# ASSESSMENT OF NATURAL RESOURCES AND LAND USE PLANNING IN CHEM LUI SUB-WATERSHED, KOLASIB DISTRICT, MIZORAM.

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

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DEPARTMENT OF GEOGRAPHY AND RESOURCE MANAGEMENT

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**CERTIFICATE**

This is to certify that David B Lalhruaitluanga, registered under MZU/Ph.D./ 536 of 13.05.2013 is a research scholar working under my supervision on a thesis entitled 'Assessment of Natural Resources and Land Use Planning in Chemlui Sub-watershed, Kolasib District, Mizoram'. He has fulfilled all the requirements laid down in the Ph.D. regulations of the Mizoram University. I further certified that the thesis in this form is the result of the research scholar's original work. Neither the thesis as a whole nor any part of it was ever submitted to any other University for any research degree.

I recommend the thesis for due evaluation and recommendation.

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# DECLARATION

I, David B Lalhruaitluanga, hereby declare that the subject matter of this thesis 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/Instituted.

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**David B Lalhruaitluanga**

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# INTRODUCTION

## 1.1 Introduction

Natural resources are invaluable for the sustenance of mankind and must be managed in a proper way for sustainable development and optimal utilization. Land is the basis for most of the life supporting systems either directly or indirectly. For effective management and development of natural resources, baseline information of the existing resources is very much essential. As the population is ever-increasing it is necessary to manage the available basic land, water and vegetation resources to meet the basic needs like food, fodder, fuel and shelter. Land use is found to be the most important human induced factor influencing land cover. It is found that land use/land cover dynamics are heterogeneous in space and time, and it is a complex phenomena to understand as there are several complex interactions of biophysical, demographic and socio-economic factors as inferred by Ojima and Moram (2004).

Human interference may lead to several changes in land cover thereby degradation of natural resources in an area. It is essential to analyze the existing physical anthropogenic causes for conservation natural resources effectively. As land use planning is the systematic assessment of physical and social economic conditions, it is important to identify the available resources at micro level more precisely. The management of resources at watershed or sub-watershed level is convenient and the most effective for their development.

Quantification of resources is possible through accurate mapping using advanced techniques of remote sensing and geographical information systems. The present research proposal is an attempt to assess the existing natural resources using remote sensing and GIS techniques and the evaluation of land suitability for specific use in ChemLui sub-watershed in Kolasib district.

**1.2 Scope of the Study**

The present study includes in its ambit the study of geomorphic features and land use/ land cover pattern of the study area. As they are closely associated with climatic phenomena therefore, the study of surface water, ground water potential and soils is imperative. An attempt is made to assess the physical and chemical properties of soils as they form an important aspect in assessing land capability and soil erosion status. Slope is also one of the important parameters in land use planning as it controls vegetation and soil formation in the area. It is essential to study the climatic parameters such as rainfall, temperature and humidity to understand the influence on the growth and development of vegetation in the area. The thematic data has to be integrated in GIS environment in order to arrive at reasonable conclusions for land use planning.

**1.3 Statement of the Problems**

Natural resources should be monitored periodically to utilize properly. Land use planning is highly essential to manage the natural resources such as soils, land, water and forest. Forest areas provide raw materials for housing, lumber industries in order to satisfy the need of ever-growing population and also as an important habitat for wildlife. Similarly, wet lands and water bodies' cover the vast areas of land are important in sustaining aquatic habitat and water supplies. Thus, the base needs of food, water, food, clothing and shelter are met from the land which is increasingly is becoming limited in supply.

Chemlui watershed is largely used by the surrounding population in a different ways. Still now a day, there is no proper planning and organization of land use in the area to attain more efficient use of natural resources. So it is highly essential to conduct a study to formulate land use planning and further reaching optimum use of natural resources in a sustainable ways. The temporal changing pattern of land use in the watershed area is necessary to understand clearly for the future utilization of natural resources.

### 1.4 Research Questions

Following research questions were set for the present study

1. Are natural resources used efficiently?
2. Are land use patterns change through time?
3. Is the watershed support land capability?
4. How land use plan is effectively used for sustainable development?

### 1.5 Objectives

The present study is aimed to achieving the following:

1. To evaluate the existing natural resources

2. To find out temporal changes in land use / land cover pattern

3. To classify land capability

4. To suggest land use plan for sustainable development of natural resources

### 1.6 Review of Literature

A number of studies have been carried out globally on several aspects of natural resources evaluation mostly by using remote sensing and GIS techniques.

Kauzeni et al. (1993) have carried out soil mapping in the three regions of Tanzania namely, Tanga, Tabora and Mbey using aerial photographs coupled with extensive field investigations. The main goal of the study was to develop a planning system that would rectify the problems of over-crowding, both of people and livestock, and poor land utilization and to train local staff to follow proposed planning system and training of basic skills in surveying and soil conservation. The main land use Problems were identified through observations of visible land use problems during field investigations. Based on the resources mapping they have suggested various land use farming systems for the development of those areas. Land use planning was perceived as the need to increase agricultural production.

Zhou (1998) has highlighted the use of Geographical Information Systems (GIS) technology for land resource inventories and modeling for sustaining regional development in China. The technical implementation of the study focused on the operational approach by which GIS and remote sensing spatial database was initially established using a workstation-based ARC/INFO system and was integrated for comprehensive land resource inventory and its assessment. He has carried out a study in selected semi-arid areas of northern China to address the problems of desertification and land degradation. His study revealed the practical use of geographic information system and remote sensing techniques in a developing countries for the regional development planning, particularly where the ecosystem is fragile, land productivity is relatively low, and conflicts in land use.

Spatio-temporal changes in land use/ land cover during the years 1976–2001 in Valencia municipality area; Spain has been studied by Yesserie (2009) using multi-temporal Landsat MSS of the year 1976, TM of the year 1992 and ETM of the year 2001 satellite imagery with the help of the techniques. His research objectives were focused on generating mapping and determining the nature, extent and rate of changes and analyse the spatio-temporal land use/land cover changing patterns and fragmentation of the study area. The basic method used to calculate the total land cover changes for each land use/land cover type is tabulating and examining the trends of change between the investigation periods. The study revealed that distinct changes have occurred on the land use land cover between the investigated periods. He has inferred that a majority of the changes have occurred in agricultural land during this period due to dramatic urban growth and development. He also carried out that mapping of the spatio-temporal land use/land cover changes detected in GIS environment can be used to supplement the available tools for urban planning and environmental management of a region.

Gunton (2003) has analyzed the impact of natural resources development on the regional economic condition in British Columbia, Canada. His study has revealed that the most productive analytical approach for understanding the role of natural resources which has frequently been ignored in development theory must be reintegrated into the unified framework to improve the understanding of the role of natural resources in the regional development.

Margaret and Zwick (2005) have used Geographical Information Systems to identify and solve the potential land use conflicts in north-central Florida based on suitability analysis technique. The study revealed that identification of geographic information system datasets is the inventory phase to provide relevant information to create land use suitability layers representing the goals and objectives of the research output.

Nakai and Bae (2010) have made a landform classification based on land use and its changes using object based classification and altitude data in Chiba city and its surrounding areas of Japan. Previous land use has been obtained from a topographic map drawn on a scale of 1:50,000 and are extracted and converted to a digital form by using an electronic digitizer. Present satellite data that was used in this study is Landsat Thematic Mapper (TM) data. They have used Digital Elevation Model (DEM) to distinguish between terrace and relief. The study revealed that by taking into consideration a set of attributes in addition to spectral intensity and improvement of land use classification based on satellite imagery data can be prepared. Utilization of altitude data is effective for the distinction between terrace and local relief and is inferred that the natural disaster risk is high in those areas where ground condition is poor.

Serneels et al. (2007) have carried out a multi-level analysis to study the impact of land use on inter-annual land cover change in east Africa by using MODIS satellite data with the help of vegetation indices like Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) to compute the enhancement of vegetation. The study has revealed that the areas with different types of land use have interacted with the climate differently. The study has revealed that the climatic variability along with human activities have led to the changes in land cover in the area.

Bhattarai and Conway (2008) have studied the consequences of socio-economic and demographic factors on land use and forest cover dynamics between

1973 and 2003 in the Bara District of the central Tarai region of Nepal by using Landsat Multi-Spectral Scanner, Thematic Mapper (TM), Advanced Earth Observing Satellite (ADEOS), Enhanced Thematic Mapper (ETM) and IKONOS satellite imagery to create land use and land cover change. The study has revealed that the areas of secondary growth increased mostly due to the conversion of farmlands into tree stands and those areas in the farmland and the dry sandy soil were decreased. The transition methodology used in this research may be applicable in detecting land use and forest cover changes at temporal and spatial scales in other culturally complex, tropical forest regions having similar geographic, socioeconomic, and demographic conditions.

Gautam et al. (2002) have made an assessment of land use and land cover changes associated with community forestry implementation in the Roshi watershed in the middle hilly area of Nepal by using remote sensing and geographic information system techniques. The study has revealed that a net of 1981 hectares of forest was declined between 1978 and 1992 over a period of 14 years.

Markon and Derksen (1994) have carried out the identification of Tundra land cover types in Teshekpuk lake area of Alaska Arctic coastal plain by using SPOT MSS satellite imagery. They have identified twelve classes of Tundra land cover such as clear water, turbid water, flooded tundra, wet sedge meadow tundra, moist sedge meadow tundra, moss, grass meadow tundra, moist grass sedge meadow tundra, dwarf shrub graminoid tundra, moist/peat shoreline, sparsely vegetated tundra and unvegetated tundra using unsupervised clustering techniques.

Erich and Ulrike (2002) have studied the impact of land use changes and its effect on vegetation with the help of Geographic Information System (GIS) and

SPSS statistical software techniques from 1996 to 1998 in the sub-alpine-alpine belt in the Passeier Valley (South Tyrol, Italy) in the central Alps at an elevation of 1500-2300 meters comprising both sub-alpine and alpine meadows. The meadows are limited by dense forest at an altitude of 1700 -1800 metres above MSL. Present and past practices used in meadow management information were determined by interacting with farmers and from series of aerial photographs to specify the actual type and intensity of use since abandonment. ArcInfo and ArcView software were used for recording procedure. The result of the analysis revealed that current land use is mainly controlled by the degree of accessibilities which are being used more and more intensively, while poorly accessible areas are being abandoned or used as pasture. Therefore, meadows are more intensively used, while other parts have been converted to pasture or have been abandoned.

Walker and Solecki (1999) have carried out a study for managing land use and land cover change in the New Jersey Pinelands biosphere reserve. Satellite imagery in digital form was used to estimate the conversion of natural area. The statistical assessment analyses derived from integration of satellite imagery, corelational social data using Geographic Information System (GIS) software have been used to determine the natural area conversion magnitudes.

Knox and Weatherfield (1999) have studied by developing Geographic Information System (GIS) based methodology to quantify and mapping the total financial benefits of irrigation water resource management in England and Wales. They have used Geographic Information System with linkages to various databases and an external mode as a modeling and decision making tool to manage water resources in the area.

Pabi (2007) has identified changes in land use/land cover within a period of 10 years using multi-date satellite imagery Landsat TM and Geographic Information System techniques in Ghana. Due to acquiring accurate measurement of area, direction and distance, geometric correction and image registration were carried out. Using unsupervised classification algorithm of Iterative Self-Organizing Data Analysis Technique (ISODATA) the imagery was explored for the existence of distinct classification of land use land cover. The study has revealed that there have been significant land use/ land cover changes across the human dominated landscape in the area. The study indicated that the common perception and interpretation of land use land cover change as spatially generalized could not be authenticated.

Roy (1973) has carried out a study to examine the influence of geographical factors on agricultural pattern in West Bengal using district-wise data. The study analysed impacts of disturbance on landscape structure using satellite remote sensing and a geographic information system (GIS) in Madhav National Park of India. The Landsat TM data have been used to identify vegetation types. The biomass of vegetation species was calculated by using site specific regression equations. He has analyzed that the regional differences in land use pattern in the districts and changes therein are due to the potentials of arable areas and the techno-economic variables. Interpretations of the satellite remote sensing were useful to analyse spatial pattern of land use land cover.

Shinde (1973) has brought out the significance of principal crops in the Panchganga basin and analyzed the influence of physical and socio-economic environment on agricultural practices and the distribution of main crops in the area. He has concluded that the role of physical variables operating as an integrated system seems to be more decisive in producing different cropping patterns and the crop distribution is influenced by the fertility of soil and the availability of irrigational facilities.

Yadav (1975) has inferred based on the comprehensive spatio-temporal analysis of physical and non-physical factors that are affecting the choice of farming systems in Gurgaun district of Haryana state. He has also discussed the use of land and associated cropping patterns and regional balances in the levels of agricultural production and changes therein within the frame of physical and non-physical variables of agricultural activity.

Datta (1995) has developed a decision support system for micro-watershed management in India. Spatial database of natural resources has been developed to integrate decision support model designed for generating alternate water allocation and agricultural production scenarios for semi-arid regions. The model has been tested in Radharamanpur Micro-watershed management system (MWMS) in Bankura district of West Bengal covering an area of about 364 hectares.

Suresh Kumar et al. (2001) have carried out a land use study on Behta Block in Sitapur district of Uttar Pradesh using remote sensing techniques. IRS-1B LISS-II geo-coded FCC images 1:50,000 scale and Survey of India topographical maps scaled 1:50,000 were used as primary source of data to prepare thematical maps and were integrated to get there composite unit for generating an optimal land use plan for development of block on a sustainable basis. Classification scheme suggested by National Remote Sensing Centre (NRSC) has been adopted and accordingly, four major land use land cover types viz. built up land, agricultural land, wasteland and water bodies were identified. Physio-chemical analysis of soils was carried out and their suitability for various land uses was assessed. They have suggested different land use systems for the area development based on the integration of the thematic layers such as soils, land use landforms, underground and surface water using GIS techniques.

Vipin (2017) has studied the area of the Medkhali river basin a tributary of Ghaggar river to assess the drainage characteristics for the prioritization of sub-watersheds using the topographical sheets published by survey of India on a scale of 1:50000. The total area of the basin is 63.25 $km^2$ and the whole basin is divided into 25 sub-watersheds for micro analysis. Climatic data like rainfall, temperature, humidity, wind direction, frost etc. has been collected from secondary sources. The variables of the study of morphometric aspects of the basin including stream orders, stream numbers, stream length, bifurcation ratio, basin circularity, drainage texture, relief ratio etc. have been analysed using the standard quantitative techniques. The morphometric parameters are divided into two categories - areal and linear parameters which have been measured and calculated manually. The study reveals that the analysis of morphometric aspects can play an important role to understand the geological environment and it is helpful to find out the erosive zones in any area.

Prabhakaran and Raj (2018) have studied the form and geomorphic/hydrologic processes of the 20 watersheds of the Pachamalai hills and its adjoining located in Tamil Nadu State of southern India from the analysis of its drainage morphometric characteristics. Using survey of India's topographic sheets of 1:50,000 stream networks and watersheds of the study area were demarcated followed by the analysis of their morphometric characteristics using ArcGIS software. The result of the analysis reveals the basis for deducing the form and processes of the watersheds of the study area. The form of the watersheds inferred from the analysis includes shape, length, slope steepness and length, degree of branching of streams, dissection and elongation of watersheds. The understanding of variations of forms and processes mentioned can be used towards prioritizing the watersheds for development, management and conservation planning.

Haldar, et al. (2011) have studied landform and topography of a place determines the recharge and transmission of ground water of Alwar district, Rajasthan. To evaluate the ground water resources, the ground water potential for the study area was computed from DEM derived parameters like drainage density, slope, parent material and accumulation parameters. Comparison was done considering the fractional area of a ground water depth corresponding to a ground water potential under a particular landform class resulting that alluvial plain and colluvial plain though had high water reserve in the past are presently being depleted at a faster rate. The study reveals that ground water recharge zones was found to be mostly confined to the pits region in the plain landform and valley bottom region in the transitional landform.

Lisa (1997) has studied the dynamics of land-use/land cover change in the Hindu Kush-Himalaya. The study identified the critical changes in the study area as it changed in forest cover, including conversion as well as modification of structure and species composition and also changed in land use, including growth of agriculture.

Dewan and Ziaur (2012) have studied the land use change of Dhaka, the capital of Bangladesh. The study reveals that rapid urban expansion lead to large scale of land use/cover change, particularly in developing countries becomes a matter of concern since urbanization drives environmental change at multiple scales. Using multi-temporal remotely sensed data, dynamics of land use dynamics of land use/cover changes and the quantification of landscape patterns in Dhaka metropolitan were demonstrated in this study by using geospatial techniques with landscape metrics. Due to socio economic development and rapid population growth, the urban built-up area significantly increased at the expense of natural land covers, e.g. wetlands, vegetation and agricultural lands. The study reveals that the human activities in Dhaka being intensified in recent past resulted in the fast increase of urban area.

Richter (1984) has studied the types and pattern of land use in the German Democratic Republic (GDR) are controlled both by the historical development and the strong influences of technological, social and political alterations during the last four decades. The two basic features of land transformation are land use alteration and intensification. The study reveals that most alterations of land use drastically reduce the agricultural area and intensification consequently is the main type of land transformation in all sections of regional development.

César and Arturo (2002) have carried out a multi temporal post-classification study with data from the Landsat Multi Spectral Scanner (MSS) and accordingly, Thematic Mapper (TM) was made to detect changes in the landscape of the Majahual coastal system, along the Mexican Pacific. Six land-use classes were used as direct indicators of the landscape condition. Mangrove, lagoon, saltmarsh, dry forest, secondary succession, and agriculture were the categories selected to evaluate the changes by comparing four thematic maps of the year ranging from 1973 to 1997. It was reveals that the accuracy of the classification was calculated from an error matrix, using the overall accuracy assessment and the Kappa coefficient. Both values indicate that the agreement in the classification was moderate, but better than one obtained by chance. The analytical comparison of data sets was done by using a change detection matrix and the Kappa coefficient. The general trends of change in the system are mainly typified as loss of natural cover and the fragmentation of the landscape, with agricultural activities and their subsequent effects.

Dale (1997) has studied about the relationship between land use change and climatic change. His study reveals that land-use change is related to climate change as both are causal factor and a major way in which the effects of climate change are expressed. As a causal factor, land use influences the flux of mass and energy, and as land-cover patterns change, these fluxes are altered. Projected climate alterations will produce changes in land-cover patterns at a variety of temporal and spatial scales, although human uses of the land are expected to override many effects. In his study, a review of the literature dealing with the relationship between land-use change and climate change clearly shows that - in recent centuries land-use change has had much greater effects on ecological variables than has climate change. The majority of land-use changes have little to do with climate change or even climate and humans will change land use and especially land management, to adjust to climate change and these adaptations will have some ecological effects. It reveals that socioeconomics and politics cause land-use change are necessary to manage ecological functions effectively on regional and global scales.

Huang and Victor (2012) have carried out a study on land use and land cover in a costal watershed in South East China. Their study reveals practical remote sensing techniques for land cover change monitoring that relates land use/ land cover, landscape patterns, and temporal scales to the water quality of runoff from a coastal watershed in South East China. The results of the study proved that the percentage of built-up land was a good predictor for downstream water quality.

Ravan and Roy (1997) have studied the impacts of disturbance due to landscape structure using satellite remote sensing and geographic information system (GIS) in Madhav National Park of India. The geographic information system (GIS), which is primarily a data storage, display and analysis technique, holds great promise to achieve landscape ecological analysis. The Landsat TM datasets have been used to identify vegetation types. The patch characteristics of the vegetation like size, shape, porosity and patch density have been studied. The physical and human made features have divided the national park into three zones. The study revealed the effect on species diversity and biomass distribution in the different disturbance regimes.

Drzewiecki (2008) has explained the application of the landscape functions and natural potentials methodology for environmental assessment in the upland area of Pradnik and Dlubnia rivers catchments of south Poland. He proposed evaluation methodology applied in geographic information system (GIS) environment and based on available digital spatial data function can be found in Bastian and Röder (2002). Different kinds of data like Digital Atlas of Krakow Voivodship (KAWK), Sozological Map of Poland, scanned topographical maps, satellite images, meteorological data and hydro geological maps were used during the study. The study proved that evaluation of landscape functions and natural potentials as a useful tool in land-use decision support process. Proposed assessment methods can be implemented not only in the investigated area, but also in similar areas in the South of Poland.

Cruz (1999) has proposed a study of discussion regarding the key issues and concerns regarding sustainable watershed management in the Philippines. It emphasised the various requisites of sustainable watershed management, sharply focusing on the critical roles of land use planning. The result of the study led to a better understanding of the topics discussed and contribute to an improved operationalization of a truly sustainable watershed management in the study area.

Eludoyin et al. (2011) have studied assessment of the spatio-temporal land use and land cover changes between 1986 and 2000 for the whole Obio (Akpor) Local Government Area of Rivers State, Nigeria. Landsat images of 30 m × 30 m resolution of both 1986 and 2000 were used whereby seven land use types were detected and captured in ArcView 3.3 version after the images have been geo-rectified. The land use types include farmland, built up area, water, sparse vegetation, primary forest, secondary forest and mangrove. The area in square kilometres of each land use type in each year was calculated and thereafter the change was determined by subtracting the area of the same land use type in 1986 from 2000 and the percentage of change is therefore calculated. The probability of change of twenty years was also determined from one land use type to another using Markovian Transition Estimator (MTE) from IDRISI Andes software. The study reveals that the farmland, mangrove, primary forest and sparse vegetation of the study area were reduced over time.

Oliver, et al. (2011) examined the dynamic links in shifting cultivation systems among asset poverty, land use and land cover in a community where poverty is persistent and primary forests have been replaced overtime. Land cover change is assessed using aerial photographs, satellite imagery from 1965 to 2007. Household and plot level data are used to track land holding, portfolios, and use as well as land cover over the past few years with particular attention to forest status. They study reveals that the initial conditions of land holding by forest peasants have long-term effects on future forest cover and household welfare. These findings suggest a new mechanism driving poverty traps: insufficient initial land holdings induce land use patterns that trap households in low agricultural productivity. It also results that the evolution of household land portfolios and land use strategies strongly influence not only the wellbeing of forest people but also the dynamics of tropical deforestation and secondary forest regrowth.

Kenneth and David (1996) applied model to data for southern Belize for an area experiencing rapid expansion of both subsistence and commercial agriculture, using geographic information system (GIS) techniques to select sample points at 1-kilometre interval. Market access, land quality, and tenure status affect the probability of agricultural land use synergistically, having differential effects on the likelihood of commercial versus semi subsistence farming. The study results suggest that roads and buildings in areas with agriculturally poor soils and low population densities may be a "lose-lose" proposition, causing habitat fragmentation and providing low economic returns.

Kebrom and Hedlund (2000) have evaluated the land use/land cover change in a specific area of Kalu District, Southern Wello, Ethiopia, by comparing two aerial photographs from 1958 and 1986. An attempt is also made to discuss possible implications of these land cover changes for land degradation. By applying Geographic Information Systems (GIS), two maps of the study area for the years 1958 and 1986 were produced. The maps show a decrease in coverage by shrub lands, riverine vegetation and forests, and an increase in remaining open areas, settlements, floodplains, and a water bodies. The areal extension of nine categories of land cover was calculated and, by overlaying the two maps, the percentage of each type of land cover that was converted into other categories was computed. As a result, land cover changes were most noticeable for shrub lands, with a decreasing rate and for remaining open areas with an increasing rate. Areas under cultivation remained unchanged. It also reveals that using remote sensing and GIS land cover changes observed in this study were the result of clearing of vegetation for fuel wood, grazing lands, new cultivation areas, etc., thus contributing to the current problem of land degradation of this region.

Rubia and Jhariya (2016) carried-out a study in municipal corporation area Chhattisgarh, India. Raipur municipal corporation area is situated in western part of Raipur district, Chhattisgarh, India. Their study reveals the application of remote sensing and geographic information techniques to access the change in LULC by using satellite images of year 1999 and 2016. With the help of georeferenced toposheet, few ground control pints are taken and rectified the satellite image. The image of the study area was clipped by overlaying district boundary over the geo-referenced image. For the preparation of LULC map on screen visual interpretation of satellite images Google earth, Survey of India toposheet and field checking was adopted using visual interpretation key. It is observed that there were dramatic changes occur from year 1999 to 2016.The LULC changes were of highest amount in settlement and cultivation. Comparison of LULC 1999 to 2016 indicates that the anthropogenic activity like settlement, road and industrial area is largely extended.

Selçuk (2008) has studied and investigated land use land cover changes by using of remote sensing and geographic information systems (GIS) in Rize, northeast Turkey between 1976 and 2000. He applied supervised classification technique to six reflective bands of two Landsat images by using maximum likelihood method with the aid of ground truth data obtained from aerial images dated. The study mainly focused on land use land cover changes by using change detection comparison. In this study, the land cover changes were analyzed according to the topographic structure of slope and altitude by using GIS functions. The results of the study indicate that severe land cover changes have occurred in agricultural, urban, pasture and forested areas. It was seen that the land use land cover changes were mostly occurred in coastal areas and in areas having low slope values.

Lachowski (1998) has opined that remote sensing is a source of current and repeatable information on the location, quantity, and quality of land cover and other resource information, particularly vegetation. It also allows change detection and monitoring of land cover and vegetation over time. The study examined the ability to integrate remote sensing imagery in a GIS combined with ancillary data, including cartographic feature files (CFFs), digital elevation models (DEMs), digital orthophotoquads (DOQs), and other resource data layers to provide a solid geospatial data foundation for support of forest service management of natural resources.

Singh, et al. (2017) has emphasised the importance of remote sensing, GIS and GPS technologies. They concluded that with the increasing pressure on natural resources due to the rising human population, remote sensing and GIS can be used to manage these limited resources in an effective and efficient manner. Geospatial data are effective in the analysis and determination of factors that affect the utilization of these resources. Thus, with the understanding of these factors, sound decisions can be arrived at that will ensure the sustainable use of natural resources to meet the needs of the present as well as future generations.

Praveen and Kumra (2011) have discussed about the modern technology of remote sensing which includes both aerial as well as satellite based systems which collect a lot of physical data rather easily, with speed and on repetitive basis and together with Geographic Information System helps to analyse the data spatially, offering possibilities of generating various options thereby optimizing the whole planning process. These information systems also propose interpretation of physical data with other socio-economic data, and thereby provide an important linkage in the overall planning process and making it more effective and meaningful.

Vikhel and Patil (2014) have discussed in brief the land use planning using remote sensing and geographic information system with reference to the agricultural crops. According to their discussion, integration of remote sensing data such as aerial photographs, IRS-ID, IRS ID LISS-III fused with PAN data, LANDSAT TM image, Cartosat and GIS environment such as software ARC/ INFO and ARCVIEW along with ILWIS, SWAT, ERDAS imagine and GPS can be effectively used for land use planning. Therefore, land use planning with reference to engineering conservation measures may be planned by using remote sensing and geographic information system technique.

Laley and Adel Ranji (2014) have demonstrated the need to maintain remote sensing for mapping and managing natural resources in Iran as well as enhancing and supporting the decision making capabilities of the government regarding the use of its natural resources. They reveal that using satellite based remote sensing approach in generating data ensures updated cost effective natural resources monitoring and management in Iran. According to their study it is cleared that any nation's economic development is largely supported by the richness of its water and land resources. The management capability and mapping tools use to monitor these resources are crucial to raise the economic development of specific regions. Accuracy is a general requirement in managing delicate land and water resources for sustainable development.

Nigam (2000) has applied remotely sensed data to discover the trend of development of the rural urban fringe of Enschede city using COSMOS data merged with TM of 1993 and IRS Pan data with LISS-III of 1996 coupled with GIS technology. The methodology adopted involved the visual interpretation of land use on acetate overlays according to the land use classification. Satellite images were used of the years 1993 and 1996 at the scale of 1:25000. A minimum mapable unit of 5 mm x 5 mm was used for mapping. Data was then digitised using ILWIS software, by creating a digital database for further analysis. Subsequently land use maps were overlaid with each other to identify and quantify the land use change. The land use change analysis shows higher magnitude of change in Residential and Industrial areas during the study period also during the same period cropland is changed into the construction site and again construction site is changed into residential and new construction sites have come into picture.

Mallupattu and Sreenivasula Reddy (2013) have carried out land use/land cover (LU/LC) changes in an urban area of Tirupati, using 1976 and 2003 satellite images with the help of geographical information systems and remote sensing technology. The methodologies were done by using the Survey of India topographic map 57 O/6 and the remote sensing data of LISS III and PAN of IRS ID of 2003. The study area was classified into eight categories on the basis of field study, geographical conditions, and remote sensing data. The comparison of land use/land cover indicates that there is a significant increase in built-up area, open forest, plantation, and other lands. It is also noted that substantial amount of agriculture land, water spread area, and dense forest area vanished during the period of study which may be due to rapid urbanization of the study area.

Rawat and Manish Kumar (2015) have studied the spatio-temporal dynamics of land use/cover of Hawalbagh block of district Almora, Uttarakhand, India. Landsat satellite imageries of two different time periods, i.e., Landsat Thematic Mapper (TM) of the year 1990 and 2010 were acquired by Global Land Cover

Facility Site (GLCF) and earth explorer site and quantify the changes in the Hawalbagh block from 1990 to 2010 over a period of 20 years. Supervised classification was employed using maximum likelihood technique in ERDAS 9.3 Software. The images of the study area were categorized into five different classes namely vegetation, agriculture, barren land, built-up and water body. The results indicate that during the last two decades, vegetation and built-up land were increased while agriculture, barren land and water body were decreased. The result of the research work highlights the importance of digital change detection techniques for natural resources.

Kumar, et al. (2015) carried the usefulness of remote sensing and Geographical Information System (GIS) offers an abundant opportunity to monitor and manage natural resources at multi-temporal, multi-spectral and multi-spatial resolution. It is an urgent need to understand the specialized capabilities of an ever-expanding array of image sources and analysis techniques for natural resource managers. In their reviewed, they compiled the various applications of remote sensing and Geographical Information System tools that can be used for natural resource management like agriculture, water, forest, soil, natural hazards. The information was useful for the natural resource managers to understand and more effectively collaborate with remote sensing scientists to develop and apply remote sensing science to achieve monitoring objectives.

Adegbenro, et al. (2020) conducted a study using existing soil data from Nawagaon and Maskara Rao watershed boundary in Shaharanpur district, India to assess land capability classes based on remote sensing and GIS approach. Landsat image was integrated with SRTM DEM for delineation of landforms and analysis of land use/land cover data. The filled SRTM DEM of the study area was extracted at 30 m resolution to extract terrain parameters such as elevation, slope and aspect. Three major landforms were identified. These were further delineated according to slope and finally into eight physiographic units. The slope map and aspect map were produced using filed DEM and were classified into nine and two classes respectively. Land use/land cover map was generated using satellite image for the study area. The dominant land use was: dense forest, degraded forest, crop land I, crop land II, scrub/barren, settlement, river, canal and road. Based on the slope map, land characteristics of each physiographic unit and land capability criteria for land qualities, land capability classes were assigned and were translated into a land capability map. The soils were classified and grouped into seven classes (I, II, III, IV, VI, VII and VIII). Both the GIS approach and LCC evaluation using criteria rating of FAO gave the same classes for the mapped soil. The study revealed that soils from the study areas varied with different physiographic unit, therefore, soils of the hilly areas should be put to use for nature conservation other than arable production while the lower portion should be cultivated with intensive care for arable crops.

Lalchamreia and Pachuau (2010) have made an attempt to find out temporal changes between 1987 and 2007 in land use/land cover pattern in Tuichhuahen watershed in Kolasib district, Mizoram using multi-date satellite imagery. They have inferred that the non-forest area is doubled with an increase of 6% and there is about 16% of decrease in evergreen miscellaneous forest including bamboo.

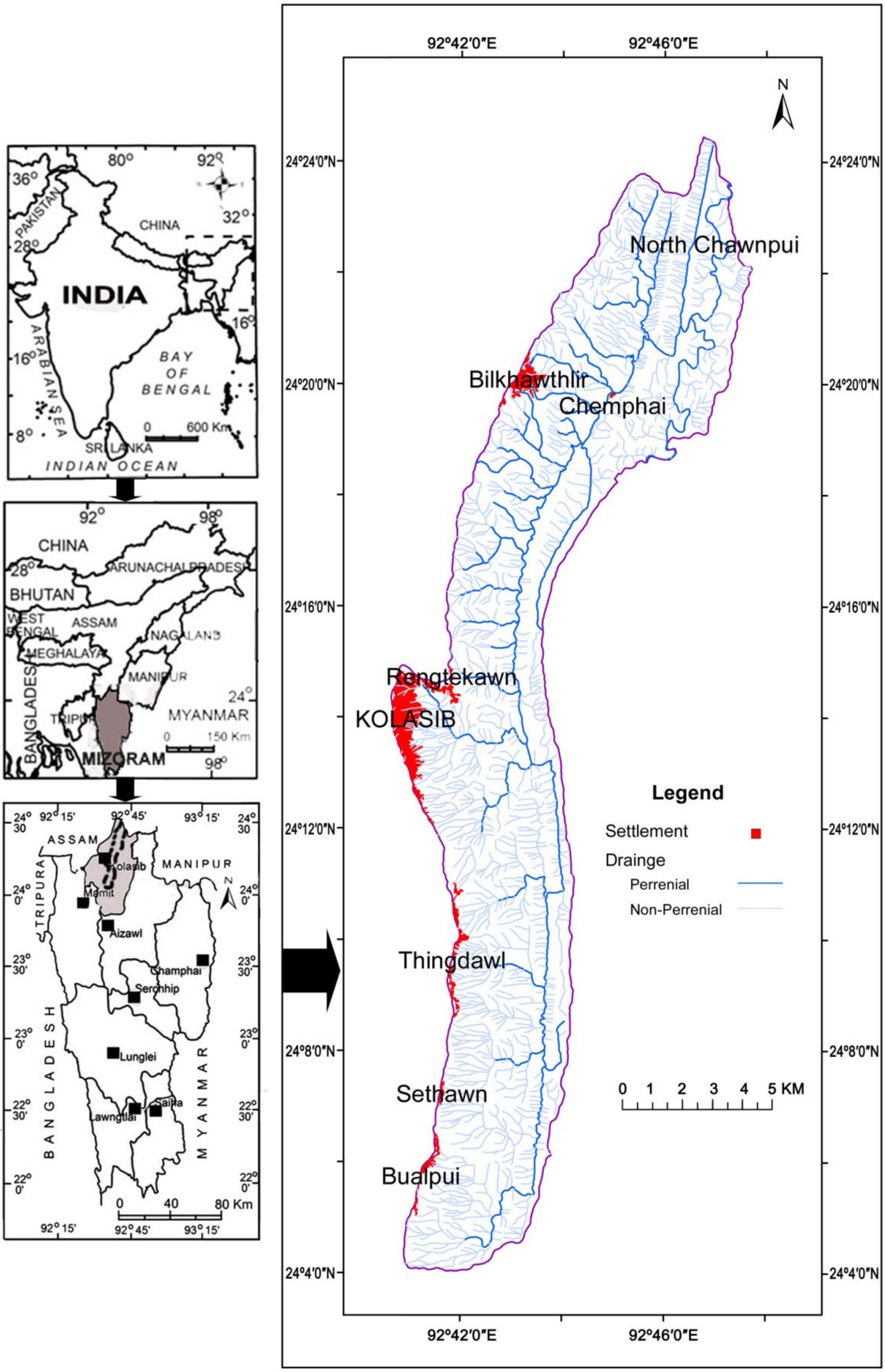



Figure 1.1: Location map of the study area - Chemlui sub-watershed, Kolasib District, Mizoram.

### 1.7 Study Area

Chem Lui sub-watershed is located between $92^o$ 40' – $92^o$48' east longitudes and $24^o$ 04' – $24^o$ 24' north latitudes covering an area of 165.63 sq.km. (Fig. 1.1). The name 'Chem Lui' is also popularly written as 'Chemlui'. The area falls in parts of survey of India toposheets 83D/11, 83D/12 and 83D/15.

The river Serlui is a tributary to the river Tuirial which is flows towards north in Mizoram. ChemLui is the tributary to the river Serlui. The area experiences humid tropical climate. Linear to arcuate shaped hills separated by narrow and deep structural valleys controlled by faults and fractures are the prominent geomorphic features seen in the area. The maximum elevation of 1100 meters is seen in the southern part of the watershed and the minimum of 60 meters is found at its confluence with Serlui near Saiphai village. The whole watershed is composed of sedimentary rocks such as sandstones, siltstones and shales.

### 1.8 Organization of the Chapters

The present study has been organized into seven chapters,

The first chapter is an introduction of the study. It deals with scope of the study, statement of the problems, objectives of the study, review of literature, and study area.

The second chapter is devoted for methodology of the study including selection of the study site, construction of maps and technique of analysis.

The third chapter deals with the evaluation of natural resources in the study area.

The fourth chapter is land use change. It includes the changing patterns of land use between the years 2006 to 2016. Land use change of the study area has been work out and discussed.

The fifth chapter is on land capability classification. It has been classified different levels of land capability classes and its utility.

The sixth chapter is land use planning. It deals with the problems and prospects of natural resources utilization in the study area. Future land use planning prospects for sustainable natural resources in the study area is also discussed.

The seventh chapter is summary and findings. It provides conclusion, summary of the findings and suggestion for future prospects.

# CHAPTER – II

# METHODOLOGY

# CHAPTER – II

# METHODOLOGY

## 2.1 Introduction

The present study utilizes the standard techniques of remote sensing and Geographic Information System (GIS) for preparing various thematic data information which are finally represented in the form of layers and maps. Remote sensing techniques, in short, refers to the collection and utilization of information collected from a remote device and shaped in the form of satellite imagery without necessitate for coming in physical contact with the element under observation. It represents the organized form of raw data obtained from remotely sensed products and presented in a form which is understood by the user known as spatial and non-spatial data. Thus, the valuable information collected using remote sensing can be integrated with the help of Geographical Information System to generate products that become important tools for almost every aspect of land resource management and land use planning.

Methodology includes selection of study sites, preparation and analysis of satellite imagery, production and analysis of thematic data.

## 2.2 Selection of study site

Chemlui sub-watershed is essentially used by the surrounding rural population for various available natural resources. It serves the basic livelihood requirement of those inhabitants. Along the bank of the river agriculture and its allied occupation have been running largely. It is one of the main rivers serving the livelihood requirement in the surrounding areas. Since the people practice agriculture and horticulture farming and plantations, shifting cultivation still the dominant form of agricultural system. It is highly necessary to make land use plan to reach optimum utilization of natural resources. The watershed is small enough to conduct case study and large enough to depict the whole picture of geography of Mizoram and other hilly region. Thus, the watershed has been selected for case in order to find out the availability of natural resources, land use/land cover change, land capability classification and for recommendation of land use plan.

### 2.3 Base map

Base map preparation is a must in the studies of geographical in relation to spatial analysis to locate geographical phenomena. Geographical location map of the selected study area has been prepared and traced from India toposheets number 83D/11, 83D/12 and 83D/15 on 1:50,000 scale to delineate boundary of the sub-watershed comprising road network, drainage and other topographic information. Traced map presenting the detail of such geographical location has been scanned and digitized by using GIS tools of ArcGIS software 10.2.2. After digitizing the layer, it is projected to geographical co-ordinate system for collecting every measures and location of the study area.

### 2.4 Preparation and analysis of satellite imagery

This study deals with the application of remote sensing and GIS for land use planning in Chemlui sub-watershed, Kolasib District, Mizoram, India. The current use of remote sensing for sustainable land management is based on the preparation and analysis of the different thematic layers such as drainage network, land use/land cover and geomorphic features from satellite imagery.

