SPATIAL PLANNING OF SUSTAINABLE AGRO-HORTICULTURE DEVELOPMENT USING REMOTE SENSING TECHNIQUES IN AIZAWL DISTRICT, MIZORAM

BY

LALNUNSIAMA COLNEY

THESIS SUBMITTED IN FULFILMENT OF THE DEGREE OF DOCTOR OF PHILOSOPHY (Ph. D) IN HORTICULTURE, AROMATIC AND MEDICINAL PLANTS

MIZORAM UNIVERSITY
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*I, **Mr. Lalnunsiama Colney**, hereby declare that the subject matter of this thesis entitled **"Spatial Planning of Sustainable Agro-Horticulture Development using Remote Sensing Techniques in Aizawl District, Mizoram"** is the record of the work done by me, that the contents of this thesis did not form basis of the award of any previous degree or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.*

This is being submitted to the Mizoram University for the degree of Doctor of Philosophy in Horticulture, Aromatic & Medicinal Plants.

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Place : Aizawl

Date : 28th June, 2013

(LALNUNSIAMA COLNEY)

Dedicated to

my beloved late father who passes away on 5th May 2007,

Mr. RANGKHUMA COLNEY,

who has always encouraged me in every step of my career

and my beloved mother,

MRS. SANGHLUNI,

who even at an old age has continuously prayed for me

and given me support in all aspect.

ABSTRACT

The present investigation was carried out during 2009 – 2012 in Aizawl district, Mizoram. Aizawl district is one of the eight districts of Mizoram and lies in the northern part of Mizoram with a total geographical area of 3576.31 sq km which accounts for 16.96% of the total geographical area of the state. It is situated between 23˚ 18' 17” to 24˚ 25' 16 " N Latitudes and 92˚ 37' 03" to 93˚ 11' 45" E Longitudes. The main aim of the research was to develop a spatial planning for sustainable agro-horticulture sector in the district using remote sensing and geographic information system. The main emphasis was on an identification of potential areas for wet rice cultivation and horticulture crops including medicinal and aromatic plants.

To achieve the objectives of the investigation, standard methods of remote sensing and geographic information system were utilized for the mapping of various natural resources such as – drainage, watershed, geology, geomorphology, slope, aspect, altitude, land use land cover and soils. Indian Remote Sensing Satellite (IRS-P6) LISS III data with spatial resolution of 23.5m with three season data along with collateral data were used for the present research.

Pre field interpretation of satellite imagery was done followed by ground truth checking. Ground truth information and other ancillary data were incorporated in the post field work in which different natural resources were integrated along with socio-

economic and meteorological data for generation of spatial planning of sustainable agro-horticulture development.

Drainage mapping was done from satellite imagery and topo-sheets, and watershed classification was done according to Watershed Atlas of all India Soil and Land use Survey Organisation. The drainage system of Aizawl district as a whole is elongated in north to south direction showing angulated, dendritic to sub-dendritic drainage patterns. There are 11 watersheds, 27 sub-watersheds, 92 mini-watersheds and 384 micro watersheds within the district.

The general geology of the district represents a monotonous sequence of argillaceous and arenaceous rocks, which are classified into two formations viz., Middle Bhuban and Upper Bhuban Formations. The formations are folded into almost N – S trending anticlines and synclines and affected by longitudinal, oblique and transverse faults of varying magnitudes. The formations were classified into two based on lithological assemblage and sedimentary structures. Five different rock types were mapped in which Siltstone and Shale occupies majority of the area covering 63.31% of the total geographical area. The geomorphology consists of three geomorphic class viz., Structural Hill, Valley Fill and Flood Plain. Structural hills constitute the main geomorphic class and dominate the study area. From the geology and geomorphological classes and topography of the area, ground water potential zone are derived into 4 types i.e. very good, good, moderate and poor. However, more than half of the area of the district falls under poor zones.

Slope, aspect and altitudinal zones of the area were generated from Digital Elevation Model (DEM). Slope is expressed in percentage. Among the nine slope

facets, 35–50% and 3–10% slopes covers maximum and minimum areas constituting 38.33% and 0.08% of the total geographical area of the district, respectively. The area was conveniently divided into 9 aspects. As the hill ridges mainly run from north to south in their formation trend, the largest area is the western aspect followed by north-western aspect. Northeast aspect is often considered most suitable for agriculture development, establishing orchards, farms and other residential areas and only occupies 13.18% of the geographical areas. The altitudes of the area vary from 100 to 1905m above sea level. The altitude was divided into 9 classes in which 500 – 700m above mean sea level occupies maximum area covering 24.41% of the area.

The major land use/land cover classes within the district were broadly categorized into settlements, agricultural land, forests, bamboo forest, forest plantations, shifting cultivation, and scrubland and water body. The forest cover type is mainly tropical wet evergreen forest mixed with semi evergreen and tropical moist deciduous forests comprising mainly of bamboo. There is also sub-tropical forest found at higher altitudes. The vegetation consists of a mixture of several species. Depending on the density of the canopy cover, the forests have been divided into dense/closed, medium dense and less dense. The existing forests and bamboo forests cover 40.55% and 16.86% area of the district, respectively. The aged old practice of shifting cultivation is still continued and every year an area of 185.44 sq km was under shifting cultivation which accounts for 5.19% of the total area of the district.

Soils of the areas was classified on the basis of their physico-chemical and morphological properties. The soils identified at order levels are: Entisols, Inceptisols and Ultisols. The soils were classified upto series level and there were 14 soil series.

These soils are formed under humid tropical with mean annual rainfall of 3155mm. The pedons comprises of mixed mineralogy and hyperthermic temperature class. Soil texture was classified into 7 classes in which clay loam surface occupies maximum area which is optimum for growing different agricultural and horticultural crops. The physiographic soil data was further processed and analysed for deriving land capability classes for a specific usage of the area. The maximum area occupied by 'land capability class' was Class VI accounting to 47.03%. This shows that fairly good land on steep to very steep slopes covered maximum area within the district.

Since the main aim of the present research was to prepare spatial planning of sustainable agro-horticulture development using remote sensing techniques. Therefore, such an objective can be accomplished through development of land, water, vegetation and other resources of an area in a sustainable manner so that the changes proposed to meet the needs of people are brought about without diminishing the potential for future. The natural resources data generated by using remote sensing and GIS with collateral data in GIS domain were integrated to generate database for spatial planning of sustainable development. Based on the natural resources of the area silvi-pasture, sericulture, agro-horticulture, silviculture/afforestation and agriculture (WRC) are therefore planned for sustainable development. In addition to that, water resources inventory development plan such as minor irrigation tanks, water harvesting bunds, check dams and farm ponds were planned depending upon the sites and the command areas for irrigation.

Based on observations conducted during the course of this study, it is planned that agriculture mainly, wet rice cultivation (WRC) to be taken up in narrow valleys with an area of 26.46 sq km, constituting only 0.74% of the total geographical area. System of Rice Intensification (SRI) is recommended for cultivation in the area. Silvipasture and sericulture are proposed to be taken up in 120.16 sq km and 204.56 sq km accounting to 3.36% and 5.72% of the total area, respectively. Agro-horticulture is proposed to be developed in a land upto 50% slope with a minimum of 1 m soil depth and the potential area for the system identified is around 710.97 sq km, which is 19.88% of the total geographical area. Silviculture/ afforeastation is proposed to be developed in 398.41 sq km or 11.14% of the area of the district. The existing forest and bamboo forests should be conserved for maintaining eco-balance of the nature and it accounted for 40.55% and 16.86%, respectively. The total forest cover including silviculture/afforestation will be 68.55% of the total geographical areas, i.e., two-third of the area will be covered by forest.

Water resources inventory for sustainable development are also proposed to be develop for providing irrigation of crops, pisciculture and for drinking water purposes. The proposed structures to be developed are minor irrigation tanks, water harvesting bunds, check dams and farm ponds and the numbers of structures to be developed are 46, 42, 102 and 57, respectively. For soil conservation measures, gully control/ plugging, stream bank protection and road side erosion control are also proposed to be developed in erosion prone areas.

Other allied activities like cultivation of medicinal and aromatic plants, animal husbandry and veterinary, pisciculture, floriculture, infrastructure facilities including industries and organic farming are also recommended in the district for sustainable development plan. Considering the soil texture, climatic requirements and economic viability, 10 medicinal and aromatic plants are proposed for finding out the potential area for cultivation in the study area. Five crops viz., Pachauli, Sarpagandha, Greater Yam, Kalmegh and Geranium are highly suitable for cultivation in Aizawl district.

Since the sustainable development of natural resources is based on maintaining a fragile balance between productivity functions and conservation practices through monitoring and identification of problem areas, remote sensing and GIS makes the task easy. With the developments in satellite technology and data availability, considerable progress has been made towards effective utilization of the available data for conservation, monitoring and management of natural resources.

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LIST OF ABBREVIATIONS AND SYMBOLS

@	: At the rate
^{0}C	: Degree Celsius
A.D.	: Anno Domini
B.C.	: Before Christ
B.S.	: Base Saturation
Ca	: Calcium
Cartosat	: Cartographic Satellite
CEC	: Cation Exchange Capacity
cm	: centimeter
DOS	: Department of Space
F.L.	: Fine Loamy
GIS	: Geographic Information System
gm	: gram
ha	: Hectare
IRS	: Indian Remote Sensing Satellite
ISRO	: Indian Space Research Organisation
K	: Potash
Km	: Kilometer
L.S.	: Loamy Skeletal
LISS	: Linear Imaging Self Scanner
MAPS	: Medicinal and Aromatic Plants
Meq	: Milli-equivalent
Mg	: Magnesium
MIRSAC	: Mizoram Remote Sensing Application Centre
mm	: millimeter
Na	: Sodium
NASA	: National Aeronautics and Space Application
NESAC	: North Eastern Space Application Centre
NRSA	: National Remote Sensing Agency
NRSC	: National Remote Sensing Centre
OC	: Organic Carbon
pH	: Power of Hydrogen
ppm	: parts per million
Resourcesat	: Resources Satellite
RS	: Remote Sensing
SD	: Sustainable Development
Sqkm	: Square Kilometer
SWIR	: Short Wave Infra Red
viz.	: videre licet; videlicet: namely

CHAPTER I

INTRODUCTION

1.1 The Concept of Sustainable Development:

The concept of sustainable development came into prominence in 1980 and evolved itself as one of the mainstream developmental paradigms by late 1980s. In the process it has undergone numerous changes in its definitions and objectives. World Commission on Environment and Development (WCED, 1987) defined sustainable development as “the development that meets the needs of present without compromising the ability of the future generations to meet their own needs". This definition include two concepts: (i) the concept of ‘needs’, especially the essential needs of the world’s poor to which overriding priority should be given; and (ii) the idea of ‘limitations’ imposed by the state of technology and social organization on the environmental ability to present and future needs.

There has been much discussion on the concept and various issues inextricably connected with sustainable development. Consequently there are various points of view. The definitions of ‘sustainable development’, therefore, are many, depending on the nature of the problem addressed. A review of these definitions suggests that despite of wide acceptance of the concept of sustainable development, no single definition is yet available which everybody accepts, and hence, ecologists, conservationists and economists, all have different views (De Groot, 1987). Repetto (1990) asserted that “Sustainable development does not mean the preservation of the current stock of natural resources or of any particular mix of

human, physical and natural assets since as development proceeds the composition of the underlying asset base changes". UNDP (1991) in its Human Development Reports defined sustainable development as “development that improves health care, education and social well-being”. Such human development is now recognized as critical to economic development and to early stabilization of population. It further stated that “men, women, and children must be the centre of attention with development woven around people and not people around development” (UNDP, 1991). Goodland and Ledec (1987) stress that “using renewable resources in a manner that does not eliminate or degrade them or otherwise diminish their ‘renewable’ usefulness for future generation as sustainable development”. Similarly, World Conservation Union (WCU, 1991) defined sustainable development as “improving the quality of human life while living within the carrying capacity of supporting eco-systems”. This report focused on sustainable development as a process requiring simultaneous global progress in a variety of dimensions such as economic, human, environmental and technological.

Likewise, Barbier (1987) defined sustainable development as one, which is directly concerned with increasing the material standard of living of the poor at the grassroots level which could be quantitatively measured in terms of increased food, real income, educational services, health care, sanitation and water supply, emergency stock of food and cash etc., and only indirectly concerned with economic growth at the aggregate, commonly at national level. In more specific terms, sustainable development aims at reducing the absolute

poverty of the world's poor through providing lasting and secure livelihoods that minimize resource depletion, environmental degradation, cultural disruption and social instability. Adiseshiah (1989) definition comes closer to this. He wrote "Sustainable development is development which meets the basic needs of all, particularly the poor majority for employment, good, energy, water and housing, and ensures growth of agriculture, manufactures, power and services to meet these needs. In that sense sustainable development merges economics and environment both in theory and decision making".

Basically, when we talk of sustainable development, the easiest definition is that we, the present generation, have inherited a certain amount of ecology and environmental surrounding in terms of land, water, and air; when we leave it to the next generation, we should leave it at least in the same condition, if not in a better condition than what we inherited (Geethakrishnan, 1990). This is the sum and substance of sustainable development, putting it in elementary terms". Mishra (1993) defined sustainable development as "a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations".

Ray and Ghosh (1996) have tried to define the concept of sustainable development in a broader sense, as: a) a process of change that is continuous and can be sustained in the long-term; b) a process that does not seriously damage our physical and geographical environment; and indeed that the complex ecological system for the survival of human beings improves (not deteriorates) as a result of

the process of economic change; and c) a process that would eventually raise the standard of living of a community at large not only in the narrow material sense but also in the wider sense of literary, and other cultural activities". According to Gupta and Gurjar (1993) sustainable development is “the development of natural resources to meet the immediate needs of the present population, without hampering the requirements of future generations as well as endangering the ecology and environment as such i.e., to take into account the local and global effects to arrive at an optimal solution for meeting the basic aspirations of the affected people". Srivastava (1996) considers sustainable development as ‘environmentally responsible’ and ‘environmentally friendly’ a development that takes present and future, long-term and short-term; and a development that is environmentally begin and which focuses on the need for better environmental stewardship”.

However, one thing is clear that sustainable development cannot be a static concept and hence cannot be defined once and for all. It is a dynamic process and will be applied by different countries in tune with their own culture, political and economic perspectives. But unless there is a broad agreement on goals, directions and means, the concept will prove sterile and the business of development will continue as usual with more tensions among the nation states and regions and localities within the nation state (Mishra, 1993). Recently, it has also been realized by the scholars and researchers that indigenous knowledge systems should constitute the core of development models in the third world (Long and Long, 1992; Hobart, 1993; Dudley, 1993; Brush and Stabinsky, 1996). Because indigenous knowledge has

permitted its holders to exist in ‘harmony’ with nature, allowing them to use it sustainably, it is seen as especially pivotal in discussions of sustainable resource use (Compton, 1989; Flora and Flora, 1989; Ghai and Vivian, 1992; Moock, 1992; Sen, 1992; Inglis,1993; Farooquee, *et al*., 2004).

Therefore, when we speak of sustainable development we mean a development appropriate to the needs of today’s generation, yet without jeopardizing future generations’ chances of satisfying their own needs and choosing their lifestyle. The demand that this development be made ‘sustainable’ applies to all countries and to all people. Future generation chances of satisfying their own needs are equally jeopardized by pollution in the Western industrialized countries and by environmental destruction as a result of under-development in the third world. In the light of this discussion, the concept of ‘sustainable development’ may be conveniently described as ‘a pattern of social and structural economic transformation (development) which optimizes the economic and other social benefits available in the present without jeopardizing the likely potential for similar benefits in the future’.

1.2. Strategies for Sustainable Development:

The challenges facing present generation are formidable. Many countries have not yet achieved acceptable living standards for their people. Economic growth that improves human welfare is urgently needed. Protecting the environment will be an important part of improving the well- being of people today, as well as the well- being of their children and grandchildren.

The World Development Report (World Bank, 1992) suggested a threefold strategy for meeting the challenge of sustainable development. These are: 1)- build on the positive links: policies for growth promote efficient use of resources, technology transfer, and better- working markets- all of that can help in finding solutions to environmental challenges. Rising incomes can pay for investments in environmental improvement. Policies that are effective in reducing poverty will help reduce population growth and will provide the resources and knowledge to enable the poor to take a longer- term view. 2)- break the negative links*:* rising incomes and technological advances make sustainable development possible, but they do not guarantee it. Usually, additional incentives that capture the true value of the environment will be required to induce less- damaging behavior. Effective environmental policies and institutions are essential and 3)- clarify and manage the uncertain links : many relationships between human activity and the environment remain poorly understood, and there will always be surprises. The response should be investment in information and research and the adoption of precautionary measures, such as safe minimum standards, where uncertainties are great and there is a potential for irreversible damage or high costs in the long run.

1.3 Goals of Sustainable Development:

Sustainable development has a fixed set of goals although; approaches and means to achieve them can differ in various ways. Misra (1993) sets following goals: 1)- basic needs of all human beings, i.e., food, clothing, shelter, education, health, security, and self- esteem must be met adequately. Priority must go to these needs. Level of these needs will be determined by natural and technological

resources available and the global socio-economic context; 2)- development processes should be so articulated that ecological balance and environmental purity is least disturbed, if at all; and 3)- all nations and people must join hands to support each other and world with each other to create a world in which the above two goals are optimized. Each country should find ways and means to promote this interdependence.

In addition, sustainable development also demands a change in our attitude towards nature. And finally, sustainable development is not the business of the government and private companies alone. It is the business of the people in general. It is a process, which has to be initiated at each level of human endeavor and life. It involves individuals, families, communities, corporate bodies, nations and global society. It has to be a movement, because it involves paradigm change which is difficult to bring about unless great many people get involves. Democratization of decision- making and decentralization of power and authority is, therefore, a must.

1.4. Sustainable Agriculture Development:

In the overall debate on sustainable development, agricultural sector is often at the centre of discussions due to the obvious environmental problems associated with farming activities apart from being the dominant sector in the developing countries which are in the centre of controversies related to environment and it is now recognised that sustainable agricultural production not only involves identification and application of improved technologies but also ecological and socio-economic concerns (Global Open University, 2008). According to Food and Agricultural

Organisation (FAO), sustainable agriculture is the management and conservation of the resource base and the orientation of technological and institutional changes in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development is environmentally non-degrading, technically appropriate, economically viable and socially acceptable (The Global Open University, 2008).

Therefore, sustainable agriculture is a model and economic organisation based on an equitable and participatory vision of development which recognises the environment and natural resources as the foundation of economic activity. Agriculture is sustainable when it is ecologically sound, economically viable, socially just, culturally appropriate and based on a holistic scientific approach (Global Open University, 2008). It preserves bio-diversity, maintains soil fertility and water purity, conserves and improves the chemical, physical and biological qualities of soil, recycle natural resources, and conserves energy. Sustainable agriculture uses locally-available renewable resources, appropriate and affordable technologies, and minimizes the use of external and purchased inputs (Tandon, 1991), thereby increasing local independence and self sufficiency and insuring a source of stable income for peasants, family and small farmers and rural communities. This allows more people to stay on the land, strengthens rural communities, and integrates humans with their environment (Farooquee *et al.*, 2004). It also respect the ecological principles for diversity and interdependence and uses the insights of modern science to improve rather than displace the traditional wisdom accumulated over centuries by millions of farmers around the world.

1.5. Importance of Sustainable Development in Mizoram:

Mizoram is characterized by hilly rugged terrain. The parallel structural hill ranges run north to south direction tapering at both ends with alternating narrow valleys. The ridges show serrated tops which are highly dissected and separated by intervening 'V' shaped valleys. The hill side slopes are steep to very steep and escarpment are common. Steep hill side slopes are utilized for shifting cultivation (Colney, 1988). As the name implies, it is a system of non-settled agricultural practices. Operationally, shifting cultivation or Jhumming involves selection of site followed by slash and burn of the forests and cropped the land for a year or two before it is abandoned for replenishment. Due to population pressure, the jhum cycle is shortened which resulted in gradual decrease of production per unit area. This type of cultivation is not sustainable now and will be increasingly so in the future.

Agriculture is the main livelihood and shifting cultivation or Jhumming is the usual practice. About 70% of the people are practicing Jhum cultivation (Colney, 1991). It has been notice that there is a drastic change in land use caused by shifting cultivation. This causes deforestation and thereby causing serious soil erosion, denudation, degradation and effect the eco-balance of the nature. Wild animals which are abundantly available in the past have retreated to the interior due to wanton destruction of their habitat. Reports indicates that various species of wildlife, large and small animals, birds, reptiles etc. have become rare and gradually will disappear or even extinct in the long run (NRSA, 1979). Therefore, proper land use planning for sustainable development is indispensable to meet the needs of the present without hampering the environment for future generations.

1.6. Remote Sensing and GIS for Sustainable Development:

Applied Remote Sensing and Geographic Information System (GIS) became more and more inevitable technology tool contributing to human's progress toward sustainability by support solving environment-related tasks on local, regional and global level. Major challenges are the exploitation of the research and the global co-operation, where the application potential brings direct benefits in climate change research, agriculture, environmental monitoring, cartography and natural resources management (Rao, 1996). It helps policy decision making to reduce negative societal-economic impacts and assist to ensure sustainable development on the long run. In order to have spatial planning for sustainable agro-horticulture development, various natural resources viz. soil, land use/cover, geology and geomorphology, drainage, slope, transport network and settlements, etc. are to be mapped from remotely sensed data of Satellite imagery and socio-economic data, demographic data, meteorological data and other collateral data have to be integrated in the Geographic Information System (GIS) for generation of action plan. The natural resources information and other collateral data integrated in the GIS environment will prescribe suitable site specific action plan for appropriate land use plan and water management practices.

1.7. Scope of the Study:

Agriculture is the mainstay of the people of Mizoram and more than 60% of the total population is engaged in Agriculture (Pachuau, 2009). The age old practice of Jhum cultivation is the usual practice. The climatic condition in the state with well distributed rainfall of 2000mm to 3000mm spread over eight to ten months in the year

and location in tropic and temperate zone with various soil types have contributed to the occurrence of a wide spectrum of rich and varied flora and fauna. These natural features and resources also offer opportunities for growing a variety of agriculture and horticultural crops. Rice is the staple food of Mizoram and it is grown in the flood plains of narrow valleys, foot hills and in all the jhum land. Horticulture crops such as vegetables, spices and other cash crops were grown as mixed cropping along with rice in the jhum lands (Colney, 1991). Likewise, owing to diversified topographic and climatic conditions of the state, cultivation of medicinal and aromatic plants (MAPs) can be a profitable option to farmers as a cash crop in the state besides generating self employment options. Considering the importance of rice cultivation and horticultural crops in Mizoram, it is imperative to identify best soil and land for improving production of these crops.

In order to find out the potential areas for sustainable agro-horticulture development, various natural resources viz. land use land cover, soil resources, slope categories, drainage, hydro-geomorphology, transport network and settlements, etc. have to be studied using remote sensing technology and geographic information system. These different natural resources information along with meteorological data and demographic and socio-economic data have to be integrated for generation of sustainable agro-horticulture development (NRSA, 1995).

Recently, concept of precision farming is much debated subject to forecast and identifies potential sites for specific crop cultivation. Remote Sensing and Geographic Information System are used as major tools in precision farming. The information on spatial variability in soil fertility status and crop conditions is a pre-requisite for

adoption of precision farming (Mishra and Chidambaram, 2005). Space technology including global positioning system (GPS) and GIS holds good promise in deriving information on various data for adopting precision farming. Though, it has been widely practiced in developed countries, the adoption of precision farming in India is yet to take a firm ground primarily due to its unique pattern of land holdings, poor infrastructure, lack of farmers' inclination to take risk, socio-economic and demographic conditions (Mishra and Chidambaram, 2005). However, the information acquired through space borne data and geo-reference data projected with the help of Geographic Information System will give the potential areas for wet rice cultivation and horticultural crops of the study areas for sustainable development. Keeping above facts in view, present thesis was focused on following objectives:

1.8. Objectives:

The main aim of the research was to have a spatial planning for sustainable agro-horticulture development in Aizawl district, Mizoram, with main emphasis on identification of the potential areas for wet rice cultivation and horticulture crops development. To achieve this main aim, the following objectives were set forth.

1. To make a survey of the area for identification of land use pattern using remote sensing techniques.
2. To collect the socio-economic data and meteorological data from different meteorological centers.
3. To generate maps of land use land cover, soil resources, geomorphology, watershed boundaries, transport network and settlement location using remote sensing and geographic information system (GIS).
4. To suggest a model of spatial plan for sustainable agro-horticulture development.

CHAPTER II

REVIEW OF LITERATURE

2.1 Introduction:

Land is the assemblage of biotic and abiotic components on the earth surface and it is the crucial properties of the earth system. It has very aptly been described as the nation's ultimate asset and is, to all intents and purposes, fixed in area and inextensible. The study of land use and sustainable development is important not only in agricultural dominated regions but also throughout the world because of its relationship with different human phenomenon. Moreover, its significance has increased manifolds during recent years due to the scientific innovations and increased pressure on land. In the past, there was enough land to support the limited population but today population explosion has remarkably reduced the man-land ratio. Intensive and proper use on land has become essential due to the increasing pressure of land.

There have been a number of studies on land use and sustainable development in different parts of the world. But, an interesting point to be made is that the number of studies conducted in the hill regions of the world inhabited by the tribes is lesser than that of the plain region. A brief survey of the earlier studies has been attempted in this chapter, which can be split into two parts. Part one deals with the land use and second part with studies on sustainable development. The studies were mainly based on Remote Sensing and Geographic Information System (GIS) and some of the studies were conventional method.

2.2 Land use:

The study of land use in India and abroad have been carried out by many workers in order to understand the land and its characteristics for suitable and proper planning of land in future for increasing high yield per hectare and total production. From this point of view many countries have carried out land use survey which is discussed as follows.

During the last 40 years numbers of land use studies have been made in various parts of the world. Prof. O.E. Baker examined the problem of land use in the United States in 1923. Glen Trewartha with a Japanese associate broadly portrayed on a series of maps land utilization in Manchuria and J.W. Coulter with a Korean associate presented a similar study for Korea in 1934 (Geographical Review, 1934).

Stamp (1951) pioneered the land use studies in Britain. His monumental work have encouraged and provided guidelines to geographers all over the world. In 1930, Stamp established an independent research organisation called “Land Utilization Survey of Britain”. The objective of the research was to record the use of every parcel of land in Britain. For this purpose, intensive fieldwork was conducted and different land use maps were prepared. Such maps were available in size 18” by 12”, quite handy for field work. A large number of students from schools, colleges and universities came forward to take up the land use work. Almost the whole of Britain was mapped before the outbreak of the war in 1939. On the basis of these maps a voluminous book -*The Land of Britain: Its Use and Misuse* was published in the year 1962 (Stamp, 1962). A second land use survey

of England and Wales, on a scale of 1:25000 has been recently undertaken under the direction of Coleman and Maggs (1961) in addition to numerous sheets and reports.

In the United States also several land use studies have been made. The beginning of land utilization survey in U.S.A. can be traced back to Baler's (1926) published article entitled "*Land Utilization in the United States: Geographical Aspect of the Problems*". In this paper he has depicted the trends in land utilization and emphasized the need of land classification and survey. Besides this paper, government also encouraged the land use studies in the country. Although the programme of land use survey was launched in the year 1935, it was properly executed only after 1938. Nearly one thousand communities were organised and 1,40,000 individuals mostly laymen, took part in the work (Hillman, 1957) and studied the land use including map making and their analyses. Special attention was laid on kind of farming, size of farms in each land use area, area to be recommended for forestry, wild life, recreation, settlements and land recovery, etc.

Land use studies in U.S.A., on the other hand, were made with the purpose not only to select certain areas for proper use but also to train the students for the method of research in land utilization, to make available the knowledge of advanced method of agriculture, and to arouse interest among people, land utilization, food and population problems. However, this can be remarked that U.S.A. has not made so remarkable progress in the field of land use survey like Britain (Kumar, 1986).

Land Utilization maps of Cyprus (1:2,50,000) have been prepared under the direction of Rawson and (1956) in the Department of Geography, London School of Economics. The maps were prepared from about 10,000 air photographs (1:10,000 to 1:13,000) taken in 1949 (Melamid, 1958). The land use maps of Italy are being published representing Calabria. It is in tune with the implementation of the decisions taken by the Italian National Research in the early 1950s to participate in the drawing of a world map of land utilization. As a result of recommendations made by the Commission on World Land Use Survey of the International Geographical Union, the Italian delegation to the 1952 International Geographical Congress presented a map, on the scale of 1:2,00,000 dealing with land utilization in Tuscany. The task of preparing the series was entrusted to the Centre of Studies in Economic Geography at the University of Naples and design scale and other details were worked out by a committee composed of the leading Italian specialists in agricultural economics and economic geography (Kish, 1968).

Dziewonsk and Kostrowicki (1956) have conducted land use survey in Poland on the guideline of land use survey done in Britain by Stamp. Under the direction of Kostrowicki (1968), Department of Geography, Polish Academy of Sciences developed a new pattern of land utilization based on agricultural typology, agricultural regionalization and planning or programming agricultural development.

While coming to land use studies in various countries it should be noted that very few countries hold significant position in this respect. Certainly Japan

has more enthusiasm in this field. The main motivating factor was how to support a huge population with less cultivated land and therefore land use survey has been given the highest priority (Stamp, 1964). Mediterranean countries assessed the use of land, agricultural efficiency in terms of productivity, and changing cropping patterns, and have established their inter-correlations by calculating *r* values (Chauhan and Singh, 1972).

Vink (1975) analysed the concepts of land, land use, land utilization type, land resources, land evaluation, development and management of land. Land resources comprise into two main categories viz., natural land resources and artificial land resources. He carried out land use into two broad categories: (a) Rural land use in its widest sense, including agriculture, forestry and game-cropping as well as wild life conservation and the development and management of recreation grounds; and (b) Urban and industrial land use, including cites, towns, villages, industrial complexes, highways and mining activities.

Devis (1976) suggested a framework for understanding land use in principle and practice in the context of actual land use situation and concerns of both urban and non-urban were addressed. Likewise, Mather (1986) also analysed the uses and management of land and regarded land as a resource base rather than a resource in itself. Land does not fit neatly into the conventional classification of natural resources. Regarding the patterns of land use, he suggested that a direct relationship should exist between land value and location, land use and land value, and hence, between land use and its location.

The research work carried out by Opeyemi (2006) in Kwara State of Nigeria demonstrates the ability of GIS and Remote Sensing in capturing spatial-temporal data. Attempt was made to capture the possibility of different land use and land cover classes as they change through time by using multi-temporal imagery of Landsat Thematic Mapper with a spatial resolution of 30 meters.

Dewan and Yamaguchi (2009) studied and evaluated land use/cover changes and urban expansion in Greater Dhaka, Bangladesh, between 1975 and 2003 using satellite images and socio-economic data. The analysis revealed that substantial growth of built-up areas in Greater Dhaka over the study period resulted significant decrease in the area of water bodies, cultivated land, vegetation and wetlands.

Hendrick and Copenheaver (2009) studied landscape vegetation changes during the period of 1880–2008 in southern Appalachian Mountains, Virginia, USA. Forest land was the most stable cover type (98%) during the assessment period. Nearly 19% agricultural land converted to forest (19%), 18% residential and commercial land to forest and about 57% transportation systems converted to forest or agricultural land according to this study.

Recently, the shrinking glaciers of Kilimanjaro have received much attention as it is one of the few remaining tropical glaciers in the world. Torbick *et al*. (2009) made observations to delineate ice cap fluctuations and land surface phenology on Kilimanjaro over the past two decades by using complementing remote sensing data sets with systematic measurements. Multi-temporal, fine-scale Landsat imagery (30 m) showed approximately a 70% reduction in ice coverage since 1976. High-frequency (bimonthly) image analysis conducted along a human activity–elevation

ecocline showed that the entire mountain, including the subalpine and alpine regions, has undergone an increase in vegetative signal indicating a ‘‘greening up’’ of Kilimanjaro over the past two decades. In addition, upper elevations of Kilimanjaro have undergone a temporal shift, or lengthening, in dry season phenology on the order of one month over the past two decades. The shift in dry season timing is concordant with maximum ablation periods. Overall, this study provides insight into land surface trends at resolutions that are currently lacking in Kilimanjaro climate change analysis.

Monitoring and assessing karsts rock resulting from desertification is important to local sustainable development in the Karsts mountain regions of Southwest China. Huang and Cai (2009) studied the rarsts rock by using the Normalized Difference Rock Index (NDRI). The research mapped karsts rock using supervised classification of Landsat TM bands 3–5, NDVI, and NDRI. The comparison of the final results shows that the combination of NDVI and NDRI has a greater accuracy than other methods. It appears to be a reasonable method for rapid and efficient estimation of karsts rock using digital imagery. The NDRI may also be a useful tool for land use and land cover mapping.

In addition, Kuwari and Kaiser (2011) analyzed the impact of gas field development on landuse/landcover pattern by using remote sensing and GIS. Image data obtained through remote sensing were integrated with data collected from topographic and morphologic maps and field investigations in order to quantify the landuse/landcover changes in the area following the infrastructure development during 1977 to 2008. Land use/land covers were changed over time following the construction of planned developments on the Al Khore area.

In India, several geographers have paid attention on different aspects of land use studies. However, real work started when Stamp visited India and attended the 25th session of the Indian Science Congress held at Calcutta in the year 1938. He put impetus on mapping of land utilization and suggested that the model of land utilization survey of England can also be effectively followed in India.

Thereafter, during the year 1940, Chatterjee (1941) tried to organize the land use survey in India. In his presidential address before the Geography and Geology Section of the Indian Science Congress Association, 1940, he pointed out the necessity of understanding the land use survey. Based on his presentation, Government of India established a National Committee for the purpose under the direction of Chatterjee. He surveyed 800 villagers of West Bengal and brought out 11 land use sheets on the scale of 4 inches to mile. Prior to this, a scheme was drawn for preparing land use maps on scale 1:10,00,000 as a part of the National Atlas Organization. By that time, no systematic land use survey had been initiated for entire country. Rao (1947) has suggested land use classification on the lines of soil survey technique while working on land use analysis of the Godavari region. In addition, Karimi (1949-50) made study of land use in Dinapur Ghusahra village near Patna. Lahiri (1950) studied the major land use types and agricultural problems for four typical villages, near Jasidih. The land utilization survey of 24 Parganas and Howrah districts conducted by Chatterjee (1952) and survey in Eastern Utter Pradesh conducted by Shafi (1961) have made a strong plea to carry out the land use survey combined with the survey of land

capability. These studies helped in determining the best utilization of the land in relation to their intrinsic qualities. Likewise, Ahmad (1954) has analysed land use types in relation to physical elements mainly slopes.

The study of land utilization of five villages of Ballia district has been made by Roy (1961). He has studied the physical conditions, occupational structure and changes in the general land use pattern by comparing the Khasra records of 1882-1883 and 1955-1956 and has revealed the acute pressure of population on land and suggested the facility of irrigation to improve agriculture of the region. Mishra (1964) has studied land use for better adjustment of agriculture to the physical environment and optimum exploitation and conservation of natural resources in Khadar and ravines of the Lower-Middle Gomati Valley. Likewise, Sinha (1965) intensively studied the land use of canal irrigated area of Patna district. Yadav (1965) has studied the broad regional variations in agricultural land use in Rajasthan. Chauhan (1966) studied land utilization of agriculture and discussed the theme covering scope, concept, principles and pattern of land utilization with relative emphasis on land use policy to promote national plan of economic growth.

However, the credit for making an intensive land use study in India for the first time goes to Shafi (1966). He mentioned that land use survey of a vast country like India is easier to be conducted on the basis of sampling as it is very difficult to procure data for all the villages to be surveyed. Later on, Shafi (1972) proposed various sampling techniques for land use survey in India. He preferred

purposive sampling over other four types, i.e., random, stratified, cluster and systematic.

Ahmad and Siddiqui (1967) have studied the crop land pattern in the Luni basin and identified various crop combinations and the scheme of regional classification and recommended the same classification as the basic framework for the future micro level studies in agricultural geography of the area. For analyzing the crop combinations various other methods were also applied i.e., Sinha (1968) has taken the help of Weaver's and Nelson's techniques and; Tripathi (1968) and Garg (1968) have applied Weaver and DOI's methods. Roy (1968) made a study in land utilization in Balia district and measurement of rural land use in Azamgarh, middle Ganga valley. Likewise, Mandal (1969) has elaborated the Weaver's method in analysing crop combination regions with special reference to north Bihar. Das (1969) also studied about population and land resources in north Bihar.

Singh and Pandey (1972) have studied variations in land use classes for the period 1965-66 to 1969-70 in Saryupar plain. Sharma (1972) discussed the problems confronting agricultural land use in the Himalayan Ravi-Chenab doab. He has divided the area into ecological sub-regions and tried to investigate the cropping pattern, etc. and suggested measures for improvements in agricultural land use and cropping pattern and for stepping up the agricultural productivity. In addition, Biswas (1973) found a significant ecological variations giving rise to variations in the spatial organization of the land use and cropping pattern even in a village. Das (1973) presented a generalized picture of overall land use pattern

of Dehradun district and has displayed the effect of physical environment on the agricultural land use. The study revealed the changes in area devoted to forests and it is expected that agricultural land use will improve with modification and improvement in constraints imposing restrictions.

Sen (1974) has reviewed in detail all the different schemes of land use classification proposed by various organizations in India and has suggested a tentative scheme of the land utilization units for the arid zone. The use of aerial photo interpretation techniques in expediting and increasing the efficiency of land use mapping was also highlighted. Yadava (1974) has conducted a land use survey in Zamina tehsil (Ghazipur district) and related the land utilization with various natural and manmade factors. Chouridule (1974) analysed rural land use and nutrition levels in Bhandara district, suggested the bridging of food gap through aquaculture.

Chatterjee and Jana (1975) have selected five villages surrounding Tarakewsar in Uttarakhand for land use survey and land mapping. They pointed out that though area is intensively cultivated giving high yields per unit area, yet comprehensive area development programmes are needed for future improvement of agriculture. Singh (1975) has attempted a study of rural land resources use at meso-regional level covering Baraut block of Meerut district. He has analysed the mutual relationship among different components of land use by making use of a statistical model, i.e., coefficient of correlation (*r*) and found a direct, very high relationship between irrigated area and area cropped more than once. Chouridule

(1975) has referred to various studies relating to rural land use, land use planning and mapping of land use that have been undertaken in India.

A statistical relationship was observed between land use and settlements in the districts of Bhojpur and Rohtas, Bihar (Roy, 1976). Similarly, Prasad (1976) in his study on land use pattern in west Champaran district found an increase in net sown area by 25% with the increase in population. Singh (1977) studied the land use efficiency of Shahganj tehsil and identified 5 land use efficiency categories based on rank-coefficient correlation under four different sets of socio-economic variables. Moreover, Gupta, 1978; Prasad *et al*., 1978; Shinde and Patwar, 1978; and Das, 1979 have also studied land use pattern in various parts of the country.

Banerjee (1979) studied recent changes in the land use pattern of India and has shown that agricultural area of the country may record a marginal increase by 10 to 15 million hectares in the next few years. Although, with little scope for any radical change in the land use pattern of the country in the near future. Accordingly, the emphasis should be given on the production of high value crops like wheat, groundnut etc. in the cropping pattern.

A noticeable work by Sharma and Sharma (1980) on land capability classification of Padrauna block, Deoria district in U.P. and Khan (1980) on distributional pattern of land use in the Ganga Yamuna doab suggested an optimum use of the land sustainably. Likewise, Jha (1980) studied the problems of land utilization in the Kosi basin and Sharma (1980) has emphasized the influence of market factor on agricultural land use with reference to Sagar city.

Raghavaswamy and Vidyanadhan (1980) have also made a detailed study on the land use pattern of Visakhapatnam and its environment with the help of serial photographs.

The changing patterns of crop-land use in Aligarh district have been worked out by Weaver's and DOI's methods (Singh and Wase, 1981). Mandal (1982) has completed a commendable work on land utilization in which he highlights the basic concepts and methods of land-use studies with special reference to factors, principles, approaches of study, land-use models, carrying capacity of the land, land-use classification, agricultural efficiency, remote sensing and airphoto interpretation, land conservation and resource measurement, land reforms, agricultural regions and land-use planning. Hence, this study has an added significance of spatial analysis for better development and economic progress.

A strategy for optimal use of land in U.P. Himalaya and the changing pattern of crop-land use in eastern Uttar Pradesh using a statistical method was carried out by Jalal (1982) and Khan (1982), respectively. Mitra and Roy (1982) have made a study on the changing pattern of agricultural land use at Rangli-Rangliot region in Darjeeling district of West Bengal. A close relationship has been established among farm size, irrigation and intensity of land use in Indian agriculture (Sharma and Chadha, 1982).

For appropriate land use planning, Mishra (1983) have given emphasis on ecological considerations. However, the holistic view of land classification and its impact on environment, as presented by Kostrowicki (1983) is yet to be tested

in India. Saxena *et al.* (1984) with the help of visual interpretation of Landsat imagery studied available ground-water data with subsequent field work. A rational land use plan of the basin has been chalked out on the basis of the soil, land and water potentials of the area. Another useful contribution on the land use study was made by Kumar (1986). He has attempted to portray and analyze the land use patterns of an important area based on first hand study of 12 sample villages readily selected from 12 development blocks of district Nalanda in Bihar. In his work a purposive random sample method has been applied. He also identified a number of problems, some of which arise of defective agricultural practices and lack of consolidation of holdings resulting in misuse of land and therefore, has made useful suggestions for batter use of land.

Taragi *et al.* (1989-90) have studied inter and intra-regional differences in the pattern of land use in the Kumaon Himalaya where physical factors are prominent. Three typical distinctive locations, viz., valley, slope and upland, have been taken into account for the comparison of land use characteristics. It is found that the valley area is best suitable for agricultural activities especially for cultivation. Singh (1989-90) examined the production capabilities of land use of the various size of land holding in Uttar Pradesh. Kumar (1995) presented a new approach to land use planning called organisational analysis and observed that focus is shifted from development plan and development control mechanisms to the elements of the planning function.

Vaidya (1997) in his case study of the Yashoda basin of Wardha district in Maharastra presented an analysis of physical and socio-economic variables,

which impinge on the land use and cropping systems. In his study he identified the relationship between selected land use variables and environmental variables by quantitative techniques, namely, correlation coefficient, multiple regression and factor analysis and examined the role of these variables in the agricultural land use pattern in the study area.

The North-eastern region of India, characterized by rugged terrain is still lacking information on various aspects of natural resources including land use study. The study of the changing pattern of land use in a village of Kamrup district of Assam, called Deharkuchi by Sarma (1970a) is perhaps the first publication of its kind in the whole region followed by another attempt of Sarma (1970b). Kar (1972) made an attempt to analyse the geography of Nagaland based on the study of 4 villages around Kohima. Greater attention has been given to agriculture especially on *jhum* and terrace cultivation. Noticing the dearth of any geographical investigation in rural land use in Nagaland, even such a brief geographical note may be of great aid to geographers to understand the prevailing agricultural land use.

The work of Das (1976) adequately reflected the concern of the scholars on the problems associated with land use of north east region. Sukla (1976) have assessed the land use pattern of Arunachal Pradesh for the first time. A detailed study on general and agricultural land use in the state of Assam was attempted by Das (1982, 1984). Singh (1980) made a micro-study of urban places and identified the various categories of land use in Shillong, Meghlaya. He also attempted to highlight some basic problems in the light of the work done by

social scientists in India and abroad. The study concluded with the identification of problems of urban land use and made suggestions for sound land use planning.

Subsequently, Rai *et al*. (1981) have established a correlation between hill slopes, land use and soil erosion around Shillong. Das (1982) has analysed the agricultural land use and cropping pattern in Assam, wherein he has given greater emphasis on increasing the productivity of crops and on multiple crop-ping of the existing farmlands in the coming decade. The publication- Land Use Pattern in North-East Indi*a*, edited by Dutta (1986) has a remarkable significance. The book contains seventeen papers related various issues, like, the problems and prospects of development of land use pattern and its allied attributes, human resources and use of land in north-eastern India, land use under shifting cultivation, etc.

Das and Dutta (1986) described land use pattern in the states of north-east India. Based on secondary data, they identified various land use problems in different parts of the region. Goswami (1988) has given an analytical account of the land utilization and its economic implications and has also suggested the planning for land use should be prepared in the context of the increase of population in future, their need for education and medical facilities, roads and transport services, requirement of food grains etc. Barman (1989) has portrayed the land use pattern in Assam in an attempt to estimate the rise and fall in the land-area devoted to different classes of land use and their possible causes for a period of 1969-1970 and 1982-1983. Wherein, in view of the increasing demand for various agricultural, forestry and livestock products, a rational land-use

planning is urgently needed so that each piece of available land is put to its best use.

Konwar (1990) has analysed the land utilization and cropping practices in the West Khasi hills district of Meghalaya, one of the most vulnerable hill ecologies of the north eastern region. Singh (1995) has assessed the land use patterns in Meghalaya state and found that the state land use is being directly influenced by various physical characteristics of land. Besides, at micro areal processes, the social traditions and economic factors like increasing demands for agricultural products and production prices also play significant roles in determining the land use characteristics. Sarmah and Bora (1995) have studied the impact on the pattern of land utilization in the Dhaleswari basin of north-east India. Considering the slope zones and their respective land use component, they attempt to make a suggested land use model for proper management of land resources in the basin. Similarly, Singh (1995) have made an attempt to examine the emerging general land use patterns of the Meghalaya plateau by considering the ‘community development block’ as an aerial unit for showing its regional disparities. From the land use classification they found that the relief features and slope are the main determinants of land use patterns emerging in the Meghalaya state.

Bandopadhyaya (1987) has studied the land relations and land use pattern in Mizoram and found that land use pattern is more important than availability. Subsequently, Mizoram Remote Sensing Application Centre (MIRSAC, 1990) studied land use land cover of Aizawl district (undivided) using remote sensing

technology. They classified as built up land, agricultural land, forest, wasteland, water bodies and jhum land. Apart from these, a number of well-organised and useful works on land use in north east region are: Rynjah (1981), Singh (1982), Chattraj (1984), Bhagabati (1985) and Das and Das (1989) are worth mentioning in this connection.

