

developed as a stable secondary community on the disturbed evergreen and semi-evergreen subtropical broad-leaved forest sites, which are seasonally dry and nutrient-poor.

3.1.1.7.3 Grassland and Savannah

Typical grassland is not found in the state. The rolling grasslands covering large areas in Khasi and Jaintia Hills and in major parts of West Garo Hills are found on degraded land developed either due to biotic pressure or due to interactive influence of topography, climate, fire and grazing.

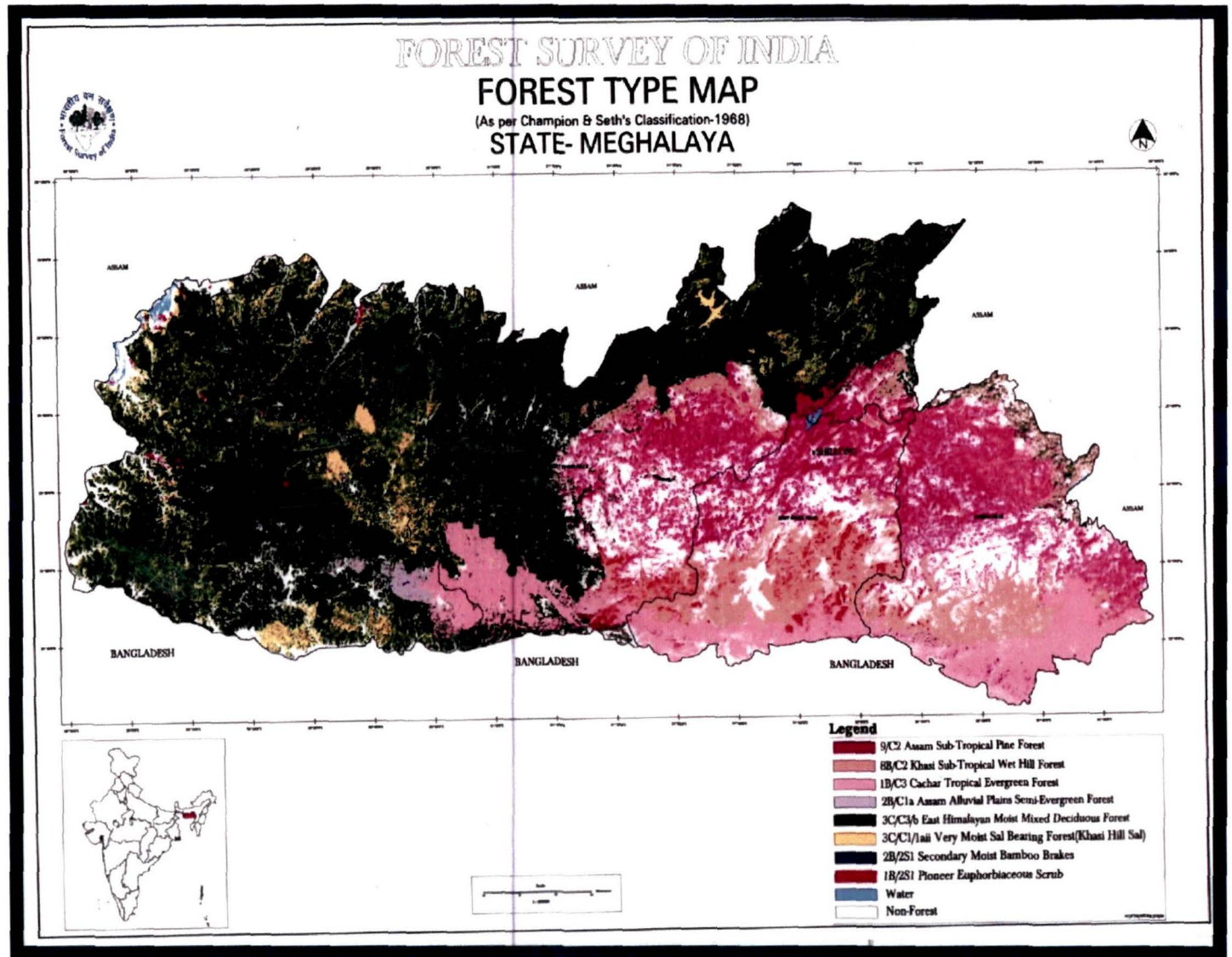


Fig 3.1.1.7: Vegetation type/land use of Meghalaya (Source: Forest Department of Meghalaya)

3.1.1.8 Forest cover

The forest cover based on satellite data of December, 1998 is 15,633 sq. km which is 69.70 per cent of the total geographic area of the state. Dense forest extends to 5,925 sq. km and open forest to 9,708 sq. km. A comparison with the previous assessment reveals that there is net loss of 24 sq. km. Based on the 1999 FSI report there has been an overall increase of 1,881 sq. km of dense forest. This is the result of improvement of 1,877 sq. km of open forest and 32 sq. km of non-forest. On the other hand there has been a degradation of 28 sq. km of dense forest to open forest. The decrease of 1,905 sq. km of open forest is on account of conversion of 1,877 sq. km of open forest to dense forest (Anon., 2005).

In the year 2001, the actual forest cover of the state was recorded at 15,584 sq. km. This accounts for around 69.5% of the state's geographic area. Per capita forest area in the state is 0.64 hectares compared to the national average of 0.11 hectares (Table 3.1.1.9a). However, the total recorded forest area is 9,496 sq. km. The area of the Reserved and Protected forests under the control of the state government is only 1,124 sq. km. The Un-classed Forests, managed by Autonomous District Councils, village durbars and other traditional institutions, and private owners cover an area of 8,372 Sq. Km (Anon., 2001). During 1985-87, 73.41% (16,466 sq. km) of the total geographical area of the state was under forest cover. It decreased to 69.75% (15,645 sq. km) by the year 1987-89 and then increased to 69.48% (15584 sq. km) in 1999-2001 (Table 3.1.1.9b).

Table 3.1.1.8a: Forest-man ratio in Meghalaya

Population	Geographical area '000 ha	Total forest (x10 ³ ha)		Dense forest (x10 ³ ha)	Dense forest (x10 ³ ha)	Per capita forest cover in ha
		Recorded	Cover			
23, 06, 069	2243	949.60 (42.34)	1563 (69.70)	592	971	0.64

Figures in the parentheses represent the forest area as percentage of the total geographical area. Dense forest (>40% Canopy cover), Open Forest (10-40% Canopy cover)

Table 3.1.1.8b: Change in forest cover (Sq. Km) in the State since 1991 (FSI report, 1999)

1991	1993	1995	1997	1999
15,875	15,769	15,714	15,657	15,633

Source: www.meghalaya.nic.in

3.1.1.9 Economic Base

Agriculture is the main occupation of the people of Meghalaya. The Garos practise 'jhum' cultivation. They are also good fishermen but indifferent to hunting. The Garos residing adjacent to Goalpara district of Assam also practised settled cultivation. The Hajongs however, do not practise 'shifting' cultivation. The Khasi have four main types of land uses, viz. (1) the forest land for jhum cultivation, (2) wet paddy land, (3) high grass land and (4) homestead land which is situated close to their courtyard. Some of them are engaged in bee-keeping, as labourers who are employed on road and building construction, etc. In addition to the above occupations, educated individuals have taken up teaching, government jobs and private services as their profession. Besides, a very small fraction of the population depends on business of varying nature and size (Anon., 2005).

Meghalaya has abundant but untapped natural resources, including coal, limestone, kaolin, feldspar, quartz, mica, gypsum, bauxite, and other minerals. Its

sillimanite deposits (a source of high-grade ceramic clay) are reported to be the best in the world and account for almost all of India's sillimanite output. Meghalaya has no heavy industries; small-scale industries include cement, plywood, and beverage factories, in addition to a few newly established ferro-alloys factories in Burnihat area.

Important fruits grown here are orange, pineapple, lemon, guava, jackfruit and bananas, while potato, jute, mesta, cotton, areca nut, ginger, turmeric, betel leaf, black pepper and broom grass are the chief commercial crops. In recent years, vegetable productions have also tremendously increased in the areas adjoining Shillong and Nongpoh. Although there has been a slow transition towards settled cultivation in recent years.

3.1.1.10 Diversity of Livelihood

There is a diversity of household livelihood strategies due to differential landholding pattern and availability of different opportunities. For instance, livelihood strategy of the people in a village varies with the landownership pattern, i.e. when most village land is communally owned, shifting cultivation and collection of forest products from the forest for sustenance are the main livelihood activities, but when the lands are privately owned, settled agriculture and cash crop cultivation are the main activities. The availability of different opportunities is usually policy driven, which are provided by the government and other donor agencies. Besides, closeness to market, and exposure to skill up gradation, entrepreneurship development and market information system are some of the other opportunities. The patterns of livelihood dependency on resources vary greatly between Khasi Hills and Garo Hills. In case of marginal land holdings or landlessness (non-availability of permanent

agriculture land), which is more prevalent among Garos, there are a variety of complimentary livelihood activities, such as livestock holding, collection of forest products and seasonal migration for labour. However, in case of Khasis, migration for labour is practically absent. Because of the community ownership of land, shifting cultivation is still prevalent form of agriculture among all the tribes of Meghalaya, although there has been a slow transition towards settled cultivation in recent years. Other area-specific livelihood activities of the people include, vegetable cropping, ginger cropping, broomstick cultivation, horticulture, fishery, selling of non-timber forest products such as bay leaf, honey and bamboo shoots, coal and lime stone mining, and small trading (Barik and Darlong, 2008).

3.1.2 Umbaniun Micro-Watershed

3.1.2.1 Location and Accessibility

The Umbaniun micro-watershed is located at latitude 25°31'49"N to 25°30'40"N and longitude 91°47'31"E to 91°51'08"E. It drains water in the southwestern part of Meghalaya. This micro-watershed having an area of 3985.62 ha can easily be approached by National Highway No.40 (Figs 3.1.2.1a and 3.1.2.1b).

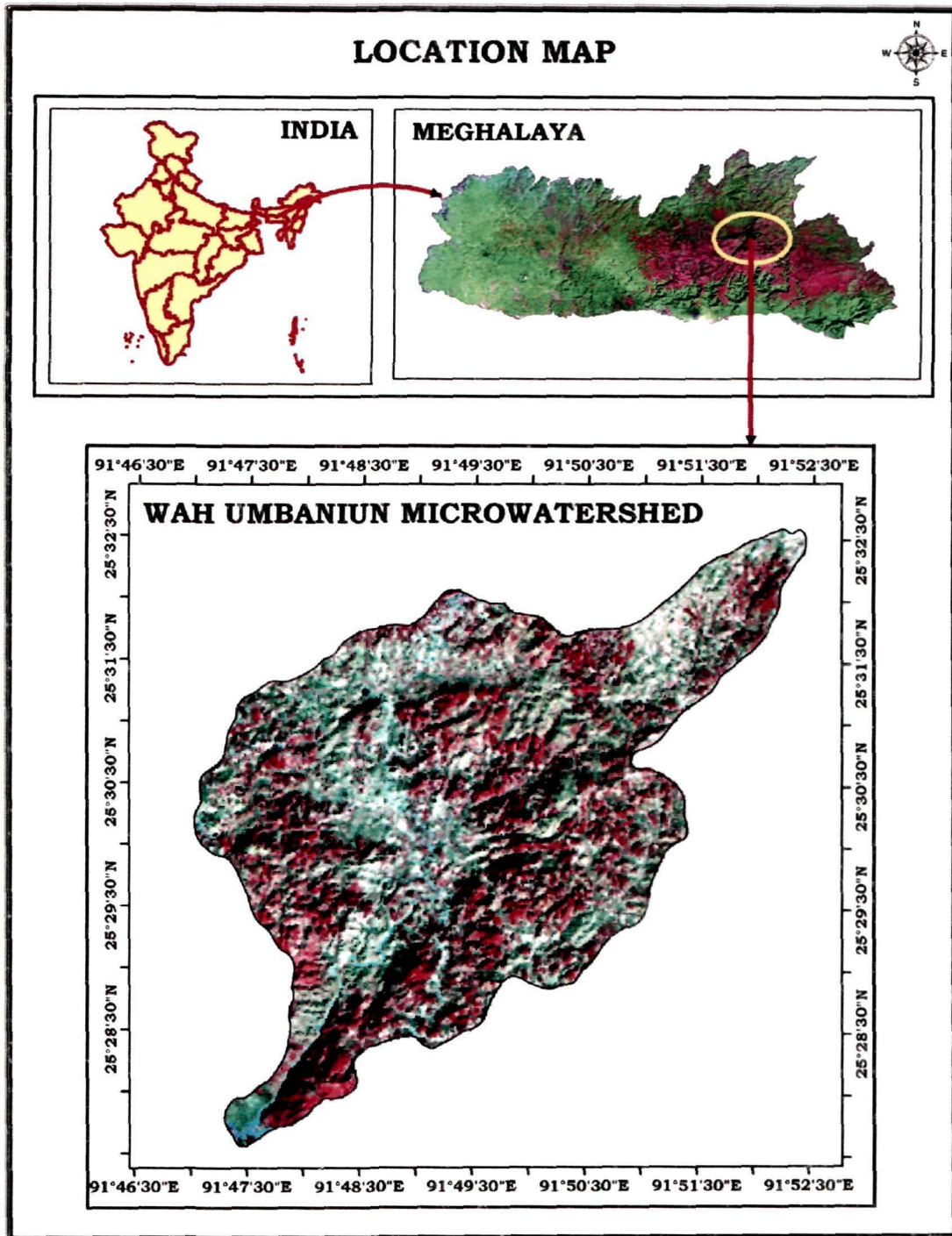


Fig 3.1.2.1a: Location of Umbaniun Micro-watershed

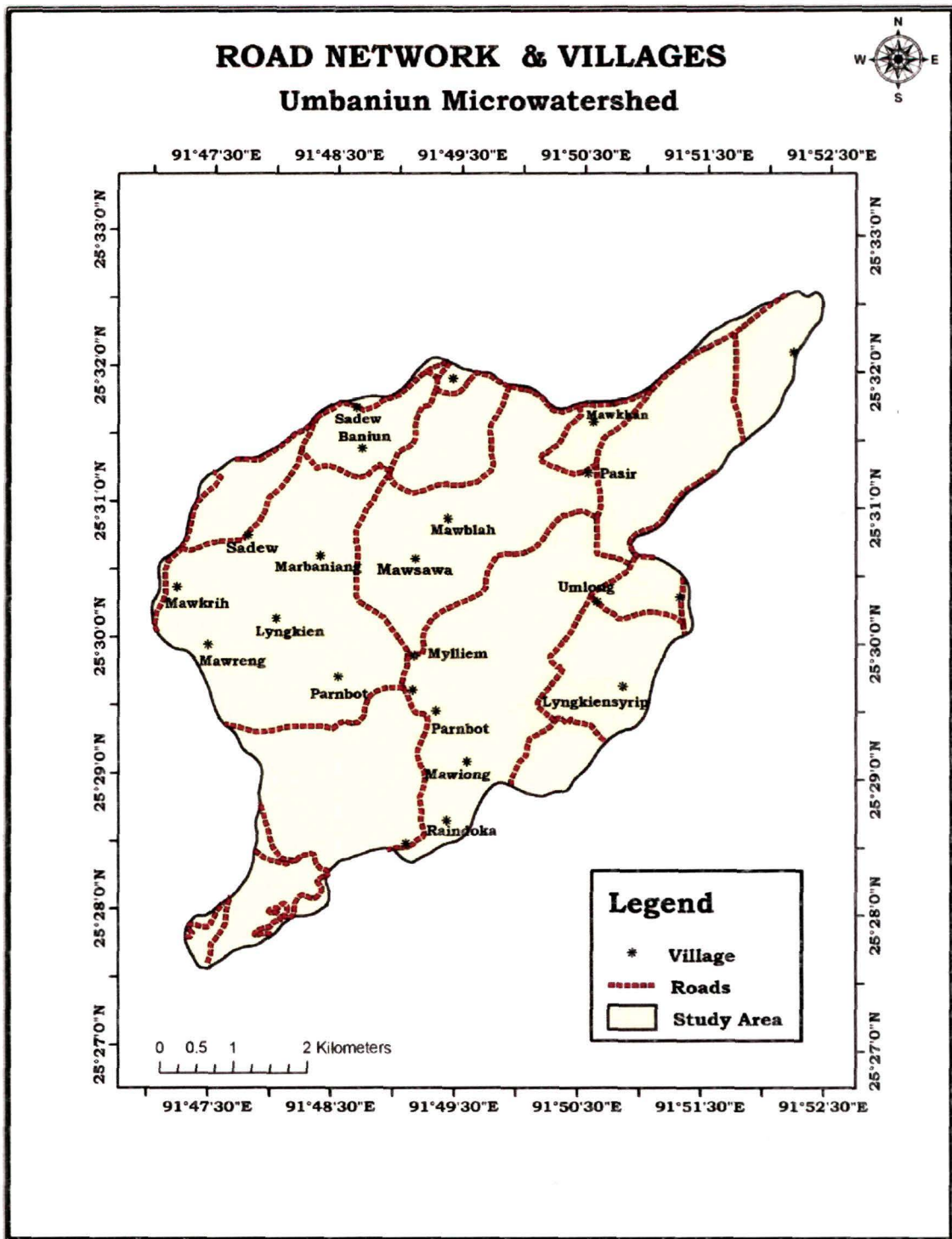


Fig 3.1.2.1b: Road network and villages of Umbaniun Micro-watershed

3.1.2.2 Description of Umbaniun Micro-Watershed

This micro-watershed is more or less elongated in shape and merges with the Umiew river at 25°27'37" N and 91°47'28" E that finally falls in Bangladesh plain towards the Southern direction.

Umbaniun River originates at an altitude of 1890m in Mawkhan village and discharges in the Umiew River at an altitude of 1582m. It covers an area of 3985.62 ha. This micro-watershed is drained by a fifth order stream and has a dendritic drainage system.

The average annual rainfall in the micro-watershed is 2148.28 mm and the mean maximum temperature is 21.05°C. Summer (March to June) experiences a maximum temperature of 24°C and a minimum temperature of 15°C. Winters during November to February are freezing and minimum temperature reaches 2°C. Ground-frost formations are common here during winter.

Different kinds of land use systems are found in the Umbaniun micro-watershed where, the agricultural lands occupy the major portion of the area. Agriculture is being practised on the hill slopes and valleys, without any measure being taken to conserve the soil. A number of sand-stone quarries are also found in the area. This has caused so much degradation to the micro-watershed and it needs to be looked into without delay to prevent further degradation.

3.2 Methodology

3.2.1 Slope

Slope is one of the major controlling factors in the development and formation of different landforms. Slope and elevation are also important hydrologic characteristics. The slope of a watershed channel greatly influences the velocity and therefore the erosion potential of stream flow. Slope is also related to infiltration, evapotranspiration, soil moisture, and ground water contribution to stream flow. The variations in elevation of a watershed are important factors with respect to temperature and precipitation patterns, especially in mountainous topography (Avery, 1975). The study area has been carved out from SOI toposheets 78O14 and 78O15 using AOI tool in ERDAS IMAGINE 9.2 and the contour map has been prepared at an interval of 20 m. It is then digitized and transformed to GIS environment and DEM has been generated. The DEM is then transferred to Arc GIS 9.3 software for generation of slope map using “3D Analysis Tool”.

3.2.2 Relative Relief

Relative relief is the ratio of the maximum watershed relief to the watershed perimeter, both expressed in the same units. Since, a circle has the minimum perimeter for a given area, for a given relief and a given watershed area, the more elongated the watershed is, the lower will be the value of relative relief. If the elongation is along the major slope towards the outlet, the watershed has a milder slope and more time of concentration in the major direction of runoff flow and if the elongation is across the slope, the watershed has a steeper slope and less time of concentration towards the outlet (Sarangi *et al.* 2003). The greater the relief the greater is the erosional forces acting on the river catchment (Pallaris, 1998). Relief is

the maximum vertical distance between the lowest and the highest points of a basin. Basin relief is an important factor in understanding the denudational characteristics of the basin. For the detailed study of the relief pattern of the micro-watersheds, the DEM is taken as the base input layer and with the help of relief pattern analyzing function of ERDAS Imagine software. For better representation of the relief pattern the “Painted Relief” method is used.

3.2.3 Morphometric Parameters

The quantification of the morphologic features of the earth surface is essential for the knowledge of physical, chemical and biological processes that take place in the landscape (Blaszczynski, 1997) as landforms influence water-flow, sediment transport, nature and distribution of habitats of plants and animals. In addition, it also expresses weathering processes that act on the formation of the landscape.

Morphological parameters along with hydrological parameters are used to quantify and simulate the hydrological behaviour of the various catchments, particularly ungauged catchment (Maidment, 1993; Chalam *et al.* 1969). Morphometric studies involve evaluations of streams through the measurement of various stream properties. Evaluation of morphometric parameters necessitates the analysis of various drainage parameters such as ordering of the various streams, measurement of basin area and perimeter, length of drainage channels, drainage density (D_d), stream frequency (F_s), bifurcation ratio (R_b), texture ratio (T), basin relief (B_h), ruggedness number (R_n) and time of concentration (T_c) (Verstappen 1983; Kumar *et al.* 2000). In some studies, the characteristics of basin morphometry have been used to predict or describe geomorphic processes such as prediction of flood

peaks, assessment of sediment yields and estimation of erosion rates (Baumgardner, 1987; Gardiner, 1990).

Umbaniun micro-watershed has been divided into three sub micro-watersheds- Sub micro-watershed no.1, Sub micro-watershed no.2 and Sub micro-watershed no.3 (Figs. 3.2.3a, 3.2.3b and 3.2.3c) for an in-depth study of different geomorphologic features. Thus, a separate morphometric parameters analysis for these three sub micro-watersheds will help in framing efficient management strategy in the micro-watershed.

Table 3.2.3a: Morphometric parameters

Sl. No.	Morphometric Parameters	Definition
1	Watershed Area (A)	Measure tool of ArcGis9.3 software
2	Length of the watershed (L_b)	Longest side of triangle enclosing the watershed
3	Perimeter of the watershed (L_p)	Measure tool of ArcGis9.3 software
4	Length of main stream (L_s)	Length of principal drainage line
5	Cumulative length of stream (L_u)	Total length of streams of different orders
6	Horizontal distance parallel to main stream (L_h)	The distance parallel to principal drainage order.
7	Length of remotest point of outlet (L_r)	The distance between outlet and hydraulically farthest point
8	Maximum elevation (H_s)	The elevation of the highest point of the watershed
9	Minimum elevation (H_d)	The elevation of the lowest point of the watershed
10	Elevation of remotest point (H_r)	The elevation of the hydraulically remotest point in the watershed.
11	Watershed Relief (H)	Difference in elevation between the remotest point and the lowest point in the watershed.
12	Number of stream order (N_i)	Total number of streams of particular order.
13	Total number of stream (N_s)	Total number of streams of different orders.
14	Contour interval (N)	Difference in elevation between the two successive contours
15	Equivalent diameter (D)	Diameter of circle having equal area of the watershed.
16	Equivalent circumference (C)	Circumference of a circle having equal area of the watershed expressed in km.
17	Equivalent area (A_c)	Area of circle having diameter equal to the length of the watershed.