### 2.4.1 Drainage

For the purpose of drainage analysis, drainage map of the study area has been prepared based on Survey of India topographical map on 1:50,000 scale with FCC geo-coded satellite imagery of IRS P6 LISS III to collect the elements o imagery interpretation by using ArcGIS 10.2.2. Density of stream network has long been recognised as topographical characteristics of fundamental significance. This arises from the fact that network density is a sensitive parameter which in many ways provides the link between the forms attributes of the basin and the processes operating along the stream course. The study area is divided into seventeen sub-basins. To find out the drainage density, the area and length of each different basin has been measured and calculated from attribute tables in ArcGIS. After that, the length of the stream is divided by the area of the sub-basins. The drainage density of the sub-basins have been grouped into five classes such as – (i) very low density, (ii) low density, (iii) medium density, (iv) high density and (v) very high density. Drainage frequency map has also been prepared by using ArcGIS software. For the purpose of analyzing of drainage frequency, seventeen basins have been made on the drainage map of the study area. The drainage frequency has been classified into five classes such as – (i) Very low frequency, (ii) low frequency, (iii) moderate, (iv) high frequency and (v) very high frequency.

### 2.4.2 Slope

There are various methods suggested by many geographers for the preparation of average slope map. Slope map is prepared by ArcGIS using digital elevation model acquired by Shuttle Radar Topographic Mission (SRTM) DEM satellite image of 30m spatial resolutions and by using Survey of India toposheets on 1:50,000 scale adopting the methodology proposed by All India Soils and Land Use Survey (AIS & LUS, 1971). Slope map layer has been generated in nine major slope classes with the help of spatial analyst module of ArcGIS 10.2.2 ranging from nearly level to very steep slope area. The slope of the study area has been categorised into nine slope layers such as – (i) level slope, (ii) nearly level slope, (iii) very gentle slope, (iv) gentle slope, (v) gentle to moderate slope, (vi) strongly slope, (vii) Strongly slope to steep slope, (viii) Steep slope to high steep slope, and (ix) steep slope.

### 2.4.3 Geomorphic map

Geomorphic map of the study area has been prepared based on Survey of India topographical maps and FCC geo-coded satellite imagery IRS P6 LISS III and field checks. The data are interpreted and digitized using editing tools and the shape file has been planed again to polyconic co-ordinate from geographic co-ordinate system in order to make measurement in ground units. The area exhibits two prominent type of landforms such as – (i) structural and (ii) fluvial. The structural landforms include – (i) low structural hills (ii) medium structural hills and (iii) high structural hills. Similarly, the prominent fluvial landforms are – (i) flood plain and (ii) valley fill.

### 2.4.4 Soils

Mostly the soils found in the study area are yellow loamy (Loamy Skeletal Typic Hapludults, Fine Loamy Umbric Dystrochrepts and Loamy Skeletal Umbric Dystrochrepts) and red soil. In nature it is acidic with pH values ranging from 4.5 to 6.3. The percentage of organic carbon content, is medium. The available nitrogen is medium while available phosphorus found to be Low. The available potash in this area is found to be high. On the basis of their physico-chemical and morphological properties, the soils found at order level are: - (a) Entisols (b) Inceptisols and (c) Ultisols United States Department of Agriculture (USDA, 1994). It is obvious that due to high rainfall area, the soils might be deficient in base materials like calcium, manganese, aluminium etc. Iron content in the soils seems to be high effecting soil nutrient availability.

### 2.4.5 Land Use Land Cover

The satellite image IRS P6 LISS-III of the year 2006 and 2016 has been interpreted by following elements of image interpretation such as shape, size, texture, colour, pattern, location and resolution through on-screen digitization (figure 2.1 and figure 2.2). Land use/land cover maps thus prepared has been validated by field checks. The two date's satellite images have been compared to find out changes in the land use/land cover. The present land use/land cover in the study area has been broadly classified into built-up land, agricultural land/horticultural land, forest (dense, medium and less), bamboo, forest plantation, shifting cultivation (current and abandoned), scrubland and water body as per the scheme of land use/land cover of NRS (1995) Table 2.1.

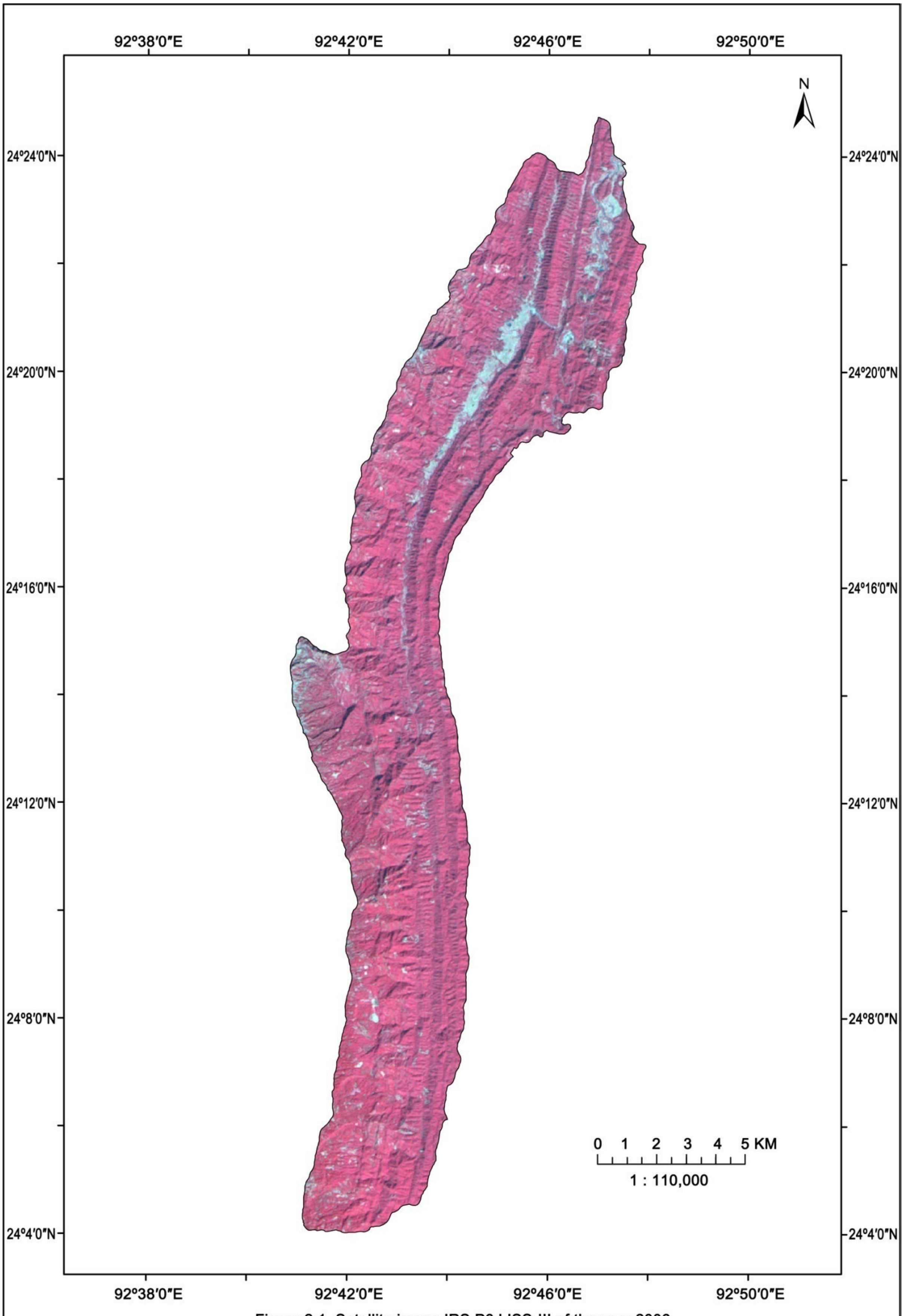



Figure 2.1. Satellite image IRS P6 LISS-III of the year 2006

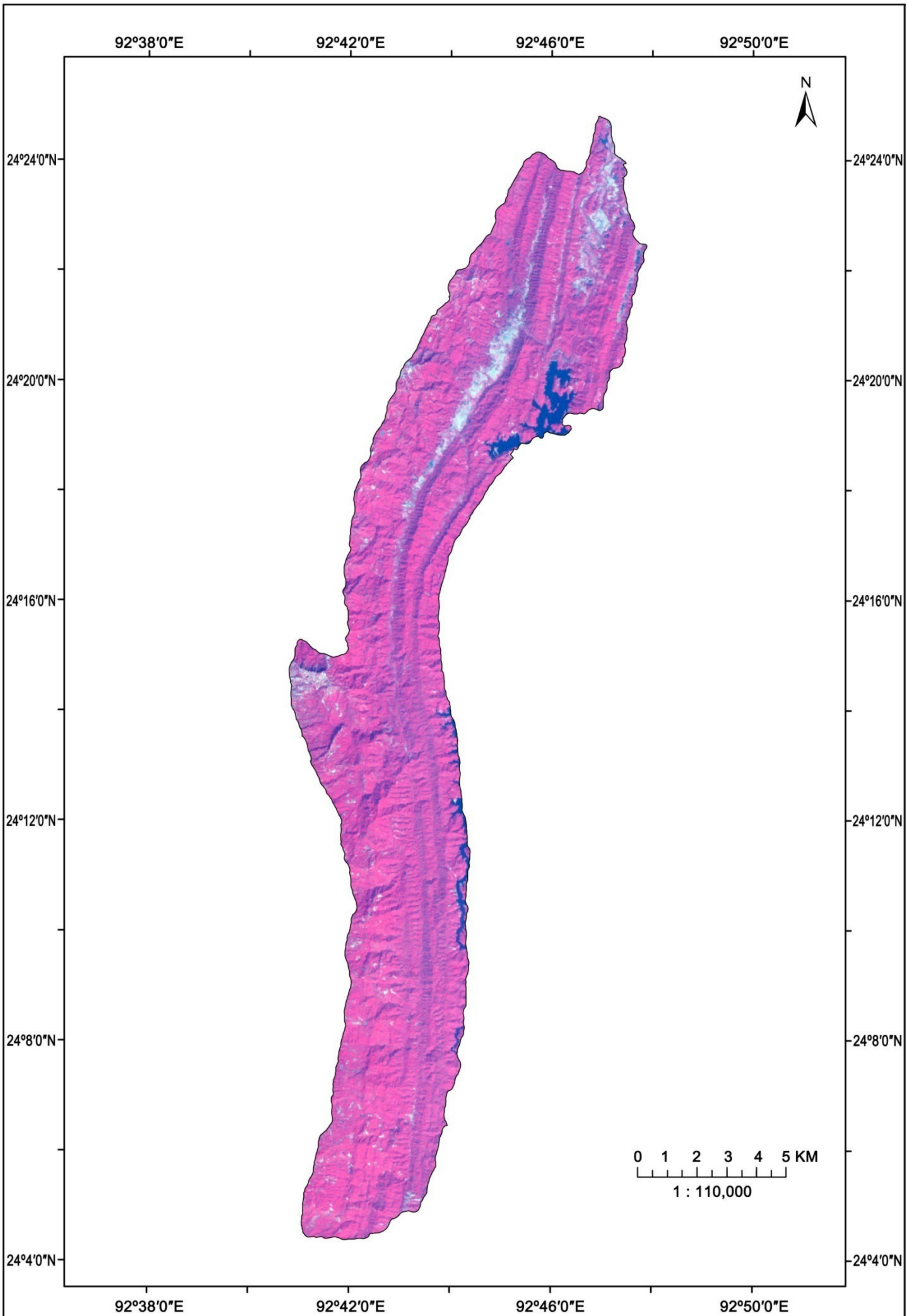



Figure 2.2. Satellite image IRS P6 LISS-III of the year 2016

Table 2.1. Classification of land use/land cover

| Land Use/Land Cover Class | Sub-class |
|---|---|
| Built Up | Built Up-Built Up(Rural)-Built Up Area(Rural) |
| | Built Up-Built Up(Urban)-Residential |
| Agricultural Land | Agricultural Land-Crop Land-Kharif Crop |
| | Agricultural Land-Plantation-Horticulture Plantation |
| Forest | Forest-Evergreen/Semi Evergreen-Dense/Closed |
| | Forest-Evergreen/Semi Evergreen-Open |
| | Forest-Forest Plantation |
| | Bamboo |
| | Forest-Scrub Forest |
| Wastelands | Scrub Land-Open Scrub |
| Water bodies | River/Stream |
| Others | Shifting Cultivation-Abandoned |
| | Shifting Cultivation-Current |

### 2.4.6 Water Resources

A surface and ground water potential maps have been prepared based on the interpretation of satellite image (IRS P6 LISS III FCC geo-coded) of the year 2016, survey of Indian topographical maps and field checks. The groundwater potential map has been prepared based on the integration of the data on drainage density, drainage frequency, slope, geomorphic features and litho-units for the evaluation of water resources.

### 2.4.7 Lithology

For delineation of major lithological unis of the study area, lithological map has been prepared from the geomorphic features and lithology classified by Geological survey of India. The lithological units identified are mostly Bhuban formation of rock types like sandstone, siltstone & shale, gravel, sand & silt and clayey sand.

**2.4.8 Land capability**

Land use capability classification indicates the suitability of various kinds of soil for economic uses, mainly for agriculture. The land capability classification was made into eight capability classes which are indicated by Roman numbers I to VIII along with capability sub-classes based on the inherent properties of soils. These sub-classes of capability are made on the basis of four dominating limitations - risk of erosion (e), wetness, drainage or overflow (w), rooting zone limitations (s) and climatic limitations (c). There are no sub-classes in Class I. The risks of soil damage or limitations are gradually larger from class I to class VIII. Soils of Classes I to IV include land suited for cultivation and should be maintained under natural vegetation of forests or grasses. Soils in classes V, VI, and VII are suited to the use of adapted native plants. Soils in class VIII are extremely rough, arid or swampy and are not suitable for forestry or grazing and cultivation (fig.2.3).

According to the classification made by USDA, soils of the study area have been classified into 5 land capability classes i.e. IIe, IIIe, IVe, VIe and VIIe. The land capability Classes I to IV are considered as capable of producing cultivated crops with good management and conservation treatment. Classes V to VII are best suited to perennial vegetative species, but may be capable of producing some specialized crops with highly intensive management. Class VIII soils are not suitable for managed vegetative production. Subclass ***'e'*** is made up of soils for which the susceptibility to erosion is the dominant problem or hazard affecting their utilization. Erosion susceptibility and past erosion damage are the major soil factors that affect soils in this subclass.

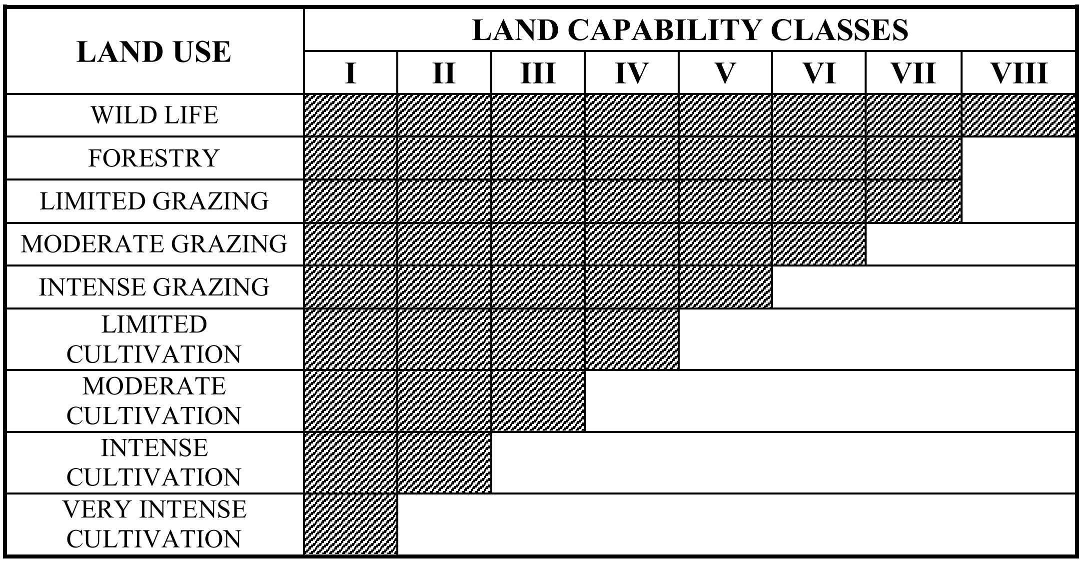


Fig. 2.3 Land Capability Classification

In land capability classification, the arable soils are grouped according to their potentialities and limitations for sustained production of the common cultivated crops that do not require specialized site conditioning or site treatment. Non arable soils (soils unsuitable for long time sustained use for cultivated crops) are grouped according to their potentialities and limitations for the production of permanent vegetation and according to their risks of soil damage if mismanaged. It is mainly based on the inherent of soil properties, external land features, and environmental factors that limit the land use.

## 2.5 Climate

The Climate of the study area is generally pleasant and moderate and there is no extremity of average temperature which ranges between $12^0$C to $33^0$C. The mean average relative humidity varies from 39% to about 81%. The rainfall is well distributed, with a span of almost 6 months from May to October. Although pre-monsoon rains break from the early part of March with occasional thunder-storms, the Monsoon period really starts from the middle part of April. The average annual rainfall is about 2913.8 mm and there are some year's even receiving more than 3000mm of rainfall. The rainfall declines gradually and come to an end during November. Dry spell occurs during the month of November to December. Occasional showers of low to medium intensity also take place during the month of January to February due to the influence of the northeast retreating monsoon. Mizoram state has been delineated into the following three agro-climatic zones based on rainfall, temperature, topography and soil characteristics into humid mild tropical, humid – sub- tropical hill and humid temperate sub Alpine. The study area of Chemlui sub-watershed falls in two distinct agro-climatic zones namely:- humid mild tropical and humid – sub- tropical hill zones.

## 2.6 Data Integration

The integration of the thematic data was done using the raster calculation in Arcmap Spatial Analyst as per the weights assigned (Table 2.2).

Table 2.2. Theme weights (Ranks 1,3,5,7 & 9 are in the order of low to high)

| Sl. No. | Theme | Sub-class | Category | Weight (%) | Rank |
|---|---|---|---|---|---|
| 1. | Drainage Density | Very low density | Less than 3.4 km/ km$^2$ | 10 | 1 |
| | | Low density | 3.4 – 4.0 km/ km$^2$ | | 3 |
| | | Moderate density | 4.1 – 4.2 km/ km$^2$ | | 5 |
| | | High density | 4.3 – 4.7 km/ km$^2$ | | 7 |
| | | Very high density | More than 4.7 km/ km$^2$ | | 9 |
| 2. | Land use / land cover | Built up land | Settlement | 10 | 1 |
| | | Agriculture | Crop Land-Kharif Crop, Plantation-Horticulture Plantation | | 1 |
| | | Forest | Evergreen/Semi Evergreen, Forest Plantation, Scrub forest, Bamboo | | 1 |
| | | Wasteland | Scrub Land-Dense, Scrub Land-open | | 9 |
| | | Water body | River/Stream-Perennial, Lakes/Ponds-Seasonal, Reservoir/Tank-Permanent | | 1 |
| | | Others | Shifting Cultivation-Current and Abandoned | | 3 |
| 3. | Geomorphic Features | Structural landforms | | | |
| | | High Structural Hill | | 10 | 1 |
| | | Medium Structural Hill | | | 1 |
| | | Low Structural Hill | | | 3 |
| | | Fluvial landforms | | | |
| | | Valley Fill | | | 9 |
| | | Flood Plain | | | 9 |
| 4. | Lithology | Sandstone | | 15 | 7 |
| | | Siltstone and Shale | | | 1 |
| | | Gravel, Sand and Silt | | | 9 |
| | | Clayey Sand | | | 9 |
| 5. | Slope | Level slope | 0 - 3 | 20 | 9 |
| | | Nearly level slope | 3 - 10 | | 9 |
| | | Very gentle slope | 10 - 15 | | 9 |
| | | Gentle slope | 15 - 25 | | 9 |
| | | Gentle to moderate slope | 25 - 35 | | 9 |
| | | Strongly slope | 35 - 50 | | 3 |
| | | Strongly slope to steep slope | 50 - 70 | | 3 |
| | | Steep slope to high steep slope | 70 - 100 | | 3 |
| | | Very Steep slope | > 100 | | 1 |
| 6. | Soils | Hill top/ hill crest | | 15 | 1 |
| | | Hill side 0-25% slope with | | | 9 |

| | | | | | |
|---|---|---|---|---|---|
| | | current Jhum Cultivation and scrubland | | | |
| | | Hill side 25-50% slope with current Jhum Cultivation and scrubland | | | 7 |
| | | Hill side >50% slope with current Jhum Cultivation and scrubland | | | 5 |
| | | Valley / WRC | | | 9 |
| 7. | Land Capability | IIe | Good arable land on gentle slopes, susceptible to slight Water erosion, very deep soil, suitable for agricultural practices. | 10 | 9 |
| | | IIIe | Good land with moderate sloping to steep, susceptible to severe water erosion, deep to very deep soil, suitable for horticultural and agricultural practices. | | 9 |
| | | IVe | Highly susceptible to Water erosion, good land on steep to very steep slopes and hill ridge with deep to very deep soil and is suitable for agro-horticultural and sericulture purpose. | | 1 |
| | | VIe | Moderate land with limitations on very steep slope, highly susceptible to water erosion, deep to very deep soil, suitable for horticultural plantation and forestry. | | 1 |
| | | VIIe | Land with severe limitations on very steep slopes, subject to severe erosion and is not suitable for agricultural purpose but suitable for social forestry and grazing. | | 1 |
| 8. | Groundwater | Very Good | | 10 | 9 |
| | | Good | | | 9 |
| | | Moderate | | | 7 |
| | | Poor | | | 1 |

## 2.7 Limitations of the Study

1. There is no proper record of land properties keep by the villagers regarding natural resources utilization.
2. Some variables are complicated to interpret because they may load onto more than one factor which is known as split loadings. These variables may correlate with each other to produce a factor despite having little underlying meaning for the factor.

# CHAPTER – III

# ASSESSMENT

# OF

# NATURAL RESOURCES

# CHAPTER – III

# ASSESSMENT OF NATURAL RESOURCES

## 3.1 Introduction

Utilization of natural resources in rural areas value resources differently due to complex socio-economic, demographic, environmental and cultural attributes of the households. While the importance of these aspects is well recognized in analyzing livelihood strategies and sustainability, the rationality behind household strategies/ decision-making processes from users' perspective has not received due attention, especially in the context of environmental degradation and natural resource assessment. As a result, resource degradation in rural areas of the developing world is often erroneously linked with population explosion and poverty (Vyas, 1991; Leach and Mearns, 1991; Tiffen et al. 1994; Reddy, 1995). Moreover, users' perceptions also depend on the existing institutional set- up and property rights regimes in rural areas. Therefore, understanding users' rationality in resource valuation, economic as well as non-economic, is crucial for policy on environment and sustainable agricultural development.

The literature on issues of relationships between poverty and resource degradation on the one hand, and property rights and institutions in natural resource management on the other, shows divergent views. It is often argued that the poor degrade the environment more due to their greater reliance on the natural system and also due to the high discount rates of future returns consequent upon the absence of alternative income sources. However, many observers challenge the argument of a high discount rate by the poor. Since the poor depend heavily on a limited natural resource base they have a greater motivation to conserve it. It is further argued that a number of factors like the existing institutional structures, awareness and attitudes of the people towards natural resources and environment influence the discounting of the future significantly. It is also not clear whether this is true of both private and common resources or limited to commons only. On the other hand, resource degradation can be an optimal response to economic and environmental circum- stances under a much wider range of property rights regimes than conventionally accepted ones, i e, private and common property rights (Larson and Bromley, 1990). Here optimal response is from the user point of view rather than the community's. Individual rationality may have negative social effects manifested in ecological degradation (Mamdani, 1992) while protecting the resources in scarcity conditions is an optimal solution from individual as well as community point of view. The debate is, therefore, mainly centered on the superiority of either market or institutional approaches in explaining resource degradation.

The validity of these arguments needs to be verified in diverse agro-climatic (environmental), socio-cultural, political and economic conditions. There are enormous diversities in valuation of resources and benefits by the users, and the missing distorted markets pose further problems in some instances. This requires a 'bottom up' approach. In the Indian context there have been no attempts to study the valuation of resources and benefits from the users' perspective. The studies on valuation that are available have analyzed the allocation and innovation decisions of farmers to upgrade responsiveness at macro as well as micro level. It is, however, clear now that the responsiveness is not uniform across space. Market distortions, missing markets or tenure over resources, socio- cultural aspects, initial endowments, etc, are crucial in determining valuation by users. Hence, a study of this nature demands an integrated approach of economic and non-economic aspects rather than following just one of them.

In this chapter, it has been analyzed and assessed the natural resources of Chemlui sub-watershed such as the physiological aspects of slope, geomorphic features, land use/land cover, surface water resources, groundwater potential, soils, drainage, climate and land capability along with forest resource using the most advanced technology of remote sensing and geographical information system (GIS).

### 3.2. Assessment of physical aspect

Land resources utilization has its impact on the biodiversity and environment of allied region either positively or negatively depending on how it is used in time and space. As land-use planning is defined as a systematic assessment of land and water potential, alternatives for land use, and the economic and social conditions required to select and adopt the best land-use options, therefore, it is important to identify the available resources at micro level more precisely. The management of resources at watershed or sub-watershed level is convenient and the most effective for land use development. Land use planning activities are usually started with the objectives to increase productivity and to improve the sustainability of natural resources. The remote sensing technology along with GIS tools is a perfect device to identify, locating and prepared maps of various types of lands associated with different landform units.

The land use pattern of the study area is strongly influenced by the physiographic, climate and mountainous terrain, especially in agricultural system. A land resource is one of the major natural resources. The changes of land use pattern over a time period control the stress on land.

### 3.2.1 Slope

Slope is considered as one of the most important elements of topography which affects directly to the agricultural activities. Slope is also very important in delineation of ground water potential zones as the degree of slope controls the infiltration capacity of the water potentiality in the study area. In wide-ranging the steep sloping areas assist high run-off consenting to less time percolation of rainwater while gently sloping areas consent more water to infiltrate into the sub-surface layer. Therefore, assessment of slope is very essential in order to manage the areas of potential zones for agricultural plan.

The study area is characterized by many hill ridges running parallel to each other, most of which roughly runs from north to south and is broadly suitable for wet rice cultivation and horticultural practices. The south-western most parts consist of high degree of slopes, while northern parts are characterized by nearly level sloping and low lying areas. Narrow valleys separate hill ridges and most of them have nearly level to steep slopes with observable escarpments on hillside slopes.

Nine major slope classes have been generated which range from nearly level slope area to very steep slope area (Table 3.1). The nine slope classification are – (i) level slope, (ii) nearly level slope, (iii) very gentle slope, (iv) gentle slope, (v) gentle to moderate slope, (vi) strongly slope, (vii) Strongly slope to steep slope, (viii) Steep slope to high steep slope, and (ix) steep slope. The present slope map (Fig.3) and statistics data is given below:

Table 3.1. Major Slope Classes in Chemlui sub-watershed.

| **Slope Classification** | | **Area in Ha.** | **Area in %** |
|---|---|---|---|
| **Slope Class** | **Slope %** | | |
| Level slope | 0 - 3 | 454.46 | 2.74 |
| Nearly level slope | 3 - 10 | 2049.00 | 12.37 |
| Very gentle slope | 10 - 15 | 67.33 | 0.41 |
| Gentle slope | 15 - 25 | 1211.30 | 7.31 |
| Gentle to moderate slope | 25 - 35 | 3125.46 | 18.87 |
| Strongly slope | 35 - 50 | 6732.19 | 40.65 |
| Strongly slope to steep slope | 50 - 70 | 2438.16 | 14.72 |
| Steep slope to high steep slope | 70 - 100 | 435.29 | 2.63 |
| Very Steep slope | > 100 | 49.80 | 0.30 |
| | **Total** | **16563.00** | **100%** |

Slope class of 0 to 3 percent of level slope covers a total area of 454.46 hectares comprising 2.63% of the total study area. The slope class of 3 to 10 percent of nearly level slope covers a total area of 2049 hectares comprising 12.37% of the total area. The slope class of 10 to 15 percent of very gentle slope covers only a total area of 67.33 hectares comprising 0.41% of the total area. The slope class of 10 to 25 percent of gentle slope covers a total area of 1211.30 hectares comprising 7.31% of the total area. Slope class having 25 to 35 percent of gentle to moderate slope covers a total area of 3125.46 hectares comprising 18.87% of the total study area. The slope class having 35 to 50 percent of strongly slope covers a large area of 6732.19 hectares comprising 40.65% of the total watershed area. The slope class having 50 to 70 percent of strongly slope to steep slope covers a large area of 2438.16 hectares comprising 14.72% of the total area of the watershed. Slope class of 70 to 100 percent of steep slope to high slope covers an area of 435.29 hectares comprising only 2.63% of the total area. Slope class having more than 100 percent of very steep slope covers a quite small area of 49.80 hectare which comprising only 0.30% of the total study area.

The slope class which covers the largest area is strongly slope class having 35 to 50 slope percent and occupied 40.65% of the total study area of Chemlui sub-watershed and the smallest area is covered by a very steep slope class which is only 49.80 hectare which comprising only 0.30% of the total study area of the watershed.

**3.2.2 Soils**

Soil is formed due to interaction between parent materials, climate and biotic factors as modified by the conditions of terrain and the period over which the interface has been going on. Variation in the concentration of formation influencing factors results into different kinds of soils. The rocks of this area are generally sandstone, siltstone and shale, gravel, sand and silt and Clayey sand and the derived soils are mostly red and yellow loamy. The soil is acidic in nature due to heavy rainfall with pH values ranging from 4.5 to 6.3. It contains a high amount of organic carbon and is high in available nitrogen, low in phosphorus and potassium content.

Classification of soils of the study area has been done according to soil taxonomy United States Department of Agriculture (USDA, 1994) on the basis of their

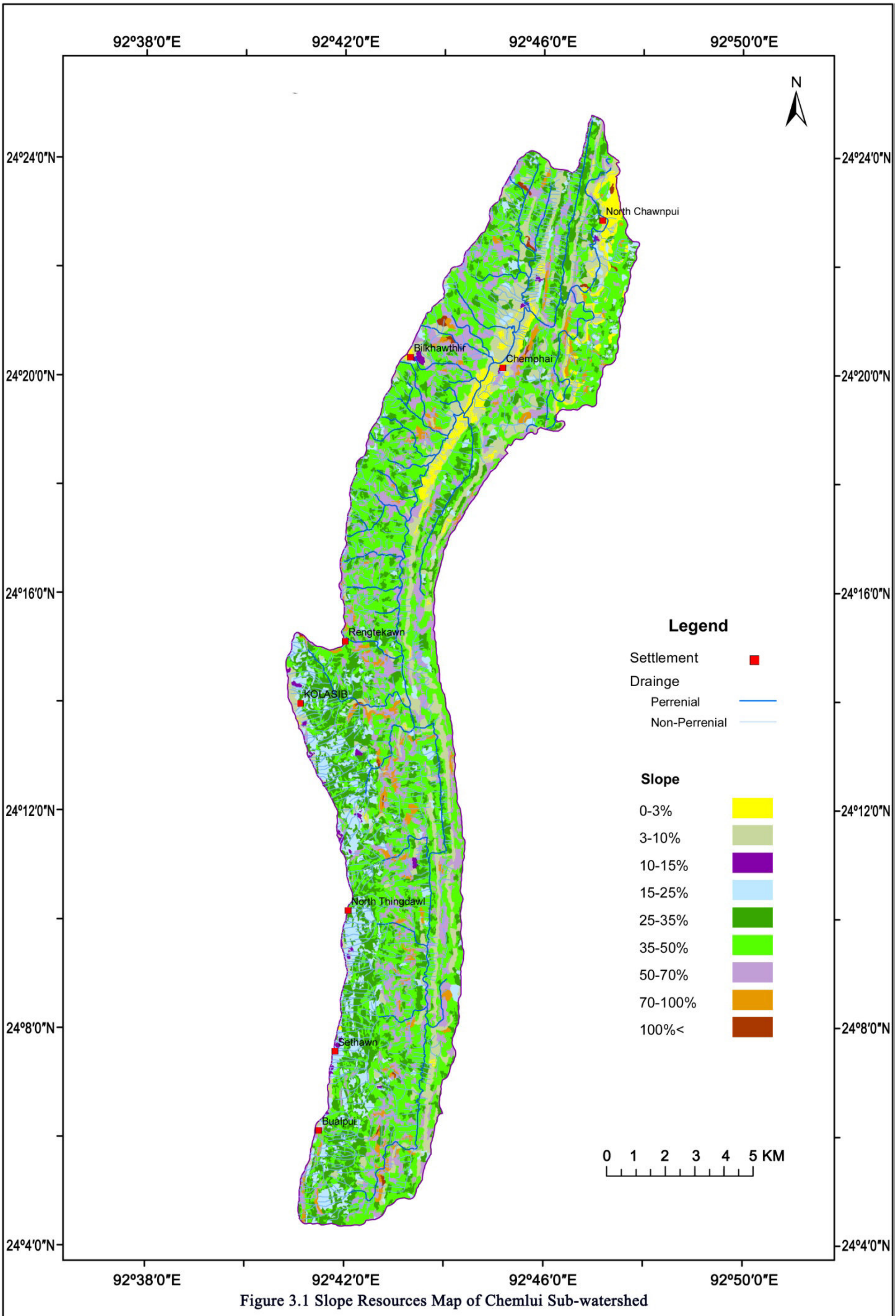



Figure 3.1 Slope Resources Map of Chemlui Sub-watershed

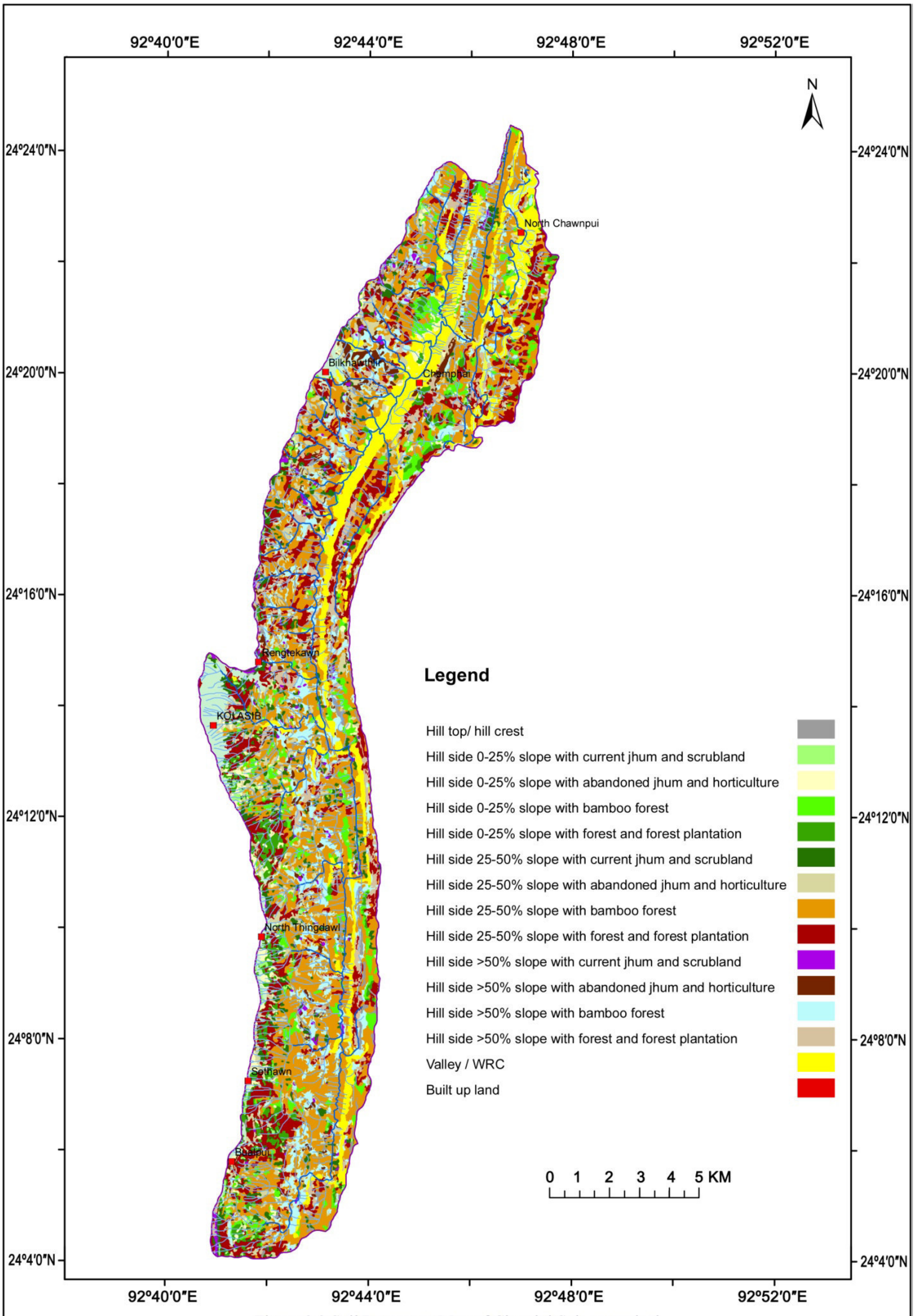



Figure 3.2 Soil Resources Map of Chemlui Sub-watershed

physical, chemical and morphological properties. The soils found at order level are: (i) Entisols (ii) Inceptisols and (iii) Ultisols (Table. 3.2). The soil types and classification of Chemlui Sub-watershed is shown in Table. 3.3.

Eleven types of soils composition with different characteristics and having a varied resources utility were identified in the study area such as loamy skeletal typic dystrochrepts, loamy skeletal humic hapludults, loamy skeletal typic hapludults, loamy skeletal umbric dystrochrepts, fine loamy typic hapludults, fine loamy humic hapludults, fine loamy umbric dystrochrepts, fine loamy typic dystrochrepts and fine loamy aquic dystrochrepts, valley/wet rice caltivation soil and soil under water body (Fig.3.2).