National Remote sensing Centre (NRSA, 2011) prepared 'Land Use Land Cover Atlas of India' based on multitemporal satellite data of 2005 – 06, in which land use land cover of Mizoram is classified as built up, water bodies, wetlands, wastelands, grass/grazing land, forest and agricultural lands. The statistics of each category is shown in district wise. It is an important database and shows the potential of Indian Remote Sensing Satellite series in deriving the requisite spatial information.

Vora (2011) attempted to apply remote sensing and GIS techniques for generation of development plans for the watershed area in consonance with the production potential and limitations of terrain resources and for assessing of the impact of the measures undertaken before their implementation in the field. An integrated use of remote sensing and GIS for development of watershed and for evolution of its hydrologic response, to various land use and management changes was also displayed. The spatial analysis of thematic information, which can be derived from remote sensing helps in the assessment of development plans before they are implemented.

A study was undertaken by Singh (2012) in Mohan Rao watershed, located in two states of Uttarkhand and Utter Pradesh to prepare an inventory of the present land

use/land cover of the area using satellite data and a land use map for land use planning from satellite data, interpreted physiography and soils and terrain information, by following a land evaluation approach through GIS environment. The results indicated the immense potential of multispectral satellite remote sensing and GIS for effectively monitoring regional changes in land use/land cover over a period of time and for preparing a suggested optimum land use map for land use planning.

2.3 Sustainable Development:

The increasing sacking of the non-renewable resources, coupled with skewed distribution of income and wealth, associated with the present style of development being pursued by both developed and developing countries is causing a serious concern to the humankind. Social scientists, scientists and policy makers have of late started wondering whether the type of development that is being pursued at present can last. Beginning with the publication of Brundtland Commission's Report on development and environment in the late eighties, there has been a sustained debate in the academic and administrative quarters on the need for sustainable development. Accordingly, enormous literature is available now regarding concepts, criteria and measurement of sustainable development as well as on the need for, and constraints in, attaining it.

The view that substitution between resources and types of capital can achieve a sustainable outcome was presented for the first by Solow (1974). The World Commission on Environment and Development Report (WCED, 1987) is a

major document in the sustainable development debate. The commission highlighted a judicious balance between the conflicting views and accepting in principle that the world has enough resources to meet the long term human needs, provided proper and efficient management strategies and methods for sustainable development are followed.

Redclift (1987) identified two contradictions that lie within 'sustainable development'. The first contradiction is one which we ignore at our peril: if we cannot rely upon market forces to sustain our environment, we need to place very much greater reliance on international agreement and planning, without which individual, personal or national, interests will dictate the course of the development process. A second contradiction concerns the relationship between the political struggles over the environment between developed and developing countries. He also noticed three important areas for which sustainable development has implications: the view that we hold of 'environmental rationality', the changing role of technology in our relationship with the environment and the body of social theory that can help us interpret and understand this relationship.

The sustainable development is the total development of the society, economic changes, social and cultural transformation taking into consideration the social well being and security of the poorer sections (Barbier, 1987). Tisdell (1988) investigated the differing perspectives of ecologists and economists on sustainable development, and it relevance to LDCs. It was noticed that to aim for a sustainable society, for sustainable economic development and for a productive

system is desirable. This reflects the outlook of ecologists rather than the majority of economists. A basis is established for considering whether sustainability of productive systems is likely to be a more important goal in less developed countries than in developed countries. Further examples of the stress of ecologists on the production sustainability goal are given and additional policy prescriptions are discussed.

The sustainable use of natural resources in developing countries was discussed by Pearce (1988). He has argument that conventional economic analysis can provide valuable insights. He indicated that both price and fiscal reforms could do much in the short term to conserve scarce environmental resources. The market pricing of fuels and the imposition of resource exploitation taxes would both contribute to a more sustainable use of renewable resources in developing economies. Pearce *et al.* (1989) investigated the blueprint for a green economy by using vector notation to explain the term sustainable development. In such notation, development is considered to be a vector D, defined as a function of increases in real income per capita, improvement in health and nutritional status, educational achievement etc. For sustainability to exist development (as captured by the vector D) should monotonically increase over time, i.e., dD/dt should be non-negative.

A reasonably good inter disciplinary work in the form of collection of articles, on sustainable development is available in a volume edited by Adiseshiah (1990). Most of the social scientists contributed paper on the volume, covers sustainable development: what it is and its coverage; sustainable

development in operation; governing of resources and resources of governing; technology and environment in water development; the problem and project displaced persons; and synthesis of the discussion on sustainable development.

Operational guidelines on sustainability in general were discussed by Daly (1990) and he suggested 4 basic rules i.e.; 1) the main principle is to limit the human scale to a level which, if not optimal and at least within carrying capacity and therefore sustainable; 2) technological progress for sustainable development should be efficiency increasing rather than throughput increasing; 3) harvesting rates should not exceed regeneration rates and waste emissions should not exceed the renewable assimilative capacity of the environment and; 4) non-renewable resources should be exploited at best at a rate equal to the creation of renewable substitutes.

However, review of the literature available on the concept of sustainable development indicated a lack of consistency in its interpretation (Lele, 1991). While the all-encompassing nature of the concept gives it political strength, its current formulation by the mainstream of sustainable development thinking contains significant weaknesses. How these weaknesses can lead to inadequacies and contradictions in policy making is demonstrated in the context of international trade, agriculture and forestry. Lele (1991) further suggested that if sustainable development were to have a fundamental impact, politically expedient fuzziness would have to be given up in favor of intellectual clarity and rigor.

World Bank (1992) described how environmental problems can and do present obstacles to development, such as situations where the benefits of rising incomes are offset by the costs imposed on health and the quality of life by pollution. Future productivity can be jeopardized if rising income today result in soil degradation, depleted aquifers and destroyed ecosystems. Alleviating poverty is a moral imperative and a prerequisite for environmental sustainability; the poor are both the main victims and among the agents of environmental damage. Rapid economic growth will be required to alleviate poverty and to lower population growth rates. However, that growth brings with it the risk of appalling environmental degradation. The challenge, the report asserted, is to ensure that the past links between economic growth and a deteriorating environment are broken.

Meadows *et al.* (1992) discussed that human use of essential resources and generation of pollutants has surpassed sustainable rates. Unless there are significant reductions in material and energy flows, the world faces an uncontrolled decline in per capita food output, energy use, and industrial production. In order to avoid this decline, growth in material consumption and population must be eased down at the same time, as there is a rapid and drastic increase in the efficiency of materials and energy use. A sustainable society is technically and economically feasible. Environmentally sound development strategy for hill areas was studied by Maithani (1992). The study was confined to conceptualize and design an environment-friendly strategy for hill area

development as well as to ample scope for formulating micro level programmes for sustainable development in Himachal Pradesh.

Misra (1993) investigated the concept of sustainable development and its goal, the essential components of environmental sustainability and then highlighted the rich tradition of sustaining environment in India since ancient times, drawing supportive evidence from *Vedic* literature. Inamdar (1993) attempted a broad survey of the global environmental crisis, its causes, and initiatives at international flora to prescribe directions of policy for remedial measures including plan, policies, and legislations in India and followed by achievements shortfalls in attaining objectives along with reasons thereof.

Reviewing the sustainability therefore indicated that our current course is not sustainable, given that our concern is, and must be, for the welfare of present and future generations (Viederman, 1993). Barnabas (1993) has also analyzed the development process in India, indicating its achievements and drawbacks. Subsequently, he focused on policy implications of sustainable development, discussing the steps that need be taken to promote sustainability of the achievements envisaged in development programmes and diluting their negative impact.

A volume on economics and ecology; new frontiers and sustainable development was edited by Barbier (1993). This volume besides highlighting traditional environmental economics also focused on mathematical models. Also, a survey of conceptual issues of sustainable development carried out by

Santhanam (1993) and he identified the factors that facilitate people's participation.

The purpose of people's participation in the context of sustainable development was examined by Mishra (1993) and he evolved a new model. Similarly, Gupta and Gurjar (1993) stressed on 'environmental facets' and 'human ecological and planning basis' for sustainable development as well as agricultural resources and sustainability'. Agarwal (1992) argued that sustainable development will be the outcome of a political order in which a society is so structured that it will learn fast from its mistakes in the use of its natural resources and rapidly rectify its human-nature relationships in accordance with the knowledge it has gained. Besides, Nayar (1994) discussed the politics of sustainable development as it is deeply rooted in the very conceptualization of the approach, which is ill defined and vague. A sustainable development for the south cannot at the same tie ignore the fact that the present models of development do not cater to needs of the vast majority. Bringing the notions of population growth and carrying capacity into our own national environmental strategy is tantamount to what the north would consider a safe approach to sustainable development. Gowariker and Sachs (1994) studied redefining the good society- a north-south dialogue on challenges of 21st century and observed that the complex problems facing humanity demand the evolution of a strategy of sustainable development.

Appropriate policy instruments for fostering sustainable development and which institutions will best implement these policies and sustain them in the

years to come was discussed by Scott *et al.* (1995). Chaudhry (1995) mentioned that the nature of environmental problems depends upon the level of economic development, the nature of industrialization, the degree of urbanization and the effectiveness of public policies. Hammond *et al.* (1995) focused on policy-making and provided concrete measures of effectiveness and, hence, accountability. Unlike economic and social indicators, which are well developed and widely used, indicators for the environment are just beginning to be formulated. Drawing on illustrative examples and case studies, Hammond *et al.* (1995) also provided a conceptual model for designing environmental indicators and proposes specific, highly aggregated indicators at a national level. Moreover, compilation of work on sustainable development: policy and practice by Moore and Ryan (1995) also contributed significantly.

The relationship between development and the environment at the global and the national level was analyzed by Roy (1996) to understand sustainable development. He emphasized on shift from state to market led development policies. This analysis provides some insights into the process of sustainable development and issues for further research. Likewise, Dale and Robinson (1996) make a multidisciplinary look at sustainable development in Canada in its entire dimensions including ecological, social, political and economic. It brought together the views of some Canada's leading researchers and policy analysts in the field and argued for changes in decision-making, institutional transformation, equity between and within nations.

Iyer (1996) critically analyzed the existing paradigm of development and presents a perspective of sustainable development, which ensures the compatibility between environment and development needs of the present and future generations. Besides the adverse effect of the GATT agreement, topdown approach, rice/wheat rotation, impact of heavy doses of fertilizers, impact of industrial pollution and role of voluntary organisations in the development of sustainable agriculture etc. have been discussed. Ray and Ghosh (1996) pointed out the bottlenecks of current development and concluded that India is unlikely to achieve sustainable economic growth, despite the current phase of economic reforms which began in 1991. Other noticeable work carried out by Franks (1996), Franke and Chasin (1996), Kumar and Singh (1996), Pratap (1996), Shukla and Sharma (1996) and Tisdell *et al*. (1996) on various aspects of sustainable development.

Current sustainable development indicators without the application of clear methods may be ineffective in promoting sustainable development and possibly detrimental to the process (Mitchell, 1996). He further outlined fundamental steps that should be followed to produce any list of sustainable development indicators. Franks (1996) reviewed successive paradigms for appraising and managing the environment as a background to define three dimensions of the management of sustainable development i.e. natural resources systems, institutional development and appropriate management skills with key areas for development also suggested.

To make development more sustainable under economic reforms, decentralized programme for rural upliftment should be tied up with plans for betterment of eco-systems so that the ecological objectives could also be tackled almost simultaneously (Ghosh, 1997). Subsequently, Ray and Ghosh (1997) discussed the kinds of economic and administrative reforms that would be required to achieve sustained improvements in the standard of living in India. Mezher (1997) also stressed the importance of eco-efficiency in the development of the economy in Lebanon. It also discusses the environmental problems in the country and proposes technological, industrial, and sustainable development strategies. Likewise, Scott (1997) assessed the development and potential of forums in progressing sustainable development within Britain. The example of Cardigan Bay Forum is used to assess how one forum's approach has contributed to sustainable management and development outcomes. Daly (1997) argued for global understanding of developing welfare that does not entail expansion.

Issues related to designing a management programme that attempts to incorporate sustainable development as a core theme at a time of uncertainty and rapid change were reviewed by Hailey (1998) and outlined the structure and process of a management programme to become more aware of the centrality of sustainability to their work and the decisions they make. Stressing on some key issues of sustainable development, Sharma (1998) argued that any economic activity that continues without a healthy balance between the natural resources, its ecology and environment shall result in unsustainable development. In general, we need to reconcile ecology, economics and ethics in an integrated

manner by keeping our needs at the possible minimum level so as to ensure sustainable development (Jena, 1998). In addition, Sharma and Chattopadhyay (1998) highlighted many case studies from India for micro-planning, farming systems, ecological impact evaluation and land use plan for sustainable development.

Important dimensions and issues in sustainable development were highlighted by Singh (1999) and he suggested that there is an urgent need to formulate and implement strategies that will allow us to move from the present, often unsustainable processes of growth and development onto sustainable development paths. He also spelled out important elements of a pragmatic strategy for sustainable development. As economic development of a rural area is largely governed by use of its land resources, Satyal *et al.* (1999) analysed land resource in the context of economic development keeping in mind the sustainability of fragile mountain ecosystem. With hardly any scope for expansion of arable land, sustainable utilization of resources for their traditional sectors of tribal economy like cultivation of medicinal plants and herbs in pasture land, use of barren land for increasing sheep population based on its biomass production capacity and strengthening the woolen industries are suggested as a viable option for sustainable economic development.

Chopra and Kadekodi (1999) made an attempt to develop an operational model of sustainable development in a regional setting through an in-depth case study of Palamau district in the Chotanagpur region of India. The study has made a significant methodological contribution by developing a manageable economic-

ecological model that can be used to simulate the economic development process along with environmental interactions. Desta (1999) examined the question "can sustainable economic development be achieved without strong environmental protections?" and explored ways that environmental sustainability has been and might be incorporated into existing theories of economic development. Protection of the environment is an essential part of development, and the best chance for achieving long-term sustainable development is to systematically incorporate environmental issues into key aspects of economic development paradigms. Furthermore, Desta (1999) also described use of theoretical approaches, drew policy implications, and illustrated each point with in-depth case studies from developing countries.

In addition, Taori (2000) dealt with rural industrialization related aspects of sustainable development and Hempel (2000) made an attempt to draw together the different strands of thought from the scientific, economic and political fields and make up a coherent vision of what may be possible in future. It may be an optimizer's rather than either a cornucopia or catastrophic vision of what lies ahead but the work remains, for all that, an impressive achievement in 'reconceptualisation' of the global environmental problems. Ellis *et al.* (2001) highlighted the shrinking natural resource base in Asia and emphasized on rise in production to meet food security needs while preserving the environment and the livelihoods of generations to come. Modern technology options are available; however access to knowledge is the key to bridging the farm technology gap and getting this knowledge to farmers.

Causal relationship between population growth and environmental degradation was studied by Rohini and Bhat (2001). Similarly, Sengupta (2001) analysed the basic concepts of ecological study and the inter linkages between environment and economics for sustainability. He outlined 3 main laws or processes relating to the functions of nature i.e. entropy, flow of solar energy, and bio-geo-chemical cycles of nutrients and enriched the analysis with examples and case studies from the Indian context. Carvalho (2001) examined the roots of the sustainable development concept and argued that within the current international political economic system it would be nearly impossible to adopt development strategies that are conducive to truly sustainable development and therefore, profound changes in economic, political and social structure would be necessary to foster sustainable development. Therefore, focus should be on a regional partnership like a multi-sectary partnership agency promoting sustainable development in the north-west of England (Shaw and Kidd, 2001). Likewise, Bebarta (2004) highlighted the environmental problems and global forest resource crisis, the concept of sustainable development per se and its application in the field of environment and forestry and also dealt with the concepts and principle of sustainable forest management, policy and strategies on holistic basis.

Kalra *et al.* (2010) identified soil constraints for sustainable development using remote sensing and GIS in Bhilwara district, Rajasthan in which Indian remote sensing satellite Imagery (IRS LISS – III FCC images) were interpreted for soil constraints by using physiography soil approach, field checking and laboratory

analysis. The study reveals that 17% of the area has constraints due to salinity, 48% were due to uneven terrain and shallow soils, and the remaining area has no constraints with high potential for crop production.

Bante *et al*. (2012) studied characterization and evaluate land resources for watershed management in Taroda watershed, Nagpur district, Maharastra by using remote sensing and GIS in which landuse/land cover, slope and physiographic soil were generated for deriving land capability and suitability for crop production. The thematic maps in conjunction with physical and chemical properties of soils were overlaid for generating sustainable development plans of the watershed.

In general, sustainable development is a complex process that encompasses the different dimensions of development such as economic, environmental, and social (Campagna, 2006). Therefore, we need to look on diverse perspectives of the problem, taking into account methodological, technical, organizational, and societal issues related to the use of tools including GIS to solve complex problems faced by practitioners in planning and implementing the objectives of sustainable development.

It is to be noted that the studies /reports on sustainable development of the whole of north-eastern region of India or any part of it are very limited. Velde (1979) reviewed the efforts made by geographers in planning and development process that focused upon north-east India to ascertain whether the ecological principles have been perceived. He concluded with the observation that there has been a notable absence of serious consideration of the value of a need for an ecological perspective. However, after a long time since then, Gopalakrishnan

(1990) tried to relate the development processes operating in the region should be conceived only after taking the ecological aspects fully into account.

Based on papers presented during national seminar on horticulture for sustainable income and environment protection held in Kohima during 24th – 26th February, 2004, Singh *et al*. (2006) presented a book with two volumes on database of horticulture crops and their produces and advances in general horticulture practices. Chapters of the books further deal with strategy to enhance production and productivity of major fruits and ornamental crops based on generated research and development activity to meet regional, national and international demand as well as post harvest management and marketing strategies.

The development strategies for the north-east region were also dealt with by Pathak (1990) who expressed that the starting point of development process should be the careful inventory of agricultural resources including *jhumming* practices and the ecological balance is not upset. Nayak (1990) referred to certain environmental and human characteristics of the hilly states of north east India and expressed that the development activities should emphasise on community rather than individual and maintaining equilibrium between society and environment. The work of Goswami (1989) discussed various aspects of flood and its impact on agriculture of Assam and advocated for re-organisation of the cropping pattern and crop rotation according to the flood environment to ensure sustainable development of agriculture. Similarly, Barua (1990) compiled a volume comprising information on ecology and land use, approach to

development, rural and man power development in north east region of India. Pandey (1990) discussed some measures to control environmental degradation in the north eastern region and highlighted the degradation of the hill ecology due to deforestation and shifting cultivation. He prepared a blue print of hill agriculture management in the region. John (1995) made an in-depth analysis of what has happened so far and continues to happen in the north-eastern region in the name of development. He observed that sustainable development in the region requires strengthen in agriculture, transportation, marketing, education and serious evaluation of government development schemes, bank loans etc. The basic assumption should be to use local resources to boost local economy and then export the surplus. Only then will sustainable development come to north-east India.

A study on the sustainable agriculture development strategy for north-eastern hill region of India was carried out by Singh *et al*. (1996). Subsequently, land use systems identified as very important aspect to ensure sustainable agriculture development. Das (1996) studied traditional socioeconomic aspects of Arunachal Pradesh and sought for alternative approach to ensure sustainability. Similarly, Mukherjee (1996) has examined the issues connected with utilisation and conservation of forests in reference to sustainable development and argued shift from exploitative approach to protective approach to avoid conflicts between ecology and development. Srivastav (1996) also discussed the status of environment and levels of economic development. He sought for holistic, feasible and balance approach, which considers social economic and environmental

aspects of development keeping human aspirations and requirements at priority. This approach would definitely a forward step in the direction of achieving the goal of 'just' and sustained economic development (Srivastav, 1996; Ganguly, 1996). Chaudhari and Parvati (1996) made an attempt to identify the major problems and analyzed the impact of development processes on the forest resources of the country with main emphasis on north-east states. Due to hilly terrains, region is facing hazards of unstable relief and slope, rapid erosion of soils of "*jhum*" sites and presence of wet desert (Cherrapunji).

Horticulture developments in north-eastern India were also dealt by Ghosh (1985) and he outlined the current position and potentiality of horticulture industry for sustainable development. Likewise, Das *et al*. (2009) observed climate change and its impact on agricultural production in north-east India. It also suggested the urgent need for reassessment of the agricultural practices that conserves natural resources for enhancing productivity and mitigate the climate change in the region. Similarly, Agarwal (1999) analyzed the structure of the economy of tribal areas in north-east India. Besides, he also suggested a development strategy based on agro-based industries for the sustainable development of tribal areas in north-eastern region.

Sarma (2005) carried out satellite based assessment of deforestation in Karbi Anglong district of Assam and suggested remedial measures. Role of remote sensing and GIS based inputs in livelihood improvement from forests in north eastern region was carried out by Chakraborty and Sarma (2008). He identified natural resources of the areas as a key for planning sustainable development.

Kumar (1996) made an attempt to assess the level of environmental degradation as the artifacts of developmental processes through the chosen study of the state of Mizoram. Later on, Jha (1997) edited a volume of research articles on the natural resource management of Mizoram. This volume gives detail account of resource bases of Mizoram; land tenure system; shifting cultivation; role of co-operative society in agriculture sector; forest resources etc. Likewise,

Laldailova (2001) carried out land ownership pattern, land use and sustainable development for Mizoram state highlighting that the needs of the society are highly dynamic. Accordingly, measures are needed to achieve sustainable development.

Upadhyaya (1987) suggested that encouragement of orderly growth and better income and asset distribution of the subsidies, which have mainly benefited only a few, individual, should be withdrawn in a systematic and phased manner in Mizoram. Colney (1988) studied soil and watershed characteristics of part of Tlawng river catchment, Mizoram using remote sensing techniques in which soil survey and watershed analysis have been carried out. The report showed soil classification up to series level and land has been evaluated for their suitability. Devi *et al.* (2008) worked on change in vegetation cover of Dampa Tiger Reserve, Mizoram in which she concluded that deforestation could leads to a serious threat to tiger population.

Department of Horticulture, Government of Mizoram (2011) highlighted different horticultural crops with the success story of farmers in fruit crops, spices, flowers, vegetables, aromatic and medicinal plants, mushroom cultivation, etc. where farmers earned thousand of rupees for their produces and mentioned that there is a

good scope for horticulture development in Mizoram. Furthermore, sector may also contribute to achieve the ultimate goal of sustainable development in the state.

Mizoram Remote Sensing Application Centre (MIRSAC), Dept. of Science and Technology, Aizawl in collaboration with National Remote Sensing Agency (NRSA), Hyderabad had taken up a joint project “Integrated Mission for Sustainable Development of Mizoram” using remote sensing and geographic information systems in 1998 in which different natural resources have been studied and analysed for generation of action plan for land and water resources. Under the sponsorship of North Eastern Council (NEC), MIRSAC (2009 had taken up natural resources mapping of Mizoram using remote sensing and geographic information system (GIS). As outcome, different natural resources of Mizoram have been mapped and prepared an Atlas for the whole state of Mizoram.

Based on review of the work as cited above, it may be concluded that a considerable work on land use and sustainable development in the global context has been carried out. Besides noticeable work carried out in Indian context, and still lot more is required especially at regional level including i.e. north eastern Indian states. In fact, there is hardly any literature in this field as far as the state of Mizoram is concerned. Despite the absence of previous works compounded by difficulty in obtaining data, the present work will consequently, pave the way for future land use plan, and will help the economists and planners of various departments and farmers in some aspects for sustainable agro-horticulture developments of the state.

CHAPTER III

MATERIALS AND METHODS

3.1. The Land:

Mizoram, literally means the land of the Mizos, is one of the full fledged state of the Indian Union. It was formerly known as Lushai hills and administered by a political officer under the British in 1890. In 1952, it was elevated to the status of an autonomous district, and in 1954, by legislation; it was renamed as Mizo district. The North-eastern reorganization act of 1971 granted it the status of a Union Territory under its present name Mizoram. It attained statehood on 20th February, 1987 (Pachuau, 2009). Geographically, the state is located between 21° 30´ N to 23° 15´N Latitudes and 92° 16´E to 93° 26´ E Longitudes. It is located on the north-east corner of India sandwiched between Myanmar and Bangladesh. With a geographical area of over 21, 087 sq km and perched on the high hills and possibly has the most difficult terrain, over 80% of the total geographical area being hilly and with steep hills separated by rivers flowing north to south. The average height of hill ranges is around 920 m, although the highest peak, the Blue Mountain (Phawngpui), goes up to 2165 m. The international boundary with Myanmar and Bangladesh is 404 km and 318 km, respectively and the total share of international boundaries is 722 km (Statistical Handbook of Mizoram, 2010). It is bounded on the east and south by Myanmar; on the west by Bangladesh; on the north-west by Tripura state of India; on the north and north-east by Assam and Manipur states of India, respectively. Its geographical borders with Assam, Manipur and Tripura extend over 123 kms, 95 kms and 66 kms, respectively (Statistical Handbook of Mizoram, 2010).

Aizawl district is one of the eight districts of Mizoram and lies in the northern part of Mizoram. It is situated between 24˚ 25' 16.04" and 23˚ 18' 17.78" N Latitudes and 92˚ 37' 03.27" and 93˚ 11' 45.69" E Longitudes (SRSC, 2006). It is bounded on the east by Champhai district and Manipur state, on the west by Mamit district and Kolasib district, on the north by Cachar district of Assam state and on the south by Serchhip district. The total geographical area of Aizawl district is 3576.31 Sq km and accounts for 16.96% of the total geographical area of the state. Aizawl district falls in the survey of India topo- sheet nos. 83D/15, 83D/16, 84A/9, 84A/10, 84A/11, 84A/13, 84A/14, 84A/15, 84E/1, 84E/2, 83H/3 and 83H/4. The location map of Aizawl district is shown in figure 3.1.

The terrain of Aizawl district is young and immature. It shows prominent relief features with steep slopes and it is still undergoing denudation in response to various exogenic and endogenic processes (AFC Ltd., 1989). Since the terrain is young, there is not much diversity in the formation of landforms. Most of the landforms are of an erosional nature. The hill ranges run from north to south direction and are separated by a number of rivers creating deep gorges in between the north-south hill ranges. The hill slopes are steep to very steep and escarpments are common. The western slopes are comparatively having higher degree of slopes. There are few patches of flat land scattered at places and they are mostly located in the midst of hills and narrow valleys. The plain areas located in narrow valley covered by rich alluvial soils and are utilized for permanent rice cultivation.

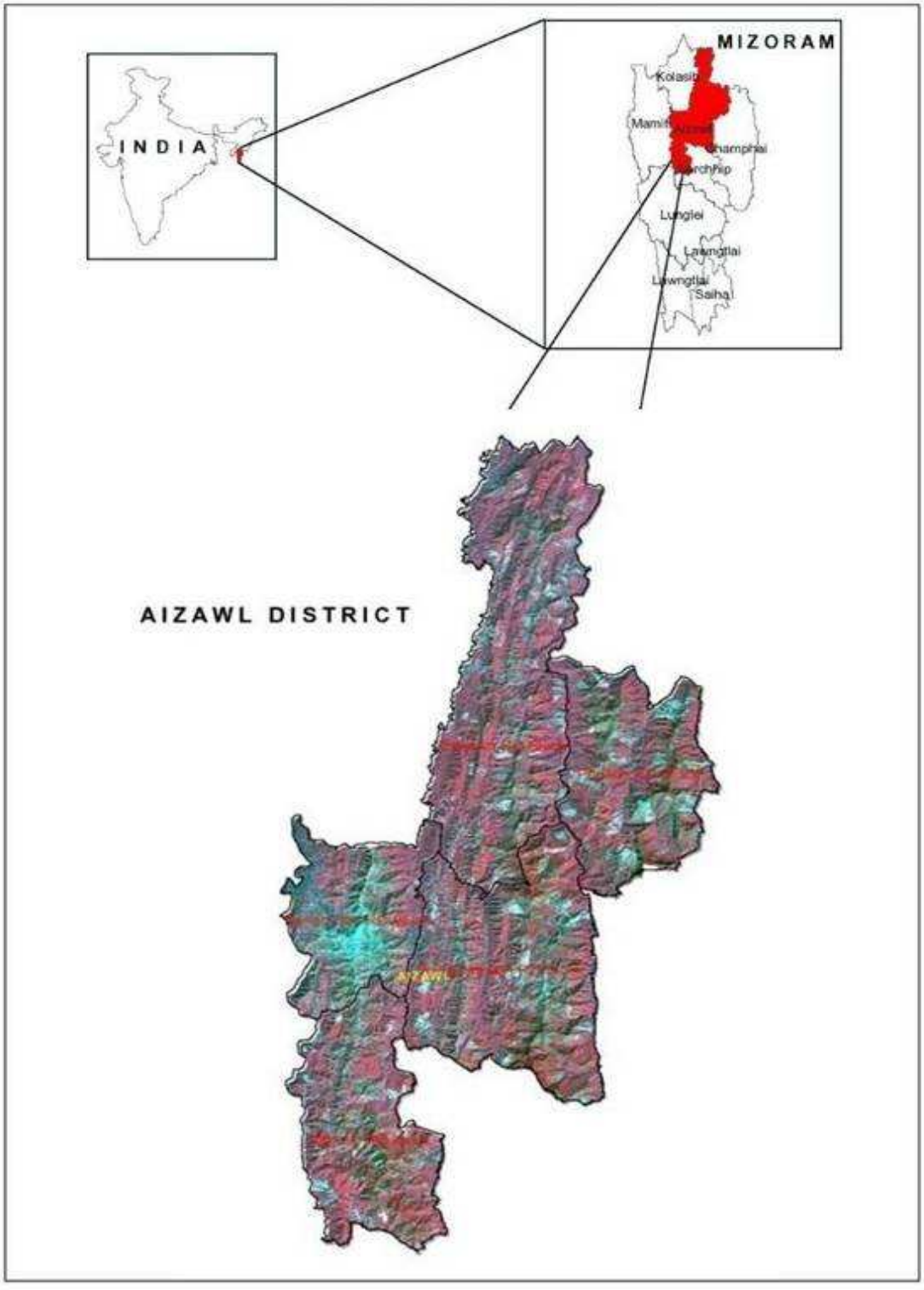


Figure 3.1 : Location map of Aizawl district, Mizoram

The district has great natural beauty and endless varieties of landscape. It is very rich in flora and fauna. It has an abundant growth of vegetation (MIRSAC, 2009). Bamboos of different kinds grow abundantly everywhere. The flowering of the bamboos at an interval of about 50 years has always been accompanied with famine caused by swarms of rats which literally devour all the crops (MIRSAC and NESAC, 2009). These resulted famine in the entire hill state. Besides bamboos, there are many valuable species of tropical and sub-tropical trees. The forest produce includes timber, fuel wood, bamboos and canes, medicinal plants, orchids and domestic resources. The common timber species found in the area are *Dipterocarpus turbinatus, Artocarpus chaplasa, Terminalia myriocarpa, Duabanga sonneratoides* and *Michelia champaka* (Anonymous, 2003). The dominant species in the district are *Celtis tetrandra, Anthocephalus chinensis, Wendlandia grandis, Protium serratum, Phoebe lanceolata, Phoebe attenuate, Ficus benghalensis, Garuga pinnata, Callicarpa arborea, Albizzia chinensis, Oroxyllum indicum,Aporusa octandra* and *Erythrina stricta* etc.

Based on Champion and Seth (1968) classification, the following types of forests are found in the state: (a) Tropical wet evergreen forests (up to 900 m); (b) Tropical semi evergreen forests (900-1500 m), and (c) Montane sub-tropical pine forests (1500-2158 m). The tropical wet evergreen forest is the predominant forest with dense tall trees. The tropical semi-evergreen forest, dominated by deciduous species and the montane sub-tropical forest mainly on upper reaches of mountainous ridges and dominated by pine, quercus, etc (E and F Department, 1989). The first two types of forests covered major portion of Aizawl district, while parts of north and eastern regions of montane regions are under the third type of forests. Many of the

natural forest have been degenerated due to slash and burn method of cultivation (shifting cultivation), timbering and fueling. In order to minimize the degradation of forests, the government has started afforestation by planting valuable tree species, such as, Teak, Gomari, Pines, Eucalyptus and many other indigenous trees. New Land Use Policy (NLUP) was introduced by the state government in order to change the age old practice of shifting cultivation to permanent cultivation. Attempts have been made to develop Tea, Rubber, Eleurites, etc. in many places of the state. Agriculture is the main occupation and the main crops grown are Rice, Ginger, Pineapple, Banana, Orange, Maize, Sugar cane, Passion fruits, Squash and other vegetables.

The climate and vegetation of Aizawl district offers ideal sanctuary to wildlife animals. The population of wildlife fauna has dwindled considerably due to age old practice of shifting cultivation and excessive hunting. The Rhino and the Brow-antlered deer were also said to have existed once in the state. Even the Elephant and Bison which were quite abundant in the past have become rare and confined in deep forests. In order to bring awareness among the people, the government has set up wildlife and birds sanctuary at different places (Lalramnghinglova, 2003). The government and voluntary organisations of the state have taken step towards protection of wildlife.

3.2. The Climate:

Climate is an aggregate of all atmospheric or meteorological influences such as moisture, wind pressure, temperature and evaporation which combine to characterize a region and give it individuality by influencing the nature of its landforms, soils, vegetation and land use. Climate is one of the most important factors of the

geographical environment to which man is a subject (Lal, 1993). The elements of the climate that control the economic development of a region are rainfall, temperature, humidity, sunshine hours, wind and the number of rainy days (Bote and Pillai, 2010).

The climate of Mizoram as a whole is controlled by its location, physiographic, pressure regime in the north west India and Bay of Bengal, warm and moist maritime tropical air masses from the Bay of Bengal, local mountain and valley winds. In addition, the Chin hills, Arakan Yoma hill tracts and Chittagong hill tracts also play an important role in shaping the climatic condition of the state (SRSC, 2004).

The climate of Mizoram is tropical monsoon type. It is neither very hot nor too cold throughout the year. Aizawl district falls under the direct influence of the south west monsoon. As such the area receives an adequate amount of rainfall which is responsible for a humid tropical climate characterized by short winter and long summer with heavy rainfall.

3.2.1. Seasons:

Based on the variation in temperature, rainfall, humidity and other general weather conditions, 4 different types of seasons are observed in the district. The cold or winter season is the coldest season of the year. It starts from the month of December to first half of February. The spring season is the shortest season of the year which starts from the second half of February to the first half of March. The summer season or rainy season is the longest season covering about seven months starting from the second half of March till the first half of October. A study from the daily rainfall records also reveals that the heavy outpour generally starts from the second quarter of May and this heavy outpour is usually subsides in the first quarter

of October. Rainfall during May, June, July, August and September i.e. 5 months alone contributed 76 % of the total annual rainfall. The cyclonic rains are also often felt. The temperature remains high, but is kept down to a considerable extent by the usual rains. The autumn season covers for a period generally starting from the second part of October to November. The season is very pleasant and the summer rain already diminished.

3.2.2. Temperature:

The temperature data of Aizawl district obtained from meteorological data of Mizoram (MIRSAC, 2012) are presented in table No. 3.1. The thermo-characteristics of Aizawl district indicated that temperature do not fluctuate much throughout the year. The highest temperature observed during the last 25 years was recorded as high as 36.7^{o}C in the month of April, 1999. In general, July, August and September were the warmest months for the whole year with average monthly maximum temperature of 30.4°C, 30.7°C and 30.9°C, respectively whereas, the average monthly minimum temperature during these months were 18.7°C, 18.9°C and 18.5°C, respectively. The temperature remains high; however, the enduring monsoon brings down the temperature.

The temperature started to fall down sharply from the month of November and it is minimized in December and January. January is the coldest month with the average monthly maximum temperature of 25.9°C and the average monthly minimum of 8.2°C. However, the lowest minimum temperature recorded was 5.4°C in December, 1991.

Table 3.1: Monthly Average Mean, Maximum and Minimum Temperature Data of Aizawl district, Mizoram (1986 - 2011)

Year	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		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
1986	25.0	9.1	27.7	10.2	33.2	12.4	31.8	12.4	31.4	13.6	32.9	17.0	32.4	16.7	31.9	17.4	29.2	16.4	29.9	14.5	27.5	12.6	26.9	9.4
1987	26.6	7.8	28.1	9.4	30.7	10.0	32.4	11.7	33.0	15.2	31.5	18.9	30.5	18.9	30.4	19.2	29.8	18.4	32.4	16.4	29.9	12.4	23.4	10.9
1988	24.0	10.4	27.2	11.2	30.6	13.4	34.6	14.2	29.6	15.8	32.0	18.2	29.4	18.0	30.6	16.6	31.6	15.8	30.4	17.8	28.6	16.2	25.6	11.8
1989	23.0	5.8	27.2	8.2	32.2	14.8	34.4	14.6	33.2	16.6	31.6	18.8	31.8	18.6	30.0	19.0	30.2	19.2	30.3	17.2	26.0	13.8	23.4	9.3
1990	25.8	9.4	25.4	10.0	28.6	11.2	27.4	12.4	30.2	15.6	28.8	17.8	27.4	19.0	NA	NA	30.3	18.6	31.3	15.4	27.3	13.6	25.2	11.0
1991	26.4	8.2	28.0	11.0	31.8	13.4	33.8	12.4	30.2	14.0	29.8	17.6	31.0	19.2	32.0	19.0	29.0	18.0	31.0	16.2	26.4	12.0	24.6	5.4
1992	23.0	7.4	23.4	9.4	32.6	10.2	33.0	13.0	33.8	13.4	33.6	17.4	31.2	18.2	31.4	18.0	32.2	17.8	30.0	15.4	31.0	12.0	24.4	9.6
1993	24.6	6.8	27.6	8.4	30.6	12.4	32.6	11.6	32.0	13.8	29.0	15.0	30.2	17.6	28.9	18.0	31.8	17.4	30.0	15.2	27.2	13.8	NA	NA
1994	29.8	8.4	29.6	8.4	31.4	11.6	34.0	12.7	34.0	17.2	31.7	17.2	31.2	19.2	30.2	18.8	30.9	18.7	31.3	17.5	30.7	15.2	26.0	13.7
1995	27.8	11.7	28.7	14.7	34.4	17.2	34.7	16.5	32.7	19.7	32.1	19.7	29.7	18.4	31.5	20.2	31.1	21.2	30.9	20.2	29.7	13.0	25.9	11.3
1996	24.3	8.3	27.5	12.2	31.3	17.8	33.9	18.2	32.3	19.7	30.9	20.9	30.5	21.9	30.5	22.8	33.9	23.8	32.5	21.2	29.7	16.3	NA	NA
1997	25.1	7.0	26.3	8.4	30.9	12.7	30.9	13.2	33.3	16.1	30.7	16.8	30.1	19.5	NA	NA	30.0	17.9	30.0	17.0	29.9	13.8	24.5	9.0
1998	24.1	8.4	27.5	9.3	30.3	11.0	31.2	14.1	32.6	17.2	32.3	18.5	30.0	19.3	29.3	18.8	31.2	19.1	30.5	15.2	30.1	16.2	26.7	12.3
1999	27.0	9.4	32.9	11.3	33.1	13.4	36.7	16.0	35.3	15.4	30.9	16.5	29.7	18.6	30.9	18.7	29.1	18.7	30.0	17.7	28.4	13.7	25.3	10.4
2000	26.1	7.0	27.1	10.5	31.5	11.5	32.1	12.9	33.1	13.9	31.9	17.5	30.5	18.0	30.7	16.9	29.7	17.1	31.1	15.8	29.6	10.0	23.4	9.7
2001	26.5	6.5	30.5	10.0	33.8	12.4	35.1	13.3	32.8	12.9	32.3	16.9	31.2	17.2	31.4	20.4	30.6	19.4	30.4	17.9	28.0	13.2	25.6	12.0
2002	28.2	10.0	31.2	10.0	32.6	13.0	31.5	11.2	31.8	14.0	29.7	18.2	28.5	19.4	30.2	19.2	30.6	19.0	31.0	16.4	30.2	12.8	26.2	9.0
2003	26.2	8.6	27.8	11.4	30.4	10.6	32.4	14.4	33.3	14.9	31.6	19.4	31.0	20.6	30.8	19.0	30.2	19.0	29.0	18.0	28.0	14.2	25.4	9.0
2004	26.0	9.0	28.0	7.8	32.2	11.8	29.6	13.2	32.6	16.0	30.0	18.0	29.2	17.2	31.2	19.2	29.7	18.2	30.5	16.7	28.8	13.8	28.2	9.2
2005	28.2	7.7	29.4	10.2	29.7	12.7	32.0	13.6	30.0	13.2	31.0	15.7	30.0	18.2	29.5	18.2	33.1	17.2	31.2	16.2	29.0	12.5	28.7	10.2
2006	29.5	8.9	30.0	12.2	32.1	13.7	33.3	12.4	32.3	14.2	30.5	15.2	33.2	18.0	32.2	18.6	31.8	18.5	30.7	18.2	28.7	11.2	27.4	10.9
2007	26.9	9.1	27.0	9.7	31.7	12.8	32.7	12.3	33.2	15.7	30.8	18.2	29.8	19.0	31.5	19.5	32.0	19.5	31.7	18.2	29.7	13.4	28.5	10.2
2008	27.1	7.7	28.3	7.3	30.8	11.2	34.0	11.7	31.7	16.7	32.3	17.2	29.7	19.1	30.7	10.6	31.8	19.1	32.9	14.7	30.2	13.8	27.1	10.6
2009	26.5	10.5	30.5	12	32.7	14.7	32.1	14.5	33.5	15.3	30.7	17.5	31.6	19.9	30.4	19.2	32.7	19.3	32.1	18.0	32.8	14.1	26.5	10.1
2010	28.7	11.2	27.8	11	34.1	13.3	33.7	14.9	30.1	16.5	29.3	17.7	30.3	19.3	30.2	19.3	30.7	19.1	33.1	17.3	30.2	13.3	27.4	9.3
2011	27.3	6.2	29.9	12	32.0	12.5	33.0	14.7	30.9	16.2	30.2	18.9	31.2	19.2	32.3	19.2	33.2	19.3	31.3	16.5	31.4	13.8	27.6	10.7
Average	26.3	8.5	28.3	10.2	31.7	12.8	32.8	13.5	32.3	15.5	31.1	17.7	30.4	18.8	30.8	18.6	31.0	18.7	31.0	17.0	29.2	13.5	26.0	10.2
Avg Max	26.3		28.3		31.7		32.8		32.3		31.1		30.4		30.8		31.0		31.0		29.2		26.0	
Avg Min	8.5		10.2		12.8		13.5		15.5		17.7		18.8		18.6		18.7		17.0		13.5		10.2	
Avg Mean	17.4		19.3		22.3		23.2		23.9		24.4		24.6		24.7		24.9		24.0		21.4		18.1	

3.2.3. Rainfall:

The entire state of Mizoram is under the direct influence of south west monsoon; hence, Aizawl district also receives an adequate amount of rainfall during the monsoon season. The study of the available rainfall data for past 25 years obtained from MIRSAC (2012) presented in table 3.2. Data reveals that generally the heavy rainfall starts from the second part of May and this heavy outpours usually ends in the first half of October. The average rainfall of Aizawl district for 25 years is 3155 mm per annum. Precipitation is heavy during summer. June, July and August are the rainiest months while December and January and February are the driest months. Aizawl district falls under high rainfall region which have high potential for agriculture, forestry and horticulture (Bote and Pillai, 2010).

3.2.4. Humidity:

Humidity is a general term referring to the water vapour content of air at particular place and time. Of the various components of atmosphere, water vapour constitutes only a small fraction varying from nearly zero to about 4 per cent by volume. However, the meteorological significance of even this very small percentage of water in the air cannot be over-emphasized. In fact, in the heat budget as well as in day to day weather changes that we observed, atmospheric moisture plays a very important role.