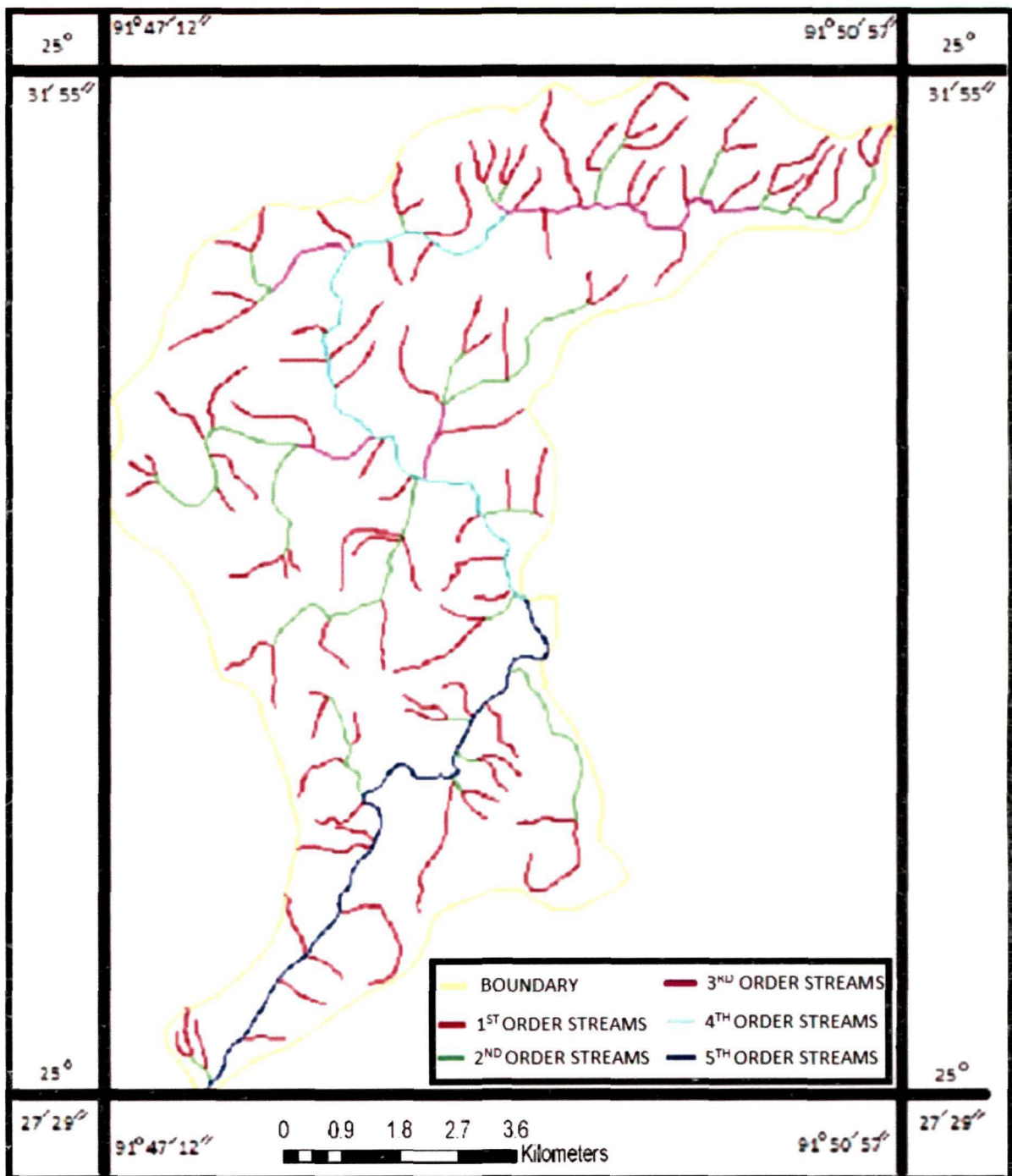


Fig 3.2.3a: Sub micro-watershed no. 1

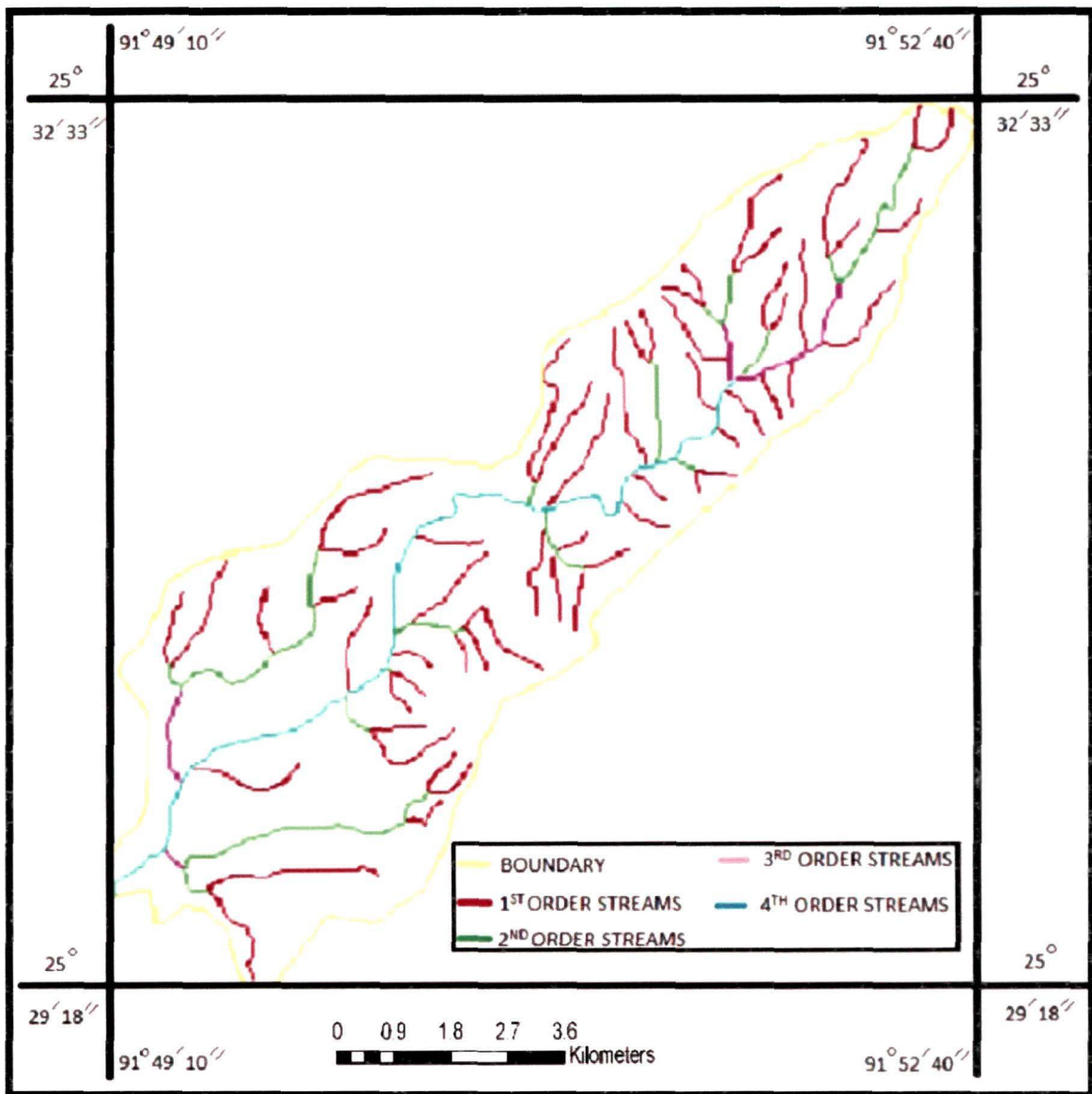


Fig 3.2.3b: Sub micro-watershed no. 2

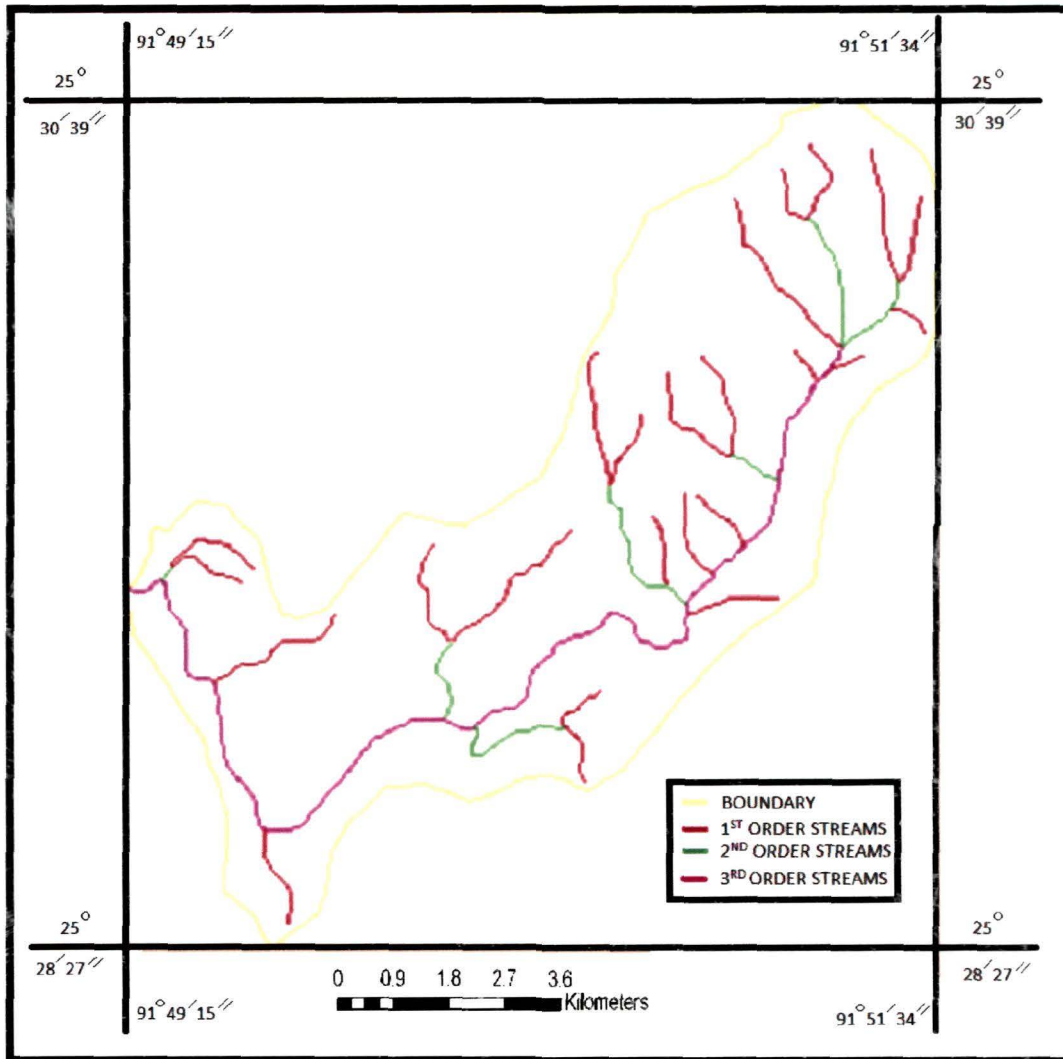


Fig 3.2.3c: Sub micro-watershed no. 3

Table 3.2.3b: Drainage pattern and Topographic parameters

Drainage Pattern Parameters	
Bifurcation Ratio, R_b (Horton, 1932)	$R_b = \frac{N_u}{N_{u+1}}$
Drainage Density, D_d (m/m^2) (Horton, 1932)	$D_d = \frac{L_s}{A}$
Stream Frequency, S_f (per Sq. metre) (Horton, 1945)	$S_f = \frac{N_s}{A}$
Stream Grade, S_g (%)	$S_g (\%) = \left(\frac{H_s - H_d}{L_s} \right) \times 100$
Length of Overland Flow, L_o (m) (Horton, 1945)	$L_o = \frac{1}{2D_d}$
Time Of Concentration, T_c (minutes)	$T_c = 0.0195(L_r^3/H)^{0.385}$
Topographic Parameters	
Total Watershed Relief, H (m)	$H = H_r - H_d$
Relief Ratio, R_h (Schumm, 1956)	$R_h = H/L_h$
Relative Relief, R_r (Melton, 1964)	$R_r = H/L_p \times 100$
Ruggedness Number, R_n	$R_n = H \times D_d$
Channel Maintenance factor, C_m (per metre) (Schumm, 1956)	$1/D_d$

Table 3.2.3c: Shape Parameters

Shape Index (S_i) (Horton, 1932)	$S_i = \frac{L_b^2}{A}$
Form Factor (F_f) (Strahler, 1957)	$F_f = \frac{A}{L_b^2}$
Compactness Coefficient (C_c) (Morisawa, 1958)	$C_c = \frac{0.282 L_p}{A^{0.5}}$
Elongation Ratio (R_e) (Schumm, 1956)	$R_e = \frac{1.128 A^{0.5}}{L_b}$
Circulatory Ratio (C_r) (Miller, 1964)	$C_r = \frac{4\pi A}{L_p^2}$
Rotundity Factor (R_f) (Chorley <i>et al.</i> 1957)	$R_f = \frac{L_b^2}{4A}$

3.2.4 Soil

The soil survey report of North Eastern Space Application Centre (NESAC), 2008 has been used to generate data on soil of the study area (http://megapib.nic.in/natural_resource_info.htm 27/05/2012).

3.2.5 Hydro-Meteorological Data

Various climatic variables such as rainfall, temperature, wind direction and evapotranspiration together with physiographic factors such as drainage pattern, slope and aspect factors play significant role in the Hydro-meteorology of a river basin. These factors are guided by geographical position and topography of the basin, which in turn controls the vegetation, rock and soil covers. These hydro-meteorological parameters represent and exhibit the nature of the environment of a river basin. Therefore, the hydro-meteorological parameters are needed to be studied in detail in watershed management. The detailed information on meteorological data has been collected from India Meteorological Department (Ministry of Earth Sciences, Govt. of India), Shillong.

3.2.6 Land-Use/Land-Cover Study

Human interventions in natural systems have resulted in large changes in vegetation composition and distribution patterns. Changes in land use and hence in vegetation cover, due to climatic change and human activity, affect surface water and energy budgets directly through plant transpiration, surface albedo, emissivity and roughness (Roy and Tomar, 2010).

Satellite images of the years 1977 and 1987 are LANDSAT-MSS and LANDSAT-TM image with a spatial resolution of 59 m and 30 m respectively

whereas, the imageries of the year 2004 and 2007 have a resolution of 23.5 m. The 1977 LANDSAT-MSS image with a spatial resolution of 59 m was resampled to 25 m resolution using resampling technique so that it can be compared with the other images of higher resolution. Then, the images were registered and geo-referenced based on topographic maps at a scale of 1:50,000. After the completion of geometric correction, images were truly checked by radiometric and geometric correction. For the purpose of image correction polynomial equation has been applied. The analysis of remotely sensed data is done by using the “Digital Image Processing” technique. The digital image processing includes three general steps, namely (i) Pre-processing (ii) Display and enhancement and (iii) Information extraction. In this particular classification method each information pixel is supervised for the classification of data. Supervised classification method was used to classify the land-use/land-cover types of the microwatershed area, which was followed by the process of accuracy assessment and ground truth matching and ultimately the final land-use/land-cover maps prepared.

These land-use maps were again brought back into Arc GIS 9.3 environment for the decadal land-use change analysis. Finally, all the four different land use classes were input in the “Union” segment of Analysis tool to calculate the actual rate of decadal change of different land use categories.

3.2.7 Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum, and is adopted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not (Rouse *et al.* 1973).

Generally, healthy vegetation absorbs most of the visible light that falls on it, and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light. Bare soils on the other hand reflect moderately in both the red and infrared portion of the electromagnetic spectrum (Holme *et al.* 1987).

The Normalized Difference Vegetation Index (NDVI) is a calculation, based on several spectral bands, of the photosynthetic output (amount of green stuff) in a pixel in a satellite image. It measures, in effect, the amount of green vegetation in an area (Ryan, 1997).

The NDVI used in this particular study is derived from the GIMMS (Global Inventory Modelling and Mapping Studies) National Oceanographic and Atmospheric Administration's (NOAA) Advanced Very High Resolution Radiometer (AVHRR) data-set maintained by the university of Maryland Global Land Cover Facility (Anon, 2004) (<http://www.landcover.org> 7/September/2009). The same method was followed by Milesi *et al.* (2010).

3.2.8 Geophysical Parameters

The physical behaviour of the watershed is controlled by various geomorphic, drainage and topographic factors and these are used in estimating run-off volume as well as estimation of sediment production rate. Various watershed shapes, drainage and topographic factors have been evaluated based on methods suggested by Horton (1932 and 1945); Chorley *et al.*(1957); Eyles (1965); Linsley *et al.* (1982); Melton (1964); Miller (1964); Morisawa (1958); Schumm (1956); and Strahler (1954, 1957 and 1964).

3.2.9 Run-off and Sedimentation Production Rate

Run-off and Sedimentation Production Rate is calculated using the equation given by Jose and Das, 1982.

$$\text{Log } Q = 2238.43 + 22.12 \text{ Log}(100 + R_f) - 608.28 \text{ Log}(100 + C_r) - 530.02 \text{ Log}(100 + C_c)$$

Where,

Q = Run-off in sq km - cm/sq km.

R_f = Rotundity factor [$Lb^2/4A$]

C_r = Circulatory ratio [$4\pi A/Lp^2$]

C_c = Compactness coefficient [$0.282Lp/A^{0.5}$]

$$\text{Log } \text{SPR} = 4919.80 + 48.64 \text{ Log}(100 + R_f) - 1337.77 \text{ Log}(100 + C_r) - 1166.64 \text{ Log}(100 + C_c)$$

Where, SPR = Sediment production rate in ha - m/100 sq km/year

R_f = Rotundary factor

C_r = Circulatory ratio

C_c = Compactness coefficient

3.2.10 Phytosociological Study

Phytosociology is the study of the characteristics, classification, relationships, and distribution of plant communities (The American Heritage Dictionary, 3rd Ed.). It is useful to collect such data to describe the population dynamics of each species studied and how they relate to the other species in the same community (<http://www.yale.edu/fes519b/saltonstall/page3.htm> 6/September/2009). Subtle differences in species composition and structure may point to differing abiotic

conditions such as soil moisture, light availability, temperature, exposure to prevailing wind, etc. 70 quadrates of 10 x 10m², 5 x 5m² and 1 x 1m² for trees, shrubs and herbs respectively were taken randomly to evaluate the species diversity of the micro-watershed. In case of trees, individuals with GBH (Girth at Breast Height) of ≥ 15 cm were enumerated. Frequency, density, dominance, basal area and Important Value Index (IVI) were analyzed following methods outlined by Misra (1968) and Mueller-Dombois & Ellenberg (1974). The community indices such as Shannon's diversity index, Simpson's dominance index were calculated using the formulae (Magurran, 1988) as given below.

$$\text{Shannon-Wiener diversity index (H')} = -\sum(n_i/N) \times \ln(n_i/N)$$

$$\text{Simpson's dominance Index (D)} = \sum P_i^2$$

Where, n_i = importance value of i^{th} species

N = sum of importance value of all species

3.2.11 Cropping Pattern

Cropping systems of a region are decided by and large, by a number of soil and climatic parameters which determine overall agro-ecological setting for nourishment and appropriateness of a crop or set of crops for cultivation. Nevertheless, at farmers' level, potential productivity and monetary benefits act as guiding principles while opting for a particular crop/cropping system. These decisions with respect to choice of crops and cropping systems are further narrowed down under influence of several other forces related to infrastructure facilities, socio-economic factors and technological developments, all operating interactively at micro-level (Das, 2002).

These are:

Infrastructure facilities: Irrigation, transport, storage, trade and marketing, post-harvest handling and processing etc.

Socio-economic factors: Financial resource base, land ownership, size and type of land holding, household needs of food, fodder, fuel, fibre and finance, labour availability etc.

Technological factors: Improved varieties, cultural requirements, mechanization, plant protection, access to information, etc.

Cropping system was studied by interviewing 10% of families practicing agriculture in each of the 12 villages in Umbaniun Micro-watershed with the help of a detailed questionnaire. The questionnaire was developed way to find out cropping systems being carried out by the farmers, the major crops grown for commercial purposes in different seasons of the year and also, to analyze the net income of each crop the farmers derived in a year.

3.2.12 Socio-Economic

Study on socio-economy of a region, needs analysis on the size, spatial distribution, composition and growth pattern of the population (Meintjes, 2001).

Data regarding population, population-composition, land tenure and land holding system, educational institution, literacy, medical facilities, drinking water facilities, occupation and occupational structure, transport and communication, market, medicinal facilities and other economic activities of the study area have been collected from primary and secondary sources.

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RESULTS

4.1. Physiography

4.1.1. General Remark

The physiography relates to the study of all the natural features on the earth's surface (landforms, climate, soil, vegetation, hydrology and distribution of flora and fauna) and delineation and description of regions from the viewpoint of landforms, including their origin and evolution, and the processes that shape them (Strahler, 1964).

Sediment fluxes in lakes and reservoirs often reflect the interplay of watershed physiographic characteristics such as degree of topographical steepness, slope orientation, climate, geology, watershed area, surface runoff, soil characteristics, sediment grain size, etc (Dendy *et al.* 1973; Gilbert, 1980; Pemberton, 1980; Abrahams and Parsons, 1991). In addition, watershed land cover and land use can greatly influence rates of surface denudation, sediment yield, and ultimately sedimentation in reservoirs (Chen, 1998; Canfield *et al.* 2001; Young *et al.* 2001).

The proper use of land and water resources of a watershed is a must for optimum production and utilization with minimum hazard to natural resources. This can only be achieved by proper understanding the physical behaviour of the watershed. Evaluation of various morphometric parameters and examination of their interrelationship are a necessary input for understanding the physiography of any

watershed. Moreover, quantitative analysis of drainage system is an important aspect of characterisation of watershed (Strahler, 1964).

4.1.2. Estimation of Morphometric Parameter

Morphometric analysis is a significant tool for prioritization of watersheds even without considering the soil map (Biswas *et al.* 1999; Mishra and Nagarajan, 2010). Morphometric analysis requires measurement of the linear features, gradient of channel network, and contributing ground slopes of the drainage basin. For in-depth morphometric parameters analysis, it is necessary to divide the Umbaniun micro-watershed into three sub micro-watersheds: Sub micro-watershed No.1, Sub micro-watershed No.2 and Sub micro-watershed No.3. This helps in getting a clear-cut picture on the shape, drainage pattern and topographic factors which can vary even between the different Sub micro-watersheds and thus affecting differently, in terms of run-off, discharge and sediment production rate on the micro-watershed. Thus, separate morphometric parameters analysis for all the three different Sub micro-watersheds is important in best management practices for Umbaniun micro-watershed. The various morphometric attributes were computed for each of the Sub micro-watersheds of Umbaniun Micro-watershed from the contour and drainage maps and presented in Table 4.1.2. The Length of the main stream, L_s ; Cumulative length of the stream of the Watershed, L_u ; Watershed area, A ; Perimeter of the Watershed, L_p ; Length of the Watershed, L_b ; Horizontal distance parallel to the main stream, L_h ; Length of the remotest point to the outlet, L_r ; Maximum elevation, H_s ; Minimum elevation, H_d ; Number of stream order, N_i ; Total number of streams, N_s ; Contour interval, N ; Equivalent diameter, D ; Equivalent circumference, C ; Equivalent area, A_c ; and Watershed relief, H of Umbaniun Sub micro-watershed No. 1 has been

calculated 15053.33 m; 76234.69 m; 2173.54 ha; 27088.3 m; 15147.82 m; 12782.32 m; 9409.36 m; 1880 m; 1600 m; 5; 128; 20 m; 5261.98 ha; 16522.62 m; 21257.72 ha; and 260 m respectively. The Length of the main stream, L_s ; Cumulative length of the stream of the Watershed, L_u ; Watershed area, A ; Perimeter of the Watershed, L_p ; Length of the Watershed, L_b ; Horizontal distance parallel to the main stream, L_h ; Length of the remotest point to the outlet, L_r ; Maximum elevation, H_s ; Minimum elevation, H_d ; Number of stream order, N_i ; Total number of streams, N_s ; Contour interval, N ; Equivalent diameter, D ; Equivalent circumference, C ; Equivalent area, A_c ; and Watershed relief, H of Umbaniun Sub micro-watershed No. 2 are 9170.71 m; 47193.61 m; 1186.68 ha; 18972.11 m; 9185.34 m; 8353.94 m; 7738.13 m; 1960 m; 1660 m; 4; 78; 20 m; 3888.05 m; 12208.51 m; 6904.91 ha; and 260 m respectively. Whereas in Sub micro-watershed No. 3 Length of the main stream, L_s ; Cumulative length of the stream of the Watershed, L_u ; Watershed area, A ; Perimeter of the Watershed, L_p ; Length of the Watershed, L_b ; Horizontal distance parallel to the main stream, L_h ; Length of the remotest point to the outlet, L_r ; Maximum elevation, H_s ; Minimum elevation, H_d ; Number of stream order, N_i ; Total number of streams, N_s ; Contour interval, N ; Equivalent diameter, D ; Equivalent circumference, C ; Equivalent area, A_c ; and Watershed relief, H are 6884.52 m; 20137.8 m; 625.40 ha; 13428.24 m; 7050.51 m; 6360.85 m; 3874.73 m; 1880 m; 1660 m; 3; 32; 20 m; 2822.57 m; 8862.84 m; 3456.34 ha; and 220 m respectively.

Table 4.1.2: Morphometric-parameter

Morphometric-parameter	Sub micro-watershed No.1	Sub micro-watershed No.2	Sub micro-watershed No.3
Length of the main stream, L_s (m)	15053.33	9170.71	6884.52
Cumulative length of the stream of the Watershed, L_u (m)	76234.69	47193.61	20137.8
Watershed area, A (ha)	2173.54	1186.68	625.40
Perimeter of the Watershed, L_p (m)	27088.3	18972.11	13428.24
Length of the Watershed, L_b (m)	15147.82	9185.34	7050.51
Horizontal distance parallel to the main stream, L_h (m)	12782.32	8353.94	6360.85
Length of the remotest point to the outlet, L_r (m)	9409.36	7738.13	3874.73
Maximum elevation, H_s (m)	1880	1960	1880
Minimum elevation, H_d (m)	1600	1660	1660
Number of stream order, N_i	5	4	3
Total number of streams, N_s	128	78	32
Contour interval, N (m)	20	20	20
Equivalent diameter, D (m)	5261.98	3888.05	2822.57
Equivalent circumference, C (m)	16522.62	12208.51	8862.84
Equivalent area, A_c (ha)	21257.72	6904.91	3456.34
Watershed relief, H (m)	260	260	220

4.1.3. Watershed Shape Factor

Basin shape is not usually used directly in hydrologic design methods; however, parameters that reflect basin shape are used occasionally and have a conceptual basis. Watersheds have an infinite variety of shapes, and the shape supposedly reflects the way that runoff will “bunch up” at the outlet. A circular watershed would result in runoff from various parts of the watershed reaching the outlet at the same time. An elliptical watershed having the outlet at one end of the major axis and having the same area as the circular watershed would cause the runoff to be spread out over time, thus producing a smaller flood peak than that of the circular watershed (Saud, 2009).

A number of watershed parameters have been developed to reflect basin shape and same is presented in Table 4.1.3. The Shape Index (S_i); Form Factor (F_f); Compactness Coefficient (C_c); Elongation Ratio (R_e); Circulatory Ratio (C_r); and Rotundity Factor (R_f) has been estimated 10.43; 0.095; 1.639; 0.347; 0.372; and 2.639 respectively of Sub micro-watershed No. 1. Whereas in case of Sub micro-watershed No. 2 Shape Index (S_i); Form Factor (F_f); Compactness Coefficient (C_c); Elongation Ratio (R_e); Circulatory Ratio (C_r); and Rotundity Factor (R_f) are recorded 7.08; 0.14; 1.553; 0.423; 0.414; and 1.778 respectively. The estimated values of Shape parameters of sub micro-watershed No. 3 are 7.58; 0.13; 1.514; 0.400; 0.436; and 1.987 for Shape Index (S_i); Form Factor (F_f); Compactness Coefficient (C_c); Elongation Ratio (R_e); Circulatory Ratio (C_r); and Rotundity Factor (R_f) respectively.

The values of various shape parameters calculated for all the three sub micro-watersheds are found to deviate from unity suggesting that all the three sub micro-watersheds have an elongated shape.

Table 4.1.3: Shape Parameter

Shape parameter	Micro-Watershed No.1	Micro-Watershed No.2	Micro-Watershed No.3
Shape Index (S_i)	10.43	7.08	7.58
Form Factor (F_f)	0.095	0.14	0.13
Compactness Coefficient (C_c)	1.639	1.553	1.514
Elongation Ratio (R_e)	0.347	0.423	0.400
Circulatory Ratio (C_r)	0.372	0.414	0.436
Rotundity Factor (R_f)	2.639	1.778	1.987

4.1.4. Drainage Pattern Factor

The drainage system, which develops in an area, is strictly dependent on the slope, nature of bedrock and on the regional and local fracture pattern. Drainage,

which is easily visible on remote sensing imagery, therefore reflects to varying degrees the lithology and structure of a given area. Drainage is studied according to its pattern type and its texture (or density of dissection) (Way, 1973). Whilst the first parameter is associated to the nature and structure of the substratum, the second is related to rock/soil permeability. Actually, less permeable rock surfaces give rise to a well-developed and fine drainage system due to concentrated surface runoff. The values of Bifurcation ratio and other drainage pattern parameters are given in tables 4.1.4a and 4.1.4b. The Bifurcation Ratio (R_b) is found to increase with stream order in all the three Sub micro-watersheds and the mean R_b is 3.7, 3.9 and 5.2 in Sub micro-watershed No.1, Sub micro-watershed No.2 and Sub micro-watershed No.3 respectively (Table 4.1.4a). Bifurcation Ratio, R_b ; Drainage Density, D_d ; Stream Frequency, S_f ; Stream Grade, S_g ; Length of Overland Flow, L_o ; and Time of Concentration, T_c of Sub micro-watershed No.1 has been estimated 3.7; 0.00069 m/m^2 ; 0.0000059 per Sq. metre; 1.73 %; 724.64 m; and 89.1 minutes respectively - Bifurcation Ratio, R_b ; Drainage Density, D_d ; Stream Frequency, S_f ; Stream Grade, S_g ; Length of Overland Flow, L_o ; and Time Of Concentration, T_c of Sub micro-watershed No.2 are 3.9; 0.00077 m/m^2 ; 0.0000066 per Sq. metre; 3.27 %; 649.35 m; and 71.1 minutes respectively. The values of - Bifurcation Ratio, R_b ; Drainage Density, D_d ; Stream Frequency, S_f ; Stream Grade, S_g ; Length of Overland Flow, L_o ; and Time Of Concentration, T_c of Sub-microwatershed No.3 have been calculated 5.2; 0.00110 m/m^2 ; 0.0000051 per Sq. metre; 3.20 %; 454.55 m; and 34.1 minutes respectively (Table 4.1.4b and Fig 4.1.4).