Table 3.2. Soil Classification of Chemlui sub-watershed.

| Sl.No. | Soil Order | Sub-order | Soil Group | Sub Group | Soil family |
|---|---|---|---|---|---|
| 1 | Entisols | Orthents | Udorthents | Aquic Udorthents | Fine Loamy, Hyperthemic, Mixed |
| 2 | Inceptisols | Ochrepts | Dystrochrepts | Aquic Dystrochrepts<br>Typic Dystrochrepts<br>Umbric Dystrochrepts | Fine Loamy, LoamySkeletal, Hyperthemic, Mixed |
| 3 | Ultisols | Udults | Hapludults | Typic Hapludults | Fine Loamy, LoamySkeletal, Hyperthemic, Mixed |

Table 3.3. Soil Types of Chemlui sub-watershed.

| Sl.No. | Soil mapping unit | Soil Composition | Area in Ha. |
|---|---|---|---|
| 1 | Hill top/ hill crest | Loamy Skeletal Typic Dystrochrepts, Fine Loamy Typic Hapludults, Loamy Skeletal Typic Hapludults | 231.93 |
| 2 | Hill side 0-25% slope with current Jhum Cultivation and scrubland | Fine Loamy Typic Dystrochrepts , Fine Loamy Typic Hapludults , Loamy Skeletal Humic Hapludults | 157.09 |
| 3 | Hill side 0-25% slope with abandoned Jhum Cultivation and horticulture | Loamy Skeletal Typic Hapludults, Fine Loamy Humic Hapludults , Loamy Skeletal Typic Dystrochrepts | 290.51 |
| 4 | Hill side 0-25% slope with bamboo forest | Fine Loamy Typic Dystrochrepts, Loamy Skeletal Umbric Dystrochrepts, Fine Loamy Humic Hapludults | 807.54 |
| 5 | Hill side 0-25% slope with forest and forest plantation | Fine Loamy Umbric Dystrochrepts, Fine Loamy Typic Hapludults, Loamy Skeletal Humic Hapludults | 536.65 |
| 6 | Hill side 25-50% slope with current Jhum Cultivation and scrubland | Loamy Skeletal Humic Hapludults, Fine Loamy Typic Hapludults, Fine Loamy Typic Dystrochrepts | 700.94 |
| 7 | Hill side 25-50% slope with abandoned Jhum Cultivation and horticulture | Fine Loamy Typic Hapludults , Loamy Skeletal Umbric Dystrochrepts, Loamy Skeletal Typic Dystrochrepts | 993.70 |
| 8 | Hill side 25-50% slope with bamboo forest | Loamy Skeletal Umbric Dystrochrepts Fine Loamy Umbric Dystrochrepts Fine Loamy Humic Hapludults | 5510.86 |
| 9 | Hill side 25-50% slope | Fine Loamy Humic Hapludults , | 2293.83 |

| | | | |
|---|---|---|---|
| | with forest and forest plantation | Loamy Skeletal Typic Hapludults, Loamy Skeletal Umbric Dystrochrepts | |
| 10 | Hill side >50% slope with current Jhum Cultivation and scrubland | Fine Loamy Typic Dystrochrepts, Loamy Skeletal Typic Hapludults , Fine Loamy Typic Hapludults | 147.72 |
| 11 | Hill side >50% slope with abandoned Jhum Cultivation and horticulture | Fine Loamy Umbric Dystrochrepts, Loamy Skeletal Typic Hapludults, Loamy Skeletal Typic Dystrochrepts | 333.56 |
| 12 | Hill side >50% slope with bamboo forest | Loamy Skeletal Umbric, Dystrochrepts, Fine Loamy Typic Dystrochrepts, Loamy Skeletal Humic Hapludults | 1549.48 |
| 13 | Hill side >50% slope with forest and forest plantation | Loamy Skeletal Humic Hapludults , Loamy Skeletal Umbric Dystrochrepts | 841.76 |
| 14 | Valley / WRC | Fine Loamy Aquic Dystrochrepts, Fine Loamy Typic Hapludults | 1709.58 |
| 15 | Water body | | 254.56 |
| 16 | Built up land | | 203.29 |
| **Total** | | | **16563** |

### 3.2.3 Geomorphic features

Landforms provide clues to understand surface as well as sub-surface lithological and terrain conditions. The geomorphic feature of study area is represented by a repetitive series of argillaceous and erinaceous rocks, which are classified by Geological Survey of India into two formations viz., Middle Bhuban and Upper Bhuban Formations. These formations are folded into almost North-South trending anticlines and synclines, and affected by longitudinal, oblique and transverse faults of varying magnitudes. The rock succession is classified into two formations on the basis of lithological group and sedimentary structures. The topography is controlled by the lithology and geological structure of the confined area. But, in many places the immature topography is being modified by structural disturbances. On the western side, the major ridge line bordering the Chemlui sub-watershed area which is dominated by linear ridges, subdued hillocks and valley fills. There are no other prominent ridge lines within its surrounding area except the ridge line of Chemtlang on the eastern side which is almost 26 kilometers in length. Between the main ridge of Kolasib and the Chemtlang ridge Chemlui river flows parallel to the ridges from south to north direction.

The geomorphic features of the study area are broadly classified into (i) Structural and (ii) Fluvial origin. Structural hill constitutes the main geomorphic class covering 93.84 percent of the study area which is associated with folding, faulting and other tectonic processes. Structural hills are further divided into three classes viz., high structural hill, medium structural hill and low structural hill. High Structural hills above 1000 meters of an altitude covers an area of only above 40.13 hectare which accounts only 0.24% of the study area, and are found in the southern part of Bualpui village area. Medium Structural Hills above 700 - 1000 meters of an altitude covered an area of 394.96 hectare which accounts 2.39% of the study area are found at Bualpui, Sethawn, Thingdawl village and Kolasib town. Low Structural Hills below 700 meters of altitude covers the most of the area of 15108.34 hectares which accounts 91.22% of the study area are found almost throughout the entire study area.

Valley fill is a very important geomorphic feature in the study of fluvial origin, and are characterized by unconsolidated sediments deposited by rivers and streams in a narrow fluvial valley. They are found mainly along Chemlui river and lower Serlui river around Chemphai and North Chawnpui village. Valley Fill covers an area of 748.85 hectares which accounts 4.52% of the study area. Flood plain is another geomorphic class found along the main courses of the rivers in the study area which are formed by deposition of alluvium on the sides of the rivers. This geomorphic unit covers an area of 270.72 hectares which accounts 1.63% of the total study area. The spurs are generally oriented in east to west directions. The spurs on the eastern side of the Chemtlang ridge line are comparatively short and gentler than the spurs of the Kolasib ridges on the western side. Steep slopes and scarps are found along the sides of the western main ridge lines. The landform classification is presented in Table. 3.4 and Figure. 3.3.

Table. 3.4 Geomorphic Classification of Chemlui Sub-watershed.

| Sl.no | Geomorphic Unit | Area in Hactares | Area in % |
|---|---|---|---|
| 1 | Structural landforms | | |
| | (i) High Structural Hill | 40.13 | 0.24 |
| | (ii) Medium Structural Hill | 394.96 | 2.39 |
| | (iii) Low Structural Hill | 15108.34 | 91.22 |
| 2 | Fluvial landforms | | |
| | (i) Valley Fill | 748.85 | 4.52 |
| | (ii) Flood Plain | 270.72 | 1.63 |
| | **Total** | **16563.00** | **100** |

### 3.2.4 Lithological features

The lithological mapping of the study area has been done based on the interpretation of geological maps of Geological survey of India with field checks. Accordingly, the study area is divided into the following four lithological classes (Table 3.5 and Figure 3.4).

Table No. 3.5. Lithological classification of Chemlui Sub-watershed.

| **Rock Types** | **Area in Hectares** | **Area in %** |
|---|---|---|
| Sandstone | 6772.42 | 40.89 |
| Siltstone and Shale | 9124.88 | 55.09 |
| Gravel, Sand and Silt | 469.49 | 2.83 |
| Clayey Sand | 196.21 | 1.19 |
| **Total** | **16563** | **100** |

(i) Sandstone - Sandstone is the predominant rock type in the study area which is comparatively harder rock formation found mainly along the ridges due to its resistance to erosional elements. This rock unit covers an area of 6772.42 hectares which accounts 40.89% of the Chemlui sub-watershed.

(ii) Siltstone and shale –This unit class covers most of the study area. It spreads over an area of 9124.88 hectares which accounts 55.09% of the watershed.

(iii) Gravel, sand and silt - These are alluvium deposits mainly found along the rivers of Chemlui and Serlui which covers an area of 469.49 hectares which accounts 2.83% of the study area.

(iv) Clayey Sand deposits are found scattered all over the area along the small streams and valley fills with an area of 196.21 hectare which accounts 1.19% of the study area.

The Lithological classification is shown in Table.3.5 and Figure. 3.4.

### 3.3 Land use/land cover

Land use is found to be the most important human induced factor influencing land cover. It is found that land use/land cover dynamics are heterogeneous, and it is a complex phenomenon to understand as there are several complex interactions of biophysical, demographic and socio-economic factors as inferred by Ojima and Moram (2004). As land-use planning is defined as a systematic assessment of land and water potential, alternatives for land use, and the economic and social conditions required to select and adopt the best land-use options, it is important to identify the available resources at micro level more precisely. Land resources utilization has its impact on the biodiversity and environment of allied region either positively or negatively depending on how it is used in time and space. The management of land resources at sub-watershed level is convenient and the most effective for their development. Accordingly, land use and land cover for the year 2006 and 2016 has been prepared and analyzed to identify land cover and changes that occurred between the two selected years to prepare propose land use map in order to suggest alternative land use farming systems for the development of resources in Chemlui sub-watershed (Fig. 4.1 and Fig. 4.2).

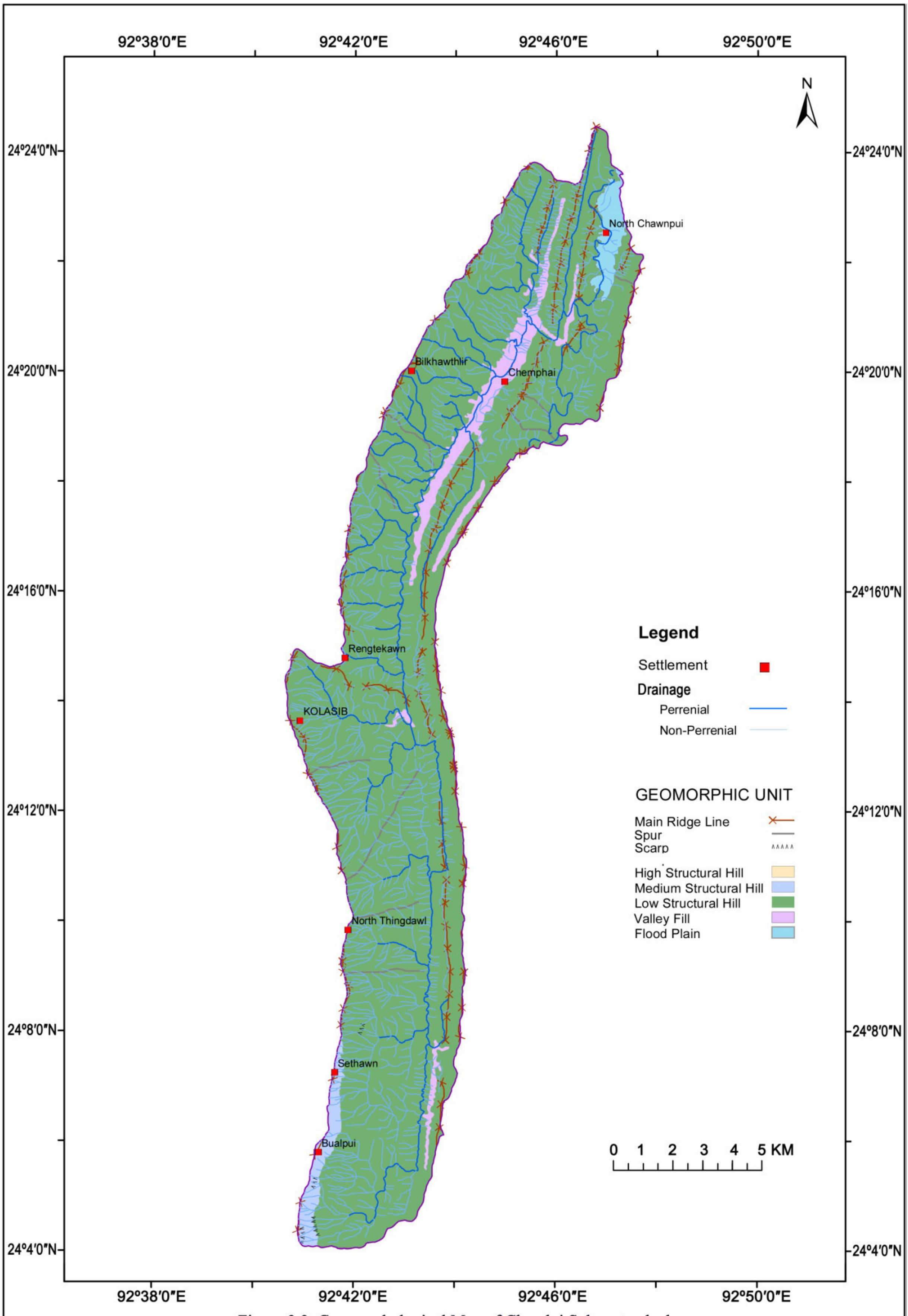


Figure 3.3. Geomorphological Map of Chemlui Sub-watershed

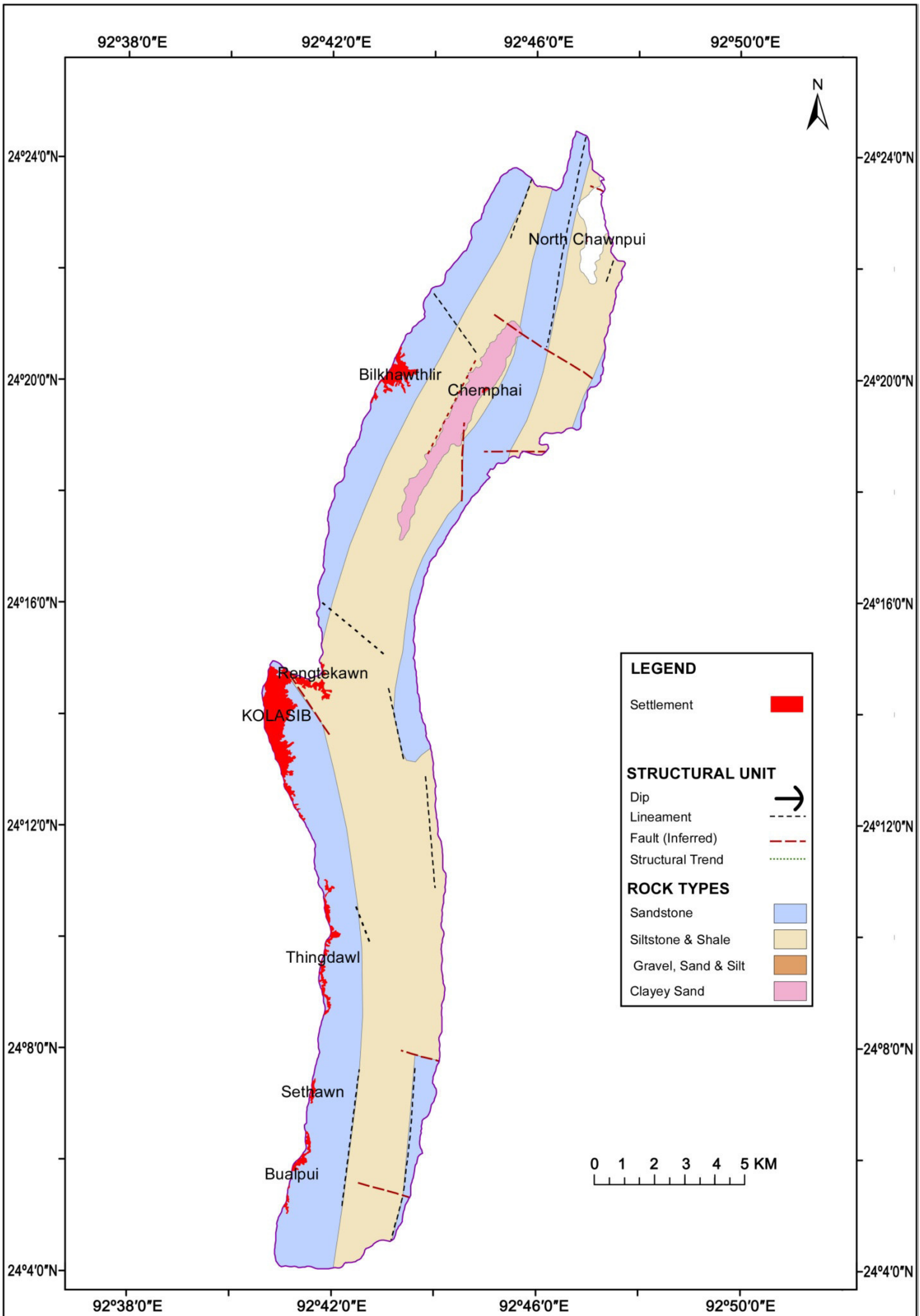



Figure 3.4. Lithological Map of Chemlui Sub-watershed

In current land use land cover, the thematic map identified and shows more kinds of land use/ land cover which is not found in the last one decade. Land use units like Water bodies-Lakes/Ponds-Seasonal and Water bodies-Reservoir/Tank-Permanent have been identified with significance. Thus land use/land cover of the watershed area is classified into 6 broad categories such as built up land, agricultural Land, Forest, wastelands-scrub land-dense and open, Water bodies and others such as Shifting Cultivation (Table. 3.6). It has been analyzed that more than half of the watershed is covered by bamboo forest which comprises 55.79 per cent of the total watershed area. A wide area of land are also found at different land use classes such as built up (1.71%), agricultural land-crop land-kharif crop (5.19%), agricultural land-plantation-horticulture plantation (1.28%), forest-evergreen/semi evergreen-dense/closed (11.23%), forest-evergreen/semi evergreen-open (9.34%), forest-forest plantation(0.31%), forest-scrub forest (9.77%), wastelands-scrub land-dense (0.52%), wastelands-scrub land-open (0.15%), water bodies-reservoir/tank-permanent (1.74%), water bodies-river/stream-perennial (0.25%), and water bodies-lakes/ponds-seasonal accounting (0.02%) shifting cultivation-current (1.22%), shifting cultivation-abandoned (1.49%) of the total watershed area.

### 3.3.1 Built up land

Built-up land includes settlement, road and site plan for transport, communication lines and commercial areas. The study area covered and area of 283.06 hectares which accounts for 1.71% of the total area of the Chemlui Sub-watershed. The built up land comprised of two towns namely Kolasib and North Thingdawl and five villages namely Bilkhawthlir, Bualpui, Sethawn, North Chawnpui and Chemphai. Kolasib town is the district headquarters and located at the centre of the study area.

### 3.3.2 Agricultural Land-Crop Land-Kharif Crop

Agriculture land includes those areas, which are permanently used for crop cultivation. Kharif crop is confined only to the area of wet rice cultivation (WRC). Majority of the crop lands are found in the northern part of the watershed covering an area of 858.82 hectares which accounts for 5.19% of the total area of the Chemlui Sub-watershed.

### 3.3.3 Agricultural Land-Plantation-Horticulture Plantation

Chemlui Sub-watershed also accommodates a variety of agricultural/horticultural plantations, of which the prominent ones includes *Coffespp* (Coffee), *Areca catechu* (Betelnut) and *Citrus* plantation. Coffee plantation is found at Bualpui village and is undertaken by the Coffee Board, Government of India. It covers an area of 17 hectares, which accounts for 0.10% of the total area of the district. *Areca catechu* (Betelnut) plantation is one of the major successful plantations among horticultural crops within the watershed. They are found in the north western part of the study area like Bilkhawthlir, Bualpui and Thingdawl villages and is found to be growing well in the warmer climate. It covers an area 182 hectares, which accounts for 1.10% of the total study area. Citrus woodland includes *Cirus reliculata* (Orange) plantation and *Citrus macropetera* (Hatkora) plantation is also found in some parts of Bualpui and Thingdawl area. *Parkia speciosa(zawngtah)* is also sparsely found all over the area.

### 3.3.4 Forest

The forest cover type of Chemlui Sub-watershed is mainly tropical wet evergreen forest and tropical semi-evergreen forest associated with moist deciduous forests. Moist deciduous forests are commonly found in small compact areas on the hill slopes. The vegetation consists of a mixture of several species. Depending on the density of the canopy cover, the forests have been classified into forest-evergreen/semi evergreen forest of dense and opened type.

Dense forest class includes natural forests which are not disturbed by any features like shifting cultivation and other human activities. Evergreen and semi-evergreen forests cover the major portion of this area which is considered as a very dense. It covers an area of 1860.58 hectares, which accounts for 11.23 % of the total study area. Vast dense forests are found near Sethawn, Bualpui and Thingdawl villages.

Evergreen and semi evergreen forest of opened type covers an area of 1547.49 hectares, which accounts for 9.34 % of the total study area. It is distributed throughout the watershed in small patches. The vegetation of this forest is more or less similar to those species found in dense forests. The difference lies only in density of the vegetation.

Scrub Forest has a very less extent. It covers an area of 1618.65 hectares, which accounts for 9.77 % of the total study area. This type of forests is commonly found at the periphery of Kolasib, Bualpui, Thingdawl and North Chawnpui villages. This type of forest includes forest, which were once disturbed and affected by biotic factors like shifting cultivation and human activities. These forests are characterized by those lands where Jhum cultivation had been practiced and then left fallow for years and regenerated to form new forests.

### 3.3.5 Bamboo

Bamboo forests are found in low lying areas along the bank of rivers and are also found on the hill slopes in some areas. This type of forest covers the largest area of 9239.77 hectares which accounts for 55.79% in the study area. The main bamboo species found in this area *Dedrocalamus hamiltonii, Dedrocalamus longispathus and Meloccana bamibusoides.*

### 3.3.6 Forest Plantation

Forest plantations are spotted sparsely all over the study area. It covers an area of 50.83 hectares, which accounts for 0.31% of the total area. Some area has large cover while most of them are with area below the minimum unit for mapping. The major forest plantations are Teak *(Tectona grandis)* and Gmelina *(Gmelina arborea)*. Teak plantation is the most predominant forest plantation found in the study area. They are usually planted along the roadside and is found abundantly at Thingdawl and Bilkhawthlir area. Gmelina plantations are found in small patches within Bualpui, Kolasib and Bilkhawthlir villages.

### 3.3.7 Wastelands-Scrub Land

In the study area, scrub lands are those lands that are frequently disturbed by biotic factors and other human activities as such flora cannot grow in proper order. There are two category such as wastelands-scrub land-dense and wastelands-scrub land-open and are found along the roadside and in some part of hinter's area. The two classes of scrub land such as dense and opened cover an area of about 86.59 hectares and 24.80 hectares respectively. These areas are mostly dominated by grass species like *baccharum longisetosum and Imperata cylindrica, Eupatorium odoratum, Mikania micrartha* and others scrub items.

### 3.3.8 Water bodies

Chemlui sub-watershed is drained by Chemlui river which is flowing from south to north and Serlui river which flows towards northwestern side of the study area. Water body of the study area has been classed into three categories – (i) water bodies-river/stream-perennial covers an area of 40.84 hectares, which accounts for 0.25% (ii) water bodies-lakes/ponds-seasonal covers an area of 2.82 hectares, which accounts for 0.02% and (iii) water bodies-reservoir/tank-permanent covers an area of 287.49 hectares, which accounts for 1.74% of the total study area. This class includes rivers and streams within the study area.

### 3.3.9 Shifting Cultivation-Current

Current shifting or jhum cultivation is the main agricultural practice by the inhabitant partially on the hill slopes of the study area. The location of shifting cultivation is always related to altitude and slope characteristics. Therefore, locations where there is very steep slope are not often possible for shifting cultivation. The highest percentage of shifting cultivation is found on the gentler slopes and progressively decreases on steeper slopes (15% - 70% slope). The shifting is always associated with abandoned jhum and secondary forests. The jhum plots are small in size and irregular in shape. It covers an area of 201.54 hectare, which accounts for 1.22% of the total study area of Chemlui sub-watershed.

### 3.3.10 Shifting Cultivation-Abandoned

Abandoned shifting cultivation of roughly up to two years is considered in the study area. It covers an area of 247.01 hectares which accounts for 1.49% of the total area. The area of recent abandoned shifting cultivation is having large number of young bamboo shoots, tree seedlings and saplings. Though these areas are very recent abandoned, it is covered by the dominant varieties of tree species.

Table No. 3.6. Land use/ land cover classification of Chemlui Sub-watershed.

| Sl.no | Land Use Class | Area in Ha | Area in % |
|---|---|---|---|
| 1 | Built Up | 283.06 | 1.71 |
| 2 | Agricultural Land-Crop Land-Kharif Crop | 858.82 | 5.19 |
| | -Plantation-Horticulture Plantation | 212.71 | 1.28 |
| 3 | Forest-Evergreen/Semi Evergreen-Dense/Closed | 1860.58 | 11.23 |
| | -Evergreen/Semi Evergreen-Open | 1547.49 | 9.34 |
| | -Forest Plantation | 50.83 | 0.31 |
| | -Scrub Forest | 1618.65 | 9.77 |
| | -Bamboo | 9239.77 | 55.79 |
| 4 | Wastelands-Scrub Land-Dense | 86.59 | 0.52 |
| | -Scrub Land-Open | 24.80 | 0.15 |
| 5 | Waterbodies-River/Stream-Perrenial | 40.84 | 0.25 |
| | -Lakes/Ponds-Seasonal | 2.82 | 0.02 |
| | -Reservoir/Tank-Permanent | 287.49 | 1.74 |
| 6 | Others - Shifting Cultivation-Current | 201.54 | 1.22 |
| | - Shifting Cultivation-Abandoned | 247.01 | 1.49 |
| | **TOTAL** | **16563** | **100.00** |

### 3.4 Water Resources

Water is one of the most valuable resources that the earth provides to mankind. The availability and quality of water constantly have played a significant role in determining not only human livelihood, but also for the development of land use as well as agricultural improvement. Even if there always have been plenty of fresh water resources, water is not constantly been available when and where it is required nor it is always of suitable quality for all uses. It must be considered as a limited resource that has confines and limitation for its availability and suitability to utilize. The balance between supply and demand for water resource is an elusive one. The availability of usable water has and will continue to state where and to what extent development will occur. Therefore, water resource must be sufficient supply for an area to develop.

Despite the fact that the study area of Chemlui Sub-watershed receives high amount of rainfall during the main part of the year as it is partially due to its seasonal characteristics. During the dry periods, groundwater appears to be the main source of water for agricultural activities at several places in the watershed. It is therefore necessary to evaluate the water resources for capable utilization in the development agricultural activities. The present study of water resources is an attempt to assess the existing surface water resources in the form of drainage system river, stream, tanks, ponds, reservoirs and groundwater potentiality in the area.

#### 3.4.1 Surface Water Resources – River/stream/ tanks /ponds /reservoirs

Ever since the drainage system for the study area is preside over mainly by the natural course of drainage and topography, therefore, the drainage system of Chemlui

Sub-watershed has been divided into seventeen micro-watershed areas based on the visual interpretation of satellite imagery and the Survey of India topographical maps (Table 3.7).

Chemlui Sub-watershed is drained by Chemlui River and a good number of streams and rivulets of different patterns and length. The main river Chemlui is originated from the place named ‘Khawserhsang tlang’ near Bualpui village in the north of the area (Figure.3.5). In the north western part, lower Serlui River is confluent by Chemlui River near North Chawnpui village. Most of these streams and rivulets are fleeting in nature. The study area provides a fertile agricultural land near Bilkhawthlir village at Chemphai. The Chemphai plain, after the name of Chemlui is popular in agricultural development where individual can find the agricultural research firm. In Chemlui drainage system, a trellis drainage pattern can be seen in the northern area presenting some structural control. It is found that all the prominent tributaries streams of Bualpui Lui, Pingpi Lui, Sakei Lui, Dum Lui, Bangla Lui, Kem Lui, Luipui Lui, Fuanlian Lui, Pang Lui, Thingdelh Lui, Buarchep Lui and Chepte Lui are perennial in nature.

The drainage complex could provide efficient water resources in the study area. Similarly, there are some prominent ponds and tanks particularly in the northern and central parts of the watershed along the low lying areas where clayey sands exist. Most of the ponds and tanks in this area are converted into aqua-farms for fish farming and also for irrigation to agricultural sites. The existing drainage system plays a dual role in recharging and also in discharging groundwater as the main river is controlled by faults and fractures to the large extent.

Table. 3.7 Micro Watershed Statistics of Chemlui Sub-watershed

| Sl. No. | Micro -Watershed No. | Micro-Watershed Area in Sq.Km | No. of Stream | Stream Length in Km | Drainage Density $km/km^2$ | Drainage Frequency |
|---|---|---|---|---|---|---|
| 1 | 3c2b2b5c | 11.393 | 159 | 50.826 | 4.46 | 14.45 |
| 2 | 3c2b2a3i | 7.709 | 178 | 44.152 | 5.73 | 22.98 |
| 3 | 3c2b2a3h | 9.764 | 141 | 45.425 | 4.65 | 14.44 |
| 4 | 3c2b2b5a | 11.670 | 159 | 48.134 | 4.12 | 13.62 |
| 5 | 3c2b2a3g | 8.440 | 73 | 32.653 | 3.87 | 8.65 |
| 6 | 3c2b2a2d | 13.547 | 159 | 46.726 | 3.35 | 11.73 |
| 7 | 3c2b2a3f | 8.881 | 78 | 34.101 | 3.84 | 8.78 |
| 8 | 3c2b2a3e | 7.537 | 95 | 33.461 | 4.44 | 12.60 |
| 9 | 3c2b2a3d | 7.489 | 101 | 30.254 | 4.04 | 13.48 |
| 10 | 3c2b2a3b | 11.508 | 150 | 53.743 | 4.67 | 13.03 |
| 11 | 3c2b2a3a | 8.578 | 100 | 38.699 | 4.51 | 11.66 |
| 12 | 3c2b2a2b | 6.273 | 80 | 27.931 | 4.45 | 12.76 |
| 13 | 3c2b2a2c | 10.705 | 156 | 45.311 | 4.23 | 14.57 |
| 14 | 3c2b2a2a | 10.935 | 148 | 52.386 | 4.79 | 13.53 |
| 15 | 3c2b2a1c | 10.710 | 124 | 48.017 | 4.48 | 11.78 |
| 16 | 3c2b2a1b | 7.340 | 79 | 29.604 | 4.03 | 10.76 |
| 17 | 3c2b2a1a | 13.151 | 133 | 58.821 | 4.47 | 10.11 |
| | Total | **165.630** | **2113** | **720.244** | **74.23** | **218.93** |

### 3.4.1.1 Drainage – Density

In drainage system, density and frequency are the most important aspects of a drainage basin, which affect the run-off capacity of a basin. According to All India Soil and Land Use Survey of the Ministry of Agriculture 1972, the study area of Chemlui sub-watershed has been divided into seventeen micro-watershed areas. On the basis of this division of micro-watershed, drainage density and frequency has been mapped and analyzed.

Drainage density is the length of stream channels present per unit area. The drainage density reflects the climate over the basin and the influence of other basin characteristics including rock type, soil, vegetation, land use, and topographic characteristics (Goudie, et. al., 1985). According to Rogers (1971), high drainage density is represented by metamorphic, whereas sedimentary exhibits low drainage values. The high drainage density indicates a large proportion of precipitation run off and low drainage density indicates that, most rainfall infiltrates the ground and few channels are required to carry runoff.

Analysis of drainage density has also revealed significant clues about the distribution of stream of the study area. The drainage density ranges from 3.35 to 5.73 km/ $km^2$ of the geographical study area. The drainage density of the study area is shown in Table 3.8 and Figure 3.6 show the drainage density map of the study area. For the purpose of analyzing drainage density, five categories of drainage density have been formed –

Table. 3.8 Drainage Density Classification of Chemlui Sub-watershed.

| Sl.No. | Drainage Density Class | Drainage Density Categories | Micro - Watershed No. | Micro-Watershed Area in Sq.Km | Stream Length in Km | Drainage Density Km/km$^2$ |
|---|---|---|---|---|---|---|
| 1 | Less than 3.4 | Very low Density | 3c2b2a2d | 13.547 | 46.726 | 3.35 |
| 2 | 3.4 – 4.0 | low Density | 3c2b2a1b | 7.340 | 29.604 | 4.03 |
| | | | 3c2b2a3d | 7.489 | 30.254 | 4.04 |
| | | | 3c2b2a3f | 8.881 | 34.101 | 3.84 |
| | | | 3c2b2a3g | 8.440 | 32.653 | 3.87 |
| 3 | 4.1 – 4.2 | Moderate Density | 3c2b2b5a | 11.670 | 48.134 | 4.12 |
| | | | 3c2b2a2c | 10.705 | 45.311 | 4.23 |
| 4 | 4.3 – 4.7 | high Density | 3c2b2a3e | 7.537 | 33.461 | 4.44 |
| | | | 3c2b2a2b | 6.273 | 27.931 | 4.45 |
| | | | 3c2b2b5c | 11.393 | 50.826 | 4.46 |
| | | | 3c2b2a1a | 13.151 | 58.821 | 4.47 |
| | | | 3c2b2a1c | 10.710 | 48.017 | 4.48 |
| | | | 3c2b2a3a | 8.578 | 38.699 | 4.51 |
| | | | 3c2b2a3h | 9.764 | 45.425 | 4.65 |
| | | | 3c2b2a3b | 11.508 | 53.743 | 4.67 |
| | | | 3c2b2a2a | 10.935 | 52.386 | 4.79 |
| 5 | More than 4.7 | very high Density | 3c2b2a3i | 7.709 | 44.152 | 5.73 |
| **Total** | | | | **165.630** | **720.244** | **74.13** |

(i) Very low density

The drainage density less than 3.4 km/ $km^2$ have been categorized as very low density. It is found only in one micro-watershed out of seventeen micro-watersheds with a total area of 13.55 sq.km. It is found in the central eastern side of the study area.

(ii) Low density

The low drainage density of 3.4 to 4.0 km/ $km^2$ occupies four micro-watersheds which are distributed mostly in the northwestern side and small portion in the southern part covering an area of 32.15 sq.km.

(iii) Moderate density

This category of stream density of 4.1 to 4.2 km/ $km^2$is observed in two micro-watershed, one in the southwestern part and the other one in the north western part of the sub-watershed area covering 22.36 sq.km of the study area.

(iv) High density

The area of high density of 4.3 to 4.7 km/ $km^2$ is observed in nine micro-watershed. It covers an area of 89.85 sq.km. which is almost half of the total study area. The larger area is found in the southern side and two micro-watershed in the north side of the study area.

(v) Very high density

The area of very high density of more than 4.7 km/ $km^2$ is observed in the northern corner of the study area occupying only 7.71 sq.km. of the total sub-watershed.

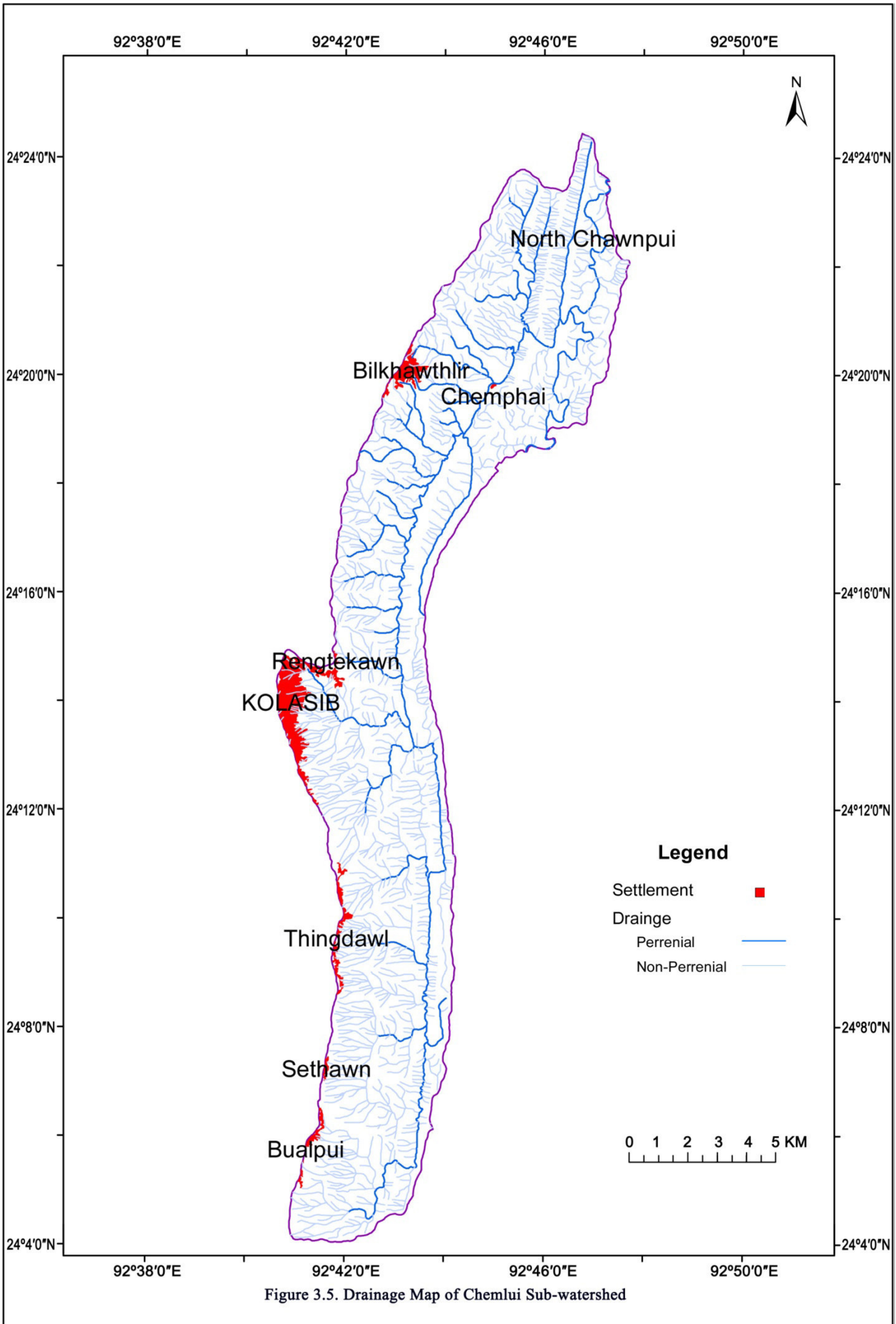


Figure 3.5. Drainage Map of Chemlui Sub-watershed

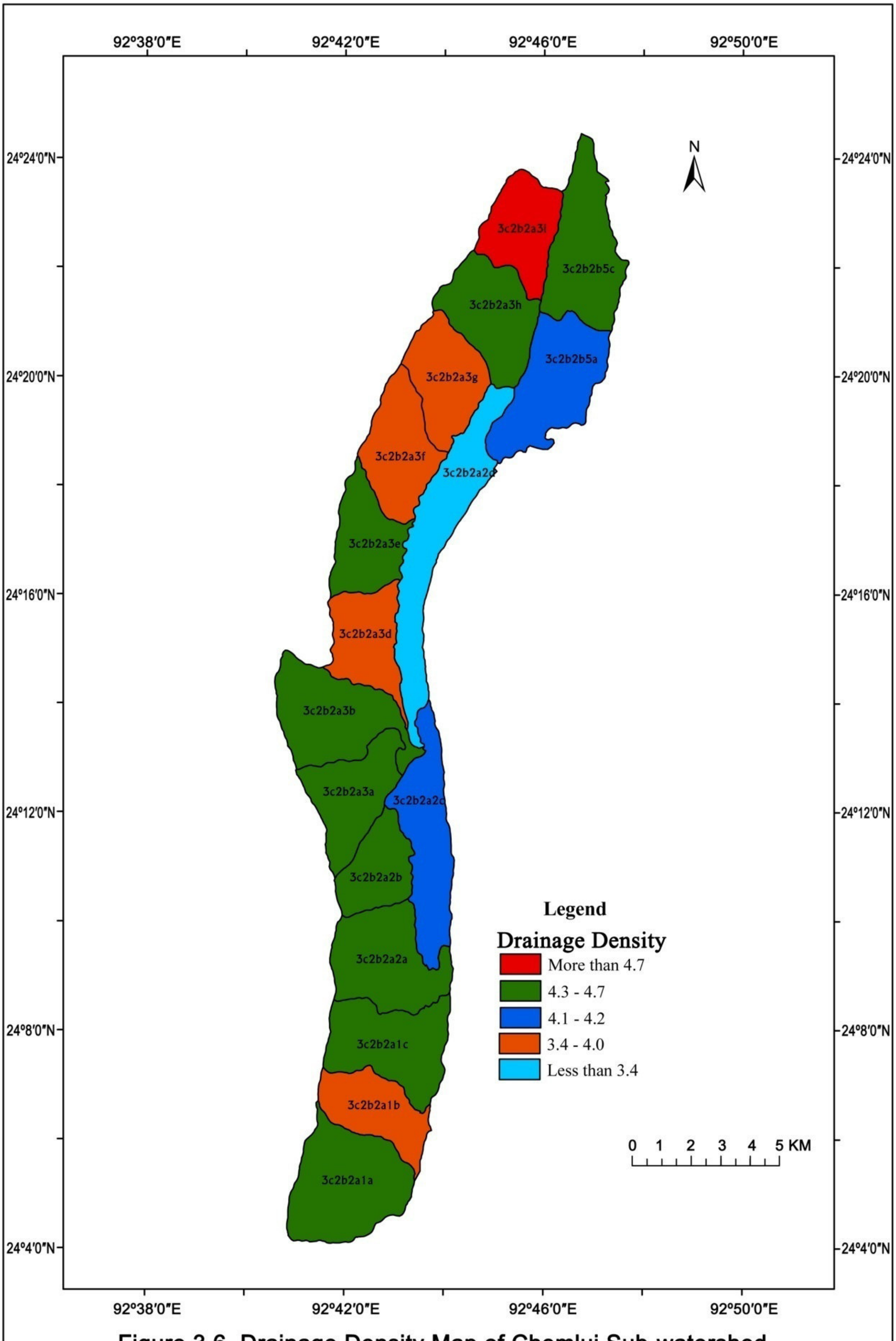



Figure 3.6. Drainage Density Map of Chemlui Sub-watershed

#### 3.4.1.2 Drainage – frequency

Drainage frequency is the number of streams in per unit area. It is associated with lithology, degree of slope, stages of fluvial cycle and amount of surface run-off. Investigations reveal that high frequency of stream is found in the areas of non-porous bedrocks, relatively high degree of slope, high rainfall, and thin vegetation cover. The high values of drainage frequency are represented by mature basins whereas; low range of drainage frequency indicates the youth stage of development (Sidhu, et. al., 1974).