Relative humidity is the ratio of the air's water vapour content to its water vapour capacity and being directly related to the rate of evaporation, it affects man' s comfort. The relative humidity is given in table No. 3.3. The average relative humidity of Aizawl district for a period of twenty five years is 78 % (MIRSAC, 2012)

Table 3.2: Average monthly rainfall (in mm) of Aizawl District, Mizoram during 1986 – 2011

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
1986	5.7	21.3	58.3	360.3	247.3	343.3	490.7	399.7	320.0	204.3	188.7	62.7	**2702.3**
1987	15.0	40.7	64.3	148.3	162.3	480.3	438.7	481.7	477.0	134.0	134.0	102.7	**2679.0**
1988	0.0	53.7	80.7	185.0	488.0	380.3	439.3	429.7	320.0	279.7	58.7	4.3	**2719.3**
1989	0.0	32.3	34.3	148.3	138.3	498.3	499.3	479.3	459.7	396.7	3.3	5.7	**2695.6**
1990	1.3	55.3	290.7	339.3	297.0	393.0	353.3	456.0	338.3	193.0	138.3	79.7	**2935.3**
1991	26.7	55.0	46.0	375.0	523.7	441.0	292.7	368.3	279.0	333.7	36.7	25.0	**2802.6**
1992	2.0	49.7	40.0	124.0	253.7	375.7	393.3	456.0	479.3	363.3	31.0	12.7	**2580.6**
1993	10.7	98.7	90.0	135.3	427.3	534.7	502.3	419.7	315.7	192.7	12.7	0.0	**2739.6**
1994	14.3	14.0	191.0	220.0	140.7	371.0	434.3	482.0	248.7	137.7	24.7	0.0	**2278.3**
1995	0.0	42.0	131.3	88.3	427.0	597.7	399.0	654.0	319.3	230.0	297.3	0.0	**3186.0**
1996	10.7	26.0	367.7	131.7	291.0	377.7	475.0	426.7	569.0	155.7	37.3	0.0	**2868.3**
1997	8.7	24.7	226.3	117.3	320.0	334.3	797.3	362.0	555.3	69.7	45.3	82.7	**2943.6**
1998	63.0	33.3	147.0	169.0	456.0	306.3	575.3	496.7	303.3	125.7	55.0	0.0	**2730.6**
1999	0.0	0.0	33.5	30.5	578.3	488.2	532.0	493.8	540.8	259.8	23.7	14.3	**2995.0**
2000	22.2	28.5	152.7	303.2	517.2	336.3	258.7	657.7	330.7	268.3	28.3	0.0	**2903.6**
2001	0.0	57.3	67.7	103.7	398.7	525.7	390.7	410.7	407.7	328.0	120.0	0.0	**2810.0**
2002	24.7	0.5	68.0	179.8	587.0	363.0	505.7	519.0	273.2	188.8	78.3	0.5	**2788.5**
2003	2.8	15.0	130.6	166.2	333.2	833.6	374.6	469.2	399.0	186.6	0.0	59.8	**2970.6**
2004	0.0	0.0	18.0	379.3	262.0	535.8	865.5	450.0	395.3	195.8	6.5	0.0	**3108.3**
2005	9.8	11.3	179.1	86.6	405.5	178.7	545.4	337.4	386.9	241.8	43.0	10.9	**2436.4**
2006	0.0	2.2	2.7	67.4	578.8	685.5	491.3	346.9	393.7	144.4	4.4	0.0	**2717.3**
2007	0.0	70.7	28.0	343.9	411.9	548.2	452.0	562.5	686.5	147.2	124.5	0.0	**2797.6**
2008	49.3	10.6	40.5	50.8	260.8	416.6	433.5	497.2	354.8	195.7	20.3	0.0	**2330.1**
2009	0.0	0.5	36.5	153.0	203.4	331.9	2036.5	2872.5	1668.7	1178.7	175.8	0.0	8657.5
2010	0.0	10.9	131.2	298.0	407.4	496.7	387.4	466.7	2777.8	1658.3	92.8	358.0	7085.2
2011	19.3	0.5	99.6	125.6	453.5	477.8	349.6	534.0	399.0	118.6	0.0	0.0	2577.5
Average	**11.0**	**29.0**	**106.0**	**185.8**	**368.1**	**448.1**	**527.4**	**558.8**	**538.4**	**304.9**	**68.5**	**31.5**	3155.3

Table 3.3: Averaged Monthly Relative Humidity of Aizawl district, Mizoram (1985 – 2011)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	NA	43.75	68.34	87.53	91.25	89.20	83.65	82.62	83.14	72.39	58.80	59.65
1986	57.81	48.00	55.75	70.20	69.55	78.97	87.49	86.84	85.74	74.84	69.90	71.26
1987	87.07	55.00	60.57	69.53	69.73	85.27	84.88	86.68	85.20	85.55	72.87	61.49
1988	NA	54.00	57.65	55.07	75.52	75.87	86.09	83.46	85.60	84.78	67.30	63.91
1989	56.23	55.04	53.07	63.27	74.65	85.50	90.36	89.59	85.17	85.33	59.13	50.46
1990	62.94	63.50	66.62	77.20	81.78	87.80	85.88	NA	87.50	77.33	76.87	68.97
1991	64.91	65.58	64.55	72.93	81.13	89.60	89.20	90.04	91.90	85.71	69.83	71.42
1992	78.19	91.24	78.32	69.83	75.68	87.93	91.97	91.03	87.43	83.90	72.43	66.35
1993	58.90	67.04	56.19	84.43	86.45	92.03	90.90	90.35	88.53	82.77	74.43	NA
1994	69.19	64.78	72.67	67.37	82.93	86.97	92.70	93.54	90.06	78.13	73.23	67.02
1995	68.09	65.43	52.10	65.55	85.84	74.47	76.55	94.45	88.17	78.61	84.06	79.77
1996	74.39	63.24	72.77	77.63	81.87	86.17	91.51	92.03	90.27	83.74	74.37	NA
1997	75.52	68.79	72.23	77.80	82.04	90.87	95.06	NA	90.60	82.09	75.40	83.59
1998	76.33	73.36	66.59	77.17	83.33	87.00	93.09	89.07	87.00	85.23	78.00	65.39
1999	62.88	51.54	51.91	69.10	81.46	89.30	91.09	87.97	86.97	84.39	87.23	69.91
2000	54.09	55.59	84.23	88.17	90.97	91.57	87.26	92.87	89.27	78.65	72.46	73.68
2001	68.36	71.65	73.23	68.33	82.88	86.76	91.09	89.22	90.73	89.81	79.80	65.59
2002	70.28	57.25	57.84	84.50	85.80	89.00	95.29	92.80	89.63	86.00	85.16	81.80
2003	79.09	81.42	90.09	70.2	81.09	91.53	84.83	87.35	87.53	85.54	80.73	83.22
2004	73.77	63.44	70.93	84.47	87.58	92.33	93.38	89.48	89.73	82.87	78.33	73.16
2005	74.77	71.57	76.97	78.23	84.09	88.17	91.26	91.12	85.4	77.77	76.33	74.77
2006	66.80	71.53	69.93	79.26	84.61	90.26	91.54	89.12	88.6	84.06	75.66	69.41
2007	66.16	67.75	58.67	77.5	83	86.86	94.06	94.67	91.2	85.67	81.76	70.64
2008	69.58	64.89	68.87	66.1	82.25	89.7	94.48	96.43	89.13	87.09	75.13	73.9
2009	65.84	54.39	51.61	68.4	77.81	87.73	88.13	92.06	87.3	89.42	74.47	70.48
2010	58.23	56.46	51.48	79	86.35	91.67	93	93.88	93.17	82.74	77.57	68.16
2011	68.81	61.68	59.29	71.17	87.97	92.17	92.77	93.19	91.17	82.9	69.77	67.9
Avg Humidity %	68.3	64.0	65.2	73.6	81.8	87.5	90.1	90.7	88.6	83.3	75.5	70.5

The driest month of the year is February with 64% relative humidity and August is the highest relative humidity (90.7%) followed by July (90.1%).

3.2.5. Wind:

The monsoon wind is the most important wind that prevails in Mizoram. During summer, the sub-tropical high pressure belt and the thermal equator are displaced northward in response to the changing pattern of solar heating of the earth. From the ocean, particularly from the north Indian Ocean and Bay of Bengal, they move towards the land mass and blow over the Asian continent. This south-west monsoon usually reaches Mizoram during second half of May and prevails up to the first half of October. The summer monsoon is characterized by highly variable weather with frequent spells of drought and heavy rains. Besides this, the winter monsoon also prevails which is a gentle drift of air in which the winds generally blow from the north east. This retreating monsoon cause sporadic rainfall especially in Mizoram and other north eastern states producing sometimes heavy cyclonic rains (SRSC, 2004).

As evidence from the earlier records, Mizoram state is vulnerable to impact of tropical cyclones which develop in north Indian Ocean and Bay of Bengal, and in these the cyclones of the post monsoon season (October to December) are more intense than those of pre-monsoon season (April and May). Cyclones are associated with strong winds, torrential rains and storms. The impacts of these cyclones are quite devastating; it often led to loss of properties, houses, power line cut-off, blockage of road, damages to crops and even human lives, etc. Generally these winds come from the north western part of the state as the winds originate from the Bay of Bengal.

Vulnerability analysis of cyclone in Mizoram has been conducted by State Remote Sensing Centre (SRSC), Mizoram, (SRSC, 2004) and cyclonic vulnerability has been classified. There are 160 villages and towns in the state falling in different classes of vulnerability. Out of this, 15 villages (9.38 %) are falling in the high vulnerable areas; 39 villages and towns (i.e. 24.38 %) are in the medium class and the rest 106 villages and towns (i.e. 66.25 %) are in the low vulnerability areas (SRSC, 2004).

3.3. The People:

According to traditional belief, the Mizo claimed themselves that they came out of a cave in the east called “Chhinlung” which means “covering stone”. It is hard to believe that man came out of the earth through a hole. Many attempts have been made by historian to explain this story and Lorrain (1983) in his book “Dictionary of the Lushai Language” made following remarks “their ancestral home would appear to have been somewhere in the neighborhood of south east Tibet and western China, whence, by slow degrees through the centuries, they have pressed southward and westward to their present habitat”. Mizo belongs to Mongoloid stock who came to Mizoram from Chin hills of Burma and that their ancestors had originated somewhere from China. The Mizo language belongs to the Tibeto-Burman group and it is written in Roman script.

The inhabitants of Mizoram are now known by the generic term “MIZO” which literally means “highlanders” or “people of the hills”. All the Mizo tribes have more or less similar culture, dialects, traditions, etc. The Mizo tribe consists of Lusei, Ralte, Hmar, Paite, Thahdo (Kuki), Lai (Pawi), Mara (Lakher) etc. with their many sub-clans. Lai and Mara with their different sub-clans are concentrated in the south

and south eastern part of the state bordering Myanmar (Sangkima, 1992). Other Mizo tribes with their sub-clans are inhabited in the north and middle part of the state constituting majority of the population. The non-mizo tribes formed a small minority. The biggest single non-mizo ethnic group is the Chakmas followed by Riangs (Bru). They were concentrated in the south-west and the western belt of the state. Both the tribes were late-comers and they came from Chittagong hill tract of Bangladesh and Tripura state of India with their own dialects. The Chakmas follow the Buddhist religion and the Riangs, aside from their animistic belief, are in the process of embracing Christianity. Smaller groups like Nepalis, Bengalees, Assamese, Santalis and others make up the rest of the non-Mizos. About 82 percent of the total populations are Mizos and non-mizos formed 17 percent in which The Chakmas and the Riangs have 6.99 and 2.96 percent of the population respectively. Other non-Mizo groups have less than 2 percent of the population (Sangkima, 1992).

The inhabitants of Aizawl district are mostly Mizos' consisting of different Mizo tribes and sub-tribes. The non-mizo tribes mainly Chakmas and Riangs (Bru) formed a small minority. They are concentrated in the western belt of the district.

3.3.1. Socio Economic Condition:

The area of Aizawl district is 3576.31 sq km and is divided into three sub division viz: Aizawl, Sakawrdai and Saitual. According to 2011 census, the population of Aizawl district is 4,04,054, out of which 2,01,072 are male and 2,02,982 are female. Of this population, 94.75% constituted scheduled tribes. This population constitutes around 37.03% of the state population and ranked first among the districts. The density of population is 113 per sq km compared to 52 per sq km of

Mizoram. The literacy rate of Aizawl district is 98.50% compared to 91.58% of entire state (Directorate of Census Operations, 2011). More than 2/3rd of the population of Aizawl district lives in urban areas. The rural-urban composition was 22.58 and 77.42% of the total population of the district.

Agriculture is the mainstay of the district and jhuming is the usual practice. More than half of the people are engaged in jhuming (MIRSAC, 2009). Owing to its high composition of urban population, the socio-economic condition of Aizawl district is good compare to other districts Mizoram. Agriculture and its allied sector is the main occupation followed by industry sector. In the district, there are 14922 families engaged in jhum cultivation, 585 families are engaged in WRC agricultural practice and there are 797 fish ponds within the district (Directorate of Economics & Statistics, 2010). The district have a number of infrastructure facilities which includes education, hospitals, Banking facilities, post offices, water supply schemes, etc. The detailed socio-economic statistics of the district is given in Appendix – I.

3.3.2. Transport Network:

Aizawl district is well connected with road network spanning to other towns and villages. The National Highway 54 runing from Kolasib district passes through Aizawl city and the National Highway 150 also runs along the northern ridges starting from Seling village to Tuivai river which passed through Manipur state. The state highway starting from Seling village run towards eastern part of the district upto Tuivawl river where it enters the Champhai district. This road serves inter-state road network with Manipur and Mizoram. Beside this road network, a good number of agricultural and horticultural link roads have been constructed which serve for trans-

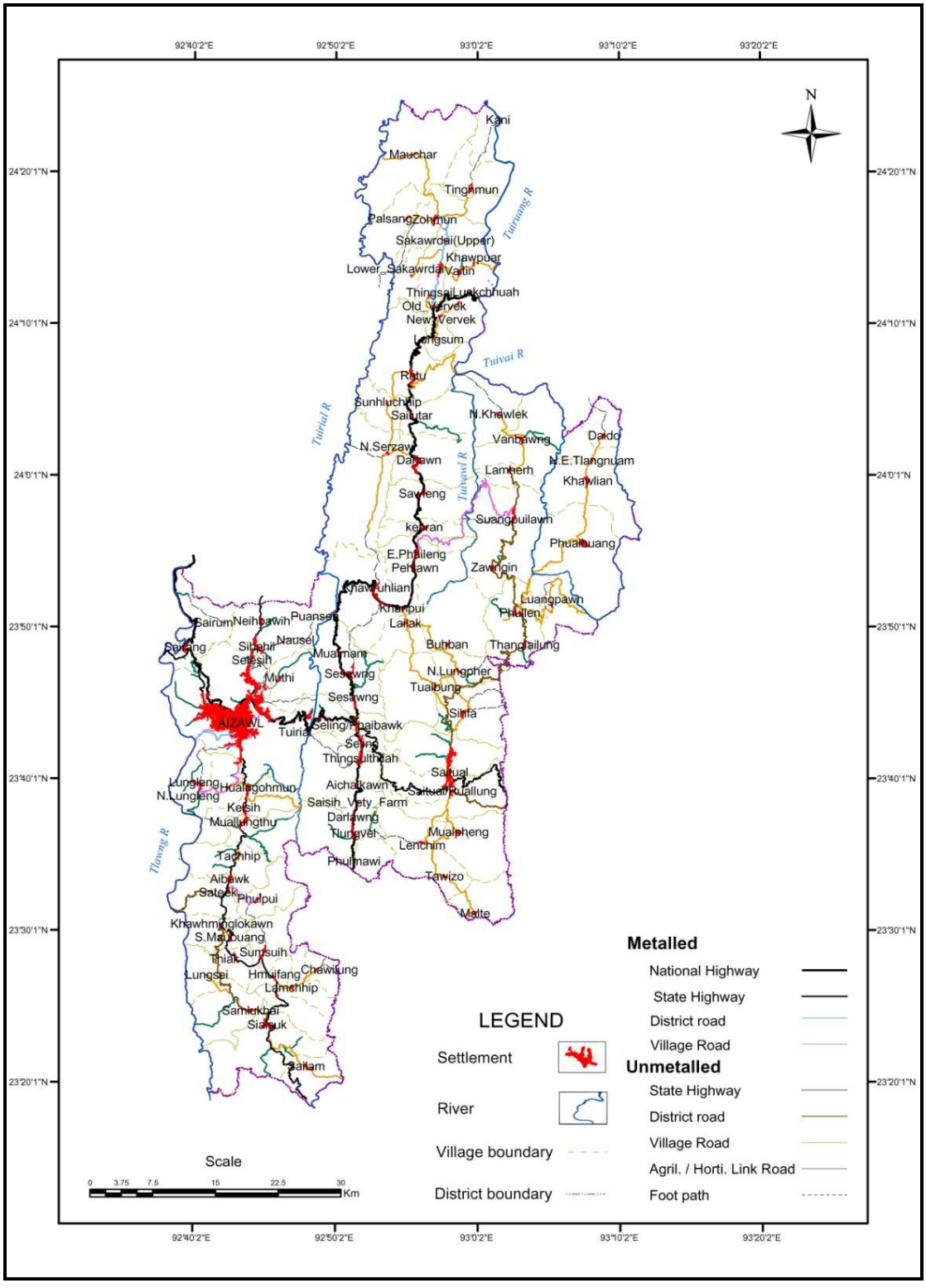


Figure 3.2 : Transport network and settlement location map of Aizawl district, Mizoram

portation of agricultural and horticultural produces from the interior parts of the district. Transport network and settlement location map is shown in figure 3.2.

3.4. Source of Data

Different types of data were used to get natural resources information. These data include satellite imagery, collateral data and ground data.

3.4.1. Satellite Data:

RESOURCESAT-1 or Indian Remote Sensing Satellite (IRS-P6) is the 10^{th} satellite of ISRO in IRS series, intended to not only continue the remote sensing data services provided by IRS-1C and IRS-1D, both of which have far outlived their designed mission lives, but also to vastly enhance the data quality. RESOURCESAT-1 is the most advanced Remote Sensing Satellite built by ISRO as of 2003. IRS-P6 LISS-III data are well suited for agricultural and forestry monitoring tasks. A natural colour impression can be achieved using our synthetic blue band. IRS-P6 LISS-III data are delivered as 4 band products (2=green, 3=red, 4=NIR, 5=SWIR). The Linear Imaging Self Scanning Sensor (LISS-III) is a multi-spectral camera operating in four spectral bands, three in the visible and near infrared and one in the SWIR region, as in the case of IRS-1C/1D. The new feature in LISS-III camera is the SWIR band (1.55 to 1.7 microns), which provides data with a spatial resolution of 23.5m.

Indian Remote Sensing Satellite (IRS-P6) LISS III, which provides data in four spectral bands (0.5 – 0.75 micrometer) with spatial resolution of 23.5m on digital CD-ROM, with three season data were used for the present research. The particulars of the satellite data are as given below:

Sl No	Satellite	Sensor	Path	Row	Date and Year
1.	IRS –P6	LISS III	112	55	10th December, 2005
2	IRS –P6	LISS III	112	55	27th January, 2006
3	IRS –P6	LISS III	112	55	14th April, 2006

3.4.2. Collateral Data:

The collateral data were collected from various sources. Census data of the year 2011 were collected from Directorate of Census Operation, Govt. of India, Aizawl, and statistical data regarding socio-economy were obtained from Economics and Statistics department; agriculture data from department of Agriculture; data on horticultural crops from department of Horticulture and information regarding natural resources from Environment and Forest department; Govt. of Mizoram. Similarly, meteorological data were collected from Directorate of Science and Technology, Govt. of Mizoram; BRTF, Pushpak and also from department of Agriculture, Govt. of Mizoram. Reports and publications from various sources like Mizoram Remote Sensing Application Centre (MIRSAC), Local Administration department, Public Health Engineering department, Geology & Mining Wing, Govt of Mizoram etc., were also referred. Moreover, Survey of India (SI) Toposheets No. 83D/15, 83D/16, 84A/9, 84A/10, 84A/11, 84A/13, 84A/14, 84A/15,84E/1, 84E/2, 83H/3 and 83H/4 were utilized for physiographic information like altitudes, contours, aspects, drainage, etc. as well as for preparing the base maps.

3.5. Methods

With the advent of remote sensing in the early seventies after launching of LANDSAT series of satellites by NASA, SPOT satellite by France and IRS series of

satellites by ISRO, Department of Space, Government of India, there has been an increasing utilization of satellite imagery for inventory and monitoring of natural resources in India and abroad. Remote sensing techniques have proved to be rapid, cost effective and provide timely information with the capacity of repetitive coverage of the same area within a span of 18 to 22 days (Rajan, 2000).

Remote sensing is the process of sensing and measuring objects from a distance without directly coming physically into contact with them. Remote sensing is largely concerned with the measurement of electromagnetic energy from the sun which is reflected, scattered or emitted by the objects on the surface of the earth. Different surface objects return different amounts of energy in different wavelengths of the electromagnetic spectrum (NRSA, 2004). Detection and measurement of these spectral signatures enables identification of surface objects both from air borne and space borne platforms. But often, similar spectral response from surface objects creates spectral confusion leading to misinterpretation and misclassification. Therefore, to overcome this constraint, systematic ground data verifications are required.

Geographic Information System (GIS) technology has assumed great importance in the last decade. It is a mapping system with a capability of recording, storing, processing, manipulating and retrieving data (Chang, 2006). GIS comprises dedicated computer software for handling geographically referenced spatial data and corresponding attribute information. It has the capability of digitizing maps, of overlaying spatial data, and of displaying information needed in decision making. Geographic and attribute information can be merged and manipulated in the GIS,

which can function as a data base management system. Its graphic display capability allows information retrieval in map form. Input maps are digitized and the GIS software sorts the data in either raster (cell-based) or vector based systems (Heywood *et al*., 2003). Software development trends in recent times promises easy transfer from one to another.

The present study utilized the standard techniques of remote sensing and GIS for preparation of the various thematic informations which are finally represented in the form of maps. Remote sensing techniques, in short, refers to the collection and utilization of information gathered from a remote device and produced in the form of satellite imagery etc, without the need for coming in physical contact with the component under observation (Lillesand *et al*., 2002). GIS, in itself is useless unless relevant data is supplied to it. It represents the organized form of raw data obtained from remotely sensed products and presented in a form which is understood by the end-user, known as spatial and non-spatial data. The standard technique of remote sensing and GIS is shown in figure 3.3.

Thus, the valuable information collected using remote sensing was integrated with the help of GIS to generate products that become important tools for almost every aspect of land resource management and planning. To ensure that information collected through remote sensing and GIS were accurate, a well designed methodology is necessary. The methodology adopted in each phase of the plan should comply with standard data collection procedures so that both spatial and non-spatial data co-relate and are accurate at the final stage of product generation. Keeping this in mind, the methodology adopted for the present study has been divided into three phases, viz. pre-field, field and post-field works.

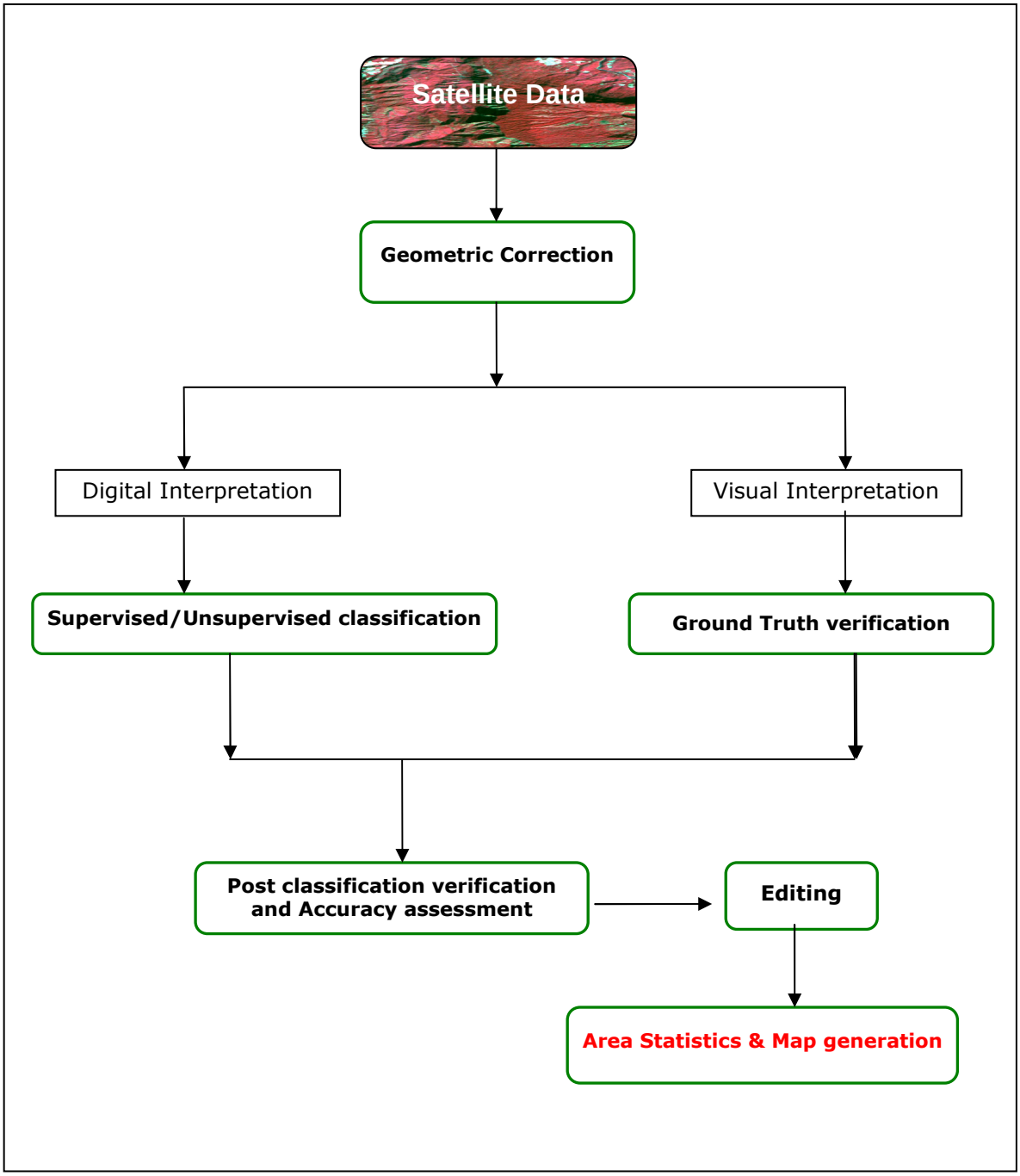


Figure 3.3 : Standard method of remote sensing and geographic information system (GIS)

3.5.1. Pre- Field Work

During the pre-field works available information like literature, maps, socio-economic data, meteorological data were collected from various sources. Satellite data procured from data centre of National Remote Sensing Centre (NRSC), Hyderabad were used for visual interpretations and digital classifications. The satellite data were registered with respect to Survey of India toposheets, and base maps for various themes of natural resources i.e. water resources including drainage system, springs and waterholes; watershed classification; geology and geomorphology; topography; ground water resource potentials; land use pattern including shifting cultivation and soil mapping were prepared.

Digital classifications were carried out using Image Processing System (Erdas Imagine) and GIS (Arc Info). Preparation of contour map and slope map were also carried out from the topographical maps. Pre-field maps were printed out for field verification. The methodology for preparing Geology and Geomorphology, slope map, soil map and Land capability were as given below:

3.5.1a. Geology and Geomorphology:

Geological mapping was done using satellite imagery based on tone/colour, texture pattern, shape, size, shadows, site and association of the interpretation elements. The flow chart methodology for geological mapping is shown in figure 3.4.

3.5.1b. Ground Water Potential Zonation mapping:

To locate the occurrence and potential zones of groundwater within the study area, thematic maps of lithology, geomorphology, geological structure and slope were prepared as suggested by Subramanian and Seshadri (2010). These maps were

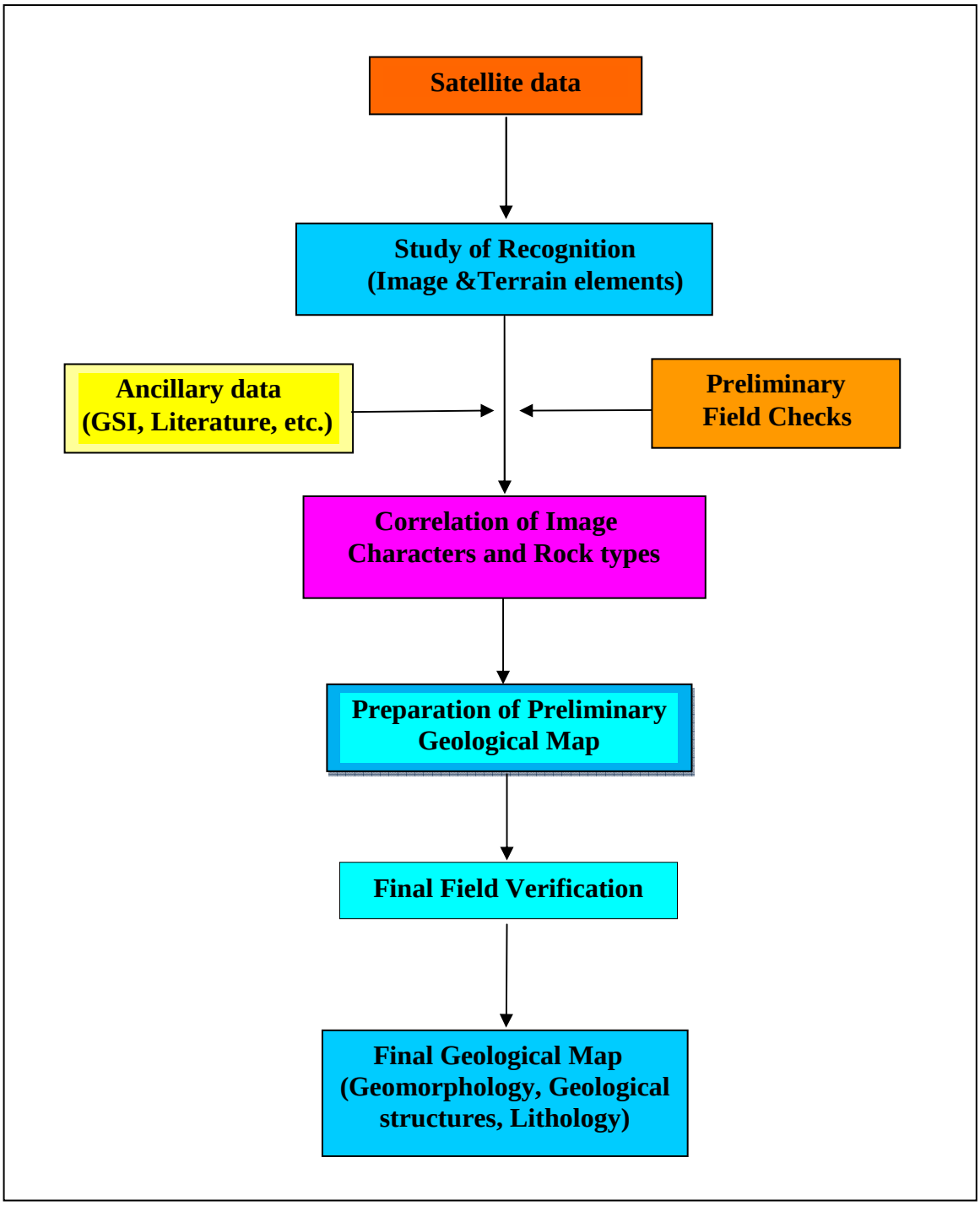


Figure 3.4 : Flowchart showing various stages of interpretation of satellite data for Geological mapping

combined together by using ARC/INFO GIS package to generate the final map. Thereafter, different ground water potential zones were derived. Besides, the existing hand pumps and spring inventory data were also added to the final map. Since geological structure is one of the major factors controlling the occurrence of ground water, areas within 50m on both sides of the lineaments and faults were included. Similarly, areas proximity to spring and hand pumps were manually selected and delineated with the help of Digital Elevation Model of the study area.

The different units of these thematic parameters were taken into consideration by giving different weightage values according to their respective hydrological properties. This form the main criterion by which different potential zonation was done. Since hand pumps and springs are direct expression of the ground water condition below the ground surface, they were given the highest weightage value. The final map is then prepared and the area is classified into Very Good (Valley fill, flood plain, low lying areas, etc,); Good (50 metres on both sides of Faults, Joints, Fracture, etc.) ; Moderate (Sandstone, Silt stone, gently sloping land having slope less than 50%) and Poor (High elevation, steep slopes with more than 50%) zones (MIRSAC, 2009).

3.5.1c. Land use land cover mapping:

The standard techniques of remote sensing for interpretation of land use/land cover mapping from satellite imagery is utilized for the present study. Mapping is carried out visually base on tone/colour, texture pattern, shape, size, shadows, site and association of the interpretative elements supported by Ground truth collection (Sudhakar and Rao, 2010). The flow chart methodology for land use land cover mapping is shown in figure 3.5.

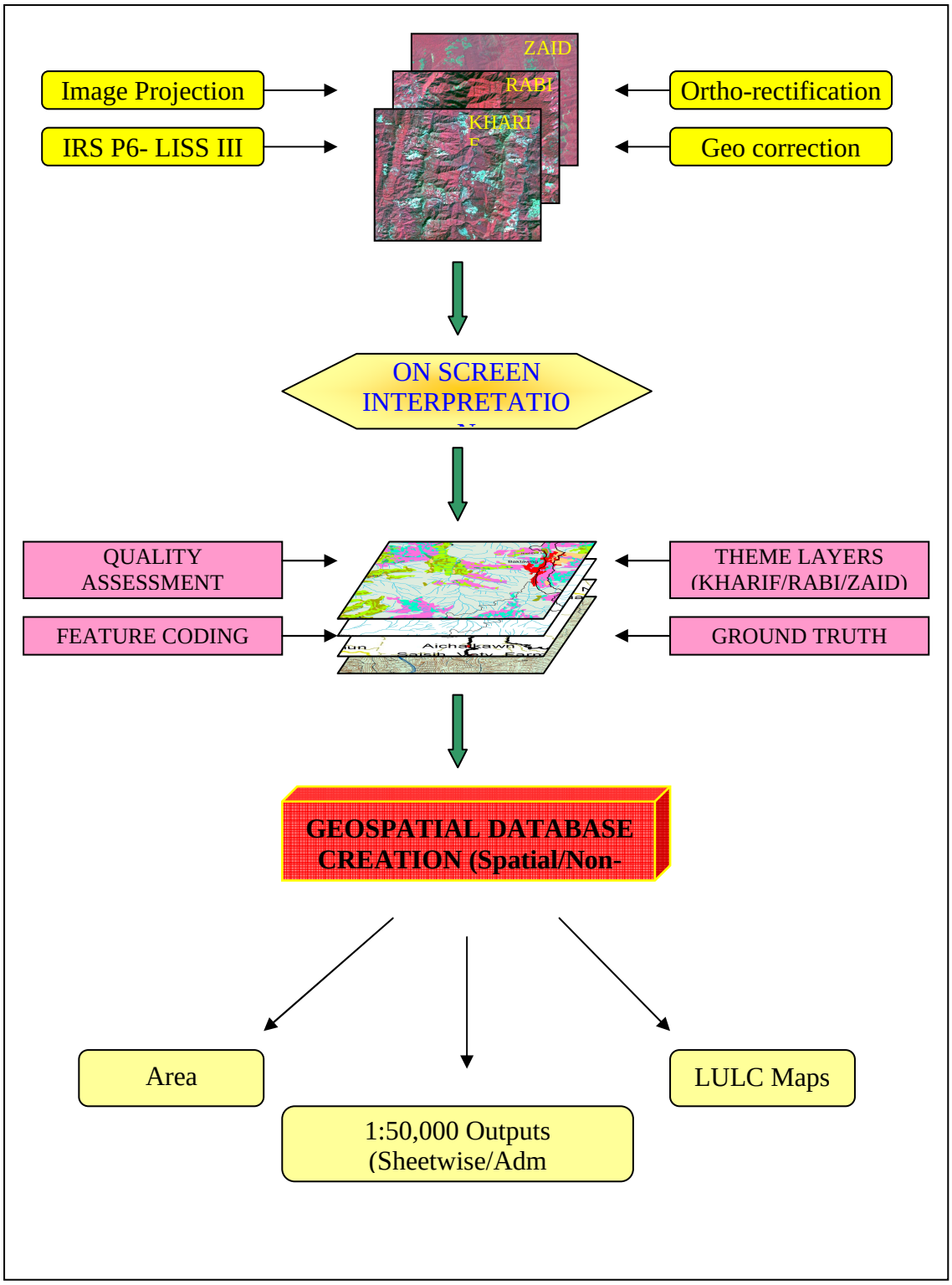
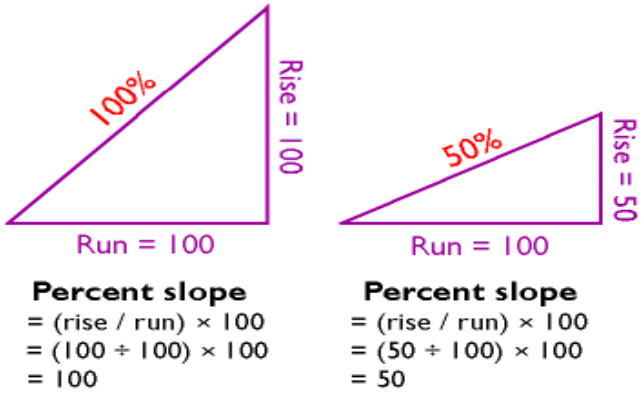


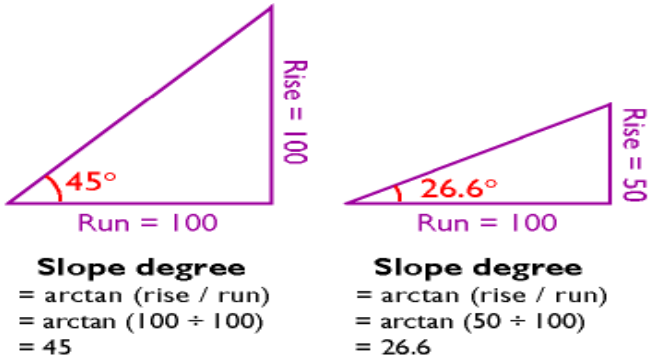
Figure 3.5 : Land use/land cover data generation methodology

3.5.1d. Slope map:

To calculate percent slope, difference between the elevations of two points was divided by the distance between them, then multiply the quotient by 100. The difference in elevation between points is called the rise. The distance between the points is called the run. Thus, percent slope equals (rise / run) x 100 which is demonstrated as:



A rise of 100 feet over a run of 100 feet yields a 100 percent slope. A 50-foot rise over a 100-foot run yields a 50 percent slope. Another way to express slope is as a slope angle, or degree of slope. As shown below, if we visualize rise and run as sides of a right triangle, then the degree of slope will be the angle opposite the rise. Since degree of slope is equal to the tangent of the fraction rise/run, it was calculated as the arctangent of rise/run as:



A rise of 100 feet over a run of 100 feet yields a 45° slope angle. A rise of 50 feet over a run of 100 feet yields a 26.6° slope angle.

3.5.1e. Soil Mapping:

Soil mapping was carried out by using Indian Remote Sensing Satellite (IRS – P6) LISS III False Colour Composite of 1:50,000 scale. The standard methodology for soil mapping is followed (Ravishankar and Sreenivas, 2010) which is shown in figure 3.6. Physiographic unit were delineated from the satellite imagery. The physiographic unit and soil profiles studied at ground truth and analysis were incorporated for preparing soil map of the area. The Arc GIS software was used for spatial and attribute database generation and preparation of thematic maps. Sample strips selection was done for detailed examination of the soils occurring in various units.

3.5.2. Field Work:

Various field information's like geological information, soils, name of the plant species, distribution of crops and vegetation, plantations, name of streams, etc. were collected from the ground. For this, series of surveys were conducted in Aizawl district. Collection of plants was carried out throughout the year using herbarium press, blotters, news papers and even polythene bags. Collection of plants was followed by processing i.e. pressing, sweating, drying, preserving and preparation of herbarium sheets according to the method suggested by Radford (1986). Dry specimens were poisoned by using Kew Mixture (115 gm $HgCl_3$ + 4.5 lit, Ethyl alcohol or sprit). Poisoned and dried specimens were mounted on the standard (42x28 cm) herbarium sheets adopting the usual herbarium techniques as suggested by Fosberg and Sachet (1965), Smith (1971) and Jain and Rao (1977). Plants were

identified by using various floras including regional flora (Sawmliana, 2003) and has been compared with and verified from internationally indexed Herbarium, North eastern circle of BSI (Shillong). Also, local information from the local people through semi structured questionnaires was collected for incorporation in generating the action plans.

Field verification or ground truth collection is a very important part in remote sensing technology. Important ground information was collected during the field visits and doubtful areas on the pre-field interpreted maps were verified on the ground. Some information which cannot be obtained on the satellite imagery was collected during the field work. Soil survey was carried out and soil samples were randomly collected to represent various physiographic units. The soil colour was measured by using Munsell Soil Colour Chart (Munsell, 1990). A total of 143 soil profiles were examined, out of which 14 soil profiles, which represents each physiographic unit were collected for analysis of various physico chemical properties. Hand-held GPS was used for recording geographical location of the interested areas.

3.5.3. Post – field work

After field verification, the pre-field maps were finalized by making necessary corrections and modifications. Various data collected from the field were studied and analyzed. Soil texture analysis was done in the laboratory by following mechanical analysis of hydrometer method (Bouyoucos, 1962) in which sand, silt and clay percentage were determined. Similarly, other parameters were observed by using standard methods such as pH (Goel and Trivedi, 1992), Organic carbon (Okalebo *et*

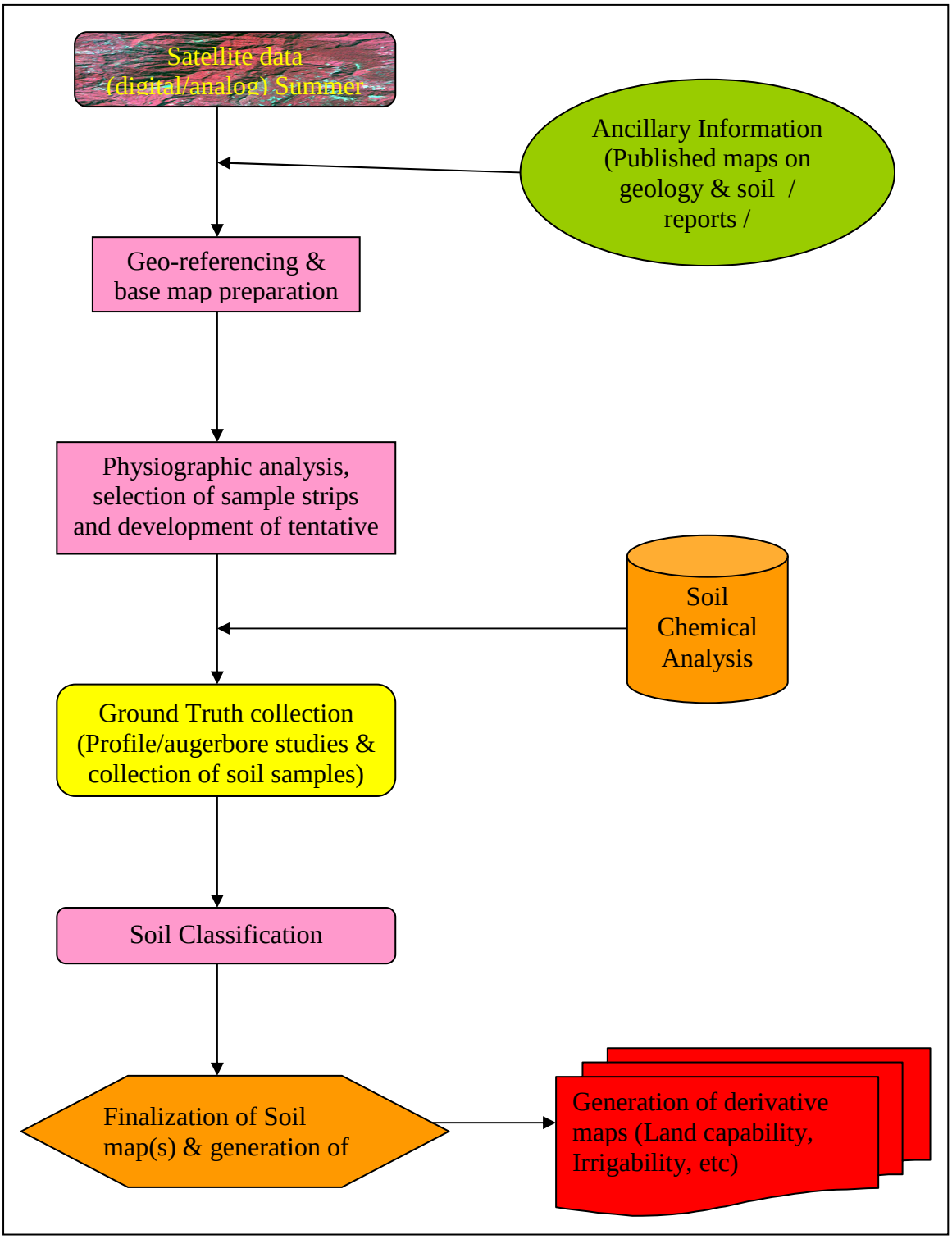


Figure 3.6 : Flow Chart for Preparation of Soil Map

al., 1993), Sodium and Potassium by the standard procedures of (Jackson, 1973), Mechanical analysis by hydrometer method (Bouyoucos, 1962), Cation Exchange Capacity (CEC) by the method of (Schollenberger and Simon, 1945), Calcium and Magnesium by complex-metric titration using ethylene diamine tetra-acetic acid (EDTA) by the method of (Barrows and Simpson, 1962). Percent base saturation (BS) was calculated by dividing the sum of basic ions (S) by total cations (T) multiplied by 100 as: S/T x 100.

Taxonomic classification of soils of the area have been done according to Soil Taxonomy (USDA, 1988) on the basis of their physico-chemical and morphological properties. The soils found at order level are: - (1) Entisols (2) Inceptisols and (3) Ultisols. The distribution of the soils and soil associations was then shown according to their physiographic positions.

3.5.3a. Soil Textural Classification:

Soil texture class were classified with the help of the triangular texture chart as shown in figure 3.7 where clay, clay loam, sandy clay loam, sandy clay, loam, silty loam, silty, sand etc. were determined. The relative proportion all over the particles of different size groups in a soil is known as texture. It is the average size of the soil particle which depends on the relative proportion of sand, silt and clay in the soil. The mechanical analysis data such as Sand, Silt and clay particles present in the soil were determined for textural classification.