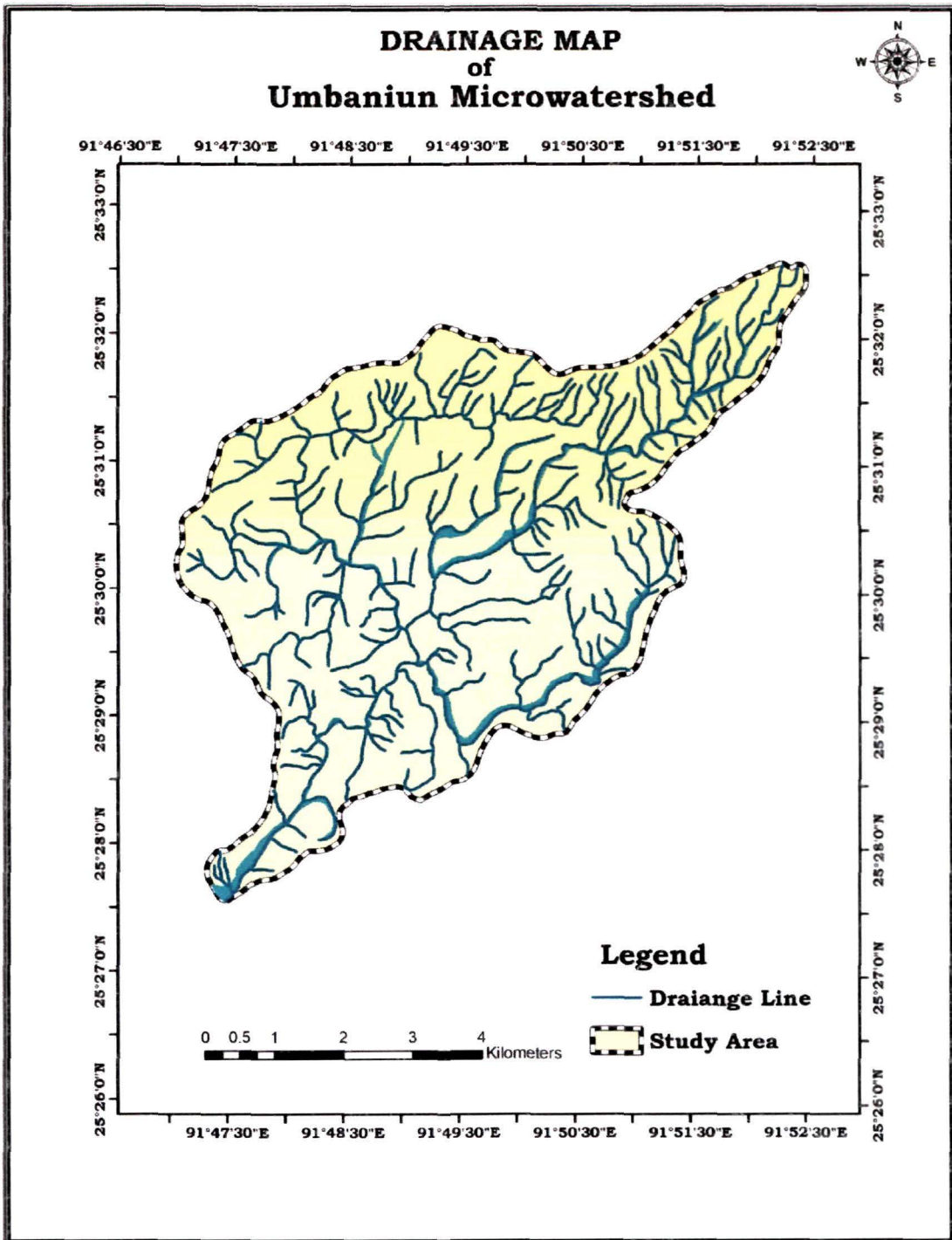


Fig 4.1.4: Drainage systems of Umbaniun micro-watershed

Table 4.1.4a: Stream Orders and Bifurcation Ratio

Stream Order	Total no. of streams in different stream order (N_u)			Bifurcation Ratio (R_b)			Average R_b		
	Sub micro-watershed No.1	Sub micro-watershed No.2	Sub micro-watershed No.3	Sub micro-watershed No.1	Sub micro-watershed No.2	Sub micro-Watershed No.3	Sub micro-watershed No.1	Sub micro-watershed No.2	Sub micro-watershed No.3
I	99	57	24	4.5	3.6	3.4	3.7	3.9	5.2
II	22	16	7	4.4	4	7			
III	5	4	1	5	4	-			
IV	1	1	-	1	-	-			
V	1	-	-	-	-	-			

Table 4.1.4b: Drainage Pattern Parameter

Drainage Pattern Parameter	Sub micro-watershed No.1	Sub micro-watershed No.2	Sub micro-watershed No.3
Bifurcation Ratio, R_b	3.7	3.9	5.2
Drainage Density, D_d (m/m^2)	0.00069	0.00077	0.00110
Stream Frequency, S_f (per Sq. metre)	0.0000059	0.0000066	0.0000051
Stream Grade, S_g (%)	1.73	3.27	3.20
Length of Overland Flow, L_o (m)	724.64	649.35	454.55
Time Of Concentration, T_c (minutes)	89.1	71.1	34.1

4.1.5. Topographic factor

Topography is recognized as an important factor affecting the stream flow response of watersheds to precipitation (Kirkby and Chorley, 1967; Dunne *et al.* 1975; Beven and Kirkby, 1979; O'Loughlin, 1981; Beven and Wood, 1983). It defines the effects of gravity on the movement of water in a watershed, and, therefore, influences many aspects of the hydrologic system (Wolock and Price, 1994). The Topographic Parameters viz. Total Watershed Relief (H), Relief Ratio (R_h), Relative Relief (R_r), Ruggedness Number (R_n) and Channel Maintenance factor (C_m) are presented in Table 4.1.5. The estimated values for H, R_h , R_r , R_n , and C_m , for Sub micro-watershed No.1, are 260 m, 0.02, 0.96, 0.1794 and 1449.275/m respectively. The Sub micro-watershed No.2's values for H, R_h , R_r , R_n , and C_m are 260 m, 0.03, 1.37, 0.2002 and 1298.701/m respectively. Whereas for Sub micro-watershed No.2 estimated values are 220 m, 0.04, 1.64, 0.2002 and 909.091/m for H, R_h , R_r , R_n , and C_m respectively.

Table 4.1.5: Topographic Parameter

Topographic Parameter	Sub micro-watershed No.1	Sub micro-watershed No.2	Sub micro-watershed No.3
Total Watershed Relief, H (m)	260	260	220
Relief Ratio, R_h	0.02	0.03	0.04
Relative Relief, R_r	0.96	1.37	1.64
Ruggedness Number, R_n	0.1794	0.2002	0.2002
Channel Maintenance factor, C_m (per metre)	1449.275	1298.701	909.091

4.1.6. Estimation of Run-off and Sediment Production Rate

In general, the transport of detached sediment from the watershed areas through the drainage network, gives rise to appreciable loss of soil fertility, rapid sedimentation of the reservoirs and decrease in available water for irrigation in command areas. A comprehensive watershed management programme may have multiple objectives such as controlling damaging runoff and managing and utilizing the same for useful purposes, controlling erosion and effect reduction in the sediment production, enhancing groundwater storage and the appropriate use of the land and water resources in the watershed.

Watershed prioritization is the ranking of different sub watersheds of a watershed according to the order in which they have to be taken for treatment and soil conservation measures (Suresh *et al.* 2004; Khare *et al.* 2007; Kanth and Hazzan, 2012). Once the watersheds were prioritized, quantitative assessment of hydrological parameters of watersheds such as peak flow and volume of runoff serve as the basic information for adopting suitable soil and water conservation measures in a watershed.

Surface runoff estimation is of immense importance as it directly affects any planning. Chaudhary and Sharma (1998) performed erosion hazard assessment and prioritization based on morphometric parameters like relief ratio, drainage density, drainage texture and bifurcation ratio. For assessing erosion, several empirical models based on the geomorphological parameters were developed in the past for quantifying the sediment yield (Jose and Das, 1982; Misra *et al.* 1984; Rao *et al.* 2006).

4.1.6.1. Run-off

Considering the broad physiographic characteristics, Jose and Das (1982) developed a multivariate model to estimate run-off from a watershed. The mathematical model developed by Jose and Das to calculate the run-off has been followed. The value of Rotundity Factor, R_f of Sub micro-watershed No.1, 2 and 3 has been computed 2.639, 1.778 and 1.987 respectively. The Circulatory Ratio, C_r has been estimated 0.372, 0.414 and 0.436 in case of Sub micro-watershed No.1, 2 and 3 respectively. The Compactness Coefficient, C_c for the three Sub micro-watersheds No.1, 2 and 3 has been estimated 1.639, 1.553 and 1.514 respectively. Whereas Run-off for Sub micro-watersheds No.1, 2 and 3 are recorded 22.988, 20.893 and 21.878 Sq Km-Cm/Sq Km respectively (Table 4.1.6.1).

Table 4.1.6.1: Run-off, Q (Sq Km-Cm/Sq Km)

Parameter	Sub micro-watershed No.1	Sub micro-watershed No.2	Sub micro-watershed No.3
Rotundity Factor, R_f	2.639	1.778	1.987
Circulatory Ratio, C_r	0.372	0.414	0.436
Compactness Coefficient, C_c	1.639	1.553	1.514
Run-off, Q	22.988	20.893	21.878

4.1.6.2. Sediment Production Rate

Sediment production rate (SPR) is useful in deciding the priority of watersheds for adopting conservation measures. Sediment production rate is the volume of sediment produced per unit drainage area per unit time. In the present study, Jose and Das (1982) model was used to estimate SPR. The Rotundity Factor (R_f), Circulatory Ratio (C_r), Compactness Coefficient, (C_c) and Sedimentation Production Rate, (SPR) calculated for three sub micro watersheds are presented in Table 4.1.6.2. The Sedimentation Production Rate has been estimated 0.008913, 0.006397 and 0.007158 ha-m/100 Sq Km/Year for the sub micro watersheds 1, 2 and 3 respectively.

Table 4.1.6.2: Sedimentation Production Rate, SPR (ha-m/100 Sq Km/Year)

Parameter	Sub micro-watershed No.1	Sub micro-watershed No.2	Sub micro-watershed No.3
Rotundity Factor, R_f	2.639	1.778	1.987
Circulatory Ratio, C_r	0.372	0.414	0.436
Compactness Coefficient, C_c	1.639	1.553	1.514
SPR	0.008913	0.006397	0.007158

4.2. Soil

According to Soil Survey Report, NESAC, 2008, Umbaniun micro-watershed has six different soil types: Type 1 (7.61 sq. km)- Deep, excessively drained, fine soils on moderately sloping side-slopes of hills having loamy surface with moderate erosion hazard associated with: Moderately deep, excessively drained, coarse-loamy soils on gently sloping hill tops with very severe erosion hazard and strong stoniness., Type 2 (3.265 sq. km)- Deep, excessively drained, fine soils on gently sloping side-

slopes of hills having loamy surface with moderate erosion hazard associated with: Deep, poorly drained, fine-loamy soils on very gently sloping valleys with very slight erosion hazard and ground water table below one metre depth of the surface., Type 4 (7.253 sq. km)- Deep, excessively drained, fine soils on moderately steep side-slopes of hills having loamy surface with moderate erosion hazard and strong stoniness associated with: Moderately deep, excessively drained, loamy-skeletal soils on very gently sloping hill tops with severe erosion hazard and strong stoniness, Type 5 (16.39 sq. km)- Deep, excessively drained, fine soils on moderately sloping side-slopes of hills having loamy surface with moderate erosion hazard associated with: Moderately deep, excessively drained, fine-loamy soils on gently sloping hill tops with very severe erosion hazard and strong stoniness, Type 7 (4.612 sq. km)- Moderately deep, excessively drained, coarse-loamy soils on very steeply sloping hill escarpment having sandy surface with very severe erosion hazard and strong stoniness associated with: Deep, excessively drained, coarse-loamy soils on steeply sloping hill tops with severe erosion hazard and strong stoniness and Type 8 (0.66 sq. km)- Moderately deep, excessively drained, loamy-skeletal soils on moderately steep side-slopes of hills having sandy surface with very severe erosion hazard and strong stoniness associated with: Shallow, excessively drained, loamy-skeletal soils on moderately steep side-slopes of hills with very severe erosion hazard and strong stoniness (Table 4.2; Figs 4.2a and 4.2b).

Table 4.2: Soil Types and Their Distribution

Sl. No.	Soil type	Area in Sq.km	Description
1	01	7.671	Deep, excessively drained, fine soils on moderately sloping side-slopes of hills having loamy surface with moderate erosion hazard associated with: Moderately deep, excessively drained, coarse-loamy soils on gently sloping hill tops with very severe erosion hazard and strong stoniness.
2	02	3.265	Deep, excessively drained, fine soils on gently sloping side-slopes of hills having loamy surface with moderate erosion hazard associated with: Deep, poorly drained, fine-loamy soils on very gently sloping valleys with very slight erosion hazard and ground water table below one metre depth of the surface.
4	04	7.253	Deep, excessively drained, fine soils on moderately steep side-slopes of hills having loamy surface with moderate erosion hazard and strong stoniness associated with: Moderately deep, excessively drained, loamy-skeletal soils on very gently sloping hill tops with severe erosion hazard and strong stoniness
5	05	16.39	Deep, excessively drained, fine soils on moderately sloping side-slopes of hills having loamy surface with moderate erosion hazard associated with: Moderately deep, excessively drained, fine-loamy soils on gently sloping hill tops with very severe erosion hazard and strong stoniness
6	07	4.612	Moderately deep, excessively drained, coarse-loamy soils on very steeply sloping hill escarpment having sandy surface with very severe erosion hazard and strong stoniness associated with: Deep, excessively drained, coarse-loamy soils on steeply sloping hill tops with severe erosion hazard and strong stoniness
7	08	0.66	Moderately deep, excessively drained, loamy-skeletal soils on moderately steep side-slopes of hills having sandy surface with very severe erosion hazard and strong stoniness associated with: Shallow, excessively drained, loamy-skeletal soils on moderately steep side-slopes of hills with very severe erosion hazard and strong stoniness.

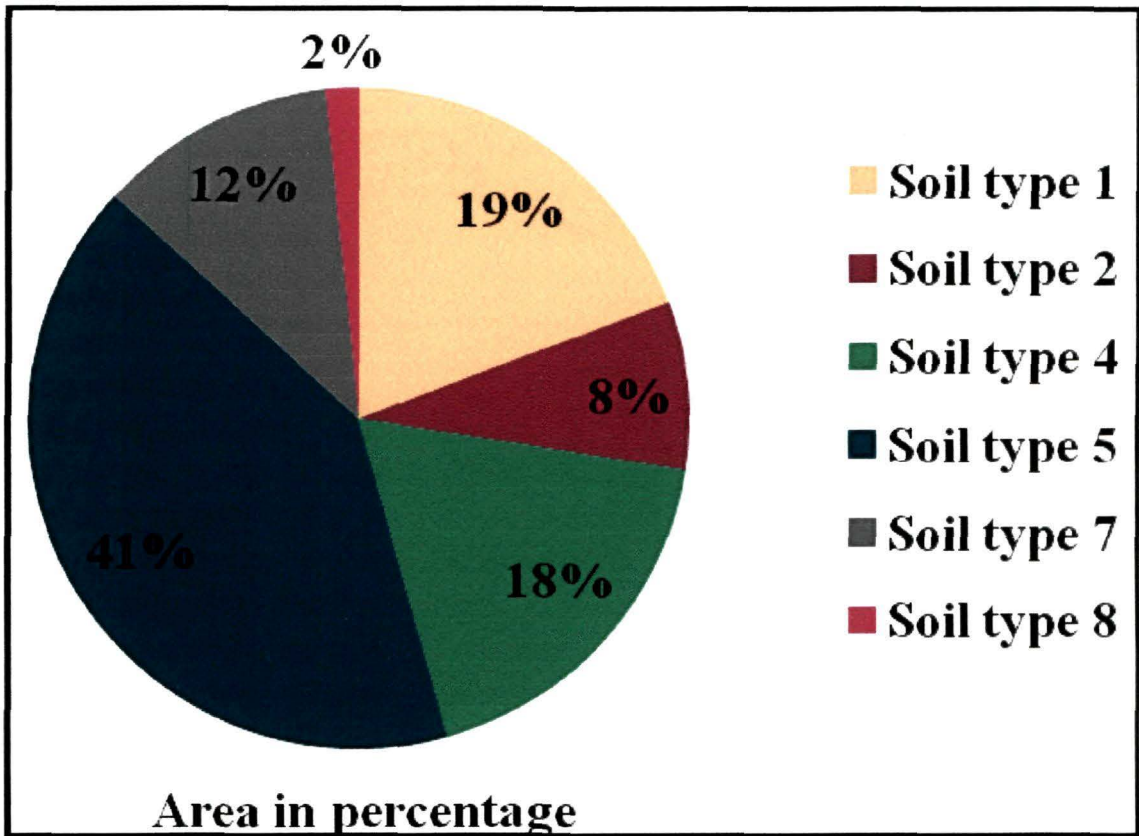


Fig 4.2a: Distribution of different soil types of Umbanion micro-watershed in percentage

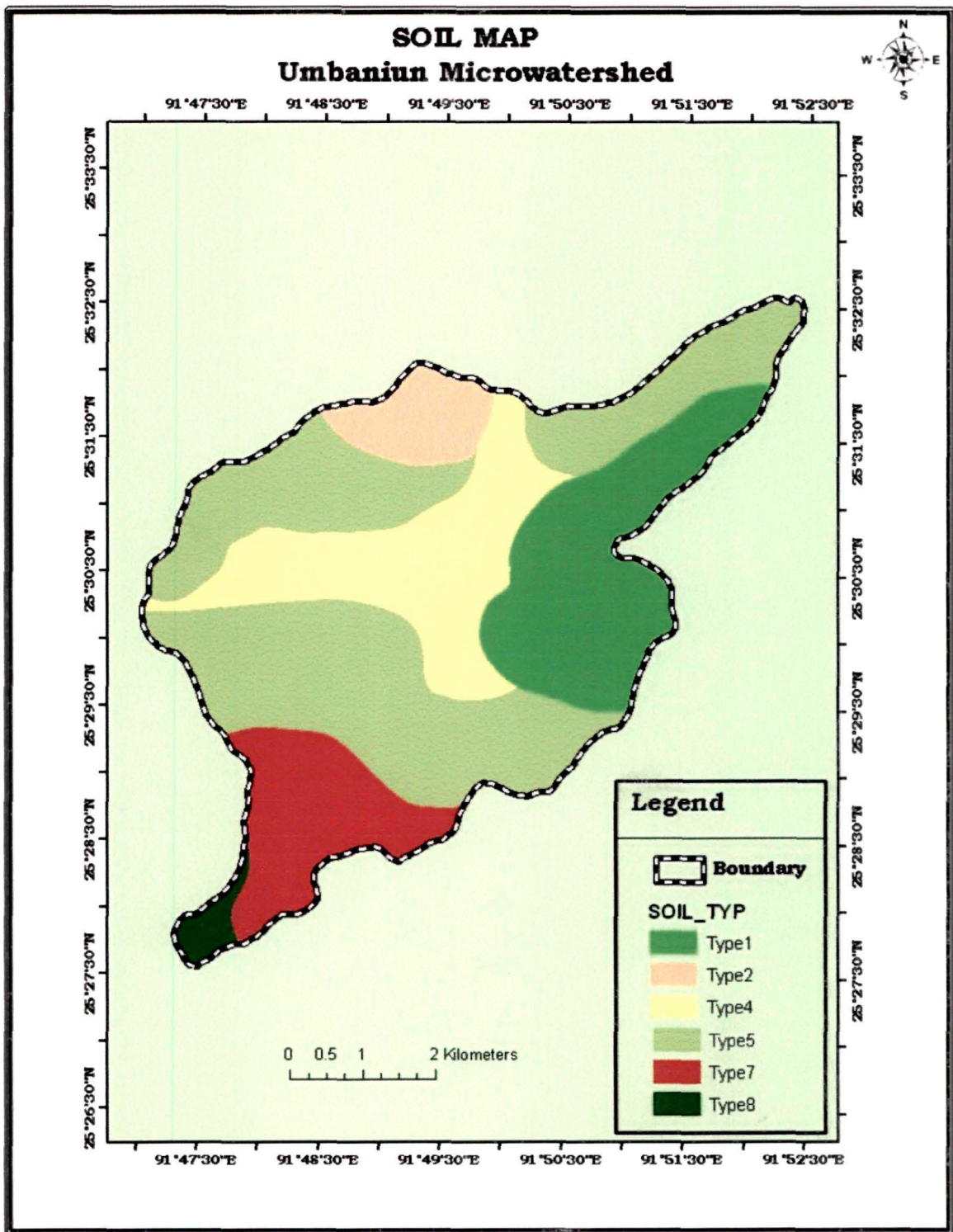


Fig 4.2b: Soils of Umbaniun micro-watershed

4.3. Climate

Climate is one of the most important factors of geographical environment to which man is subject to. It governs agriculture, forests, supply of water, human settlements, industries, tourism, etc.

Four distinct seasons are observed in the study area- Spring - March and April, Summer (Monsoon) - May to September, Autumn - October and November and Winter - December to February.

During March and April, the atmosphere gradually warms up with the advent of Spring. From the middle of April the temperature starts rising to the maximum in the month of June and then decreases gradually. This period may be termed as the Summer (Monsoon) Season. October and November are the two months when the climate is cool and temperate. After November, the winter season sets and continues up to the end of February.

Rainfall starts by the third week of May and continues right up to the end of September and sometimes well into middle of October. The Rainfall (mm), Maximum and minimum temperature ($^{\circ}\text{C}$) and Relative humidity (%) for twenty years (1991-2010) of the study area has been presented in Table 4.3.

Table 4.3: Meteorological Data

Year	Rainfall (mm) (Normal- 2243.7mm)	Temperature (°C)		Relative Humidity (%)	
		Maximum	Minimum	Morning	Evening
1991	2544.6	20.7	13.0	-	-
1992	1855.3	20.7	12.8	-	-
1993	2093.7	20.6	12.8	-	-
1994	1564.7	21.0	13.1	69	83
1995	2292.2	21.1	13.3	73	78
1996	1796.4	21.3	13.2	67	83
1997	2113.3	20.3	12.4	71	86
1998	2016.0	21.4	13.5	75	86
1999	2304.7	21.7	13.8	68	82
2000	2278.6	20.8	12.8	70	83
2001	2101.2	20.6	13.2	68	83
2002	2480.6	20.6	12.7	71	84
2003	2138.0	20.9	12.4	70	85
2004	3071.5	20.8	12.9	71	84
2005	2067.7	21.2	13.5	70	84
2006	1409.6	21.5	13.5	68	83
2007	2920.0	20.7	12.9	72	86
2008	1948.9	21.1	12.9	71	85
2009	1947.1	21.8	12.7	71	84
2010	2021.4	21.9	12.9	70	82

4.4. Elevation

“Elevation” is the height in feet (or meters) above sea level of a particular point or line. An individual “contour line,” seen in brown on topo-maps, connects points of equal elevation. Elevation is a topographic concept often associated with mountains and hills. Elevation plays an important role in erosion control, irrigation, agricultural planning etc. Even slight changes in elevation can make big differences in the human relationship with the environment. The elevation of the micro watershed ranges from 1571 m to 1955 m. The area under different elevation classes are presented in Table 4.4. Maximum and minimum area of land falls under class 1700 m

to 1741 m and 1571 m to 1613 m elevations respectively (Table 4.4; Figs 4.4a and 4.4b).

Table 4.4: Elevation

Elevation (m)	Area (ha)
1913 to 1955	101.767
1871 to 1912	167.147
1827 to 1870	485.214
1785 to 1826	765.207
1742 to 1784	1018.6
1700 to 1741	900.328
1656 to 1699	500.480
1614 to 1655	26.9216
1571 to 1613	25.9552

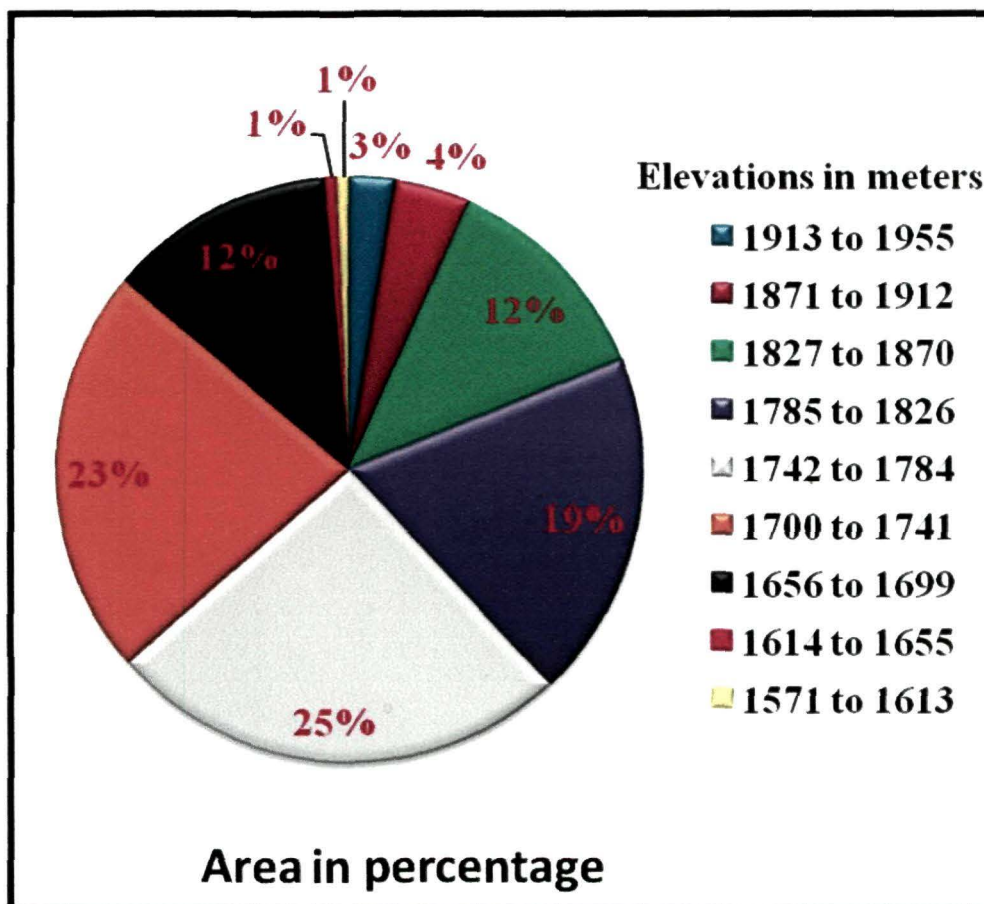


Fig 4.4a: Percentage distribution of different elevations (in meters) of Umbanui micro-watershed.