The drainage frequency of the Chemlui sub-watershed range between 8.65 to 14.57. The drainage frequency of the watershed has been classified into five categories based on the range values obtained. For the purpose of analyzing of drainage frequency, seventeen basins have been made in the drainage map of the study area. The drainage frequency of the study area is shown in table 3.9 and Figure 3.7. The drainage frequency has been categorized in to five groups –

(i) Very low frequency (Less than 11.5)

The drainage frequency less than 11.5 has been categorized as very low and is found in four micro-watershed with a total area of 37.81 sq.km. It is found in the southern part of Bualpui and Sethawn area and north western side of Bilkhawthlir of the study area.Bualpui Lui and Pingpi Lui are the two main streams.

(ii) Low frequency (11.6 – 12.5)

Three micro-watersheds which are distributed in the some part of Thingdawl and Sethawn area in the southern part, Kolasib and Chemphai area in the central western side covering an area of 32.84 $km^2$ exhibit low drainage frequency of 11.6 – 12.5. Sakei Lui and Dum Lui are the two main stream found in this area.

(iii) Medium frequency (12.6 – 13.5)

This category of drainage frequency 12.6 – 13.5 is observed in four micro watersheds in the central region of the sub-watersheds area covering 32.81 $km^2$ of the study area. The main streams found in this area are Kem Lui, Luipui Lui and Fuanlian Lui.

(iv) High frequency (13.6 – 14.5)

The area of high drainage frequency 13.6 – 14.5 is observed in five micro watersheds. It covers an area of 54.47 $km^2$. which is one-third of the total study area. This area is mainly found in the southern part of North Chawnpui area and one micro watershed is located in the northern side at Thindawl of the study area. Pang Lui, Thingdelh Lui and Ser Lui River are the main stream.

(v) Very high frequency (More than 14.5)

The area of very high drainage frequency is observed in only one confine area in the northern corner of the study area occupying only 7.71 $km^2$. of the total sub-watershed. The main streams are Buarchep Lui and Chepte Lui.

Table. 3.9 Drainage Frequency Classification of Chemlui Sub-watershed.

| Sl. No. | Drainage Frequency Class | Drainage Frequency Categories | Micro-Watershed No. | Micro-Watershed Area in Sq.Km | No. of Stream | Drainage Frequency |
|---|---|---|---|---|---|---|
| 1 | Less than 11.5 | Very low ferquency | 3c2b2a3g | 8.440 | 73 | 8.65 |
| | | | 3c2b2a3f | 8.881 | 78 | 8.78 |
| | | | 3c2b2a1a | 13.151 | 133 | 10.11 |
| | | | 3c2b2a1b | 7.340 | 79 | 10.76 |
| 2 | 11.6 – 12.5 | Low ferquency | 3c2b2a3a | 8.578 | 100 | 11.66 |
| | | | 3c2b2a2d | 13.547 | 159 | 11.73 |
| | | | 3c2b2a1c | 10.710 | 124 | 11.78 |
| 3 | 12.6 – 13.5 | Medium ferquency | 3c2b2a3e | 7.537 | 95 | 12.60 |
| | | | 3c2b2a2b | 6.273 | 80 | 12.76 |
| | | | 3c2b2a3b | 11.508 | 150 | 13.03 |
| | | | 3c2b2a3d | 7.489 | 101 | 13.48 |
| 4 | 13.6 – 14.5 | High ferquency | 3c2b2a2a | 10.935 | 148 | 13.53 |
| | | | 3c2b2b5a | 11.670 | 159 | 13.62 |
| | | | 3c2b2a3h | 9.764 | 141 | 14.44 |
| | | | 3c2b2b5c | 11.393 | 164 | 14.45 |
| | | | 3c2b2a2c | 10.705 | 156 | 14.57 |
| 5 | More than 14.5 | Very high ferquency | 3c2b2a3i | 7.709 | 178 | 22.98 |
| **Total** | | | | **165.630** | **2113** | **218.93** |

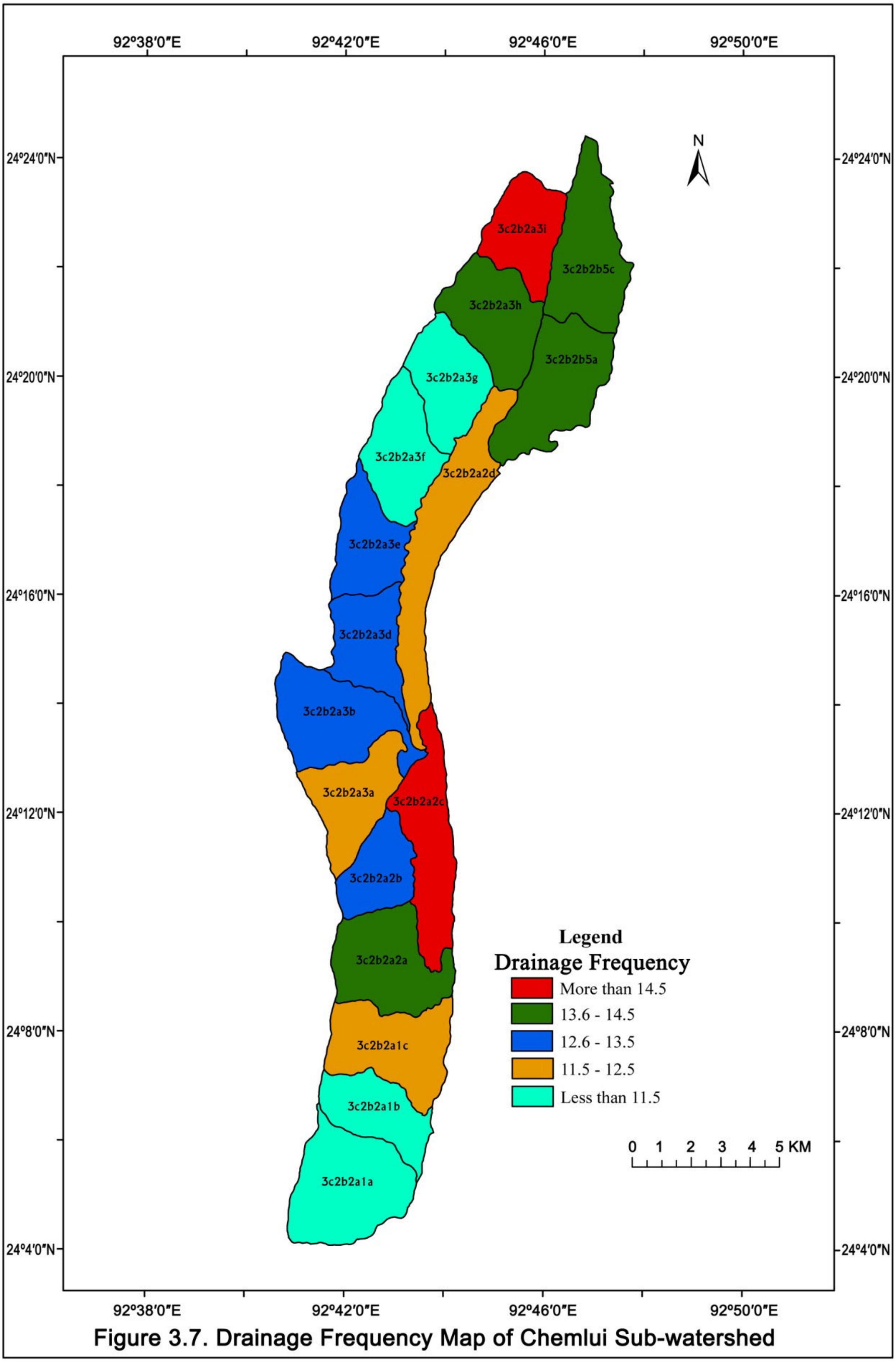



Figure 3.7. Drainage Frequency Map of Chemlui Sub-watershed

### 3.4.2 Ground water resources

Groundwater is one of the most valuable natural resources which support human health, economic development and ecological diversity (Hutti and Nigangunnapa, 2011). No doubt human development is hinge on availability of groundwater and surface water resources. Groundwater is a dynamic and replenishing natural resource (Nagarajan & Singh, 1997). Anthropogenic activities affect the infiltration and runoff characteristics of the land surface, which affects groundwater recharge and quality (Scanlon et al., 2005; Vijay et al., 2011). Physical factors affect the occurrence and movement of groundwater

With the rapid urbanization and growth of population, the demand for water supply increases. Sometimes, a surface water resource is often inadequate to meet the ever-increasing demand of water supply. Therefore groundwater resources have been developed on a large scale, and have been tapped and harnessed to a considerable extent. For an area experiencing constant drought and which faces water scarcity problem, groundwater resources have been an alternative solution to the problem. Groundwater resources have been exploited not only for domestic purposes, but also for irrigation and agriculture purposes.

For delineation of potential zones of groundwater within the study area, thematic layers of lithology, geomorphology, land use/land cover, geological structure and slope are prepared. Thematical layers integrated have been derived by using ArcGIS tools to generate the final layer from which different groundwater potential zones. Besides, the existing hand pumps and spring inventory data are added to the final data. Since geological structure is one of the major factors controlling the occurrence of groundwater, areas within 40 metres distance on both sides of the lineaments and faults are included. Similarly, areas proximity to spring and hand pumps are manually selected and delineated. The different units of these thematic parameters are taken into consideration by giving different weightage values according to their respective hydrological properties. This form the main criterion by which different potential zonation is done. Since hand pumps and springs are direct expression of the ground water condition below the sub surface, they are given the highest weightage value. The final layer is then prepared and the study area is classified into very good, good, moderate and poor as shown in figure 3.8.

Table 3.10 Ground water potential zones of Chemlui subwatershed.

| **Sl.no** | **Potential zone** | **Area in Ha** | **Area in %** |
|---|---|---|---|
| **1** | Very Good | 1536.14 | 9.27 |
| 2 | Good | 3146.13 | 18.99 |
| 3 | Moderate | 5442.19 | 32.86 |
| 4 | Poor | 6438.53 | 38.87 |
| | **Total** | **16563.00** | **100** |

#### 3.4.2.1 Very Good Zone

This zone generally covers valley fill, flood plains and low lying areas which are located within the proximity of water bodies, where there will be continual recharge. Beside it includes the intersection of the structural units such as lineaments and faults, which valley fill and flood plains. These geological structures offer channels for the sub-surface flow of water. Groundwater can easily move through these fractures and are found to be very suitable sites for ground water occurrence. Lithologically, this zone comprises areas where unconsolidated sediments, such as gravel, sand and silt are deposited. These have a high potentiality of retaining water since they allow maximum percolation due to their maximum pore space between the grains. Locally, this zone covers the areas along the main rivers.

Very good zone covers 1536.14 hectares of land which comprise 9.27 per cent of the total watershed area. The area extent is narrow in the southern part of the watershed and extent widely towards the northern part. This zone also covers the low lying areas of Bilkhawthlir, Chemphai and North Chawnpui settlements.

#### 3.4.2.2 Good Zone

Good potential zone covers 3146.13 hectares accounting 18.99 per cent of the total watershed area. The entire geological structures fall under this zone and the low-lying areas including flood plains and valley fills are also included in this zone as low and gentle slope areas have a great extent of better conditions for infiltration and subsequent yield of groundwater. In the midst of the rock types exposed in the study area, sandstones are generally capable of storing and conveying water through their interstice pore spaces present in grains, and are considered to be suitable aquifer. Hence, parts of areas where sandstones are exposed come under this zone. It mainly covers low lying areas of Kolasib, some parts of Bilkhawthlir and Thingdawl villages.

#### 3.4.2.3 Moderate Zone:

This zone comprises 5442.19 hectares which is 32.86 per cent of the total watershed area. This zone mainly includes areas where the water recharge condition and the yielding capability of the underlying materials are neither suitable nor poor. Topographically, it covers gently sloping smooth surface of the hills while the lithology may comprises good water-bearing rock formations like sandstone. The potentiality is minimized by the sloping nature of the topography where run-off is limited. In general, the moderate zone falls within the poor water-bearing rock formations such as silty shales which are characterized by the presence of secondary structures in them. This zone is predominantly high in terms of areal extent.

**3.4.2.4 Poor Zone:**

Poor ground water potential zone covers 6438.53 hectares of land which is 38.87 per cent. The poor zone is mainly distributed along the southern ridges of the study area such as Bualpui, Sethawn and the western ridge of Thingdawl in the study area. This zone is mainly scattered in the elevated areas of high relief features where large amount of precipitation exposed as surface run-off, which is a poor condition for infiltration beneath the ground surface. Therefore, the ground water potential is generally assumed to be in low. Except the elevated areas are traversed by geological structures, and possess high drainage density and suitable water-bearing rock formation. Usually, the ground water yield is low.

The groundwater potential of the study area grouped into very good, good, moderate and poor (Table 3.10) based on the range of values obtain in the groundwater sources. The watershed does not have much high in groundwater sources. Very high potential area accounts 9.27 per cent of the total watershed area. Good availability found with 3146.13 hectares of land comprising 18.99 per cent of the total watershed area.

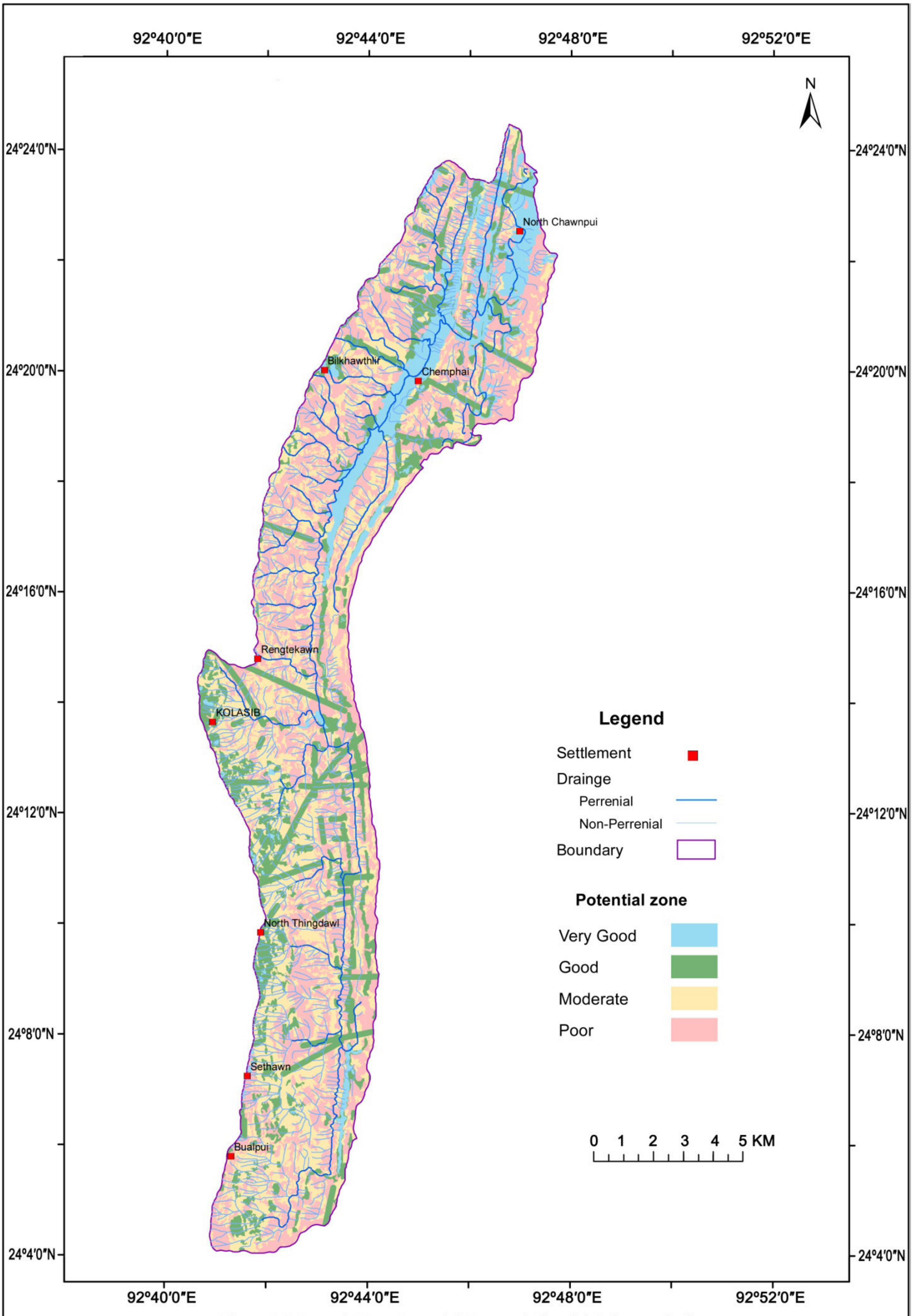



Figure 3.8 Ground Water Potential Zones of Chemlui Subwatershed.

The area of 6438.53 hectares of land is considered as moderate potential. The moderate zone accounts 32.86 per cent of the total watershed. Majority of the watershed area is poor in groundwater resources. The poor groundwater potential zone occupies an area of about 6438.53 hectares of land which comprises 38.87 per cent of the total watershed area.

**3.5 Forest Resources**

Rapid population growth and its demand for agricultural land and forest products such as firewood, fodder, timber and lumber have accelerated deforestation processes in many developing tropical countries. Scientific interest in tropical deforestation and its impacts on livelihood have focused largely on high profile countries like Brazil (Brondizio et al., 1996; Mc Cracken et al., 1999). Similar research has also been done in low profile (internationally low research focus) countries like Nepal (Tokola et al., 2001; Zomer et al., 2002) to explore the causes of deforestation. A study on deforestation in a low profile country such as Nepal is needs to understand how agrarian rural population depends on limited natural resources, responds to increasing resource scarcity with technological advancement as envisioned by Ecological Modernization Theory (Ehrhardt Martinez, 1998, 1999; Ehrhardt-Martinez et. al, 2002).

Ecological Modernization Theory (EMT) is based on the assumption that capitalist development is able to reform and promote environmental goals through technologically innovative processes. As development proceeds, environ mental damage, including deforestation, will eventually cease (Mather et al 1999). However, the theory also warns that not all types of development help reduce deforestation and alleviate environmental problems due to changes in consumptive patterns (Carolan, 2004) because in extractive farming systems, deforestation often becomes a 'casualty' of development (Rostow, 1960; Rudel and Roper, 1997). For example, increasing road access leads to deforestation due to increasing commodity prices (Rudel 1995) and increasing consumption of forest products (Bhattarai et. al, 2002; Gautam, 2003). Some authors (Anderssen and Massa, 2000) consider ecological modernization theory only makes sense for a reference to more radical structural changes that promote ecological consistence rather than ordinary efficiency. However, Ehrhardt-Martinez et. al, (2002) argue that EMT might help to design a specific type of forward-looking and preventive environmental policy based on the long-term structural change of patterns of production and consumption. EMT assumes that deforestation and environmental problems initially accelerate with population growth because of the use of rudimentary 'development technology' and subsistence farming, but that problems are later alleviated as technology advances (Tole, 1998) and public awareness increases (Fox, 1993). This is because the growing population tends to adjust to limited resources by increasing land productivity (Boserup, 1965; Fox, 1993).

The forest cover type of the study area, Chemlui Sub-watershed is mainly covered by tropical wet evergreen forest and tropical semi-evergreen forest associated with moist deciduous forests. Moist deciduous forests are commonly found in small compacts areas on the hill slopes. The vegetation consists of a mixture of several species. Depending on the density of the canopy cover, the forests have been classified into forest-evergreen/semi evergreen-dense/closed and opened types.

Dense and closed forest class includes natural forests which are not disturbed by any features like shifting cultivation and other human activities. Evergreen and semi-evergreen forests cover the major portion of the study area and the round off density of this forest type is very thick. It covers an area of 1860.58 hectares, which accounts for 11.23 % of the total study area. Vast dense forests are found near Sethawn, Bualpui and Thingdawl villages. Forest-evergreen/semi evergreen-open covers an area of 1547.49 hectares, which accounts for 9.34 % of the total study area. It is distributed throughout the whole watershed in small patches. The vegetation of this forest is more or less similar with those species found in dense forests. The difference lies only in density of the vegetation. Forest under Forest-Scrub Forest category has a very less vegetation cover of 1618.65 hectares, which accounts for 9.77 % of the total study area. This type of Forests is commonly found at the periphery of Kolasib, Bualpui, Thingdawl and North Chawnpui Villages. This type of forest includes forest, which were once disturbed and affected by biotic factors like shifting cultivation and human activities. These forests are characterized by those lands where shifting (Jhum) cultivation had been practiced and then left fallow for over years and regenerated to form a fresh forest.

Bamboo forests are found in low lying areas near the bank of rivers and are also found on the hill slopes in some areas. This type of forest covers the largest area of about 9239.77 hectares which accounts for 55.79% of the study area. The main bamboo species found in this area *Dedrocalamus hamiltonii, Dedrocalamus longispathus and Meloccana bamibusoides.*

### 3.6 Climate

The climate of the study area is generally pleasant and there is no extremity of temperature which ranges between $12^0$C to $33^0$C. The mean relative humidity varies from 39% to about 81%. The rainfall in the study area is well distributed, with a span of almost 6 months from May to October. Although pre-monsoon rains break in form the early part of March with occasional thunder-storms, the monsoon period really starts from the middle part of April. The average annual rainfall is about 2913.8 mm and there are some year's even receiving more than 3000mm of rainfall. The rainfall declines gradually and comes to an ends during November. Dry spell occurs during the month of November to December. An occasional shower of low to medium intensity also occurs during the months of January to February due to the influence of the Northeast retreating Monsoon. Mizoram state has been delineated into the following three agro-climatic zones based on rainfall, temperature, terrain and soil characteristics such as Humid mild tropical, Humid – sub- tropical hill and Humid Temperate Sub Alpine. The study area Chemlui sub-watershed falls under two distinct agro-climatic zones namely:- Humid mild tropical and humid – sub- tropical hill zones.

In the Study area, four different types of seasons are observed on the basis of variation in rainfall, temperature, humidity and weather conditions such as – (i) The spring season (Thal) – begins in the third week of February to the mid month of March, (ii) Summer or Rainy season (Nipui /Fur) – It start from mid month of March to the first week of October , (iii) Autumn season (Favang) – It start from the first week of October to the end of November and (iv) The winter season (Thlasik) – It start from the first week of December and continued up to February.

### 3.6.1 Rainfall

The state of Mizoram is under the direct influence of south west monsoon consequently the study area Chemlui Sub-watershed also receives sufficient amount of rainfall all through the monsoon season. The existing rainfall data recorded exposes that the heavy rainfall begins from the mid month of March and end to the first week of October. The highest rainfall received during a particular month was 954.9 mm recorded during the month of July in 2014. The average annual rainfall of Chemlui Sub-watershed is 2914 mm. This occurrence of the southwest monsoon and the summer makes the climate favourable for inhabitants of the Chemlui Sub-watershed since the temperature is kept down to a considerable extent by the typical rains. Usually the month of July and August are the rainiest months while December and January are the driest months. The mean monthly rainfall data recorded from the years 2006 - 2016 is shown in Table 3.11 and the monthly average rainfall and maximum and minimum rainfall of the area is shown in Figure 3. 9.

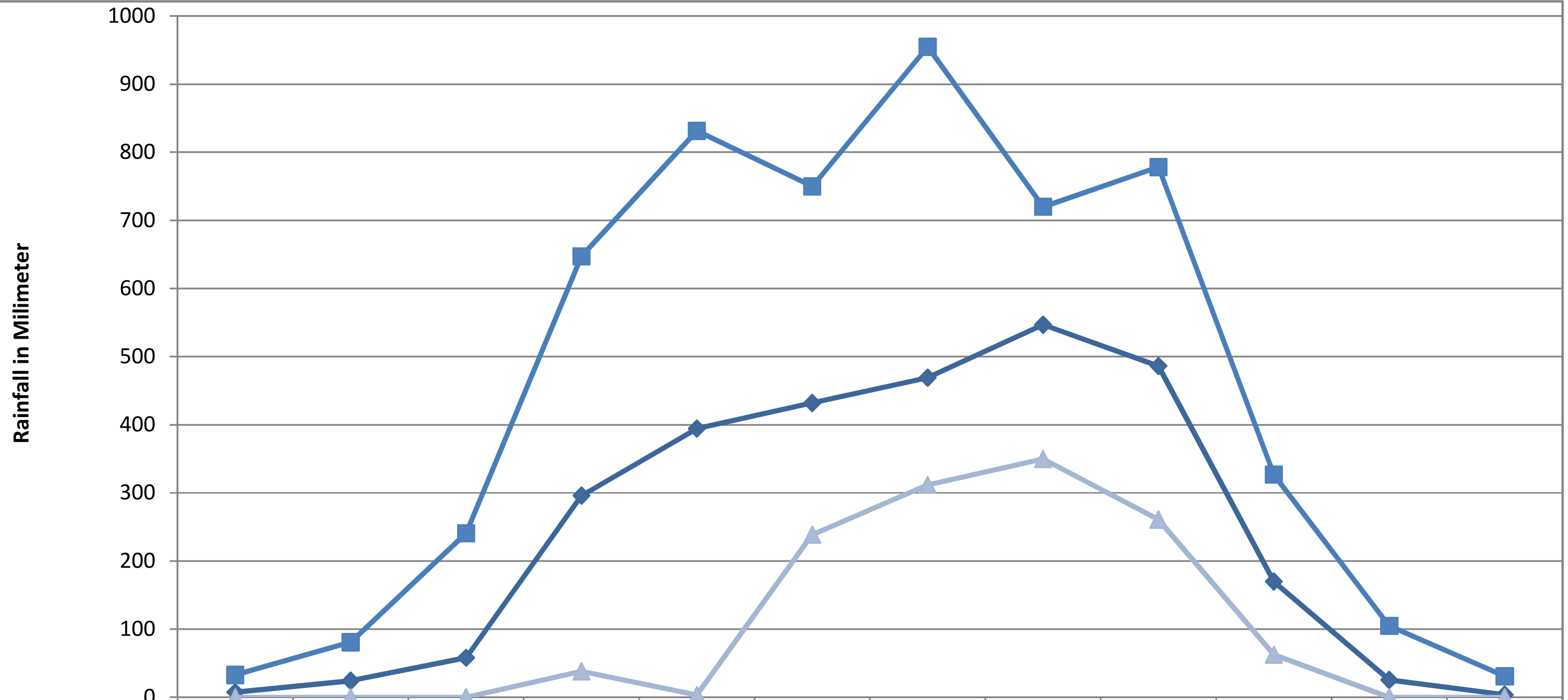
### 3.6.2 Temperature

The temperature of Chemlui sub-watershed does not vary much throughout the year. The highest temperature observed during the study was 32.5 degree Celsius during the month of April in 2014. Usually the month of June and July are the warmest months with mean monthly maximum temperature at about 31°Celsius and the mean monthly minimum at about 21 degree Celsius respectively. The temperature of this area started to decrease gently from the month of November and it is decreased in the month of December and January.

Table 3.11. Monthly rainfall data recorded for the period of 2006 – 2016 of Chemlui Sub-watershed.

| Years | Monthly Rainfall in mm | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC | |
| **2006** | 0 | 0 | 2 | 267 | 559 | 750 | 584 | 389 | 348 | 184 | 43 | 0 | **3126.0** |
| **2007** | 0 | 81 | 34 | 314.5 | 416 | 674 | 409.5 | 720 | 704.8 | 287.5 | 105 | 0 | **3746.3** |
| **2008** | 32 | 30 | 56 | 38 | 197 | 390 | 391.8 | 682.3 | 260.8 | 327 | 0 | 0 | **2404.9** |
| **2009** | 0.5 | 0 | 0 | 192 | 233.9 | 239 | 335 | 395 | 566 | 130 | 2 | 0 | **2093.4** |
| **2010** | 0 | 0 | 241 | 620 | 385 | 340 | 401 | 693 | 435.9 | 138 | 17 | 31 | **3301.9** |
| **2011** | 0.05 | 4 | 63.9 | 116.4 | 03.5 | 354.9 | 455.9 | 585.7 | 313.3 | 157 | 0 | 0 | **2054.7** |
| **2012** | 33.5 | 9.5 | 32.7 | 647.5 | 268.4 | 471.9 | 312 | 515 | 526.5 | 180.2 | 24.8 | 0 | **3022.0** |
| **2013** | 0 | 5.1 | 7.8 | 104.8 | 831.5 | 322.6 | 454.6 | 717.1 | 516.3 | 107.1 | 0 | 0 | **3066.9** |
| **2014** | 0 | 25.6 | 51.8 | 93.3 | 473.9 | 334.3 | 954.9 | 349.7 | 596.7 | 62.7 | 3.8 | 0 | **2946.7** |
| **2015** | 16.4 | 34.2 | 7.8 | 522.6 | 443.8 | 431.6 | 509.8 | 453.6 | 301.6 | 162.2 | 14.6 | 10.6 | **2908.8** |
| **2016** | 2.4 | 77.2 | 143 | 337.1 | 525.4 | 443.4 | 353.4 | 513.5 | 778.3 | 133.2 | 70.3 | 2.7 | **3379.9** |
| **Average** | **7.7** | **24.2** | **58.2** | **295.8** | **394.3** | **431.9** | **469.3** | **546.7** | **486.2** | **169.9** | **25.5** | **4** | **2913.8** |
| **Max** | **33.5** | **81** | **241** | **647.5** | **831.5** | **750** | **954.9** | **720** | **778.3** | **327** | **105** | **31** | |
| **Min** | **0** | **0** | **0** | **38** | **03.5** | **239** | **312** | **349.7** | **260.8** | **62.7** | **0** | **0** | |

Source: ICAR, Research Complex Mizoram Center, Kolasib, Mizoram.




| | Jan | Feb | March | April | May | June | July | August | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Rainfall | 7.7 | 24.2 | 58.2 | 295.8 | 394.3 | 431.9 | 469.3 | 546.7 | 486.2 | 169.9 | 25.5 | 4 |
| Maximum Rainfall | 33 | 81 | 241 | 647.5 | 831.5 | 750 | 954.9 | 720 | 778.3 | 327 | 105 | 31 |
| Minimum Rainfall | 0 | 0 | 0 | 38 | 3.5 | 239 | 312 | 349.7 | 260.8 | 62.7 | 0 | 0 |

Figure 3.9. Average Monthly Rainfall Data of Chemlui Sub-watershed for the period of 2006 – 2016.

The month of January is the coldest period with the mean monthly maximum temperature at 24.5 degree Celsius and minimum of 12.2 degree Celsius. Still, the lowest minimum temperature was recorded as 12.2 degree Celsius during January in 2016 as shown in Table 3.12 and Figure 3.10.

### 3.6.3 Relative Humidity (RH)

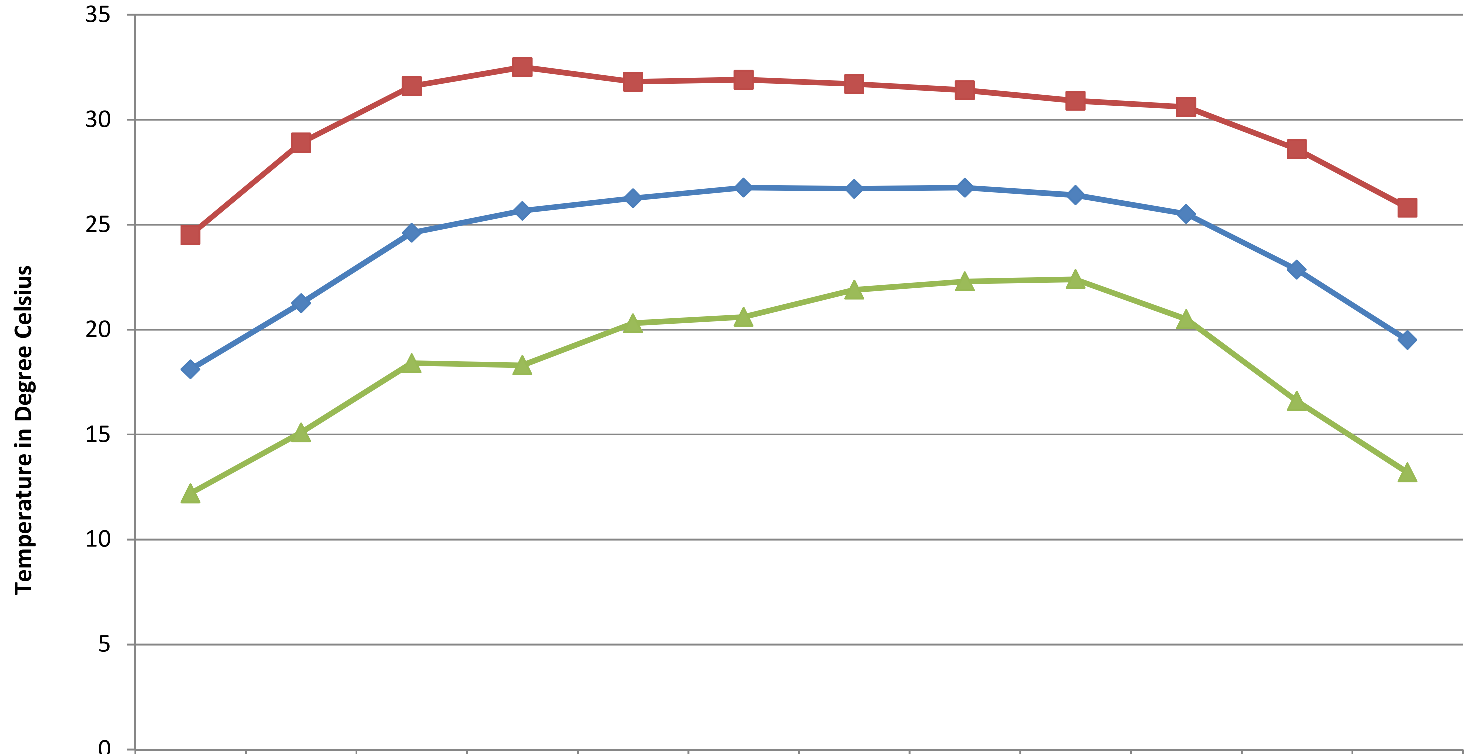
Relative humidity is the ratio of the amount of water vapour actually present in the air expressed as a percentage of the maximum amount of water vapour the air can hold at the same temperature of a region.

The relative Humidity (RH) of Chemlui Sub-watershed does not very much like temperature throughout the year round. The highest average mean relative humidity observed during the study was 81 percent during the months of August and September in 2013. Usually the month of June is the wettest month with mean monthly maximum at about 98 percent and mean monthly minimum of about 42 percent as shown in Table 3.13 and Figure 3.11.