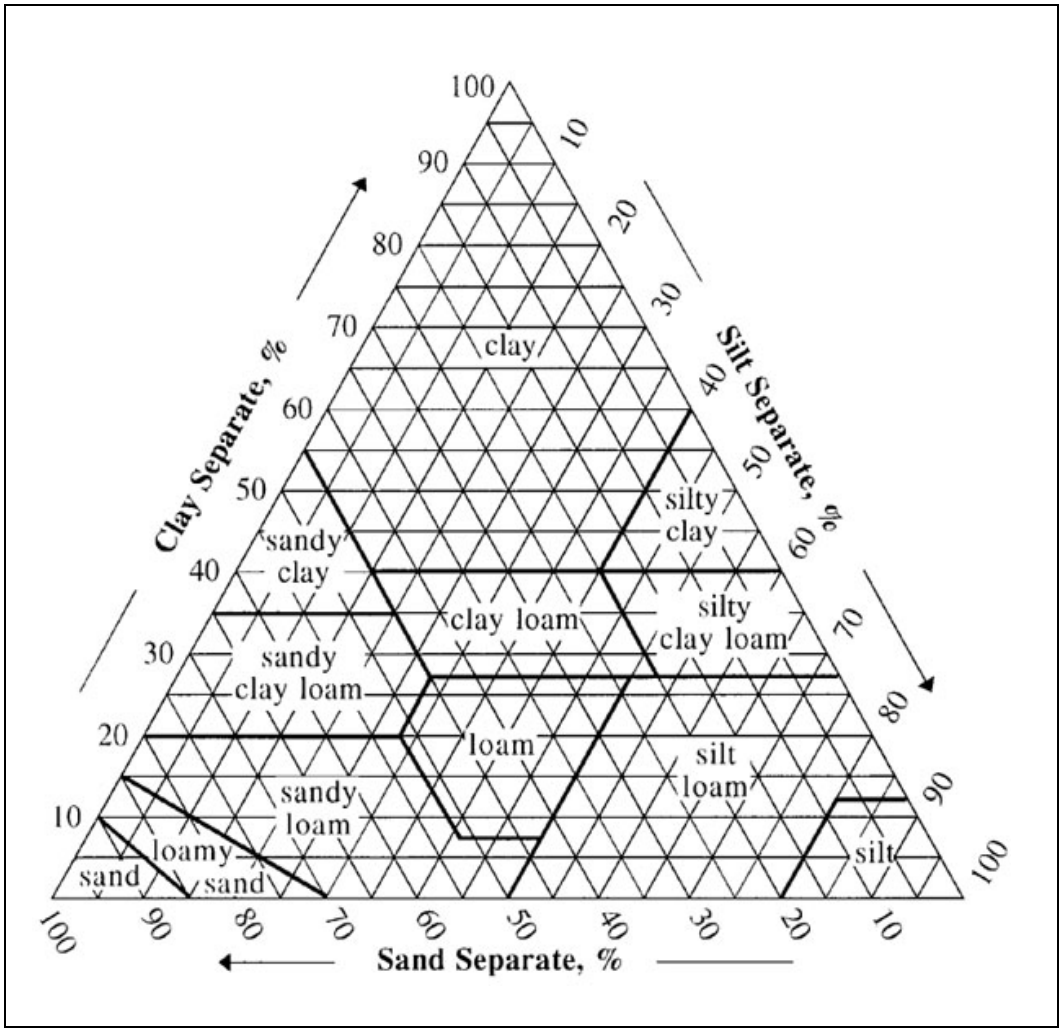


Figure 3.7: Triangulation Soil Texture Chart

3.5.3b. Land Capability Classification:

Land capability classification generally based on least limitations or hazard and soil respond best to management. This classification system also evaluates soils with respect to their susceptibility to erosion, soil depth, drainage problem and other soil characteristics. Land capability classification was done by using the criteria laid by Klingebiel and Montgomery (1961).

After finalization of the primary layers, the derived layers were prepared by using two or more primary layers. Area calculation is also done to obtain area statistics. Finally, the findings of various natural resources maps such as geology and geomorphology, slopes, soil, land use/land cover, etc. were prepared on 1:50,000 scale. The physical features like drainage, road network and settlement, village boundary, etc. were also prepared on the same scale. These natural resources information with socio-economic and demographic data were integrated in order to prescribe suitable site specific action plan for appropriate spatial plan for sustainable agro-horticulture development in the district which is shown in a map forms.

CHAPTER IV

RESULTS AND DISCUSSION

4.1. NATURAL RESOURCES OF THE AREA

Land is a physical entity as well as a system of natural resources. Land resources include soils, minerals, water and biota, which include microorganisms, plants and animals in all their biological and genetic diversity. All these elements interact to provide essential services, such as the recycling of wastes and materials, formation of soils, moderation of the water cycle and pollination of plants that maintain the productive capacity of the environment. These interactions form important components of global cycles and geochemical processes, and as such are closely linked to climate and other atmospheric phenomena. In general, land must be regarded first as a set of terrestrial ecosystems and only secondly as a basis of resources.

This complex system provides much of the basic capital and resources on which development is built. It satisfies primary human requirements for food, fibre and fuel, supplies many basic materials for industry and manufacturing, and provides space for human habitation and activities. Land also meets the needs of all other terrestrial species, be they mild or managed. Hence, land resources are of importance to panoply of human activities, from agriculture, forestry, water management and energy production to industry and construction, human settlements, communications infrastructure and waste disposal, among others.

Since this finite resource cannot easily provide for rapidly increasing numbers of people and for a growing intensity of human activities, conflicts over land use are on the rise; among different social and economic interests, between humans and the environment, and between immediate and long-term needs. Current management practices tend to approach these needs in isolation from each other, with the result that important links and impacts are ignored. Pressures on certain resources are leading to their deterioration and eventually, permanent degradation. In the past, traditional systems took account of land's complexity and diversity, and evolved effective management practices that conserved the resource base. However, these traditional systems have not been able to cope with the sheer scale of modern activities. If development is to be sustainable, these conflicts over the use for land and its resources must be resolved. More effective practice must be developed to promote the ecologically and economically efficient allocation of land resources, as well as the effective management of land resources and their socially equitable use (The Global Open University, 2008).

Governments, in collaboration with appropriate local, national and international institutions and groups, should give immediate priority to promoting the most efficient use of land and land resources and create mechanisms to facilitate active involvement by all parties concerned in decision-making. Goals should be set policies formulated to address the environmental, social and economic fact involved in land and land resources use. Out of this, policies should be enacted to encourage the efficient use, protection and management of land and land resources, and improved distribution of population and activities according to the productivity of the

land resource base. A general framework for land use and physical planning should be based on integrative units, such as the ecosystem or watershed, within which more specialized and sectoral plans can be developed. Improved planning and management system would require the application of more appropriate tools for data collection and interpretation, as well more accurate assessment and accounting of values, costs, benefits, risks and impacts.

Therefore, the task of optimal resources management and sustainable development has been greatly synergized by the enhanced speed and reliability with which spatial information is generated by using Satellite Remote Sensing and Geographical Information System in a cost-effectives manner. A comprehensive survey of natural resources will help in identifying areas having different kinds of potentials and problems. Remote sensing has emerged as a powerful tool in providing reliable and timely information on various natural resources at different levels of detail (State Land Use Board, 1999). So, mapping of natural resources both physical and biological were carried out during the course of this study using satellite data in order to create the database for integration of spatial and non-spatial for planning sustainable development.

4.1.1. WATER RESOURCES

Water is a chemical substance connected by covalent bonds between one oxygen and two hydrogen atoms. Water is a liquid at ambient conditions, but it often co-exists on Earth with its solid state, ice, and gaseous state (water vapor or steam). Water covers 71% of the Earth's surface, and is vital for all known forms of life. On Earth, 96.5% of the planet's water is found in oceans, 1.7% as groundwater, 1.7% in

glaciers and the ice caps of Antarctica and Greenland, a small fraction in other large water bodies, and 0.001% in the air as vapor, clouds (formed of solid and liquid water particles suspended in air), and precipitation. Only 2.5% of the Earth's water is fresh water, and 98.8% of that water is in ice and groundwater. Less than 0.3% of all freshwater is in rivers, lakes, and the atmosphere, and an even smaller amount of the Earth's freshwater (0.003%) is contained within biological bodies and manufactured products (Pollack, 2011).

Water is one of the fundamental elements in sustaining the integrity of the natural environment and it is the key driver of economic and social development. It is the major renewable resource amongst the various natural resources. Water being an indispensable constituent for all life supporting processes, its assessment, conservation, development and management is of great concern for all those who manage, facilitate and utilize (Rao *et al*., 2010). Therefore, detail observations were carried out during the course of this work on drainage system and springs of Aizawl district. Subsequently, watersheds of the district were classified using remote sensing and geographic information system.

4.1.1.1. Drainage system:

Aizawl district is drained by north flowing rivers like Tlawng, Tuirial, Tuirini, Tuivawl, and Tuivai rivers and only the southern tip of the district is drained by the south flowing river of Mat. Besides these there are a good number of streams and rivulets of various patterns and length. Most of these streams and rivulets are ephemeral in nature.

Since the drainage system for a particular area is governed mainly by the natural drainage course and topography, therefore, the drainage system of Aizawl district has been studied with the help of satellite imageries and the Survey of India topographical maps. It is found that most of the drainage patterns of the study area as a whole are dendritic to sub-dendritic patterns, where the stream with its tributaries resembles the braches of a tree which indicates that the rocks below have a uniform resistance to erosion. The topography is young and the soils are highly erosional in character. Similar observations were made earlier by Bhattacharya (2008) for drainage system of Aizawl.

The drainage map of the study area is given in figure 4.1 where the drainage patterns of the study area can be observed and the perennial and non-perennial streams are also shown. The district capital as well as state capital- Aizawl city lies between the two most important rivers of the district i.e. Tlawng and Tuirial rivers. However, the main drainage system of Aizawl district is Tlawng, Tuirial, Tuivawl and Tuivai drainage systems. The total length of perennial streams and non-perennial streams are 30,44,676.06 km and 99,90,229.47 km, respectively.

Tlawng river is one of the most important rivers of Mizoram and it is the longest river in Mizoram with a length of 185.15 km (Directorate of Economics and Statistics, 2012). It passes through five districts of the state forming district boundary lines while running along its course. It is a district boundary line between Aizawl and Mamit district in the south western part of the state. It is navigable by small boat throughout the year and hence it provides water transport route with neigh-

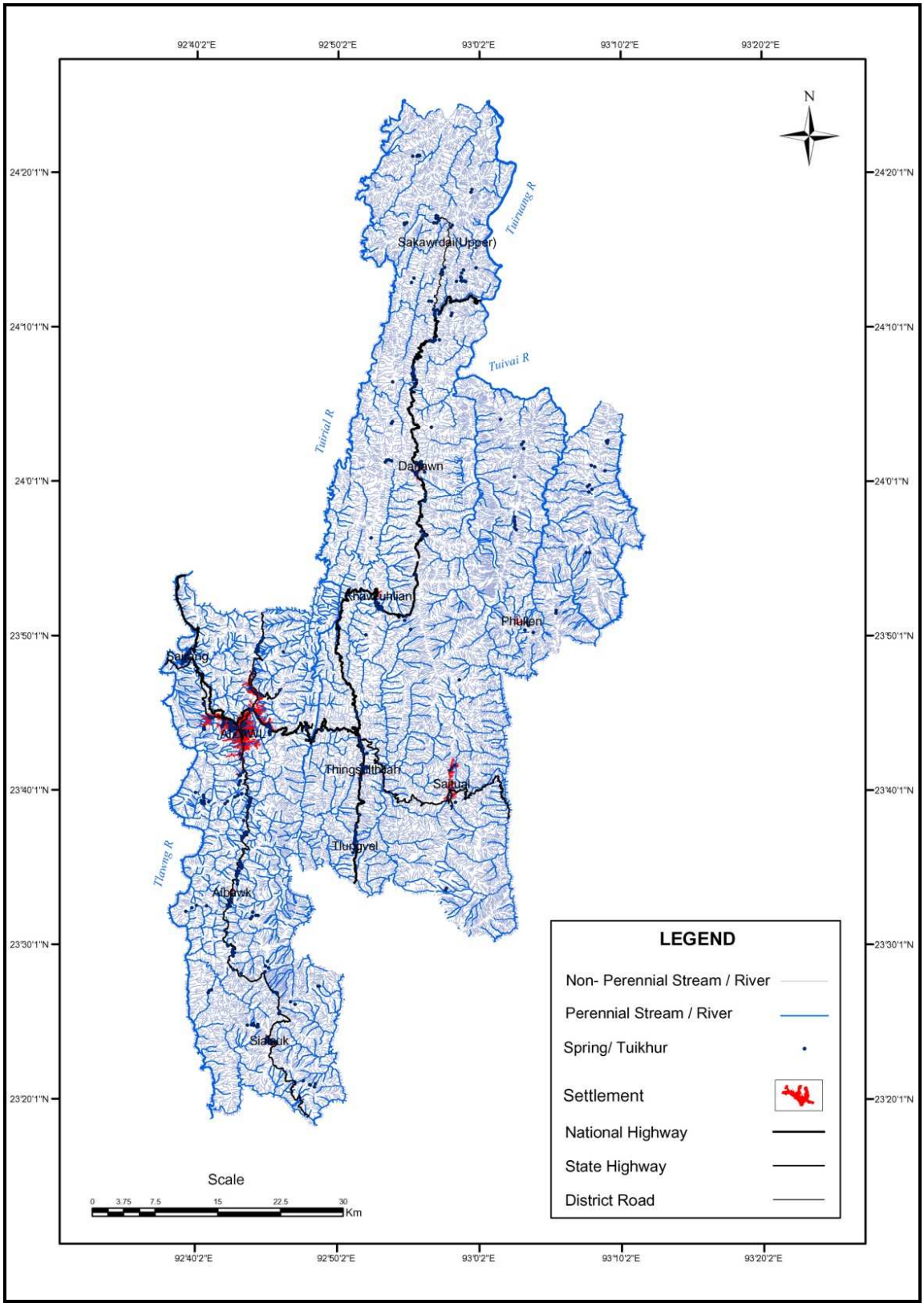


Figure 4.1 : Drainage map of Aizawl district, Mizoram

bouring state of Assam. Important tributaries of Tlawng river from the Aizawl district are Lau lui, Changte lui, Serlui A, Tuikual lui, Kurung lui and Dur lui before it enters to Kolasib district. Among these tributaries Changte lui and Lau lui have created fluvial flood plains making the areas suitable for agricultural and horticultural development.

Tuirial river originates from north Chawilung hill within the district and flows northward throughout the whole length of the district till it enters Cachar district of Assam. The length of Tuirial river is 117.53 km (Directorate of Economics and Statistics, 2012). It is an important river for the district as well for the state of Mizoram since it is navigable by small boat to a considerable length and on this river, a multipurpose hydro-electricity project is being under construction. It also formed the district boundary with Kolasib district in the west and north-western side. The important tributaries in the southern part of the river are Tuirivang, Tuinghaleng, Suanghuan lui and Chite lui. In the middle course of the river, streams like Tuipawl lui, Sihphir lui, Tuirini, Tuiphu, Tuitung, Tuitla are the important tributaries. Among the tributaries Tuirini river is the biggest tributary. The main tributaries in the north are Tuisual lui, Mairang lui, Chengkawl lui and Matai lui are the notable ones.

Tuivawl river originates from Rullam tlang near Rullam village and flows northward till it confluences to Tuivai river in the north. The length of Tuivawl river is 72.45 km (Directorate of Economics and Statistics, 2012). It formed a district boundary with Champhai district in the eastern side of the district up to a considerable length and then flows through the north-eastern part of the district. Tuivawl river does not create much fluvial flood plain along its course except a few narrow valley fills.

Its main tributaries within the district are Ralzawh lui, Thang lui, Puantawm lui, Tuichhiahlian lui, Tuiraih lui, Tuituai lui, Aier lui, Siktui lui, and Lozal lui.

Tuivai river is the largest river that passes through and along the district of Aizawl by volume. The length of Tuivai river is 134.61 km (Directorate of Economics and Statistics, 2012). It originates from Manipur state in the north east of Mizoram and it forms a state boundary line between the two states for a considerable length and then after entering Mizoram it forms again district boundary line between Aizawl and Champhai districts. Again this river made a U-turn towards north, and then again it form state boundary line with Manipur and after that it flows westwards and then northwards till it confluence to Tuiruang (Barak) river in the north. Tuivai river has many important tributaries which have fluvial flood plains along their courses, such as Tuiphal lui, Tuiriza lui, Tuitut lui etc.in the southern part of the watershed and in the northern part Rahnam lui, Luak lui, Zilthaw lui, Sumlung lui and Rungdung lui are the notable ones where agricultural development is seen here and there.

4.1.1.2. Springs and Waterholes:

Number of springs and waterholes are identified at various places of the district especially near the settlements. The locations of these springs and waterholes were observed aspect-wise and it reveals that the eastern aspects yield more springs/waterholes as compared to the western flanks in hill ranges. This is due to the fact that area with eastern aspects of the district is generally dip slopes. Generally the springs located within or near the periphery of settlement area are utilized for tapping drinking water. The total number of springs observed was 60 and that of waterhole, where water is drawn for household purpose within the district was found to be as

many as 356. The total number of working hand pumps found during the field visits was 88. The locations of these springs and waterholes were plotted and are shown in the drainage map (figure 4.1).

4.1.2. WATERSHED CLASSIFICATION

A watershed is a drainage area on Earth's surface from which runoff, resulting from precipitation flows past a single point into a larger stream, a lake or the ocean. In other words, it is a land surface (body of soil) bounded by a divide which contributes runoff to a common point. The size of the watershed is governed by the order of the stream and the point of interception of the stream.

Table 4.1: Watershed statistics of Aizawl district

Sl.No	Name of watershed and watershed number	Area of watershed (sq km)	% of Watershed area
1	3c2a8 – Tlawng - A2	294.26	8.23
2	3c2a9 – Tlawng - A1	247.49	6.92
3	3c2b3 –Tlawng - A3	242.87	6.79
4	3c2b4 –Tuirial - A2	352.72	9.86
5	3c2b5 –Tuirial - A1	946.60	26.47
6	3c2c6 – Tuivai - A3	163.84	4.58
7	3c2f1 – Tuivai - A	814.15	22.77
8	3c2f2 – Tuivai - A2	313.15	8.76
9	3c2f3 – Tuivai - A1	97.81	2.74
10	3d1a6 – Mat - A	103.42	2.88
	TOTAL	**3576.31**	**100.00**

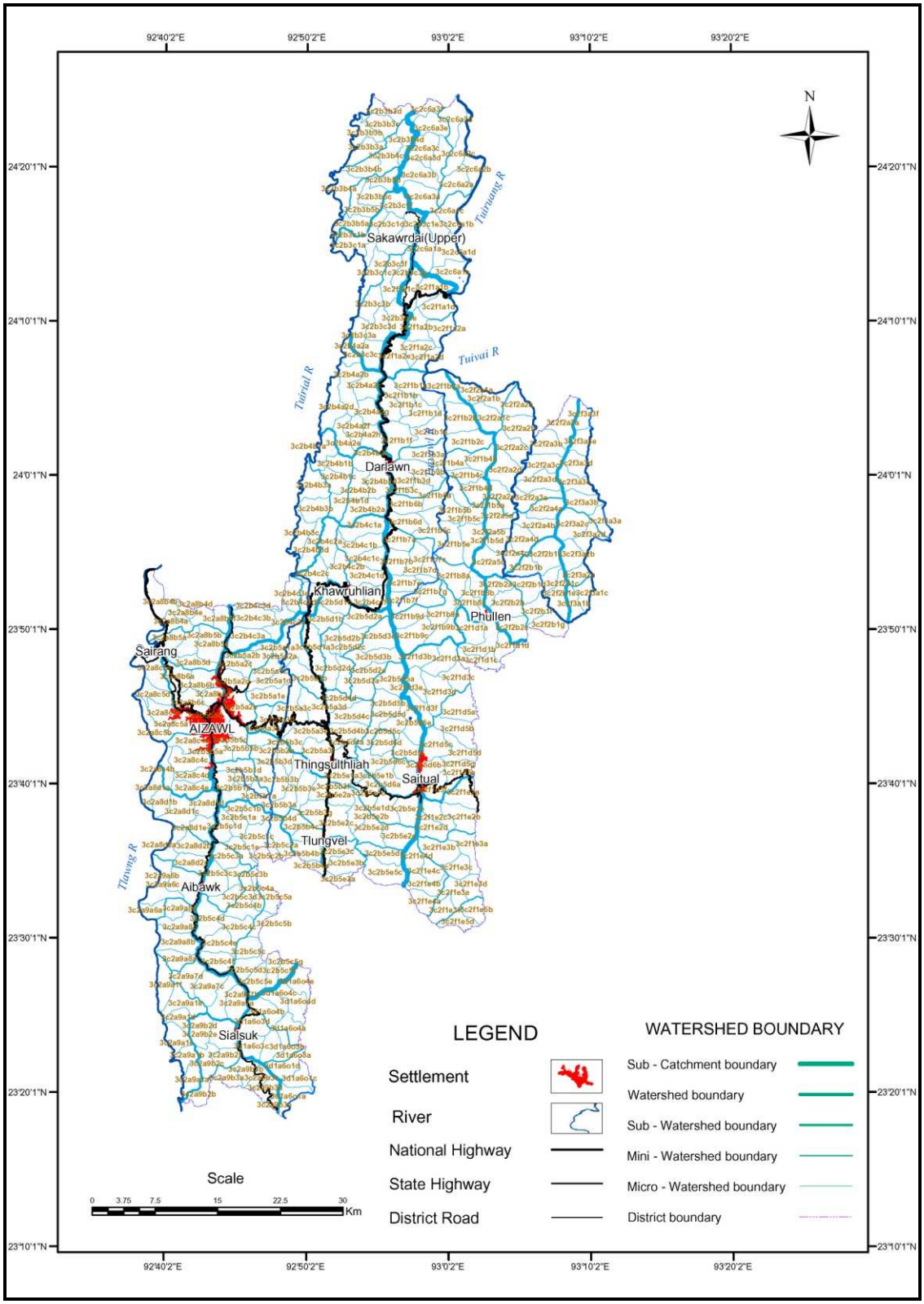


Figure 4.2 : Watershed map of Aizawl District, Mizoram

The concept of watershed as planning unit for development of land and water resources has gained importance since 1974 when the Ministry of Agriculture, Government of India initiated various development programmes like Hill Area Development Programmes (HADP); Drought Prone Area Programmes (DPAP); Desert Development Programmes (DDP) etc (SRSC, 2006). It is therefore, necessary to delineate watershed boundaries at various levels of hierarchy to identify development activities under various schemes in each watershed. Moreover, drainage networks help in delineation of watershed and for suggesting various water harvesting structures and soil conservation measures.

All India Soil and Land Use Survey (AIS & LUS) of the Ministry of Agriculture has developed a hierarchical system of watershed delineation like water resources region, basin, catchments, sub-catchments and watershed. Beyond this, the following three levels of watershed delineation had been carried out using Survey of India topographical maps up to micro-watershed levels (NRSA, 1995). These are: 1)-Sub-watershed (30 – 50 sq km); 2) Mini-watershed (10 – 30 sq km) and; 3) Micro-watershed (5 – 10 sq km).

As per the Watershed Atlas of India (Soil and Land Use Survey Organization, AIS and LUS, 1990), observations reveal that the Mizoram state falls into region 3 that is Brahmaputra and Northeastern state rivers comprising 2 basins of 3C (Brahmaputra tributaries that flow upto Bangladesh, Kalni Myanmar) and 3D (Eastern part of Manipur and Mizoram draining into Chindwin, Myanmar). These two basins have three catchments which fall under Mizoram states i.e. 3C2 (mostly Barak), 3C3 (partial drainage of Tripura and Mizoram flowing into Bangladesh) and 3D1 (eastern

part of Mizoram and Ngengpui lui). Furthermore, these catchments are sub-divided into 6 sub-catchments and 34 watersheds. These watersheds are further sub-divided into sub-watersheds, mini-watersheds and micro-watershed. The whole district of Aizawl falls into sub-catchments of 3C2A, 3C2B, 3C2F and 3C2C and 3D1A. The watershed statistics of Aizawl district are given in table 4.1 and the watershed map of Aizawl district is given in figure 4.2. Watershed code and statistics of micro-watershed is given in Appendix – II.

4.1.3. GEOLOGY AND GEOMORPHOLOGY

Aizawl district occupies the north-central part of the state and represents a monotonous sequence of argillaceous and arenaceous rocks, which are classified by Geological Survey of India into two formations viz., Middle Bhuban and Upper Bhuban Formations (GSI, 2011). The formations are folded into almost N – S trending anticlines and synclines and affected by longitudinal, oblique and transverse faults of varying magnitudes. An attempt has been made to classify the rocks into various stratigraphic divisions, but lack of any characteristic rock type and index fossils make it difficult to classify in detail. Therefore, the formations are classified into two formations on the basis of lithological assemblage and sedimentary structures.

4.1.3.1. Structures

In satellite imagery, geological structures like folds appear as crest and trough which are the indication of anticlines and corresponding synclines. The axis of the synclines usually follows prominent river valleys and their corresponding axis of anticlines passes through the ridges (sometimes along the flanks of the ridges).

Other geological structures called lineaments were also mapped using satellite imagery. This is done with the help of Digital Elevation Model and ground checking. Some lineaments, which are confirmed from Geological Survey of India report (Nandy, 1982), are classed as faults (well-defined cracks along which the rock masses on either side have relative displacement), while other lineaments, which show lateral displacements, are referred to as 'inferred faults' and other major lineaments with no prominent displacements are classed as Lineaments. The lineaments were identified mainly on their linear nature and straight stream segments, etc. The structural elements noticed in the area are both primary and secondary in nature. The beds generally trend N-S to roughly NNW-SSE and dip on either side from 15° to 65° with local variations at the vicinity of faults. Similar pattern earlier was also reported by Jaggi *et al.* (1986) in Aizawl district.

The area has been affected by a number of faults of varying magnitude. They are mostly transverse/oblique in disposition, except Uaithlâk lui – Sêr lui fault located between Sâmtlâng and Lunglêng villages, which is longitudinal in disposition. Major oblique faults are Châng te fault, which divides Sialsûk and Châmring villages; Chite fault and Chakai lui fault which are located within the city; Muthi lui – Sabual lui fault which cuts across the Tuirial river; Sihdarh lui – Tuirini lui fault which runs in between Tualbung and Hriangtlâng villages; Matai lui fault in the northern part of the district, and Rawkawn lui fault near Suangpuilawn village. The faults are delineated with the help of Satellite Imagery, SOI topographical maps on the basis of field criteria like shifting of axial plane, course of the rivers, etc and subsequent ground check. The general trend of the oblique faults is roughly NNW-SSE. In some cases,

the throw of the fault could not be measured or estimated due to the absence of any marker horizon. Presence of other minor faults is indicated in the area by reversal of dips. The total length of lineaments (including faults and inferred faults) is 101.06 km (SRSC, 2006)

4.1.3.2. Lithology

The lithological mapping was done with the help of topography and field checks. Different rock types were delineated from satellite imagery based on drainage pattern, texture and tone (Kumar *et al.*, 2010). Sandstone being resistant to weathering form massive hills and hogback ridges when they are horizontally bedded. Sandstone terrains shows coarse drainage texture and are usually with dendritic to rectangular in pattern due to high porosity and permeability.

Shale being incompetent rocks form subdued topography. They have fine drainage texture and parallel to sub-parallel pattern. As it has impervious nature therefore has high drainage density. The Surma Group of rocks is represented in the area by Middle and Upper Bhuban formations. The Middle Bhuban formation is mainly a thinly bedded sequence with sandstone–shale/siltstone ratio of about 50 : 50, with mudstone. Sandstone are fine to very fine grained, ash to bluish grey in colour, compact and hard, thinly bedded; rarely yellowish brown medium grained and friable. Few thick beds of sandstones are found in some areas. Shale and siltstone are dark grey and grey in colour and usually splintery. This group of rocks occupies the core of anticlines, flanked on either side by the rocks of Upper Bhuban formation. A few thickly bedded sandstone bands are noticed at certain places. These beds are important source of building and road construction materials in the area, and they

form the main ridges of the area. The contact between Middle and Upper Bhuban formations is gradational and transitional.

The Upper Bhuban formation occupies the core of Tlawng, Tuirial, Tuivawl and Tuirini synclines, and the lithology in these areas is mainly represented by shale – siltstone and little mudstone. The arenaceous – argillaceous ratio is about 50 : 50 in the lower part and 80 : 20 in the upper part of the formation. Geomorphologically, this unit occurs as subdued hills giving rise to hummock topography.

Table 4.2 : Geological/Lithological statistics of Aizawl district, Mizoram

Sl No.	Rock Types	Area (sq km)	Percentage (%)
1	Sandstone	1279.63	35.78
2	Siltstone & Shale	2264.32	63.31
3	Limestone	1.47	0.05
4	Clayey Sand	25.52	0.71
5	Gravel, Sand & Silt	5.36	0.15
	Grand Total	**3576.31**	**100.00**

(Source: MIRSAC – Natural Resources Atlas of Mizoram, 2009)

The lithological mapping was done with the help of topography and field checks, based on observations; lithology of the district was divided into 5 litho classes – 1) Sandstone, 2) Siltstone and Shale, 3) Limestone, 4) Gravel, Sand and Silt and, 5) Clayey sand. Sandstone is the harder rock formation and was found mainly along the ridgeline owing to its resistance to erosion. Overall, it covers an area of 1,279.63 sq km of the district which is 35.78 % of the total area. Siltstone and shale were put together for mapping as they are almost inseparable, and this unit covers most of the

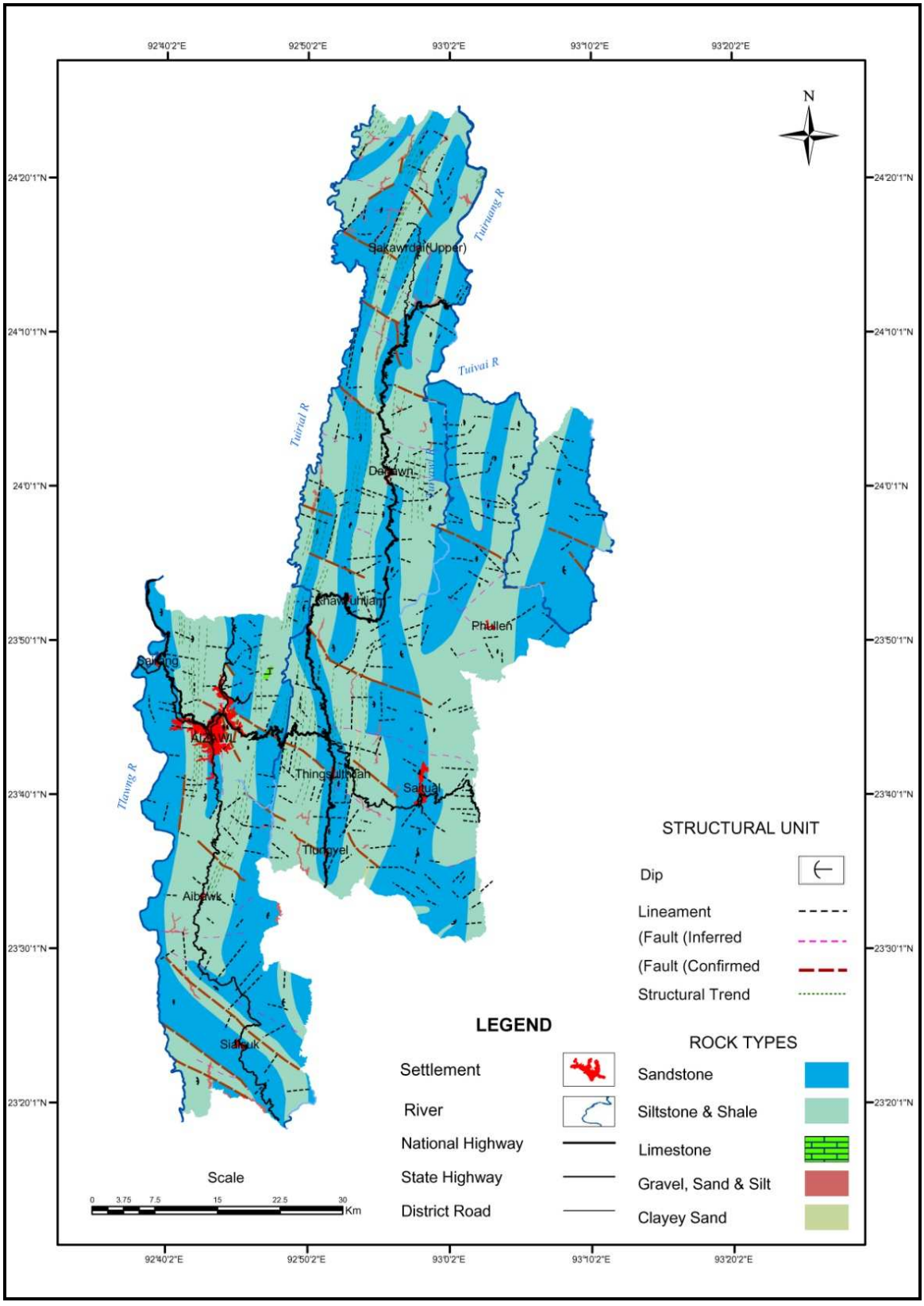


Figure 4.3 : Geological map of Aizawl district, Mizoram

study area. A total area of 2,264.32 sq km identified under this class which is 63.31 % of the Aizawl district. Gravel, sand and silt were found along the major rivers i.e. Tlawng, Tuirial, Tuivawl and Tuirini and cover an area of 5.36 sq km which is 0.15 % of the total area. Clayey sand deposits were found scattered all over the area along with small streams covering an area of 25.52 sq km (only 0.71 % of the study area). Limestone is found in small outcrop near Muthi village and along the banks of Tuirial River. It only covers about 1.47 sq km and constitute only 0.05 % of the total area. The detail statistics of lithology is given in table 4.2 and the geological map is shown in figure 4.3.

4.1.3.3. Economic minerals:

Earlier observations (GSI, 2011) along with present work indicated that Aizawl district as a whole is void and empty as far as major mineral deposits are concerned. However, stray deposits of certain mineral was noted and presented here. Bands of shell limestone deposit were noticed near Muthi and Sesawng villages (Directorate of Industries, Govt of Mizoram, 1995). The limestone bands occur as detached lensoidal bodies associated with sandstones and siltstones (Singh *et al*., 1996). The limestone is very hard, massive and grey to dark grey in colour. Apart from this, the Geological Survey of India have reported the occurrence of small quantities of limestone deposits in the Tam dil lui *nala* section, in the east of Sesawng village at Dam lui, Ngharum lui near Tuirial bridge and near PHE rest house on Reiek-Aizawl road (Jaggi *et al*., 1986). Besides, limestone also found as stalactitite deposits at Tam dil lui and Dam lui.

The sandstones within the study area were bluish-ash to khaki-coloured, hard, compact and massive. They are being used as road metals and for building construction materials. They are extensively mined near Hlimen, Thiak, Sentezel, Tlungvel, Keifang, Zemabawk and Lawipu areas also reported earlier by SRSC (2006). In addition to these, minor quarrying operations have been taken up in various places of the district.

4.1.3.4. Geomorphology:

Geomorphology is essentially the study of relief features of the earth's surface and factors that produced them. Besides satellite data, slope and contour lines readily available on toposheets were used for geomorphology mapping as suggested earlier by Kumar and Guha (2010). In addition, field survey was also carried out for geomorphologic mapping of the study area.

Structural hill constitutes the main geomorphic class and dominates the state of Mizoram. Structural hills as the name implies, is of structural origin, associated with folding, faulting and other tectonic processes. Geological structures like folding and faulting can be delineated from satellite imagery. For better understanding, structural hills were further divided into three classes viz., high structural hills (above 1200m), medium structural hills (500-1200m) and low structural hills (below 500m) during the course of this study as suggested by SRSC (2006). This classification was done with the help of contour lines from toposheets.

Structural hill constitutes the main geomorphic class and dominates the entire area of Aizawl. Observation reveals that high structural hills (above 1200m) covers an area of 180.21 sq km (5.04 % of the study area) and were mainly found at the peaks of

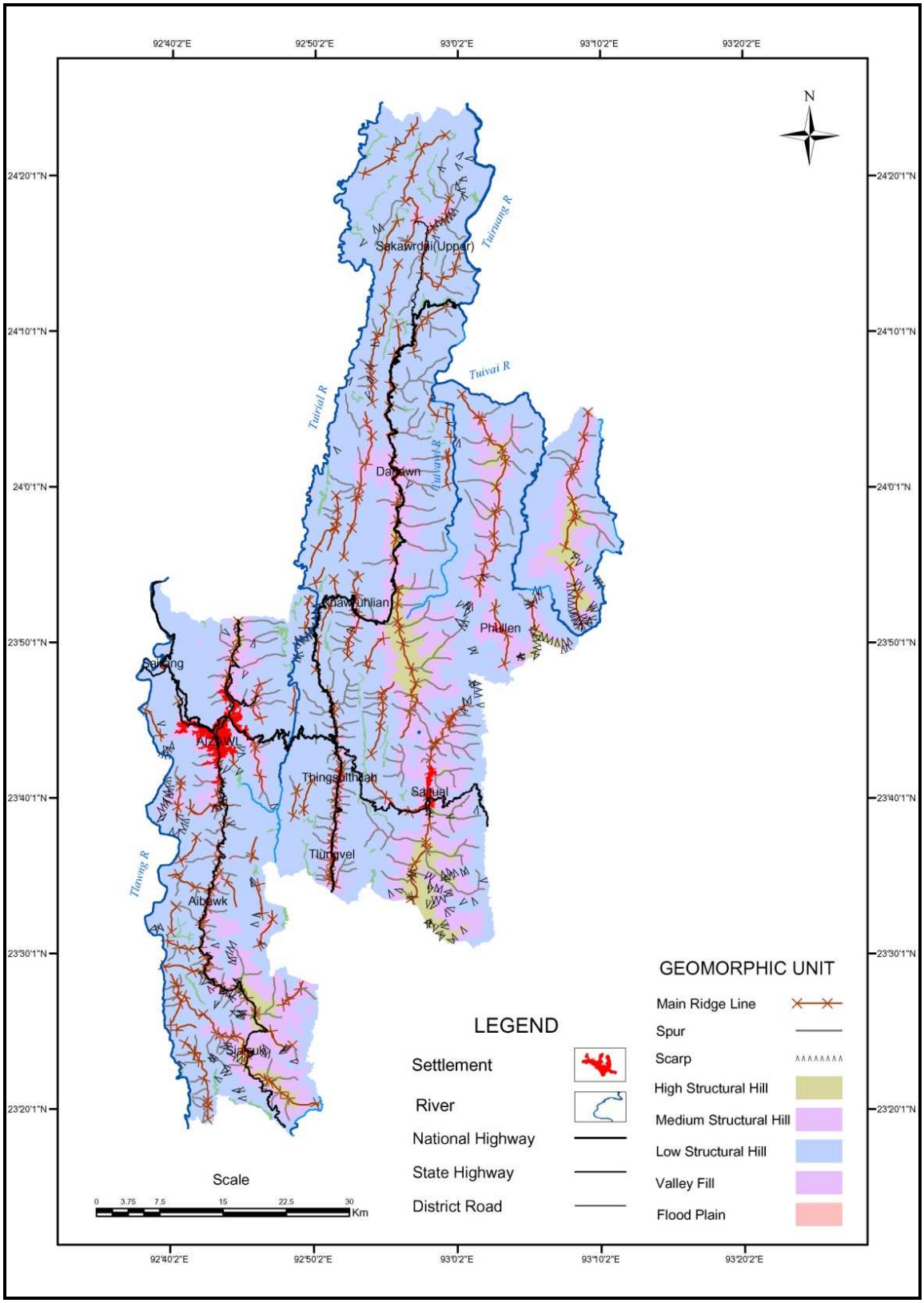


Figure 4.4 : Geomorphogical map of Aizawl district, Mizoram

Table 4.3 : Geomorphological satistics of Aizawl district, Mizoram

Sl No.	Geomorphic Unit	Area (sq Km)	%
1	High Structural Hill (above 1200m asl)	180.21	5.04
2	Medium Structural Hill (500 – 1200m asl)	830.37	23.22
3	Low Structural Hill (500 & below m asl)	2530.93	70.77
4	Valley Fill	33.07	0.92
5	Flood Plain	1.73	0.05
	Grand Total	**3576.31**	**100.00**

(Source: MIRSAC – Natural Resources Atlas of Mizoram, 2009)

Hmuifang, Tawi, Chalfilh and Mawmrang tlang. Medium structural hills (500-1200m) covers an area of 330.37 sq km (23.22% of the study area) were found along the Aizawl town, Neihbawih and along East Phaileng ridge. It was also found below the peaks of Hmuifang, Tawi, Chalfilh, Mawmrang tlang and Suangpuilawn ridges. Low structural hills (below 500m), covers an area of 2,530.93 sq km which contributed maximum 70.77 % of the study area and was most common hill structure throughout the entire area.

Other geomorphic classes like valley fill and flood plain were delineated directly from FCC satellite imagery as they are usually associated with water body (river) which appears as black colour. Flood Plains are usually found along the major rivers and they are formed by deposition of recent alluvium, such as gravel, sand and silt. The materials constituting the flood plain will appear as bright patches in FCC satellite imagery. Valley fill is of fluvial origin characterized by the unconsolidated sediments deposited by streams or rivers in a narrow fluvial valley. Valley fill existed mainly along Tuirial and Tuirini rivers and their tributaries, and along the streams in

the northern part of the district. It covers an area of 33.07 sq km which is only 0.92 % of the total area of Aizawl district. Flood plains were found along the major rivers. This unit covers an area of 1.73 sq km (only 0.05 % of the total area). The detail statistics of geomorphology is shown in table 4.3 and geomorphological map is shown in figure 4.4.

4.1.4 GROUND WATER POTENTIAL ZONATION

With the rapid urbanization and increased population, the demand for water supply increases. 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. An area experiencing constant drought and facing 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 agricultural purposes.

Preparation of ‘ground water potential zonation map’ is one of the first steps in exploring and exploiting the ground water resources. Ground water potential zonation map divides an area into zones of varying degrees of ground water potentiality based on an estimated significance of various geo-environmental factors operated and observed on the surface which are responsible for inducing the potentiality of an area. Ground water potential zonation map helps to choose and identify the potential zones, selecting viable sites for carrying out exploration and provides the basic data of the different potential zones of ground water resources for the study area.

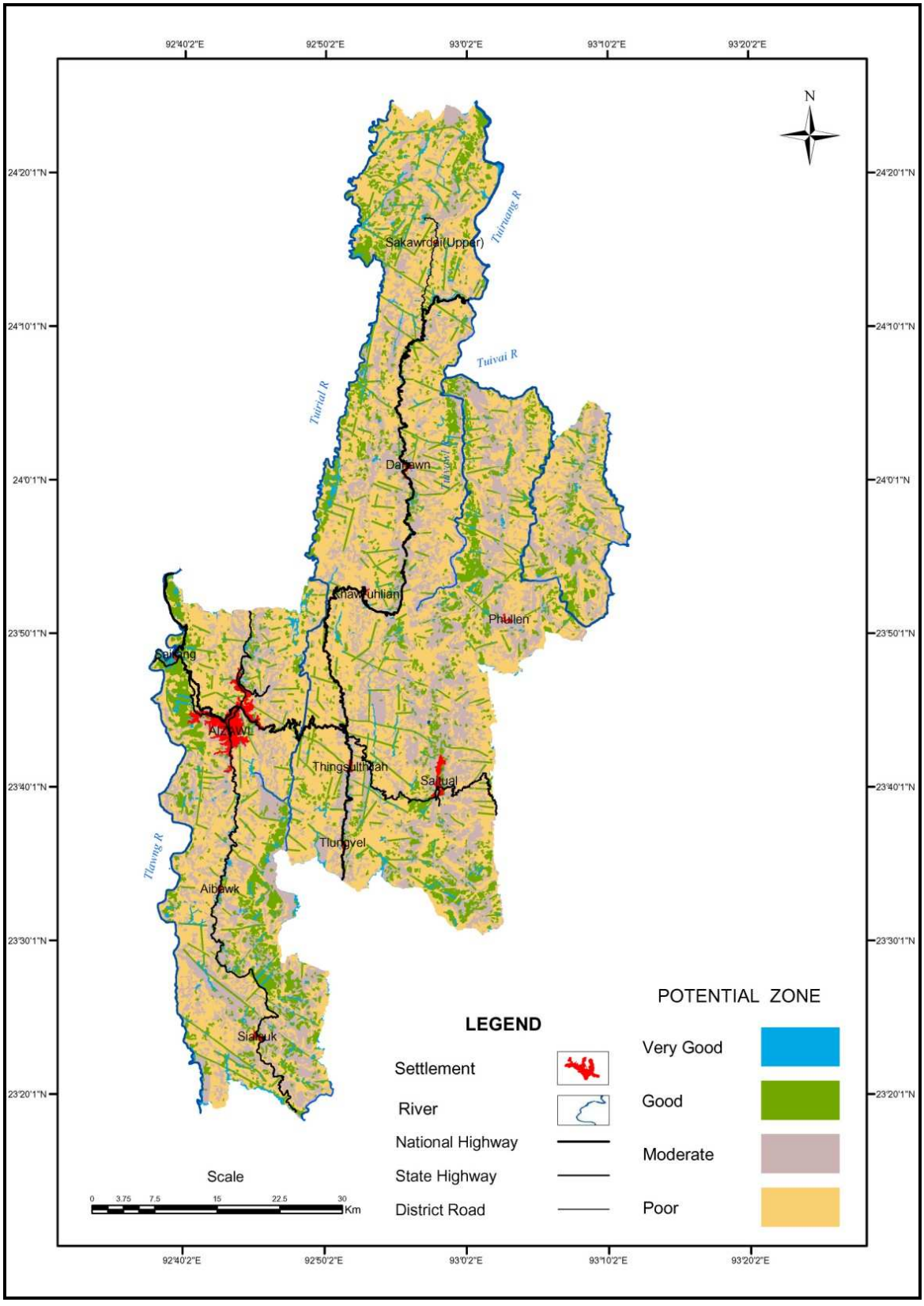


Figure 4.5 : Ground water potential map of Aizawl district, Mizoram

Table 4.4 : Statistics of ground water potential zones of Aizawl district

Sl No.	Potential Zone	Area (sq km)	Percentage (%)
1	Very Good	109.14	3.05
2	Good	593.55	16.60
3	Moderate	1005.20	28.11
4	Poor	1868.42	52.24
	Grand Total	**3576.31**	**100.00**

(Source: MIRSAC – Natural Resources Atlas of Mizoram, 2009)

The ground water potential zones map of the Aizawl district is shown in figure 4.5 and the area statistics is given in table 4.4. During the course of this study, very good zone identified in valley, flood plain and low lying areas of the district and covers an area of 109.14 sq km and therefore contributed only 3.05 per cent of the total study area. Good zones spreads over an area of about 593.55 sq km located near faults, joints and fractures and forms 16.60 per cent area only. Moderate zone was evenly distributed within the study area and covers an area of 1,005.20 sq km which occupied 28.11 per cent of the total area. Likewise, poor zone occupied an area of 1,868.42 sq km which is 52.24 per cent of the total study area. In General, the study indicates that overall status of the underground water in the district is very poor.