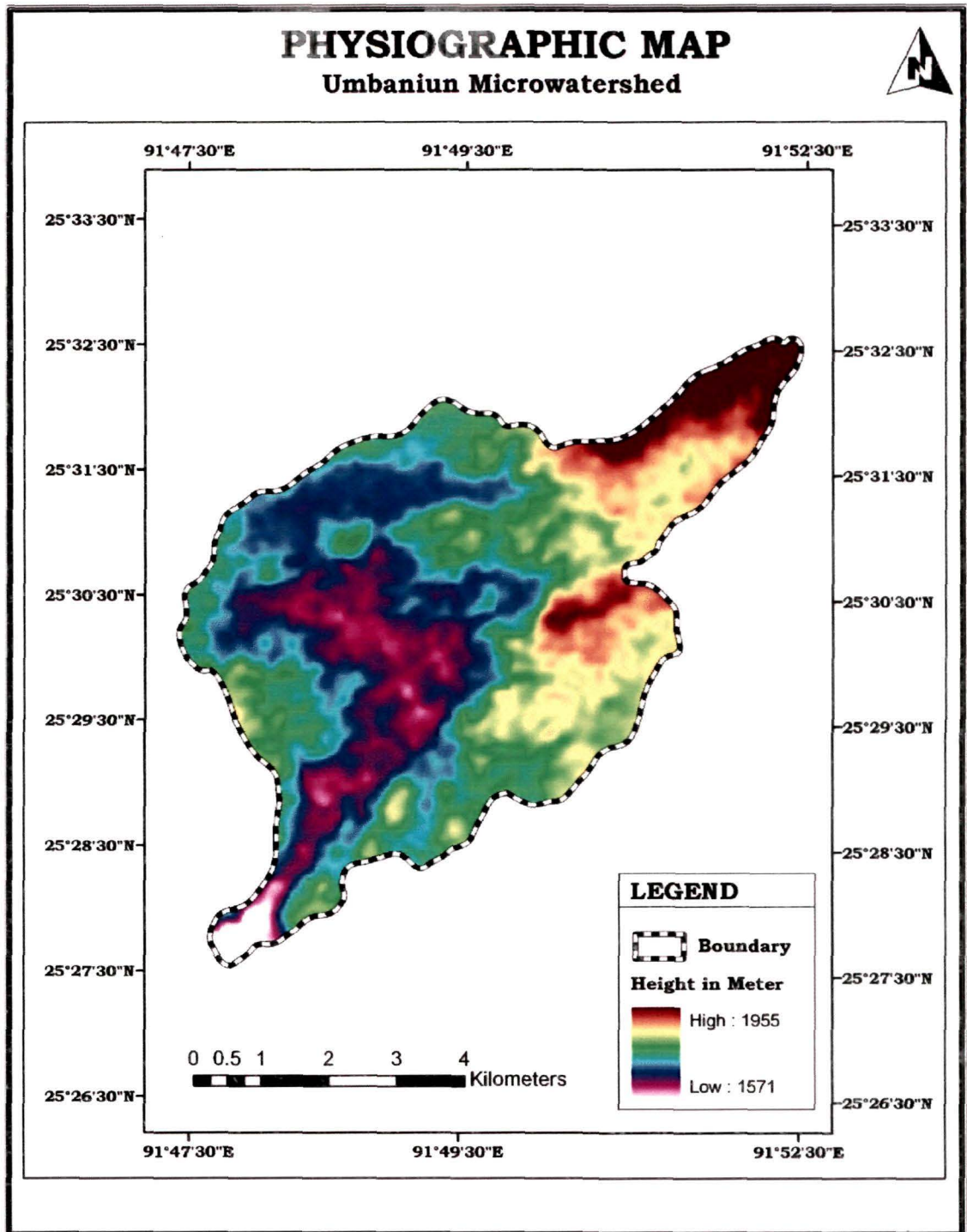


Fig 4.4b: Physiography of Umbaniun micro-watershed

4.5. Aspect

The aspect of land mass/hills plays an important role in erosion. It has been established that the South-facing slopes appear to be more susceptible to soil erosion while the north-facing slopes are the least affected (Luk *et al.* 1997). South-east facing slope (679.59 ha) occupies the highest portion as compared to the north-east facing slope (399.978 ha) in the Umbaniun micro-watershed (Table- 4.5; Figs 4.5a and 4.5b).

Table 4.5: Aspect Data

ASPECT DATA	Area (ha)	%
North	429.382	10.77
West	423.846	10.63
South-west	416.598	10.45
North-west	580.352	14.56
South	597.893	15.00
South-east	679.59	17.05
East	457.98	11.49
North-east	399.978	10.04

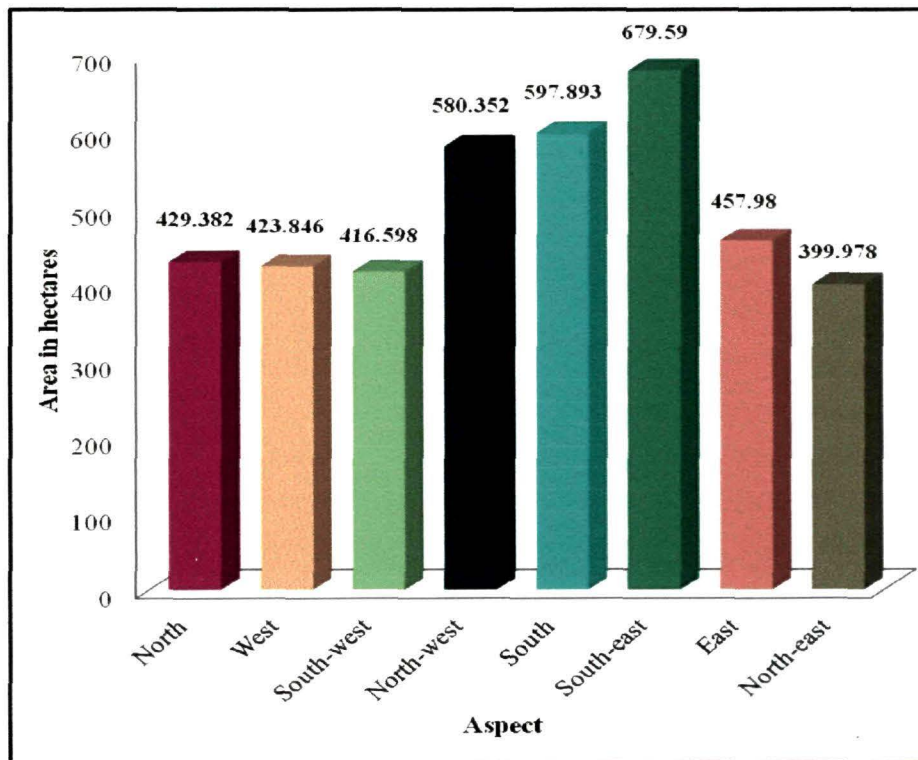


Fig 4.5a: Bar diagram showing distribution of different aspects of Umbaniun micro-watershed.

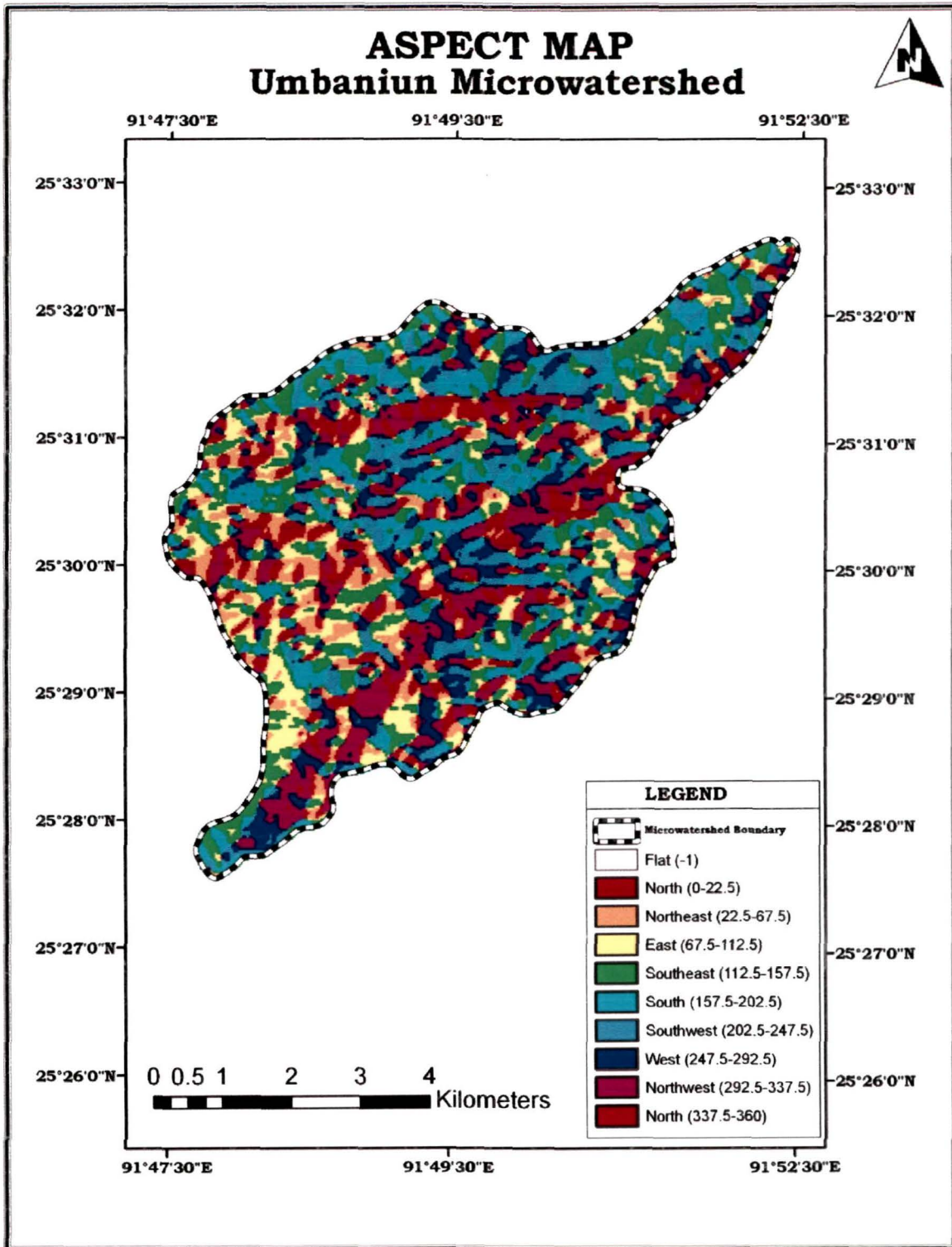


Fig 4.5b: Aspect of Umbaniun micro-watershed

4.6. Slope

Slope map is generated from DEM in Arc GIS 9.3 software using “3D Analysis Tool”. Five slope categories are found in the Umbaniun micro-watershed, Nearly level to Gentle slope(0-10), Moderate slope(11-20), Moderately steep slope(21-30), Steep slope(31-40), Very steep slope(more than 40) of which the first category is found to occupy the major portion of the micro-watershed as shown in Table 4.6 (Fig 4.6).

Table 4.6: Slope categories

Slope in degree	Slope categories	Area in ha.	Percentage of the total area
0-10	Nearly level to gentle slope	3727.28	93.518
11-20	Moderate slope	7.19	0.1804
21-30	Moderately steep slope	0.30	0.0075
31-40	Steep slope	250.65	6.2889
>40	Very steep slope	0.20	0.0050

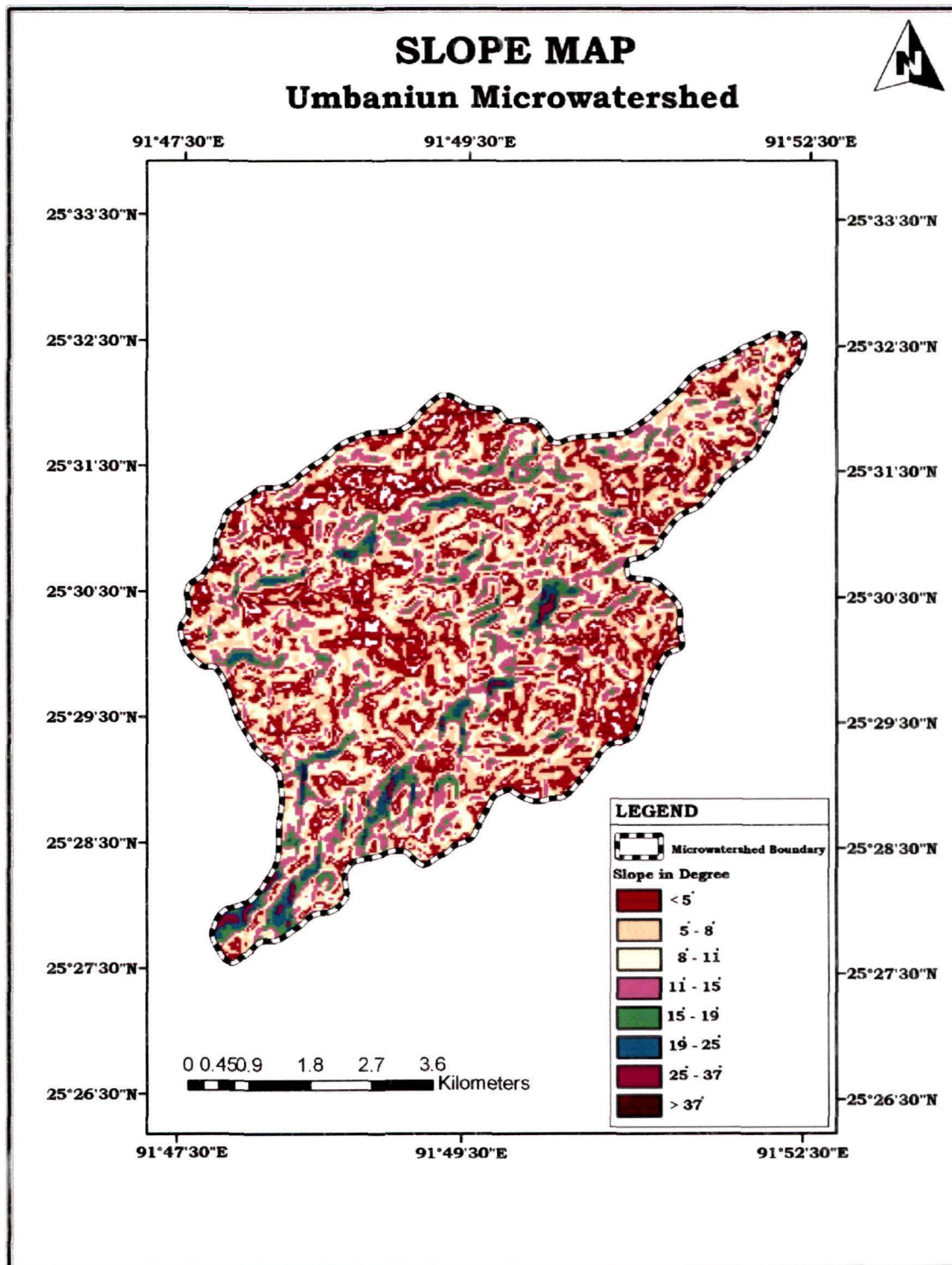


Fig 4.6: Slope of Umbaniu micro-watershed

4.7. Land Capability Class

Land capability classification is a system of grouping soils primarily on the basis of their capability to produce common cultivated crops and pasture plants without deteriorating the sites over a long period of time. Umbaniun micro-watershed has been classified into 7 classes based on slope, aspects and land cover (Table 4.7). The area within land capability class 1, 2, 3, 4, 5, 6, and 7 has been estimated 1953.790, 344.907, 870.755, 279.960, 289.678, 95.593 and 150.938 hectares respectively. The limitations of land mass under different land capability class are recorded and mentioned in table 4.7. This information would help in adoption of appropriate cropping systems and conservation measures to maintain the sustainability of land in the study area (Figs 4.7a and 4.7b).

Table 4.7: Land Capability Class

Class	Area (ha)	Limitation
I	1953.790 (49.02%)	Good Soils have no or minimum limitations. Good for farming.
II	344.907 (8.65%)	Soils have slight to moderate limitations that reduce the choice of plants or require moderate conservation practices.
III	870.755 (21.85%)	Soils have moderate to severe limitations that reduce the choice of plants or require special conservation practices, or both.
IV	279.960 (7.02%)	Soils have very severe limitations that restrict the choice of plants or require very careful management, or both.
V	289.678 (7.27%)	Soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
VI	95.593 (2.40%)	Soils have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
VII	150.938 (3.79%)	Soils have very severe limitations that make them unsuited to cultivation and that restrict their use mainly to grazing, forestland, or wildlife.

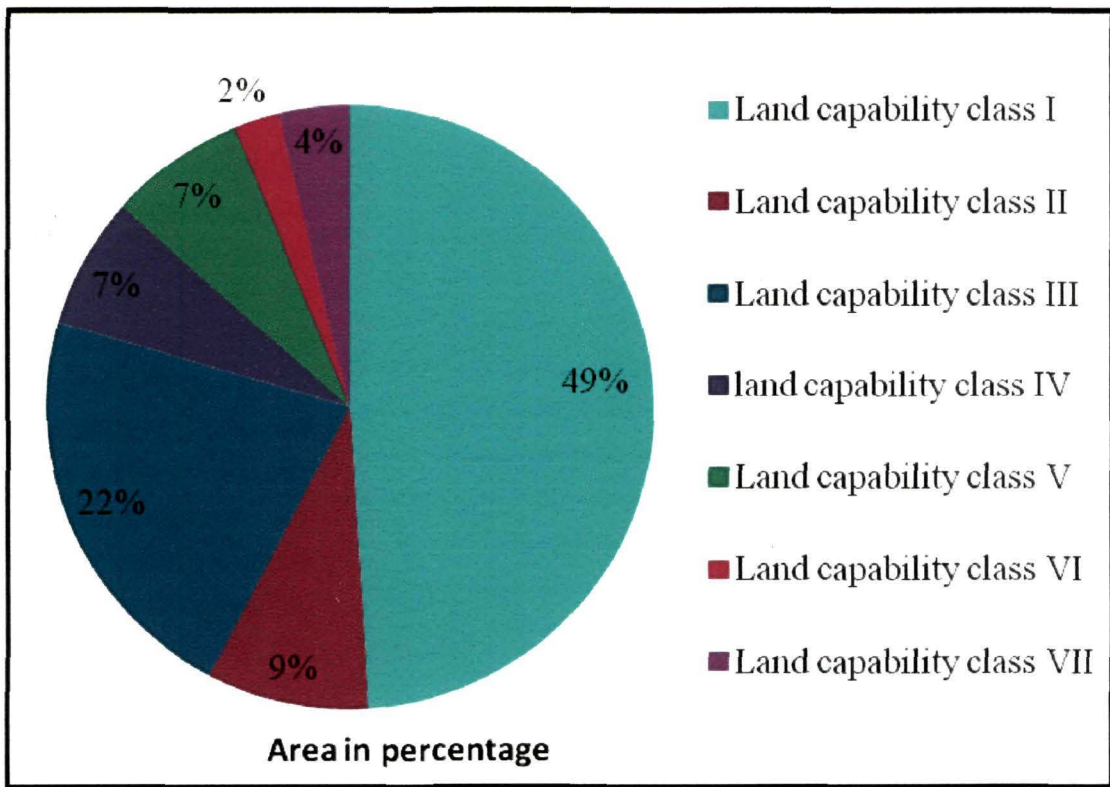


Fig 4.7a: Percentage distribution of different land capability classes of Umbaniun micro-watershed.

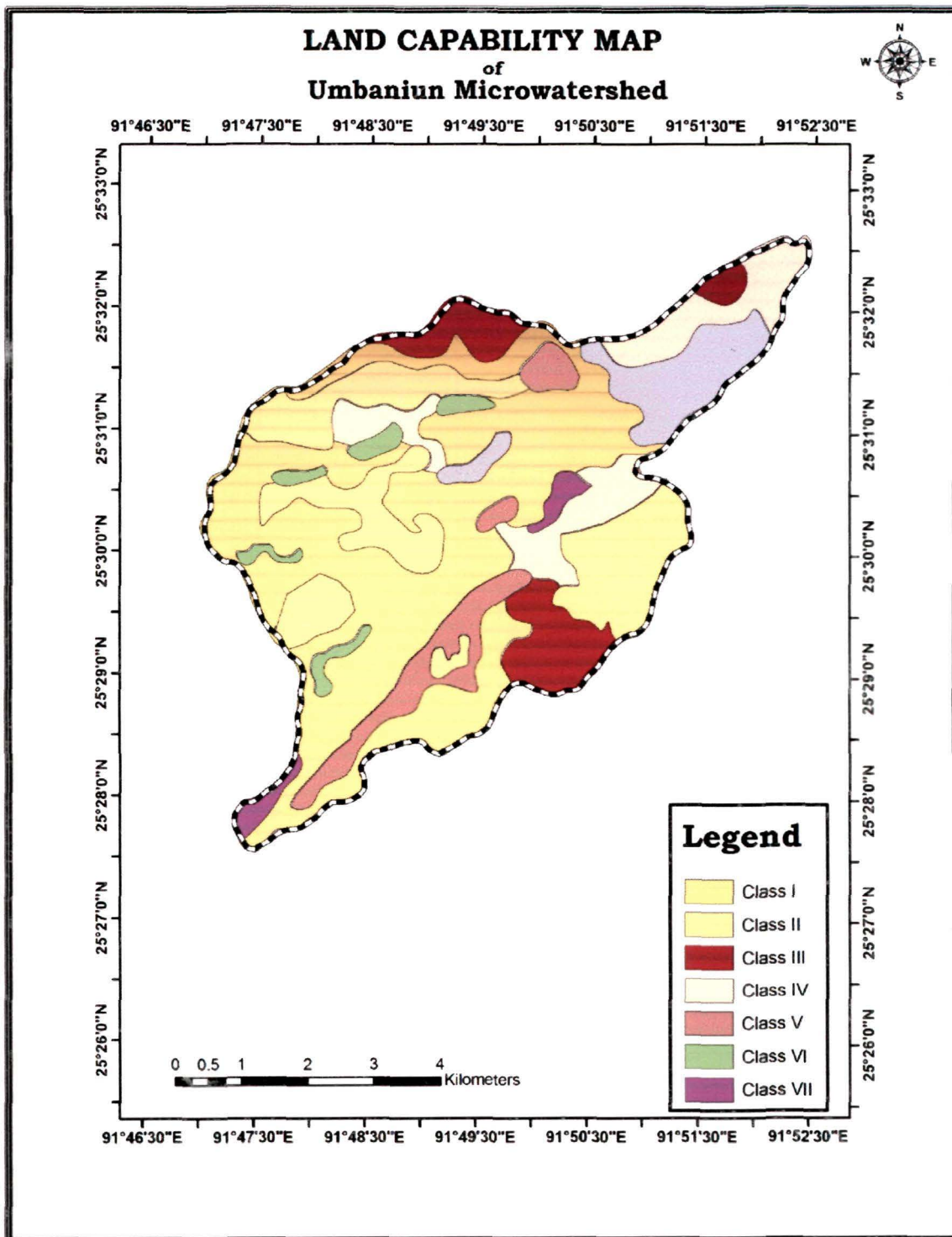


Fig 4.7b: Land capability class of Umbaniun micro-watershed

4.8. Land Use/Land Cover

A decadal change in land use systems has been studied for 30 years from 1977 to 2007 using Arc GIS 9.3 software. In the present study, a big change in land use/land cover of Umbaniun micro-watershed is observed where natural ecosystems like water bodies, dense forest and shrub/grass land declined to a large extent in 30 years with the advent of other land uses as shown in the Table 4.8 below.

Dense forest cover decreases from 48.8 percent in 1977 to only 0.11 percent in 2007 in a very short period of time (i.e. in three decades) whereas the open forest cover increases from 17.2 percent in 1977 to 31.5 percent in 2007. Table 4.8 shows a slight increase in water bodies from 12.25 ha in 1977 to 21.62 ha in 2003 however, a major decline of the same takes place in just four years time i.e. from 21.62 ha in 2003 to only 4.41 ha in 2007 and in three decades, there is a loss of 7.84 ha water bodies. Land uses like Settlement area and Agricultural land increase rapidly and consistently in three decades from 1977 to 2007 (Figs 4.8a to 4.8i).

Table 4.8: Decadal Change in Land Use/Land Cover (1977 To 2007)

Parameter	Landuse 1977 (ha)	Landuse 1987 (ha)	Landuse 2003 (ha)	Landuse 2007 (ha)	Change in 30 years (ha)
Water bodies	12.25 (0.31%)	13.94 (0.35%)	21.62 (0.54%)	4.41 (0.11%)	(-) 7.84
Dense Forest	1943.21 (48.8%)	1738.86 (43.6%)	1440.75 (36.1%)	1146.76 (28.8%)	(-) 796.45
Open Forest	687.00 (17.2%)	811.12 (20.4)	1081.44 (27.1%)	1257.20 (31.5%)	(+) 570.2
Agricultural land	575.15 (14.4)	589.34 (14.8%)	722.06 (18.1%)	953.07 (23.9%)	(+) 377.92
Abandoned land	218.73 (5.49%)	197.40 (4.95%)	159.40 (4.0%)	34.84 (0.87%)	(-) 183.89
Shrub/grass	163.67 (4.11%)	127.19 (3.19%)	95.36 (2.39%)	129.22 (3.24%)	(-) 34.45
Degraded land	134.42 (3.37%)	212.98 (5.34%)	190.56 (4.78%)	60.85 (1.53%)	(-) 73.57

Mining/Quary	191.90 (4.81%)	173.41 (4.35%)	61.00 (1.53%)	114.04 (2.86%)	(-) 77.86
Settlement Area	59.29 (1.49%)	121.38 (3.05%)	213.43 (5.36%)	285.23 (7.16%)	(+) 225.94

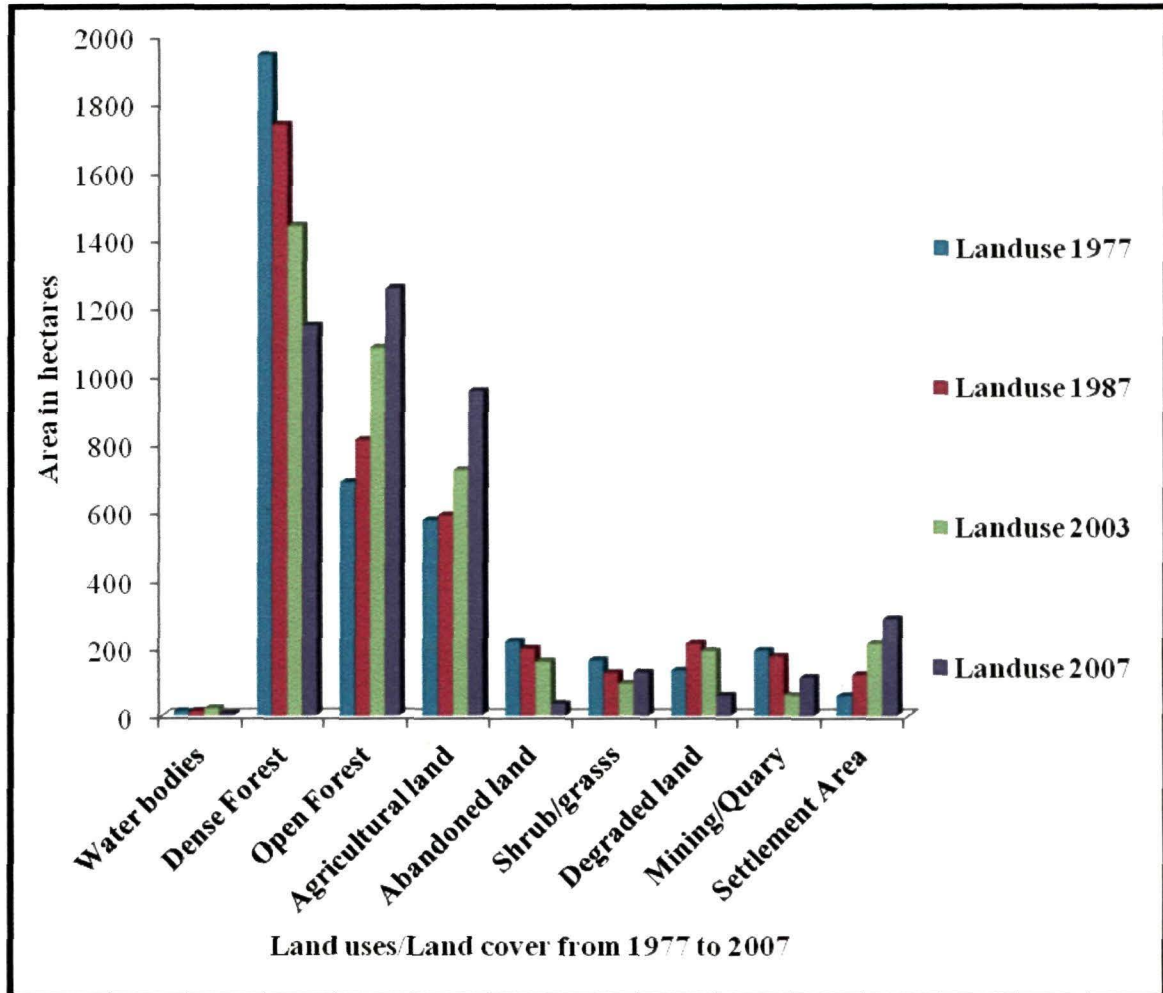


Fig 4.8a: Graphical representation Land use/Land cover in 1977, 1987, 2003 and 2007