Table 3.12. Monthly Temperature data recorded for the period of 2006 – 2016 of Chemlui Sub-watershed

| YEAR | Monthly Temperature in degree Celsius | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | | Feb | | March | | April | | May | | June | | July | | Aug | | Sept | | Oct | | Nov | | Dec | |
| | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min |
| **2006** | 21.7 | 15.9 | 25.7 | 21.1 | 29.1 | 22.7 | 29.6 | 24 | 29.6 | 23.8 | 28.5 | 23.6 | 30.5 | 23.3 | 30.3 | 25.1 | 29.4 | 23.6 | 29 | 23.4 | 25.7 | 20.1 | 23 | 17.1 |
| **2007** | 21.2 | 14.6 | 23.2 | 16.8 | 26.8 | 19.5 | 28.2 | 21.4 | 29.6 | 23.3 | 28.7 | 23.2 | 27.5 | 22.9 | 28.9 | 23.1 | 28 | 22.7 | 27 | 20.9 | 25.9 | 19.8 | 22.3 | 15.3 |
| **2008** | 20.7 | 14.5 | 22.3 | 15.1 | 26.9 | 20.9 | 31.2 | 24.3 | 31.4 | 24.9 | 30.1 | 25.4 | 30.3 | 23.8 | 30.7 | 25.3 | 30.9 | 24.5 | 28.8 | 22.3 | 27.3 | 19.1 | 24.9 | 17.2 |
| **2009** | 23.5 | 13.5 | 26.9 | 17.1 | 26.7 | 20.7 | 28.8 | 21.2 | 30.6 | 21.3 | 30.6 | 23.6 | 29.9 | 23.5 | 29.1 | 23.4 | 28.8 | 23.3 | 28 | 21.7 | 24.7 | 18.6 | 21.8 | 14.8 |
| **2010** | 22.7 | 14.7 | 24.1 | 16.4 | 29.9 | 21.4 | 28.6 | 21.7 | 31.3 | 21.3 | 31.3 | 20.6 | 31.7 | 21.9 | 31.4 | 23.4 | 30.7 | 23.1 | 30.6 | 22.9 | 27.8 | 19.1 | 25.8 | 15.9 |
| **2011** | 23.5 | 13.1 | 27.1 | 16.4 | 27.9 | 19.3 | 30.3 | 21.1 | 29.4 | 20.3 | 30.3 | 22.7 | 30.1 | 22.9 | 30.5 | 23.2 | 28.6 | 22.4 | 28.8 | 21.4 | 27.6 | 19 | 22.9 | 15.2 |
| **2012** | 20.2 | 12.9 | 26.1 | 16.6 | 30.3 | 20.5 | 28.4 | 19.8 | 31.8 | 22.3 | 30.6 | 22.9 | 30.3 | 23.7 | 30.8 | 23.4 | 30.3 | 23.3 | 29.9 | 22.1 | 26.7 | 18.6 | 24.6 | 14.2 |
| **2013** | 23 | 12.5 | 28.9 | 17.7 | 31.3 | 20.7 | 32.3 | 20.8 | 29.5 | 21.2 | 31.9 | 23.8 | 30.7 | 23.9 | 29.9 | 22.3 | 30.2 | 22.5 | 28.7 | 22.2 | 27.8 | 18.8 | 23.6 | 16.2 |
| **2014** | 24.3 | 14.9 | 26.2 | 15.3 | 29.9 | 19.5 | 32.5 | 23.1 | 30.9 | 22.5 | 31 | 24.3 | 31.6 | 24.1 | 30.1 | 22.8 | 29.8 | 22.8 | 30.3 | 21.9 | 28.6 | 18.9 | 24.5 | 13.2 |
| **2015** | 24.5 | 13 | 26.7 | 15.9 | 31.6 | 19.2 | 29.3 | 18.3 | 31.7 | 21.4 | 31.4 | 22.2 | 30.8 | 22.9 | 30.5 | 22.4 | 30.9 | 23.6 | 30.4 | 20.5 | 28.2 | 18.5 | 23.1 | 13.9 |
| **2016** | 21.2 | 12.2 | 24.9 | 16.3 | 27.5 | 18.4 | 29.3 | 19.5 | 28.2 | 20.4 | 28.9 | 22.5 | 28.9 | 22.6 | 29.4 | 22.6 | 28.7 | 22.6 | 28.4 | 21.6 | 25.5 | 16.6 | 24.5 | 14.8 |
| **Average** | **22.4** | **13.8** | **25.7** | **16.8** | **28.9** | **20.3** | **29.9** | **21.4** | **30.4** | **22.1** | **30.3** | **23.2** | **30.2** | **23.2** | **30.1** | **23.4** | **29.7** | **23.1** | **29.1** | **21.9** | **26.9** | **18.8** | **23.7** | **15.3** |
| **Mean Temp.** | **18.1** | | **21.25** | | **24.6** | | **25.65** | | **26.25** | | **26.75** | | **26.7** | | **26.75** | | **26.4** | | **25.5** | | **22.85** | | **19.5** | |
| **Max** | **24.5** | | **28.9** | | **31.6** | | **32.5** | | **31.8** | | **31.9** | | **31.7** | | **31.4** | | **30.9** | | **30.6** | | **28.6** | | **25.8** | |
| **Min** | **12.2** | | **15.1** | | **18.4** | | **18.3** | | **20.3** | | **20.6** | | **21.9** | | **22.3** | | **22.4** | | **20.5** | | **16.6** | | **13.2** | |

Source: ICAR, Research Complex Mizoram Center, Kolasib, Mizoram.



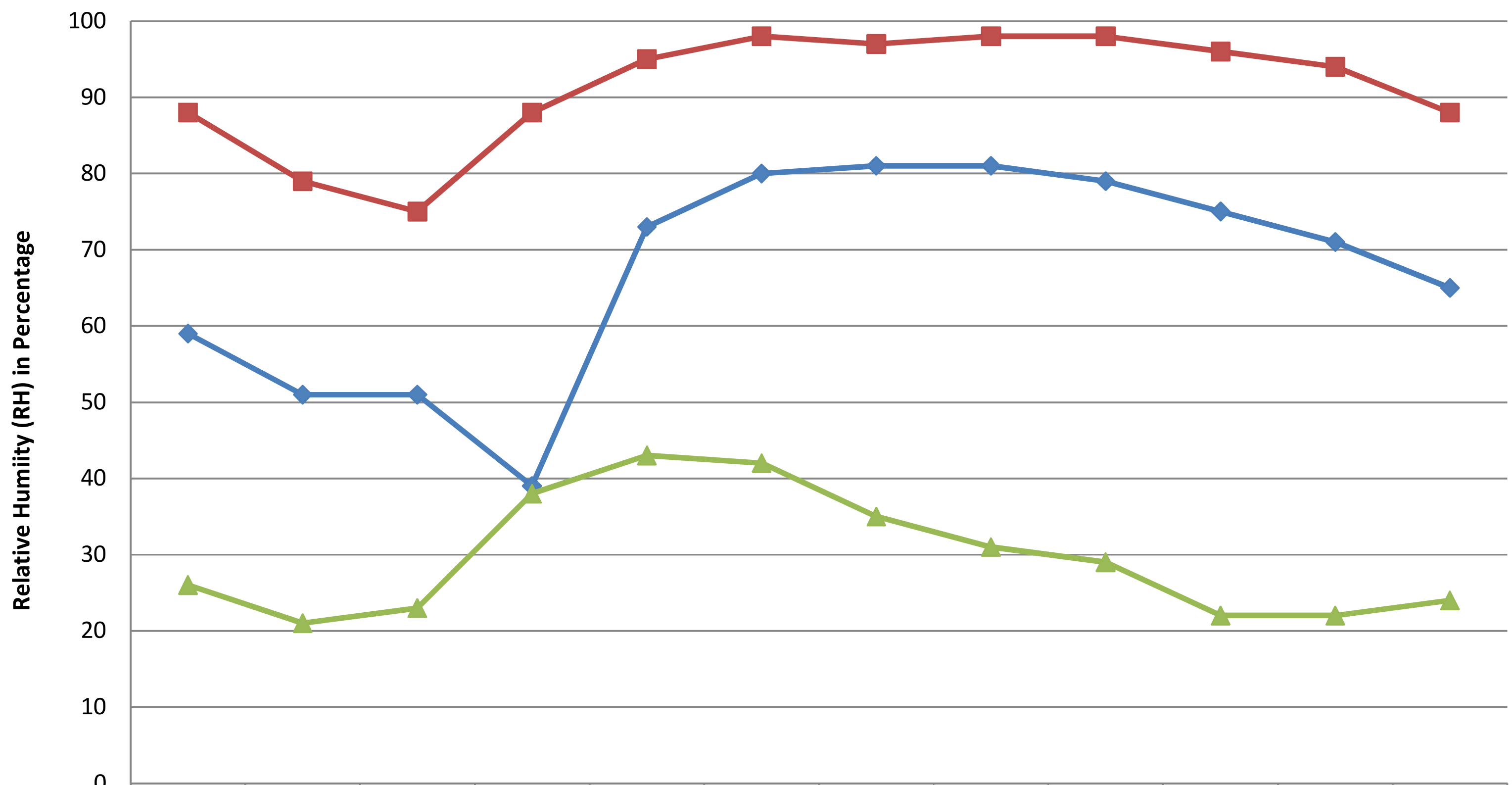

| | Jan | Feb | March | April | May | June | July | August | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Temperature | 18.1 | 21.25 | 24.6 | 25.65 | 26.25 | 26.75 | 26.7 | 26.75 | 26.4 | 25.5 | 22.85 | 19.5 |
| Maximum Temperature | 24.5 | 28.9 | 31.6 | 32.5 | 31.8 | 31.9 | 31.7 | 31.4 | 30.9 | 30.6 | 28.6 | 25.8 |
| Minimum Temperature | 12.2 | 15.1 | 18.4 | 18.3 | 20.3 | 20.6 | 21.9 | 22.3 | 22.4 | 20.5 | 16.6 | 13.2 |

Figure 3.10. Mean Monthly Temperature Data of Chemlui Sub-watershed for the period of 2006 – 2016.

Table 3.13. Monthly Relative Humidity data recorded for the period of 2006 – 2016 of Chemlui Sub-watershed

| YEAR | Monthly Relative Humidity in Percentage | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | | Feb | | March | | April | | May | | June | | July | | Aug | | Sept | | Oct | | Nov | | Dec | |
| | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min |
| **2006** | 67 | 57 | 49 | 60 | 55 | 37 | 68 | 55 | 77 | 63 | 89 | 79 | 84 | 68 | 74 | 64 | 79 | 65 | 79 | 66 | 73 | 60 | 68 | 56 |
| **2007** | 62 | 50 | 63 | 52 | 59 | 40 | 71 | 58 | 74 | 62 | 79 | 70 | 88 | 80 | 88 | 78 | 85 | 74 | 82 | 70 | 79 | 68 | 72 | 59 |
| **2008** | 70 | 58 | 67 | 52 | 72 | 52 | 73 | 51 | 78 | 63 | 86 | 73 | 89 | 78 | 92 | 78 | 91 | 77 | 86 | 76 | 79 | 67 | 83 | 70 |
| **2009** | 62 | 40 | 47 | 21 | 62 | 35 | 84 | 61 | 78 | 66 | 85 | 70 | 91 | 69 | 91 | 67 | 85 | 57 | 87 | 64 | 86 | 62 | 85 | 54 |
| **2010** | 75 | 47 | 61 | 37 | 61 | 36 | 88 | 74 | 91 | 84 | 96 | 83 | 94 | 82 | 93 | 82 | 92 | 83 | 91 | 79 | 85 | 70 | 70 | 51 |
| **2011** | 54 | 37 | 51 | 21 | 56 | 23 | 75 | 38 | 82 | 49 | 98 | 78 | 97 | 77 | 97 | 81 | 95 | 78 | 85 | 69 | 85 | 63 | 68 | 49 |
| **2012** | 66 | 54 | 56 | 35 | 68 | 42 | 80 | 55 | 86 | 64 | 95 | 78 | 96 | 80 | 96 | 79 | 97 | 80 | 95 | 74 | 88 | 71 | 84 | 61 |
| **2013** | 83 | 57 | 64 | 40 | 58 | 31 | 73 | 43 | 95 | 72 | 92 | 74 | 94 | 80 | 98 | 77 | 98 | 81 | 96 | 71 | 90 | 52 | 82 | 48 |
| **2014** | 79 | 40 | 79 | 31 | 66 | 31 | 71 | 41 | 75 | 43 | 65 | 42 | 63 | 35 | 68 | 31 | 76 | 29 | 57 | 22 | 65 | 22 | 59 | 24 |
| **2015** | 73 | 26 | 64 | 32 | 67 | 31 | 74 | 41 | 90 | 56 | 88 | 58 | 94 | 59 | 94 | 58 | 88 | 50 | 88 | 51 | 81 | 48 | 80 | 48 |
| **2016** | 88 | 55 | 79 | 51 | 75 | 55 | 87 | 67 | 86 | 74 | 94 | 78 | 93 | 80 | 96 | 83 | 96 | 81 | 93 | 77 | 94 | 69 | 88 | 63 |
| **Average** | **71** | **47** | **62** | **39** | **64** | **38** | **77** | **53** | **83** | **63** | **88** | **71** | **89** | **72** | **90** | **71** | **89** | **69** | **85** | **65** | **82** | **59** | **76** | **53** |
| **Mean Re.Humidity.** | **59** | | **51** | | **51** | | **39** | | **73** | | **80** | | **81** | | **81** | | **79** | | **75** | | **71** | | **65** | |
| **Max** | **88** | | **79** | | **75** | | **88** | | **95** | | **98** | | **97** | | **98** | | **98** | | **96** | | **94** | | **88** | |
| **Min** | **26** | | **21** | | **23** | | **38** | | **43** | | **42** | | **35** | | **31** | | **29** | | **22** | | **22** | | **24** | |

Source: ICAR, Research Complex Mizoram Center, Kolasib, Mizoram.




| | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Mean RH | 59 | 51 | 51 | 39 | 73 | 80 | 81 | 81 | 79 | 75 | 71 | 65 |
| Maximum RH | 88 | 79 | 75 | 88 | 95 | 98 | 97 | 98 | 98 | 96 | 94 | 88 |
| Minimum RH | 26 | 21 | 23 | 38 | 43 | 42 | 35 | 31 | 29 | 22 | 22 | 24 |

Figure 3.11. Mean Monthly Relative Humidity Data of Chemlui Sub-watershed for the period of 2006 – 2016.

In Chemlui sub-watershed there are abundant natural resources such as water, soil and rich forest resources. As the area receives high amount of rainfall water resources are found in huge quantities. Ground water is found to be the alternate source. Proper measures should be taken to preserve the natural resources in order to preserve the biodiversity and also for the survival of human and cattle population.

# CHAPTER – IV

# LAND USE LAND COVER CHANGE

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# LAND USE LAND COVER CHANGE

## 4.1. Introduction

Land use is found to be the most important human induced factor influencing land cover. It is found that land use/land cover dynamics are heterogeneous, and it is a complex phenomenon to understand as there are several complex interactions of biophysical, demographic and socio-economic factors as inferred by Ojima and Moram (2004). Land resources utilization has its impact on the biodiversity and environment of allied region either positively or negatively depending on how it is used in time and space. As land-use planning is defined as a systematic assessment of land and water potential, alternatives for land use and the economic and social conditions required to select and adopt the best land-use options, it is important to identify the available resources at micro level more precisely. The management of land resources at sub-watershed level is convenient and the most effective for their development.

Land use and land cover change is one of the most peculiar forms of environmental change occurring in all parts of the world especially mountain area (Keorner and Ohsawa, 2005). The term land use refers to human activity on certain piece of land, whereas land cover refers to its surface features (Lambin and Meyfroidt, 2010). The most important characteristic of land is its complexness and dynamic nature.

Land is a combination like topography, geology, soils, hydrology, microclimate and communities of flora and fauna. All the components are continually interacting and interdepending under the influence of climate and of human activities

(Hudson, 1995). Land-use and land cover changes have recently become a burning issue in research and a debate among academicians, researchers, policy makers and governments. Land use refers to pattern of man's activity or economic function on a piece of land and land cover changes are relates to the type of feature changes on the surface of the Earth due to different reasons (Lillesand and Kiefer, 1994). Broadly speaking land use land cover change is the result of anthropogenic interaction with the natural environment. Besides affecting the quality of life of the people living in the area, land use land cover change affect surface run-off as also erosion intensity (Piyoosh, 2002).

Land-use is the function of four variables of land, water, air and man. Each has its own role to compose its life history. Land constitutes its body, water runs through its veins like blood, air gives it life and man acts as a dynamic agent to reflect its types, pattern and distribution. In fact, man the user of land himself is the product of atmospheric behavior, hydrological action and lithospheric expressions.

"Man can survive without air for a few minutes, without water for a few hours and without food for a few days". The use of land likewise was limited. As man multiplied, their wants also increased and became complex. Consequently, the uses of land also increased. Subsequently the methods and technology of land-use also changed. Man was making his own map on the face of the earth to portray his link, adaptation, creation and destruction.

Land-use requires a multi-disciplinary approach to arrive at sustained land-use planning. Land-use survey information should include details of physical, social and economic aspects along with environmental aspects in detail to find out the suitability, productivity, capability and potentiality for suitable land-use planning, especially in the field of agriculture.

The concept of land-use is a wide and complex one. It is a concerted function of land, water, air and man. It has been used by man since time immemorial to fulfill his changing demand with the passage of time. Land with its varied topography, slope, field pattern, soil, temperature, precipitation, natural cover and countless creatures has to be planned suitably to engrave an economy whereby man can maintain a satisfactory standard of existence.

Sauer (1919) defined "Land-use as the use to which the entire land surface is put." Land-use is the most important resource for a human being. Man started using land since his origin to meet his requirements such as food, fodder for the cattle, fuel, and timber etc. With the continuous process of development land utilization was determined according to human needs, which later on was converted into the land-use pattern. Though there is a mutual conflict between the different forms of land-use pattern; land is only a limited resource. But its ecology is also limited. The available land has certain priorities.

Stamp (1962) stated that the land as a whole must be so used as to satisfy to the possible extant the needs and legitimate desires as to satisfy of the people of the nation as a whole.

### 4.2 Basic Concepts of Land Use

Clawso (1968) has given nine major ideas/concepts about land use.

1) Location or the relation of a scientific specific parcel of land to the poles, the equator and the major oceans and landmasses. There is also relationship between various tracts of land, as well as political location.

2) Activity on the land, i.e. for what purpose this piece of land or tract is used.

3) Natural qualities of land, including its surface and subsurface characteristics and its negative cover.

4) Improvements to and on the land. This is closely related to activity.

5) Intensity of land-use or amount of activity per unit of area.

6) Land tenure, i.e. who owns the land and who uses it.

7) Land prices, land market activity and credit as applied to land.

8) Inter-relation between activities on the land and other economic and social activities.

9) Inter-relation in the use between different tracts of land.

Vink (1975) explained land-use as any kind of permanent or cyclic human intervention to satisfy human needs, either material or spiritual or both, from the complex natural or artificial resources, which together comprises land-use classification. The five categories were forests, which are not available for cultivation, and other uncultivated land excluding current fallows, fallow land and net area sown.

### 4.3 The Significance of the Land-Use Study

Land-use is the latest branch of the fast growing tree of economic geography. Geographers can present a clear picture of the potentials of land-use, conducive to fruitful planning for a massive agricultural turnover. According to Buck (1937), "Land utilization is the satisfaction, which the farm population derives from the type of agriculture development, the provision for the future production and the contribution to national needs."

Land utilization research can be described as dealing with problem situations, in which people in a given locality are in the process of transformation according to their requirements. In India, the land-use survey is mostly carried out on the pattern of British survey. Stamp played a vital role in 1930's for preparing the land-use map of entire United Kingdom. This survey had contributed much to enrich the food production of United Kingdom and to reorient its agriculture on more scientific basis.

Agriculture land-use is constantly changing with time. The land-use pattern of a country or a region at any particular point of time is determined by the physical, economic and institutional factors and their interplay over a period. In other words, the existing land-use pattern in different regions is a result of action and interaction of various factors such as the physical characteristics of land institution framework, Government policies, the structure of other resources available and location of the region in relation to other aspects of economic development in a dynamic context. A scientific study of land-use is a pre-requisite for rational land- use planning, especially for optimizing use of arable land. The land use planning is in essence the determination of the optimum use of every hectare of land in the country.

There is a growing public consciousness of the need for conservation and a wide use of our land resources. It is difficult to trace the origin of this consciousness and it may not be unreasonable to assume that it dates back to antiquity and to the earliest of the primitive human societies.

The importance of land utilization survey lies in the detailed information it gives about forms and localization of production which in analysis leads to a full appreciation of the rationality or irrationality of the present possibilities of its improvement.

**4.4 Land use model**

Land use model attempts to specify the existing and the potential inter-relationships of spatial and non-spatial elements that contribute to the pattering of land uses in rural and urban areas. An important theoretical base for rural land use studies exists in the Von Thunen's model and its later elaboration. These models emphasize such parameters of lane uses as transportation costs, distances to markets, but assume a homogenous rural landscape. The validity of Von Thunen's model of land uses has not been empirically tested, while there is every indication that the model may proved to be an appropriate base for studies of rural land use in India. However, certain of the assumptions in Von Thunen model will have to be discarded. For example future studies of land use in India should consider the spatial variations in the Physical base particularly variations relating to land capability and the contrasting regional structure and problems relating to specific studies along these lines especially in watershed region should emphasize any one among the several important aspects: a) Temporal change in the land utilization patterns, b) The impact of fragmentation and consolidation of holdings on land use patterns c) The impact of technological change on rural land use patterns and d) interrelationship of land use and the spacing and functions of market centers

## 4.5 Land-Use Problems

The main problem of land-use includes under-utilization, over-utilization and miss-utilization of land. The land available for agricultural and other purposes is finite and limited. The ever increasing pressure of population and decreasing land-man ratio poses challenging problems to the land-use planners and agricultural geographers. There is a premium on the horizontal expansion of arable land. To circumvent some of the problems, a critical examination of land-use is essential as regards the questions as to how the land is utilized and what the Land-use pattern is.

For example, in Bihar the northern part is fertile plain but the havoc of floods each and every year, irregular monsoon rainfall, lack of adequate irrigation facilities and high population density make the residents poor in most cases.

There are innumerable problems, which may affect land-use in a particular area:

**i) Soil Erosion:** Soil erosion is a comprehensive process of wearing down of loosened land surface through natural agents such as running water, ground water, sea waves, glaciers wind etc.

**ii) Leaching:** Leaching is a process by which soluble materials such as mineral salts and organic matter are washed out of from the upper layer of soil into the lower layer by percolation of rainwater. High temperature and heavy downpours favour the degree of decomposition of rocks, which causes thorough leaching within the soil profile. For example in the laterite areas of the tropical region leaching is predominant. Heavy leaching arising out of high rainfall accelerates the process of humidification and mineralization, which keeps the surface low in organic matter thereby affecting the land use is affected,

**iii) Bad effect of pesticides:** Use of pesticides deteriorates the quality of land-use through the contamination of air, water and soil. There are some of the direct consequences arising out of pesticides on land. When pesticides are exposed to environment, these not only destroy the harmful insects but also destroy the microbes beneficial to the plants, Nitrogen enriched green foliage of plant tissues attract the insects. Due to the lower intensity of solar energy during winter, blight and crop diseases are caused, pesticide residues on plant tissues/leaves/ soil undergo photo-chemical reaction under broad daylight and thereby cause photo-toxicity, pesticides hinder the microbial activity in the soil and thus the organic matter synthesis is hampered. The humus formation in soil, as a result, becomes impossible. Consequently, soil suffers from prolonged nutrient deficiency.

**iv) Drought Hazards:** Any type of land-use practice needs water. Drought is an environmental hazard, which reflects deficiency of water in a particular region. It may be mentioned that prolonged dryness causes drought conditions, which depend on the amount of rainfall, its departure from the normal annual average and demand of water for multipurpose uses. Drought poses a serious bearing in the biospheric system. The cumulative effects of prolonged drought cause extensive and enormous damage to natural vegetation and agriculture. Thus, deficiency of water hinders optimum utilisation of land.

The land use pattern of Mizoram State is strongly influenced by the unfavourable conditions especially in agricultural system. A land resource is one of the major natural resources. The changes of land use pattern over a time period control the stress on land.

The basic principle of soil and water conservation is use to the land and according to its capability and treat the land according to its needs. Land capability classification is usually started with the objectives to increase productivity and to improve the sustainability of natural resources. The remote sensing technology along with GIS is a perfect device to identify, locating and prepared maps of various types of lands associated with different landform units. Land capability is the ability of land to support a given land use without causing damage. Assessment of land capability considers the specific requirements of the land use, e.g. rooting depth or soil water availability, and the risks of degradation associated with the land use. Land Capability Classification (LCC) is a system of grouping soils primarily on the basis of their capability to produce common cultivated crops and pasture plants without deteriorating over a long period of time. Each soil map unit is assigned a capability class of I through VIII, and classes II through VII are assigned a sub-classes describing limitations or hazards for agricultural purposes (USDA).

Based map was prepared from India toposheets number 83D/11, 83D/12 and 83D/15 comprising road network, drainage and other topographic information. Slope map is prepared from CartoDEM by using Survey of India toposheets on 1:50,000 scale by adopting the methodology proposed by All India Soils and Land Use Survey (AIS & LUS, 1971). For land use land cover pattern and land capability classification satellite image of IRS P6 LISS-III sensor 2016 has been used. Slope map is obtained from CartoDEM satellite image of 30m spatial resolutions. Geomorphic map has been prepared by using SOI Map and satellite imagery. Soil map prepared by Mizoram Agriculture department has been used coupled with field investigations. A surface and ground water potential map is prepared based on the integration of the data on drainage density, drainage frequency, slope, geomorphic features and litho-units for the evaluation of water resources. In land capability classification, the arable soils are grouped according to their potentialities and limitations for sustained production of the common cultivated crops that do not require specialized site conditioning or site treatment. Non arable soils (soils unsuitable for long time sustained use for cultivated crops) are grouped according to their potentialities and limitations for the production of permanent vegetation and according to their risks of soil damage if mismanaged. It is mainly based on the inherent of soil properties, external land features, and environmental factors that limit the land use.

### 4.6 Land Use/ Land Cover 2006

In 2006, land use/land cover of the watershed is broadly characterized by 5 different land use classes such as built-up land, agricultural land, forest, wastelands, water bodies and others including shifting cultivation.

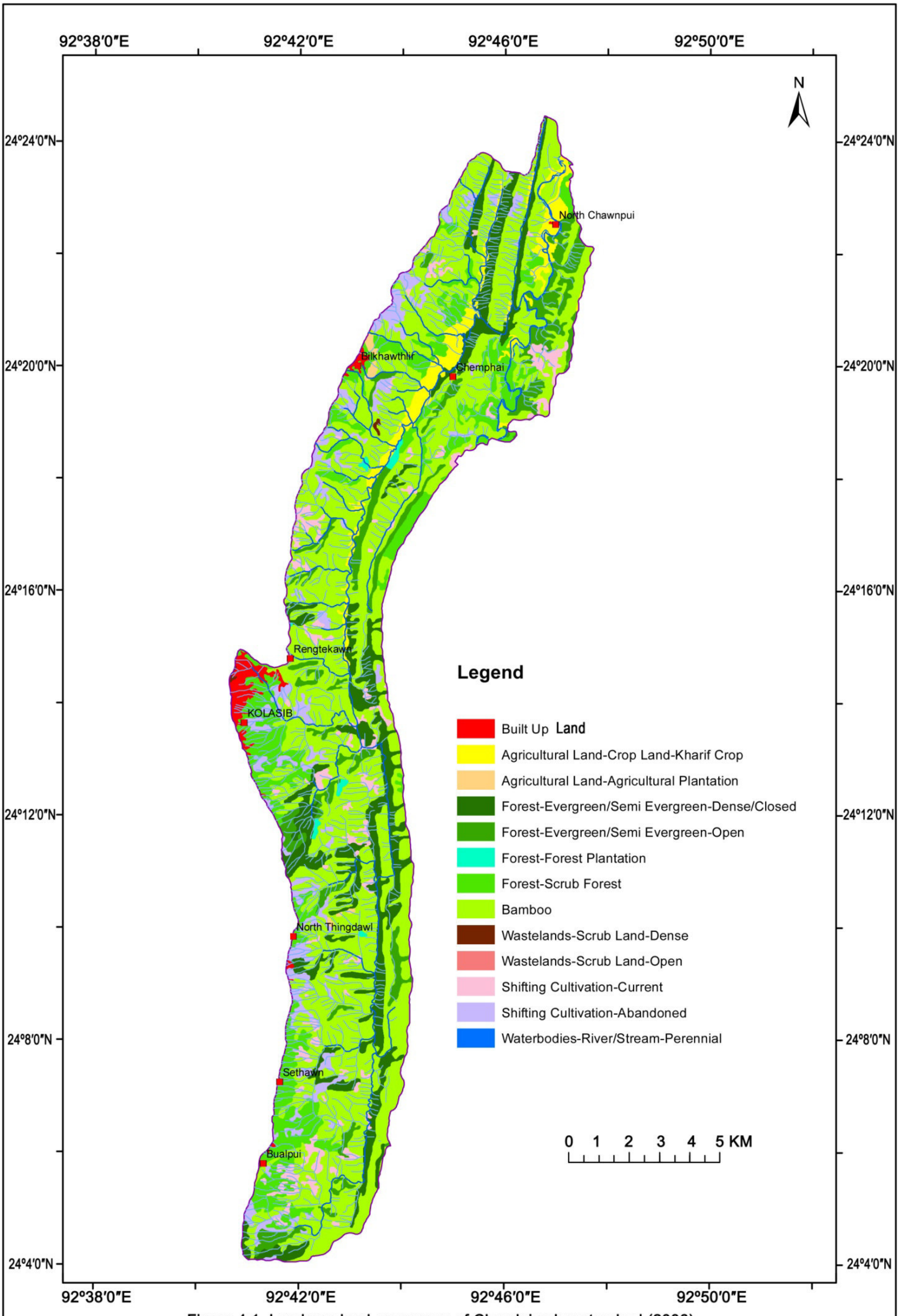


**Figure 4.1. Land use land cover map of Chemlui sub-watershed (2006)**

Built-up land including roads and settlements cover an area of about 1.23 percent which is 203.28 hectares of the total study area. A Kharif crop covers an area of 3.85 percent which is 637.20 hectares of the total study area. An agricultural and horticultural plantation covers an area of only 0.27 percent of the total study area. More than half of the total study area is covered by bamboo forest which is 54 percent.

Table 4.1: Land Use/ Land Cover, 2006

| **Sl.no** | **Land Use Classes** | **Area in Hectare** | **Area in %** |
|---|---|---|---|
| 1 | Built-up land | 203.28 | 1.23 |
| 2 | Agricultural Land | | |
| | Crop Land-Kharif Crop | 637.20 | 3.85 |
| | Plantation-Horticulture Plantation | 45.21 | 0.27 |
| 3 | Forest | | |
| | Evergreen/Semi Evergreen-Dense/Closed | 1976.05 | 11.93 |
| | Evergreen/Semi Evergreen-Open | 1119.38 | 6.76 |
| | Forest Plantation | 56.72 | 0.34 |
| | Scrub Forest | 1927.73 | 11.64 |
| | Bamboo | 8983.32 | 54.24 |
| 4 | Wastelands | | |
| | Scrub Land-Dense | 11.71 | 0.07 |
| | Scrub Land-Open | 0.28 | 0.00 |
| 5 | Water bodies-River/Stream-Perennial | 61.62 | 0.37 |
| 6 | Others | | |
| | Shifting Cultivation-Current | 646.58 | 3.90 |
| | Shifting Cultivation-Abandoned | 893.92 | 5.40 |
| | **TOTAL** | **16563** | **100.00** |

Scrub forest occupied an area of 11.64 percent. The wasteland features such as land with scrub dense and open occupied only 0.07 percent of the total study area. The water bodies occupied 61.62 hectare (0.37 percent). Others land use class includes current shifting cultivation occupied 3.90 percent and abandoned shifting cultivated land occupied 5.40 percent of the total study area.

**4.7 Land Use/ Land Cover, 2016**

In 2016 the thematic map identified and shows more kinds of land use/ land cover which is not found in the last one decade. Land use classes like Water bodies-Lakes/Ponds-Seasonal and Water bodies-Reservoir/Tank-Permanent have been identified with significance. Thus land use/land cover of the watershed area is classified into 6 broad categories such as (i) Built-up land, (ii) Agricultural Land includes -Crop Land-Kharif Crop, Plantation-Horticulture Plantation, (iii) Forest includes - evergreen/semi evergreen-dense/closed, evergreen/semi evergreen-open, forest Plantation, scrub Forest, and bamboo, (iv) Wastelands includes - Scrub Land-Dense and Open, (v) Water bodies like River/Stream-Perennial, Lakes/Ponds Seasonal, Reservoir/Tank-Permanent. (vi)Others includes shifting cultivation-Current and shifting cultivation-abandoned.

In 2016, built-up land covered (1.71%), agricultural land-crop land-kharif crop (5.19%), plantation-horticulture plantation (1.28%), forest-evergreen/semi evergreen-dense/closed (11.23%), forest-scrub forest (9.77%), forest-evergreen/semi evergreen-open (9.34%), forest-forest plantation (0.31%), more than half of the sub-watershed is cover by bamboo forest which comprises 55.79 per cent of the total watershed area.

Table 4.2. Land Use/ Land Cover, 2016

| Sl.no | Land Use Class | Area in Ha | Area in % |
|---|---|---|---|
| 1 | Built Up | 283.06 | 1.71 |
| 2 | Agricultural Land | | |
| | Crop Land-Kharif Crop | 858.82 | 5.19 |
| | Plantation-Horticulture Plantation | 212.71 | 1.28 |
| 3 | Forest | | |
| | Evergreen/Semi Evergreen-Dense/Closed | 1860.58 | 11.23 |
| | Evergreen/Semi Evergreen-Open | 1547.49 | 9.34 |
| | Forest Plantation | 50.83 | 0.31 |
| | Scrub Forest | 1618.65 | 9.77 |
| | Bamboo | 9239.77 | 55.79 |
| 4 | Wastelands | | |
| | Scrub Land-Dense | 86.59 | 0.52 |
| | Scrub Land-Open | 24.80 | 0.15 |
| 5 | Water bodies | | |
| | River/Stream-Perrenial | 40.84 | 0.25 |
| | Lakes/Ponds-Seasonal | 2.82 | 0.02 |
| | Reservoir/Tank-Permanent | 287.49 | 1.74 |
| 6 | Others | | |
| | Shifting Cultivation-Current | 201.54 | 1.22 |
| | Shifting Cultivation-Abandoned | 247.01 | 1.49 |
| | **TOTAL** | **16563** | **100.00** |

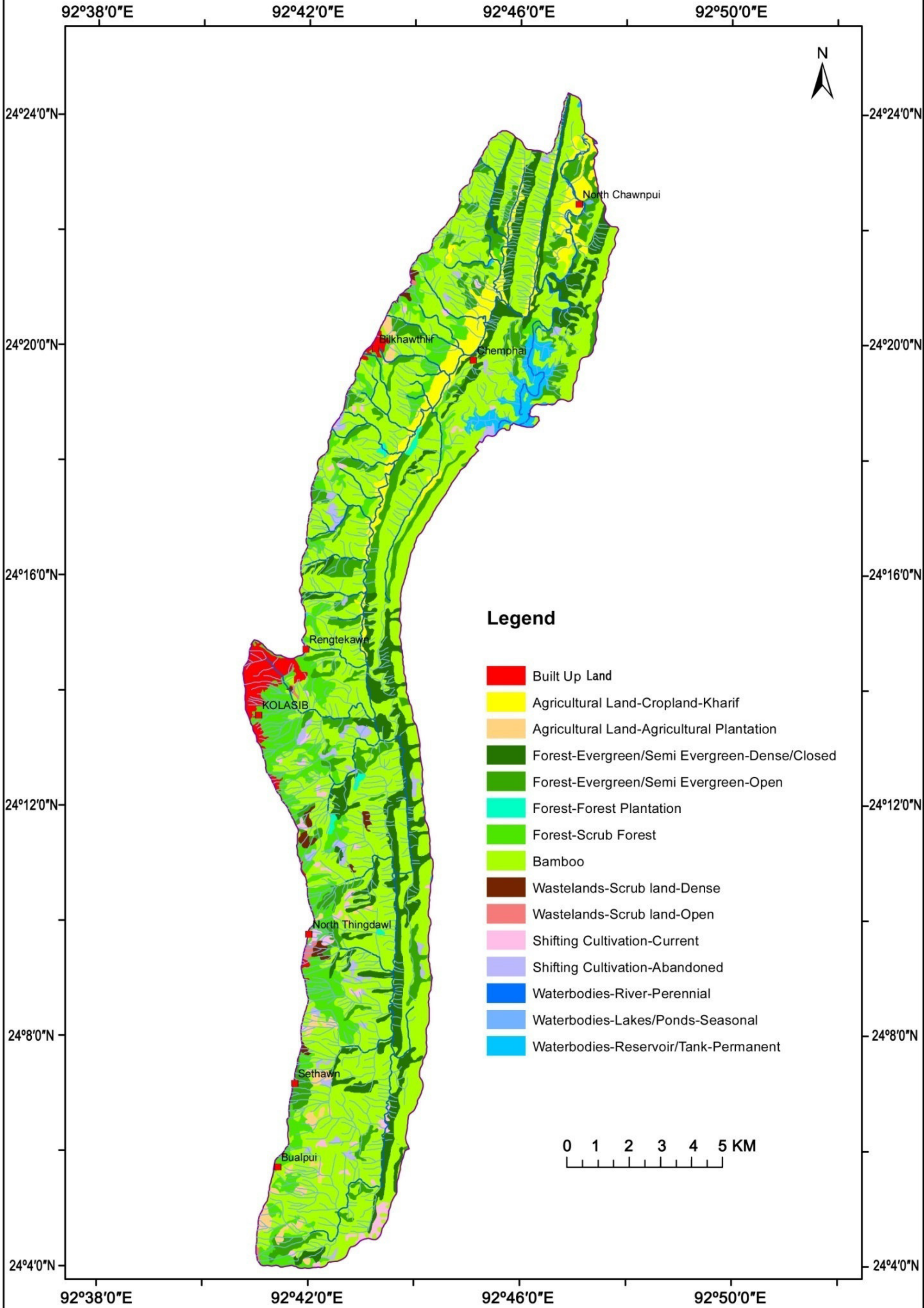


**Figure 4.2. Land use land cover map of Chemlui sub-watershed (2016)**

A wide area of land are also found at different land use classes such as wastelands-scrub land-dense (0.52%), wastelands-scrub land-open (0.15%), shifting cultivation-current (1.22%), shifting cultivation-abandoned (1.49%), water bodies-river/stream-perennial (0.25%), and water bodies-lakes/ponds-seasonal accounting 0.02 per cent of the total watershed area. water bodies-reservoir/tank-permanent (1.74%).

**4.8 Land Use Land Cover Change (2006 - 2016)**

Both increasing and decreasing trend of land use/ land cover units was detected during the decade. Table 4.3 shows the temporal patterns and rate of changes in the watershed between 2006 and 2016. Increasing patterns of land use/ land cover change was detected for 9 categories such as Built Up, Agricultural Land-Crop Land-Kharif Crop, Agricultural Land-Plantation-Horticulture Plantation, Forest-Evergreen/Semi Evergreen-Open, Bamboo, Wastelands-Scrub Land-Dense, Wastelands-Scrub Land-Open, Water bodies-Lakes/Ponds-Seasonal, Water bodies-Reservoir/Tank-Permanent. In the decade, the increasing change was found highest at Forest-Evergreen/Semi Evergreen-Open in which it was decreased by 2.58 per cent covering 428.11 hectare of land. Water bodies-Reservoir/Tank-Permanent was also increased by 1.74 per cent (287.49 ha). Bamboo cover land was increased by 1.55 per cent (256.45 ha). Area under Agricultural Land-Crop Land-Kharif Crop was increased by 1.34 per cent (221.62 ha). Agricultural Land-Plantation-Horticulture Plantation area was increased by 1.01 per cent (167.5 ha), Increasing changes was also detected but not high in some land use classes such as Built Up was increased by 0.48 per cent (79.78 ha), Wastelands-Scrub Land-Dense by 0.45 per cent (74.88 ha), Wastelands-Scrub Land-Open by 0.15 per cent

(24.52 ha), Water bodies-Lakes/Ponds-Seasonal increased by 0.02 per cent which was 2.82 hectare of land.

In the decade (2006-2016), an enormous increasing trend has been seen. In the land under scrub land which was increased by 0.60 per cent of the area cover. The land covers by water bodies of lakes/ponds-seasonal and reservoir/tank-permanent was also increased to 287.49 hectares. Wet Rice Cultivation areas were increased from 637.20 hectares to 858.82 hectares (1.34%). Forest cover with less dense was increased by 2.54 per cent in the watershed area where it was 1119.38 hectares in 2006 while it was 1547.49 hectares in 2016. Area under plantation agriculture was increased by 1.01 per cent during the decade. Forest land cover by bamboo was also increased from 8983.32 in the year 2006 hectares to 9239.77 in 2016 which is 1.55 per cent.

Decreasing pattern of changes have been also identified at another 6 land use classes such as Forest-Evergreen/Semi Evergreen-Dense/Closed, Forest-Forest Plantation Forest-Scrub Forest, Shifting Cultivation-Current, Shifting Cultivation-Abandoned and Water bodies-River/Stream-Perennial. Area under Shifting Cultivation-Abandoned was largely decreased by 3.91 per cent accounting 646.91 hectares of land. Land use under Shifting Cultivation-Current was also highly decreased by 2.69 per cent which was 445.04 hectares of land. Decreasing patterns was also identified at Area under Forest-Scrub Forest was decreased by 1.87 per cent (309.08 ha), Forest-Evergreen/Semi Evergreen-Dense/Closed by 0.7 (115.47 ha), Water bodies-River/Stream-Perrenial by 0.13 (20.78 ha) and area under Forest-Forest Plantation by 0.04 per cent which was 5.89 hectares of land.