4.1.5. SLOPE, ASPECTS AND ALTITUDE

Satellite imagery and Survey of India toposheets were utilized for deriving the information on slopes, aspects and altitudes. ERDAS Imagine and Geographic Information System (GIS) package were utilized for generating Digital Elevation Model (DEM) (ERDAS, 1999). The different slope facets, aspect and altitudinal zones were derived for Aizawl district. The result is presented in following paragraphs under different subheads.

4.1.5.1. Slope

Slope is a measure of change in elevation. It is a crucial parameter in several well-known predictive models used for environmental management, including the universal soil loss equation and agricultural non-point source pollution models.

Aizawl district is uniquely characterized by several prominent hill ridges running parallel to each other, most of which roughly runs from north to south, except the southernmost hill ridges around Sialsuk and Chamring villages. The hill ridges in these locations run in north-west to south-east direction. Hill ridges in the study area include many hill tops, several of which occupy prominent locations. The length of these hill ridges varies widely, and the hill ridges are often terminated by valleys and river plains.

The district is lacking in important plain areas. Few plain areas of small dimensions in between the hills and along the river banks are noticed in certain parts of the study area. They are more confined to the northernmost part of the district. The plain areas within the district are too small in area to be utilized for wetland rice

cultivation (WRC). However, few areas including Tuirini and Changte rivers valley are utilized for wet rice cultivation. During the present observation, the slope of the area were conveniently divided into 9 slope facets as presented in table 4.5 and slope map is shown in figure 4.6.

Table 4.5 : Slope satistics of Aizawl dstrict, Mizoram

Slope (%)	Area (sq km)	% of total geographical area
0 – 3	22.93	0.64
3 – 10	2.72	0.08
10 – 15	5.90	0.17
15 – 25	119.35	3.34
25 – 35	341.20	9.54
35 – 50	1370.70	38.33
50 – 70	1164.75	32.57
70 – 100	450.35	12.59
> 100	98.40	2.75
Total	**3576.31**	**100.00**

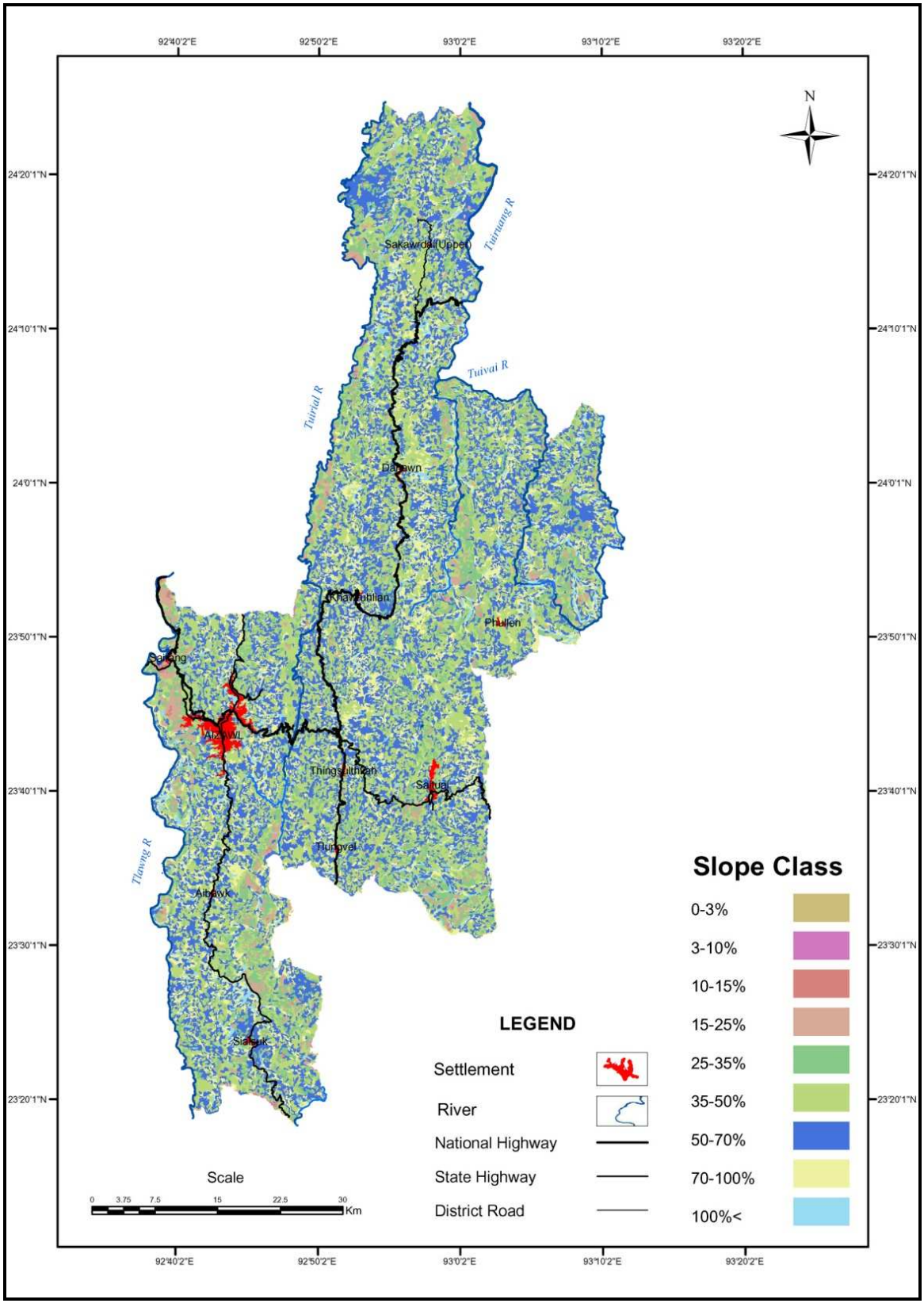


Figure 4.6 : Slope map of Aizawl district, Mizoram

Area having 0 to 3% slope covers a total area of 22.93 sq km constituting only 0.64% of the total area of Aizawl district. Area having 3 to 10% slopes covers a total area of 2.72 sq km (only 0.08% of the total area). Likewise, area having 10 to 15% slope covers a total area of 5.90 sq km (0.17%). Nearly, 119.35 sq km i.e. 3.34% of total area was covered with slope of 15 to 25%. Landscape with 25 to 35% slope constituted 9.54% of the area with a total cover of 341.20 sq km. Likewise, area having 35 to 50% slope covers an area of 1370.70 sq km (38.33 %), 50 to 70% slope covers 164.75 sq km area (32.57%), 70 to 100% slope covers 450.35 sq km area (12.59%). Area having > 100% slope covers a rather small area of 98.40 sq km which constitutes to 2.75% slope of the total area. In general, area having 35 to 50% slopes covered the largest area followed by slope having 50 to 70% slopes. Whereas, area having 3 to 10% slope has the smallest area followed by 10 to 15% slope and 0 to 3% slope, respectively.

4.1.5.2. Aspect

The slope aspects of the hills within the study area are more or less evenly distributed. Locations within the study area having no aspect or relatively flatland occupied an area of 2.24 sq km constituted small fraction i.e. only 0.06 % area of the Aizawl district. Overall, the aspect of the area was conveniently divided into 9 aspects after the observation and detail is presented in table 4.6 and aspect map is shown in figure 4.7. The statistics of the aspect data reveals that the total area having North aspect contributed 9.53% to total land with an area of 340.75 sq km. Likewise, the total area having Northeast aspect was 471.20 sq km (13.18 %), East aspect 493.11 sq km (13.79 %), Southeast aspect 434.59 sq km (12.15 %), South aspect 382.64 sq km

Table 4.6 : Aspect statistics of Aizawl district, Mizoram

Aspect	Area (sq km)	Percentage (%)
North	340.75	9.53
North-east	471.20	13.18
East	493.11	13.79
South-east	434.59	12.15
South	382.64	10.70
South-west	438.20	12.25
West	520.20	14.54
North-west	493.38	13.80
Flat-land	2.24	0.06
Total	**3576.31**	**100.00**

(10.70 %), Southwest aspect 438.20 sq km (12.25 %), West aspect 520.20 sq km (14.54 %), Northwest aspect 493.38 sq km (13.80 %). Approximately, only 2.24 sq km area was recognized without aspect with only 0.06 % share to the total area of Aizawl district. Similar observations made earlier by MIRSAC (2009).

Observation reveals that western aspect covered maximum area followed by North-western aspects in the study site. This can be accounted duly because of the fact that the hill ridges mainly run from north to south in their formation trend. North-east aspect is often considered most suitable for agriculture development, establishing orchards, farms and other residential areas. Few places within the area would not be utilized for cultivation as it has already used for built up land, populated

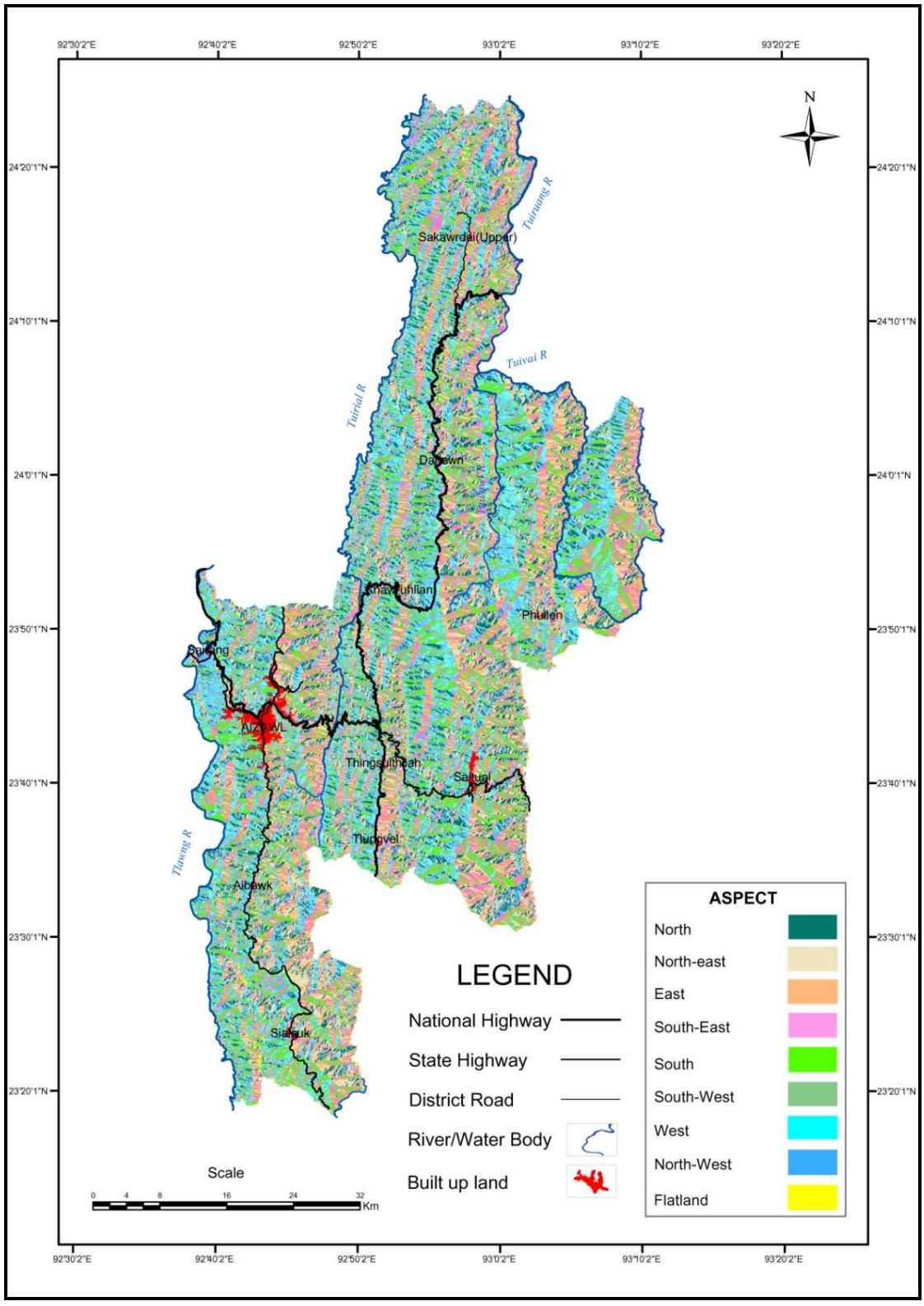


Figure 4.7 : Aspect map of Aizawl district, Mizoram

for other purposes and as majority of the area is reserved to be under forest. The vast remaining areas could be, however, be utilized effectively according to the need and constraints prevalent within their respective areas. Aspect covering the least area is flat land followed by north. Few major rivers *viz.* Tlawng, Tuirial, Tuvai, Tuirini and Tuivawl rivers have not influenced the topography of the study area in the formation of flatland areas.

4.1.5.3. Altitude

The altitude of Aizawl district can be described to have uncommon features in their existence. While many places include montane zones and several areas fall under low altitude area. Chalfilh tlang (1905 m asl) is highest peak located in the central part of the district near Hriangtlang village. The lowest elevation within the study area, on the other hand, is represented by the Tlawng river valley near Sairang and the Tuirial river valley in the central part of the district, where the elevation ranges from 100 to 200 m asl.

The altitude within the Aizawl city is also fairly high. The altitude of Thokaw tlang, near Hlimen locality is 1191 m asl, while top of Tlangnuam locality attains an altitude of 1156 m asl. Likewise, Laipuitlang, located in the centre of the city and Buiahmun tlang, near Durtlang locality attains a height of 1188 m asl. However, the highest peak within the city area is Neihbawih tlang near Sihphir locality (1500 m asl).

The altitudinal zone map and detail statistics of the study area are given in figure 4.8 and table 4.7 respectively. Overall, the altitude ranges between 500 – 700 m

asl covers the largest area with 872.98 sq km which is 24.41% of total land. This was followed by 300 – 500m asl altitudes (802.52 sq km and 22.44% of the district area). The altitude ranging from 1400 – 1500 m asl covers the least (only 0.78%) with an area of 27.90 sq km followed by the altitude > 1500 m asl (33.26 sq km and 0.93% of the district area).

Table 4.7 : Altitude statistics of Aizawl district, Mizoram

Sl.No.	Height (m asl)	Area (sq km)	% of total geographical area
1	0 - 300	521.07	14.57
2	300 - 500	802.52	22.44
3	500 - 700	872.98	24.41
4	700 - 900	676.64	18.92
5	900 - 1000	241.4	6.75
6	1000 - 1200	281.46	7.87
7	1200 - 1400 Mts	119.09	3.33
8	1400 - 1500 Mts	27.9	0.78
9	> 1500 Mts	33.26	0.93
TOTAL		**3576.32**	**100**

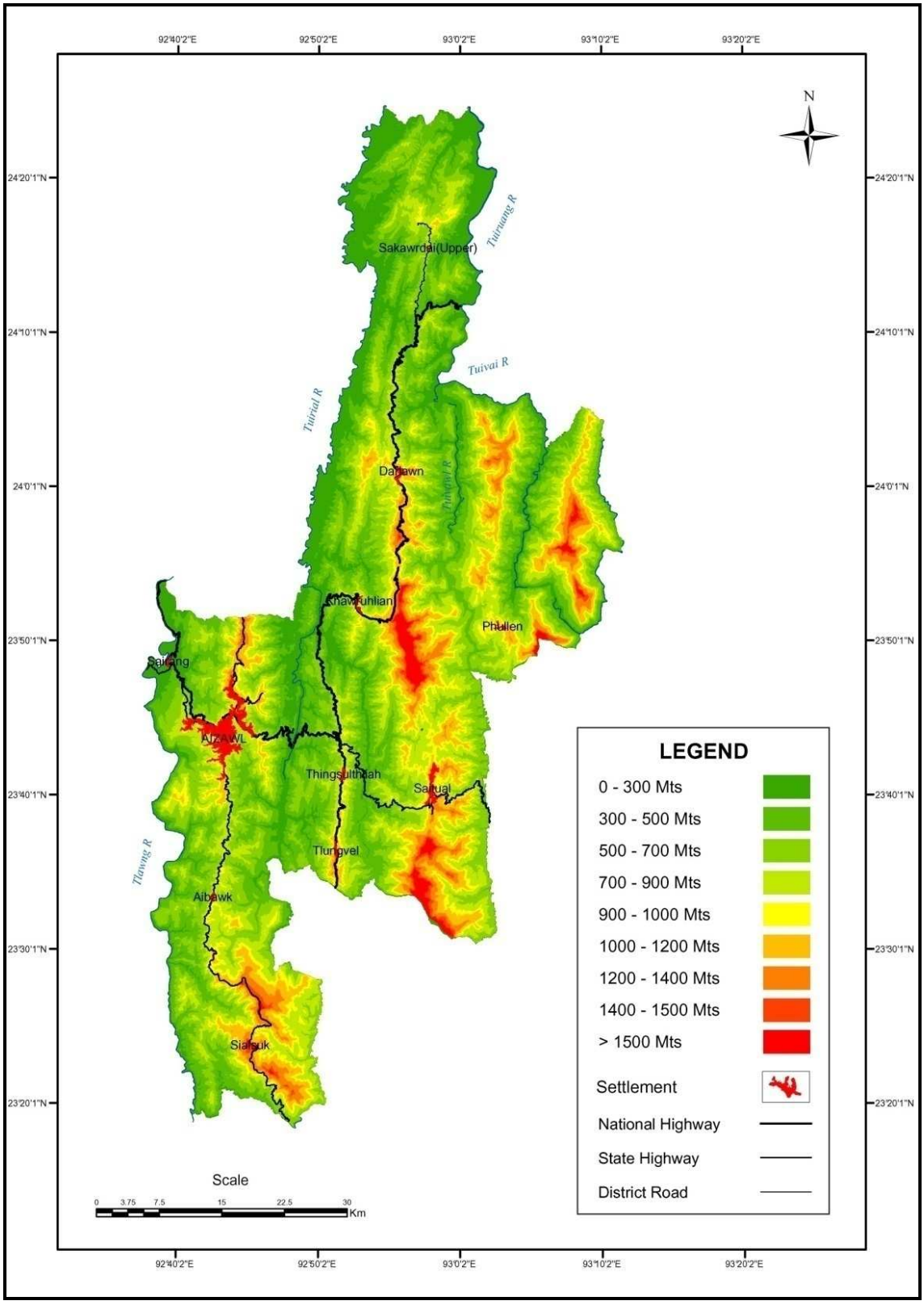


Figure 4.8 : Altitude map of Aizawl district, Mizoram

4.1.6. LAND USE / LAND COVER

The land use / land cover statistics of the district Aizawl in Mizoram is given in table 4.8 and corresponding map is shown as figure 4.9. After observations, the major land use/land cover classes within the district were broadly categorized into: 1)-settlements, 2)- agricultural land/horticultural land, 3)- forests, 4)-bamboo forest, 5)-forest plantations, 6)- shifting cultivation, 7)- scrubland and, 8)- river/water body as suggested by NRSC (2011).

4.1.6.1. Settlements

Settlements include residential and non-residential areas including recreational and commercial areas. The study area includes one city i.e. Aizawl city, three notified towns namely Sairang, Darlawn and Saitual and 98 villages. Aizawl city is the capital of Mizoram and also the headquarters for all government departments and educational institutions. City and towns are usually appearing as relatively large and the rural areas or villages vary in size from big to small, irregular and discontinuous in appearance; and can be seen in clusters, non-contiguous or scattered in the FCC satellite imagery. Overall, settlements cover an area of 48.16 sq km, which accounts for 1.35 % of the total area of the district.

4.1.6.2. Agricultural land

Agriculture land comprises those areas, which are permanently used for crop cultivation. This class of land has been divided further into Kharif crop land and agricultural/horticultural plantation.

Table 4.8 : Land use / Land cover statistics of Aizawl district, Mizoram

Sl. No.	Land category	Area (sq km)	% of total area of the district
1	**Settlements**	48.64	1.35
2	**Agriculture Land**		
	2.1 Kharif (WRC)	2.23	0.06
	2.2 Agri/Horti Plantation	11.93	0.33
3	**Forest**		
	3.1 Dense	642.55	17.97
	3.2 Medium Dense	410.21	11.47
	3.3 Less Dense	399.73	11.18
	3.4 Bamboo	1403.01	39.23
	3.5 Forest Plantation	15.09	0.42
4	**Shifting Cultivation**		
	4.1 Current Shifting Cultivation	185.44	5.19
	4.2 Abandoned Shifting Cultivation	407.72	11.41
5	**Scrub land**	35.38	0.99
6	**Water body**	14.29	0.40
	Total	**3576.31**	**100.00**

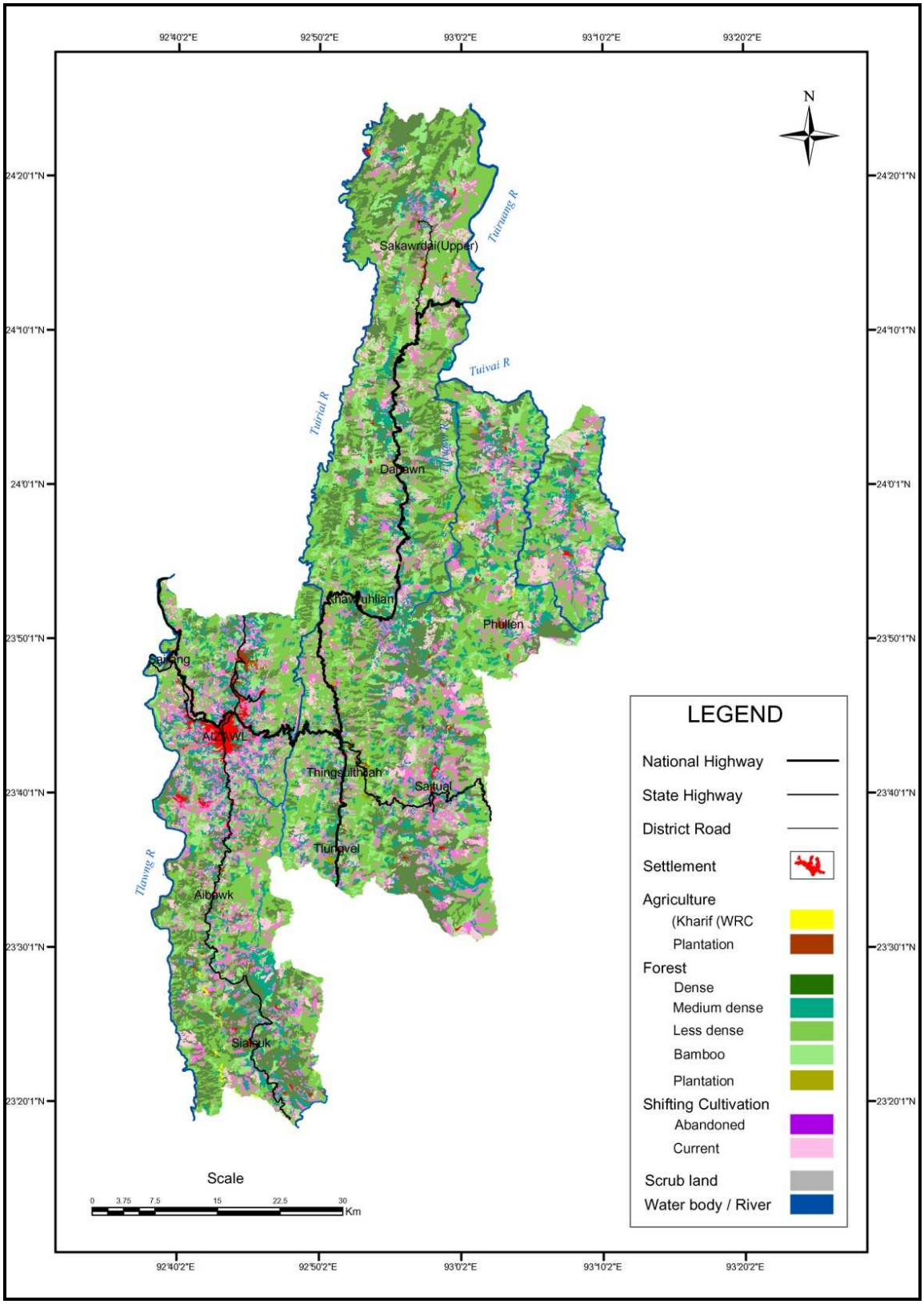


Figure 4.9 : Land use land cover map of Aizawl district, Mizoram

4.1.6.2a. Kharif crops:

Wet rice cultivation (WRC) areas located in the low lying plains represent this class in Aizawl district. The terrain features greatly predict the practice of this form of farming. A small and scattered patch of lands representing the Kharif crop found in the central and southern part of the district. The WRC areas are usually located at the banks of rivers, streams and sometimes close to settlement areas, where soil and water supply is suitable for its establishment and growth. Based on observation and data collected, it can be said that most of the WRC areas are found in flat areas at the banks of Tuivawl, Tuirini and Tuivai rivers, which eventually irrigates the paddy fields either directly or through its tributaries. Therefore small patches are also found near the banks of rivers Tuirial, Chite, Changte, Lik, Lao and Mat. In the FCC satellite imagery, they were recognised by their location, shape and association. They are usually regularly shaped, found in low lying valley plains and with bright reflectance during dry season and reddish tinge during rainy season. Observation reveals that total area under WRC in Aizawl district was 2.23 sq km, which accounts for only 0.06% of the total area of the district. MIRSAC (2008) recorded similar data for WRC in the district.

4.1.6.2b. Agricultural/Horticultural Plantation:

This class of land use pattern includes areas, which are being utilized for the plantation of traditional as well as cash crops. Observation reveals that agricultural/horticultural plantation covers an area of 11.93 sq km in Aizawl district, and therefore, occupied only 0.33% of the total district area. As the agricultural/horticultural plantations were mixed plantations, each plantation could

not be delineated from the satellite imagery due to scale factor. The prominent plantations includes Citrus woodlands (Orange - *Citrus reticulata Linn.* and Lemon - *Citrus limon* L.Burm.*),* Tea (*Camellia sinensis* L. Kuntze), Pineapple (*Ananas comosus* Merr.), Banana (*Musa paradisiacal* Linn.), and Tung (*Aleurites fordii* Hemsl.) plantations. Such plantations are seen near Thiak, Tachhip, Samlukhai, Muallungthu, Sateek, Phulpui and N.Khawlek. Few scattered patches of the plantations are also found along roadsides and settlement areas of Sakawrtuichhun, Khawruhlian, Thingsulthliah, Phulmawi, Sihfa and Sailam villages. Banana plantations are found near Seling, Sesawng, Tlungvel, Sihfa, Thingsulthliah, Sawleng, Selesih etc. Tea plantation is found near N.Khawlek village and it is also found wild in other higher altitude places like Hmuifang and Sialsuk villages. Tung plantation is found near N.Khawlek, Phuaibuang, Dilkhan, Sesawng, Tuirial, Sihfa, Darlawng and Samlukhai villages.

The other miscellaneous plantations observed during ground verification were cash crops which includes Beans (*Phaseolus vulgaris* Linn.), Squash (*Sechium edule* Jacq.), Maize (*Zea mays* Linn.), Pumpkin (*Cucurbita maxima* Deuch.), Brinjal (*Solanum melongena var. esculentum* Linn.), Mustard (*Brassica juncea* Linn.), Tobacco (*Nicotiana tobacum* Linn.), Papaya (*Carica papaya* Linn.), Cucumber (*Cucumis sativa* Linn.), Cow pea (*Vigna sinensis* Linn.), Cabbage (*Brassica oleracea var. capitata* Linn.), Sugarcane (*Saccharum officinarum* Linn.) (ICAR, 2010). Squash plantation is found at higher altitude places like Durtlang and Sihphir where they are growing luxuriantly. Other crops are grown in a mixed form.

4.1.6.3. Forest Types

The forest cover type of Aizawl district is mainly tropical wet evergreen forest mixed with semi evergreen and tropical moist deciduous forests comprising mainly of bamboo (Champion and Seth, 1968). Sub-tropical forest found at mountainous ridges in certain places like Chalfilh, Tawizo and Hmuifang. Overall forests were represented by diversified and rich vegetation. Depending on the density of the canopy cover, the forests during the course of this study were divided into dense/closed, medium dense and less dense forest as per SRSC (2006).

4.1.6.3a. Dense/Closed Forest:

This class includes natural forests, which are not disturbed by any biotic factors like shifting cultivation and other human activities and are having very thick crown density (> 40%) as suggested by NRSA (2006). Evergreen and semi-evergreen forests in the district represented this class and covers major portion of this area. Similar observations reported earlier by Negi (1989). It covers an area of 642.75 sq. km, which accounts for 17.97 % of the total area of the district. Vast dense forests are found near the location viz., Sailam, Hmuifang, Tawizo, Lenchim, Buhban, Mauchar, Palsang, Vanbawng, Luangpawn, Sialsuk, Samlukhai, Lungsei, Sailutar and Khanpui (Chalfilh and its environs) villages.

The dominant species in the upper storey are *Celtis tetrandra (Roxb.)*, *Anthocephalus chinensis* (Lam.) Rich.Ex.Walp, *Wendlandia grandis* (Hook.F.), *Protium serratum* (Wallich), *Phoebe lanceolata* (Nees), *Phoebe attenuate* (Nees), *Ficus benghalensis* (L.), *Garuga pinnata* Roxb., *Terminalia myriocarpa* (Van Heurck

& Muller), *Wightia speciosissima* (D.Don), *Lagerstroemia speciosa* (L), *Aporusa octandra* (Buch.Ham ex D.Don), *Rhus succedanea* (L), *Litsea salicifolia* (Roxb ex Nees), *Xantolis hookeri* (C.B.Clarke), *Lithocarpus dealbata* (J.D.Hooker & Thomson), *Magnifera sylvatica* (Roxb), *Symplocos racemosa* (Roxb), *Quercus helferiana* (A.DC), *Sapindus mukorossi* (Gaertn), *Ficus religiosa* (L), *Ficus tinctoria* (G.Forst), *Macaranga indica* (Wt.), *Derris robusta* (Roxb. Ex DC), *Palaquium polyanthum* (Wall.), *Engelhardtia spicata* (Blume), *Careya laciniosa* (Shellbark), *Betula acuminate* (L), *Albizia procera* (Roxb), *Myrica esculenta* (Buch. Ham. ex Don), *Prunus jenkinsii* (Hook.f.&Thomson), *Hedyotis scandens* (Roxb), *Acacia oxyphylla* (Graham), *Acacia pennata* (L), *Elaeocarpus lanceaifolious*(Roxb), *Sterculia villosa* (Roxb), *Sterculia colorata* (Roxb.), *Hydnocarpus kurzii* (King), *Juglans regia* (L), *Schima wallichii (*DC), *Cinnamomum glanduliferum* (Wallich), *Bischofia javanica* (Blume), *Syzygium cumini* (L), *Prunus nepalensis* (L), *Morus macroura* (Miq), *Acrocarpus fraxinifolius* (Wt & Arn), *Eriobotrya bengalensis* (Roxb), *Michelia oblonga (*Wall.ex Hook. f. & Thomson), *Bombax insigne* (Wallich), *Quercus lineate* (Blume), *Ulmus lanceifolia* (Roxb), *Macropanax dispermus* (Blume), *Bombax ceiba* (L), *Mitragyna diversifolia (*Wall ex G.Don), *Castanopsis indica* (Roxb Ex. Lindl), *Calophyllum polyanthum* (Wall ex Choisy), *Heliconia excels* (L.Anderson), *Pterospermum acerifolium (*Willd), *Artocarpus chama* (Buch.-Ham), *Artocarpus nitidus sp.griffithii* (King), *Toona ciliate* (M.Roem), *Kydia calycina* (Roxb), *Kadsura heteroclite* (Roxb), *Prunus undulate* (Buch.-Ham ex Don.), *Elaeocarpus aristatus* (Roxb), *Styrax polysperma* (C.B.Clark), *Ficus semicordata (*Buch.-Ham. ex Sm), *Tetrameles nudiflora (*R.Br.), *Derris robusta (*Roxb. Ex DC.), *Vitex*

pendicularis (Wall), *Glochidion khasicum (Hook. F.)*, *Albizzia odoratissima* (L.f.) Benth, *Castanopsis tribuloides* (Smith), *Sapium baccatum* (Roxb), *Dysoxylum gobara* (Buch.-Ham)Merr, *Gmelina arborea* (Roxb), *Saurauia punduana* (Wallich), *Garuga floribunda var. gamblei (*King ex Smith), *Albizzia chinensis* (Osbeck)Merr., *Bauhinia variegata* (L), *Drymycarpus racemosus* (Roxb), *Garcinia sopsopia* (Buch.-Ham), *Anogeissus acuminate* (Roxb.ex.DC), *Alphonsea ventricosa* (Roxb), *Stereospermum chelonoides* (L.f. DC), *Duabanga grandifolia* (Roxb ex. DC) *and Embelia ribes* (Burm. F.). *Entada pursaetha* (DC), *Smilax glabra* (Roxb) *and Cayratia obovata* (Thunb) are the dominant climbers, which are associated with the above tree species (Sawmliana, 2003).

In the middle storey, the dominant species identified were*: Pithecellobium heterophyllum* (Roxb), *Zanthoxylum armatum (*DC), *Maesa Montana* (A.DC), *Alangium chinense* (Lour.), *Trema orientalis* (L) Blume, *Ostodes paniculata* (Blume), *Ligustrum robustum* (Roxb.), *Mucuna gigantean (*Wild.) DC., *Aechynanthus maculate* (Roxb.), *Garcinia kydia* (Roxb), *Zizyphus incurve* (Roxb), *Mesua ferrea* (L), *Wrightia arborea* (Dennstedt), *Styrax serrulatum* (Roxb), *Syzygium claviflorum* (Roxb), *Litsea lancifolia* (Roxb. ex Nees), *Dillenia pentagyna* (Roxb), *Fagerlindia fasciculate* (Roxb), *Pittosporum nepaulense* (DC), *Leucosceptrum canum* (Roxb), *Symplocos racemosa* (Roxb), *Beilschmiedia gammieana* (King ex.Hook. f.), *Boehmeria rugulosa* (Wedd), *Leea compactiflora* (Kurz), *Cordia dichotoma* (forst f.), *Helicia robusta* (Roxb), *Bridelia monoica* (Lour.) Merr., *Flacourtia jangomas* (Lour.) Raeus., *Antidesma bunius* (L) Spreng. *etc.* And in the undergrowth, *Rubus ellipticus* (Smith), *Cissampelos maxima* (L), *Mikania micrantha* (Kunth), *Justicia adhatoda* (L), *Leea*

indica (Burm.f.) Merr., *Schefflera venulosa* (wight & Arn.), *Premna coriacea* (C.B.Clarke), *Arisaema speciosum* (Wall) and different types of ferns are the dominant species. There are also different species of canes - *Arenga nana* (Griff.), *Caryota mitis* (L), *Calamus acanthospathus* (Griff.), *Cordia dichotoma* (Forst. F.), *Calamus guruba* (Buch.-Ham.), *Pinanga gracillis* (Blume), *Arenga pinnata* (Merr.), *Calamus tenuis* (Roxb), *and Licuala peltata* (Roxb) (SRSC, 2006).

4.1.6.3b. Medium Dense Forest:

The forests that have a crown cover between 10-40% were classed under this category. It covers an area of 410.21 sq km, which accounts for 11.47% of the total area of the district. It is distributed throughout the district and found in close association with dense forests. The vegetation of this forest is more or less similar with those species found in dense forests. The only difference lies in the crown density of these forests.

4.1.6.3c. Less Dense Forest:

Forests under this category were characterized by a thin crown cover (<10%). These forests in the district are represented by abandoned shifting cultivation land left fallow for over a years; subsequently new vegetation occupied the land and converted into new forest. Forests of this class are distributed throughout the district in small patches usually associated with bamboo forests and adjoining abandoned jhum lands. However, notable large patches are found near Zohmun, Ratu, Suangpuilawn, N.E.Tlangnuam, Saitual, Khanpui, Thingsulthliah, Sumsuih, Aibawk, Tachhip villages and surrounding areas of Aizawl city. It covers an area of 399.73 sq km, which accounts for 11.18% of the total area of the district. The dominant species in the upper storey are *Callicarpa arborea* (Roxb), *Albizia chinensis* (Osbeck)Merr,

Oroxylum indicum (L), *Phoebe lanceolata* (Nees), *Aporusa octandra* (Buch.-Ham ex.D.Don), *Erythrina stricta* (Roxb), *Mangifera sylvatica* (Roxb), *Mesua ferrae* (L), *Quercus helferiana* (A.DC), *Callicarpa arborea* (Roxb), *Engelhardtia spicata* (Blume), *Betula acuminate* (Wall), *Rhus javanica (*L), *Schima wallichii* (DC) Korth, *Bischofia javanica* (Blume), *Syzygium cumini* (L), *Litsea monopetala* (Roxb), *Bombax insigne* (Wall), *Macropanax dispermus* (Blume), *Ficus hirta* (Vahl), *Castanopsis indica* (Roxb), *Heliconia excels (L.), Emblica officinalis* (Gaertn), *Artocarpus nitidus sp.griffithii* (King Ex.Hook.f.), *Spondias pinnata (*L), *Quercus leucotrichophora* (Roxb), *Castanopsis tribuloides* (Sm) A.DC., *Sapium baccatum* (Roxb) etc. In the middle storey, the dominant species are *Rhus javanica* (L), *Symplocos racemosa* (Roxb), *Bischofia javanica* (Blume), *Securinega virosa* (Roxb), *Oreocnide integrifolia* (Gaud), *Ficus hirta* (Vahl), *Cinnamomum glanduliferum* (Wall), *Ficus geniculata* (Kurz), etc. And in the undergrowth, *Hedychium ellipticum* (Buch.-Ham. ex J.E.), *Hedychium villosum* (Wall), *Maesa Montana* (A.DC.), *Conyza stricta* (Willd.), *Osbeckia sikkimensis* (Craib), *Caesalpinia cucullata (*Roxb), *Mimosa pudica* (L), *Mikania micrantha* (Kunth), *Microlepia strigosa* (Thunb), *Tabernaemontana divaricata* (L), *Premna coriacea* (C.B.Clark), *Lantana camara* (L), *Curculigo crassifolia* (Bak), *Clerodendrum viscosum* (Roxb), *Scleria levis* (Retz*), Eupatorium odoratum* (L), *Ageratum conyzoides* (L), *Bidens biternata* (Lour), *Ipomea spp., Polygonum spp. etc (*Sawmliana, 2003*).*

4.1.6.3d. Bamboo:

Moist deciduous bamboo forests were found throughout the Aizawl district. These forest classes were mostly found in low-lying areas near streams and rivers. In

some places it was also found on hill slopes. It covers an area of 1403.01 sq km, and accounts for 39.23% of the total area of the district. Therefore, constitutes the largest cover among the land use classes as reported earlier by IIRS (2002). The dominant bamboo species found in this area are *Dendrocalamus hamiltonii* (Nees), *Dendrocalamus longispathus* (Kurz), *Melocanna bambusoides* (Trin), *Bambusa tulda* (Roxb) *and Dinochloa compactiflora* (Kurz) (syn. *Melocalamus compactiflora*) (SRSC, 2006). There are also a different species of bamboo like *Schizostachyum polymorphum (Munro)* and *Chimnobambusa callosa (Tabyo),* which are found only in mountainous ridges like Hmuifang, Chalfilh, Sialsuk and Tawizo in association with other tree species as reported earlier by Sawmliana (2003).

4.1.6.3e. Forest Plantation:

Forest plantations were distributed throughout the district. However, barring few plantations, most of them have an area below the minimum mappable unit. The prominent forest plantations noticed were Teak (*Tectona grandis* Linn.). However, it has replaced natural forest in many places (SRSC, 2006). They are usually planted along the roadside and were found abundantly near Suangpuilawn, Tuirini, Sesawng, Tuirial, Thingsulthliah, Tlungvel, Sairang villages and near the vicinity to the city i.e, PTC Lungverh areas. Large areas of Teak plantations were found near river banks of Tuirini, Tuirial, Tuivawl and Tlawng. Other miscellaneous plantations included Michelia (*Michelia champaca* Linn.), Gamari (*Gmelina arborea* Roxb.) and Pine (*Pinus kesiya* Royle ex Gordon*)* (SRSC, 2006). Michelia plantation was reported near Saitual and Thingsulthliah villages in small patches. Pine plantations were found near Sakawrdai, Ratu, Darlawn, Sawleng, Khawlian, Phullen and Sialsuk villages.

Gmelina plantations were found near Khawruhlian, N.Lungpher, Tuirial and Samlukhai villages. Bamboo plantation near Mualpheng was also found where a better variety of bamboo has been planted since the last ten years. Overall, forest plantation covers an area of 15.09 sq km, which accounts for 0.42% of the total area of the district.

4.1.6.4. Shifting cultivation

Shifting cultivation area in the district Aizawl can be classified into two categories i.e. current shifting cultivation and abandoned shifting cultivation.

4.1.6.4a. Current Shifting Cultivation:

Shifting cultivation commonly known as *Jhuming* is still a prominent farming system practiced by farmers in the study area, mostly in small patches/land holdings near forests and settlements. Observation reveals that most of the jhum plots were small in size and irregular in shape. Current jhums are always associated with young abandoned jhum and secondary forests. The location of jhum is depending on altitude and slope therefore; sites above 1200 m.asl are seldom jhumed (MIRSAC, 2009). The percentage of jhuming was found to be highest on the gentle slopes and gradually decreased on steeper slopes. It covers an area of 185.44 sq km which accounts for 5.19% of the total area of the district.

4.1.6.4b. Abandoned Shifting Cultivation:

In the present study, young abandoned jhums of approximately up to three years were considered. Nevertheless, it covers an area of 407.97 sq km which accounts for 11.41% of the total area of the district.

Areas of young abandoned jhums were found all over the district, closely associated with current jhums, settlement areas and forest fringes. Depending on how long the land was left fallow and phytogeography, there can be vegetative variations among young abandoned jhums consisting of young bamboo shoots, tree seedlings and saplings. However, in general, the dominant species in young abandoned jhum areas were *Melocanna bambusoides* (Roxb.), *Eupatorium odoratum* (Linn.), *Thysanolaena maxima* (Roxb.), *Erianthus longisetosus* (Anderss.), *Cyperus kyllinga* (Rottb.), *Cynodon dactylon* (Linn.), *Lantana camara* (Linn.), *Plantago major* (Linn.), *Osbeckia chinensis* (Linn.), *Imperata cylindrica*, *Mikania micrantha* (Linn.), *Ageratum conyzoides* (Linn.) etc.

4.1.6.5. Scrub land

Scrub lands are those lands which are frequently disturbed by biotic factors; as such vegetation cannot grow properly. Scrub land covers an area of 35.38 sq.km which accounts for 0.99% of the total area of the district. These areas were mostly dominated by grass species like *Saccharum longisetosum* (Anderss.), *Imperata cylindrical* (Linn.), *Drepanostachyum intermedium* (Munro), *Scleria levis* (Retz.), *Cynodon dactylon* (Linn.), etc. and herbs like *Eupatorium odoratum* (Linn.), *Artemissia vulgaris* (Linn.), *Mikania micrantha* (Linn.). They were found along roadsides and hill rugged/rocky terrains. Large patches of scrub land were found near Sakawrdai, Darlawn, Mimbung, Vanbawng, Phuaibuang, Chamring, Sialsuk villages and around Aizawl city, noticeable large areas were found near Durtlang, Lawipu, Chalfilh and Hmuifang villages.

4.1.6.6. Water body

Under this class, big rivers, lakes and ponds within the study area were included. It covers an area of 14.29 sq. km and therefore contributed only 0.40% of the total area of the district. Four important rivers namely Tlawng, Tuirial, Tuivawl and Tuivai drain through Aizawl district. Two well known lakes are found within the district, namely, *Tam Dil* near Saitual town and *Rung Dil* near Suangpuilawn village with an area of 0.042 and 0.025 sq km, respectively.

4.1.7. SOILS

Soil is the product of interaction between parent materials, climate and biotic factors as modified by the terrain conditions and the duration over which the interaction has been going on. Any variation in the intensity of any of these influencing factors results into different kinds of soils.

The rocks of this area are generally sandstone and shale; the derived soils are mostly red and yellow loamy. The soils of Mizoram are the product of slow diagenic changes of acidic parent material causing inherent soil acidity. High precipitation further aggravates this problem due to leaching of basic cations. It contains a high amount of organic carbon and is high in available nitrogen, low in phosphorus and potassium content (Mehta, 2006). The area experiences warm humid sub-tropical climate. It is under the direct influence of monsoon. The average annual rainfall from 1986 to 2011 was 3155.3mm. Observation based on rainfall pattern and humidity, suggests a classification of soil moisture regime as ‘Udic’. It was observed that the mean summer temperature (June to August) was 24.56ºC and mean winter

temperature (December to February) was 18.26ºC (difference of 6.3ºC > than 5˚C) and therefore, soil qualified for 'Hyperthermic temperature' class as per USDA (1988).

4.1.7.1. Soil classification:

Soil taxonomy is a comprehensive classification system which keys out soil Order, Suborder, Great group, Sub-group and Family in different steps. The investigation reveals that soils of Aizawl district is divided into three soil order viz. Entisols, Inceptisols and Ultisols. Inceptisols is the dominant order followed by Ultisols and then Entisols, this finding is similar to the findings of (NBSS and Directorate of Agriculture, 2001, unpublished data). The soil classification of Aizawl district is given in table 4.9. The soils/pedons of Tuirini, Tuivawl, Saitual, Aizawl, Sialsuk, Aibawk, Suangpuilawn and Darlawn series have Cambic horizon and thus were categorized as Inceptisols and Ochrepts suborder owing to the presence of Umbric epipedon. It is less than 25 cm in thickness and soil temperature regime is warmer than mesic. As this pedons base saturation (BS) is less than 60% and have udic soil moisture regime hence classified as Dystrochrepts soil group. The series Tuirini has been classified under the subgroup Aquic owing to the decrease in organic carbon content with depth and do not have a lithic contact and argillic horizon in the pedon. The series Aizawl, Sialsuk, and Aibawk belongs to subgroup Typic owing to decrease in organic carbon content with depth and characterized by moderately deep, deep to hard rock. The series Tuivawl belongs to subgroup Fluventic owing to their formation on flood plains of rivers draining regions. The series Saitual belongs to subgroup Fluventic Umbric by having darker epipedons than the Typic. The series

Suangpuilawn and Darlawn belongs to subgroup Umbric as this soil occurred in steep slope. The soils/pedons of Sihphir, Thingsulthliah, Khawlian, Chalfilh and Tawizo series have clay enriched subsurface horizons with base saturation less than 35%, so they are classified under soil order Ultisols and Udults suborder owing to udic soil moisture regime. These were classified under soil group Hapludults owing to the presence Ochric epipedon and a thin or moderately thick Argillic horizon. The series Sihphir, Thingsulthliah and Khawlian belongs to the subgroup Typic as this soils are freely drained soils, have an Ochric epipedon that is not both thick and sandy while the series Chalfilh and Tawizo belongs to the subgroup Humic owing to the presence of Umbric epipedon. The soils/pedons of vervek series belongs to the order Entisols as these soils does not have any diagnostic horizon. As these soils are not permanently saturated with water and have slope greater than 25 %, they are classified as suborder Orthents and soil group Udorthens owing to the Udic soil moisture regime. These soils are not saturated with water for as long as 1 month within the surface and there is no lithic contact within 50 cm of the surface, they are classified as Typic Udorthens.