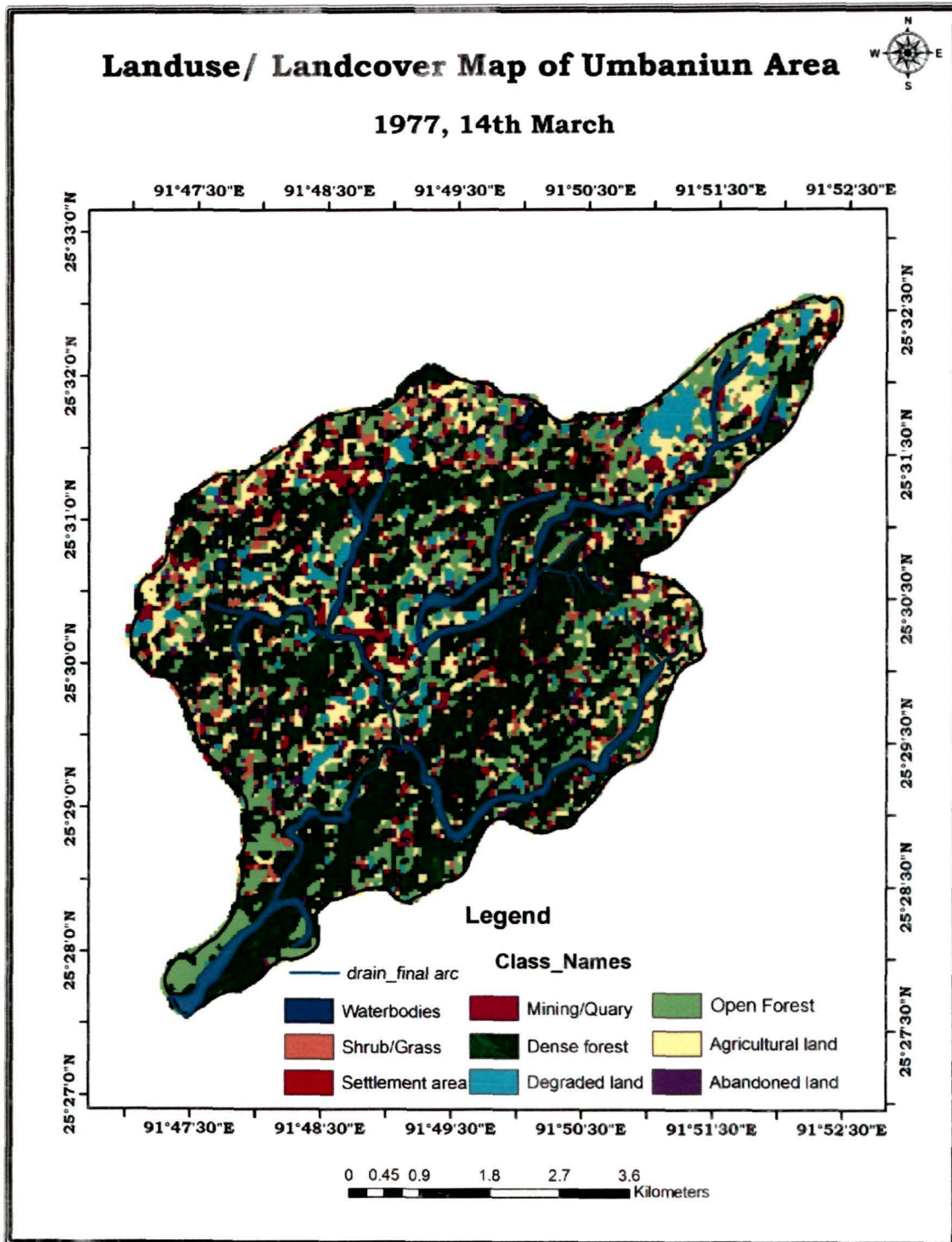


Fig 4.8b: Land use/land cover of Umbaniun micro-watershed in 1977

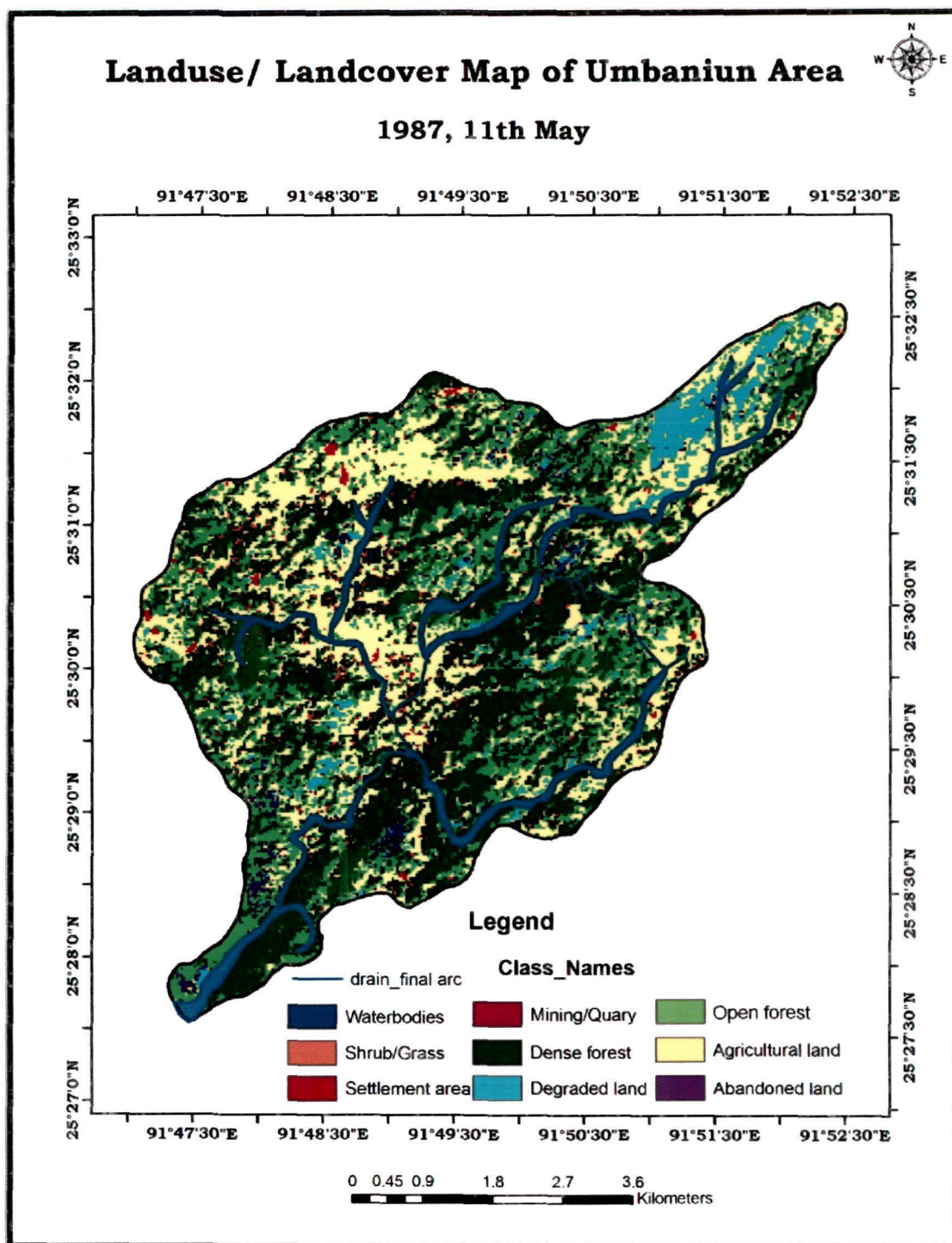


Fig 4.8c: Land use/land cover of Umbaniun micro-watershed in 1987

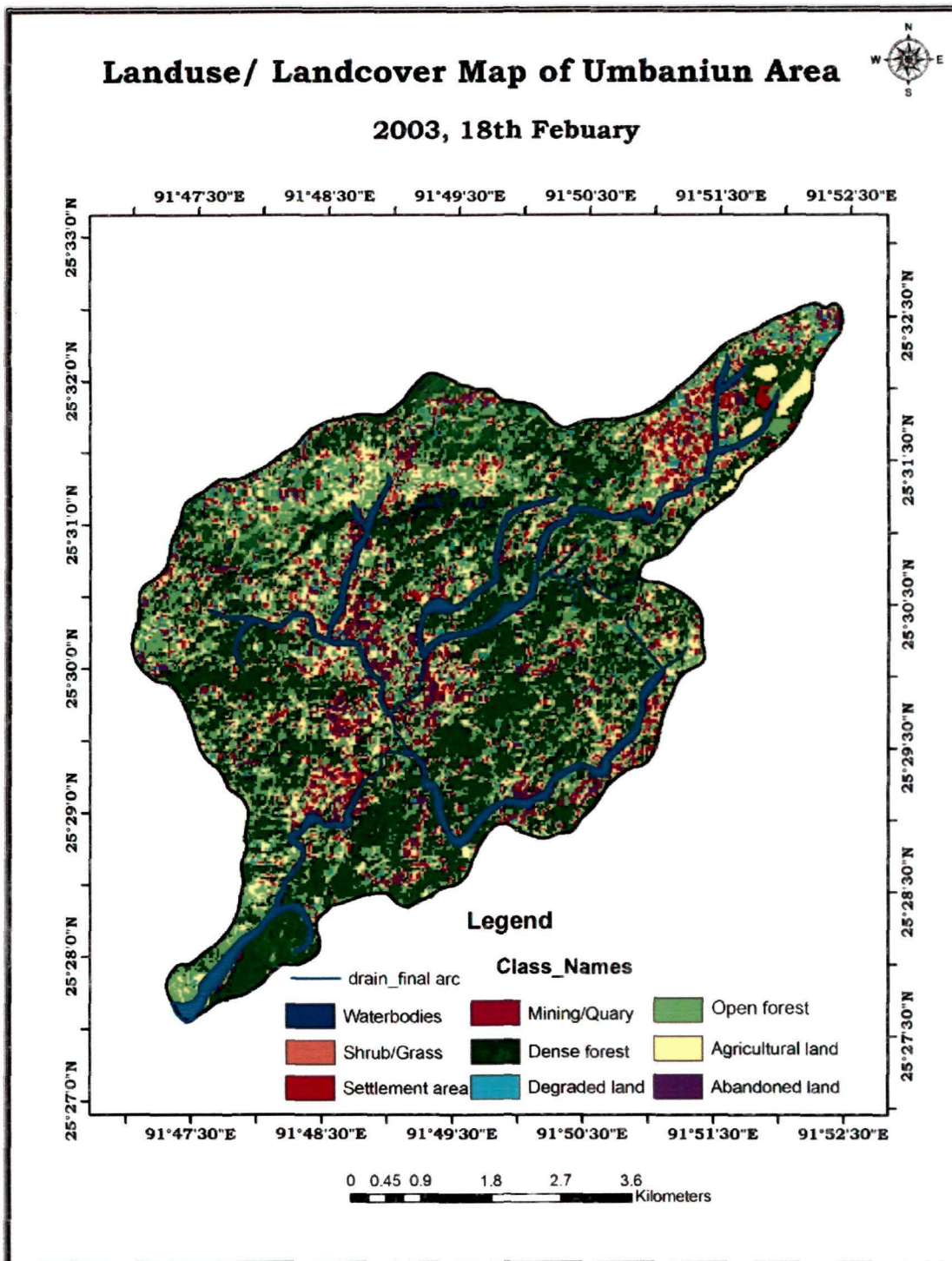


Fig 4.8d: Land use/land cover of Umbaniun micro-watershed in 2003

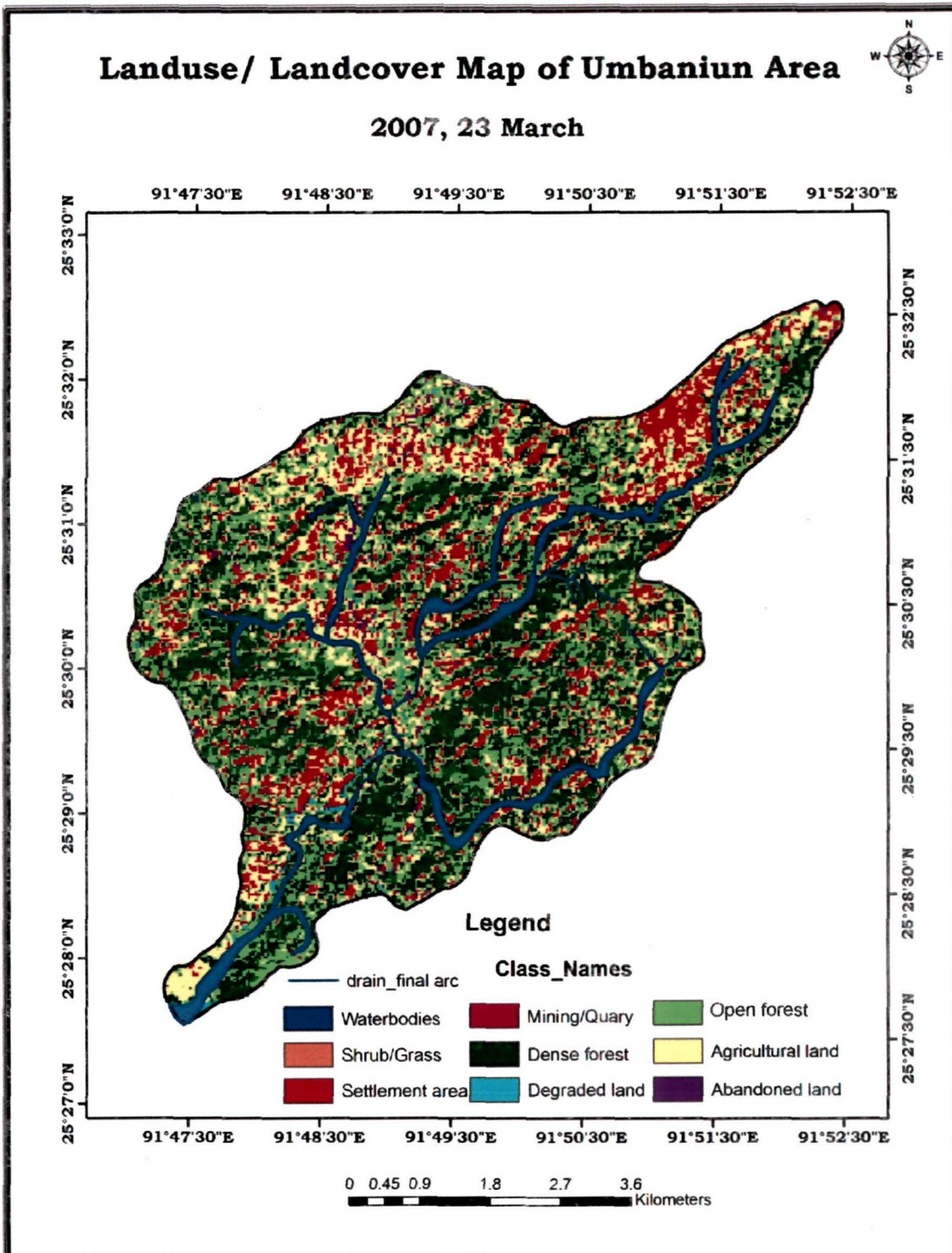
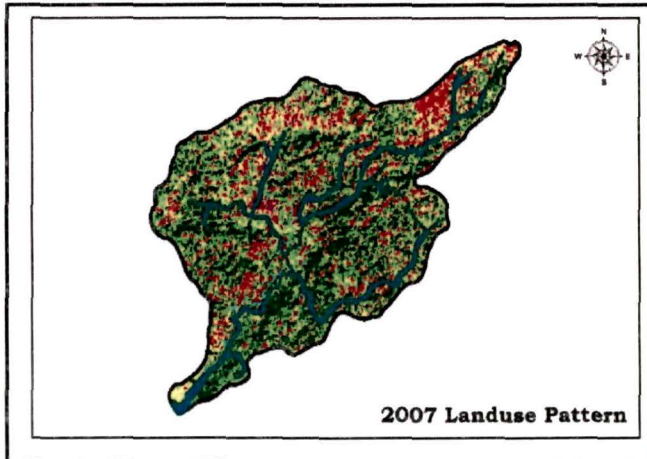
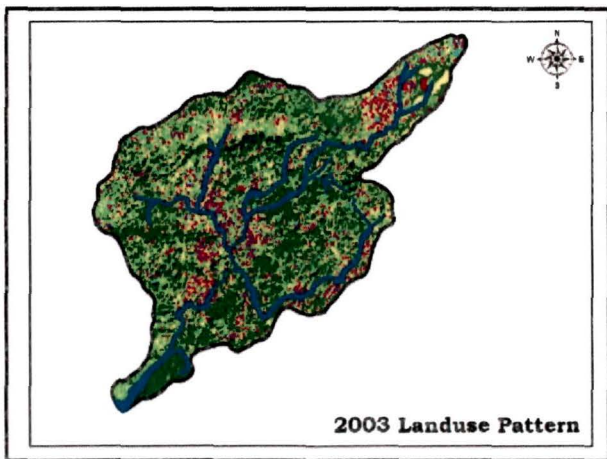
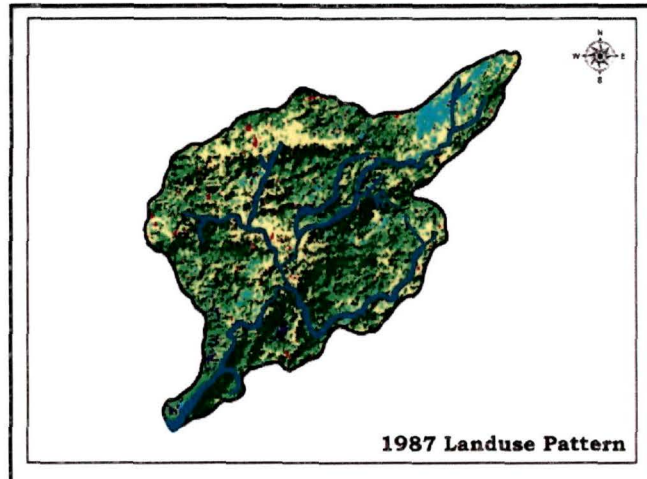
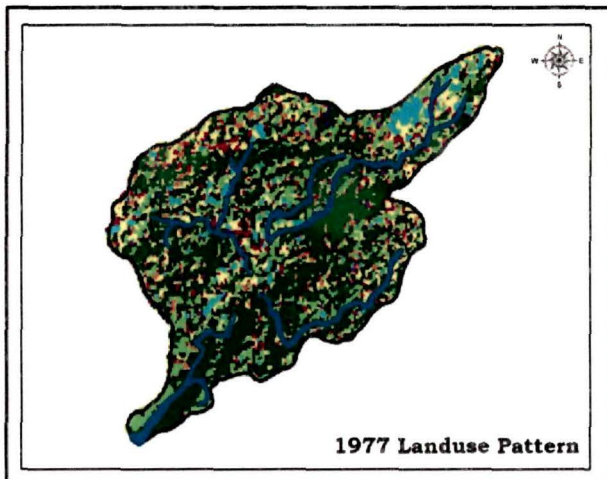


Fig 4.8e: Land use/land cover of Umbaniun micro-watershed in 2007

Landuse/Landcover Changing Scenario



0 1.25 2.5 5 7.5 10
Kilometers



Fig 4.8f: Change in land use/land cover of Umbaniun micro-watershed from 1977 to 2007

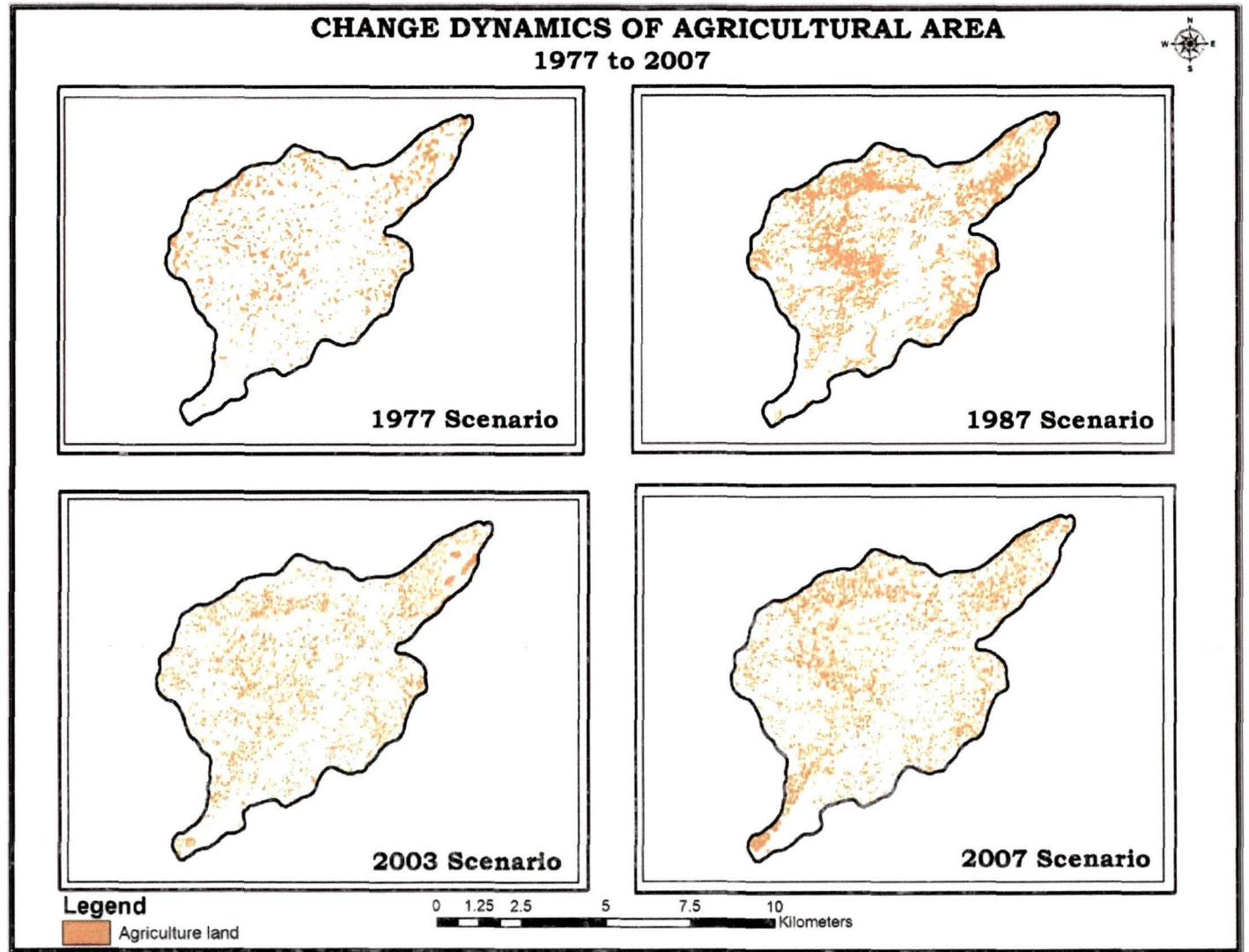


Fig 4.8g: Change in agricultural land cover of Umbaniun micro-watershed from 1977 to 2007

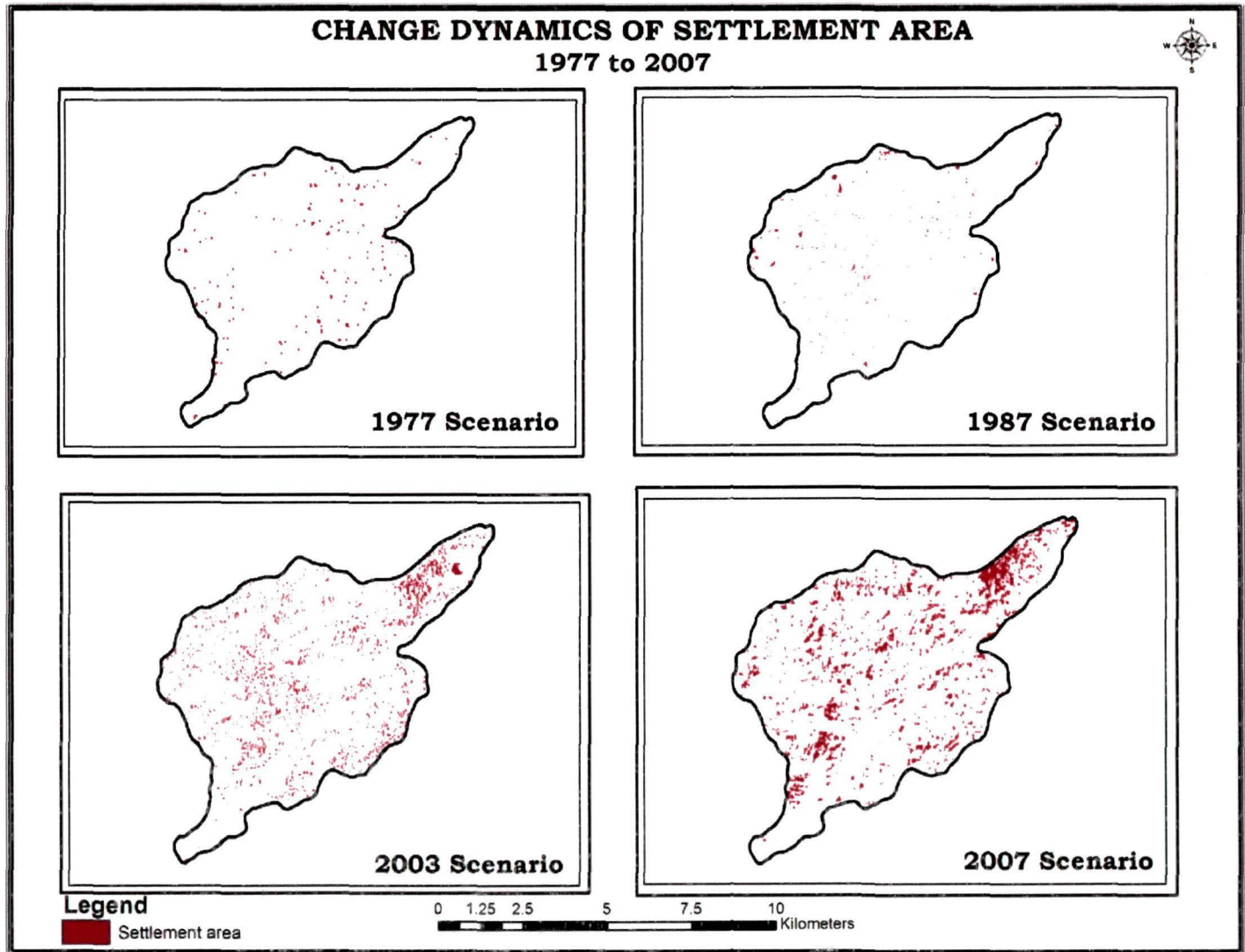


Fig 4.8h: Change in Settlement area of Umbaniun micro-watershed from 1977 to 2007