**Table 4.3 Land Use/ Land Cover Change (2006-2016)**

| Sl.no | Land Use Class | Area in Ha | | Changed in Area Ha | Changed in Total Area % | Patterns of Change |
|---|---|---|---|---|---|---|
| | | 2006 | 2016 | | | |
| 1 | Built Up | 203.28 | 283.06 | **79.78** | **0.48** | **Increased** |
| 2 | Agricultural Land-Crop Land-Kharif Crop | 637.20 | 858.82 | **221.62** | **1.34** | |
| 3 | Agricultural Land-Plantation-Horticulture Plantation | 45.21 | 212.71 | **167.50** | **1.01** | |
| 4 | Bamboo | 8983.32 | 9239.77 | **256.45** | **1.55** | |
| 5 | Forest-Evergreen/Semi Evergreen-Open | 1119.38 | 1547.49 | **428.11** | **2.58** | |
| 6 | Wastelands-Scrub Land-Dense | 11.71 | 86.59 | **74.88** | **0.45** | |
| 7 | Wastelands-Scrub Land-Open | 0.28 | 24.80 | **24.52** | **0.15** | |
| 8 | Water bodies-Lakes/Ponds-Seasonal | - | 2.82 | **2.82** | **0.02** | |
| 9 | Water bodies-Reservoir/Tank-Permanent | - | 287.49 | **287.49** | **1.74** | |
| 10 | Forest-Evergreen/Semi Evergreen-Dense/Closed | 1976.05 | 1860.58 | **-115.47** | **0.70** | **Decreased** |
| 11 | Forest-Forest Plantation | 56.72 | 50.83 | **-5.89** | **0.04** | |
| 12 | Forest-Scrub Forest | 1927.73 | 1618.65 | **-309.08** | **1.87** | |
| 13 | Shifting Cultivation-Current | 646.58 | 201.54 | **-445.04** | **2.69** | |
| 14 | Shifting Cultivation-Abandoned | 893.92 | 247.01 | **-646.91** | **3.91** | |
| 15 | Waterbodies-River/Stream-Perrenial | 61.62 | 40.84 | **-20.78** | **0.13** | |
| | **TOTAL** | **16563** | **16563** | | | |

In the hilly region, changing of land-use/cover even in a year is very common. In the Chemlui watershed, tremendous changes in land use/cover have occurred during the study period between 2006 and 2016. These changes have an impact on the agriculture, biodiversity, forest and ecology etc., of the region. Changes in the cropping pattern shows that farmers substantially benefit by replacing traditional food crops into cash crops but at the cost of increased vulnerability to climatic and market uncertainties. Abandonment of traditional crops means a loss of agro-biodiversity that remains 'lesser known' or 'unknown' to wider communities and associated indigenous technologies and knowledge. Expansion of agriculture in marginal land and declining crop yields are considered to be major unsustainable trends in the hilly region like Himalaya (Eckholm, 1979, Jodha, 1990). Adaptive responses to stress factors by farmers played a significant role in evolution of traditional agriculture in the past when farming was the only option for securing livelihood. In the present circumstances, it often becomes more cost effective for the farmers to find employment than to spend his costly and scarce resources for rehabilitating the land of low productivity (Turner, 1982). With increasing needs as well as pressure of population, the traditional farming has become unsustainable both economically and ecologically (ICIMOD, 1996).

In the study area, as the population is growing, the area cover by built-up is increasing at a large degree. Similarly, open forest, bamboo and waste land is increasing during the decade. It shows land use change in the study area need to control forest degradation as well as high rate of increasing built-up land. Decreasing patterns found in forest like evergreen, semi-evergreen and dense forest in the watershed during the study period. Perennial water bodies extent is also reducing. At the same time area under shifting cultivation current and abandoned are also declined in the decade. It shows that occupation patterns change from shifting to permanent farming and allied. It is likely to become forest regeneration and further result improvement in environment condition. It is expected to enrich biodiversity, land and water resources in the watershed also.

Changes in the land use / land cover are quite common but drastic changes are not good for the sustainable development of natural resources. The changes at abnormal rates should be monitor periodically to manage the natural resources for the sustenance of mankind. Appropriate advanced measures should be followed to maintain or manage the natural resources.

# CHAPTER – V

# LAND CAPABILITY

# CHAPTER V

# LAND CAPABILITY

## 5.1 Introduction

Land resources utilization has its impact on the biodiversity and environment of allied region either positively or negatively depending on how it is used in time and space. As land-use planning is defined as a systematic assessment of land capability and water potential, alternatives for land use, and the economic and social conditions required to select and adopt the best land-use options, it is important to identify the available resources at micro level more precisely. The management of resources at watershed or sub-watershed level is convenient and the most effective for their development.

The basic principle of soil and water conservation is to use the land and according to its capability and treat the land according to its needs. Land capability classification is usually started with the objectives to increase productivity and to improve the sustainability of natural resources. The remote sensing technology along with GIS is a perfect device to identify, locate and to prepared maps of various types of land associated with different landform units. Land capability is the ability of land to support a given land use without causing damage. Assessment of land capability considers the specific requirements of the land use, e.g. rooting depth or soil water availability, and the risks of degradation associated with the land use. Land capability Classification (LCC) is a system of grouping soils primarily on the basis of their capability to produce common cultivated crops and pasture plants without deteriorating over a long period of time. Each soil map unit is assigned a capability class of I through

VIII, and classes II through VII are assigned a sub-classes describing limitations or hazards for agricultural purposes (USDA, 1994).

**5.2 Land capability classification**

For land capability classification Satellite image of IRS P6 LISS-III sensor of the year 2016 has been used. Slope map is obtained from CartoDEM satellite image of 30m spatial resolution. Base map has been prepared from India toposheets 83D/11, 83D/12 and 83D/15. In this classification, the arable soils are grouped according to their potentialities and limitations for sustained production of the common cultivated crops that do not require specialized site conditioning or site treatment. Non arable soils (soils unsuitable for long time sustained use for cultivated crops) are grouped according to their potentialities and limitations for the production of permanent vegetation and according to their risks of soil damage if mismanaged. It is mainly based on the inherent properties of soil, external land features, and environmental factors that limit the land use.

According to the classification made by USDA (1994) soils of the study area have been classified into five (5) land capability classes such as IIe, IIIe, IVe, VIe and VIIe (Fig.5.1) using ArcGIS 10.2.2 software. The land capability Classes I to IV are considered as capable of producing cultivated crops with good management and conservation treatment. Classes V to VII are best suited to perennial vegetative species, but may be capable of producing some specialized crops with highly intensive management. Class VIII soils are not suitable for managed vegetative production. Subclass ‘**e**’ is made up of soils for which the susceptibility to erosion is the dominant problem or hazard affecting their utilization. Erosion susceptibility and past erosion damage are the major soil factors that affect soils in this subclass.

**5.2.1 Land capability class IIe**

This classification has very good arable lands which are occurred on gentle slopes of the study area. It is susceptible to slight water erosion, very deep, medium to moderate fine soil texture and is suitable for agricultural practices. The study reveals that 10.32% of the total area falls in class IIe occupying 1709.58 hectares.

**Recommendation**

(i) Proper bunding and levelling.

(ii) Improve drainage pattern and flood protection.

(iii) Introduction of manures and suitable varieties of crops.

(iv) Improvement of irrigation system and its facilities.

**5.2.2 Land capability class IIIe**

This classification has good arable land with moderate to steep sloping valley which are susceptible to severe water erosion, deep to very deep soil. It is suitable for horticultural and agricultural practices. The study reveals that 10.82 % of the total area falls in class IIIe occupying 1791.80 hectares.

**Recommendation**

(i) Proper bunding for terrace farming.

(ii) Improve check dams and embankments.

(iii) Utilize of manures and introduce suitable varieties of crops.

(iv) Improvement of irrigation system and its facilities.

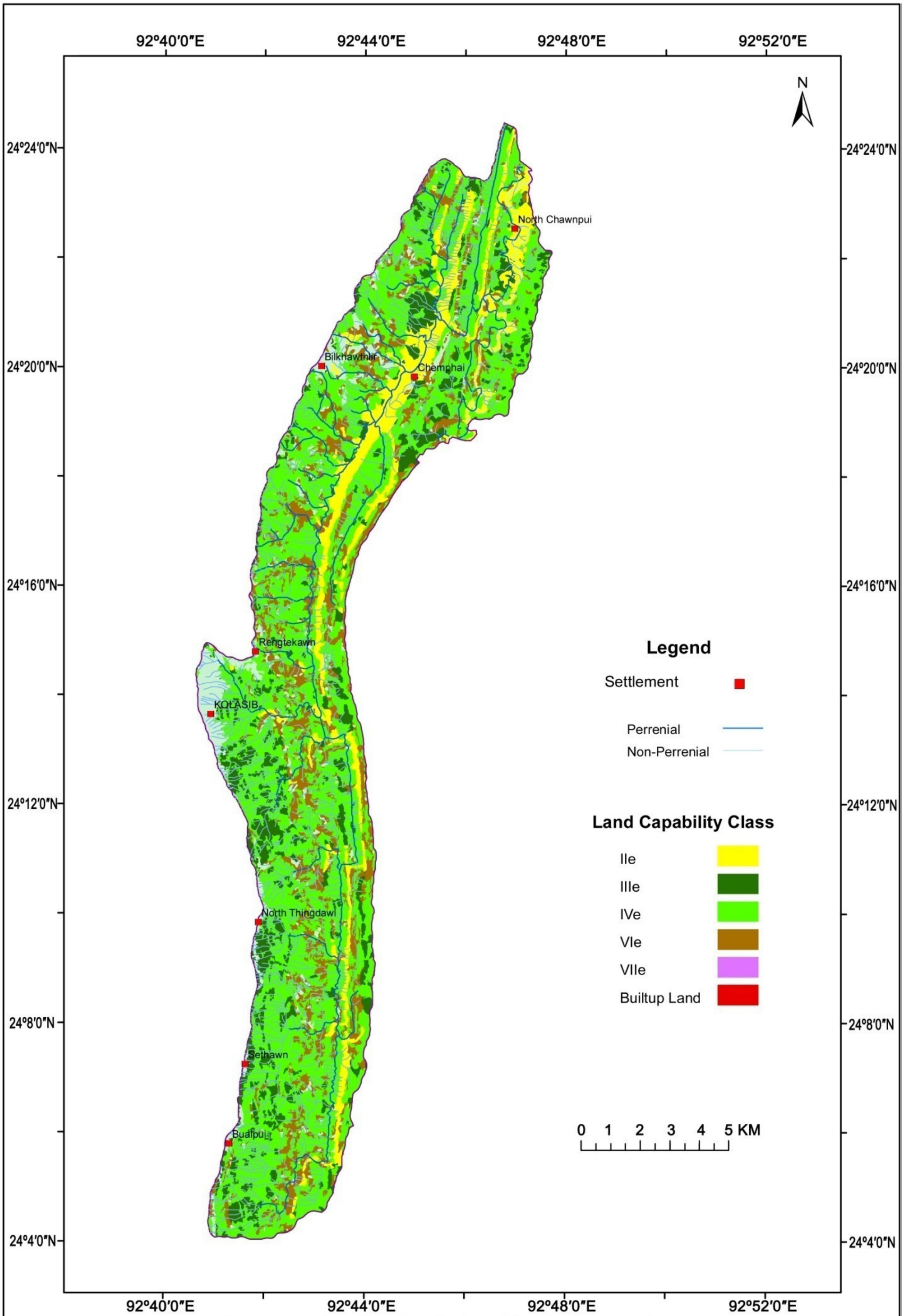


Fig.5.1. Land Capability Classification of Chemlui Sub-watershed.

### 5.2.3 Land capability class IVe

This classification has highly susceptible to water erosion, good land on steep to very steep slopes and hill ridge with deep to very deep soil and is suitable for agro-horticultural and sericulture purpose. The study reveals that 57.21 % of the total area falls in class IVe occupying 9476.66 hectares.

**Recommendation**

(i) Proper bunding for terrace farming and contour trench farming.

(ii) Introduce of agro-horticultural practices and sericulture.

(iii) Utilization of manures.

(iv) Improve check dams and embankments.

### 5.2.4 Land capability class VIe

This classification has moderate land with limitations on very steep slope. It is highly susceptible to water erosion, deep to very deep soil and is suitable for horticultural plantation and forestry. The study reveals that 13.06 % of the total area falls in class VIe occupying 2162.59 hectares.

**Recommendation**

(i) Plantation of horticultural crops.

(ii) Conservation of vegetation to control water and soil.

(iii) Improve afforestation.

(iv) Improve check dams and embankments.

#### 5.2.5 Land capability class VIIe

This classification has land with severe limitations on very steep slopes. It is subjected to severe erosion and is not suitable for agricultural purpose but suitable for social forestry and grazing. The study reveals that 4.46 % of the total area falls in class VIIe occupying 738.54 hectares.

**Recommendation**

(i) Plantation of horticultural crops along the hill sides.

(ii) Conservation of vegetation to control water and soil.

(iii) Improve afforestation for economic and commercial purpose.

(iv) Control overgrazing.

**Table.5.1. Land Capability Classification Statistics of Chemlui Sub-watershed**

| Sl.No. | Land Capability Class | Description of Land Capability Classes | Area in Hectare | Area in Percentage |
|---|---|---|---|---|
| 1 | IIe | Good arable land on gentle slopes, susceptible to slight Water erosion, very deep soil, suitable for agricultural practices. | 1709.58 | 10.32 |
| 2 | IIIe | Good land with moderate sloping to steep, susceptible to severe water erosion, deep to very deep soil, suitable for horticultural and agricultural practices. | 1791.80 | 10.82 |
| 3 | IVe | Highly susceptible to Water erosion, good | 9476.66 | 57.21 |

| | | | | |
|---|---|---|---|---|
| | | land on steep to very steep slopes and hill ridge with deep to very deep soil and is suitable for agro-horticultural and sericulture purpose. | | |
| **4** | VIe | Moderate land with limitations on very steep slope, highly susceptible to water erosion, deep to very deep soil, suitable for horticultural plantation and forestry. | 2162.59 | 13.06 |
| **5** | VIIe | Land with severe limitations on very steep slopes, subject to severe erosion and is not suitable for agricultural purpose but suitable for social forestry and grazing. | 738.54 | 4.46 |
| **6** | Built up land | | 429.32 | 2.59 |
| **7** | Water bodies | | 254.31 | 1.54 |
| **Total** | | | **16563** | **100** |

The study reveals that the application of remote sensing and GIS approach provide enormous advantage to analyse those multi-layered of satellite imagery data spatially and classify land based on its capability accordingly. The land capability of the Chemlui watershed is useful for future planning of land utilization at sub-watershed level. From the land capability classification it is observed that there is good potential for agricultural with horticultural system and plantations in the study area. And also focuses on conservation of the existing forests to maintain ecological balance while taking up improved and alternate farming practices in the sub-watershed as well.

It is highly essential to identify the land which belongs to a proper land capability class through ideal methodologies as the suggestion of the action plan for land use plan for the overall development of a region is depend on it.

# CHAPTER – VI

# LAND USE PLANNING

# CHAPTER VI

# LAND USE PLANNING

## 6.1. Introduction

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The land use planning process covers all steps extending from the collection of data and information through its processing, analysis, discussion and evaluation right up to the negotiation for a consensus concerning the form of land use to be practiced. This includes the prerequisites for preparing, initiating and implementing the plan. However, in the context of the technical co-operation, during the land use planning process not necessarily all planned measures to be carried out will be implemented in their entirety. Planning of potential land use land cover and natural resources are important for preserving the ecological balance for natural resources development and conservation, predominantly in fragile and heterogeneous erosion-vulnerable hilly region. It affects living and economic development of such region especially in developed countries. The utilization of land resources has its impact on the biodiversity and environment of related region either positively or negatively depending on how it is used in time and space. The land utilization type must be designed to ensure that the natural basis of living is sustained in the long run that means the use of the land should correspond to its natural potential. Existing environmental damage should be minimized and damaging developments avoided by supporting and developing suitable approaches.

For data base Satellite imagery of IRS P6 LISS-III sensor 2016 Mizoram Remote Sensing Application Centre (MIRSAC) has been used in the present study. Geomorphic map has been prepared by using Survey of Indian topographical Map and satellite imagery. Soil map prepared by Mizoram Agriculture department has been used and field investigations were conducted. A surface water and ground water potential map was prepared based on the integration of the data on drainage density, drainage frequency, slope, geomorphic features and litho-units for the evaluation of water resources. A land capability and soil erosion status map was prepared using toposheets and satellite imagery.

The thematic data on drainage, land use/land cover, geomorphic features, lithology, slope, soils, land capability and soil erosion status was integrated by adopting the overlay techniques of GIS with the help of ArcGIS software tools to prepare propose land use map in order to suggest alternative land use farming systems for the development of resources in Chemlui sub-watershed.

Accordingly, a proposed land use planing of the study area was generated based on different parameters of the present land utilization, soil types and percentage of slope. There are various criteria adopted for the purposed land use plan as given below table.6.1:

Table.6.1 Principle Generation Criteria for the purpose land use planing

| **Sl. No.** | **Principle Generation Criteria for the purpose land use planing** | | | **Proposed Land Utilization** |
|---|---|---|---|---|
| | **Present Land Use** | **Soil type** | **Slope %** | |
| 1. | Single cropped agricultural land, current shifting, abandoned shifting, scrubland & grassland. | Fine Loamy Typic Dystrochrepts and Fine Loamy Umbic, Loamy Skeletal Typic Hapludults Dystrochrepts, very deep, good moisture. | 0% - 30% | Wet Rice Cultivation (WRC) |
| 2. | Single cropped | Fine Loamy Umbic Dystrochrepts | 30% - 45% | Silviculture |

| | | | | |
|---|---|---|---|---|
| | agricultural land, current & abandoned shifting. | and Fine Loamy Typic, Loamy Skeletal Typic Dystrochrepts Dystrochrepts, deep, good moisture. | | |
| 3. | Current & abandoned shifting. | Fine Loamy Typic Dystrochrepts. Loamy Skeletal Umbric Dystrochrepts, Fine Loamy Humic Hapludults, very deep, good moisture. | 35% - 50% | Agro-Horticulture |
| 4. | Existing bamboo plantation. Current & abandoned Shifting. | Fine Loamy Typic Dystrochrepts. Loamy Skeletal Humic Hapludults and very deep, good moisture. | 25% - 40% | Bamboo |
| 5. | Abandoned shifting & scrub land. | Loamy Skeletal Typic Dystrochrepts and Loamy Skeletal Humic Hapludults, deep, moderate moisture. | 50% and above | Afforestation |
| 6. | Opened & dense forest, forest plantations & bamboo growing areas. | Any soil types | Any slope % | Forest and Bamboo Reserves |

Following these principle criteria, the proposed potential land use systems were done with the help of ArcGIS tools and are geospatially inserted in the GIS system by implementing appropriate spatial uncertainty and commands. Along with these, the insertion thematical layers like drainage, land capability, road and slope are the most important data throughout this planning method. Necessary field information for confirming the accurateness of the proposed maps are collected during ground truth verification surveys and integrated during the ultimate stages of the proposed plan preparation.

## 6.2 Land Use Planning

Remote Sensing and GIS techniques play major role in formulation the proposed plan in this study. Remote sensing is particularly useful in identifying remote areas and the software GIS is an effective tool for data integration to produce a picture on which positive decisions can be prepared. Information on land use / land cover and possibilities for their optimal use is essential for the implementation and planning of land use proposal of land utilization. Land use planning by using remote sensing and GIS techniques in the study area was done keeping in mind the objectives of making best use of available land for socio-economic improvement and to facilitate dependence of farmers on permanent farming system.

Table. 6.2 Classification of Land Use Planning of Chemlui Sub-watershed.

| **Description** | **Area in Hectare** | **Area in %** |
|---|---|---|
| Wet Rice Cultivation(WRC) | 1503 | 9.07 |
| Agro-horticulture | 4058 | 24.50 |
| Afforestation/Silviculture | 684 | 4.13 |
| Forest | 3647 | 22.02 |
| Bamboo | 5972 | 36.06 |
| Settlement | 425 | 2.57 |
| Waterbody | 119 | 0.72 |
| Fisheries | 154 | 0.93 |
| Total | **16563** | **100** |

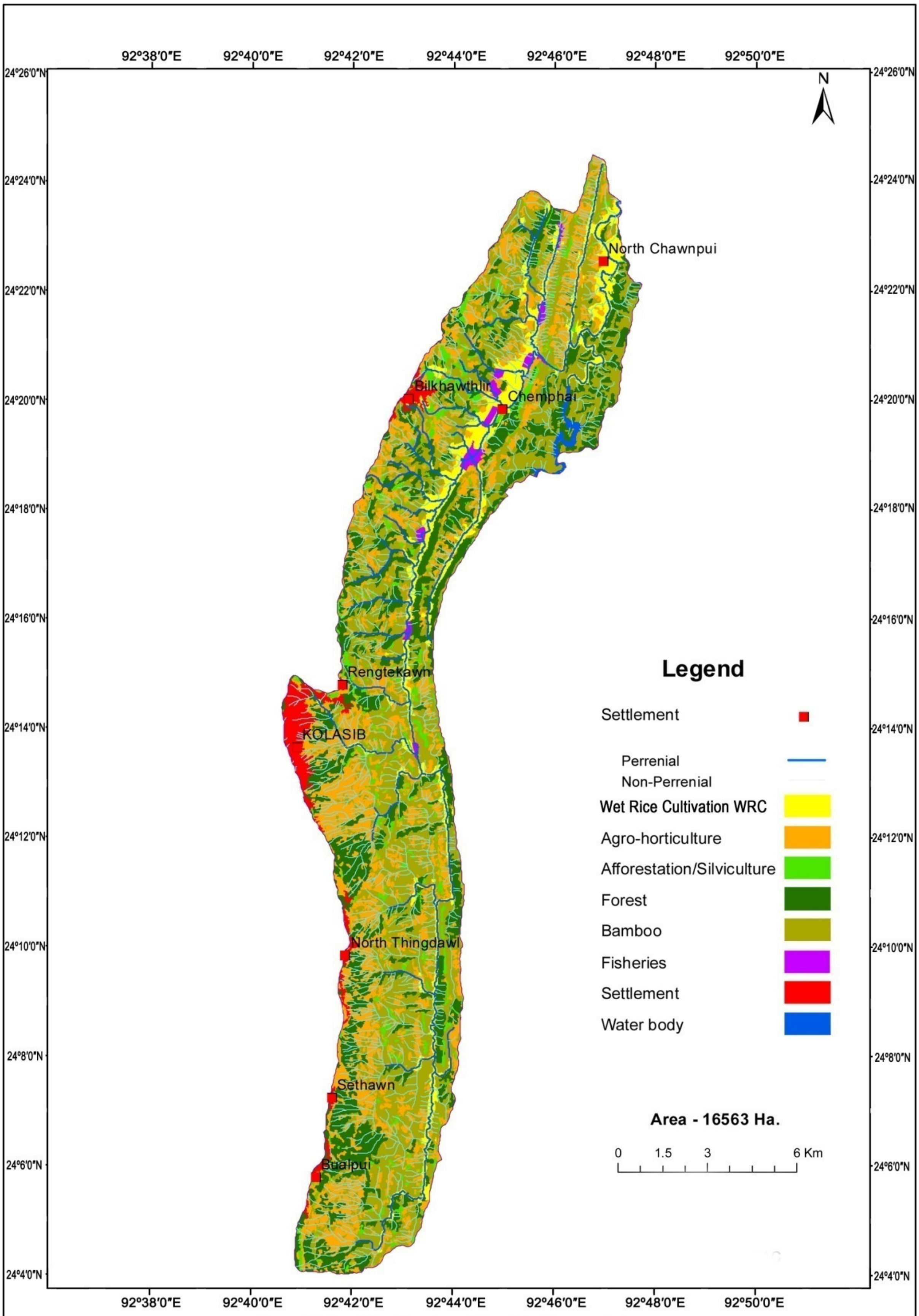

Figure 6.1. Land Use Planning of Chemlui Sub-watershed.

For efficient utilization of land to meet the requirements of the people of the block, optimal land use plan has been suggested after assessing the potential of land resources viz. soils, hydro-geomorphology and terrain conditions. The suitability is dovetailed with agro-climatic and socio-economic data to make them locally acceptable and economically viable. The Present study area is classified into eight areas of land use development planning such as Wet Rice cultivation, Agro-horticulture, Afforestation /silviculture, forest, settlement, water body and fisheries (Fig.6.1)(Table.6.2).

### 6.2.1 Wet Rice Cultivation

The total area of 15.3 sq km land is proposed for Wet Rice Cultivation which comprises 9.07 per cent of the total watershed area. Most of the area is concentrated along the sides of the river. The north eastern part of the area can be brought for cultivating both kharif and rabi crops due to availability of river water on the one hand and highly possible to bring irrigation on the other hand. More irrigation facilities can be constructed to increase productivity. Double production in a year can be attained through proper irrigation. Minor irrigation tanks, check dams and water harvesting bundhis are proposed to be constructed for irrigating the crops and to increase infiltration rate. The river valley and foothills having a slope less than 25 per cent are recommended for double cropping throughout the year. It is proposed to make bunds on the utilized flat lands and terraces on the foothills. Though the main proposed crops is rice (kharif), the river valleys are also suitable for agro-aquaculture. The composite fish culture with paddy or vegetables system is highly recommended for this land use plantation. As shown in the figure 6.2, WRC is proposed to be more in the north and

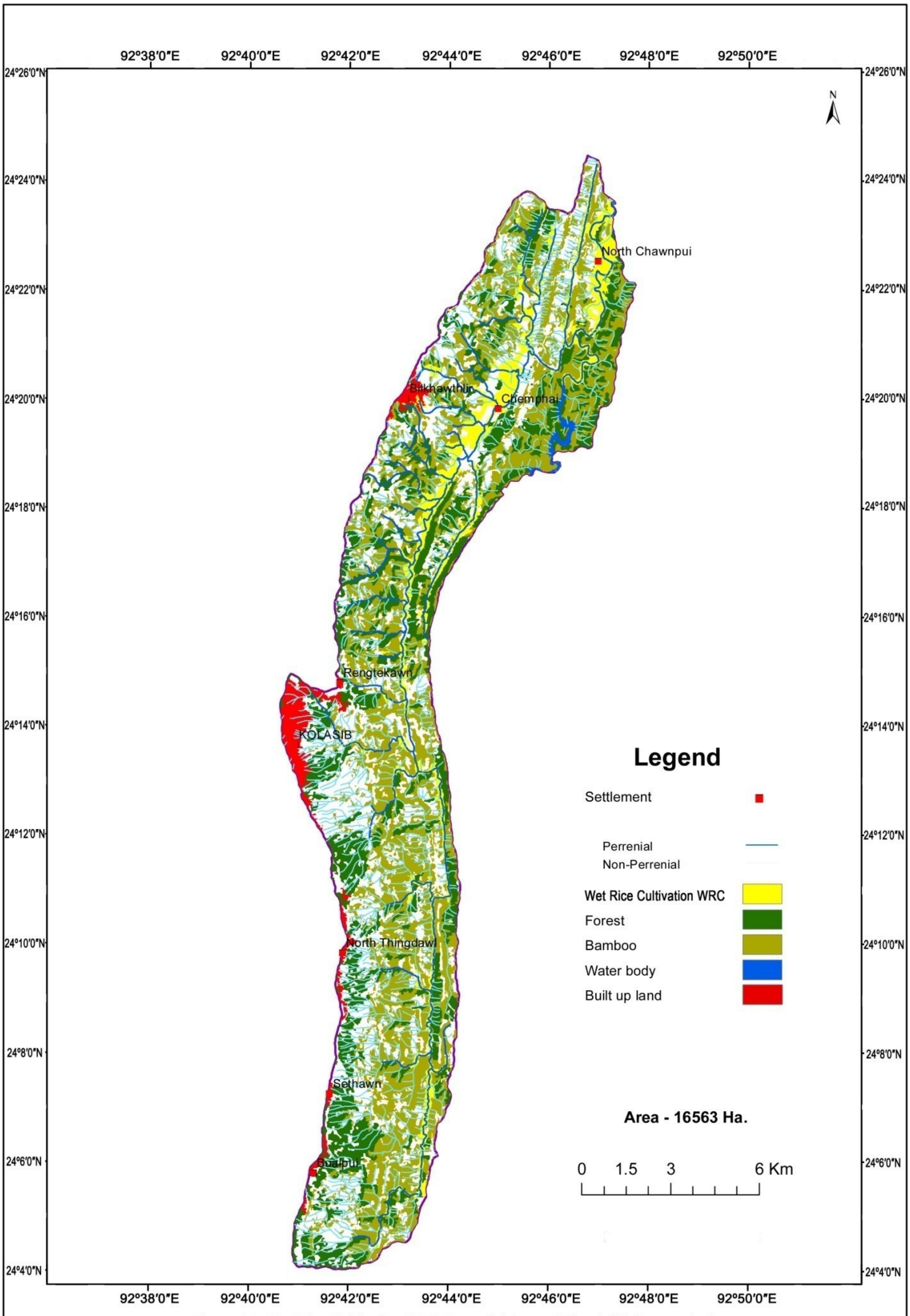

Figure 6.2. Wet Rice Cultivation WRC Potential Area of Chemlui Sub-watershed.

north eastern part of the watershed because the land is well supported by high irrigation potentials, more gentle slope and high water volume.

### 6.2.2 Land use for Agro-Horticulture

Agro-horticultural system is a farming system in which both agricultural crops and horticultural crops are grown in the same plot of land. Fruit trees and filed crops can be grown together in different ways. Perennial crops, seasonal crops and nitrogen fixing plants may be grown in an alternate manner. Crop rotation will be necessary in case of seasonal crops. Conventional terracing may be done in the foot hills and contour trench farming may be practiced wherever feasible. This type of land use can be practiced in the watershed with the total area of 4.58 sq km which comprise 24.50per cent of the total watershed area. As shown in the figure 6.3, this system of land use can be more concentrated in the western corner of the watershed area which are not far from the villages like Bualpui, Sethawn, North Thingdawl ,Rengtekawn and Kolasib town.

The recommended crops are *Areca catechu* (Betelnut), *Citrus macropetera* (Hatkora), *Camellia sinensis* (Tea), *Coffespp* (Coffee), *Musa paradisiaca* (Banana), *citrus reticulate* (Orange), *Passifloraedulsis* (Passion fruits yellow variety) etc., with vegetables and other root crops.

### 6.2.3 Land use for Afforestation/ Silviculture

This type of land use can be planned in the area covering 6.84 sq. km accounting 4.13 per cent of the total watershed area. Afforestation is the process of transforming an area into forest by planting trees. This process becomes necessary when natural regeneration cannot keep pace with human exploitation of forest as it is a slow process

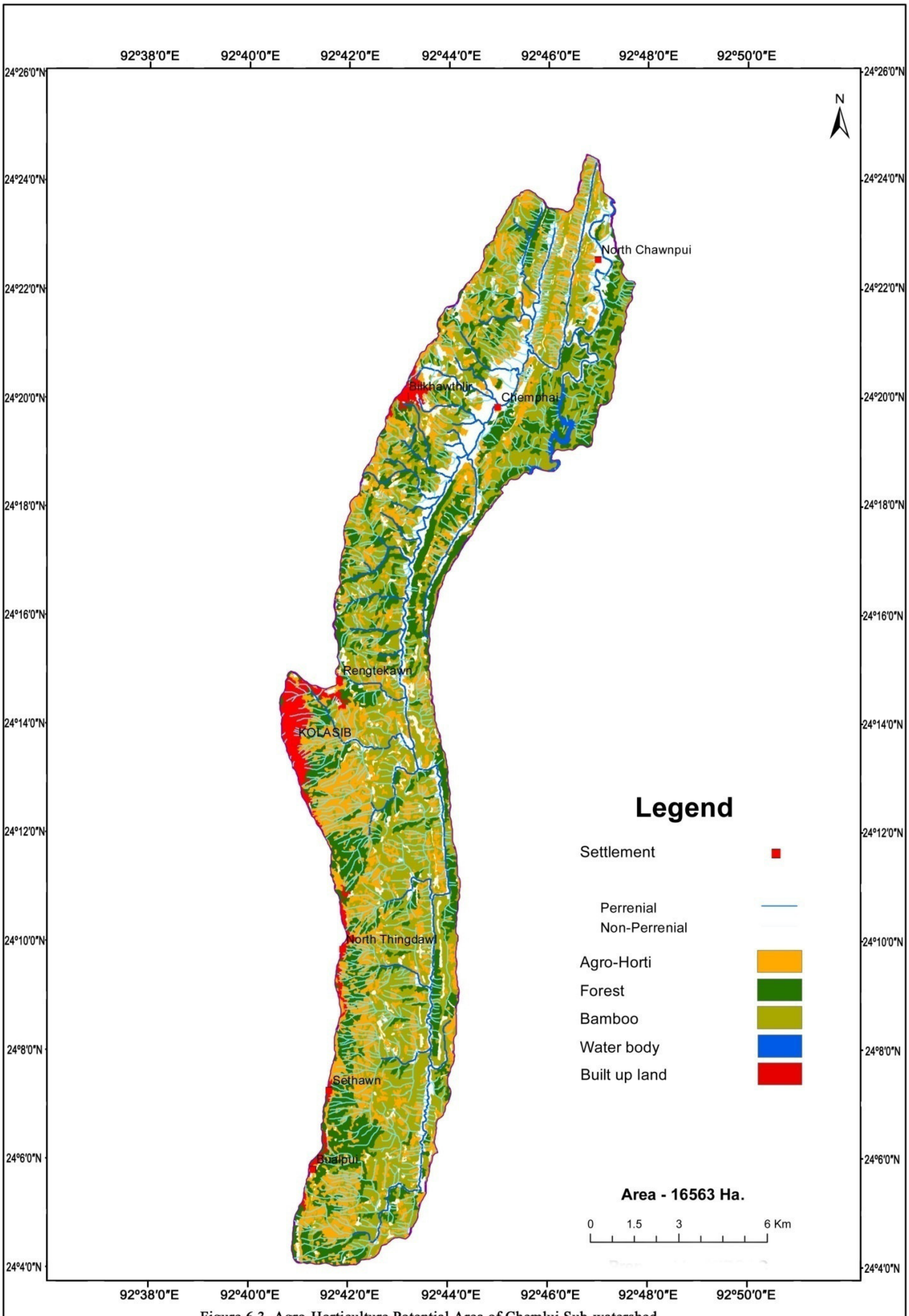


Figure 6.3. Agro-Horticulture Potential Area of Chemlui Sub-watershed.

and as a result forest could not be regenerated completely and effectively. Considering this factor as well as other biophysical and socio-economic factors, several trees species may be selected for incorporation into the afforestation program. The main species recommended for afforestation in the watershed are Far *(Pinuskesiya)* and Teak *(Tectonagrandis)*, of which the former one may be planted on the higher altitudes.

Other recommended species are Ngiau *(Micheliachampacca)*, Vawngthla *(Gmelinaoblingifolia)*, Thlanvawng *(Gmelinaarboria)* etc. this type of land use can be practiced in a sparsely manner especially along the minor tributaries of the main river (figure 6.4).

### 6.2.4 Land use for Forest (Tree) Plantation

It is proposed that the existing forest cover be preserved, and additional conservation techniques may be adopted to prevent encroachment and exploitation of forests for commercial and domestic purposes. Declaring and demarcation of these areas as reserve forest or supply reserve forest in an areas where their conservation is needed, preferably in every village/town, can aid the preservation of the forest in its natural forms. The reliable voluntary organizations/NGOs like YMA, MHIP, MUP etc., may be encouraged and entrusted the task of further protection of these forests as well as extension of the forests in the form of parks etc. active participation of the local people can also ensure the future conservation of the present forest cover. The step taken by the government through village councils or form Village Forest Development Agency in each village and various management schemes under Joint Forest Management (JFM) is noteworthy and can be made more effective for the purpose. The proposed area under

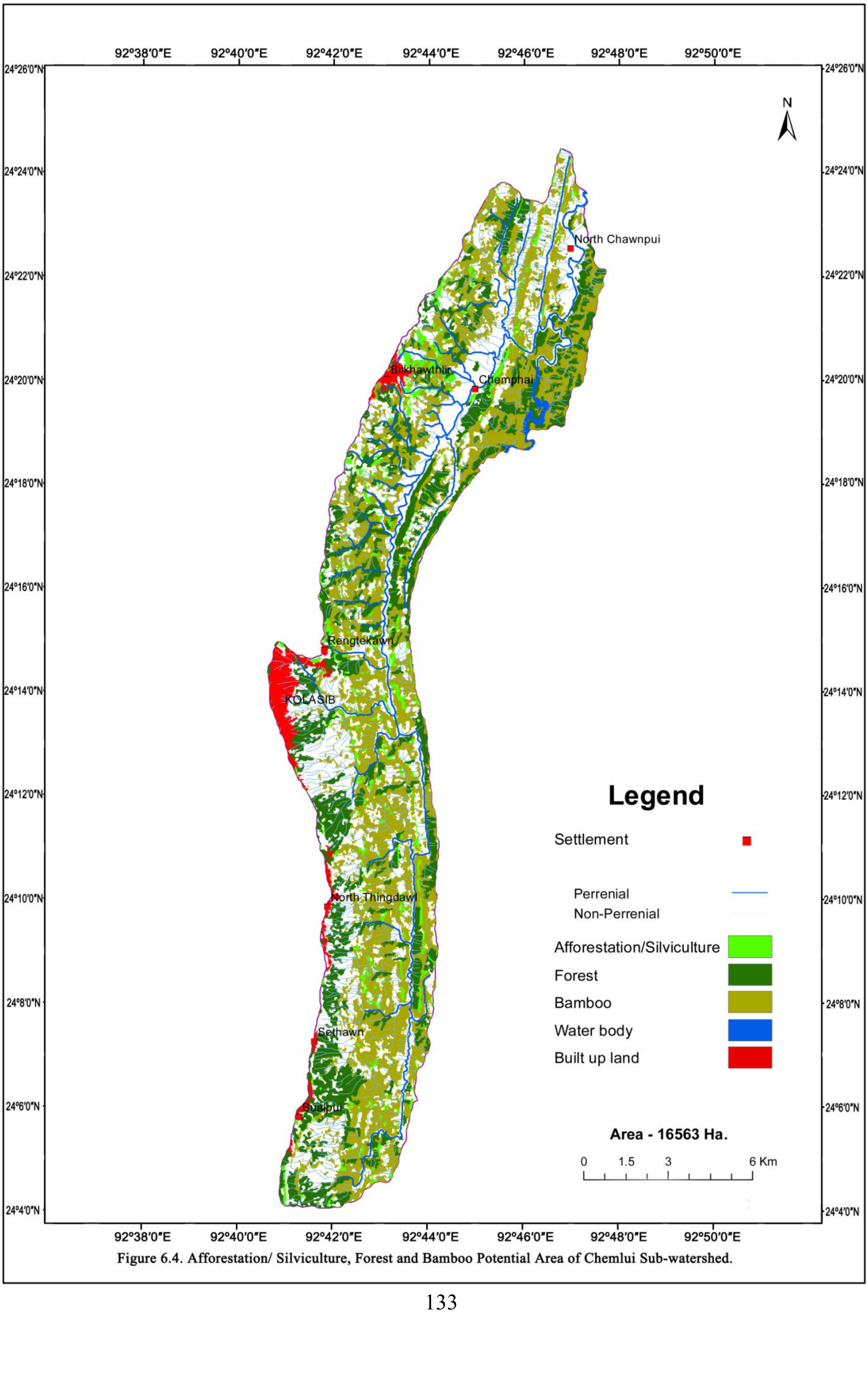


Figure 6.4. Afforestation/ Silviculture, Forest and Bamboo Potential Area of Chemlui Sub-watershed.

tree forest in the study area is 36.47 sq.km of land comprising 22.02 per cent of the total watershed area. As shown in the figure 6.4 forest tree plantations can be done along the major river and tributaries. It can be proposed in the surrounding areas of the villages and towns.