4.1.7.2. Soil characteristics and description:

On the basis of field observations and laboratory analysis, soils of the area have been classified into 14 soil series. The soils of Sialsuk and Vervek series are deep to very deep, dark yellowish brown (10YR 4/3) to yellowish brown (10YR 5/6) in colour, clay loam, well drained with moderate to severe erosion. Soils of Thingsulthliah are very deep, dark yellowish brown (10YR 4/4) to brownish yellow (10YR 6/6), strongly acidic with sandy clay loam surface and clay loam to clay sub-

Table 4.9 : Soil classification of Aizawl district

Sl No	Proposed soil series	Order	Sub order	Great soil group	Sub group	Family
1	Vervek	Entisols	Orthents	Udorthents	Typic Udorthents	Loamy skeletal, Mixed, Hyperthermic
2	Tuirini	Inceptisols	Ochrepts	Dystrochrepts	Aquic Dystrochrepts	Fine loamy, Mixed, Hyperthermic
	Tuivawl				Fluventic Dystrochrepts	Fine loamy, Mixed, Hyperthermic
	Saitual				Fluventic Umbric Dystrochrepts	Fine loamy, Mixed, Hyperthermic
	Aizawl				Typic Dystrochrepts	Fine loamy, Mixed, Hyperthermic
	Sialsuk					Loamy skeletal, Mixed, Hyperthermic
	Aibawk					Clayey, Mixed, Hyperthermic
	Suangpuilawn				Umbric Dystrochrepts	Fine loamy, Mixed, Hyperthermic
	Darlawn					Loamy skeletal, Mixed, Hyperthermic
3	Sihphir	Ultisols	Udults	Hapludults	Typic Hapludults	Fine loamy, Mixed, Hyperthermic
	Thingsulthliah					Loamy skeletal, Mixed, Hyperthermic
	Khawlian					Clayey, Mixed, Hyperthermic
	Chalfilh				Humic Hapludults	Fine loamy, Mixed, Hyperthermic
	Tawizo					Loamy skeletal, Mixed, Hyperthermic

surface, well-drained on hill side slopes and hill crest/top, moderate to severe erosion and cutans are formed. Soils of Khawlian are very deep, dark yellowish brown to strong brown (7.5YR 4/6), sandy clay to clay sub-surface, very strongly acidic, well drained on hill side slopes with moderate to severe erosion, translocated silicate clay cutans are also formed. Soils of Aibawk have very deep, dark yellowish brown to strong brown (7.5YR 4/6), clay loam, very strongly acidic, well drained on hill side slopes with moderate to severe erosion. Soils of Sihphir are very deep, dark yellowish brown, sandy clay loam to clay, medium to strongly acidic, well drained on hill side slope, moderate to severe erosion with cutans. Soils of Aizawl are very deep, dark yellowish to dark brown, strongly acidic surface and very strongly acidic sub-surface, clay loam to clay, well-drained, hill side slopes with moderate erosion. Suangpuilawn soils are very deep, dark brown to strong brown, sandy clay loam to clay, strongly acidic to very strongly acidic, well drained, hill side slopes with moderate erosion. Chalfilh and Darlawn soils are very deep, dark brown to dark yellowish brown, clay to sandy clay loam, very strongly acidic, well drained, moderate erosion with cutans. Tawizo soil are very deep, dark brown(10YR 3/3) to yellowish red(7.5YR 5/6), clay loam to clay, very strongly acid, well drained on hill side slopes with severe to moderate erosion, patchy thin cutans are formed. Tuirini soils are very deep, yellowish brown to brownish yellow (10YR 6/6), clay loam to sandy clay loam, medium to strongly acidic on narrow valley, poorly drained with slight erosion. Soils of Tuivawl are deep to very deep, dark brown to dark yellowish brown, sandy clay loam surface and clay sub-surface, very strongly acidic, poorly drained, narrow valley with slight erosion while Saitual soils have very deep, dark brown to strong brown,

sandy clay loam to clay loam, strongly acidic, moderately well drained with moderate erosion. In general soils of different profiles in Aizawl are medium to strongly acidic in reaction (pH 4.56-6.08) and experiencing moderate to heavy soil erosion.

Organic carbon content varies from 0.38 to 1.94 % and most of the soils are in medium category and in almost all the soils the organic carbon content decreased with depth which might be due to the decrease in the organic matter content with increasing depth. Cation exchange capacity (CEC) of soils varied from 2.28 to 26.15 cmol (p^+). Magnesium is the dominant exchangeable cation ranged from 0.2 to 4.6 meq/100 g, calcium from 0.1 to 1.6 meq/100 g, potassium from 0.05 to 0.54 meq/100 g and sodium from 0.10 to 0.35 meq/100 g. The physiographic soil statistics is given in table No.4.10, the detail physico- chemical properties of the soil is shown in table No. 4.11 and the physiographic soil map is shown in figure No.4.10

Table 4.10 : Soil statistics of Aizawl district, Mizoram

Map Symbol	Physiography	Soil Composition	Area (Sqkm)	%
1	Hill top/Hill Crest	L.S. Typic Dystrochrepts L.S. Typic Udorthents L.S. Typic Hapludults	10.73	0.30
2	Hill side 10-25% slope with agriculture/ Horticulture land/ Shifting cultivation	Clayey Typic Hapludults F.L. Typic Dystrochrepts F.L. Typic Hapludults	9.66	0.27
3	Hill side 10-25% slope with Secondary/ open forest/ Scrubland/ Abandoned Shifting cultivation	F.L. Typic Dystrochrepts L.S. Typic Hapludults Clayey Typic Dystochrepts	17.88	0.50
4	Hill side 10-25% slope with bamboo forest	F.L. Umbric Dystrochrepts F.L. Humic Hapludults Clayey Typic Hapludults	63.3	1.77

5	Hill side 10-25% slope with Primary forest/ Dense forest/ Forest plantation	F.L. Humic Hapludults F.L. Umbric Dystrochrepts Clayey Typic Dystochrepts	40.05	1.12
6	Hill side 25-50% slope with agriculture/horticulture land/ Shifting cultivation	Clayey Typic dystrochrepts L.S. Umbric Dystrochrepts L.S. Typic Hapludults	113.01	3.16
7	Hill side 25-50% slope with Secondary/ open forest/ Scrubland/ Abandoned Shifting cultivation	L.S. Typic Hapludults L.S. Umbric Dystrochrepts F.L. Humic Hapludults	201.35	5.63
8	Hill side 25-50% slope with bamboo forest	L.S. Humic Hapludults Clayey Typic Dystrochrepts F.L. Umbric Dystrochrepts	718.12	20.08
9	Hill side 25-50% slope with Primary forest/ Dense forest/ Forest plantation	F.L. Umbric Dystrochrepts F.L. Humic Hapludults L.S. Typic Hapludults	630.50	17.63
10	Hill side >50% slope with agriculture/horticulture land/ Shifting cultivation	F.L. Typic Hapludults L.S. Typic Dystochrepts L.S. Umbric Dystrochrepts	96.2	2.69
11	Hill side >50% slope with Secondary/ open forest/ Scrubland/ Abandoned Shifting cultivation	L.S. Umbric Dystrochrepts F.L. Humic Hapludults L.S. Typic Hapludults	203.49	5.69
12	Hill side >50% slope with bamboo forest	L.S. Humic Hapludults F.L. Umbric Dystrochrepts L.S. Typic Hapludults	602.97	16.86
13	Hill side >50% slope with Primary forest/ Dense forest/ Forest plantation	L.S. Umbric Dystrochrepts L.S. Humic Hapludults F.L. Umbric Dystrochrepts	779.64	21.8
14	Valley	F.L. Aquic Dystrochrepts F.L. Fluventic Dystrochrepts F.L. Fluventic Umbric Dystrochrepts	26.46	0.74
15	Built up land		48.64	1.36
16	Water body		14.31	0.4
	Total		3576.31	100.00

L.S.= Loamy Skeletal, F.L. = Fine Loamy

Table 4.11: Physico chemical properties of soils of Aizawl district

Horizon	Depth cm	Mechanical analysis			pH (1:2)	OC %	CEC Meq/100g	Exchangeable bases Meq/100 g				BS (%)
		Sand	Silt	Clay				Ca^{++}	Mg^{++}	K^{+}	Na^{+}	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
Vervek - Loamy skeletal, mixed, Hyperthermic, Typic Udorthens												
A1	0-14	42	23	35	5.45	1.35	26.15	1.5	1.5	0.54	0.35	14.65
AC	15-25	43	21	34	5.25	1.10	25.42	1.3	1.1	0.36	0.25	12.62
C	26-55	44	21	35	5.12	1.00	25.32	1.1	1.0	0.35	0.22	10.90
Sialsuk - Loamy skeletal, mixed, Hyperthermic, Typic Dystrochrepts												
Ap	0-14	42	19	39	5.15	1.55	7.88	0.6	4.6	0.14	0.14	56.22
A1	15-34	41	22	37	5.25	1.46	6.05	0.11	3.4	0.08	0.15	50.37
A3	35-60	42	23	35	5.12	1.24	5.83	0.3	2.1	0.07	0.15	45.07
B2	61-80	42	24	34	5.07	0.95	6.89	0.3	2.5	0.11	0.19	45.04
C	81-110	44	25	31	5.03	0.87	6.19	0.2	2.6	0.09	0.17	49.00
Aibawk - Fine loamy, mixed, Hyperthermic, Typic Dystrochrepts												
Ap	0-14	40	21	39	4.88	1.24	9.58	0.5	3.9	0.11	0.14	48.26
A1	15-34	41	21	36	4.72	1.15	8.86	0.3	3.7	0.11	0.13	42.77
A3	35-60	39	22	39	4.71	0.95	9.72	0.5	2.3	0.11	0.19	32.56
B2	61-88	38	25	37	4.60	0.72	10.94	0.4	3.1	0.11	0.17	32.68
C	89-115	37	22	40	4.56	0.54	10.74	0.5	3.1	0.10	0.12	35.80

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
Darlawn - Loamy skeletal, mixed, Hyperthermic, <u>Umbric Dystrochrepts</u>												
A1	0-14	42	19	39	5.35	1.22	5.06	0.7	1.9	0.24	0.14	63.08
A3	15-34	40	20	40	5.24	1.11	6.19	0.6	2.6	0.21	0.14	58.96
B2	35-60	44	13	43	5.12	1.08	4.62	0.6	0.9	0.19	0.15	34.18
B3	61-90	41	12	47	5.04	0.78	5.52	0.6	1.0	0.32	0.17	42.37
C	91-126	39	13	48	5.01	0.61	4.60	0.8	0.8	0.23	0.14	43.50
Suangpuilawn - Fine loamy, mixed, Hyperthermic, <u>Umbric Dystrochrepts</u>												
A11	0-14	47	24	29	5.87	1.62	7.67	1.1	2.1	0.09	0.15	53.94
A12	15-34	46	24	30	5.72	1.56	7.82	1.0	2.1	0.13	0.18	45.56
A3	35-60	42	22	36	5.35	1.24	5.64	0.4	1.1	0.12	0.21	39.03
B2	61-90	40	20	40	5.08	0.88	4.92	0.6	0.9	0.10	0.16	34.35
B3	91-112	40	18	42	4.84	0.72	4.54	0.4	0.8	0.12	0.17	30.93
C	113-135	34	17	49	4.65	0.52	4.72	0.2	0.6	0.13	0.19	24.54
Tuivawl - Fine loamy, mixed, Hyperthermic, Fluventic Dystrochrepts												
AP	0-14	52	19	29	4.82	0.99	6.01	0.6	1.8	0.12	0.19	45.16
A1	15-38	52	18	30	4.75	0.77	5.39	0.4	1.4	0.09	0.20	38.82
A3	38-60	44	20	36	4.70	0.48	4.38	0.2	1.0	0.08	0.19	33.83
B2	61-82	45	16	39	4.61	0.41	4.04	0.2	0.9	0.01	0.12	30.84
B3	91-108	35	20	45	4.55	0.38	3.29	0.1	0.8	0.07	0.12	25.47

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
Saitual - Fine loamy, mixed, Hyperthermic, Fluventic Umbric Dystrochrepts												
Ap	0-14	53	19	28	5.48	1.12	4.89	0.6	1.1	0.18	0.18	44.07
A1	15-30	50	20	30	5.42	1.05	3.36	0.6	0.9	0.11	0.12	43.87
A3	30-48	50	18	32	5.25	0.95	3.06	0.4	0.6	0.14	0.14	34.18
B1	48-70	41	22	37	5.23	0.88	2.68	0.2	0.2	0.09	0.18	29.71
B3	71-105	40	22	38	5.18	0.67	2.74	0.2	0.2	0.06	0.11	21.22
Tuirini - Fine loamy, mixed, Hyperthermic, Aquic Dystrochrepts												
Ap	0-14	41	19	40	6.08	1.44	7.79	1.1	2.9	0.09	0.19	40.79
A1	15-30	43	20	37	5.45	1.24	6.35	0.8	2.6	0.07	0.16	43.62
A3	30-56	44	19	37	5.38	1.08	6.77	0.6	2.5	0.08	0.22	44.92
B2	57-82	46	18	36	5.31	0.76	5.89	0.4	1.8	0.06	0.28	47.34
B3	83-112	48	20	32	5.22	0.65	4.27	0.4	0.9	0.14	0.27	50.42
C	113-125	50	19	31	5.11	0.62	5.66	0.6	1.1	0.22	0.21	51.22
Aizawl - Clayey, mixed, Hyperthermic Typic Dystrochrepts												
Ap	0-14	43	19	38	5.44	1.68	5.66	0.6	1.6	0.31	0.18	48.80
A1	15-34	40	20	40	5.40	1.55	4.85	0.4	1.4	0.26	0.15	52.66
A3	35-49	40	19	41	5.26	0.92	3.75	0.2	1.2	0.17	0.12	38.96
B2	50-72	34	21	45	5.11	0.78	3.13	0.2	0.8	0.11	0.14	42.62
B3	83-102	32	18	50	4.98	0.59	2.90	0.1	0.6	0.12	0.12	39.15
C	103-128	31	17	52	4.92	0.51	2.28	0.1	0.4	0.15	0.11	43.01

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
Sihphir– Fine Loamy, mixed, Hyperthermic, Typic Hapludults												
A1	0 – 12	46	21	33	5.84	2.14	12.71	2.1	2.9	0.25	0.21	42.94
B21t	12 – 28	45	20	35	5.67	1.76	10.93	1.4	2.6	0.22	0.17	34.78
B22t	28 – 62	37	21	42	5.46	1.42	8.54	0.6	1.0	0.15	0.17	27.27
B23t	62 – 84	36	20	44	5.25	0.94	8.18	0.4	1.0	0.13	0.11	23.62
B3	84–118	35	19	46	5.21	0.81	7.11	0.2	1.0	0.11	0.14	23.36
A1	0 – 12	46	21	33	5.84	2.14	12.71	2.1	2.9	0.25	0.21	42.94
Thingsulthliah - Loamy skeletal, mixed, Hyperthermic, Typic Hapludults												
A1	0-14	48	20	32	5.65	1.44	10.91	1.4	2.6	0.26	0.14	42.27
B1t	15-38	46	19	35	5.54	1.25	9.80	1.6	1.8	0.18	0.17	33.72
B2t	39-72	45	17	38	5.46	1.08	9.74	1.6	1.4	0.14	0.15	33.31
B3	73-96	42	18	40	5.32	0.82	8.58	0.8	0.9	0.12	0.11	24.77
C	96-126	37	18	45	5.21	0.74	7.87	0.6	1.0	0.11	0.18	24.19
Khawlian – Fine loamy, mixed, Hyperthermic, Humic Hapludults												
A1	0-14	46	11	43	5.21	1.94	8.07	1.1	2.7	0.24	0.12	51.69
B1t	15-38	45	13	42	4.92	1.58	7.99	1.0	1.2	0.16	0.16	33.67
B21t	39-61	38	16	46	4.82	1.32	7.16	1.2	0.6	0.16	0.18	31.60
B22t	62-82	35	17	48	4.71	0.92	6.32	0.6	0.8	0.14	0.13	27.22
B3	83-105	31	19	50	4.65	0.65	5.18	0.4	0.6	0.08	0.10	22.85
C	106-126	27	20	53	4.61	0.51	5.17	0.2	0.4	0.07	0.12	15.73

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
Chalfilh - Clayey, mixed, Hyperthermic, Humic Hapludults												
A1	0-14	34	19	47	4.96	1.67	8.63	1.2	1.6	0.11	0.12	35.15
B1t	15-35	36	19	45	4.82	1.15	9.15	0.8	2.1	0.08	0.14	34.42
B21t	36-67	37	17	46	4.76	0.92	8.51	0.6	1.3	0.06	0.12	29.52
B22t	68-92	31	18	51	4.67	0.72	8.53	0.6	1.4	0.17	0.14	27.39
B3	93-127	49	22	29	4.63	0.56	7.93	0.6	1.3	0.05	0.16	26.94
Tawizo - Loamy skeletal, mixed, Hyperthermic, Humic Hapludults												
A1	0-14	37	24	39	4.92	1.18	6.07	0.4	1.6	0.19	0.17	39.04
B21t	15-35	39	22	39	4.84	1.11	6.42	0.4	1.4	0.12	0.18	29.97
B22t	36-61	38	20	42	4.67	0.86	7.61	0.6	1.2	0.14	0.28	31.70
B3	62-98	35	19	46	4.62	0.72	6.81	0.6	0.8	0.16	0.17	25.16
C	99-130	33	18	49	4.61	0.65	5.60	0.4	0.4	0.11	0.14	23.29

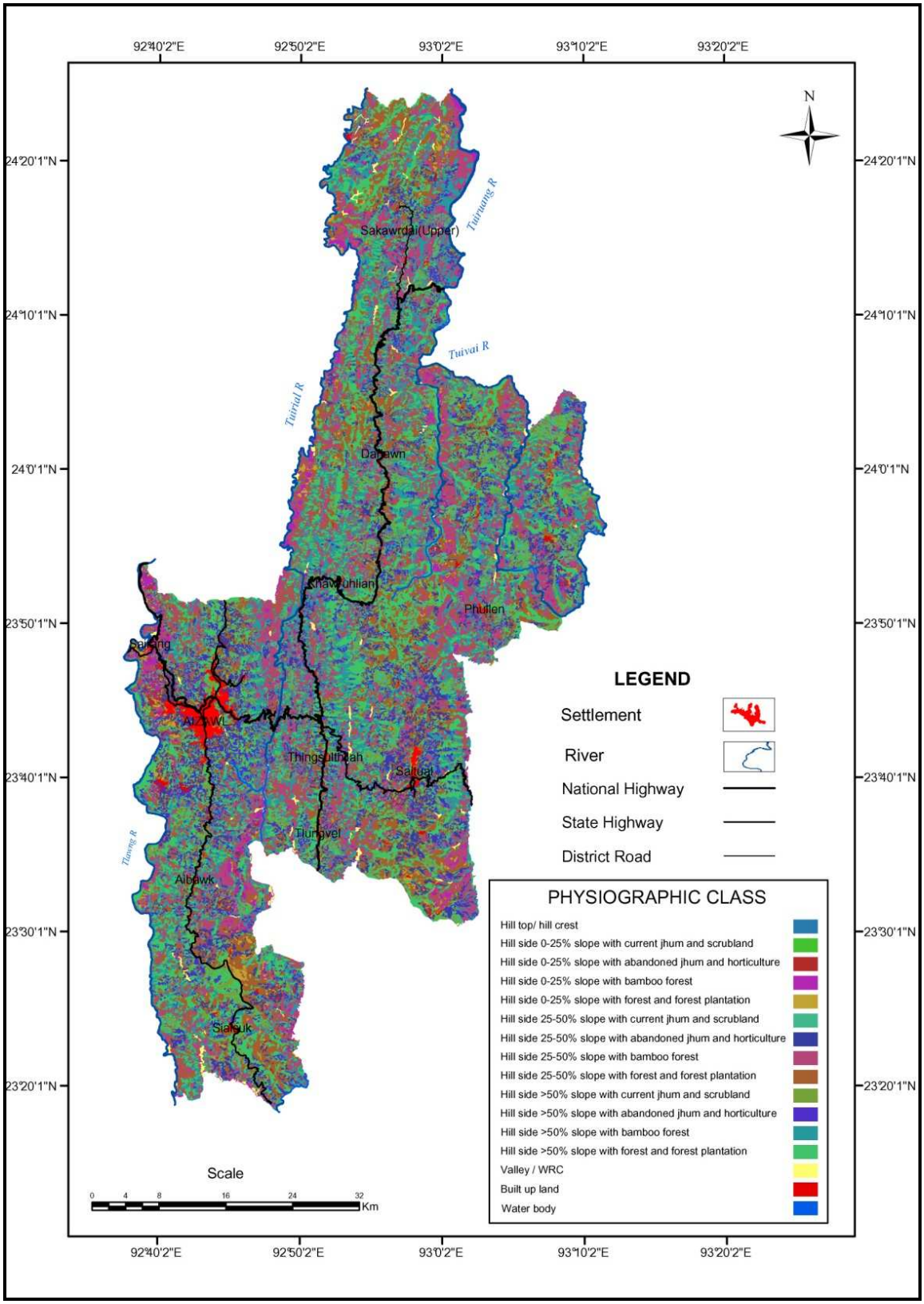


Figure 4.10 : Physiographic map of Aizawl district, Mizoram

4.1.8. LAND CAPABILITY CLASSIFICATION

Land capability classes placed soils into general order of suitability or unsuitability for various purposes such as cultivation, forestry, grassland or any other uses for sustainable production (ICAR, 2006). The soils that have the least limitations or hazard and respond best to management are placed in the highest category. This classification system also evaluate soils with respect to their susceptibility to erosion, soil depth, drainage problem and other soil characteristics that would effect to sustain production of agricultural crops (Klingebiel and Montgomery, 1961). After the observations, the soils of Aizawl have been classified into 5 land capability classes i.e. IIe, IIIe, IVe, VIe and VIIe. Land capability class II to IV are cultivable and crops can be grown under proper and specific soil management whereas Class VI to VII are not suitable for crops but are suited to permanent vegetation.

CLASS IIe are very deep, medium to fine textured soils, poorly drained and are subject to water logging during rains. It occurs on gentle slopes and valley land with slight erosion. It is mainly concentrated in the river valley of Tuirini, Tuivai, Tuivawl and Changte river. The area within the district is found to be 26.46 sq km, which is only 0.74% of the total geographical area of the district. CLASS IIIe are very deep, moderate to fine textured soils and well drained. They occur on steep slopes with moderate erosion hazards. They are mainly seen in the foot hills and the area is 130.89 sq km, which is 3.66% of the total geographical area of the district. CLASS IVe soils are deep to very deep; moderate to fine textured soils and well drained. They occur on steep to very steep hillside slopes and hill ridges with severe erosion and are distributed in different part of the district. This class occupied the

biggest area and it is of the order of 1673.71sq km, which is 46.80% of the total area of the district. CLASS VIe soils are deep to very deep, moderately fine textured soils and well drained. They occur on extreme steep slopes with severe erosion and they are found in hillside slopes of various areas of the district. The area is of the order of 1382.60 sq km, which is 38.66% of the area of the district. CLASS VIIe soils are deep, moderately fine textured soils and well drained. They occur on extreme steep slopes with very severe erosion hazards. It is unsuitable for cultivation but suitabl;e for social forestry and grazing. They are seen near Durtlang, Hmuifang, Kawlkulh, Phuaibuang villages and also in many places where escarpments are common. The area is 299.70 sq km, which is 8.83% of the total geographical area of the district. Land capability map is shown in figure 4.11 and detail land capability statistics is given in table 4.12.

Land capability classes were grouped into subclass. Land capability subclasses are soil groups within one class that are designated by small letters e, w, s or c suffixed to the class number, for example, IIIe, IVe etc. To identify subclasses of the soil, the limitations were: e = risk of erosion; w = wetness, drainage or overflow; s = root zone limitation or soil and; c = climatic limitations. It is observed that only erosion susceptibility or limitation is seen in Aizawl district.

Table 4.12 : Land capability statistics of Aizawl district, Mizoram

Sl.no	Land capability class & subclass	Brief description	Area	
			sq km	%
1	IIe	Good arable land on gentle slopes, susceptible to slight water erosion, very deep soil, suitable for agricultural development.	26.46	0.74
2	IIIe	Moderately good land on strongly sloping to steep, susceptible to severe water erosion, deep to very dee1p soil, suitable for Agricultural and Horticultural development	130.89	3.66
3	IVe	Fairly good land on steep to very steep slopes and hill ridge, highly susceptible to water erosion, deep to very deep soil, suitable for Agro-horticultural, sericulture and silvipastoral development	1673.71	46.80
4	VIe	Land with moderate limitations on very very steep, highly susceptible to water erosion, deep to very deep soil, suitable for horticultural plantation and forestry.	1382.60	38.66
5	VIIe	Land with severe limitations on very very steep slopes, subject to severe erosion. Unsuitable for cultivation but suitable for social forestry and grazing.	299.70	8.38
6	Built up land		48.64	1.36
7	Water body		14.31	0.4
		TOTAL	**3576.31**	**100**

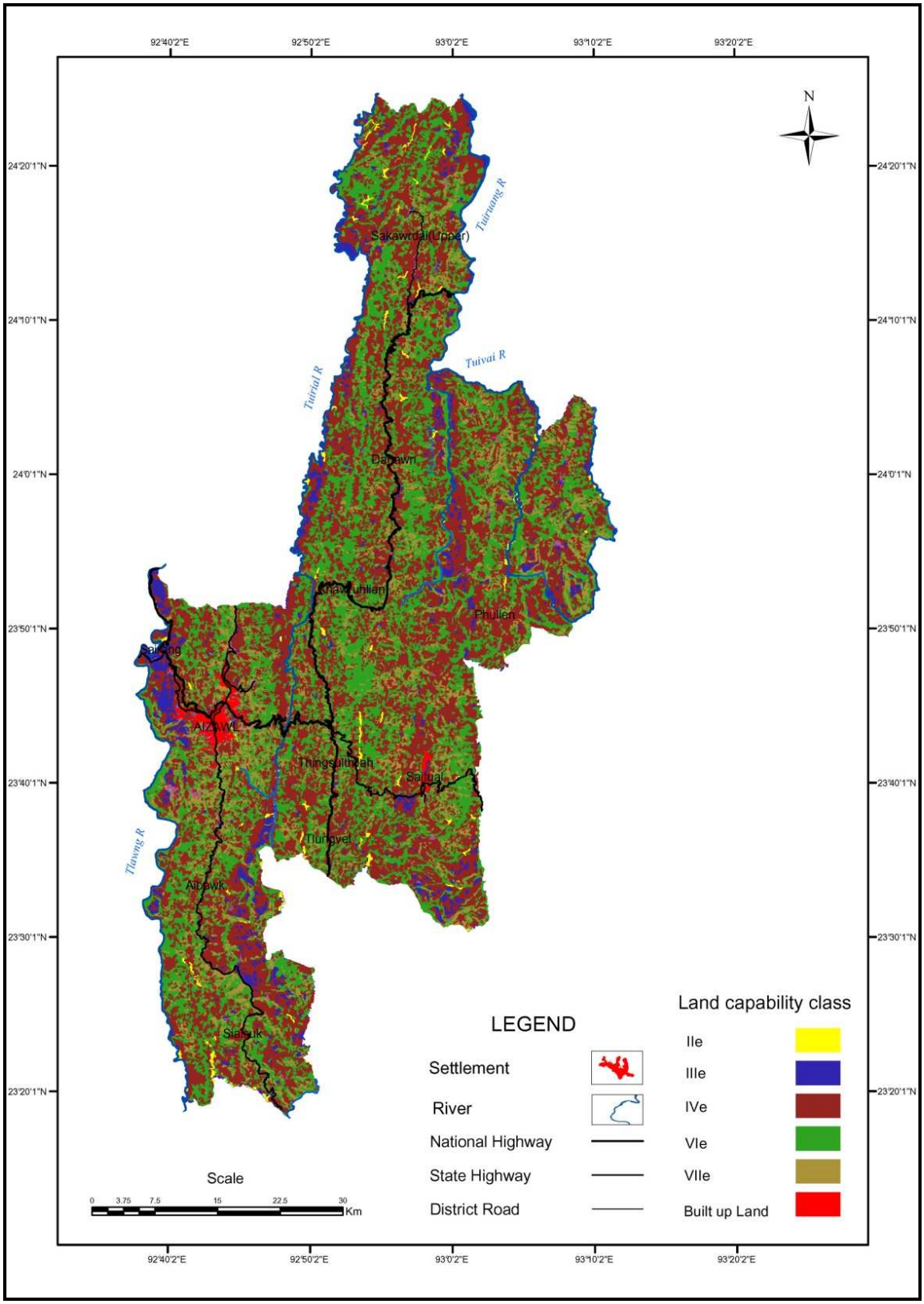


Figure 4.11 : Land capability map of Aizawl district, Mizoram

4.1.9. SOIL TEXTURAL CLASSIFICATION

The relative proportion of all particles of different size groups in a soil is known as texture. It is the average size of the soil particle which depends on the relative proportion of sand, silt and clay in the soil. If the proportion of sand in the soil is increased, the average size or the soil particles increases and the resultant soil become coarser in texture. On the other hand if the proportion of clay in the soil is increased, the average size of the soil particles decreases and the resultant soil becomes finer in texture (Kolay, 1993).

Sandy soils are highly permeable and excessively well drained with low water retention capacity and thus need more frequent irrigations for successful crop growth (Nautiyal *et al*., 2001; 2003) than finer textured soils. The clayey soils can hold more moisture, but they have high wilting point. Due to poor infiltration rate these soils are subject to water logging, resulting in poor aeration and workability. The moderately fine textured soils, e.g. loams, clay loams, or silt loams are by far the best group of soils for crop growth since they have the advantage of balanced proportion of both sand and clay (ICAR, 2006).

During the study of soils of Aizawl, clay loam to clay surface and sub-surface occupied maximum area followed by clay loam to sandy clay loam and clay loam surface and sub-surface occupied minimum area followed by sandy clay loam to cay loam in the district. The detailed soil texture statistics is given in table 4.13 and soil texture map is shown in figure 4.12.

Clay loam surface and clay sub-surface occupied maximum area covering 779.48 sq km which is 21.79% of the total geographical area of the district followed

by clay loam surface to sandy clay loam sub-surface covering 720.26 sq.km accounting 20.14% of the total geographical area. Clay loam surface and sub-surface cover the least area of 28.61 sq km which is 0.81% of the total geographical area of the district. Considering the surface texture of soil, clay loam occupied maximum area which is optimum for growing different agricultural and horticultural crops (ICAR, 2006).

Table 4.13 : Soil texture statistics of Aizawl district, Mizoram

Soil Texture Class	Area (sq km)	Percent (%) of total area
Clay	718.13	20.08
Clay loam	28.65	0.81
Clay loam to clay	779.48	21.79
Clay loam to Sandy clay loam	720.26	20.14
Sandy clay loam to clay	453.02	12.67
Sandy clay loam to clay loam	201.43	5.64
Sandy clay to clay	612.78	17.13
Settlement	48.28	1.34
Water body	14.29	0.40
Grand Total	**3576.31**	**100.00**

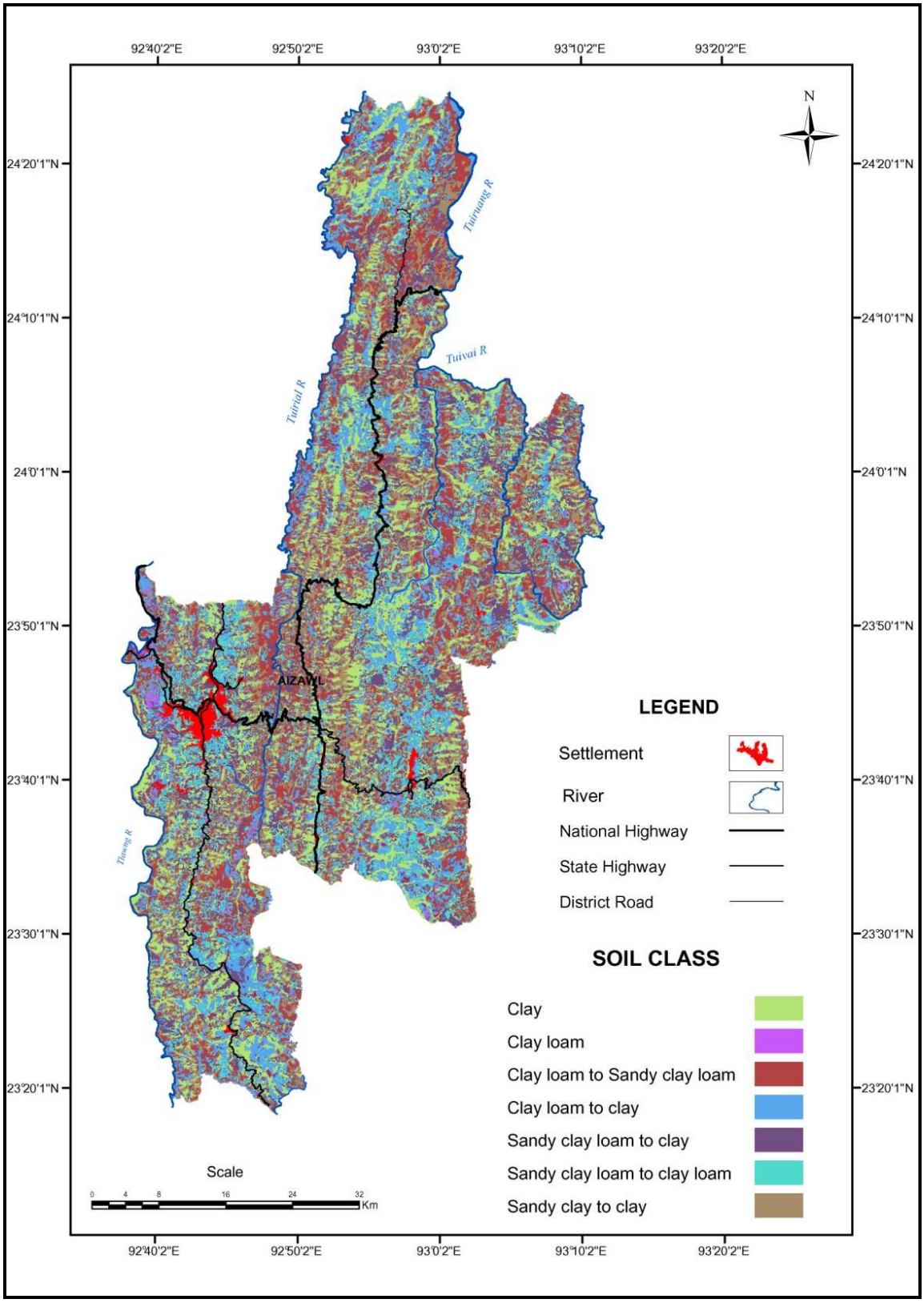


Figure 4.12 : Soil texture map of Aizawl district, Mizoram

4.2. INTEGRATION OF NATURAL RESOURCES FOR SPATIAL PLAN:

An integrated and coherent approach to the planning and management of land resources is essential. Such a system must be able to deal with the broad issues but leave sufficient flexibility for decentralized resource management. It must be able to handle diversity and change, and must satisfy the need for economic development and equity while protecting the environmental and resource base that make sustainable development possible. As a system, priorities can best be addressed through land use and physical planning; as a set of resources, land can best be managed through integration of environmental, social and economic aspect of the region.

4.2.1. MAJOR PROBLEMS OF THE AREA

Before integration of the natural resources of the area, the major hitches of the district were identified through field visits, consultations with various stakeholders' i.e. local inhabitants and administrators of various govt. departments. These constraints are briefly described so as to enable to make the need and effective locale specific prescriptions. The major problems observed during ground truth verification are:

1. The most primitive method of agricultural practice i.e. shifting cultivation or Jhumming is very prevalent in the study area. This results in rapid degradation of the primary forests resulted into heavy soil erosion and rapid water run off.
2. The slopes are very steep. This increases soil erosion and water run off. Wet-land rice cultivation could be practiced only in limited area, i.e. in the river valleys.

3. Double cropping could not be practiced due to lack of enough irrigation facilities, and also due to uncontrolled grazing near the habitation.
4. Lack of good communication is another problem especially along the river valleys. This causes difficulties in transportation and marketing of the agricultural/ horticultural products and other goods.
5. Power supply is inadequate in most of the villages. Without adequate supply of electric power, industries and preservation could not be established.
6. Appropriate land use planning is totally lacking in the study area. The people need to be more aware and educated to change their age-old practice of jhumming system.
7. As the economic condition of the people is poor, it is very difficult for them to change the usual method of agricultural practice i.e. shifting cultivation to permanent farming system as the later needs more financial and man power involvement at the initial stage.
8. Water scarcity is one of the major problems mainly during the dry season due to lack of adequate water harvesting structures and storage facilities.
9. The alarming increase of polythene deposits by human beings is another problem of the district. The disposed polythenes are found from the surface of the soil up to four feet deep. This will deteriorate the soil fertility and hindrance the extension of land development, and will obviously have great impact on flora and fauna of both land and aquatic environment. The polythene deposits in the soil may augment the landslides as they prevent mutual

cohesion among the soil particles and also retain pools of water. The polythene wastes are also a suitable breeding place for germs and mosquitoes.

4.2.2. INTEGRATION

The thematic maps of various natural resources like land use/land cover, soil, slope, geology and geomorphology, groundwater, transport network and settlement were prepared and integrated in conjunction with the socio-economic and demographic data with main aim of the present work to suggest spatial planning for sustainable agro-horticulture development in the district using GIS package software. During this process, discussion with the local people and government officials, and the recommendations made by various research centres/academic institutions were also considered before finalizing thematic maps of the Aizawl district.

Overall, following points were considered while integrating various themes for suggesting the action plan for sustainable agro-horticulture development.

1. The existing primary forest should be conserved as far as possible in order to maintain the ecosystem.
2. Major thrust should be given towards diverting shifting cultivation to potential alternatives viz., agriculture (WRC in particular), agro-horticulture, silvipasture, sericulture and silviculture/afforestation activities.
3. Cultivable lands should be increased wherever possible by improving infrastructure facilities.
4. Wherever feasible in single cropped agricultural land, provisions like minor irrigation tanks, check dams, etc. have been proposed for irrigating the second crops.
5. Transport and communication, marketing facilities and other infrastructures have been considered while suggesting the action plan.
6. The action plan aims to improve soil and water conservation.

7. Forest area should be increased especially in steep slopes where agriculture and horticulture are not feasible.
8. Subsequently, due care has been taken on the social acceptability while suggesting the action plan.

Based on the natural resources of the area, various alternate land use patterns are therefore suggested viz., silvi-pasture, sericulture, agro-horticulture, silviculture/afforestation, agriculture and planned to ensure sustainable development. The guidelines for generation of action plan for sustainable agro-horticulture development plan of the district is depicted in table 4.14 and the flowchart methodology for spatial plan of sustainable Agro-horticulture development is shown in figure 4.13.

4.3. SPATIAL PLAN FOR SUSTAINABLE AGRO-HORTICULTURE DEVELOPMENT

Despite substantial agricultural advances in the past, millions still go hungry and live under the constant threat of famine. The problem is further compounded by the fast growing human population. The global food production will have to be doubled between the year 2002 and 2025 if the expected world population of eight billion is to be fed adequately (Bebarta, 2004). The target of feeding such a huge number is to be achieved against complex socioeconomic and environmental problems that stand in the way of agricultural development. We have no option except to produce more on less land and with less water. Only way out to make this possible is to spur an evergreen revolution, rooted in the principles of ecology, economy and equity, so very fundamental to sutainable agro- horticulture development.

Table 4.14 : Guidelines for generation of spatial plan for sustainable agro-horticulture development

Sl no	Land-form	Location	Present land use/cover	Soil composition	Erosion condition	Slope	Ground water condition	Proposed land use
1	Structural Hills	Hill top/crest near habitation	Grass land, current to old abandoned jhum	Loamy skeletal, Typic Dystrochrepts, Deep, moderate moisture	Severe	0 – 10%	Poor to Moderate	**SILVI-PASTURE**
2	Structural Hills	Hill top/crest and side slopes, very near habitation	Grass land, current to old abandoned jhum	Loamy skeletal/Fine loamy, Typic Dystrochrepts, Loamy skeletal , Typic Hapludults Deep to very deep, good moisture	Moderate to severe	0 – 25%	Poor to Moderate	**SERICULTURE**
3	Structural Hills	Hill side slopes mainly away from habitation	Current jhum to old abandoned jhum	Loamy skeletal Typic Dystrochrepts, Loamy skeletal Typic Hapludults Deep to very deep, good moisture	Moderate to very severe	More than 50%	Poor to Moderate	**SILVICULTURE /AFFORESTATION**
5	Structural Hills	Hill side slopes near habitation or road	Current jhum to old abandoned jhum	Fine Loamy & Loamy Skeletal Typic Dystrochrepts, Typic Hapludults and Humic Hapludults, very deep, good moisture	Moderate to severe	10 – 50%	Moderate to Good	**AGRO-HORTICULTURE**
6	Flood plains/valley fills	River valley	Single cropped agriculture land, Current jhum to old abandoned jhum	Fine Loamy, Aquic Dystrochrepts and Fluventic Dystrochrepts, very deep, good moisture	Slight erosion	0 – 25%	Good to excellent	**AGRICULTURE (Double crop)**

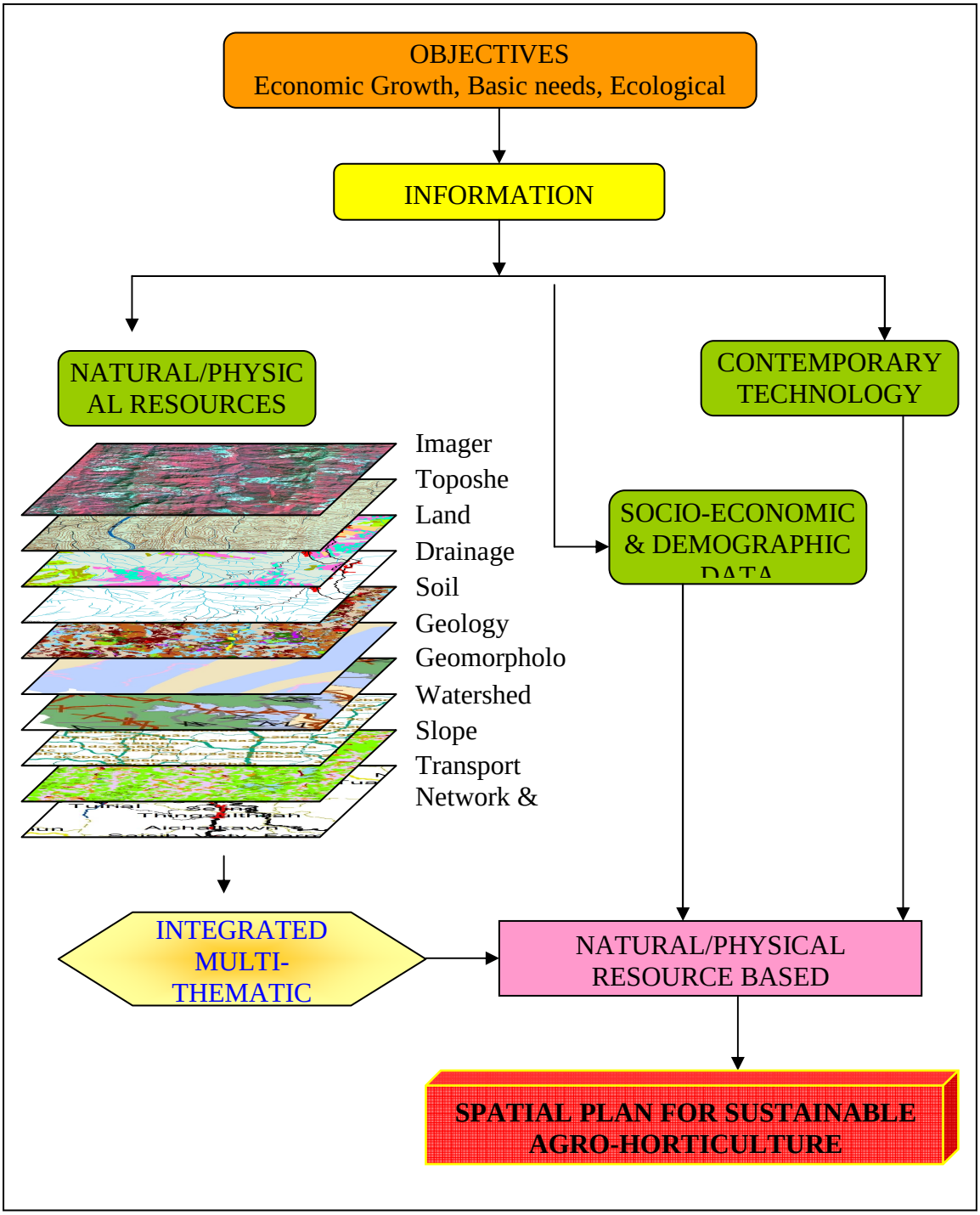


Figure 4.13 : Flowchart methodology for spatial plan of sustainable Agro-horticulture development

Sustainable agro-horticulture development is a model and economic organisation based on an equitable and participatory vision of development which recognises the environment and natural resources as the foundation of economic activity. Agro-horticulture is sustainable when it is ecologically sound, economically viable, socially just, culturally appropriate and based on a holistic scientific approach. It preserves bio-diversity, maintains soil fertility and water purity, conserves and improves the chemical, physical and biological qualities of soil, recycle natural resources, and conserves energy. Sustainable agro-horticulture uses locally-available renewable resources, appropriate and affordable technologies, and minimizes the use of external and purchased inputs, thereby increasing local independence and self sufficiency and insuring a source of stable income for peasants, family and small farmers and rural communities (Global Open University, 2008).