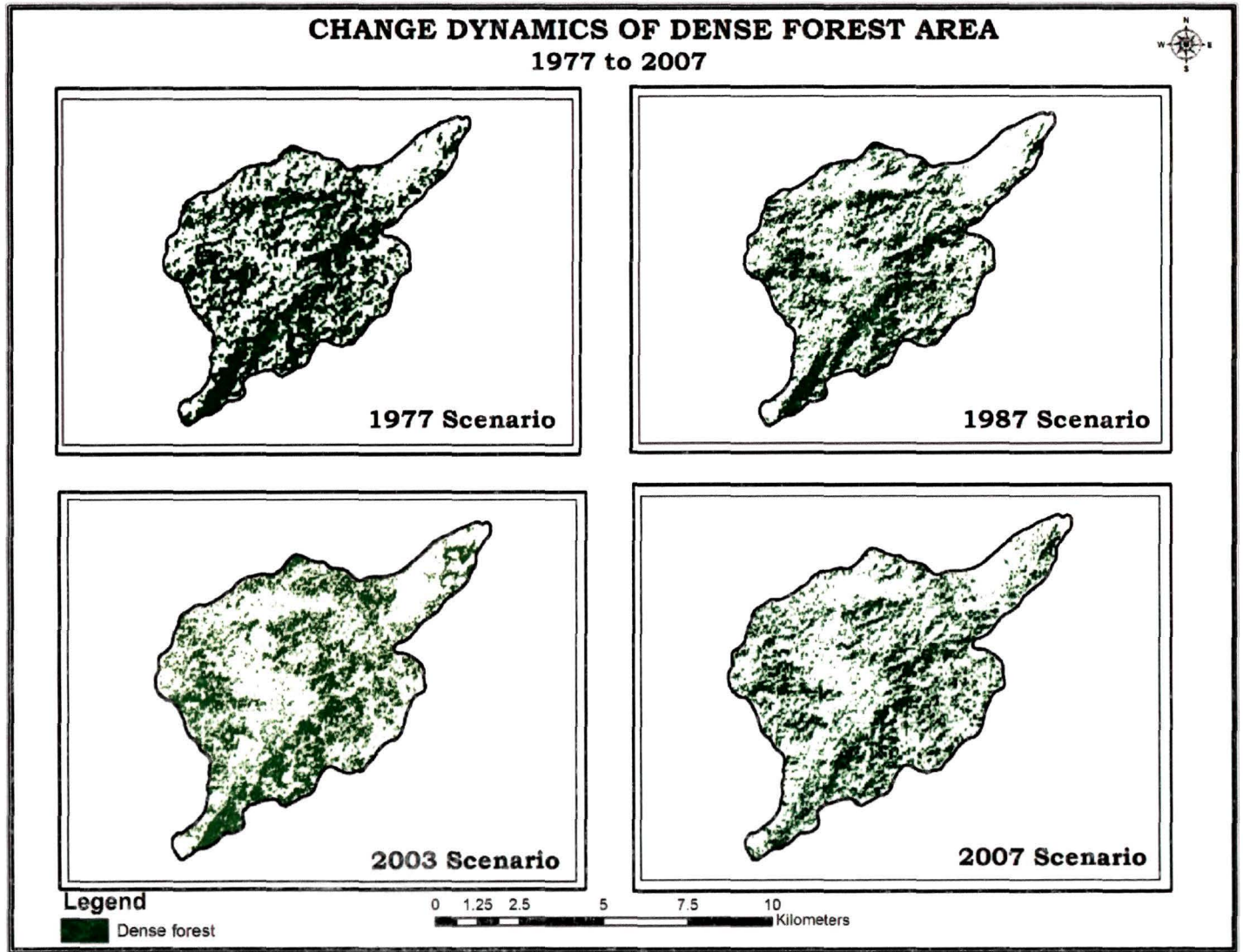


Fig 4.8i: Change in dense forest cover of Umbaniun micro-watershed from 1977 to 2007

4.9. Normalized Difference Vegetation Index

The most common measurement of density of plant growth is called the Normalized Difference Vegetation Index (NDVI). Very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow. Moderate values represent shrub and grassland (0.2 to 0.3), while high values indicate temperate and tropical rainforests (0.6 to 0.8). A decadal change of NDVI values of Umbaniun Micro-watershed has been studied for 30 years (from 1977 to 2007). In the present study it is found that there is a decrease in the density of plant growth as compared from 1977 to 2007 as shown in the Table 4.9. In 1977, Class V has an NDVI value range of 0.3333 to 0.5384 representing a good and healthy forest cover occupying an area of 11.87 sq km whereas, Class I with an NDVI value range of -0.3333 to 0.0526 representing barren areas of rock and sand occupy only 4.56 sq km. In 1987, the vegetation cover is still good as the Class I (-0.6923 to 0.05263), a representative of barren lands of rock and sand occupies only 5.79 sq km and the Class V (0.3488 to 0.5833), a representative of good and healthy forest cover occupies 10.01 sq km of Umbaniun micro-watershed. After 20 years, from 1987 to 2007, the vegetation status is found to have degraded to a great extent which is reflected by a decrease in NDVI values presented in Table 4.9 where the Class V (NDVI range is 0.1276 to 0.3181), a representative of shrub and grasslands, occupies only 5.95 sq km whereas, Class I (NDVI range is -0.5862 to -0.1923), a representative of barren lands of rocks and sand, occupies about 9.78 sq km in the Umbaniun micro-watershed (Fig 4.9).

Table 4.9: NDVI Value in 1977, 1987, 2004 and 2007

1. NDVI value range of 1977	
i. -0.333 to 0.0526	4.56 sq.km
ii. 0.0526 to 0.1528	8.57
iii. 0.1428 to 0.2307	4.45
iv. 0.2307 to 0.3333	10.11
v. 0.3333 to 0.5384	11.87
2. NDVI value range of 1987	
i. -0.6923 to 0.05263	5.79sq.km
ii. 0.05263 to 0.14851	5.99
iii. 0.14851 to 0.24074	7.86
iv. 0.24074 to 0.3488	9.54
v. 0.3488 to 0.58333	10.01
3. NDVI value range of 2004	
i. -0.5806 to -0.1666	8.99 sq.km
ii. -0.1666 to -0.0514	7.89
iii. -0.0514 to 0.0721	6.77
iv. 0.0721 to 0.19402	8.34
v. 0.19402 to 0.4666	7.96
4. NDVI value of 2007	
i. -0.5862 to -0.1923	9.78 sq.km
ii. -0.1923 to -0.0408	7.76
iii. -0.0408 to 0.0467	8.21
iv. 0.0467 to 0.1276	7.86
v. 0.1276 to 0.3181	5.95

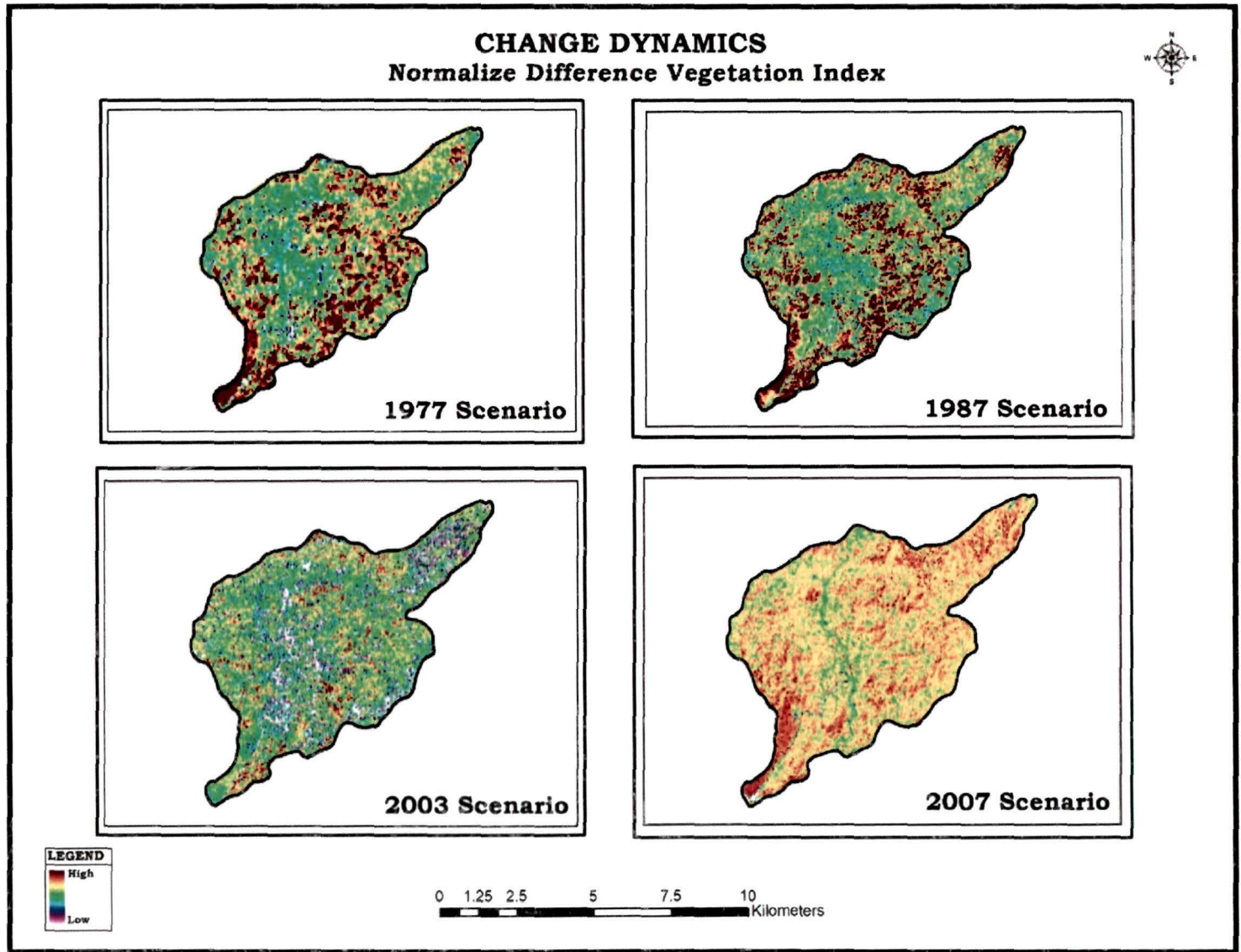


Fig 4.9: Change dynamics of NDVI of Umbanuiun micro-watershed from 1977 to 2007

4.10. Cropping system

4.10.1. Agriculture

Agriculture is the main stay of the people of Umbaniun Micro-watershed, occupying 23.91% of the total land area. In general the farmers grow their crops both in the valleys as well as on the hill slopes under permanent cultivation. The farmers practice intensive rain-fed farming with heavy application of chemical fertilizers and pesticides.

The land holdings are small with area ranging from 0.2 to 0.5 ha per family. Farming in Umbaniun Micro-watershed depends mostly on human labour from land preparation to harvesting. Farmers generally depend on local made farm implements like spade, lever, knife, baskets etc.

Wherever jhum cultivation is practised, the forest is cut down and the plant parts (branches and twigs) are left for 3 to 4 weeks till they are completely dried. Then the dried branches and twigs are collected and arranged in small rows covered with thin soil (locally known as “bun”) parallel to the slope of the hill. This practice is locally known as “Thang bun”. After the “buns” are completely burnt, the seeds (usually beet and cabbage) are sown without application of any fertilizer.

Terrace cultivation is also found to be a common practice in the hills of Umbaniun Micro-watershed. This is found on the hill slopes where the permanent/settled cultivation is practised. These traditional systems of cultivation practices are well adapted to the environmental conditions (Jeeva *et al.* 2006) especially on the hill slopes to increase productivity and also to conserve the soil, moisture and nutrients (Anon., 2001). In this system, bench terraces are constructed

on hill slopes running across the slopes. The space between two buns is levelled using cut and hill method. The vertical interval between the terraces is not usually more than one metre. Such measures help to prevent soil erosion and retaining maximum rainwater within the slopes and safely disposing off the excess runoff from the slopes to the foot hills (Awasthi & Borthakur, 1986; Misra *et al.* 1992; Sonowal & Dutta, 2002; Singh, 2002).

4.10.2. Cropping Pattern

Crop cultivation is practised nearly throughout the year starting from February to October. The major horticultural crops cultivated for commercial purposes are Potato (*Solanum tuberosum*): mid Feb to mid of June; Cauliflower (*Brassica oleracea*): July to October; French bean (*Phaseolus vulgaris*): April to July; and Radish, Muli (*Raphanus sativus* L.): July to October.

Potato (*Solanum tuberosum*) is one of the most important horticultural crops grown in the hilly regions of Meghalaya in Northeast India. Potato crop occupies a major place in the cropping pattern. Hence, it significantly contributes to the rural agrarian economy of Meghalaya. In addition, potato forms an integral part of the dietary habits of people in the state (Dubey and Sah, 2009).

In Umbaniun Micro-watershed, potato cultivation starts from the month of February and is harvested in the month of July. This is planted in rows locally known as “Nurs” using potato tubers. Cow dung or pig dung are used along with chemical fertilizers like urea and superphosphate. Potato is usually planted along with maize (*Zea mays* L.) either on both sides or in the middle of the “Nurs”.

Cultivation of cauliflower (*Brassica oleracea*) starts right after the harvest of potato, that is, in the month of July and its growing season is from July to October. It is known to be the most important crop to the people of Umbaniun Micro-watershed because of the maximum returns it gives as compared to the other crops. It is reported that growing of this particular crop is labour intensive. The crop is very sensitive to even slight change of weather and is vulnerable to pest attack, thus, special care is needed to take from the time of plantation in the nursery to the harvesting stage. It involves the use of huge quantity of fertilizers (both organic and chemical fertilizers) and chemical pesticides. It has been reported that its continuous cultivation, two or three years, results in a marked decline in the yield due to tuber formation in the roots (the disease is locally known as “*man sohlah*” and in order to fix this problem, the farmers adopt alternate farming system and grow either French bean or radish for one to two years. Adoption of alternate farming systems helps in restoring the land productivity, suitable for cauliflower cultivation.

The growing season of French bean (*Phaseolus vulgaris*) is April to July and Radish {*Raphanus sativus* L. (Muli)} is July to October in the study area.

4.10.3. Crop Yield

Study on the average income derived from some major crops of Umbaniun Micro-watershed has been carried out to rank them in term of return. Cauliflower is the most beneficial horticultural crop as it has the maximum net benefit of Rs 1, 53, 581.1/- with the total expenditure Rs 80, 540.55/- per hectare, whereas, potato has the least benefit Rs 43, 148.64/- with the total expenditure Rs 97, 391.9/- per hectare (Table: 4.10.3; Fig 4.10.3).

Table 4.10.3: Average Income Generated From Cultivation of Some Major Crops

Crop	Growing Season	Total Expenditure (1ha)	Average Income (1ha)
<i>Solanum tuberosum</i>	Mid Feb-June	Rs 97, 391.9/-	Rs 43, 148.64/-
<i>Brassica oleracea</i>	July-October	Rs 80, 540.55/-	Rs 1, 53, 581.1/-
<i>Phaseolus vulgaris</i>	April-July	Rs 58, 163.51/-	Rs 58, 593.25/-
<i>Raphanus sativus</i>	July-October	Rs 40, 986.93/-	Rs 53, 607.00/-

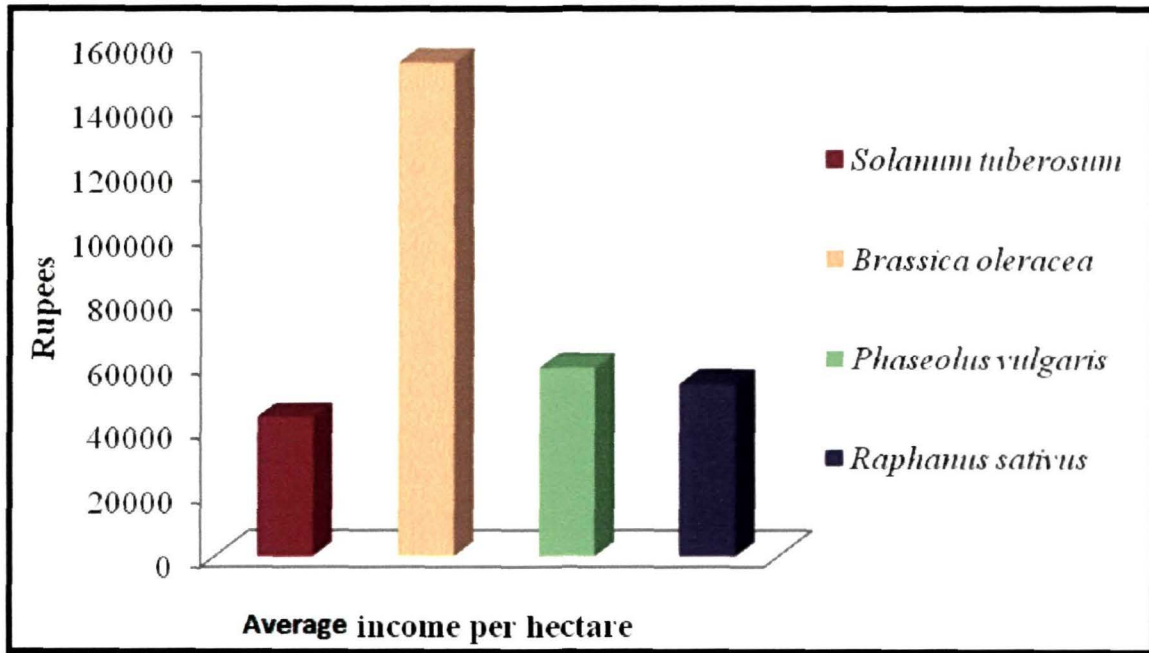


Fig 4.10.3: Average income generated from major crops in a year (in rupees)

4.11. Phytosociology

Phytosociology is the study of the characteristics, classification, relationships, and distribution of plant communities. Various measures of phytosociology of the area like density, abundance, frequency, dominance, diversity indices etc. were studied.

The forests of Umbaniun Microwatershed are dominated by *Pinus kesiya* whose IVI is 192.60. Other tree associates are *Alnus nepalensis*, *Aporosa dioica*, *Betula alnoides*, *Castanopsis indica*, *Myrica esculenta*, *Myrica nagi*, *Pyrus pashia*, *Quercus*

spicata, *Rhododendron arboretum*, *Rhus javanica* and *Schima wallichii* with IVI values 8.51, 5.58, 11.53, 5.58, 17.35, 8.57, 8.55, 20.51, 6.77, 7.06, 7.38 respectively (Table 4.11a).

Table 4.11a: Frequency, Density (Ha⁻¹), Basal Cover and Importance Value Index of tree species

Tree species	Family	Frequency	Density	Basal cover	IVI
<i>Alnus nepalensis</i>	Betulaceae	11.76	4	2.40	8.51
<i>Aporosa dioica</i>	Euphorbiaceae	5.88	3	1.45	5.58
<i>Betula alnoides</i>	Betulaceae	17.65	4	30.27	11.53
<i>Castanopsis indica</i>	Fagaceae	5.88	3	2.49	5.58
<i>Myrica esculenta</i>	Myricaceae	23.53	7	268.65	17.35
<i>Myrica nagi</i>	Myricaceae	11.76	4	21.16	8.57
<i>Pinus kesiya</i>	Pinaceae	100.00	59	27893.12	192.60
<i>Pyrus pashia</i>	Rosaceae	5.88	7	9.34	8.55
<i>Quercus spicata</i>	Fagaceae	23.53	10	332.28	20.51
<i>Rhododendron arboretum</i>	Ericaceae	5.88	5	7.31	6.77
<i>Rhus javanica</i>	Anacardiaceae	5.88	5	5.71	7.06
<i>Schima wallichii</i>	Theaceae	5.88	6	12.46	7.38
Total					300.00

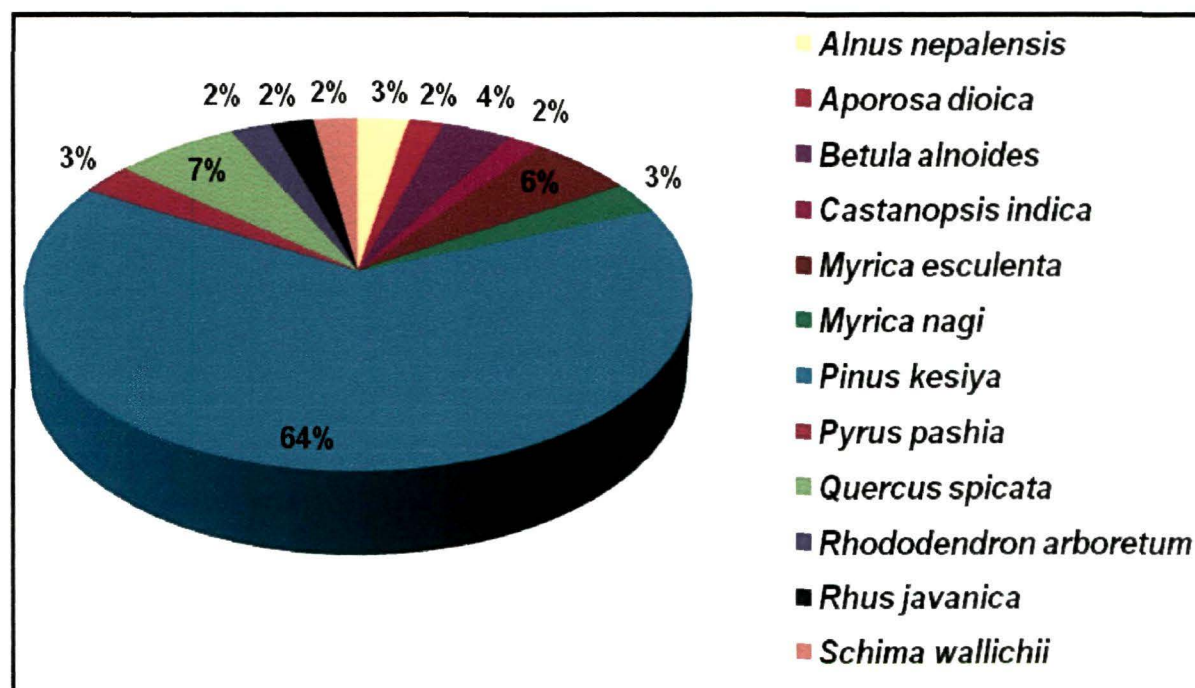


Fig 4.11a: Graphical representation of IVI of different tree species of Umbaniun micro-watershed

The study area represents 30 species of shrub associates belonging to 18 families among which Melastomaceae, Rosaceae, Rubiaceae and Theaceae are the dominant. Besides, the shrub associates of Urticaceae, Caesalpinioideae, Elaeagnaceae, Lamiaceae, Asteraceae, Moraceae, Ericaceae, Malvaceae, Zingiberaceae, Berberidaceae, Phyllanthaceae, Chloranthaceae, Smilacaceae and Caprifoliaceae are also found in the micro-watershed (Table 4.11b). Melastomaceae consists of two species- *Melastoma nepalensis* and *Osbeckia crinata* with IVI- 39.00 and 7.66 respectively. Rosaceae consists of three species- *Rubus alceifolius*, *Rubus khasiana* and *Rubus rugosus* with IVI- 6.88, 36.79 and 3.97 respectively. Rubiaceae consists of four species- *Ixora parviflora*, *Luculia pinceana*, *Mussaenda glabra* and *Saprosma ternatum* with IVI- 4.30, 12.23, 4.30 and 2.64 respectively. Theaceae consists of two species- *Eurya acuminata* and *Eurya japonica* with IVI- 23.24 and 26.22 respectively. Other shrub associates are *Boehmeria hamiltoniana*, *Cassia floribunda*, *Elaeagnus inferata*, *Elsholtzia blanda*, *Eupatorium adenophorum*, *Eupatorium riparium*, *Ficus clavata*, *Gaultheria fragranissima*, *Grewia villosa*, *Hendyichium* sp, *Mohonia nepalensis*, *Phyllanthus* sp, *Phyllanthus debilis*, *Sarcandra glabra*, *Senecio densiflorus*, *Sida cordifolia*, *Smilax aspera*, *Smilax rotundifolia* and *Viburnum foetidum* with IVI- 5.48, 3.47, 7.65, 3.47, 7.63, 1.81, 2.64, 2.64, 10.02, 5.97, 10.02, 19.56, 2.97, 5.13, 2.64, 15.53, 6.29, 13.04 and 6.80 respectively (Table 4.10b).

Table 4.11b: Frequency (F), Density [D (Ha⁻¹)], Abundance (A) and Importance Value Index of shrub Species

Shrub species	Family	F	D	A	IVI
<i>Boehmeria hamiltoniana</i>	Urticaceae	11.76	9.69	3.50	5.48
<i>Cassia floribunda</i>	Caesalpinioideae	5.88	4.15	3.00	3.47
<i>Elaeagnus inferata</i>	Elaeagnaceae	23.53	15.22	2.75	7.65
<i>Elsholtzia blanda</i>	Lamiaceae	5.88	4.15	3.00	3.47
<i>Eupatorium adenophorum</i>	Asteraceae	5.88	11.07	8.00	7.63
<i>Eupatorium riparium</i>	Asteraceae	5.88	1.38	1.00	1.81
<i>Eurya acuminata</i>	Theaceae	70.59	69.20	4.17	23.24

<i>Eurya japonica</i>	Theaceae	70.59	87.20	5.25	26.22
<i>Ficus clavata</i>	Moraceae	5.88	2.77	2.00	2.64
<i>Gaultheria fragranissima</i>	Ericaceae	5.88	2.77	2.00	2.64
<i>Grewia villosa</i>	Malvaceae	23.53	24.91	4.50	10.02
<i>Hedychium sp.</i>	Zingiberaceae	5.88	8.30	6.00	5.97
<i>Ixora parviflora</i>	Rubiaceae	5.88	5.54	4.00	4.30
<i>Luculia pinceana</i>	Rubiaceae	41.18	27.68	2.86	12.23
<i>Melastoma nepalensis</i>	Melastomaceae	82.35	157.79	8.14	39.00
<i>Mohonia nepalensis</i>	Berberidaceae	23.53	24.91	4.50	10.02
<i>Mussaenda glabra</i>	Rubiaceae	5.88	5.54	4.00	4.30
<i>Osbeckia crinata</i>	Melastomaceae	17.65	16.61	4.00	7.66
<i>Phyllanthus sp.</i>	Phyllanthaceae	11.76	48.44	17.50	19.56
<i>Phyllanthus debilis</i>	Phyllanthaceae	11.76	2.77	1.00	2.97
<i>Rubus alceifolius</i>	Rosaceae	17.65	13.84	3.33	6.88
<i>Rubus khasiana</i>	Rosaceae	23.53	134.26	24.25	36.79
<i>Rubus rugosus</i>	Rosaceae	11.76	5.54	2.00	3.97
<i>Saprosma ternatum</i>	Rubiaceae	5.88	2.77	2.00	2.64
<i>Sarcandra glabra</i>	Chloranthaceae	5.88	6.92	5.00	5.13
<i>Senecio densiflorus</i>	Asteraceae	5.88	2.77	2.00	2.64
<i>Sida cordifolia</i>	Malvaceae	17.65	44.29	10.67	15.53
<i>Smilax aspera</i>	Smilacaceae	23.53	9.69	1.75	6.29
<i>Smilax rotundifolia</i>	Smilacaceae	41.18	31.83	3.29	13.04
<i>Viburnum foetidum</i>	Caprifoliaceae	5.88	9.69	7.00	6.80
Total					300.00

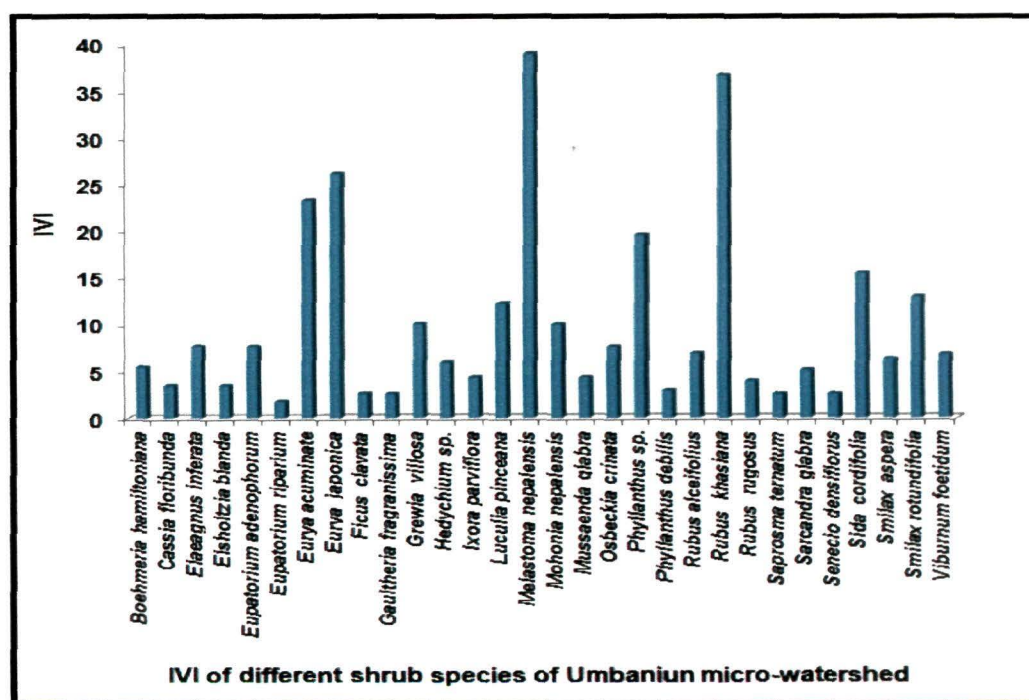


Fig 4.11b: Bar diagram showing IVI of different shrub species of Umbaniun micro-watershed.