### 6.2.5 Land use for bamboo Forest

The total area proposed for bamboo forest in the study area is 59.72 $Km^2$ i.e., 36.06 per cent of the total watershed area. Bamboo forest, though abundantly found also needs conservation and restocking due to the impending bamboo flowering in 2007 and its sub sequential natural death. Harvesting of the bamboos before their death to avert the occurrence of famine, which is associated with bamboo flowering, is a notable step to be taken. However steps have to be taken for a potential market of the harvested bamboos. Government and NGO agencies can take steps towards the encouraged use and manufacture of bamboo products through their various schemes. Controlled harvesting and further processing of the stock can help in employment generation and rural development through establishment of small-scale bamboo (handicraft) industries. Bamboo development projects may also be undertaken in collaboration with international agencies like International Network for Bamboo and Ratan (INBAR). The genetic stock of the native bamboo species also needs conservation to ensure their successful second regeneration after the flowering period. As shown in figure 6.4, bamboo plantation area will cover a very large area as it is abundant naturally.

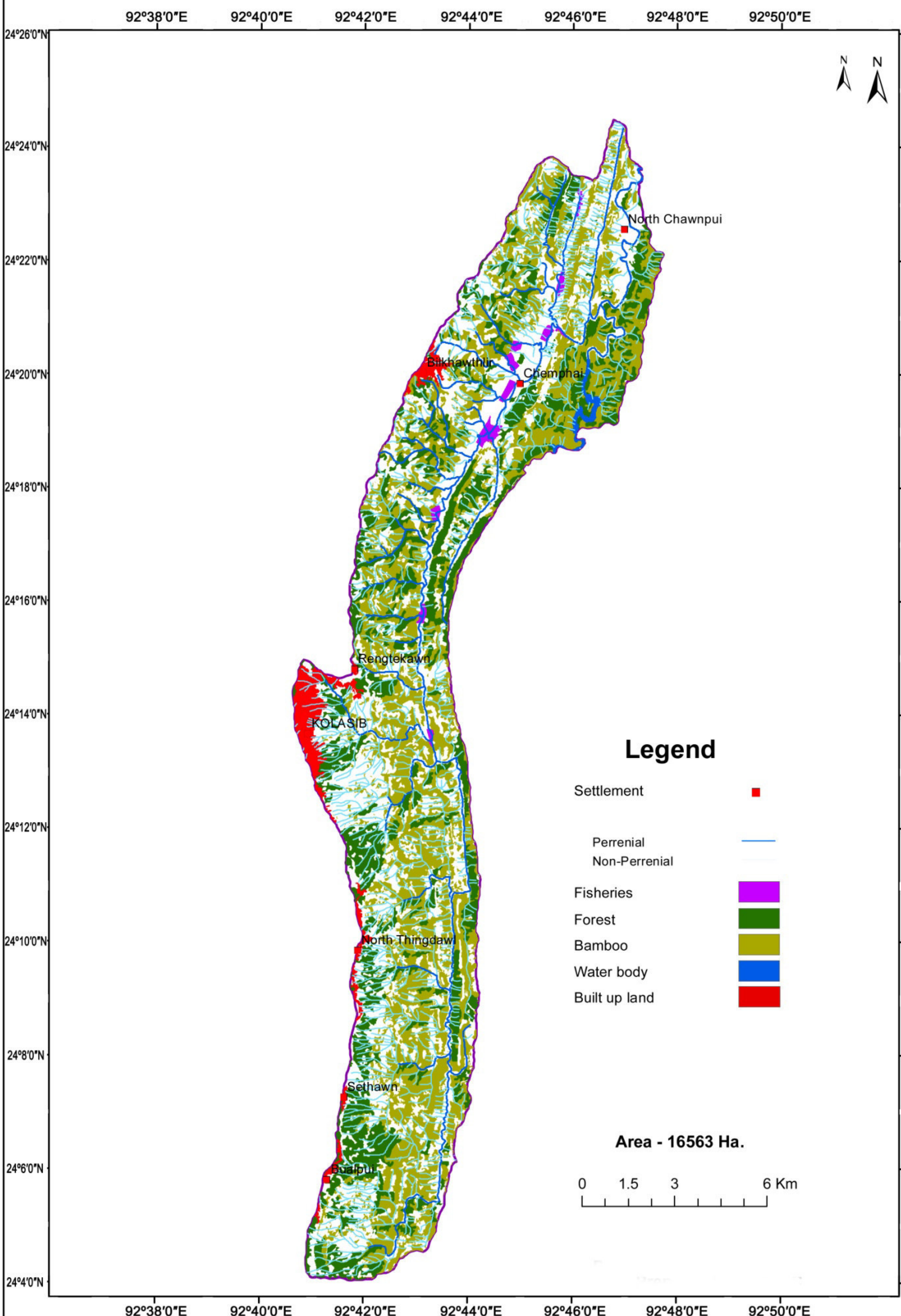


Figure 6.5. Fisheries Potential Area of Chemlui Sub-watershed.

### 6.2.6 Land Use for Settlement

The proposed settlement area is 4.25 sq. km covering 2.57 per cent of the total watershed area. The total 8 settlements are likely to be grown as human population is increasing. Thus it is very necessary to make a proper plan and make a specific area for settlement cover area. For saving of the environment settlement area must be planned wisely by considering the extension of settlements. Similarly settlement area should be planned keeping in view with safe with natural hazards like landslide, forest fire, floods and earthquakes etc. Figure 6.4 shows that the existing settlement in the study area.

### 6.2.7 Water Resources Development

Water bodies in the watershed area account 0.72 per cent of the total geographical area which is 1.19 sq. km. the main activities recommended for water resources development are discussed under.

### 6.2.8 Land use for Fisheries

Fish culture is assumed to be the most suitable for utilization of available land water resources meanwhile it has very low productivity in the area. Fish culture should be practiced as there is good possibility. Pond based integrated fish farming using poultry and pig rearing must be explored for accelerating farmer's revenue. Diversification of fishery through utilization of locally availability need to be promoted which helps to supply many fish resources production of regional inclinations.

For fisheries totally 155 sq. ha of the geographical area is proposed for fisheries sites accounting 0.93 per cent of the total watershed area as shown in figure 6.5.

### 6.3 Surface water

Surface water harvesting techniques are gaining more importance nowadays in view of the diminishing water table and erratic rainfall patterns. One of the most important aspects in surface water harvesting is the identification of suitable sites. Geographical Information System (GIS) is a modern technique of integration of both thematic and non-thematic data and analyzing through suitable models for taking up appropriate developmental activities.

The watershed has a high potential as the study area receives a very good amount of about 2914 millimeters rainfall annually on an average of water resources as shown in figure 6.6. At the same time due to unpredictable and erratic rainfall, this excess rain water has to be conserved in different storage structures for the supplement of irrigation water for the survival of agricultural and horticulture crops during the critical periods and or can be directed to artificially recharge the groundwater for its use later. On account of this, water harvesting structures are proposed in various locations within the study area. The proposed structures are briefly described below:

#### 6.3.1 Minor Irrigation Tanks

In spite of the natural gift of good amount of rainfall, most of the people in this area are able to grow only rain fed crop as only a few areas could be facilitated with irrigation facility. Hence surface water harvesting was given priority and therefore 20 minor irrigation tanks are proposed at around WRC potential and settlement areas in order to meet the demands for irrigation water in the watershed area. These minor irrigation tanks are proposed to be constructed across the perennial streams for creating

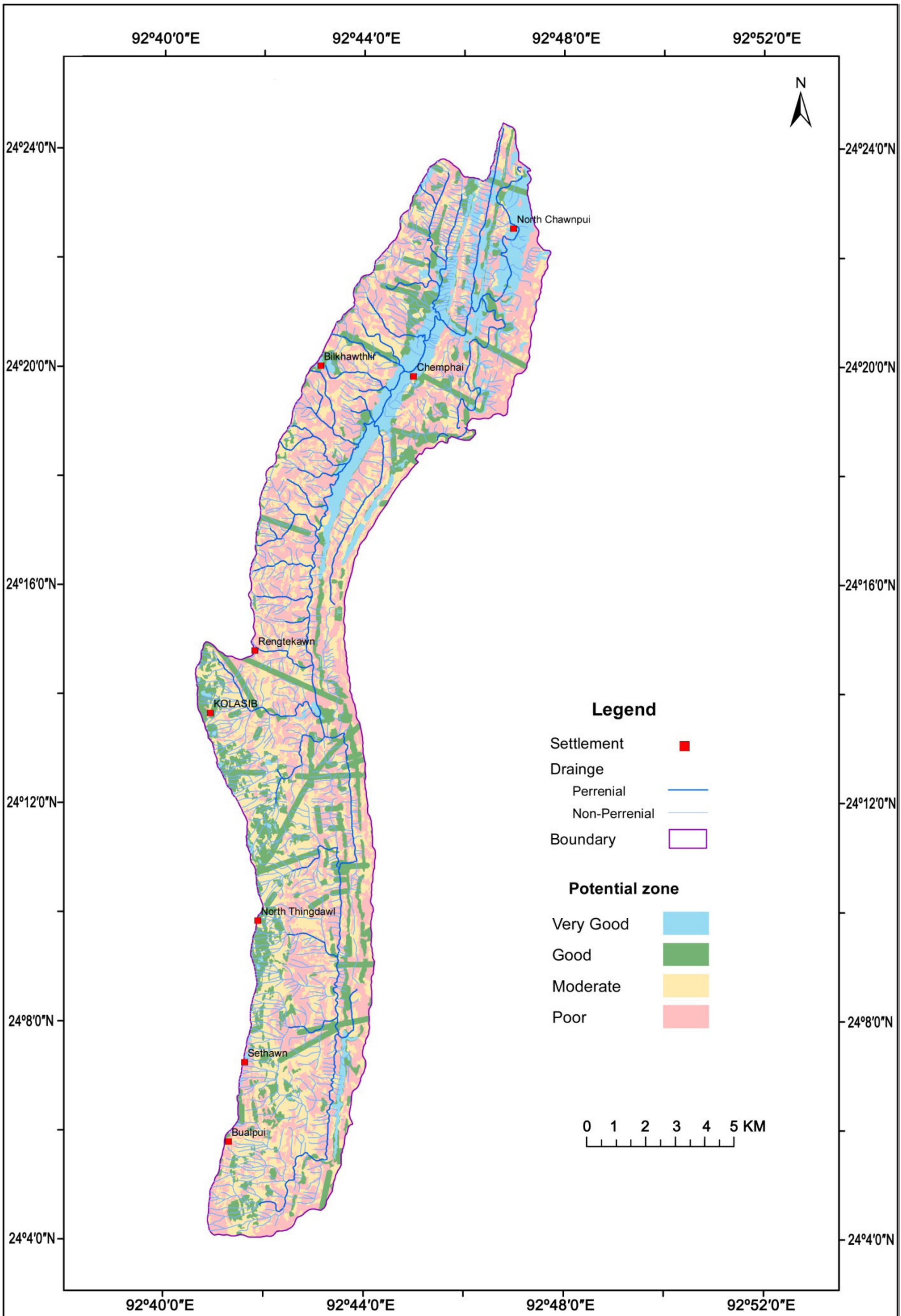


Figure 6.6. Ground Water Potential Area of Chemlui Sub-watershed.

water reservoirs for providing irrigation water to the crops during critical periods and also to facilitate the groundwater recharge in the downstream regions. The design details of the structures are depending upon the site condition. As far as possible a narrow gorge should be selected for making the dam in order to keep the ratio of earth work to storage as minimum. Beside geologically and structurally, favorable sites were selected in order to avoid major loss of water.

### 6.3.2 Water Harvesting Bunds

These are similar to minor irrigation tanks except that they do not have extensive canal system and their command area is limited to fields downstream. These harvesting bunds are proposed to be constructed in order to collect the impound surface run off during monsoon rains and facilitates infiltration to raise groundwater level in the zone of influence of the bunds and to facilitate irrigation in the field lying in close proximity of the structure. It also moderates the peak flow, partly by storing and partly by flood routing. Therefore, 30 water harvesting bunds have been proposed in every settlement.

Land use planning is the major step for the development of a region. Advance mapping techniques of remote sensing and geographic information system (GIS) can be utilized to prepare an appropriate and feasible plan to achieve the development. Proper care should be taken considering all the existing physical as well as the chemical properties of the soil conditions of the terrain.

# CHAPTER – VII

# SUMMARY AND FINDINGS

# CHAPTER-VII

# SUMMARY AND FINDINGS

## 7.1 Introduction

Resource management, however, includes the institutions, dynamics, and forces affecting the use, maintenance, conservation, and degradation of natural resources land, water, and forests. Any combination of economic, environmental, institutional, political, and technical activities and initiatives which reinforce human control over land, water, and forests is referred to as an integrated approach. The Oxford English Dictionary defines management as "to control the course of affairs by one's own action". In the broader sense 'management' may also refer to the exploration, appropriate use, and protection of natural resources, and to the prevention of waste as well as to conservation (Welsh et al., 1990). "Resource" is a subjective and functional term. A natural substance or raw material is not a resource unless it has some re- cognized economic value. The economic value of the resource varies with its quality and accessibility (Caldwell, 1990). Technology, human behavior, and politics influence accessibility and thus affect re- source supply making them crucial elements in resource management. A narrow definition of resource management refers to "the actual decision concerning policy or practice regarding how resources are allocated and under what conditions or arrangements resources may be developed" (Mitchell, 1989).

The study evaluates the uses of natural resource in the watershed mainly in terms of land, water and forest. Pattern and rate of land use change from 2006-2016 was identified and calculated from satellite imagery through GIS application. Land capability classification also done with the help of GIS technology. People's perception on land use plan and management policy of the watershed and Chemlui river were obtained. Land use plan for natural resource management in the watershed area was formulated.

## 7.2 Summary of findings

### 7.2.1 Evaluation of Natural Resources

1. Eleven types of soils composition with different characteristics and having a varied resources utility were identified in the study area such as loamy skeletal typic dystrochrepts, loamy skeletal humic hapludults, loamy skeletal typic hapludults, loamy skeletal umbric dystrochrepts, fine loamy typic hapludults, fine loamy humic hapludults, fine loamy umbric dystrochrepts, fine loamy typic dystrochrepts and fine loamy aquic dystrochrepts, valley/WRC soil and soil under water bodies.

2. The study area is divided into four groundwater resources potential zones such as very good, good, moderate and poor. The watershed does not have very high in groundwater sources. Very high potential area accounts 9.27 per cent of the total watershed area. Good availability found with 3146.13 hectare of land comprising 18.99 per cent of the total watershed area. The area of 6438.53 hectares of land is considered as moderate potential. The moderate zone accounts 32.86 per cent of the total watershed. Majority of the watershed area is poor in groundwater resources. It comprises the area of 6438.53 hectares of land which comprises 38.87 per cent of the total watershed area.

3. Bamboo is the main forest. More than half of the total watershed area is covered by bamboo forest (51.99%). Dense forest account 7.05%, less dense 6.26%, medium dense 10.24% and 1.37% is scrub forest. Forest resources are utilized for bamboo productions, furniture, household assets, foods and others domestic used.

### 7.2.2 Land Use Change

1. Land use change for one decade (2006-2016) was calculated.

2. Scrub-land, water bodies, wet rice cultivation, less dense forest, agriculture plantation and bamboo forest were increased while forest plantations, dense forest, area under shifting cultivation and water bodies of perennial streams were decreased.

3. Scrub-land was increased by 87.30%, WRC (30.96%), while shifting cultivation area decreased by 46.05 %, Dense forest (87.01%) and medium dense forest by (93.53%).

### 7.2.3 Land capability Classification

1. For land capability classification, 21.14% of the total watershed area is suitable for agriculture, while 2.59 % is good for Built up land. 1.54% is good for water resources utilization.

## 7.3 People's Perception on Chemlui River

### 7.3.1 Cleanliness of Chemlui River

People's perception was obtained on different criterion which is related for future plan and management of the watershed such as cleanliness of the river, change of water resources and changing of land resources. Suggestions from peoples were also obtained for management of the river and the whole watershed.

For cleanness or purity of the river, most of the peoples think the river water is clean. 15 per cent of the total respondents opined the river is very clean, 76 per cent said clean while only 9 per cent of the total respondents said the river is not clean as shown in figure 7.1. Reasons for still the river clean according to inhabitant's opinion are less human waste disposal to river, people of the surrounding river controls the river clean; due to protection action taken by YMA and the sources of river is clean. In this view, 56 per cent of the total respondents believe that the river is clean because the river received a less amount waste from its surrounding. 13 per cent of the total respondents opined the river is clean because of the people living in the surrounding rivers. Peoples keep the river clean by their own ways and they are living a little bit far from the river banks and the waste of the settlement could not reach and the river is free from that pollution. 25 per cent of the total respondents believe that one of the main reason which make the river clean is the source of the river. They opined that the river have a good and clean sources. Even though the river is polluted, the clean sources make it clean automatically. Like the other regions, YMA is taking protecting action in the watershed to check pollution. 6 per cent of the respondents opined that protection activities taken by YMA is one of the factors helping the river clean. Figure 7.2 clearly shows people's perception on factor contributing the river clean.

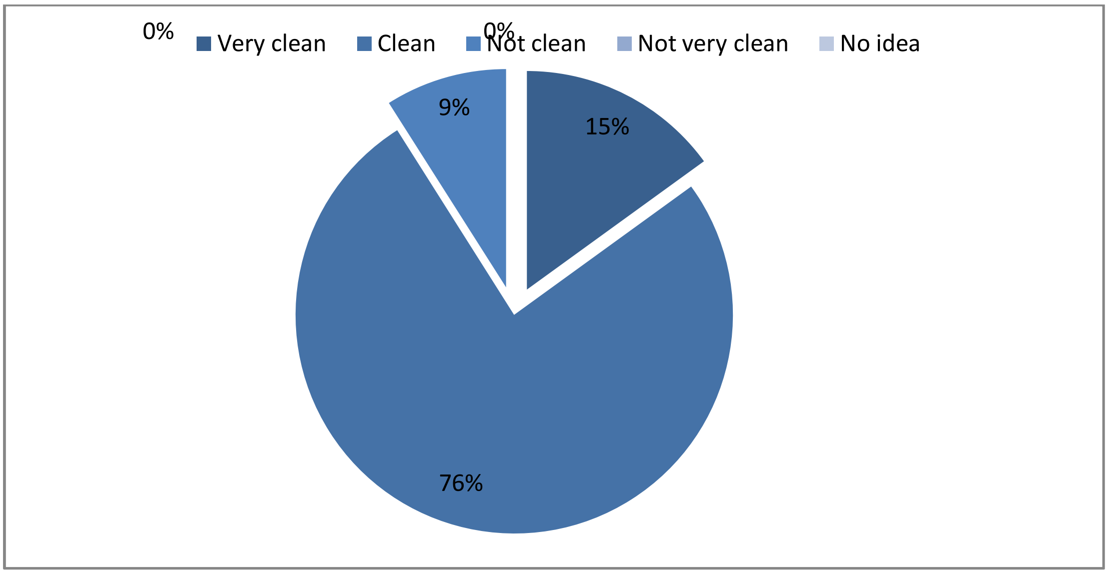


Figure 7.1 Perception on cleanliness of the river

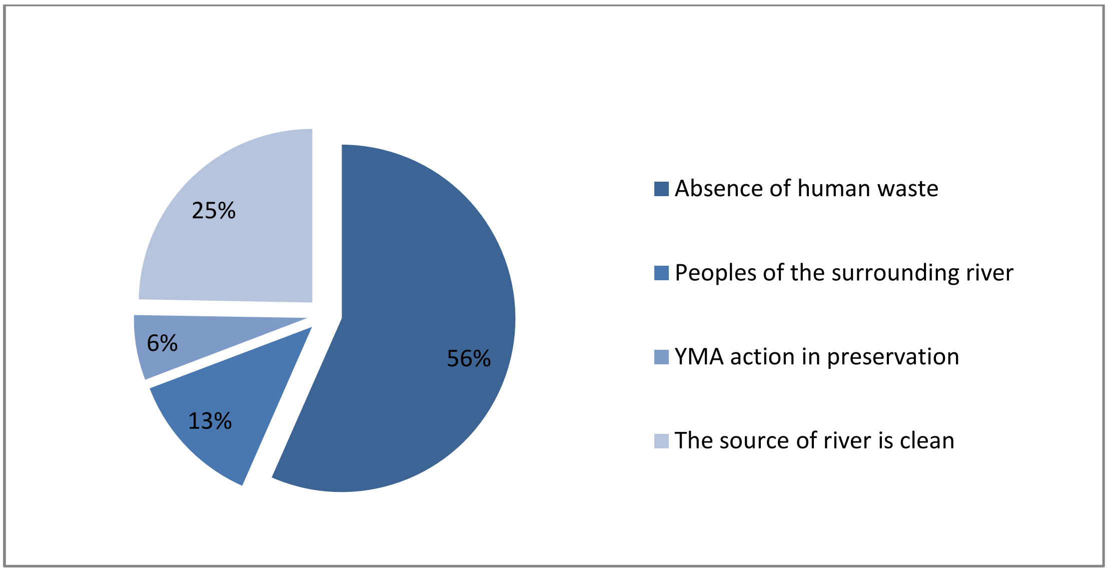


Figure 7.2 Factors controlling the river clean

### 7.3.2 Change of water volume at Chemlui River

It is belief that the water volume of Chemlui river is changing from time to time. Majority of the population (73%) opined that water volume is decreasing while 22 per cent of the total population thinks that it is not decreasing. 5 per cent of the total populations have no idea about that change. Figure 7.3 shows people's perception on change of Chemlui river water. Climate change is the leading factor which reduced water volume in the river according to opinion of the people living nearby the river. 86 per cent of the total respondents opined that the water volume is decreasing due to climate change. 6 per cent of the total respondents give direct opinion that decreasing amount of rainfall is the most relevant factor causing water volume decreases in the river. At the same time 8 per cent of the total respondents think that deforestation is the biggest factor affecting reduction of water volume in Chemlui river. Figure 7 shows people's perception on factors causing river water volume decreasing at Chemlui river.

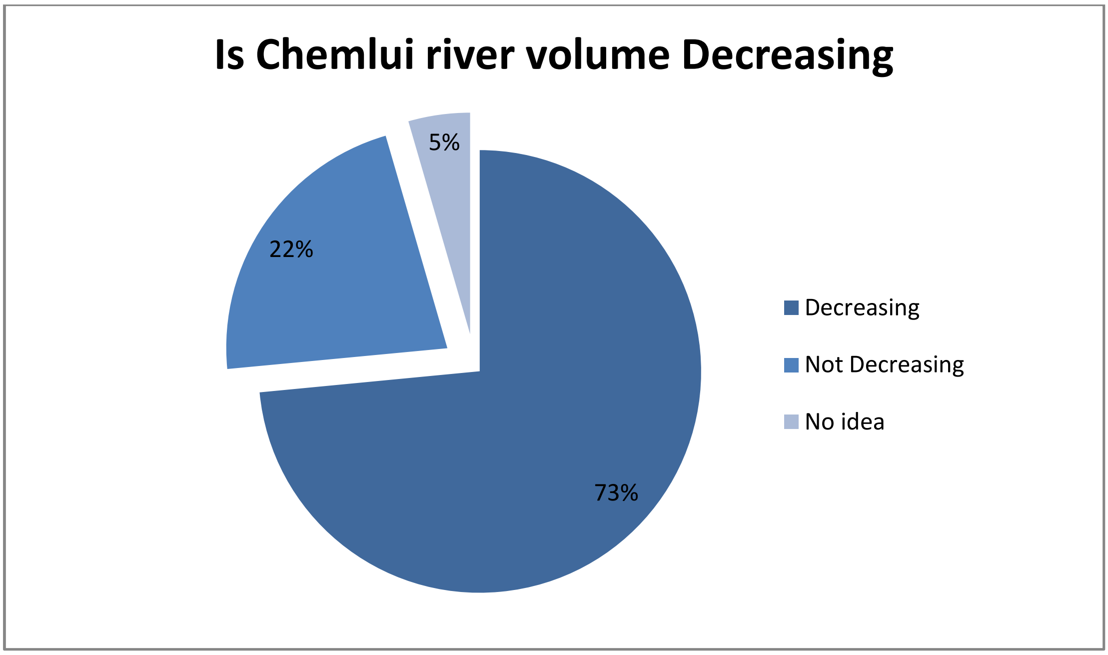


Figure 7.3 Changing of water volume at Chemlui river

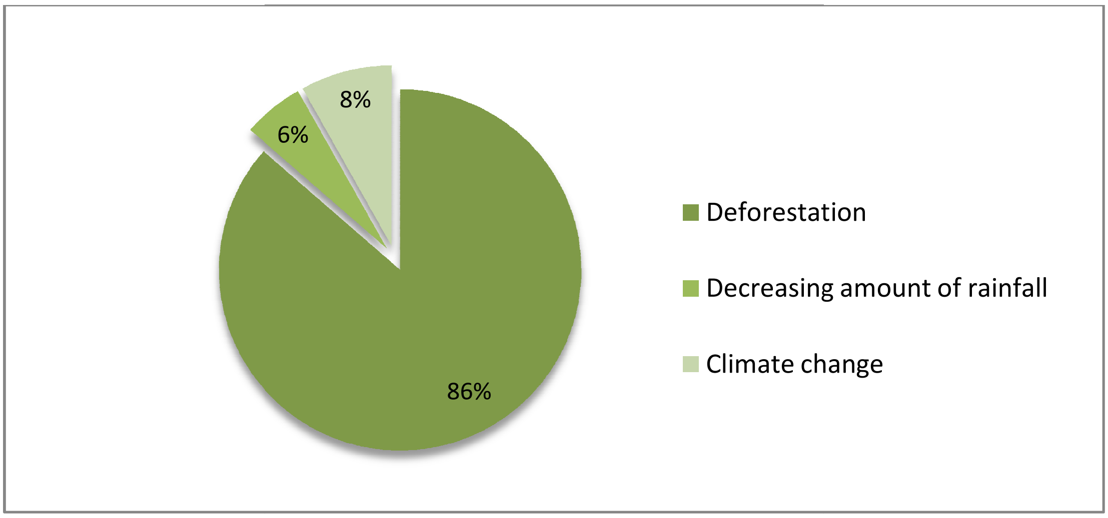


Figure 7.4 Factors controlling reduction of water volume in the river

### 7.3.3 Changing Patterns of Land Resources in the Watershed

Land resources like sands, fertile soils, stones etc. are changing in the watershed as per the people's opinion collected from their own experiences. Both for quantity and quanlity, 76 per cent of the total respondents opined that land resources are decreasing in the watershed while the remaining 24 per cent believe that there is no change (Figure 7.5). More than half of the total respondents (59%) think that increasing population size in the catchment area is the major factor which affects land resources degradation in the watershed. 22 per cent of the total respondents opined that land resources degradation in the watershed is mainly due to human development activities like road construction, quarrying and other building constructions. While 19 per cent of the total respondents said land resources in the watershed is decreasing because of the decreasing volume of water in the river. Figure 7.6 shows people's perception on factor controlling land resources degradation.

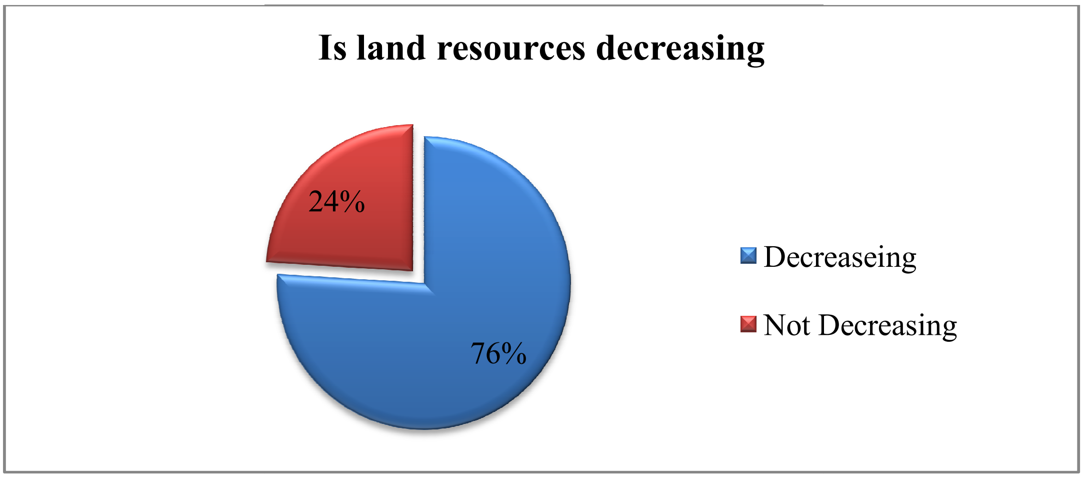


Figure 7.5 Perception on land resources change at Chemlui watershed

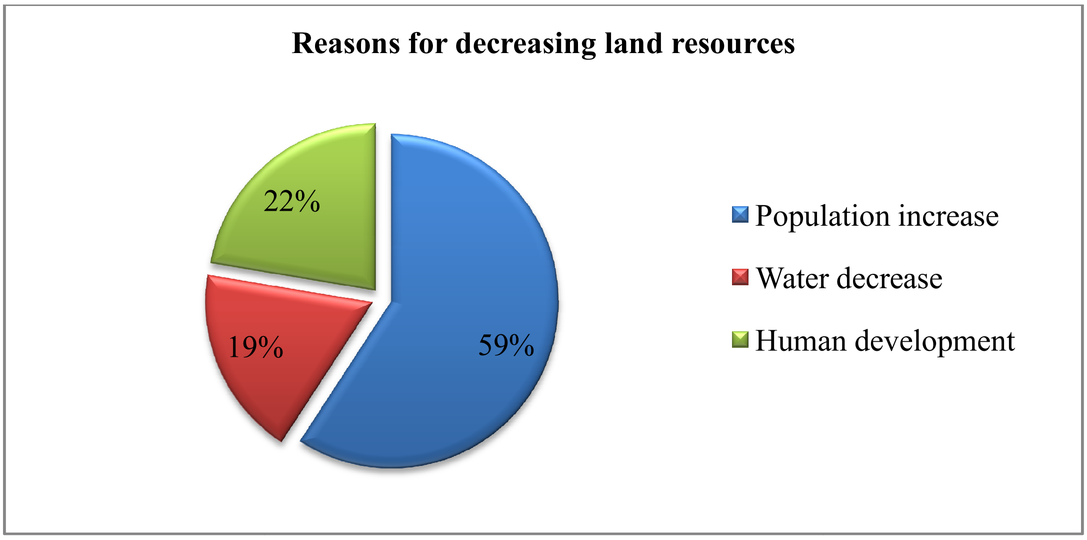


Figure 7.6 Factor affecting land resources degradation

## 7.4 People's Perception on Chemlui Watershed Management Plan

### 7.4.1 Afforestation

Under afforestation cluster, there are three suggestions from the people such as protecting forest from fire, stop cutting of trees along the river banks and checking of illegal use of forest resources. Among these 41.50 per cent of the total respondents suggest that protection of forest from fire is the first important activities should be taken for management of the watershed. About 27 per cent opined that cutting of trees especially along the river bank should be stopped to increase water volume in the river. About 31.50 per cent suggest that illegal use of forest resources should be checked for forest resources management which will help the whole watershed management plan.

### 7.4.2 River Resources Management

The second cluster i.e., river resources management plan includes reduction of human waste flowing to the river, stop water poisoning of the river and check unlawful use of river water resources. More than half of the total respondents (50.50%) suggest that reduction of human waste flowing to the river for cleaning the river water as well as enriching the water resources of the river. About 28 per cent opined that poisoning of the river water should be stopped to help the river water healthy and save water ecosystem. About 21.50 per cent suggest that illegal use of river water resources like illegal action for fishing should be stopped to develop water resources of the river.

### 7.4.3. Human Activities Control

Under the cluster i.e., controlling human activities includes reasonable use of resources, stopping of waste disposal in the river and make people aware about the importance and situation of the river. For watershed management plan, 56 per cent of the total respondents suggest that the population in the watershed should use the existing natural resources efficiently and reasonable. About 26 per cent opined that waste disposal to the river should be stopped for maintaining the river clean and further enriching marine resources. About 18 per cent think that awareness on importance and real condition of the river to the whole population should be taken properly to manage the whole watershed. Table 7.1 shows the watershed plan or suggestions taken out according to people's perception.

Table 7.1 Watershed plan proposed from People's perception

| **Clusters** | | **Future plan/ suggestions** | **No. of people in %** |
|---|---|---|---|
| A | Afforestation | Protect forest from fire | 41.50 |
| | | Stop cutting of trees along the banks of river | 27.00 |
| | | Check illegal use of forest resources | 31.50 |
| B | River Management | Reduce waste flowing to the river | 50.50 |
| | | Stop poisoning of river water | 28.00 |
| | | Check illegal use of river water resources | 21.50 |
| C | Human activities control | Use resources reasonable | 56.00 |
| | | Stop waste disposed to river | 26.00 |
| | | Make people aware of river condition | 18.00 |

### 7.5 Land use Plan

**1.** The total area of 15.3 $Km^2$ land is proposed for Wet Rice Cultivation which comprises 9.07 per cent of the total watershed area. Most of the area is concentrated along the sides of the river. The north eastern part of the area can be brought for cultivating both kharif and rabi crops due to availability of river water on the one hand and highly possible to bring irrigation on the other hand.

**2**. Agro-horticultural system is a farming system in which both agricultural crops and horticultural crops are grown in the same plot of land. Fruit trees and field crops can be grown together in different ways. Perennial crops, seasonal crops and nitrogen fixing plants may be grown in an alternate manner. Crop rotation will be necessary in case of seasonal crops. Conventional terracing may be done in the foot hills and contour trench farming may be practice wherever feasible. This type of land use can be practiced in the watershed with the total area of 4.58 $Km^2$ which comprises 24.50 per cent of the total watershed area.

**3**. Silviculture can be planned in the area covering 6.84 sq. km accounting 4.13 per cent of the total watershed area. Afforestation the process of transforming an area into forest by planting trees. This process becomes necessary when natural regeneration cannot keep pace with human exploitation of forest as it is a slow process and as a result forest could not be regenerated completely and effectively.

### 7.6 Suggestions

Resource management is concerned with choices, and the choice of posterity should be to use non-renewable resources only if and then only with the most meticulous care for conservation. Due to population growth, demands for human settlements and agricultural land is increasing every day. Availability of natural resources in the watershed is decreasing and reaching the optimal limitation stage.

Following suggestions have been made for natural resource management in the study area based on the findings and people's perception.

1 As far as anthropogenic activities are concerned, we must establish here of for aberrance that acknowledges the menace the watershed is facing; must develop a policy to check anthropogenic activities through awareness, the mass media and the government also need to be prepared thought to human activities controls. Human waste flowing to the river must be reduced.

2 As far as economic growth is concerned, we do not wish to certainly do not align ourselves with those who tell us it is jam the brakes on economic progress is not the answer; not enough the extent of the remaining resources, although the threat for us all to see. Man's adaptability and his ingenuity in devising of meeting his needs are full of hitherto unimagined resource. Continued growth of some kind is essential to the solution of these problems of poverty, obsolescence and indeed pollution. So proper utilization of natural resources should be practiced in the study areas. Illegal practices and unscientific used of natural resources should be stopped. To do this village level task force and government must do the needful.

3 Nevertheless, there are urgent things that we can and must the paramount goal of the affluent society; we must check the facials demands that needlessly consume resources. We must believe that constant change and novelty are necessarily good, that and styles are not merely out of date but automatically inferior created a year ago, and we must encourage our manufacturers obsolescence and produce goods which will last longer and be way that the resources they tie up can be readily recovered and used again.

4 Government should take action. Resource management, though it draws together skills and knowledge from many disciplines, is primarily a political activity. Government policy in one sector may affect programs in other sectors. Better management of the natural resources in the study area can be undertaken through an integrated policy approach for all the sectors of development. An evaluation of ministries and government departments should be undertaken with a view to avoid overlapping jurisdictions and to effect coordination and cooperation.

5 Afforestation should be practiced more mainly near the banks of the river.

PHOTO PLATE - 1


Photo A: Chemphai (Chemlui River on the left side)

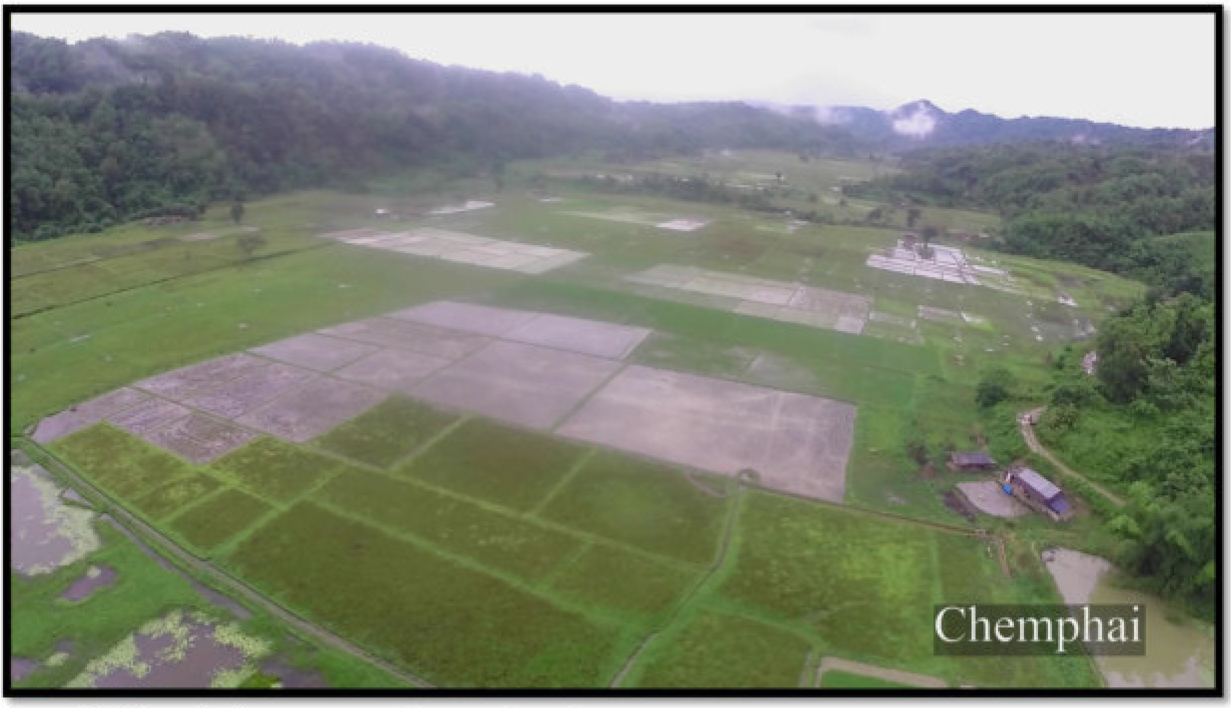


Photo B: Chemphai Wet Rice Cultivation (WRC)

PHOTO PLATE - 2


Photo A: Serlui B River


Photo B: Small islands in Serlui B River

PHOTO PLATE - 3

Photo A: Fisheries farm at Bualpui - Fish harvesting.