Therefore, in order to achieve sustainable agro-horticulture in Aizawl district, action plan was prepared based on integration of various thematic informations with socio-economic factors. During this process, discussion with the local people and government officials, and the recommendations made by research centres/academic institutions were considered. Action plan maps for land resource development and water resource development were prepared separately for the whole district. However, legal status should be considered during implementation. The statistics of the proposed spatial plan for sustainable agro-horticulture development is given table 4.15 and the proposed plan map for Sustainable Agro-Horticulture Development is given in figure 4.14.

4.3.1 SUSTAINABLE LAND RESOURCE DEVELOPMENT PLAN:

4.3.1.1. Agriculture (Double crop)

Most of the agricultural land in the district is confined in the river valley and foot hills and only *Kharif* crops (wet land rice cultivation) are practiced. These areas can be brought for cultivating both *Kharif* and *Rabi* crops provided that better irrigation facilities are constructed. The potential areas for agriculture (double crop) are proposed under the slope of upto 25 % with a soil depth of more than 1 metre with heavy soils texture. According to Indian Council of Agricultural Research (ICAR) for North Eastern Hill Region, the system can be adopted on hill slope of upto 50% where soil depth is more than 1 metre, bench terracing and contour bunding are the major soil conservation measures (Satapathy, 1993). It is proposed to make bunds on the unutilised flat land along the rivers and terraces on the foot hills. Minor irrigation tanks, Check dams/water harvesting bundhis are proposed to be constructed for irrigating the Rabi crops and to increase the infiltration rate. The area proposed for this system is 26.46 sq.kms of land i.e. only 0.74 % of the total geographical area based on the criteria's cited above. *Oryza sativa* (rice) is recommended for the main crops during the Kharif season. The Rabi crops recommended are rice, legumes of different varieties and vegetables like *Brassica oleracea* L var *capitata* (Zikhlum), *Brassica caulorapa* (Nawlkhawl) and other *Brassica spp.* (Antam/Feren), etc. *Zea mays* (Vaimim) may also be grown during the Rabi season. These types of land are mainly confined in river valley, viz. Tuirini, Tuivai, Tuivawl and Changte rivers.

System of rice intensification (SRI) is recommended for cultivating rice in the narrow valleys. SRI is a combination of several practices those include changes in

nursery management, time of transplanting, water and weed management. All these new practices are together known as System of Rice Intensification (SRI). SRI is not a fixed package of technical specifications, but a system of production with 4 main components, *viz*., soil fertility management, planting method, weed control and water (irrigation) management (Directorate of Agriculture, 2010). As uncontrolled grazing is the prominent problem near the habitation, it is proposed that grazing should be strictly controlled to protect the crops from the domestic animals.

Table 4.15: Statistics for sustainable agro-horticulture development plan of Aizawl district, Mizoram

Sl. No.	Description of spatial plan	Area (sq km)	Percentage of total geographical area
1	Agriculture (mainly,WRC)	26.46	0.74
2	Silvipasture	120.16	3.36
3	Sericulture	204.56	5.72
4	Agro-horticulture	710.97	19.88
5	Silviculture/Afforestation	398.41	11.14
6	Forest	1450.19	40.55
7	Bamboo forest	602.97	16.86
8	Built-up	48.28	1.35
9	Water body	14.31	0.40
	TOTAL	**3576.31**	**100.00**

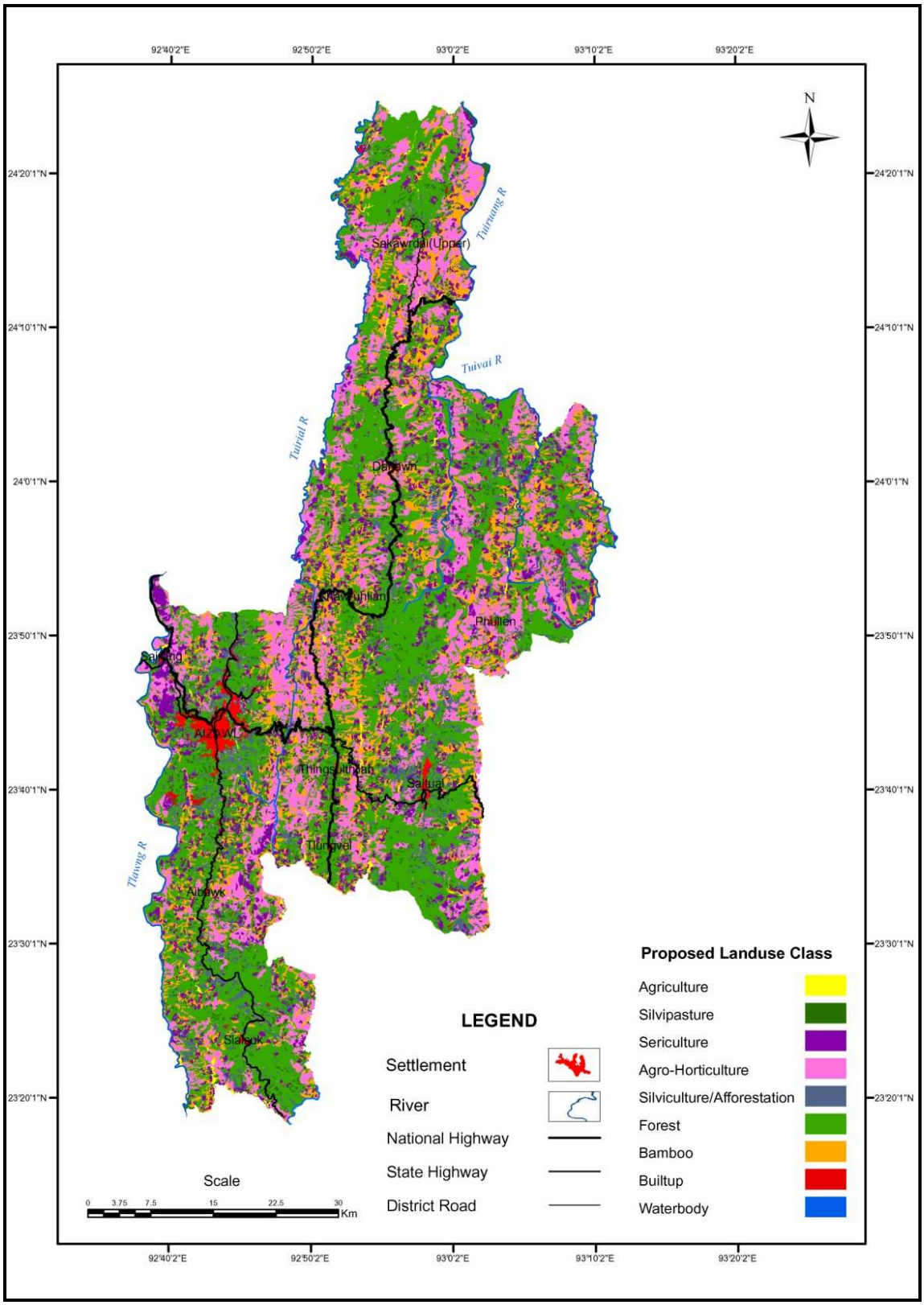


Figure 4.14 : Spatial plan map for sustainable Agro-horticulture development in Aizawl district, Mizoram.

4.3.1.2. Silvipasture

Silvipasture is a land management system in which forests are managed for the production of woods as well as for the rearing of animals. Forage, either shrubby or herbaceous is grown as the under storey crop with a mixture of top feed species of forest trees. It is found to be a dependable proposition for the utilization of degraded lands in erratic rainfall areas because trees can tolerate extreme soil and climatic conditions while grasses and legumes provide good land cover (Singh and Singh, 2004). In this system, animals are kept and permitted to graze within the forest. The system provides fuel, fodder and also maintains a good vegetation cover. According to ICAR recommendation, land upto 100% slope with 0.5 m soil depth can be utilized for livestock farming (Satapathy, 1993). In Aizawl district, hill top/crest having 10% slope with 0.5 m soil depth near habitation is proposed for Silvipasture. The silvipasture is proposed to be developed in 120.16 sq kms of land which is 3.36 % of the total area of the district. The trees selected for the purpose are fast growing, have fodder and firewood values and good cropping ability. Besides, some fruit species can be used for silvipasture. The tree species recommended for growing under this activity are given in table No. 4.16.

4.3.1.3. Sericulture

Sericulture, the technique of silk production, is an agro-industry, playing an eminent role in the rural economy of India including Mizoram. It is a labour intensive agro-industry ideally suited to all developing countries in the tropical belt where unemployment and underemployment continue to be a serious problem. It rightly fits into the socio-economic structure of the rural areas and can serve as an effective tool

Table 4.16: Trees and gasses recommended for Silvipasture

Sl.No	Name of Species	Local name	characters	Economic value
1	*Ficus hirta (Vahl)*	Sazutheipui	Fast growing,	Fodder, Fuelwood
2	*Litsea semicarpifolia (Wall.ex Nees)*	Nauthakpui	Fast growing,	Fodder, Fuelwood
3	*Castanopsis tribuloides (Smith)*	Thingsia	Fast growing,	Fodder, Fuelwood
4	*Ficus fistulosa (Reinwardt ex Blume*)	Theibate	Fast growing,	Fodder, Fuelwood
5	*Ficus semicordata (Buch.-Ham.)*	Theipui	Fast growing,	Fodder, Fuelwood
6	*Ficus benghalensis (Linn.)*	Hmawng	Fast growing,	Fodder, Fuelwood
7	*Bauhinia variegate (Linn.)*	Vaube	Fast growing,	Fodder, Fuelwood
8	*Macropanax oreaphilum (Linn.)*	Phuanberh	Fast growing,	Fodder, Fuelwood
9	*Magifera indica (Linn.)*	Theihai	Fast growing,	Fodder, Fuelwood
10	*Morus indica (Linn.)*	Thingtheihmu	Fast growing,	Fodder, Fuelwood
11	*Stylosanthese spp.*	---	Fast growing,	Fodder
12	*Pennisetum pedicellatum (Linn.)*	---	Fast growing,	Fodder
13	*Thysonalaena maxima (Kuntze)*	Hmunphiah	Fast growing,	Fodder, Broom
14	*Erianthus longisetosus (Hack)*	Luang	Fast growing,	Fodder
15	*Scleria cochinensis (Lour.)*	Thip	Fast growing,	Fodder

for rural reconstruction benefiting the weaker sections of the society (Department of Sericulture, 2008). The most important consideration is the effective utilization of family labour, particularly the aged, handicapped, illiterate and women folk. A hectare of mulberry generates remunerative employment to 12 to 13 persons throughout the year (Jolly, 1987). The produce has a ready market and fetches higher income over other cash crops and it is an export oriented industry.

The thematic study reveals that there is a great scope for sericultural activities in Aizawl district. The leaves of some natural trees like *Litsea semicarpifolia* Wall.ex Nees (Nauthakpui), *Quercus griffithii* Hook. F. & Thomson Ex. (Sasua), *Quercus semiserrata* Roxb. (Khawthli), etc. can be used for rearing silk worms (Department of

Sericulture, 2008). The leaves of *Ricinus communis* Linn. (Mutih), *Manihot esculenta* Crantz (Pangbal) and *Morus indica* Linn. (Thingtheihmu) can also be used for the purpose throughout the district. Among the silk worm plants, *Morus indica* is best suited in Aizawl district (MIRSAC and NESAC, 2011). Sericulture is proposed to be developed in 204.56 sq km area which is 5.72 % of the total geographical area of the district and therefore may be better option compared to agriculture and silvipasture.

4.3.1.4. Agro-horticulture

Agro-horticulture is a farming system in which both agricultural and horticultural crops are grown together on a plot of land. The recommendation made by ICAR Complex for North Eastern Hill Region, agro-horticulture can be practiced in a hill slope of 100% with a minimum soil depth of 1 m (Chauhan and Dhyan, 1993). Considering the thematic information and socio-economic data of the district and to ensure sustainable development, land upto 50% slope with a minimum of 1 m soil depth will be suitable for this system. This farming system is proposed to be developed in 710.97 sq kms of land which is 19.88 % of the total geographical area of the district. 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. The crops recommended to be grown under this system are presented in Table 4.17.

In addition, vegetables like *Solanum* spp. Linn. (Samtawk/Bawkbawn), *Brassica spp.* (Antam/Bulbawk), *Momordica charantia* Descourt (Changkha), *Trichosanthes anquira* Linn. (Berul), *Cucurbita moschata* Duch. (Mai), *Lychopersicon*

Table 4.17: Recommended crops for agro-horticulture development and their agronomic requirements

Sl. No.	Name of Species	Local name	Specific Agronomic requirements	References
1	*Zea mays* (Linn.)	Vaimim	Well drained, Sandy loam	Trainers manual Deptt. of Agri.(2007)
2	*Oryza sativa* (Linn.)	Buh	Well drained, Clay loam to Clay	-do-
3	*Zingiber officinalis* (Roscoe)	Sawhthing	Well drained, Friable loam to Sandy loam	-do-
4	*Curcuma longa* (Linn.)	Aieng	Well drained, sandy or clayey loam soil	-do-
5	*Daucus carota* (Linn.)	Carot	Well drained, Sandy loam to Clay loam	Thlasik thlai chin dan, Deptt. of Agri. (2008)
6	*Ipomea batatus* (Linn.)	Kawlbahra	Well drained, Sandy loam to Clay loam	-do-
7	*Colocasia esculenta* (Linn.)	Bal	Well drained, Sandy Clay loam	-do-
8	*Solanum tuberosum* (Linn.)	Bawkbawn	Well drained under any types of soil	-do-
9	*Capsicum spp.* (Linn.)	Hmarcha	Well drained, Sandy loam	Booklet, Deptt. of Horti. (2009)
10	*Allium sepi* (Linn.)	Purun sen	Well drained, Sandy loam to Clay loam	Thlasik thlai chin dan, Deptt. of Agri. (2008)
11	*Allium sativum* (Linn.)	Purun var	Well drained, Sandy loam to Clay loam	-do.
12	*Vigna spp. (*(Linn.)	Bete/Behlawi	Well drained, Sandy Clay Loam	-do-.
13	*Phaseolus vulgaris* (Linn.)	French Bean	Well drained, Sandy Clay Loam	-do-
14	*Glycine max* (Linn.)	Bekang	Fertile well drained loamy soils	Trainers manual Deptt. of Agri.(2007)
15	*Cajanus cajan* (Linn.)	Behliang	Well drained, light to medium soil	-do-
16	*Manihot esculenta* (Crantz)	Pangbal	Wide range of soil with well drained	-do-.
17	*Musa spp.* (Linn.)	Balhla	Well drained, Sandy clay loam	Booklet, Deptt. of Horti. (2009)
18	*Carica papaya* (Linn.)	Thingfanghma	Well drained, Sandy clay loam	-do-

spp. (Tomato), *Abelmoschus esculentus* Linn. (Bawrhsaiabe), etc. and some nitrogen fixing trees like *Leucaena* spp. Benth. (Japan-zawngtah), *Parkia roxburghii* G.Don. (Zawngtah), *Cassia fistula* Linn. (Makpazangkang) etc. may also be grown as climatic conditions of various locations in the district are also suitable for their conditions.

Table 4.18 : Recommended crops for horticulture development and their agronomic requirements

Sl. No.	Name of Species	Local name	Specific Agronomic requirements	References
1	*Citrus macroptera* (Montrouz)	Hatkora	Well drained,Sandy loam to Sandy clay	Booklet, Deptt. of Horti (2009)
2	*Citrus reticulate* (Blanco)	Serthlum	Well drained,Sandy loam to Clay loam	-do-
3	*Citrus sinensis* (Linn.)	Valensia	Well drained,Clay loam to Sandy clay	-do-
4	*Aleurites spp.* (Linn.)	Tung	Well drained,Sandy clay loam	-do-
5	*Coffea spp.*	Coffee	Well drained,Clay loam to Sandy clay	-do-
6	*Ananas comosus* (Linn.)	Lakhuihthei	Well drained,Sandy clay loam to clayloam	-do-
7	*Areca catechu* (Linn.)	Kuhva	Well drained,Clay loam to Sandy clay	-do-
8	*Cocos nucifera* (Linn.)	Coconut	Well drained,Sandy loam	-do-
9	*Camellia sinensis* (Linn.)	Thingpui	Well drained,Alluvial soils and sandy clay	Handbook of Horti., ICAR (2010)
10	*Elettaria cardamomum* (Linn.)	Alaichi	Well drained,Loamy soils	-do-
11	*Passiflora edulsis* (Sims)	Sapthei	Well drained, Sandy clay loam	Booklet, Deptt. of Horti. (2009)
12	*Elaeis guineensis (*Jacq.)	Oil palm	Well drained,Loamy and alluvial soils	Booklet, Deptt of Agri. (2010)
13	*Saccharum officinarum (Linn.)*	Fu	Well drained, clay loam	Trainers manual Deptt. of Agri. (2007)
14	*Eleurites spp.*	Tung	Well drained, Sandy loam to clay loam	Booklet, Deptt. of Horti. (2009)

Besides, the geo-climatic region of the entire district is suitable for growing a variety of horticultural crops (Parthasarathy, 1993). Horticulture is a good farming system proposed to be adopted as an alternative of shifting cultivation. The main crops recommended for this system are shown in table 4.18.

However, while selecting the crops to be grown, their favourite climatic and soil condition are to be considered. For example betelnut and coconut need lower altitudes with warm and humid climate whereas coffee and tea thrives well in higher altitudes of the district. Terracing/contour trench farming may be practiced depending upon the crops and the topographical conditions.

4.3.1.5. Silviculture /Afforestation:

Silviculture/afforestation is proposed to be developed in areas of hill side slopes with more than 50% under current and abandoned shifting cultivation areas, away from habitation. The depth of the soil of proposed area under this category is deep to very deep with loamy skeletal Typic Dystrochrepts and Typic Hapludults. It is proposed to be developed in 398.41sq kms of land or 11.41 % of the total geographical area. Silviculture is a system of growing trees for the production of timbers, woods etc (Bandyopadhyay, 1997). The main species recommended for silviculture are *Pinus kesya* Royle ex Gordon (Far) and Tectona *grandis* Linn. (Teak), of which the former one may be planted above 1200 m asl., and the later one may be planted below 1000 m asl. *Michelia champaca* Linn. (Ngiau), *Gmelina oblongifolia* Roxb. (Vawngthla), *Gmelina arboria* Roxb. (Thlanvawng), and the native tree species like *Castanopsis spp.* (Thingsia/Then), and *Quercus spp.* Linn. (Fah/Sasua/Hlai/Thil), etc. are also recommended. However, the tree species having timber value may be given priority for growing under this system.

Afforestation is the process of transforming an area into forest by planting suitable trees. This process becomes necessary when natural regeneration cannot keep pace with human exploitation of forests. Various afforestation programmes in which

commercial tree species are planted as government or private plantations like teak (*Tectona grandis)* plantations have been taken up. However, such plantations being monocultures have their own drawbacks like poor nutrient cycling and lower level of genetic diversity and species composition leading to a higher chance of pest and disease attack. Interplanting with other suitable, non-competing tree species at appropriate tree spacing can possibly overcome this problem. Besides, the biophysical and socio-economic factors also need to be taken into consideration before implementing an afforestation programme. The recommended species for this system are – *Michelia champaca* Linn. (Ngiau), *Gmelina oblongifolia* Roxb. (Vawngthla), *Gmelina arborea* Roxb. (Thlanvawng), *Acacia auriculiformis*A.Kunth (Kalsiamthing), *Albizzia procera* Durazz. (Kangtek), *Albizzia odoratissima* L.f.Benth (Thingri), *Albizzia lebbek* L.Benth (Thing-chawk-e) etc. All these tree species are major components of natural vegetation in the district and are recognized for their economic value as well.

4.3.2. SUSTAINABLE WATER RESOURCES DEVELOPMENT PLAN:

The district has a great scope for the development of water resources as it receives a good amount of rainfall i.e. 3,155mm per annum. Besides, supplement irrigation is also essential for survival of agricultural and horticultural crops as the area is having unpredictable and erratic rainfall. Therefore, excess rain water needs to be conserved and stored in different storage structures to serve during the critical periods. Water can also be directed artificially to recharge the groundwater. Rain water or irrigation water is not used directly by plants. It is converted to soil water and

stored in the soil before it is utilized by the plants (Prihar and Sandhu, 2002). Therefore, water has to be conserved for optimum plant growth. Based on geography and other factors, following structures are recommended for the district.

The statistics of water resources and sustainable water harvesting is given in table 4.19 and the map of water resources inventory development for sustainable agro-horticulture is given in figure 4.15. The proposed structures in the district are described below:

Table 4.19 : Statistics for water rsources development plan of Aizawl district, Mizoram

Sl.No.	Type of structure	No. of proposed structures
1	Minor irrigation tanks	46
2	Water harvesting bunds	42
3	Check dams	102
4	Farm ponds	57

4.3.2.1. Minor Irrigation Tanks:

Minor irrigation tanks are proposed to be constructed across the streams for creating water reservoirs for providing irrigation to the crops at critical periods and to facilitate the groundwater recharge in the down stream regions (NRSA, 1995). A total number of 46 minor irrigation tanks have been proposed for the whole district. It is mainly proposed to be developed for irrigation of Wet Rice cultivation (WRC) in the narrow valley of Tuirini, Tuivai, Tuivawl and Changte lui.

4.3.2.2. Water Harvesting Bundhs:

These are almost similar to minor irrigation tanks except that they do not have extensive canal system and their command area is limited to fields' downstream (NRSA, 1995). 42 water harvesting bundhs have been proposed for the whole district. It is proposed to be developed for irrigating WRC areas and agro-horticulture areas in different parts of the district. The main objectives is to collect the impound surface run off during monsoon rains and facilitate infiltration to raise groundwater level in the zone of influence of the bundh.

4.3.2.3. Check Dams:

Check dams are proposed across the stream to tap the stream water for irrigation or for the purpose of drinking water. Besides this, the structure will also reduce run off velocity, thereby will be helpful to minimize erosion as well as will allow the retained water to percolate resulted in increased recharge for the groundwater in the adjoining downstream side. Overall, 102 check dams were proposed for the whole district. It is proposed to be developed in areas where agro-horticulture and WRC are taken up in different watershed such as, Tlawng, Tuirial, Tuivawl, Tuirini, etc.

4.3.2.4. Farm Ponds:

Construction of farm ponds is recommended as an embankment across a water course or by excavating a pit or the combination of both as also suggested earlier by NRSA (1995). Overall, 57 farm ponds have been proposed for the entire district. Constructions of farm ponds are suggested to serve water storage for irrigation as well as for paddy cum pisciculture. It is also proposed for providing drinking water for livestock and human beings.

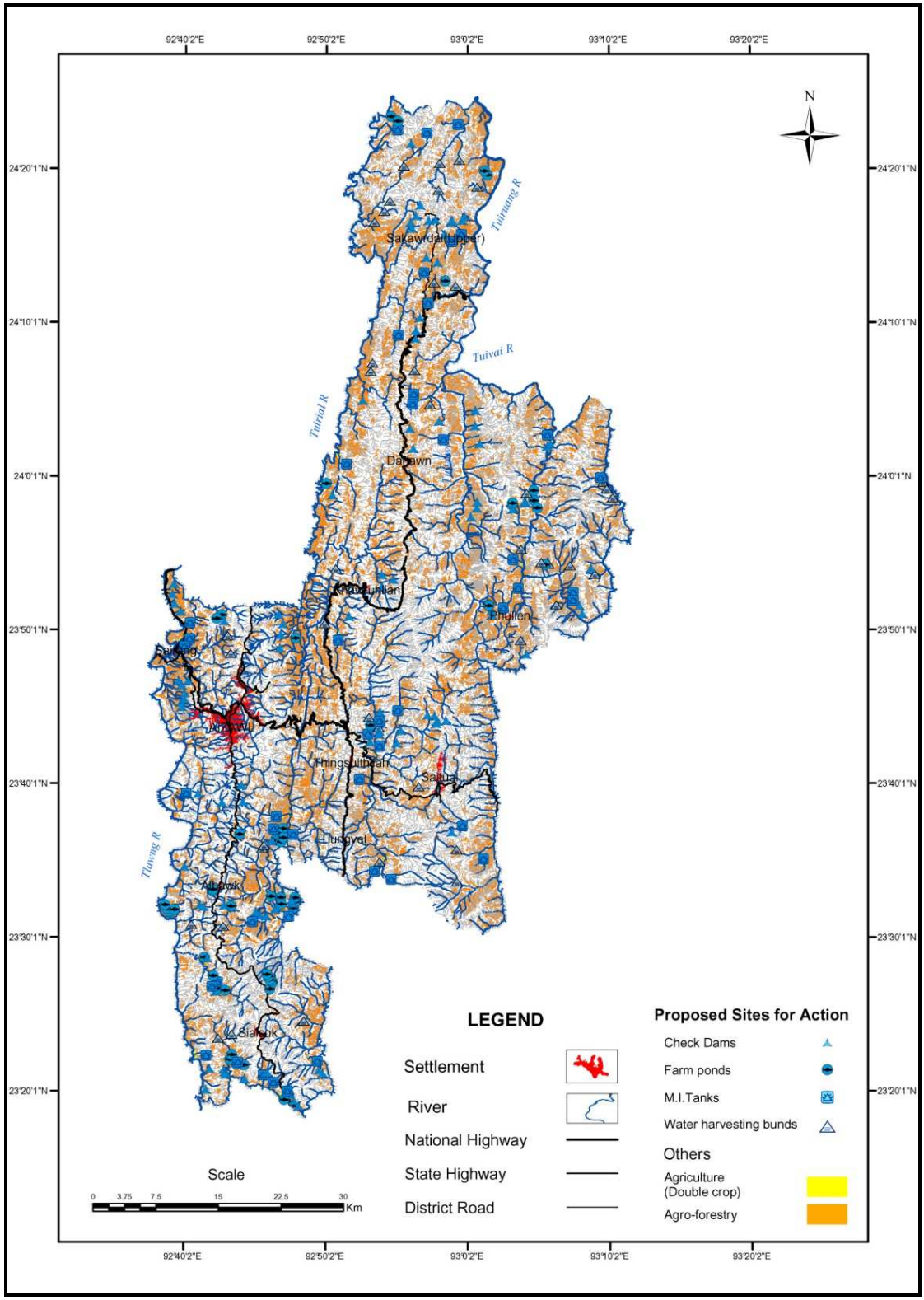


Figure 4.15: Water resource development map of Aizawl district, Mizoram

4.3.2.5. Soil Conservation activities

Soil is a nature's gift to mankind and more so in a country like India with large population leads heavy pressure on the land. It has drawn much attention to the compelling need for more systematic resource conservation efforts. In a recent analysis of soil erosion rates in India, about 5,333 million tones (16.35 t/ha) of soil is detached annually, and of this about 29% is carried away by the rivers into the sea. Nearly 10% of it is being deposited in the surface reservoirs resulting in the loss of 1 to 2% of the storage capacity (Narayana, 2002). The importance of soil conservation in arresting soil and land degradation has been well recognised. Because of the steep slopes of the area, soil erosion severely affects the area. Landslides are other problems found within the study area.

4.3.2.5a. Gully Control/Plugging:

Gully erosion is an advanced stage of soil erosion, where slopes stability of the side walls reduces and blocks of soil mass slough into the flow. An effective way of controlling a gully is to reduce run off rate by vegetative or mechanical means so as not to allow the gully flow which may clean out the slumped material (Narayana, 2002). Initial stage of Gullies formation are seen in and around Aizawl, Darlawn, Saitual, Hmuifang and near river banks of Tlawng, Tuivai, Tuirial and Tuivawl, etc. Gully control/plugging is recommended in such areas to reduce soil erosion.

4.3.2.5b. Stream Bank Protections:

There are certain reasons by which stream banks erosion occurred. Such as destruction of the vegetative cover over the stream banks, mass movement due to

unstable bank slope, undermining of the top of lower bank by turbulent flow, sloughing or sliding of slope when saturated with water, etc. Stream bank erosion has been found in various places like in the flat plain of Tuirial and Tuirini river valley and its tributaries. Protection measures involve encouraging vegetation growth or construction of retaining walls. Retaining walls may be constructed on eroded banks which are along agricultural terraces. Creating vegetal covers with locally suitable species on the eroded banks will serve good measures for other places as suggested by Young (1991).

4.3.2.5c. Road Side Erosion Control:

It is experienced in the hilly state of Mizoram that roadside erosion is caused by the road constructing activity. Frequently, because of this activity the slope stability breaks causing mass movement on the road sides which are dumped down hillside destroying vegetation and agricultural terraces as observed earlier by Young (1991). Therefore, systematization of drainage, creation of retaining wall and plantation of suitable grasses and plant species are recommended for the control measures.

4.3.3. OTHER ALLIED ACTIVITIES FOR SUSTAINABLE DEVELOPMENT PLAN:

4.3.3.1. Medicinal and Aromatic Plants (MAPs):

Plants have been used by man from prehistoric times for relieving suffering and curing ailments. Primitive people, when injured in battle or when they had a fall or cut, instinctively resorted to materials available at hand for staunching the flow of blood or the relieving of pain and by trial and error, they learnt that certain plants

were more effective than others for these purposes. For centuries, human beings have been utilizing plant genetic resources for food, medicine and other cultural purposes. More than 15000 species of higher plants occur in India of which about 9000 is economically important. Of these about 7500 are of medicinal value; 3900 are of food value; 700 are culturally important; 525 are used for fibre; 400 for fodder; 300 for pesticides and insecticides; 300 for gum, resin and dyes and 100 provide incense and perfume (Anonymous, 2004). Out of the above, over 9500 wild plant species are used by the tribal societies of India (Shankar, 2006).

India has one of the world's richest medicinal plants. The wealth is not only in terms of the number of unique species (6160) documented thus far for their medicinal use but also in terms of the tremendous depth of traditional knowledge about such uses of human and livestock health and also for agriculture. Over 4786 ecosystem specific species of plants are used by ethnic communities for human and veterinary health care, across the various ecosystems from Ladakh in the trans-Himalaya to the southern coastal tip of Kanyakumari and from the deserts of Rajasthan and Kachch to the hills of the Northeast. Such a huge number of medicinal plant species has allowed the evolution of many systems of herbal medicine. Reportedly Ayurvedic medicine includes about 2000 plant species. Other traditional medicinal systems of India also employ large numbers of species: Siddha (1121 species), Unani (751 species) and Tibetan (337 species) (Anonymous 2004, Kala 2002). The folk medicines of almost all the countries of the world abound in medicinal plants and tribal people wherever they exist, rely chiefly on herbal medicine even today.

Today, chemical and pharmaceutical investigations have added a great deal of status to the use of medicinal plants by revealing the presence of the active principles and their actions on human and animal systems. Investigations in the field of Pharmacognosy and Pharmacology have supplied valuable information on medicinal plants with regard to their availability, botanical properties, methods of cultivation, collection, storage, commerce and therapeutic uses (Faroogi and Sreeramu, 2004). All these have contributed towards their acceptance in modern medicine and their inclusion in the pharmacopoeias of civilized nations.

During the past few decades, there has been a rapid extension of the allopathic system of medical treatment in India. It generated a commercial demand for pharmacopoeial drugs and their products in the country. Thus efforts were made to introduce many of these drug plants into Indian agriculture, and studies on the cultivation practices were undertaken for those plants which were found suitable and remunerative for commercial cultivation. In general, agronomic practices for growing poppy, isabgol, senna, cinchona, ipecac, belladonna, ergot and a few others have been developed and there is now localized cultivation of these medicinal plants commercially. The average annual foreign trade in crude drugs and their phytochemicals is between 60 and 80 million rupees and these accounts for a little over 0.5 per cent of the world trade in these commodities (ICAR, 1997).

The aromatic plants possess odoriferous and volatile substances which occur as essential oils, gum exudates, balsam and oleo-resin in one or more parts. Many of these aromatics are powerful germicides and have anti-bacterial properties, but the bulk of the produce finds use in perfumery and the food-flavoring industries.

Amongst the two, the perfumery and allied industries consume much larger amounts of the natural fragrant material. According to the UN World Statistics of 1972, the annual world trade (excluding countries in Eastern Europe) in essential oils and perfumery aromatics for 1969 was of the order of Rs.2250 million; also, a large quantity of the aromatic material of plant origin is utilized in cosmetics, toiletries and allied industries (Bose *et al*., 1999). Our current volume of foreign trade in the perfumery material, essential oils and aromatic compounds is around Rs 65 million and this amount accounts for 1.6 per cent of the world trade (ICAR, 1997). Some sixty two types of essential oils come to the international market with a large and consistent demand. However, our treatment of the aromatic plants is confined to a few more important essential- oil crops grown in the country.

Considering the agronomic practices and the climatic requirements of medicinal and aromatic plants and the natural resources of the area including soil texture, altitude and climate were taken into consideration for finding out the suitability for cultivation of aromatic and medicinal plants. Some plants such as, Geranium, Coleus, Sarpagandha, Yam, Patchauli, Kalmegh are having wide range in altitude and soil texture, and they can be grown from sandy loam to sandy soil (NEIST, 2009).

Ten medicinal and aromatic values with good economic values were selected for the present study. The areas suitable for sericulture and agro-horticulture were utilized for finding out the potential areas of medicinal and aromatic plants. A separate map is prepared in order to avoid overlapping with the spatial plan. MAPs recommended under spatial planning during this study are based on climatic

suitability, location and soil requirements, availability of propagating quality material and demands in herbal market. However, trials on cultivation and quality will be required before commencing commercial cultivation. The statistics for potential areas of MAPs is given table 4.20 and agronomic reguirements are given in table 4.21, and the potential area map is given in figure 4.16.

Table 4.20: Statistics for potential area of medicinal and aromatic plants in Aizawl district, Mizoram

Sl. No.	**Name of Medicinal and Aromatic Crops**	**Area** (sq km)	**Percent(%)**	**Proposed Location**
1	Pachauli, Sarpagandha, Greater Yam, Kalmegh, Geranium.	401.96	50.51	Foot hill and River valley of Tuirial, Tuivawl, Tuivai,etc.
2	Gloriosa, Withania, Lemon Grass, Citronella, Sarpagandha, Greater yam, Patchauli	359.05	45.12	Near Aibawk, Sesawng, Saitual, Khawruhlian, etc. villages
3	Lemon Grass, Citronella, Coleus, Geranium, Kalmegh, Patchauli, Yam, Sarpagandha	26.76	3.37	Near Aizawl, Ratu, Darlawn,Muallungthu, etc. villages
4	Withania, Coleus, Geranium, Sarpagandha, Yam, Patchauli, Kalmegh	5.97	0.75	Near Sialsuk, Mualpheng,Phuai-buang,etc. villages
5	Geranium, Coleus, Sarpagandha, Yam, Patchauli, Kalmegh	2.02	0.25	Near Tawizo, Maite, Khanpui, Hmuifang, etc. villages
	Total	**795.76**	**100.00**	

Table 4.21 : Recommended crops for medicinal and aromatic plants with their agronomic requirements

Sl. No.	Name of Species	Common/ Trade name	Specific agronomic requirements	References
1	*Rauvolfia serpentine* Linn.Benth ex kurz	Sarpagandha	Altitude – upto 900masl mainly in subtropical region, Sandy loam or sandy soils rich in organic matter, pH6 - 8.5	Farm Bulletin, CIMAP; Farooqi & Sreeramu , (2004)
2	*Dioscorea spp.* Linn.	Greater Yam/ Asiatic Yam	Altitude – Wide range – subtropical to temperate region; light or sandy soils, medium soils, pH – wide range	Farooqi & Sreeramu , (2004)
3	*Pogostemon patchouli* Benth.	Patchauli	Altitude – upto 1000 m asl, Sandy loam soils rich in humus, pH 6 – 7	Farooqi & Sreeramu , (2004)
4	*Andrographis paniculata* Burm. f.	Kalmegh	Altitude – wide range, subtropical to temperate, Loam to lateritic soils, pH 5 - 6	NEIST (2009)
5	*Cymbopogon winterianus* Jowitt	Citronella	Altitude - 500 to 1200 m asl, Wide range and thrive well in Sandy loam soil, pH 5 – 5.5	NEIST (2009)
6	*Cymbopogon flexusus* Stapf	Lemon grass	Altitude - 600 to 1200 m asl, Sandy loam to clay loam soil, pH 7 – 8.5	Bose *et.al.* (1999)
7	*Withania somnifera* Linn. Dunal	Ashwagandha	Altitude - 600 to 1400 m asl, Wide range, soil pH 4.4 - 6	NEIST (2009)
8	*Pelargonium spp.* Linn. L.Her.	Geranium	Altitude – upto 2000 m asl, wide range, soil pH 6 – 6.5	Farooqi & Sreeramu, (2004)
9	*Coleus barbetus* Willd.	Pattachchur	Altitude - 1000 to 1500 m asl, Sandy loam soil, pH 5 – 8.7	Farooqi & Sreeramu ,
10	*Gloriosa superva* Linn.	Kalihari, Langli	Altitude - 600 to 1000 m asl, Sandy loam soil, pH 5 – 8	Bose *et.al.* (1999)

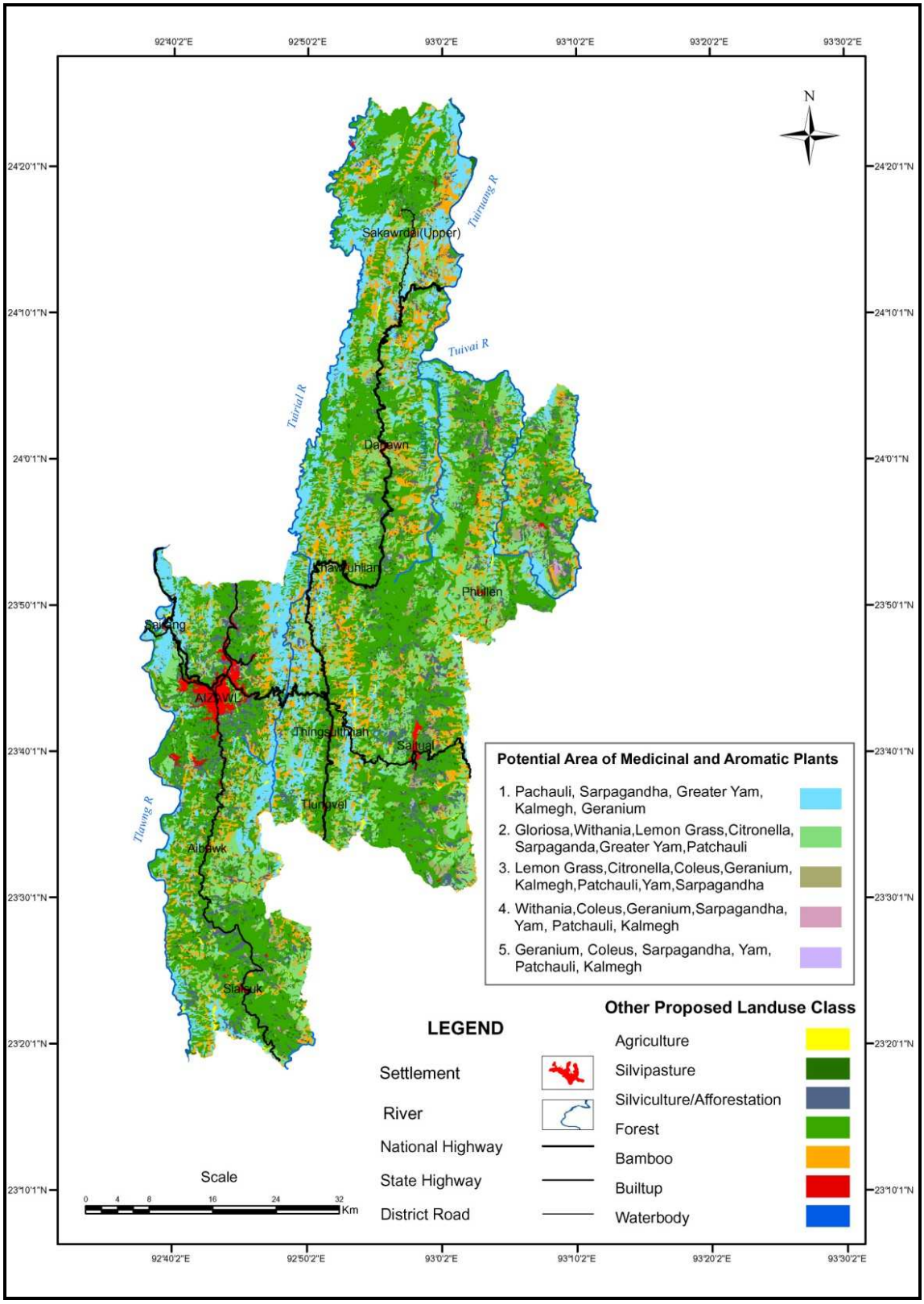


Figure 4.16 : Potential area map of Medicinal and Aromatic plants in Aizawl district, Mizoram

4.3.3.2. Animal Husbandary and Veterinary:

The area has a good potential for development of animal husbandry. Piggery, poultry and dairy developments are the major activities proposed to be taken up. For the large scale development of animal husbandry, the area given for silvi-pastural land may be used as suggested earlier by ICAR (2008). However, for the small scale purpose and under proper control it can be practiced at any place as per the convenient of the farmers. The development of veterinary services would be a very important part of this activity.

4.3.3.3. Pisciculture:

The scope for pisciculture development in general, is not very good because of the topographical condition i.e. hilly terrain. However, the river valleys are also suitable for agro-aquaculture system. This system is therefore, recommended to be practice in such areas. The components of the system are composite fish culture with paddy or vegetables. Few ponds can also be developed in shallow depressions where small streams enter into relatively flat areas. Paddy-cum-fish culture can also be introduced where small fish ponds have been developed by farmers (ICAR, 2006).

4.3.3.4. Floriculture development:

Floriculture development has a very good scope in Aizawl district. The natural resources including climatic requirements are suitable for growing annual and perennial flowers. It has been flourishing in the district as a number of farmers and individuals are commercially taking up floriculture as small businesses. The Horticulture department has also initiated various schemes for promotion of floriculture in the district by publishing manuals/booklets on cultivation of annual and

perennial flowers, organizing seminars, flower shows, exhibitions and construction of infrastructure facilities. The department has also taken up initiatives in exporting these flowers outside the state. Amongst the flowers commercially cultivated, Anthurium, Rose and Ferns are taken up at large scale, which is shown in table 4.22. Statistical records have also shown that the cultivation area of these flowers have been increasing each year. Considering all these facets of its feasibility in mass scale production, the adoption of floriculture has immense scope of potential, both aesthetically and commercially in the district.

Table 4.22: Statistics of flower production in Mizoram

Sl.No.	Name of Flower	Year 2008 - 2009			Year 2009 - 2010		
		Area (ha)	Production of flower (Lakhs)	Yield (lakh Per ha.)	Area (ha.)	Production of flower (lakhs)	Yield (lakh Per ha.)
1	Anthurium	26	75	2.88	28	79	2.82
2	Rose	6	27	4.50	6	28	4.66
3	Fern	2	40	20.00	2	35	17.50

(Source : Statistical Hanbook, Mizoram 2010)

4.3.3.5. Infrastucture Facility:

The road network needs to be improved for transportation of the agricultural, horticultural, forest and other products. Moreover a proper marketing system is required so that the farmers would not have problems in disposing their products at a reasonable price. The existing industries as well as the proposed industries may be equipped with better facilities. Villagers may also be encouraged for minor forest

based industries like carpentry, handicraft, etc. It is also proposed to give proper training and education to local people through demonstration schemes, audio and visuals etc. to convince them for the activities to be taken up. The detail map of transportation set up of the Aizawl district is given in figure 3.2.

4.3.3.6. Orgnanic farming:

Natural and organically produced herbal products have great demands world over. The residues of chemical inputs from fertilizers and pesticides entering the food chain are the major concern. The basic principle of organic farming aims at the management of agro- and ecosystems. Under such system, the farmer has to manage the farm with coherent diversity by utilizing all the on-farm and adjacent resources. Such a practice helps to conserve the ecosystem rather than destroy it. Organic farming excludes use of agro-chemicals like chemical fertilizers and pesticides (Gaur, 2010). The soil must be manured to feed the soil micro-organism for their growth and biological activities. Nutrients are recycled by composting crop residues and using farmyard manure, green manure, etc. Rotation with legume crops helps in biological nitrogen fixation (Directorate of Agriculture, 2007).

Various steps have been taken by the Mizoram state government to improve upon the farming system of the entire state. Synthetic fertilizers that were randomly utilized by the farmers are now gradually replaced by the new trend of organic farming system and are gaining popularity among the farmers. In fact, the state government has recently passed the “Organic Farming Bill 2004” and is under process for framing its rules and regulations to make the entire State as an “Organic State”, which is one of the first of its kind in India (Directorate of Agriculture, 2004).

Organic farming is, therefore recommended as it is the environmental friendly method of agricultural or horticultural practice.

4.3.3.7. Non-Biodegradable Material Disposal:

Another concerning subject is the alarming increase of polythene deposits by human beings. It is observed that more disposed polythene materials were found in the lower areas and river valleys rather than at higher altitudes. The disposed polythenes are found from the surface of the soil up to four feet deep. This will deteriorate the soil fertility and hindrance the extension of land development, and will obviously have great impact on flora and fauna of both land and aquatic environment. The polythene deposits in the soil may augment the landslides as they prevent mutual cohesion among the soil particles and also retain pools of water which is suitable breeding place for germs and mosquitoes. Therefore, efforts have to be taken to dispose off these solid wastes by making suitable dumping sites, and also to reduce or stop the use of non-biodegradable materials for packing perishable goods, etc.