The ground storey of the forest represents 12 families of herbs. Poaceae alone has 8 different species and they are dominant. Other herbaceous species represents family like Asteraceae, Rubiaceae, Apiaceae, commenlinaceae, Cyperaceae, Rosaceae, Fabaceae, Lycopodiaceae, Oxalidaceae, Polygonaceae. Poaceae consists of species- *Eragrostis tenella*, *Imperata cylindrical*, *Leptochloa panaceae*, *Oplismenus composites*, *Setaria flavidum* and three unidentified species with IVI- 3.92, 24.32, 50.98, 11.81, 2.79, 27.85, 3.92 and 2.23 respectively. Other herb associates are- *Anaphalis adnata*, *Anotis oxyphylla*, *Centella asiatica*, *Commelina benghalensis*, *Cyperus esculentus*, *Cyperus rotundus*, *Duchesnea indica*, *Eriosema chinense*, *Eupatorium odoratum*, *Lycopodium clavatum*, *Oxalis corniculata*, *Polygonum capitatum*, *Polygonum hydropiper*, *Potentilla anserine*, *Pouzolzia hirta* and *Sipilanthus acmella* with IVI- 22.67, 4.48, 2.79, 15.38, 6.78, 18.50, 11.81, 4.02, 9.35, 3.36, 4.71, 3.36, 19.38, 4.02, 32.48 and 9.08 respectively (Table 4.11c).

Table 4.11c: Frequency (F), Density [D (Ha⁻¹)], Abundance (A) and Importance Value Index of herb Species

Herb species	Family	F	D	A	IVI
<i>Anaphalis adnata</i>	Asteraceae	17.65	2249.13	21.67	22.67
<i>Anotis oxyphylla</i>	Rubiaceae	5.88	173.01	5.00	4.48
<i>Centella asiatica</i>	Apiaceae	5.88	69.20	2.00	2.79
<i>Commelina benghalensis</i>	Commenlinaceae	23.53	1280.28	9.25	15.38
<i>Cyperus esculentus</i>	Cyperaceae	11.76	346.02	5.00	6.78
<i>Cyperus rotundus</i>	Cyperaceae	11.76	1522.49	22.00	18.50
<i>Duchesnea indica</i>	Rosaceae	5.88	622.84	18.00	11.81
<i>Eragrostis tenella</i>	Poaceae	5.88	138.41	4.00	3.92
<i>Eriosema chinense</i>	Fabaceae	11.76	69.20	1.00	4.02
<i>Eupatorium odoratum</i>	Asteraceae	17.65	553.63	5.33	9.35
<i>Imperata cylindrical</i>	Poaceae	23.53	2595.16	18.75	24.32
<i>Leptochloa panacea</i>	Poaceae	52.94	7128.03	22.89	50.98
<i>Lycopodium clavatum</i>	Lycopodiaceae	5.88	103.81	3.00	3.36
<i>Oplismenus compositus</i>	Poaceae	5.88	622.84	18.00	11.81
<i>Oxalis corniculata</i>	Oxalidaceae	11.76	138.41	2.00	4.71
<i>Polygonum capitatum</i>	Polygonaceae	5.88	103.81	3.00	3.36
<i>Polygonum hydropiper</i>	Polygonaceae	23.53	1868.51	13.50	19.38
<i>Potentilla anserine</i>	Rosaceae	11.76	69.20	1.00	4.02

<i>Pouzolzia hirta</i>	Urticulaceae	35.29	3910.03	18.83	32.48
<i>Setaria flavidum</i>	Poaceae	5.88	69.20	2.00	2.79
<i>Spilanthes acmella</i>	Asteraceae	17.65	519.03	5.00	9.08
<i>Unidentified1</i>	Poaceae	23.53	3114.19	22.50	27.85
<i>Unidentified2</i>	Poaceae	5.88	138.41	4.00	3.92
<i>Unidentified3</i>	Poaceae	5.88	34.60	1.00	2.23
Total					300.00

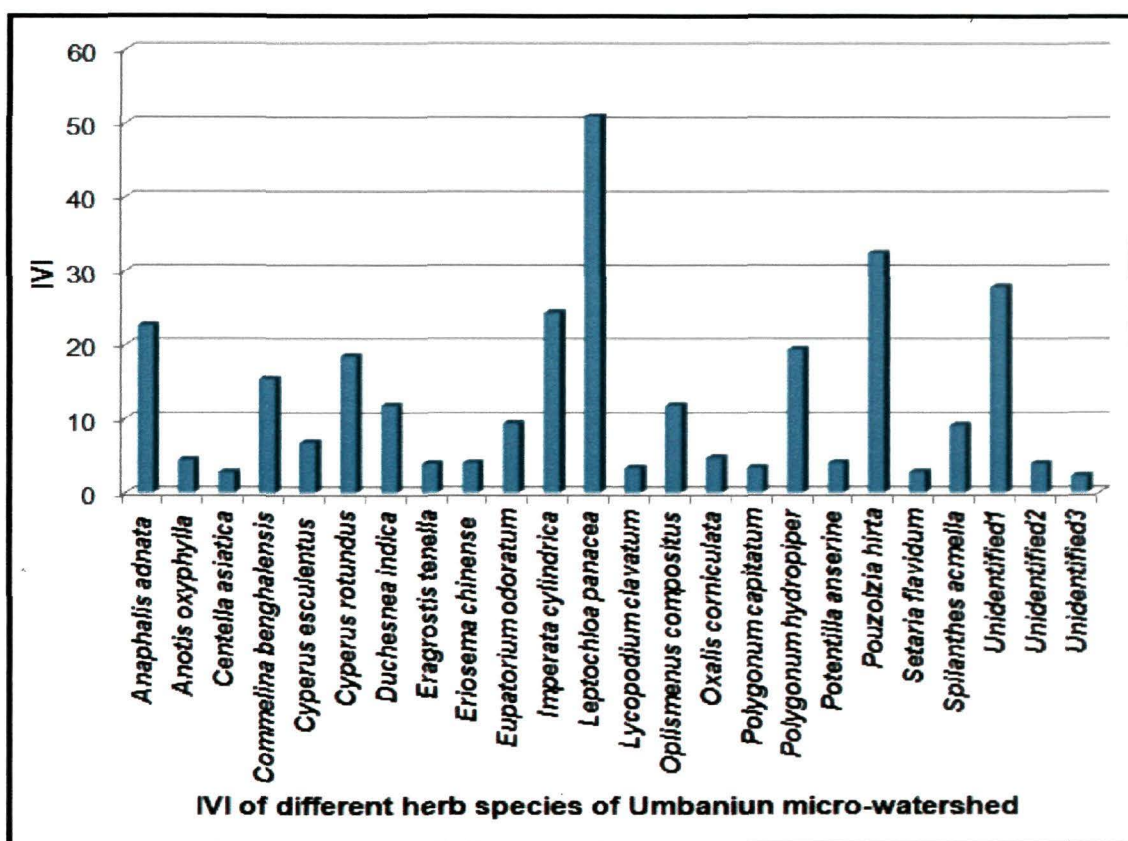


Fig 4.11c: Bar diagram showing IVI of different herb species of Umbaniam micro-watershed.

Two species of fern belonging to family Gleicheniaceae are also found in the Umbaniam micro-watershed viz., *Dicranopteris linearis* and *Gleichenia* sp.

The diversity and community characteristics of tree, shrub and herb species in the Umbaniam micro-watershed are shown in Table 4.11e. The Shannon diversity index for tree is 1.48, shrub is 2.76 and herb is 2.73. Thus, the Umbaniam micro-watershed has very low tree diversity and high shrub and herb diversity.

Table 4.11e: Diversity and Community Characteristics of tree, shrub and herb

Parameter	Tree	Shrub	Herb
Number of families	9	18	12
Number of genera	11	24	23
Species richness	13	30	24
Density (ha ⁻¹)	400	839	27439
Basal cover (m ² ha ⁻¹)	9.72	-	-
Pielou's Evenness index	0.45	0.86	0.82
Shannon diversity index	1.48	2.76	2.73
Simpson dominance index	0.43	0.05	0.09

4.12. Demographic Analysis in Umbaniun Micro-Watershed

4.12.1. Population Status

The survey revealed that in 2001, the population of Umbaniun micro-watershed was 13, 139 people living in 18 villages. The sex ratio (per 1000 males) ranges from 743.9693 in Pomlum to 1170.455 in Mawrashe. There are 2, 421 households in Umbaniun micro-watershed ranging from 6 1 (household size- 6.7) in Marbaniang to 692 (household size- 4.6) in Pomlum (Table 4.12.1a and Table 4.12.1b).

Table 4.12.1a: Population by Sex Ratio

Name of the village	Total no. Of persons	Total no. Of male	Total no. Of female	Sex ratio (per 1000 males)
12 th mile	849	433	416	960.739
Baniun	807	401	406	1012.469
Laitjem	1134	561	573	1021.39
Lyngkien	464	241	223	925.3112
Lyngkien shyiap	372	185	187	1010.811
Marbaniang	408	190	218	1147.368
Marbaniang umseiniong	456	218	238	1091.743
Mawblah	454	220	234	1063.636
Mawiong	473	246	227	922.7642
Mawjriong	426	208	218	1048.077
Mawkriah	518	267	251	940.0749
Mawkhan pasir	681	328	343	1045.732
Mawnianglah	643	323	320	990.7121
Mawrashe	382	176	206	1170.455

Nongrimsadew	488	237	251	1059.072
Pomlum	3181	1824	1357	743.9693
Rangi	407	193	214	1108.808
Sadew	996	483	513	1062.112
Total	13, 139	6, 734	6, 395	

Table 4.12.1b: Number of Households, Population in Household Size

Name of the village	No. Of households	Total population	Household size
12 th mile	151	849	5.6
Baniun	146	807	5.5
Laitjem	206	1134	5.5
Lyngkien	79	464	5.9
Lyngkien shyiap	65	372	5.7
Marbaniang	61	408	6.7
Marbaniang umseiniong	81	456	5.6
Mawblah	82	454	5.5
Mawiong	86	473	5.5
Mawjriong	83	426	5.1
Mawkriah	84	518	6.2
Mawkhan pasir	105	681	6.5
Mawnianglah	114	643	5.6
Mawrashe	69	382	5.5
Nongrimsadew	83	488	5.9
Pomlum	692	3181	4.6
Rangi	69	407	5.9
Sadew	165	996	6.0
Total	2, 421	13, 139	

The details on distribution of workers and cultivators have been given in tables 4.12.1c to 4.12.1f. In Umbaniun Micro-watershed, the percentage of workers is found to be very less, only 38.73% whereas, that of non-workers is found to be 61.27% of the total population. In the workers section, males are found to constitute the highest proportion as compared to females.

The distribution of cultivators is uneven, ranging from 97.4% in Lyngkien shyiap to 0.7% in Marbaniang Umseiniong village. The highest percentage of agricultural labourers is found in Rangi (96.2%) and the least is found in Mawkriah

(7.0%). The industrial workers constitute only a very small section of the population and are found only in 5 villages of the micro-watershed (6.6% in Laitjem, 4.4% in Mawkriah, 2.2% in Mawnianglah and 1.5% in Sadew) (Table 4.12.1f).

Table 4.12.1c: Distribution of Population by Workers and Non-Workers

Name of the village	Total workers (main & marginal workers)			Non-workers		
	Persons	Male	Female	Persons	Male	Female
12 th mile	321	219	102	528	214	314
Baniun	309	193	116	498	208	290
Laitjem	350	258	192	784	303	481
Lyngkien	168	122	46	296	119	177
Lyngkien shyiap	229	116	113	143	69	74
Marbaniang	180	91	89	228	99	129
Marbaniang umseiniong	145	101	44	311	117	194
Mawblah	178	110	68	276	110	166
Mawiong	253	136	117	220	110	110
Mawjriong	160	89	71	266	119	147
Mawkriah	199	125	74	319	142	177
Mawkhan pasir	310	143	167	371	195	176
Mawnianglah	272	146	126	371	177	194
Mawrashe	148	89	59	234	87	147
Nongrimsadew	153	114	39	335	123	212
Pomlum	1236	1065	171	1945	759	1186
Rangi	212	111	101	195	82	113
Sadew	266	192	74	730	291	439
Total	5, 089 (38.73%)	3, 420 (67.20%)	1, 769 (34.76%)	8, 050 (61.27%)	3, 324 (41.29%)	4, 726 (58.71%)

Table 4.12.1d: Number of Workers and Work Participation Rate by Sex

Name of the village	Total workers (main + marginal)			Work participation rate		
	Persons	Male	Female	Persons (%)	Male (%)	Female (%)
12 th mile	321	219	102	37.8	50.6	24.5
Baniun	309	193	116	38.3	48.1	28.6
Laitjem	350	258	192	30.9	40.6	16.1
Lyngkien	168	122	46	36.2	50.6	20.6
Lyngkien shyiap	229	116	113	61.6	62.7	60.4
Marbaniang	180	91	89	44.1	47.9	40.8
Marbaniang umseiniong	145	101	44	31.8	46.3	18.5
Mawblah	178	110	68	39.2	50.6	29.1

Mawiong	253	136	117	53.5	55.3	51.5
Mawjriong	160	89	71	37.6	42.8	32.6
Mawkriah	199	125	74	38.4	46.8	29.5
Mawkhan pasir	310	143	167	45.5	42.3	48.7
Mawnianglah	272	146	126	42.3	45.2	39.4
Mawrashe	148	89	59	38.7	50.6	28.6
Nongrimsadew	153	114	39	31.4	48.1	15.5
Pomlum	1236	1065	171	38.9	58.4	12.6
Rangi	212	111	101	52.1	57.5	47.2
Sadew	266	192	74	26.7	39.8	14.4
Total	5,089	3,420	1,769			

Table 4.12.1e: Percentage Distribution of Total Workers by Main and Marginal Category

Name of the village	Main workers (%)			Marginal workers (%)		
	Persons	Male	Female	Persons	Male	Female
12 th mile	11.8	18.0	5.3	25.0	32.6	19.2
Baniun	16.9	20.2	13.5	21.4	27.9	15.0
Laitjem	30.5	45.5	15.9	0.4	0.5	0.2
Lyngkien	36.2	50.6	20.6	0.00	0.00	0.00
Lyngkien shyiap	61.6	62.7	60.4	0.00	0.00	0.00
Marbaniang	6.4	8.4	4.6	37.8	31.5	36.2
Marbaniang umseiniong	31.6	46.3	18.1	0.22	0	0.42
Mawblah	36.8	46.8	27.4	2.4	3.2	1.7
Mawiong	38.9	54.9	21.6	14.6	6.6	30.0
Mawjriong	36.4	42.8	30.3	1.2	0.00	2.3
Mawkriah	38.4	46.8	29.5	0.00	0.00	0.00
Mawkhan pasir	42.7	40.8	44.6	2.8	1.5	4.1
Mawnianglah	11.8	16.7	6.9	30.5	28.5	32.5
Mawrashe	36.4	48.9	25.7	2.4	1.7	2.9
Nongrimsadew	31.4	48.1	15.5	0.00	0.00	0.00
Pomlum	34.9	54.4	8.7	3.9	3.9	3.9
Rangi	52.1	57.5	47.2	0.00	0.00	0.00
Sadew	26.6	39.8	14.2	0.1	0	0.2

Table 4.12.1f: Distribution of total workers by category in percentage (%)

Village	Cultivators (%)			Agricultural labourers (%)			Workers in hh industry (%)			Other workers (%)		
	P	M	F	P	M	F	P	M	F	P	M	F
12 ^m mile	8.7	7.3	11.8	38.9	28.8	60.8	0.00	0.00	0.00	52.3	63.9	27.5
Baniun	10.4	7.3	15.5	54.4	58.0	48.3	0.00	0.00	0.00	35.3	34.7	36.2
Laitjem	45.4	51.6	28.3	12.9	13.6	10.9	6.6	0.4	1.1	41.1	34.5	59.8
Lyngkien	27.4	26.2	30.4	60.7	59.0	65.2	0.00	0.00	0.00	11.9	14.8	4.3
Lyngkien shyiap	97.4	98.3	96.5	0.00	0.00	0.00	0.00	0.00	0.00	2.6	1.7	3.5
Marbaniang	0.00	0.00	0.00	86.1	83.5	88.8	0.00	0.00	0.00	13.9	16.5	12.2
Marbaniang umseiniong	0.7	0.00	2.3	58.6	59.4	56.8	0.00	0.00	0.00	40.7	40.6	40.9
Mawblah	15.2	16.4	13.2	77.5	74.5	82.4	0.00	0.00	0.00	7.3	9.1	4.1
Mawiong	100	100	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mawjriong	1.9	0.0	4.2	68.1	70.8	64.8	0.00	0.00	0.00	30.6	29.2	31.0
Mawkriah	67.3	61.6	77.0	7.0	7.2	6.8	4.5	5.6	2.7	21.1	25.6	13.5
Mawkhan pasir	46.5	42.0	50.3	38.7	34.3	42.5	0.00	0.00	0.00	14.8	23.8	7.2
Mawnianglah	4.0	4.1	4.0	71.0	61.6	87.7	2.2	0.7	4.0	22.8	33.6	10.3
Mawrashe	10.1	11.2	8.5	76.4	73.0	81.4	0.00	0.00	0.00	13.5	15.7	10.2
Nongrimsadew	7.2	5.3	12.8	68.6	67.5	71.8	0.00	0.00	0.00	24.2	27.2	15.4
Pomlum	1.5	0.8	6.4	8.1	5.1	26.9	2.0	0.7	10.5	88.3	93.5	56.1
Rangi	0.00	0.00	0.00	96.2	97.0	0.00	0.00	0.00	0.00	3.8	4.5	3.0
Sadew	14.1	18.5	3.3	43.2	50	26.7	1.5	0.7	3.3	41.3	30.8	66.7

[NB: P- persons, M- male, F- female]

4.13. Education

61.45% of the total population of Umbaniun Micro-watershed are literate and only 38.55% are illiterate. Among the literates, the number of males is found to be higher (51.49%) than females (48.50%). Among the 18 villages, Pomlum is found to have the highest literacy rate (75.45%) and the least (35.73%) is found in Mawiong (Table 4.13a).

There are ten schools in 6 villages of Umbaniun Micro-watershed, 2 – higher secondary, 6 – secondary, 1 – upper primary and 1 – middle school (Table 4.13b).

Table 4.13a: Distribution of Population among Literates and Illiterates

Village	Total Population	Literates				Illiterates			
		Persons (61.45 %)	%	Male % (51.49%)	Female % (48.50 %)	Persons (38.55 %)	%	Male % (51.06 %)	Female % (49.34 %)
12 th mile	849	321	37.81	45.79	54.21	528	62.19	54.17	45.83
Baniun	807	539	66.79	47.5	52.5	268	33.21	54.1	45.9
Laitjem	1134	789	69.58	48.67	51.33	345	30.42	51.3	48.7
Lyngkien	464	222	47.84	43.69	56.31	242	52.16	59.5	40.5
Lyngkien shyiap	372	140	37.63	45.71	54.29	232	62.37	52.16	47.84
Marbaniang	408	223	54.66	45.29	54.71	185	45.34	48.11	51.89
Marbaniang umseiniong	456	300	65.79	50.67	49.33	156	34.21	42.31	57.69
Mawblah	454	195	42.95	41.54	58.46	259	57.05	53.67	46.33
Mawiong	473	169	35.73	52.66	47.34	304	64.27	51.64	48.36
Mawjrong	426	254	59.62	44.49	55.51	172	40.38	55.23	56.4
Mawkriah	518	335	64.67	51.04	48.96	183	35.33	52.46	47.54
Mawkhan pasir	681	400	58.74	47.75	52.25	281	41.26	52.31	47.69
Mawnianglah	643	414	64.39	50.48	49.52	229	35.61	49.78	50.22
Mawrashe	382	145	37.96	44.14	55.86	237	62.04	47.26	52.74
Nongrimsadew	488	321	65.78	48.29	51.71	167	34.22	49.1	50.9
Pomlum	3181	2400	75.45	60.5	39.5	781	24.55	47.63	52.37
Rangi	407	201	49.39	41.29	58.71	206	50.61	53.4	46.6
Sadew	996	706	70.88	49.43	50.57	290	29.12	46.21	53.79
Total	13, 139	8, 074				5, 065			

Table 4.13b: Educational Institutions

Sl. No.	Village	No. of schools	Name of the school
1.	Nongrim Sadew	2	1. St. Paul's Sec. School 2. Mawpun Jingtip UP School
2.	Mawkriah	1	1. Sadew Mawkriah Sec. School
3.	Sadew	2	1. Raid Sadew-Laitjem Sec. School 2. Springtime English Medium School
4.	Pomlum	1	1. Pomlum H/S School
5.	7 th Mile	3	1. Albera Sec. School 2. Mt. Horeb Sec. School 3. Kendriya Vidyalaya H/S School
6.	Myllem	1.	1. Hermont Zenith Sec. School

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DISCUSSION AND CONCLUSION

5.1. Geomorphology, Run-Off and Sediment Production Rate

Watershed geomorphology refers to the physical characteristics of the watershed. Certain physical properties of watersheds significantly affect the characteristics of runoff and as such are of great interest in hydrologic analyses (Singh *et al.* 2010).

The shape of a micro-watershed has a significant role in determining the amount and flow of run-off which can also impact the sediment production rate of the basin. It has been reported by many workers (Carkeet, 1967; Krishna, 2005; Kumar, 2009; Sharkh, 2009; Krishna *et al.* 2010; Anwar, 2011; Pareta and Pareta, 2011) that basins with a circular shape have higher run-off and sediment production rates as compared to the ones with an elongated shape. Various shape parameters like shape index, form factor, compactness coefficient, elongation ratio, circulatory ratio and rotundity factor are used in determining the shape of a micro-watershed. When the value of all these shape parameters is 1 it indicates that the shape of the basin is circular in shape. The same was also suggested by Efiog and Eze (2010). In the present study, the shape parameters like shape index, form factor compactness coefficient, elongation ratio, circulatory ratio and rotundity factor have been calculated (Table 4.1.3). Sub micro-watersheds 1, 2 and 3. have shape index - 10.43, 7.08, 7.58; form factor – 0.095, 0.14, 0.13; compactness co-efficient – 1.639, 1.553, 1.514; elongation ratio – 0.347, 0.423, 0.400; circulatory ratio – 0.372, 0.414, 0.436; and

rotundity factor – 2.639, 1.778, 1.987 respectively. The values deviate from unity, signifying that the sub micro-watersheds are elongated in shape and have lower run-off and sediment production rates as compared to the watersheds with circular shape. Kumar, 2009 and Pareta & Pareta, 2011 have also observed that basins with elongated shape have lower run-off.

Drainage pattern analysis helps us in knowing the shape as well as nature of soil vulnerability to erosion in the micro-watershed. In the present study, parameters like bifurcation ratio, drainage density, stream frequency, stream grade, length of overland flow and time of concentration are used to analyze the drainage pattern of Umbaniun Micro-watershed (Tables 4.1.4a and 4.1.4b).

Bifurcation ratio characteristically ranges between 3.0 and 5.0 when the influence of geological structures on the drainage network is negligible (Verstappen, 1983; Pareta and Pareta, 2011) and is of natural drainage system within a homogeneous rock (Kale and Gupta, 2001). They are the expected values relative to steep areas. The mean Bifurcation ratio in Sub micro-watershed no. 1, Sub micro-watershed no. 2 and Sub micro-watershed no. 3 has been estimated 3.7, 3.9 and 5.2 respectively, which indicates that the drainage pattern is not much influenced by the geological structures. This value also is in relationship with an elongated shape of the Sub micro-watersheds. Similar findings were also reported by Kumar (2009), Sarkar and Gundekar (2007), Strahler (1964), Schumm (1956) and Morisawa (1985). In Sub micro-watershed no.1, the highest and lowest bifurcation ratios are between the IIIrd & IVth and IVth & Vth stream orders respectively. In Sub micro-watershed No.2, the bifurcation ratio is found to be very high between IInd & IIIrd and IIIrd & IVth stream orders whereas, in Sub micro-watershed No.3 the highest bifurcation ratio is found

between IInd and IIIrd orders (Table 4.1.4a). Among the three Sub micro-watersheds, Sub micro-watershed No.3 has the highest mean bifurcation ratio (5.2) as compared to Sub micro-watershed No.2 (3.9) and Sub micro-watershed No.1 (3.7). This indicates that Sub micro-watershed no.3 has more structural disturbance than micro-watershed No.1 and 2. Thus, Sub micro-watershed No.3 will have higher overland flow and more peak discharge than the other two micro-watersheds. Kumar, 2009 has also opined similarly. The bifurcation ratios between the first and second order streams are lower than the higher orders in all the Sub micro-watersheds indicating that the Umbaniun micro-watershed does not fall under areas of active gullies and ravines, hence, lower erosion rates. Ozdemir and Bird in 2009 have also suggested that the bifurcation ratios of lower order streams indicates lower erosion rate in a micro watershed.