Photo B: Preparing Fish for transporting to nearby market.

PHOTO PLATE - 4

Photo A: Aqua farm near Chemphai village.

Photo B: Aqua farm in the lower reaches of Chemlui Sub-watershed.

PHOTO PLATE – 5

Photo A: Aqua farm at upper reaches of Chemlui Sub-watershed.

Photo B: Aqua farm – Fish nursery bed at upper reaches of Chemlui Sub-watershed.

PHOTO PLATE – 6

Photo A: Arecanut (Kuhva Kung) plantation at Billkhawthlir.

Photo B: Arecanut (Kuhva Kung) plantation at Thingdawl.

PHOTO PLATE – 7

Photo A: Transforming cultivated land into fisheries pond at Chemphai.

Photo B: Small size fish farming along the foothill of Chemlui ridge.

PHOTO PLATE – 8

Photo A: Fish harvesting at Chemphai.

Photo B: Fish harvesting using fish net at Chemphai.

PHOTO PLATE - 9

Photo A: Crop land – mulching system cultivation at Chemphai.

Photo B: Preparing field for vegetables crops.

PHOTO PLATE – 10


Photo A: Land Development under RashtriyaKrishiVikasYojana (RKVY), Fawnlian Zau, Bilkhawthlir.


Photo B: Community Water Tank under HMNEH, Chemphai, Bilkhawthlir.

PHOTO PLATE - 11

Photo A: Wasteland site at the upper reach of Thingdawl village.

Photo B: Construction of link road for new farm land at Bualpui village.

PHOTO PLATE - 12

Photo A: Parkia speciosa(zawngtah) plantation at Bualpui village.

Photo B: Parkia speciosa(zawngtah).

PHOTO PLATE – 13

Photo A, B & C: Harvesting of Arecanut (Kuhva) by Bualpui farmers.

PHOTO PLATE – 14


Photo A: Siakeng Seed Farm at Chemphai.

Photo B: Seed Farm Area with Nursery beds for different plants.

PHOTO PLATE - 15

Photo A: Shifting Cultivation – Jhum cultivation practised at Sethawn area.

Photo B: Shifting Cultivation – Jhum cultivation practised at Thingdawl area.


PHOTO PLATE – 16: Field Study – Survey Team

## Bibliography


Adegbenro RO. (2020) : Land Evaluation for Land Use Planning Using Remote Sensing and GIS - A Case Study of Nawagaon Maskara Rao Watershed, Saharanpur, India, Acta Scientific Agriculture 4.2 (2020): 01-09pp.

Berlanga-Robles, César A. and Ruiz-Luna, Arturo (2002) : Land Use Mapping and Change Detection in the Coastal Zone of Northwest Mexico Using Remote Sensing Techniques, Journal of Coastal Research, Vol. 18, No. 3, 514-522 pp.

Bhattarai, Keshav and Conway, Dennis (2008): Evaluating Land Use Dynamics and ForestCover Change in Nepal's Bara District (1973-2003), Human Ecology,Vol. 36, No. 1, 81-95 pp.

Caldwell, L. K. 1990. International Environmental Policy: Emergence and Dimension. West view Press, Boulder, Colorado, p. 44.

Chomitz, Kenneth M. and Gray, David A. (1996) : Roads, Land Use, and Deforestation: A Spatial Model Applied to Belize, The World Bank Economic Review, Vol. 10, No. 3, 487-512 pp.

Coornes, Oliver T., Takasakib, Yoshito and. Rhemtullaa, Jeanine M. (2011): Land-use poverty traps identified in shifting cultivation systems shape long-term tropical forest cover, Proceedings of the National Academy of Sciences of the United States of America,Vol. 108, No. 34, 13925-13930 pp.

Colney, Lalnunsiama and Nautiyal, B.P. (2013): Characterization and Evaluation of Soils of Aizawl District, Mizoram, India using Remote Sensing and GIS Techniques, Journal of Geometrics Vol. No.1 April, 2013.

Cruz, Rex Victor O. (1999) : Journal of Philippine Development, Number 47, Volume XXVI Philippine, No. 1, First Semester, 27-49 pp.

Dale, Virginia H. (1997) : The Relationship Between Land-Use Change and Climate Change, Ecological Applications, Vol. 7, No. 3, 753-769 pp.

Datta, S (1995) : A Decision Support System for Micro-Watershed Management in India, The Journal of the Operational Research Society, Vol. 46, No. 5, 592-603 pp.

Dewan, Ashraf M., Yamaguchi, Yasushi and Rahman, Md. Ziaur (2012) : Dynamics of land use/cover changes and the analysis of landscape fragmentation in Dhaka Metropolitan, Bangladesh, Geo Journal, Vol. 77, No. 3, 315-330 pp.

Drzewiecki, W. (2008) : Sustainable Land-Use Planning Support by GIS-based Evaluation of Landscape Functions and Potentials, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B7. Beijing 2008, 1497-1502 pp.

Eckholm, E. 1979. Planting for the Future: Forestry for Human Need (World Watch Paper 26).World Watch Institute, Washington D.C., p. 73.

Eludoyin, O.S., Wokocha, C.C. and Ayolagha, G. (2011) : GIS Assessment of Land Use and Land Cover Changes in OBIO/AKPOR L.G.A., Rivers State, Nigeria, Research Journal of Environmental and Earth Sciences 3(4): 307-313 pp.

Gautam, Ambika P., Edward L. Webb and ApisitEiumnoh (2002): GIS Assessment of LandUse/Land Cover Changes Associated with Community ForestryImplementation in the Middle Hills of Nepal, Mountain Research andDevelopment, Vol. 22, No. 1, 63-69 pp.

Graumlich, Lisa J. (1997) : Dynamics of Land-Use/Land-Cover Change, Bulletin of the Ecological Society of America, Vol. 78, No. 4, 289-290pp.

Gunton, Thomas (2003): Natural Resources and Regional Development: An Assessment ofDependency and Comparative Advantage

Paradigms, EconomicGeography. Vol. 79, No.1, 67-94 pp.

Haldar, Dipanwita, Sehgal, V.K., Kumar, Gopal and Sarma, K.S. Sundara (2011) : Evaluation of ground water and land resources in relation to landforms in Alwar District (Rajasthan): A remote sensing based approach, ARCH. ENVIRON. SCI. (2011),Vol-5, 37-45pp.

Huang, Jinliang and Klemas, Victor (2012) : Using Remote Sensing of Land Cover Change in Coastal Watersheds to Predict Downstream Water Quality, Journal of Coastal Research, Vol. 28, No. 4, 930-944 pp.

Hudson. (1995). Bridging the Gap between Communities and GIS Participatory 3-D Modeling,India.

ICIMOD. 1996. Background Note for Regional Meeting of Experts on Development of MicroEnterprises in Mountain Area 25–26 July, Unpublished Text.

Jodha, N.S. 1990. Mountain perspective and sustainability: a framework for developmentstrategies. Paper presented at International Symposium on Strategies for SustainableMountain Agriculture, International Centre for Integrated Mountain Development,Kathmandu, Nepal.

Johnson, Lucinda B. (1990) : Analysing spatial and temporal phenomena using geographical information systems, Landscape Ecology vol. 4, No.1, 31-43 pp.

Kauzeni, A.S., Kikula, I.S., Mohamed, S.A. and Lyimo, J.G. (1993): Land Use Planning andResources Assessment in Tanzania: A Case Study, IIEDEnvironmental Planning Issue No.3 IRA Research, 35 pp.11

Khan, Rubia and Jhariya, D.C. (2016) : Land Use Land Cover Change Detection Using Remote Sensing and Geographic Information System in Raipur Municipal Corporation Area, Chhattisgarh, SSARSC International Journal of Geo Science and Geo Informatics, Vol 3 Issue 1, August 2016, 1-4 pp.

Knox, J.W. and Weatherfield, E.K. (1999): The Application of GIS to Irrigation Water Resource Management in England and Wales, The Geographical Journal, Vol. 165, No. 1, 90-98 pp.

Korner C, Ohsawa M, editors, (2005). Mountain systems. In: Ecosystems and Human Well-Being, *Current State and Trends*, Vol 1. Washington, DC: Island Press, pp. 681–716.

Kumar N., Yamaç S.S. and Velmurugan A. (2015) : Applications of Remote Sensing and GIS in Natural Resource Management, Journal of the Andaman Science Association Vol. 20(1), 1-6 pp.

Kumar, Suresh, C. Subrahmanyam, Jitendra Prasad, L.M. Pande, Inderjit Singh and Jha, V.K.(2001): Land use Planning Using Remote Sensing Techniques (A CaseStudy of Behta Block, District Sitapur, Uttar Pradesh, Jour. Agric.Physic, Vol.1, 35-39 pp.

Kumar, Vipin (2017) : Prioritization of Sub-Watersheds Based on Morphometric Analysis of Drainage Basin- A Case Study of Medkhali River Basin in Lower Siwalik Basin, India, International Journal of

Multidisciplinary Approach and Studies, Vol 04, No.4, 95-111pp.

Lachowski, Henry M. (1998) : Remote Sensing Applied to Resource Management, USDA Forest Service Gen.Tech.Rep.PSW-GTR-166. 327-332 pp.

Lillesand, T.M. and R.W. Kiefer. (1994). Remote Sensing and Image Interpretation, J*ohn Willey & Sons*, Inc., New York, p. 170.

Laley, Mehrdad Foj and Ranji, Adel (2014) : Remote Sensing and Evaluation of Natural Resources in Iran, Kuwait Chapter of Arabian Journal of Business and Management Review Vol. 3, No.10, 334-340 pp.

Lalchamreia, H. and Pachuau, Rintluanga (2010): Land Use Land Cover Change inTuichhuahen Watershed, Kolasib District of Mizoram, Geographic Vol. 5, 15-19 pp.

Lambin EF, Meyfroidt P., (2010). Land use transitions: Socio-ecological feedback versus socio-economic change, *Land Use Policy*. Vol 27, pp.108–118.

Margaret H. Carr and Zwick , Paul (2005): Using GIS Suitability Analysis to Identify Potential Future Land Use Conflicts in North Central Florida, Journalof Conservation Planning Vol. 1, 58-73 pp.

Mallupattu, P. K. and Reddy, J. R. Sreenivasula (2013) : Analysis of Land Use/Land Cover Changes Using Remote Sensing Data and GIS at an Urban Area, Tirupati, India, The Scientific World Journal Volume 2013, Article ID 268623, 1-6 pp.

Markon, Carl J. and Derksen, Dirk V. (1994): Identification of Tundra Land Cover near Teshekpuk Lake, Alaska Using SPOT Satellite Data, Arctic, Vol. 47,No. 3, 222-231 pp.

Mitchell, B. 1989. Geography and Resource Analysis, Second Edition, Longman Scientific & Technical, Essex, p. 3.

Nakai, Shoichi and Bae, Jaegyu (2010): Estimation of Landform Classification Based on Land Use and Its Change, IIED Environmental Planning Issue No.3 IRAResearch 1-8 pp.

Nigam, R. K. (2000) : Application of Remote Sensing and Geographical Information System For Land Use / Land Cover Mapping And Change Detection in the Rural Urban Fringe Area of Enschede City, The Netherlands, International Archives of Photogrammetry and Remote Sensing. Vol. XXXIII, Part B7. Amsterdam 2000, 993-998 pp.

NRSC (2010) : National Land Use and Land Cover Mapping Using Multi-Temporal AWiFS Data, NRSC/RS&GIS, 1-51 pp.

Ojima, D.S. and Moran, E. (2004): Global Land Project: Draft Science Plan, Geo Journal (2007), Vol. 68, No. 4, 370 p.

Pabi, Opoku (2007): Understanding Land-use/cover Change Process for Land andEnvironmental Resources Use Management Policy in Ghana, GeoJournal, Vol. 68, No. 4, 369-383 pp.

Piyoosh Rautela, Rahul Rakshit, V.K. Jha, Rajesh Kumar Gupta and AshishMunshi, (2002). GIS and remote sensing-based study of the reservoir-induced land-use/land-cover changes in the catchment of Tehri dam in GarhwalHimalaya,Uttarakhand (India). *Current Science*, Vol. 83(3), pp.308–311.

Prabhakaran, A and Raj, N. Jawahar (2018) : Drainage morphometric analysis for assessing form and processes of the watersheds of Pachamalai hills and its adjoinings, Central Tamil Nadu, India, Applied Water Science (2018), 1-19pp.

Rai, Praveen Kumar and Kumra, V. K. (2011) : Role of Geoinfomatics in Urban Planning, Journal of Scientific Research Vol. 55, 2011 : 11-24 pp.

Ravan, Shirish A. and Roy, P. S. (1997) : Satellite Remote Sensing for Ecological Analysis of Forested Landscape, Plant Ecology, Vol. 131, No. 2, 129-141 pp.

Rawat, J.S. and Kumar, Manish (2015) : Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India, The Egyptian Journal of

Remote Sensing and Space Sciences (2015) 18, 77–84 pp.

Reis, Selçuk (2008) : Analyzing Land Use/Land Cover Changes Using Remote Sensing and GIS in Rize, North-East Turkey, Sensors 2008, 8, 6188-6202 pp.

Richter, H. G. (1984) : Land Use and Land Transformation, Geo Journal, Vol. 8, No. 1, German Democratic Republic – Regional Structure and Development, 67-74pp.

Roy, B.K., (1973): Determination of Land-Use Changes, Arable Potentials and Land-UseDevelopment in West Bengal: An Analytical Investigation: InAgriculture Typology, The Nat. Geog. Jour. Ind., Vol.XIX, Part-I, 15-19 pp.

Sauer O. : "Mapping the utilization of the Land".(1919) Pub-Geographical Review Vol.-VIII.

Serneels, S., Linderman, M.and Lambin, E. F. (2007) : A Multilevel Analysis of the Impactof Land Use on Interannual Land-Cover

Change in East Africa,Ecosystems, Vol. 10, No. 3, 402-418 pp.

Shinde, Suresh., (1973): The Panchganga Basin: An Appraisal of Some Aspects of Its Agricultural Geography, Geographical Review of India, Vol. XXXV, No.3, 263-76 pp.

Singh, Preeti, et *al* (2017) : Application of Geo-informatics in Natural Resource Management, Int.J.Curr.Microbiol.App.Sci (2017) 6(5): 2168-2170 pp

.

Stamp L.D. : "The Land of Brittain its use and mis-use",(1962) Longman Green and Co. Ltd. GeographicalPublication Ltd. London, P: 335-350.

Tasser, Erich and Tappeiner, Ulrike (2002): Impact of Land Use Changes on Mountain Vegetation, Applied Vegetation Science, Vol. 5, No. 2, 173-184 pp.12

Tekle, Kebrom and Hedlund, Lars (2000) : Land Cover Changes between 1958 and 1986 in Kalu District, Southern Wello, Ethiopia, Mountain Research and Development, Vol. 20, No. 1, 42-51pp.

Trotter C.M., (1991): Remotely sensed data as an information source for geographical information systems in natural resource management – a review, *International Journal of GIS*, 5(2), 225-239.

Turner, S.D. 1982. Soil conservation: administrative and extension approaches in Lesotho.Agricultural Administration 9: 147–162.

U.S.D.A. Natural Resources Conservation Service National Soil Survey Handbook, part 622.

Vikhe, S.D. and Patil, K.A. (2014) : State of the Art of Land Use Planning Using Remote Sensing and GIS, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 11, Issue 5, 41-47 pp.

Walker, Robert T. and Solecki, William D. (1999): Managing Land Use and Land-CoverChange: The New Jersey Pinelands Biosphere Reserve, Annals of theAssociation of American Geographers, Vol. 89, No. 2 , 220-237 pp.

Welsh, B. W.W. and Butoria, P. 1990. Dictionary of Development: Third World Economy, Environment, Society. Garland Publishing Inc., NY and London, p. 666.

Yesserie, Addis Getnet (2009): Spatio -Temporal Land Use/Land Cover Changes Analysis And Monitoring in the Valencia Municipality, Spain, Geospatialtechnology, 11-69 pp.

Yadav, A.L., (1975): The Changes in Agricultural Land-Use Patterns of Gurgaun District,1951 – 66, Kurukshetra University, Unpublished Ph. D Thesis, 272p.

Zhou, Qiming (1998): Use of GIS Technology for Land Resource Inventories and Modelingfor Sustainable Regional Development, Ambio. Vol. 27, No. 6, 444-450 pp.

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ABSTRACT

# ASSESSMENT OF NATURAL RESOURCES AND LAND USE PLANNING IN CHEM LUI SUB-WATERSHED, KOLASIB DISTRICT, MIZORAM.

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

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SCHOOL OF EARTH SCIENCES AND NATURAL RESOURCE MANAGEMENT

OCTOBER, 2020

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# DECLARATION

I, David B Lalhruaitluanga, hereby declare that the subject matter of this thesis 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/Instituted.

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**Assessment of Natural resources and Land Use Planning in Chem Lui Sub-Watershed, Kolasib District, Mizoram.**

Land is the basis for most of the life supporting systems either directly or indirectly. For effective management and development of natural resources, baseline information of the existing resources is very much essential. As the population is ever-increasing it is necessary to manage the available basic land, water and vegetation resources to meet the basic needs like food, fodder, fuel and shelter. Land use is found to be the most important human induced factor influencing land cover. It is found that land use/land cover dynamics are heterogeneous in space and time, and it is a complex phenomena to understand as there are several complex interactions of biophysical, demographic and socio-economic factors as inferred by Ojima and Moram (2004).

The present study will include in its ambit the study of geomorphic features and land use/ land cover pattern of the study area. As they are closely associated with climatic phenomena therefore, the study of surface water, ground water potential and soils is imperative. An attempt will be made to assess the physical and chemical properties of soils as they form an important aspect in assessing land capability and soil erosion status. Slope is also one of the important parameters in land use planning as it controls vegetation and soil formation in the area. It is essential to study the climatic parameters such as rainfall, temperature and humidity to understand the influence on the growth and development of vegetation in the area. The thematic data has to be integrated in GIS environment in order to arrive at reasonable conclusions for land use planning. However, socio-economic studies will not be carried out in the present study as it is aimed at assessing only the existing natural resources.

Users of natural resources in rural areas value resources differently due to complex socio-economic, demographic, environ- mental and cultural attributes of the households. While the importance of these aspects is well recognized in analyzing livelihood strategies and sustainability, the rationality behind household strategies/ decision-making processes from users' perspective has not received due attention, especially in the context of environmental degradation and natural resource valuation. As a result, resource degradation in rural areas of the developing world is often erroneously linked with population explosion and poverty (Vyas 1991; Leach and Mearns 1991; Tiffen et al, 1994; Reddy 1995). Moreover, users' perceptions also depend on the existing institutional set- up and property rights regimes in rural areas. Therefore, understanding users' rationality in resource valuation, economic as well as non-economic, is crucial for policy on environment and sustainable agricultural development.

Land use and land cover change is one of the most peculiar forms of environmental change occurring in all parts of the world especially mountain area (Keorner and Ohsawa, 2005). The term land use refers to human activity on certain piece of land, whereas land cover refers to its surface features (Lambin and Meyfroidt, 2010). The most important characteristic of land is its complexness and dynamic nature.

For land capability classification Satellite image of IRS P6 LISS-III sensor of the year 2016 has been used. Slope map is obtained from CartoDEM satellite image of 30m spatial resolution. Base map has been prepared from India toposheets 83D/11, 83D/12 and 83D/15. In this classification, the arable soils are grouped according to their potentialities and limitations for sustained production of the common cultivated crops that do not require specialized site conditioning or site treatment. Non arable soils (soils unsuitable for long time sustained use for cultivated crops) are grouped according to their potentialities and limitations for the production of permanent vegetation and according to their risks of soil damage if mismanaged. It is mainly based on the inherent properties of soil, external land features, and environmental factors that limit the land use.

The land use planning process covers all steps extending from the collection of data and information through its processing, analysis, discussion and evaluation right up to the negotiation for a consensus concerning the form of land use to be practiced. This includes the prerequisites for preparing, initiating and implementing the plan. However, in the context of the technical co-operation, during the land use planning process not necessarily all planned measures to be carried out will be implemented in their entirety. Planning of potential land use land cover and natural resources are important for preserving the ecological balance for natural resources development and conservation, predominantly in fragile and heterogeneous erosion-vulnerable hilly region. It affects living and economic development of such region especially in developed countries. The utilization of land resources has its impact on the biodiversity and environment of related region either positively or negatively depending on how it is used in time and space. The land utilization type must be designed to ensure that the natural basis of living is sustained in the long run that means the use of the land should correspond to its natural potential. Existing environmental damage should be minimized and damaging developments avoided by supporting and developing suitable approaches.

Following research questions were set for the present study

1. Is natural resources use efficiently?
2. Is land use patterns change through time?
3. Is the watershed support land capability?

Major objectives of the study area

1. To evaluate the existing natural resources such as soil, water and vegetation

2. To find out temporal changes in land use / land cover pattern

3. To identify land capability classification

4. To suggest land use plan for sustainable natural resources

ChemLui sub-watershed is located between 92° 40' – 92° 48' east longitudes and 24o 04' – 24o 24' north latitudes covering an area of about 165.63sq.km. The area falls in parts of survey of India toposheets 83D/11, 83D/12 and 83D/15. The river Serlui is a tributary to the river Tuirial which is flowing towards north in Mizoram. ChemLui is the tributary to the river Serlui. The area experiences humid tropical climate. Linear to arcuate shaped hills separated by narrow and deep structural valleys controlled by faults and fractures are the prominent geomorphic features seen in the area. The maximum elevation of 1100 metres is seen in the southern part of the watershed and the minimum of 60 metres is found at its confluence with Serlui near Saiphai village. The whole watershed is composed of sedimentary rocks such as sandstones, siltstones and shales.

The area is essentially used by the surrounding rural population. It serves the basic livelihood requirement of those inhabitants. Along the bank of the river agriculture and its allied occupation have been running largely. It is one of the main river serving the livelihood requirement in the surrounding areas. Since the people practice agriculture and horticulture farming and plantations, shifting cultivation still the dominant form of agricultural system. It is highly necessary to make land use plan to reach optimum utilization of natural resources. The watershed is small enough to conduct case study and large enough to depict the whole picture of geography of Mizoram and other hilly region. Thus, the watershed has selected for case in order to find availability of natural resources, land use land cover change, land capability classification and preparation of land use plan.

Based map was prepared from India toposheets number 83D/11, 83D/12 and 83D/15 comprising road network, drainage and other topographic information. Slope map is prepared from CartoDEM by using Survey of India toposheets on 1:50,000 scale by adopting the methodology proposed by All India Soils and Land Use Survey (AIS & LUS, 1971). For land use land cover pattern and land capability classification Satellite image of IRS P6 LISS-III sensor 2016 (MIRSAC) has been used. Slope map is obtained from CartoDEM satellite image of 30m spatial resolutions. Geomorphic map has been prepared by using SOI Map and satellite imagery. Soil map prepared by Mizoram Agriculture department has been used coupled with field investigations. A surface and ground water potential map is prepared based on the integration of the data on drainage density, drainage frequency, slope, geomorphic features and litho-units for the evaluation of water resources. In land capability classification, the arable soils are grouped according to their potentialities and limitations for sustained production of the common cultivated crops that do not require specialized site conditioning or site treatment. Non arable soils (soils unsuitable for long time sustained use for cultivated crops) are grouped according to their potentialities and limitations for the production of permanent vegetation and according to their risks of soil damage if mismanaged. It is mainly based on the inherent of soil properties, external land features, and environmental factors that limit the land use.

Field surveys will be collected using GPS for ground truth verification and also to make measurements of various litho-units and landforms. Soil samples will be collected and analyzed to study various physical and chemical properties of different soil types. Survey of India toposheets pertaining to study area will be used to prepare basemap comprising road network, drainage and other topographic information. Rainfall data will be collected from various published and unpublished sources to analyze climatic variations that occurred over a period of time. Slope map will be prepared by using Survey of India toposheets on 1:50,000 scale by adopting the methodology proposed by All India Soils and Land Use Survey (AIS & LUS, 1971). Similarly, digital slope map will be prepared by using GIS software. Multi-date satellite imagery will be used to find out temporal changes in the land use/land cover pattern. Geomorphic maps will be prepared by using survey of India toposheets and satellite imagery. Soil map will be prepared by using satellite imagery coupled with field investigations. Surface and ground water potential maps will be prepared based on the integration of the data on drainage density, drainage frequency, slope, geomorphic features and litho-units for the evaluation of water resources. Land capability and soil erosion status maps will be prepared using toposheets and satellite imagery.

The thematic data on drainage, land use/land cover, geomorphic features, lithology, slope, soils, land capability and soil erosion status will be integrated by adopting the overlay techniques of GIS with the help of GIS software tools to prepare land suitability map in order to suggest alternative land use farming systems for the development of resources in ChemLui sub-watershed.

The study area is characterized by many hill ridges runningparallel to each other, most of which roughly runs from north to south and is broadly suitable for wet rice cultivation and horticultural practices. The south-western most parts consist of high degree of slopes, while northern parts are characterized by nearly level sloping and low lying areas. Narrow valleys separate hill ridges and most of them have nearly level to steep slopes with observable escarpments on hillside slopes.Nine major slope classes have been generated which range from nearly level slope area to very steep slope area. The nine slope classification are – (i) level slope, (ii) nearly level slope, (iii) very gentle slope, (iv) gentle slope, (v) gentle to moderate slope, (vi) strongly slope, (vii) Strongly slope to steep slope, (viii) Steep slope to high steep slope, and (ix) steep slope.

Slope class of 0 to 3 percent of level slope covers a total area of 454.46 hectare comprising 2.63% of the total study area. The slope class of 3 to 10 percent of nearly level slope covers a total area of 2049 hectare comprising 12.37% of the total area. The slope class of 10 to 15 percent of very gentle slope covers only a total area of 67.33 hectare comprising 0.41% of the total area. The slope class of 10 to 25 percent of gentle slope covers a total area of 1211.30 hectare comprising 7.31% of the total area. Slope class having 25 to 35 percent of gentle to moderate slope covers a total area of 3125.46 hectare comprising 18.87% of the total study area. The slope class having 35 to 50 percent of strongly slope covers a large area of 6732.19 hectare comprising 40.65% of the total watershed area. The slope class having 50 to 70 percent of strongly slope to steep slope covers a large area of 2438.16 hectares comprising 14.72% of the total area of the watershed. Slope class of 70 to 100 percent of steep slope to high slope covers an area of 435.29 hectares comprising only 2.63% of the total area. Slope class having more than 100 percent of very steep slope covers a quite small area of 49.80 hectare which comprising only 0.30% of the total study area.

Eleven types of soils composition with different characteristics and having a varied resources utility were identified in the study area such as loamy skeletal typicdystrochrepts, loamy skeletal humichapludults, loamy skeletal typichapludults, loamy skeletal umbricdystrochrepts, fine loamy typichapludults, fine loamy humichapludults, fine loamy umbricdystrochrepts, fine loamy typicdystrochrepts andfine loamy aquicdystrochrepts, valley/wet rice caltivation soil and soil under water body.

The geomorphic features of the study area are broadly classified into (i) Structural and (ii) Fluvial origin. Structural hill constitutes the main geomorphic class covering 93.84 percent of the study area which is associated with folding, faulting and other tectonic processes. Structural hills are further divided into three classes viz., high structural hill, medium structural hill and low structural hill. High Structural hills above 1000 meters of an altitude covers an area of only above 40.13 hectare which accounts only 0.24% of the study area, and are found in the southern part of Bualpui village area. Medium Structural Hills above 700 - 1000 meters of an altitude covered an area of 394.96 hectare which accounts 2.39% of the study area are found at Bualpui, Sethawn, Thingdawl village and Kolasib town. Low Structural Hills below 700 meters of altitude covers the most of the area of 15108.34 hectares which accounts 91.22% of the study area are found almost throughout the entire study area.

Valley fill is a very important geomorphic feature in the study of fluvial origin, and are characterized by unconsolidated sediments deposited by rivers and streams in a narrow fluvial valley. They are found mainly along Chemluiriver and lower Serlui river around Chemphai and North Chawnpui village. Valley Fill covers an area of 748.85hectares which accounts 4.52% of the study area. Flood plain is another geomorphic class found along the main courses of the rivers in the study area which are formed by deposition of alluvium on the sides of the rivers. This geomorphic unit covers an area of 270.72hectares which accounts 1.63% of the total study area. The spurs are generally orientedineast to west directions. The spurs on the eastern side of the Chemtlang ridge line are comparatively short and gentler than the spurs of the Kolasib ridges on the western side. Steep slopes and scarps are found along the sides of the western main ridge lines.

(i) Sandstone - Sandstone is the predominant rock type in the study area which is comparatively harder rock formation found mainly along the ridges due to its resistance to erosional elements.This rock unit covers an area of 6772.42hectares which accounts 40.89% of the Chemlui sub-watershed.

(ii) Siltstone and shale –This unit class covers most of the study area. It spreads over an area of 9124.88hectares which accounts 55.09% of the watershed.

(iii) Gravel, sand and silt - These are alluvium deposits mainly found along the rivers of Chemlui and Serlui which covers an area of 469.49hectares which accounts 2.83% of the study area.

(iv) Clayey Sand deposits are found scattered all over the area along the small streams and valley fills with an area of 196.21hectare which accounts 1.19% of the study area.

In current land use land cover, the thematic map identified and shows more kinds of land use/ land cover which is not found in the last one decade. Land use units like Water bodies-Lakes/Ponds-Seasonal and Water bodies-Reservoir/Tank-Permanent have been identified with significance. Thus land use/land cover of the watershed area is classified into 6 broad categories such as built up land, agricultural Land, Forest, wastelands-scrub land-dense and open, Water bodies and others such as Shifting Cultivation. It has been analyzed that more than half of the watershed is covered by bamboo forest which comprises 55.79 per cent of the total watershed area. A wide area of land are also found at different land use classes such as built up (1.71%), agricultural land-crop land-kharif crop (5.19%), agricultural land-plantation-horticulture plantation (1.28%), forest-evergreen/semi evergreen-dense/closed (11.23%), forest-evergreen/semi evergreen-open (9.34%), forest-forest plantation(0.31%), forest-scrub forest (9.77%), wastelands-scrub land-dense (0.52%),wastelands-scrub land-open (0.15%), water bodies-reservoir/tank-permanent (1.74%), water bodies-river/stream-perennial (0.25%), and water bodies-lakes/ponds-seasonal accounting (0.02%) shifting cultivation-current (1.22%), shifting cultivation-abandoned (1.49%) of the total watershed area.

Despite the fact that the study area of Chemlui Sub-watershed receives high amount of rainfall during the main part of the year as it is partially due to its seasonal characteristics. During the dry periods, groundwater appears to be the main source of water for agricultural activities at several places in the watershed. It is therefore necessary to evaluate the water resources for capable utilization in the development agricultural activities. The present study of water resources is an attempt to assess the existing surface water resources in the form of drainage systemriver, stream, tanks, ponds, reservoirs and groundwater potentiality in the area.

Groundwater potential zones of the study area aregrouped into 4 divisions such as very good, good, moderate and poor. Very good zone covers 1536.14 hectares of land which comprise 9.27 per cent of the total watershed area. The area extent is narrow in the southern part of the watershed and extent widely towards the northern part. This zone also covers the low lying areas of Bilkhawthlir, Chemphai and North Chawnpui settlements. Good potential zone covers 3146.13 hectares accounting 18.99 per cent of the total watershed area. The entire geological structures fall under this zone and the low-lying areas including flood plains and valley fills are alsoincluded in this zone as low and gentle slope areas have a great extent of better conditions for infiltration and subsequent yield of groundwater.It mainly covers low lying areas of Kolasib, some parts of Bilkhawthlir and Thingdawl villages. Moderate zone comprises 5442.19 hectares which is 32.86 per cent of the total watershed area.Poor ground water potential zone covers 6438.53 hectares of land which is 38.87 per cent. The poor zone is mainly distributed along the southern ridges of the study area such as Bualpui, Sethawn and the western ridge of Thingdawl in the study area.

The forest cover type of the study area, Chemlui Sub-watershed is mainly covered by tropical wet evergreen forest and tropical semi-evergreen forest associated with moist deciduous forests. Moist deciduous forests are commonly found in small compacts areas on the hill slopes. The vegetation consists of a mixture of several species. Depending on the density of the canopy cover, the forests have been classified into forest-evergreen/semi evergreen-dense/closed and opened types.

The climate of the study area is generally pleasant and there is no extremity of temperature which ranges between $12^0$C to $33^0$C. The mean relative humidity varies from 39% to about 81%. The rainfall in the study area is well distributed, with a span of almost 6 months from May to October. Although pre-monsoon rains break in form the early part of March with occasional thunder-storms, the monsoon period really starts from the middle part of April. The average annual rainfall is about 2913.8 mm and there are some year's even receiving more than 3000mm of rainfall. The rainfall declines gradually and comes to an ends during November.The relative

Humidity (RH) of Chemlui Sub-watersheddoes not very much like temperature throughout the year round. The highest average mean relative humidity observed during the study was 81percentduring the months of August and September in 2013. Usually the month of June is the wettest month with mean monthly maximum at about 98 percent and mean monthly minimum of about 42 percent

Both increasing and decreasing trend of land use/ land cover units was detected during the decade between 2006 and 2016. Increasing patterns of land use/ land cover change was detected for 9 categories such as Built Up, Agricultural Land-Crop Land-Kharif Crop, Agricultural Land-Plantation-Horticulture Plantation, Forest-Evergreen/Semi Evergreen-Open, Bamboo, Wastelands-Scrub Land-Dense, Wastelands-Scrub Land-Open, Water bodies-Lakes/Ponds-Seasonal, Water bodies-Reservoir/Tank-Permanent. In the decade, the increasing change was found highest at Forest-Evergreen/Semi Evergreen-Open in which it was decreased by 2.58 per cent covering 428.11 hectare of land. Water bodies-Reservoir/Tank-Permanent was also increased by 1.74 per cent (287.49 ha). Bamboo cover land was increased by 1.55 per cent (256.45 ha). Area under Agricultural Land-Crop Land-Kharif Crop was increased by 1.34 per cent (221.62 ha). Agricultural Land-Plantation-Horticulture Plantation area was increased by 1.01 per cent (167.5 ha), Increasing changes was also detected but not high in some land use classes such as Built Up was increased by 0.48 per cent (79.78 ha), Wastelands-Scrub Land-Dense by 0.45 per cent (74.88 ha), Wastelands-Scrub Land-Open by 0.15 per cent (24.52 ha), Water bodies-Lakes/Ponds-Seasonal increased by 0.02 per cent which was 2.82 hectare of land.

In the decade (2006-2016), an enormous increasing trend has been seen. In the land under scrub land which was increased by 0.60 per cent of the area cover. The land covers by water bodies of lakes/ponds-seasonal and reservoir/tank-permanent was also increased to 287.49 hectares. Wet Rice Cultivation areas were increased from 637.20 hectares to 858.82 hectares (1.34%). Forest cover with less dense was increased by 2.54 per cent in the watershed area where it was 1119.38 hectares in 2006 while it was 1547.49 hectares in 2016. Area under plantation agriculture was increased by 1.01 per cent during the decade. Forest land cover by bamboo was also increased from 8983.32 in the year 2006 hectares to 9239.77 in 2016 which is 1.55 per cent.

Decreasing pattern of changes have been also identified at another 6 land use classes such as Forest-Evergreen/Semi Evergreen-Dense/Closed, Forest-Forest Plantation Forest-Scrub Forest, Shifting Cultivation-Current, Shifting Cultivation-Abandoned and Water bodies-River/Stream-Perennial. Area under Shifting Cultivation-Abandoned was largely decreased by 3.91 per cent accounting 646.91 hectare of land. Land use under Shifting Cultivation-Current was also highly decreased by 2.69 per cent which was 445.04 hectare of land. Decreasing patterns was also identified at Area under Forest-Scrub Forest was decreased by 1.87 per cent (309.08 ha), Forest-Evergreen/Semi Evergreen-Dense/Closed by 0.7 (115.47 ha), Water bodies-River/Stream-Perrenial by 0.13 (20.78 ha) and area under Forest-Forest Plantation by 0.04 per cent which was 5.89 hectare of land.

According to the classification made by USDA (1994) soils of the study area have been classified into five (5) land capability classes such as IIe, IIIe, IVe, VIe and VIIe (Fig.5.1) using ArcGIS 10.2.2 software. The land capability Classes I to IV are considered as capable of producing cultivated crops with good management and conservation treatment. Classes V to VII are best suited to perennial vegetative species, but may be capable of producing some specialized crops with highly intensive management. Class VIII soils are not suitable for managed vegetative production. Subclass '**e**' is made up of soils for which the susceptibility to erosion is the dominant problem or hazard affecting their utilization. Erosion susceptibility and past erosion damage are the major soil factors that affect soils in this subclass.The land capability of the Chemlui watershed is useful for future planning of land utilization at sub-watershed level. From the land capability classification it is observed that there is good potential for agricultural with horticultural system and plantations in the study area. And also focuses on conservation of the existing forests to maintain ecological balance while taking up improved and alternate farming practices in the sub-watershed as well.

For efficient utilization of land to meet the requirements of the people of the block, optimal land use plan has been suggested after assessing the potential of land resources viz. soils, hydro-geomorphology and terrain conditions. The suitability is dovetailed with agro-climatic and socio-economic data to make them locally acceptable and economically viable. The Present study area is classified into eight areas of land use development planning such as Wet Rice cultivation (9.07%), Agro-horticulture (24.50%), Afforestation /silviculture (4.13%), forest (22.2%), Bamboo (36.06%) settlement (2.52%), water body (0.72%) and fisheries (0.93%).

Resource management is concerned with choices, and the choice of posterity should be to use non-renewable resources only if and then only with the most meticulous care for conservation. Due to population growth, demands for human settlements and agricultural land is increasing every day. Availability of natural resources in the watershed is decreasing and reaching the optimal limitation stage. Following suggestions have been made for natural resource management in the study area based on the findings and people's perception.

1 As far as anthropogenic activitiesare concerned, we must establish here of foraberrance that acknowledges the menace the watershed is facing; must develop a policy to checkanthropogenic activities through awareness, the mass media and the government also need to be prepared thought to human activities controls. Human waste flowing to the river must be reduced.

2 As far as economic growth is concerned, we do not wish to certainly do not align ourselves with those who tell us it is jam the brakes on economic progress is not the answer; not enough the extent of the remaining resources, although the threat for us all to see. Man's adaptability and his ingenuity in devising of meeting his needs are full of hitherto unimagined resource. Continued growth of some kind is essential to the solution of these problems of poverty, obsolescence and indeed pollution. So proper utilization of natural resources should be practiced in the study areas. Illegal practices and unscientific used of natural resources should be stopped. To do this village level task force and government must do the needful.

3 Nevertheless, there are urgent things that we can and must the paramount goal of the affluent society; we must check the facials demands that needlessly consume resources. We must believe that constant change and novelty are necessarily good, that and styles are not merely out of date but automatically inferior created

a year ago, and we must encourage our manufacturers obsolescence and produce goods which will last longer and be way that the resources they tie up can be readily recovered and used again.

4 Government should take action. Resource management, though it draws together skills and knowledge from many disciplines, is primarily a political activity.Government policy in one sector may affect programs in other sectors. Better management of the natural resources in the study area can be undertaken through an integrated policy approach for all the sectors of development. An evaluation of ministries and government departments should be undertaken with a view to avoid overlapping jurisdictions and to effect coordination and cooperation.

5 Afforestation should be practiced more mainly near the banks of the river.