Drainage density shows the landscape dissection, run off potential, infiltration capacity of the land, climatic conditions and vegetation cover of the basin (Verstappen, 1983; Patton, 1988; Nag, 1998; Macka, 2001; Reddy *et al.* 2004; Kumar, 2009; Pareta and Pareta, 2011). Drainage density is an indicator of surface run-off conveyance efficiency (Ozdemir and Bird, 2009). It is a measure of dissection of basin and reflects the competing effectiveness of overland flow and infiltration. Low drainage density is associated with run-off processes dominated by infiltration and subsurface flow, while basins of high drainage densities are products of erosion and dissection by overland flow. In the present study, drainage density is highest in Sub micro-watershed no.3 (0.00110 m/m²) followed by Sub micro-watershed no.2 (0.00077 m/m²) and the least, 0.00069 m/m² in Sub micro-watershed no.1 (Table 4.1.4b). This suggests that Sub micro-watersheds no. 1 and 2 are of highly resistant permeable subsurface layer of soil, dense vegetation cover with low relief showing

that the physical properties in these two Sub micro-watersheds provide suitable conditions for infiltration, thereby decreasing run-off potential which may not be in the case of Sub micro-watershed no.3. The same pattern was also observed by Ozdemir and Bird (2009); Sharkh (2009); Krishna *et al.* (2010) and Yusuf *et al.* (2011)

Generally, high stream frequency is related to impermeable sub-surface material, sparse vegetation, high relief conditions and low infiltration capacity (Reddy, *et al.* 2004; Shaban, *et al.* 2005; Kumar, 2009). Stream frequency is found to be 5.9, 6.6 and 5.1 per square kilometre in Sub micro-watersheds no.1, 2 and 3 respectively (Table 4.1.4b), suggesting that Umbaniun micro-watershed is covered by an impermeable subsurface layer of soil, having mountainous relief and sparse vegetation cover.

Stream grade has been calculated 1.73, 3.27 and 3.20 percent in Sub micro-watersheds no.1, 2 and 3 respectively. Thus, Sub micro-watersheds no.2 and 3 are having more carrying capacity than micro-watershed no.1 (Table 4.1.4b).

Length of overland flow, which is the length of flow of water over the ground before it becomes concentrated in definite stream channels, is one of the most independent variables affecting both the hydrologic and physiographic development of drainage basins (Horton, 1945). It varies inversely as the drainage density. The shorter the length of overland flow the quicker the surface run-off to reach the stream (Zende and Nagrajan, 2011). In the present study, the Length of overland flow is found to be 724.64 m, 649.35 m and 454.55 m in Sub micro-watershed no. 1, 2 and 3 respectively (Table 4.1.4b) which reflects that the length of over flow in Sub micro-watershed no.3 is comparatively shorter than that of Sub micro-watershed no.1 and 2

respectively to reach the stream. Thus, priority should be given to Sub micro-watershed no.3 in management activities.

Time of concentration is the time taken for water to travel along the hydraulic length, from the remotest point to the outlet. It is affected by surface roughness; channel shape and flow patterns; and slope. In micro-watershed no.1 the time of concentration is 89.1 minutes, whereas, in Sub micro-watersheds no.2 and 3 it is found to be 71.1 minutes and 34.1 minutes respectively (Table 4.1.4b). This indicates that the micro-watershed is less undulating.

Relief properties bring the dimension of height into morphometric analysis. Because many landscape processes are driven by gravity and relief properties are frequently used as indicators of erosion potential and denudation rates. Watershed relief, the difference between the highest elevation and the outlet of the watershed, controls the stream gradient and sedimentation in the micro-watershed. Relief ratio removes the size effect by dividing the total relief by basin length. According to Hadley and Schumm, 1961, sediment load increases with an increase in basin relief. The same has been reported by Patton (1988) and Ozdemir and Bird (2009).

The total watershed relief of Umbaniun micro-watershed is found to be less significant since the difference between the maximum and minimum elevations is very low, 260m in Sub micro-watersheds no. 1 and 2 whereas in Sub micro-watershed 3, it is only 220m. The relief ratio is found to be low in Sub micro-watershed no.1 (0.02), medium in Sub micro-watershed no.2 (0.03) and high in Sub micro-watershed no.3 (0.04) as shown in Table 4.1.5, indicating a high degree of probability in increase of flow depth when the flow width remains constant or vice-versa depending on the

topographic properties of the micro-watershed. The findings are found similar to that of Nyadawa and Mwangi (2010) in Nzoia River basin, Kenya.

The Relative relief represents actual variation of altitude in a unit area with respect to its local base level. It enumerates that the steeper the slope the higher is the surface above its base. The relative relief in Umbaniun micro-watershed is low, ranging from 0.96 in Sub micro-watershed no.1; 1.37 in Sub micro-watershed no.2; and only 1.64 in Sub micro-watershed no.3 (Table 4.1.5), indicating that the terrain is less undulating. This is further supported by Ruggedness number whose values are low ranging from 0.1794 in Sub micro-watershed no.1 to 0.2002 in Sub micro-watersheds no. 2 and 3 (Table 4.1.5). This indicates that Umbaniun micro-watershed is less susceptible to erosion and therefore low peak discharge as suggested by Ozdemir and Bird (2009) in their work on morphometric parameters analysis in Havran River basin, Balikesir (Turkey). The same is also opined by Pareta and Pareta, 2011.

Channel maintenance factor which is the reciprocal of the drainage density, expressed in per meter, suggests the unit area required to maintain a unit length of a drainage system. The present study shows that the channel maintenance factor is 1449.275 per meter, 1298.701 per meter and 909.091 per meter in sub micro-watersheds no.1, 2 and 3 respectively (Table 4.1.5). This indicates that Sub micro-watershed no.3 has lower permeability, steep to very steep slopes and higher run-off as compared to Sub micro-watersheds No.1 and 2. The findings are similar to that of Kumar, (2009) and Rekha *et al.* (2011).

Run-off depends directly on watershed characteristics such as, hypsometric integral, bifurcation ratio, circulatory ratio, elongation ratio, relief ratio, relative relief,

basin shape factor, ruggedness number, main stream channel slope and average slope of the watershed (Tripathi *et al.* 2002). Jose and Das in 1982 developed empirical models for estimating run-off (Q) and sediment production rate (SPR) using shape indices like Rotundity factor, Circulatory ratio and Compactness coefficient. Run-off estimation shows that the micro-watershed has the tendency to produce a very low run-off i.e. 22.988 sq km-cm/sq km, 20.893 sq km-cm/sq km, 21.878 sq km-cm/sq km in Sub micro-watersheds no.1, 2 and 3 respectively (Table 4.1.6.1). Sediment production rate is also estimated only 0.008913 ha-m/100 sq km/year, 0.006397 ha-m/100 sq km/year and 0.007158 ha-m/100 sq km/year in Sub micro-watersheds no. 1, 2 and 3 respectively (Table 4.1.6.2). The analysis on the observations based on empirical models of Jose and Das (1982), suggests the vulnerability of Umbaniun micro-watershed to run-off and sedimentation.

5.2 Slope and Aspect

Slope and aspect study are used in knowing the flow of water, drainage patterns on digital elevation models, identifying the habitats of plants and potential sites for rural and urban growth, and ultimately in environmental modelling. Slope measures the steepness of the surface at any particular location and it is measured in degrees or per cent rise whereas aspect measures the direction of the steepest slope for a location on the surface. It is usually measured in degrees, where 0 degrees is due north, 90 degrees is due east, 180 degrees is due south and 270 degrees is due west.

Five categories of slope viz, nearly level to gentle slope (0° - 10°), moderate slope (11° - 20°), moderately steep slope (21° - 30°), steep slope (31° - 40°) and very steep slope ($>40^{\circ}$) (Table 4.5b) have been identified in Umbaniun micro-watershed. Among these, the 'nearly level to gentle slope' occupies the major portion of the area,

i.e. 93.52 percent, whereas the steep slope category occupies the least area i.e. only 0.06 percent of the micro-watershed.

The distribution of slope aspects in Umbaniun micro-watershed (Table 4.4) is found to be more or less even, ranging from 10.04 per cent (North-east aspect) to 17.05 per cent (South-east aspect). It is also found that 42.50 per cent of the micro-watershed area falls under the South-facing slopes (South-west= 10.45 percent; South= 15 percent; South-east= 17.05 percent). This means that 42.5 percent of the micro-watershed is under severe influence of brunt action of storm rendering the area to be more susceptible to soil erosion. A similar suggestion has been made by Carkeet, 1967; Cerda, 1998; Istanbuluoglu *et al.* 2008. This also signifies that 42.5 percent of the Umbaniun Micro-watershed area will have sparser vegetation cover than the Northern aspects. Mohammad, 2008; Jin *et al.* 2008; Chmura, 2008 have opined similarly.

5.3 Land Use and Land Cover

A change in land use/land cover is analysed from 1977 to 2007 i.e. for 30 years and it is found that there was a drastic change in such a very short period of time. As it is shown in the Table 4.8 in the previous chapter, there has been a marked increase in agricultural land, settlement area and open forest by (+) 377.92 ha, (+) 225.94 ha and (+) 570.2 ha respectively leading to a sharp decline in natural ecosystems like dense forest, water bodies and shrub/grass land by (-) 796.45 ha, (-) 7.84 ha and (-) 34.45 ha respectively putting a threat to biodiversity and people of the micro-watershed.

5.4 Normalised Difference Vegetation Index (NDVI)

The Normalised Difference Vegetation Index value ranges from 0 to 1 for barren lands and dense and healthy vegetation cover respectively. A decadal change in the NDVI in 30 years (1977 to 2007) has been examined. NDVI is categorised into five categories for each year. In 1977, the Category-I of NDVI ranging from -0.333 to 0.0526, occupies an area of 4.56 sq.km which is very less as compared to Category-V with the NDVI range of 0.3333 to 0.5384, occupying an area of 11.87 sq km (Table 4.9). Similar trend observed in 1987, Category-I ranges from -0.6923 to 0.05263 which occupies an area of 5.79 sq km whereas, Category-II ranges from 0.3488 to 0.5833 which covers an area of 10.01 sq km suggesting that the micro watershed had a good cover of healthy vegetation which was mainly forest. With time, so much of ecosystem degradation is seen to have taken place in the microwatershed as indicated by a decreasing NDVI values in the year 2004 and 2007. After 30 years (in 2007), barren land occupies 9.78 sq km whereas forests diminished to a great extent and mostly replaced by shrub lands occupying 5.95 sq km of the study area. This can be supported by a land use/land cover study as can be seen in Table 4.8 where there is an abrupt decline in dense forest leading to an increase in open forest from 1987 to 2003. This is due to uncontrolled land practices and poor land management where almost all the forest is cut down for cultivation practices, sand quarries, settlement area, etc as can be seen in Table 4.8 showing a rapid increase in agricultural land, settlement area and quarries from 1977 to 2003. This is because with a decrease in vegetation cover, there is a reduction in reflection of Infrared Rays and more of Near Infrared Rays due to lack of green plant cover. The same is also explained by Milesi *et al.* 2010.

5.5 Land Capability Classification, Biophysical and Socio-Economy

Land capability classification, carried out based on guidelines of U.S.D.A. 1973 (Anon., 1973) and analysis of slope, aspect and land cover, shows that Umbaniun micro-watershed has 7 land capability classes, of which class I (where soils have slight limitations) covers 49.02 percent whereas class II, III, IV, V, VI and VII cover 8.65, 21.85, 7.02, 7.27, 2.40 and 3.79 percent respectively (Table 4.7). Agriculture is being practised irrespective of the land capability classes in the micro-watershed. Cultivation of major crops of Umbaniun micro-watershed (*Solanum tuberosum*, *Brassica oleracea*, *Phaseolus vulgaris* and *Raphanus sativus*) involves a lot of soil tillage, weeding, etc which will lead to soil erosion and sedimentation if planted in steep slopes or lands with capability class III, IV, V, VI and VII. Thus it is necessary to immediately come up with sound soil conservation strategies in agriculture practices such as growing of crops that do not require minimum soil tillage, and weeding; introduction of terrace cultivation; contour bunding; agro-forestry; cover crops, horticulture and livestock based horticulture farming systems as suggested by Majumdar *et al.* 2002, Singh *et al.* 2003 and Das *et al.* 1997. Soil erosion can also be minimised by using traditional methods such as by use of bamboo culms, stones and gunny bags filled with soil (Mishra *et al.* 2006). Land capability class III and IV can be best cultivated with soil conserving crops like non-cereal crops as for example, grass clover (*Trifolium repens* Linn) and alfalfa (*Medicago sativa* Linn) which are known to conserve soil organic matter as suggested by Mishra *et al.* (2006).

The Shannon Wiener Diversity Index and Simpson's Dominance Index for trees are found to be 1.48 and 0.43 respectively, suggesting that the forests of

Umbaniun microwatershed are dominated by a single species, *Pinus kesiya*, whose IVI is 192.60. The common tree associates of *Pinus kesiya* are *Alnus nepalensis*, *Aporosa dioica*, *Betula alnoides*, *Castanopsis indica*, *Myrica esculenta*, *Myrica nagi*, *Pyrus pashia*, *Quercus spicata*, *Rhododendron arboretum*, *Rhus javanica* and *Schima wallichii*. The forests are found to harbour a diverse shrubs and herbs species with the Shannon Wiener Diversity Index of 2.76 and 2.73 respectively (Tables 4.11a to 4.11e).

Agriculture, the main occupation of the people of Umbaniun microwatershed, is mostly permanent cultivation where the farmers grow crops both in valleys and on the hill slopes. The major cash crops grown in the microwatershed are *Solanum tuberosum*, *Brassica oleracea*, *Phaseolus vulgaris* and *Raphanus sativus*. Among them, *Brassica oleracea* is found to have the highest average income (Tables 4.10.3).

There are 18 villages, 2, 421 households and 13, 139 people in Umbaniun microwatershed. Since agriculture is the main stay of economy of the people, the majority of the population are cultivators. Distribution of cultivators varies from one village to another for example, out of the total population in Marbaniang Umseiniong, 0.7 % are cultivators; 56.8% are agricultural labourers; and 40.7% are engaged in other sectors; whereas in Mawiong village, 100% of the total population are cultivators (Tables 4.12.1a to 4.12.2a).

5.6 Suggestions and Strategies for the Sustainability of the Micro-Watershed

Water bodies: Water is a scarce resource which plays an important role in life supporting system in the study area. Interestingly, land under water bodies were 0.31

percent and 0.54 percent in 1977 and 2003 respectively. The same declined to 0.11 percent in 2007. The farmers having land in the bordering area of water bodies have encroached towards and claimed the water bodies for cultivation since increase in siltation of water bodies has made the land fertile. This tendency needs to be discouraged by the village council (Dorbar shnong) or authorities through awareness programmes and measures should be taken to maintain the water level in the water body throughout the year.

Degraded land: The degraded land area has been recorded as decreasing. This trend may be considered a positive trend. But field observations show that even degraded lands are put under cultivations. Degraded lands under capability class IV, V, VI and VII need much conservation measure. The same should be put under permanent tree cover. Further, top most attention of planners and concerned departments is needed to prevent further degradation of degraded lands of class V, VI and VII.

Forest: The study also reveals that 60.3 percent land area was under forest cover in 2007, though loss of 20.0 percent of dense forest area has been recorded in 3 decades. If dense and open forests are clubbed together then only 1 percent decline in total forest cover would be recorded. Need is felt to increase the growing stock of the degraded or open forest by introducing scientific management systems. In the study area, in general, forests are owned by the individuals, clan, community, etc. It is suggested that the concerned Government Departments should provide technical knowhow to the owners (right holders) to increase the growing stock of degraded forest. If same is not followed by the right holders, concerned department should take

up responsibility of management of forest and benefits should be transferred to the right holders as per Forest Policy, 1988.

Agricultural land: The land area under class I, II, and III are 1953.790, 344.907 and 870.755 ha respectively. In the study area, land tenure is permanent in nature i.e. propriety right is vested with the farmers. Transfer of the right made from one person to another is, in general, by inheritance and in some cases right is also transferred through sale agreement. In 1977, 19.89 percent of land was under cultivation/fallow-abandoned land. This figure increased to 24.77 percent in the year 2007 i.e. an increase of 4.88 percent of land and which declined to 0.87 percent. This indicates that due to population pressure, abandoned land, some forest land and degraded land are put under cultivation. Farmers have used degraded land for cultivation without conservation measures in the study area. Concerned department and “durbars” should take serious note of the fact that use of degraded lands without conservation measure will be a serious problem in the near future. This land should be kept under tree cover.

The farmers preferred to grow *Solanum tuberosum*, *Brassica oleracea*, *Phaseolus vulgaris* and *Raphanus sativus* crops in general which cause more soil, moisture and nutrient loss. This should be accompanied by suitable conservation measures so that degradation of cultivable land is controlled.

Introduction of conservation measures and adoption of appropriate cropping systems by individual farmers may not control the biophysical problems associated with the farming system in the study area in particular and hills in general. Thus, need is felt to establish farmers’ organisations for introduction of need-based integrated micro-watershed management plan to maintain sustainability of the natural resources.

In conclusion, it can be said that the Umbaniun micro-watershed is endowed with rich natural resources. However, degradation is on the high due to negligence and lack of awareness and the land is not used as per capability class. If this continues, time will come when the micro-watershed may not sustain the livelihood of the growing population. Our planners only consider soil conservation without giving proper emphasis on the need of the farmers. In the study area even attention is not being paid to soil conservation as indicated by decreasing water bodies.

The concerned departments should involve the farmers' community in planning and decision making process. Majority of the inhabitants of this area are khasis. The khasi society is well organized in taking care of collective and individual needs. This structure will be an effective tool in managing the land resource, provided basic infrastructure and technical knowhow is imparted in them.

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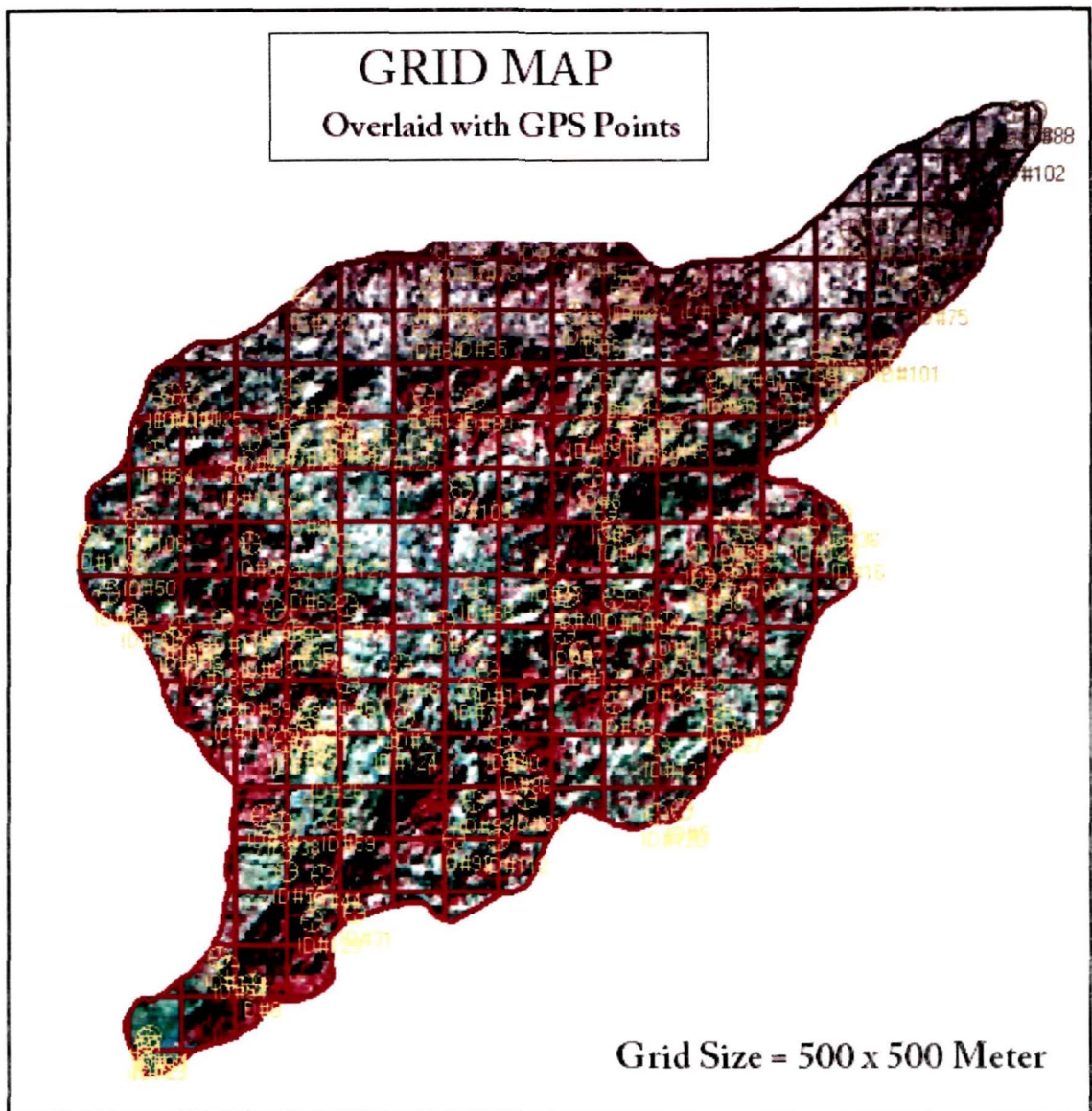


Fig 5: Grid map of Umbaniun micro-watershed



Plate1: Pine forest of Umbaniun micro-watershed



Plate 2: Pine forest and its under-growth



Plate 3: Fallow land in Umbaniun micro-watershed



Plate 4: Ground storey of forest of Umbaniun micro-watershed covered by grass



Plate 5: *Eupatorium odoratum*



Plate 6: *Cyperus rotundus*



Plate 7: *Imperata cylindrica*



Plate 8: *Centella asiatica*



Plate 9: *Oxalis corniculata*

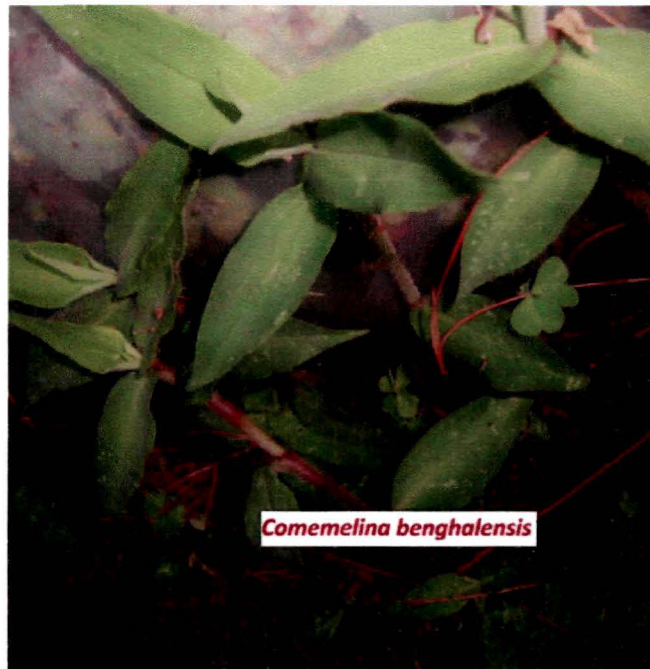


Plate 10: *Comemelina benghalensis*



Plate 11: *Rubus rugosus*



Plate 12: Crop cultivation practised on the hill slopes



Plate 13: Siltation in the stream of Umbaniun micro-watershed

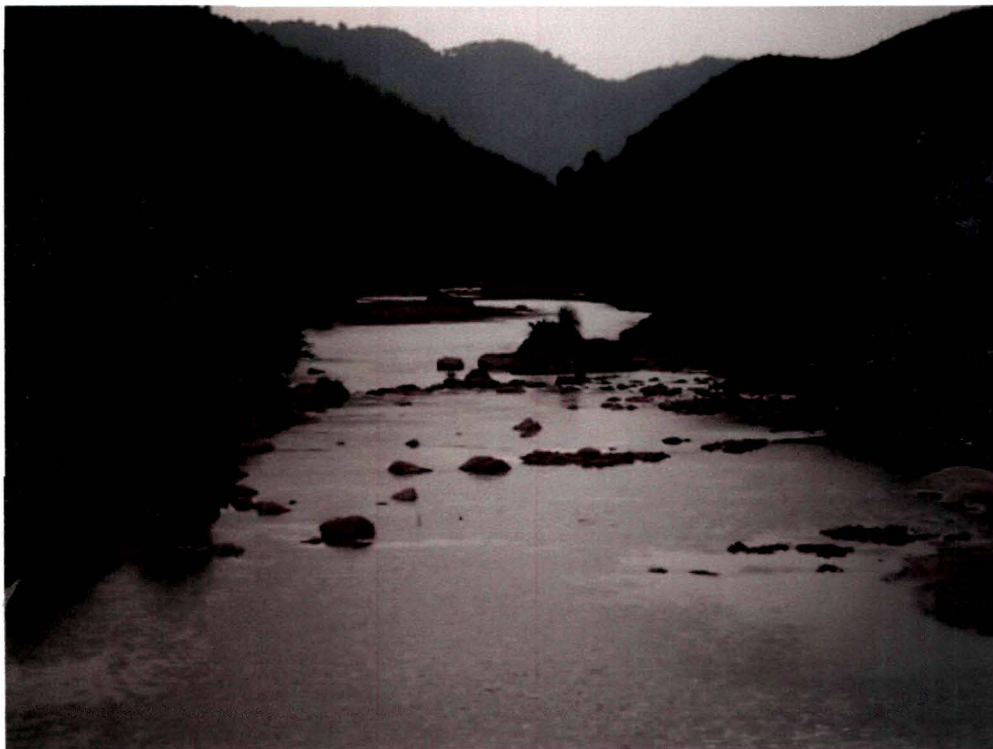


Plate 14: 5th order stream of Umbaniun micro-watershed



Plate 15: Umbaniun River opening to Umiew River



Plate 16: Sand-stone Quarries in Umbaniun micro-watershed

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List of Publications:

1. Rymbai, P. N. & Jha, L. K. (2011) Impact of geomorphology and land use system on water resource management: A case study of Umbaniun micro-watershed of Meghalaya. In: Hussain, Z. & Cajee, L. (Eds), *Proceeding of International Seminar on Water Crisis in the Indian Subcontinent*. BOOKWELL publishers, Delhi. Pp. 221 – 240.
2. Marak, J. P., Rymbai, P. N. & Jha, L. K. (2011) Management of water resources in the Ri-Bhoi District of Meghalaya with special reference to ownership of source of water. In: Hussain, Z. & Cajee, L. (Eds), *Proceeding of International Seminar on Water Crisis in the Indian Subcontinent*. BOOKWELL publishers, Delhi. Pp. 241 – 256.
3. Rymbai, P. N. & Jha, L. K. (2012) Estimation of sediment production rate of Umbaniun Micro-watershed, Meghalaya, India, *J. of Geography and Regional Planning*, Vol. 5 (11): 293 – 297.
4. Rymbai, P. N. & Jha, L. K. (2012) Population pressure resulting change in land use systems and forest cover in Meghalaya: A case study of Umbaniun micro-watershed, *NeBIO*, Vol. 3 (2): 63 – 68.
5. Rymbai, P. N., Dey, S. & Jha, L. K. (2012) Impact of topographical characteristics, land use changes on water resource quality of Umbaniun Micro-watershed, Meghalaya, *Revista Ingeniería e Investigación*. Vol. 32 (2) (In press).

Declaration: I hereby declare that all the statements mentioned above are true to the best of my knowledge and belief.


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