4.3.4. CONSERVATION AND IMPROVEMENT OF EXISTING FOREST:

The existing forest and Bamboo forest should be conserved and improved by planting native species or other suitable species for maintaining the ecological balance. It has been proposed that the area under tree forest should be 1450.19 sq kms of land which is 40.55 % of the total geographical area, and the bamboo forest should be 602.97 sq kms or 16.86 % of the total geographical area. It is proposed that each and every village/town should have supply reserved forest and safety reserved forest. The reliable voluntary organisations like Young Mizo Association (YMA), Mizo

Hmeichhe Insuihkhawm Pawl (MHIP), Mizoram Upa Pawl (MUP) etc. may also be encouraged to have reserved forests or parks in the nearby areas of their respective villages/towns (Shah, 1996). If the forest department can entrust the Village Councils or voluntary organisations in protecting the reserved forest, or if there is a combined effort among the forest and other departments and the villagers, protection of the reserved forests will be more effective. The existing forests may be improved by planting the native tree species or other species that have been mentioned to be grown under silviculture/afforestation.

4.3.5. SETTLEMENTS AND WATER BODY

Settlements include residence, institutions, offices, etc. and the area under this category is estimated to be of the order of 48.28 sq km or 1.35 % of the total geographical area. Water bodies are mainly rivers with their tributaries and occupy an area of 14.31sq km. or 0.40% of the total geographical area.

CHAPTER V

SUMMARY AND CONCLUSION

Information on the nature, extent, spatial distribution along with the potentials and limitations of natural resources is a pre-requisite to achieve the goals of sustainable development. By virtue of providing synoptic view of fairly large area at regular interval, space borne multispectral measurements hold great promise in generating reliable information on various natural resources, viz. soils, geology and geomorphology, minerals, surface and ground water, land use and land cover, forest cover, slope, etc. in a timely and cost-effective manner. Geographic information system (GIS) offers an ideal environment for integrating spatial and attributes data on natural resources and environment, and for subsequent generation of optimal land use plan. Water resources, both surface as well as ground water is very crucial for sustaining flora and fauna. Over exploitation of ground water and wastage of precipitation water as run-off are the major issues which are addressed in the context of sustainable development. Furthermore, Global positioning system (GPS) enables making precise *in situ* measurements on various terrain parameters which are used for both generating baseline as well as derivative information on natural resources for various developmental activities. Exploitation, mis-management and neglect can ruin the fragile natural resources and become threat to human survival.

The present research was started during the year 2009 with main aim to develop spatial planning of agro-horticulture development of Aizawl district in Mizoram. To achieve this objectives, mapping and generation of land use land cover,

soil resources, geology and geomorphology, watershed boundaries, slope and aspect, transport network and settlement location were set forth. Socio-economic data and meteorological data were also collected from various sources. The standard methodology of remote sensing and GIS was followed for the observations and mapping of natural resources. Pre field interpretation of satellite imagery was done followed by ground truth checking. Ground truth information and other ancillary data were incorporated in the post field work in which different natural resources were integrated along with socio-economic and meteorological data for generation of spatial planning of sustainable agro-horticulture development.

Aizawl is the capital city of Mizoram and it is the district Headquarter of Aizawl district. The district is divided into three sub division viz. Aizawl, Sakawrdai and Saitual. According to 2011 census, the population of Aizawl district is 4,04,054, out of which 2,01,072 are male and 2,02,982 are female. There is one city, 3 towns, and 96 villages. It is well connected by road and the national highway 54 and 150 run through the district. A number of agricultural/horticultural link roads have been constructed which serve for transportation of agricultural and horticultural produces from the interior parts of the district.

Drainage mapping was done from satellite imagery and topo-sheets, and watershed classification was done according to Watershed Atlas of all India Soil and Land use Survey Organisation. The drainage system of Aizawl district as a whole is elongated in north to south direction showing angulated, dendritic to sub-dendritic drainage patterns. There are 11 watersheds, 27 sub-watersheds, 92 mini-watersheds

and 384 micro watersheds within the district. Accordingly, the developmental activities can be taken up in watershed basis.

The general geology of the district represents a monotonous sequence of argillaceous and arenaceous rocks, which are classified into two formations viz., Middle Bhuban and Upper Bhuban Formations. The formations are folded into almost N – S trending anticlines and synclines and affected by longitudinal, oblique and transverse faults of varying magnitudes. The formations are classified into two based on lithological assemblage and sedimentary structures. Five different rock types are mapped in which Siltstone and Shale occupies majority of the area covering 63.31% of the total geographical area. The geomorphology consists of three geomorphic class viz., Structural Hill, Valley fill and Flood plain. Structural hill constitute the main geomorphic class and dominates the study area. From the geology and geomorphological classes and topography of the area, ground water potential zone are derived into 4 types i.e. very good, good, moderate and poor. However, more than half of the area of the district falls under poor zones.

Slope, aspect and altitudinal zones of the area were generated from Digital Elevation Model (DEM). Slope is expressed in percentage. Among the nine slope facets, 35 – 50% and 3 – 10% slopes covers maximum and minimum areas constituting 38.33% and 0.08% of the total geographical area, respectively. The area was conveniently divided into 9 aspects. As the hill ridges mainly run from north to south in their formation trend, the largest area is the western aspect followed by north-western aspects. Northeast aspect is often considered most suitable for agriculture development, establishing orchards, farms and other residential areas and only

occupies 13.18% of the geographical areas. The altitudes of the area vary from 100 to 1905m above sea level. The altitude is divided into 9 classes in which 500 – 700m above mean sea level occupies maximum area covering 24.41% of the area.

The major land use/land cover classes within the district was broadly categorized into settlements, agricultural land, forests, bamboo forest, forest plantations, shifting cultivation, scrubland and water body. The forest cover type is mainly tropical wet evergreen forest mixed with semi evergreen and tropical moist deciduous forests comprising mainly of bamboo. There is also sub-tropical forest found at higher altitudes. The vegetation consists of a mixture of several species. Depending on the density of the canopy cover, the forests have been divided into dense/closed, medium dense and less dense. The existing forests and Bamboo forests cover 40.55% and 16.86% area of the district, respectively. The aged old practice of shifting cultivation is still continued and every year an area of 185.44 sq km were under shifting cultivation which account for 5.19% of the total area of the district.

Soils of the areas is classified on the basis of their physico-chemical and morphological properties. The soils identified at order levels are Entisols, Inceptisols and Ultisols. The soils were classified upto series level and there were 14 soil series. These soils are formed under humid tropical with mean annual rainfall of 3155mm. The pedons comprises of mixed mineralogy and hyper-thermic temperature class. Soil texture is classified into 7 classes in which clay loam surface occupies maximum area which is optimum for growing different agricultural and horticultural crops. The physiographic soil data was further processed and analysed for deriving land capability classes for a specific usage of the area. The maximum area occupied by

‘land capability class’ was Class VI accounting to 47.03%. This shows that fairly good land on steep to very steep slopes covered maximum area within the district.

The main aim of the present research was to prepare spatial planning of sustainable agro-horticulture development using remote sensing techniques. Such an objective can be accomplished through development of land, water, vegetation and other resources of an area in a sustainable manner so that the changes proposed to meet the needs of people are brought about without diminishing the potential for future. The natural resources data generated by using remote sensing and GIS with collateral data in GIS domain were integrated to generate database for spatial planning of sustainable development. Base on the natural resources of the area silvi-pasture, sericulture, agro-horticulture, silviculture/afforestation and agriculture (WRC) are therefore planned for sustainable development. In addition to that, water resources inventory development plan such as minor irrigation tanks, water harvesting bunds, check dams and farm ponds were planned depending upon the sites and the command areas for irrigation.

Based on observations conducted during the course of this study, it is planned that agriculture mainly wet rice cultivation (WRC) to be taken up in narrow valleys with an area of 26.46 sq km, constituting only 0.74% of the total geographical area. System of Rice Intensification (SRI) is recommended for cultivation in the area. Silvipasture and sericulture are proposed to be taken up in 120.16 sq km and 204.56 sq km accounting to 3.36% and 5.72% of the total area respectively. Agro-horticulture is proposed to be developed in a land upto 50% slope with a minimum of 1 m soil depth and the potential area for the system identified is around 710.97 sq km,

which is 19.88% of the total geographical area. Silviculture/ afforeastation is proposed to be developed in 398.41 sq km or 11.14% of the area of the district. The existing forest and Bamboo forest should be conserved for maintaining eco-balance of the nature and it accounted for 40.55% and 16.86%, respectively. The total forest cover including silviculture/afforestation will be 68.55% of the total geographical areas, i.e., two-third of the area will be covered by forest.

Water resources inventory for sustainable development are also proposed to be develop for providing irrigation of crops, pisciculture and for drinking water purposes. The proposed structures to be developed are minor irrigation tanks, water harvesting bunds, check dams and farm ponds and the numbers of structures to be developed are 46, 42, 102 and 57, respectively. For soil conservation measures, gully control/ plugging, stream bank protection and road side erosion control are also proposed to be developed in erosion prone areas.

Other allied activities like cultivation of medicinal and aromatic plants, animal husbandry and veterinary, pisciculture, floriculture, infrastructure facilities including industries and organic farming are also recommended in the district for sustainable development plan. Considering the soil texture, climatic requirements and economic viability, 10 medicinal and aromatic plants are selected for finding out the potential area for cultivation in the study area. Five crops viz., Pachauli, Sarpagandha, Greater Yam, Kalmegh and Geranium are highly suitable for cultivation in Aizawl district.

Since the sustainable development of natural resources is based on maintaining a fragile balance between productivity functions and conservation practices through monitoring and identification of problem areas, remote sensing and GIS makes the

task easy. With the developments in satellite technology and data availability, considerable progress has been made towards effective utilization of the available data for conservation, monitoring and management of natural resources.

Out of eight districts in Mizoram, only Aizawl district is covered in the present research. It is suggested that parallel to the study area, all other district should be covered so as to make uniform sustainable development plan for the whole state. Further, better resolution of satellite sensors may be used for detailed information on natural resources which will automatically give better spatial plan. Though, the findings of this research is far from satisfactory, I hopes that it may pave the way for future land use plan for sustainable development and help other researchers, developmental departments and farmers in some aspects of sustainable development movements.

Plate 1. Panoramic view of Aizawl city, the Aizawl district headquarters and the capital of Mizoram

Plate 2. Pineapple plantation near Aibawk village. Such plantations are seen in different parts of the district

Plate 3. Orange plantation near Sesawng village. Having good potential within the district

Plate 4. Banana plantation near Thingsulthliah village. Such plantations are successful in different parts of the district.

Plate 5. Dense forest near Phulpui village. Such virgin forest should be conserved for maintaining eco-balance of the nature

Plate 6. Bamboo forest, a prominent vegetation class found throughout the district.

Plate 7. Wet Rice Cultivation in the narrow valley of Changte river.

Plate 8. Potential areas for WRC at Tuirini river valley. Land development should be taken up in such narrow valleys.

Plate 9. Terrace with water harvesting structures on the hill top at Durtlang. Terrace farming should be encouraged in the hill side slope.

Plate 10. Squash/Chow-chow plantation at Sihphir village.

Plate 11. Sugargcane Plantation near Lungleng Village

Plate 12. Forests cleared up for jhum cultivation in which local varieties of rice and vegetables were grown. Optimum for agro-horticulture development.

Plate 13. Typical Soil profile of Fine Loamy, Humic Hapludults. Such types of soil are suitable for Agriculture and Horticulture plantations.

Plate 14. Structural hills which dominate the entire district.

Plate 15. Sun set photos from Hmuifang village, one of the highest point of the district

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APPENDIX – I

SOCIO-ECONOMIC DATA OF AIZAWL DISTRICT, MIZORAM

Sl. No	**Name of Village/ Town**	**Popu-lation**	**Lite-racy %**	**Edu-cation**	**Heal-th**	**Vety**	**Water Supp-ly**	**Elec-Trici-ty**	**Com munica tion**	**Bank**	**Occupa tion**
1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***
1	Mauchar	M-397 F-361 T-758	M-96.0 F-89.7 T-93.0	P – 1 M – 1 H – 0 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-385 TAG-0 TIND-1 TOW-12
2	Kani	M-62 F-65 T-127	M-86.0 F-87.8 T-86.9	P – 1 M – 1 H – 0 HSS-0 C - 0			OS				TC-62 TAG-1 TIND-0 TOW-1
3	N.Tinghmun	M-359 F-352 T-711	M-88.9 F-82.5 T-88.8	P – 1 M – 1 H – 0 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-315 TAG-0 TIND-2 TOW-17
4	Zohmun	M-692 F-671 T-1363	M-91.3 F-83.3 T-87.4	P – 3 M – 2 H – 1 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-575 TAG-2 TIND-1 TOW-77
5	Palsang	M-187 F-188 T-375	M-95.7 F-89.5 T-92.7	P – 1 M – 1 H – 0 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-190 TAG-0 TIND-0 TOW-17
6	Upper Sakawrdai	M-67 F-69 T-136	M-96.6 F-94.9 T-95.8	P – 1 M – 0 H – 0 HSS-0 C - 0			OS/ PWS	E	BPO		TC-75 TAG-0 TIND-0 TOW-3
7	Lower Sakawrdai	M-1011 F-987 T-1998	M-93.6 F-93.7 T-93.6	P – 5 M – 4 H – 1 HSS-0 C - 0	PHC SC		OS/ PWS	E			TC-826 TAG-5 TIND-25 TOW-124
8	N.Khawd-ungsei	M-84 F-67 T-151	M-91.5 F-96.0 T-93.4	P – 1 M – 1 H – 0 HSS-0 C – 0			OS/ PWS	E			TC-88 TAG-0 TIND-0 TOW-4

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
9	Vaitin	M-474 F-435 T-909	M-82.8 F-79.1 T-81.0	P – 2 M – 1 H – 1 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-457 TAG-0 TIND-0 TOW- 27
10	Khawpuar	M-188 F-213 T-401	M-81.9 F-82.3 T-82.1	P – 1 M – 1 H – 0 HSS-0 C - 0			OS/ PWS	E	BPO		TC-201 TAG-0 TIND-0 TOW-2
11	Luakchhuah	M-6 F-5 T-11	M-100 F-100 T-100	P – 0 M – 0 H – 0 HSS-0 C - 0			OS				TC-7 TAG-0 TIND-0 TOW-0
12	E.Damdiai	M-107 F-106 T-213	M-96.4 F-84.3 T-90.4	P – 1 M – 0 H – 0 HSS-0 C - 0			OS/ PWS	E			TC-110 TAG-0 TIND-0 TOW-3
13	Thingsat	M-116 F-117 T-233	M-91.6 F-90.6 T-91.1	P – 1 M – 0 H – 0 HSS-0 C - 0	SC		OS/ PWS	E			TC-95 TAG-0 TIND-0 TOW-6
14	New Vervek	M-439 F-394 T-833	M-94.3 F-86.3 T-90.6	P – 2 M – 1 H – 1 HSS-0 C - 0	SC		OS	E	BPO		TC-336 TAG-1 TIND-1 TOW- 104
15	Lungsum	M-189 F-190 T-379	M-95.3 F-89.6 T-93.4	P – 2 M – 1 H – 0 HSS-0 C - 0			OS/ PWS	E			TC-177 TAG-0 TIND-1 TOW- 10
16	Ratu	M-1128 F-1136 T-2264	M-96.2 F-95.5 T-95.9	P – 4 M – 3 H – 1 HSS-0 C - 0	SC		OS/ PWS	E	BPO	MRB	TC-878 TAG-2 TIND- 19 TOW- 129
17	Sunhluch- hip	M-226 F-191 T-417	M-79.5 F-68.8 T-74.5	P – 1 M – 0 H – 0 HSS-0 C – 0			OS/ PWS	E			TC-221 TAG-0 TIND-4 TOW-1

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
18	Sailutar	M-234 F-231 T-465	M-91.4 F-82.0 T-86.8	P – 1 M – 1 H – 0 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-78 TAG-90 TIND-0 TOW-16
19	N.Serzawl	M-289 F-231 T-520	M-93.4 F-88.6 T-91.2	P – 1 M – 1 H – 0 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-274 TAG-5 TIND-0 TOW-25
20	Sawleng	M-742 F-678 T-1420	M-93.5 F-90.9 T-92.3	P – 3 M – 1 H – 1 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-560 TAG-10 TIND-8 TOW-43
21	Chhanch-huahna Khawpui	M-77 F-73 T-150	M-93.5 F-87.9 T-90.8	P – 1 M – 0 H – 0 HSS-0 C - 0			OS/ PWS	E			TC-85 TAG-0 TIND-1 TOW-7
22	Kepran	M-378 F-374 T-752	M-97.8 F-95.9 T-96.9	P – 2 M – 1 H – 0 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-366 TAG-1 TIND-1 TOW-30
23	E. Phaileng	M-551 F-544 T-1095	M-95.1 F-94.2 T-94.6	P – 3 M – 1 H – 1 HSS-0 C - 0	SC	RAH	OS/ PWS	E	BPO		TC-609 TAG-0 TIND-11 TOW-39
24	Pehlawn	M-319 F-287 T-606	M-97.1 F-94.7 T-95.9	P – 2 M – 1 H – 0 HSS-0 C - 0	SC		OS/ PWS	E			TC-331 TAG-1 TIND-8 TOW-19
25	Khanpui	M-680 F-635 T-1315	M-94.7 F-90.2 T-92.5	P – 3 M – 1 H – 1 HSS-0 C - 0			OS/ PWS	E	BPO		TC-597 TAG-0 TIND-6 TOW-61
26	Khawruhl-ian	M-1068 F-998 T-2066	M-94.1 F-93.8 T-93.9	P – 5 M – 2 H – 1 HSS-0 C – 0	PHC	RAH	OS/ PWS	E	BPO	MRB	TC-704 TAG-52 TIND-4 TOW-173

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
27	Tuirinikai	M-15 F-12 T-27	M-90.9 F-100 T-94.7	P – 0 M – 0 H – 0 HSS-0 C - 0			OS	E			TC-4 TAG-13 TIND-0 TOW-0
28	Hmunnghak	M-163 F-167 T-330	M-95.0 F-92.2 T-94.6	P – 1 M – 0 H – 0 HSS-0 C - 0			OS/ PWS	E	BPO		TC-160 TAG-0 TIND-0 TOW-5
29	Lailak	M-161 F-118 T-279	M-99.2 F-95.7 T-97.7	P – 1 M – 0 H – 0 HSS-0 C - 0			OS/ PWS	E			TC-159 TAG-0 TIND-0 TOW-2
30	Darlawn	M- 10409 F-9895 T-20304	M-96.2 F-92.4 T-94.3	P – 7 M – 5 H – 4 HSS-1 C - 0	PHC SC	RAH	OS/ PWS	E	SPO TE	SBI	TC-997 TAG-118 TIND-17 TOW- 500
31	N.Khawlek	M-368 F-322 T-690	M-96.1 F-96.2 T-96.1	P – 1 M – 1 H – 0 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-271 TAG-0 TIND-2 TOW- 21
32	Vanbawng	M-661 F-611 T-1272	M-96.1 F-93.2 T-94.7	P – 2 M – 2 H – 1 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-422 TAG-0 TIND-0 TOW- 72
33	Lamherh	M-254 F-204 T-458	M-94.4 F-87.4 T-91.4	P – 1 M – 1 H – 0 HSS-0 C - 0			OS/ PWS	E			TC-232 TAG-0 TIND-0 TOW-9
34	Suangpui- lawn	M-906 F-834 T-1740	M-90.6 F-89.1 T-89.9	P – 4 M – 2 H – 1 HSS-0 C - 0	SC	RAH	OS/ PWS	E	BPO	MRB	TC-703 TAG-1 TIND-2 TOW- 113
35	Zawngin	M-273 F-252 T-525	M-96.9 F-93.7 T-95.4	P – 1 M – 1 H – 0 HSS-0 C - 0			OS/ PWS	E			TC-278 TAG-2 TIND-0 TOW- 16

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
36	Phullen	M-844 F-851 T-1695	M-94.8 F-94.9 T-94.8	P – 4 M – 4 H – 2 HSS-0 C - 0	SC	RAH	OS/ PWS	E	BPO	SBI	TC-647 TAG-0 TIND-1 TOW-123
37	Thanglai-lung	M-340 F-317 T-657	M-95.9 F-92.9 T-94.4	P – 1 M – 1 H – 0 HSS-0 C - 0			OS/ PWS	E			TC-332 TAG-0 TIND-0 TOW-19
38	Luangpawn	M-195 F-189 T-384	M-94.3 F-88.7 T-91.7	P – 1 M – 1 H – 0 HSS-0 C - 0			OS/ PWS	E			TC-142 TAG-0 TIND-0 TOW-9
39	Phuaibuang	M-1119 F-1064 T-2183	M-97.9 F-92.8 T-95.4	P – 4 M – 2 H – 1 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-1527 TAG-0 TIND-14 TOW-91
40	Khawlian	M-888 F-793 T-1681	M-94.7 F-89.7 T-92.4	P – 3 M – 1 H – 1 HSS-0 C - 0	SC	RAH	OS/ PWS	E	BPO		TC-840 TAG-3 TIND-10 TOW-109
41	N.E. Tlangnuam	M-263 F-298 T-561	M-96.1 F-94.5 T-95.2	P – 1 M – 1 H – 0 HSS-0 C - 0			OS/ PWS	E			TC-260 TAG-0 TIND-0 TOW-18
42	Daido	M-257 F-234 T-491	M-97.2 F-91.7 T-94.7	P – 1 M – 1 H – 0 HSS-0 C - 0	SC		OS/ PWS	E			TC-183 TAG-0 TIND-0 TOW-21
43	Hualngoh-mun	M-294 F-315 T-609	M-98.8 F-91.2 T-94.9	P – 1 M – 1 H – 0 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-180 TAG-2 TIND-2 TOW-47
44	Thingdawl (Melriat)	M-429 F-409 T-838	M-96.4 F-95.9 T-96.1	P – 1 M – 1 H – 1 HSS-0 C - 0	SC	RAH	OS/ PWS	E	BPO		TC-386 TAG-0 TIND-0 TOW-60

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
45	Kelsih	M-331 F-348 T-679	M-96.1 F-95.6 T-95.8	P – 1 M – 1 H – 1 HSS-0 C - 0			OS/ PWS	E	BPO		TC-244 TAG-23 TIND-0 TOW-41
46	Falkawn	M-441 F-418 T-859	M-97.9 F-95.5 T-96.8	P – 2 M – 1 H – 1 HSS-0 C - 0	HO		OS/ PWS	E	BPO		TC-361 TAG-0 TIND-4 TOW-40
47	Muallung-thu	M-536 F-460 T-996	M-98.2 F-96.4 T-97.3	P – 3 M – 1 H – 0 HSS-0 C - 0		RAH	OS/ PWS	E	BPO		TC-473 TAG-0 TIND-1 TOW-44
48	Tachhip	M-470 F-423 T-893	M-99.0 F-98.1 T-98.6	P – 2 M – 1 H – 1 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-396 TAG-1 TIND-3 TOW-47
49	Aibawk	M-675 F-643 T-1318	M-98.8 F-97.9 T-98.4	P – 3 M – 1 H – 1 HSS-0 C - 0	PHC SC	D	OS/ PWS	E	SPO TE	MRB	TC-418 TAG-5 TIND-3 TOW-180
50	Sateek	M-434 F-421 T-855	M-97.2 F-96.4 T-96.8	P – 1 M – 1 H – 0 HSS-0 C - 0			OS/ PWS	E	BPO TE		TC-446 TAG-0 TIND-3 TOW-63
51	Phulpui	M-496 F-488 T-984	M-97.9 F-95.2 T-96.5	P – 2 M – 1 H – 1 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-459 TAG-0 TIND-3 TOW-36
52	Khawhmi-nglokawn	M-25 F-10 T-35	M-95.0 F-100 T-96.6	P – 0 M – 0 H – 0 HSS-0 C - 0			OS	E			TC-19 TAG-0 TIND-0 TOW-0
53	N.Lungsai	M-52 F-46 T-98	M-100 F-97.7 T-98.9	P – 1 M – 0 H – 0 HSS-0 C – 0			OS	E			TC-51 TAG-0 TIND-0 TOW-1

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
54	S.Maubuang	M-228 F-219 T-447	M-98.4 F-98.9 T-98.7	P – 1 M – 1 H – 1 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-216 TAG-1 TIND-0 TOW-17
55	Thiak	M-361 F-360 T-721	M-99.7 F-98.0 T-98.8	P – 2 M – 1 H – 1 HSS-0 C - 0			OS/ PWS	E	BPO		TC-302 TAG-0 TIND-0 TOW-27
56	Sumsuih	M-404 F-362 T-766	M-93.6 F-89.6 T-91.7	P – 2 M – 1 H – 1 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-386 TAG-0 TIND-0 TOW- 25
57	Hmuifang	M-105 F-95 T-200	M-97.8 F-98.7 T-98.2	P – 1 M – 1 H – 0 HSS-0 C - 0		RAH	OS/ PWS	E	BPO		TC-83 TAG-0 TIND-0 TOW- 13
58	Lungsei	M-130 F-103 T-233	M-100 F-98.7 T-99.5	P – 1 M – 1 H – 0 HSS-0 C - 0			OS/ PWS	E			TC-153 TAG-0 TIND-0 TOW-1
59	Samlukhai	M-637 F-617 T-1254	M-95.7 F-93.9 T-94.8	P – 2 M – 1 H – 1 HSS-0 C - 0	SC	RAH	OS/ PWS	E	BPO		TC-617 TAG-0 TIND-8 TOW- 42
60	Chamring	M-112 F-115 T-227	M-98.9 F-96.8 T-97.8	P – 1 M – 0 H – 0 HSS-0 C - 0			OS/ PWS	E	BPO		TC-86 TAG-0 TIND-0 TOW-2
61	Lamchhip	M-358 F-325 T-683	M-95.5 F-98.1 T-96.8	P – 2 M – 1 H – 1 HSS-0 C - 0	SC		OS/ PWS	E	SPO		TC-313 TAG-0 TIND-0 TOW- 17
62	Chawilung	M-244 F-209 T-453	M-95.2 F-94.8 T-95.0	P – 1 M – 1 H – 0 HSS-0 C - 0			OS/ PWS	E	BPO		TC-247 TAG-0 TIND-2 TOW-8

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
63	Sialsuk	M-1043 F-1052 T-2095	M-99.1 F-96.9 T-98.0	P – 4 M – 2 H – 1 HSS-0 C - 0	PHC SC	D	OS/ PWS	E	SPO BPO TE	MRB	TC-846 TAG-2 TIND-11 TOW160
64	Sailam	M-366 F-378 T-744	M-97.1 F-94.7 T-95.9	P – 1 M – 1 H – 1 HSS-0 C - 0		RAH	OS/ PWS	E	BPO		TC-270 TAG-1 TIND-8 TOW- 39
65	Neihbawih	M-170 F-133 T-303	M-97.1 F-92.7 T-95.2	P – 0 M – 0 H – 0 HSS-0 C - 0			OS	E			TC-64 TAG-42 TIND-4 TOW- 30
66	Sairum	M-3 F-1 T-4	M-100 F-100 T-100	P – 0 M – 0 H – 0 HSS-0 C - 0			OS	E			TC-4 TAG-0 TIND-0 TOW-0
67	Sihphir	M-2791 F-2666 T-5457	M-97.3 F-95.1 T-96.2	P – 8 M – 4 H – 2 HSS-0 C - 0	SC		OS/ PWS	E	BPO TE	MRB	TC-1463 TAG-176 TIND-24 TOW- 649
68	Nausel	M-85 F-82 T-167	M-97.1 F-91.9 T-94.7	P – 1 M – 0 H – 0 HSS-0 C - 0			OS				TC-88 TAG-2 TIND-0 TOW-1
69	Muthi	M-350 F-315 T-665	M-98.3 F-98.9 T-98.6	P – 2 M – 1 H – 1 HSS-0 C - 0			OS/ PWS	E	BPO		TC-324 TAG-2 TIND-0 TOW-30
70	Tuirial Jail	M-216 F-192 T-408	M-98.1 F-90.9 T-94.5	P – 1 M – 0 H – 0 HSS-0 C - 0			OS	E			TC-40 TAG- 117 TIND-0 TOW-21
71	Tuirial	M-296 F-174 T-470	M-97.8 F-89.6 T-95.0	P – 1 M – 0 H – 0 HSS-0 C – 0			OS/ PWS	E			TC-136 TAG-44 TIND-3 TOW- 144

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
72	Bung IB	M-80 F-71 T-151	M-91.8 F-92.5 T-92.1	P – 1 M – 0 H – 0 HSS-0 C - 0			OS	E			TC-17 TAG-9 TIND-0 TOW-15
73	Lungleng- I	M-328 F-312 T-640	M-100 F-97 T-98.5	P – 1 M – 0 H – 0 HSS-0 C - 0	SC		OS	E	BPO		TC-227 TAG-0 TIND-0 TOW-21
74	N.Lungleng	M-275 F-269 T-544	M-97.5 F-97.4 T-97.4	P – 2 M – 2 H – 1 HSS-0 C - 0		D	OS	E	BPO		TC-287 TAG-3 TIND-0 TOW-22
75	Samtlang	M-355 F-311 T-666	M-94.6 F-90.2 T-92.6	P – 1 M – 1 H – 1 HSS-0 C - 0			OS/ PWS	E	BPO		TC-269 TAG-38 TIND-0 TOW-51
76	Sairang	M-2829 F-2205 T-5034	M-97.8 F-94.8 T-95.3	P – 3 M – 1 H – 1 HSS-0 C - 0	PHC SC	RAH	OS/ PWS	E	SPO TE	MRB	TC-676 TAG-378 TIND-47 TOW-1354
77	Aizawl	M-115986 F-112294 T-228280	M-97.3 F-97.4 T-97.4	P–191 M-139 H – 85 HSS-17 C – 21 UC-1 U-1 TC-2 WP-1 ITI-1 ATI-1 FR&TI-1	HO SC NH MH TBH	HO D CVS RAH	OS/ PWS	E	TO PO TE BP O,S PO ED SP O HPO	AB, SBI, MRB UCB NABA -RD ADBI/ UIIC MUC0 LIC VB SIDBI	TC-2757 TAG-0 TIND-1459 TOW-0
78	Buhban	M-287 F-297 T-584	M-98.3 F-96.9 T-97.6	P – 1 M – 1 H – 0 HSS-0 C – 0	SC		OS/ PWS	E	BPO		TC-275 TAG-1 TIND-2 TOW-14

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
79	Mualmam	M-37 F-45 T-82	M-96.7 F-91.2 T-93.8	P – 1 M – 0 H – 0 HSS-0 C - 0			OS	E			TC-16 TAG-0 TIND-1 TOW-3
80	Sesawng	M-1438 F-1355 T-2793	M-94.9 F-91.8 T-93.4	P – 4 M – 2 H – 1 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-1165 TAG-57 TIND-5 TOW-184
81	Tualbung	M-385 F-355 T-740	M-95.3 F-95.2 T-95.3	P – 1 M – 1 H – 1 HSS-0 C - 0	SC		E				TC-391 TAG-0 TIND-1 TOW-14
82	Dilkhan	M-90 F-94 T-184	M-98.6 F-97.2 T-97.9	P – 1 M – 0 H – 0 HSS-0 C - 0			OS/ PWS	E	BPO		TC-88 TAG-0 TIND-0 TOW-2
83	N.Lungpher	M-352 F-332 T-684	M-89.7 F-89.5 T-89.6	P – 1 M – 1 H – 1 HSS-0 C - 0			OS/ PWS	E	O		TC-365 TAG-0 TIND-0 TOW-7
84	Sihfa	M-507 F-480 T-987	M-98.6 F-97.6 T-98.1	P – 2 M – 1 H – 1 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-525 TAG-0 TIND-0 TOW-32
85	Seling	M-1823 F-1091 T-2914	M-93.5 F-93.1 T-93.4	P – 3 M – 1 H – 1 HSS-0 C - 0	SC		OS/ PWS	E	BPO TE		TC-461 TAG-42 TIND-16 TOW-1069
86	Phaibawk	M-20 F-25 T-45	M-100 F-100 T-100	P – 0 M – 0 H – 0 HSS-0 C - 0			OS	E			TC-22 TAG-1 TIND-0 TOW-3
87	Edenthar	M-7 F-4 T-11	M-100 F-100 T-100	P – 0 M – 0 H – 0 HSS-0 C – 0			OS	E			TC-10 TAG-0 TIND-0 TOW-0

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
88	Tuikhurhlu	M-46 F-52 T-98	M-100 F-100 T-100	P – 0 M – 0 H – 0 HSS-0 C - 0			OS	E			TC-50 TAG-1 TIND-0 TOW-0
89	Thingsul Tlangnuam	M-763 F-577 T-1340	M-96.5 F-95.7 T-96.1	P – 2 M – 1 H – 1 HSS-0 C - 0			OS/ PWS	E			TC-484 TAG-6 TIND-7 TOW-263
90.	Thingsulth-liah	M-1927 F-1601 T-3528	M-88.8 F-91.9 T-90.2	P – 7 M – 5 H – 1 HSS-0 C - 0	SC	D	OS/ PWS	E	SPOTE	MRB	TC-1095 TAG-54 TIND-10 TOW-634
91	Aichalkawn	M-62 F-54 T-116	M-94 F-83.7 T-89.2	P – 0 M – 0 H – 0 HSS-0 C - 0			OS	E			TC-34 TAG-4 TIND-0 TOW-12
92	Saisih Vety Farm	M-36 F-32 T-68	M-96.2 F-92.0 T-94.1	P – 0 M – 0 H – 0 HSS-0 C - 0			OS	E			TC-12 TAG-2 TIND-0 TOW-16
93	Mualpheng	M-322 F-325 T-647	M-96.5 F-94.4 T-95.4	P – 1 M – 1 H – 0 HSS-0 C - 0			OS/ PWS	E	BPO		TC-217 TAG-5 TIND-2 TOW-21
94	Lenchim	M-161 F-143 T-304	M-100 F-99.2 T-99.6	P – 1 M – 1 H – 0 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-123 TAG-0 TIND-1 TOW-12
95	Darlawng	M-265 F-263 T-528	M-96.6 F-95.2 T-95.9	P – 1 M – 0 H – 0 HSS-0 C - 0			OS/ PWS	E	BPO		TC-328 TAG-0 TIND-0 TOW-14
96	Tlungvel	M-1218 F-1232 T-1450	M-96.3 F-94.9 T-95.6	P – 5 M – 2 H – 1 HSS-0 C – 0	SC	RAH	OS/ PWS	E	TE	MRB	TC-907 TAG-88 TIND-39 TOW-209

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
97	Phulmawi	M-130 F-129 T-259	M-99.1 F-96.3 T-97.8	P – 1 M – 1 H – 0 HSS-0 C - 0			OS/ PWS	E	BPO		TC-145 TAG-0 TIND-0 TOW-5
98	Tawizo	M-159 F-125 T-284	M-96 F-91.2 T-93.9	P – 1 M – 1 H – 0 HSS-0 C - 0			OS/ PWS	E			TC-118 TAG-0 TIND-0 TOW-17
99	Maite	M-401 F-381 T-782	M-95.3 F-93.0 T-94.2	P – 1 M – 1 H – 0 HSS-0 C - 0	SC		OS/ PWS	E	BPO		TC-372 TAG-0 TIND-1 TOW-16
100	Saitual	M-5768 F-5198 T-10966	M-95.5 F-95.7 T-95.6	P – 13 M – 6 H – 3 HSS-1 C - 1	PHC SC	D	OS/ PWS	E	BPO SPO TE	SBI	TC-3189 TAG-58 TIND-36 TOW-1891
	TOTAL	M-166877 F-158799 T-325676	M-96.7 F-96.3 T-96.5	P-391 M-247 H-134 HSS-19 C-22 UC-1 U-1 TC-1 CVS-1 WP-1 ITI-1 SSATI-1 FR&TI-1	HO-7 TBH-1 MH-1 NH-1 PHC-5 SC-47	HO-1 D-5 RAH-14 D-4 CVS-1	OS-100 PWS-81	E-96	PO-1 BPO-58 SPO-7 TE-11 TO-1	SBI-4 MRB-10 UCB-1 NABARD-1 IDBI-1 VB-1 SIDBI-1 UIIC-1 LIC-1	TC-39365 TAG-3145 TIND-1845 TOW-80973

N.B : M = Male, F = Female, T = Total,
P = Primary School, M = Middle School, H = High School, HSS = Higher Secondary School, C = College, SC = Sub-Centre, PHC = Primary Health Centre,
CHC = Community Health Centre, D = Dispensaries, RAH = Regional Animal Health Centre, HO = Hospital, OS = Ordinary Spring/Wells, PWS = Pipe Water Supply,
E = Electrified, BPO = Branch Post Office, SPO = Sub Post Office, TE = Telephone Exchange, SBI = State Bank of India, AB = Apex Bank, MRB = Mizoram Rural Bank, TC = Total Cultivators, TAG = Total Agricultural Labourers, TIND = Total Industrial Labourers, TOW = Total Other Workers.

APPENDIX - II

WATERSHED CODE AND STATISTICS OF MICRO-WATERSHED IN AIZAWL DISTRICT

A. Tlawng - A2 Watershed (No. 3c2a8)

Sub-watershed no.	Mini-Watershed no.	Area of Micro-watershed (in Sq km)						Area of Mini-watershed		Area of Sub-watershed	
		a	b	c	d	e	f	Sq km	%	Sq km	%
3c2a8b	4	8.59	14.94		2.92	6.12	7.06	39.63	1.11	118.28	3.31
	5	9.82	7.59	14.93	8.65			40.98	1.15		
	6	10.43	8.98	11.92	6.34			37.67	1.05		
3c2a8c	4	11.20	5.99	13.65	6.74	9.64		47.22	1.32	102.10	2.85
	5	13.47	9.12	8.78	8.89	14.61		54.88	1.53		
3c2a8d	1	7.88	7.71	13.06	9.51	8.95		47.10	1.32	73.88	2.07
	2	7.51	9.86	9.41				26.78	0.75		
								Total		294.26	8.23

B. Tlawng - A1 Watershed (No. 3c2a9)

Sub-watershed no.	Mini Watershed no.	Area of Micro-watershed (in Sq km)								Area of Mini-watershed	Area of Sub-watershed
		a	b	c	d	e	f	Sq km	%	Sq km	%
3c2a9a	1	8.23	6.72	8.54	6.54	12.37	10.85	53.25	1.49	173.16	4.84
	6	6.29	13.91	14.90				35.11	0.98		
	7	11.38	9.97	12.62	11.68			45.64	1.28		
	8	8.29	14.08	9.43	7.35			39.16	1.09		
3c2a9b	2		6.85	8.37	10.61	12.03	7.42	45.28	1.27	74.33	2.08
	3	6.79	7.72	5.54	6.76	2.24		29.05	0.81		
									Total	247.49	6.92

C. Tuirial - A3 Watershed (No. 3c2b3)

Sub-watershed no.	Mini Watershed no.	Area of Micro-watershed (in Sq km)							Area of Mini-watershed		Area of Sub - watershed	
		a	b	c	d	e	f	g	Sq km	%	Sq km	%
3c2b3b	3	9.37	7.81	8.51	9.13				34.81	0.97	99.55	2.78
	4	11.77	8.38	11.09	8.76				40.00	1.12		
	5		9.46	8.13	7.15				24.74	0.69		
3c2b3c	1	11.63	8.67	12.07	14.95	9.82	9.11		66.25	1.85	143.32	4.01
	3	8.27	9.61	9.62	9.85	10.35	10.75	8.26	66.72	1.87		
	5	10.35							10.35	0.29		
									Total		242.87	6.79

D. Tuirial - A2 Watershed (No. 3c2b4)

Sub-watershed no.	Mini-Watershed no.	Area of Micro watershed (in Sq km)								Area of Mini-watershed		Area of Sub - watershed	
		a	b	c	d	e	f	g	h	Sq km	%	Sq km	%
3c2b4a	2	5.60	14.54	12.02	12.79	9.06	7.75	8.74	9.13	79.65	2.23	79.65	2.23
3c2b4b	1	8.18	9.56	8.26	7.31					33.31	0.93	121.77	3.41
	2	14.79	8.61	10.18	10.97					44.55	1.25		
	3	12.84	10.23	10.00	10.84					43.91	1.23		
3c2b4c	1	13.29	13.31	8.73	12.46	6.65	9.31			63.75	1.78	151.30	4.22
	2	11.88	9.26	9.62	9.83					40.58	1.13		
	3	13.00	13.79	8.16	3.40	8.62				46.97	1.31		
										Total		352.72	9.86

E. Tuirial - A1 Watershed (No. 3c2b5)

Sub-watershed no.	Mini-Watershed no.	Area of Micro watershed (in Sq km)							Area of Mini watershed		Area of Sub - watershed	
		a	b	c	d	e	f	g	Sq km	%	Sq km	%
3c2b5a	1	11.81	11.89	7.29	8.45	11.16			50.60	1.42	169.17	4.74
	2	11.18	7.61	8.15	9.37	12.95			49.27	1.38		
	3	6.99	8.54	12.72	11.65	14.47	14.93		69.30	1.94		
3c2b5b	1	8.21	7.29	6.74	11.09				33.33	0.93	163.34	4.56
	2	7.72	6.69	5.68					20.09	0.56		
	3	7.73	9.47	6.27	6.90	8.36	6.39	9.96	55.08	1.54		
	4	3.03	8.29	8.05	7.17				26.53	0.74		
	5	6.41	6.76	8.64	6.51				28.31	0.79		
3c2b5c	1	9.06	6.92	11.03	9.13	6.99			43.13	1.21	203.77	5.70
	2	10.45	3.38						13.83	0.39		
	3	9.14	5.46	12.09	8.06				34.75	0.97		
	4	5.30	12.90	9.67	14.72	10.85	10.28		63.72	1.78		
	5	6.42	4.48	8.04	8.53	8.90	7.42	4.55	48.34	1.35		
3c2b5d	1	13.83	10.42	11.06					35.31	0.99	259.11	7.24
	2	11.87	10.00	6.00	9.50	8.32			45.69	1.28		
	3	14.43	13.77	13.92					42.11	1.18		
	4	5.68	12.41	12.49	8.21				38.78	1.08		
	5	13.23	10.50	7.39	6.23	11.28	9.45		58.08	1.62		
	6	13.53	7.87	9.66	8.09				39.14	1.09		
3c2b5e	1	9.26	3.95	9.55	11.55	11.94			46.25	1.29	151.21	4.23
	2	8.72	8.47	13.54	11.13	11.64			53.50	1.50		
	3	4.73	11.50	9.80					26.04	0.73		
	5			14.81	10.61				25.42	0.71		
									Total		946.60	26.47

F. Tuivai - A3 Watershed (No. 3c2c6)

Sub-watershed no..	Mini Watershed no.	Area of Micro-watershed (in Sq km)						Area of Mini-watershed		Area of Sub - watershed	
		a	b	c	d	e	f	Sq km	%	Sq km	%
3c2c6a	1	13.67	7.86	12.00	10.25	13.01		56.79	1.59	163.84	4.58
	2	12.12	7.54	11.44	11.17			42.26	1.18		
	3	14.13	13.72	11.91	8.75	10.98	5.29	64.79	1.81		
								Total		163.84	4.58

G. Tuivawl - A Watershed (No. 3c2f1)

Sub-watershed no.	Mini-Watershed no.	Area of Micro-watershed (in Sq km)							Area of Mini-watershed		Area of Sub-watershed	
		a	b	c	d	e	f	g			Sq km	%
3c2f1a	1		11.45	10.70	11.13				33.27	0.93	80.32	2.25
	2	9.25	9.44	8.15	5.94	14.26			47.05	1.32		
3c2f1b	1	14.56	9.97	7.95	11.05	14.53	14.57		72.64	2.03	414.03	11.59
	2	12.06	14.56	14.62					41.25	1.15		
	3	14.20	12.70	6.91	8.24				42.05	1.18		
	4	7.29	8.95	6.84	8.97				32.05	0.90		
	5	6.05	8.06	7.02	12.70	13.83			47.66	1.33		
	6	7.16	9.41	12.58	10.76				39.90	1.12		
	7	9.12	8.80	8.12	7.45	7.98	9.11	11.2	61.84	1.73		
	8	14.16	8.43	8.01					30.60	0.86		
	9	11.53	11.01	14.38	9.12				46.04	1.29		
3c2f1b	1	11.11	12.07	8.13	7.25				38.56	1.08	175.61	4.91
	3	12.07	9.85	9.26	13.71	7.99	8.09		60.97	1.70		
	5	14.79	12.51	12.35	9.14	10.09	9.83	7.36	76.08	2.13		
3c2f1e	2	11.90	11.72	8.84	9.88				42.34	1.18	144.19	4.02
	3	10.43	14.03	7.57	6.56	9.08	7.50		55.17	1.54		
	4	7.08	9.65	6.99	8.55				32.28	0.90		
	5		7.41	6.99					14.40	0.40		
										Total	814.15	22.77

H. Tuivai - A2 Watershed (No. 3c2f2)

Sub-watershed no.	Mini-Watershed no.	Area of Micro-watershed (in Sq km)							Area of Mini-watershed		Area of Sub-watershed	
		a	b	c	d	e	f	g	Sq km	%	Sq km	%
3c2f2a	1	8.73	7.69	10.80					27.22	0.76	213.71	5.98
	2	9.98	12.97	11.32	14.08	9.41			57.76	1.61		
	3	13.79	10.82	12.56	10.90	11.14			59.21	1.66		
	4	10.38	11.09	6.41	9.23				37.11	1.04		
	5	11.82	7.36	13.22					32.41	0.91		
3c2f2b	1	14.16	7.09	5.16	10.75	11.83	7.95	10.68	67.63	1.89	99.44	2.78
	2	8.65	12.72	10.44					31.81	0.89		
									Total		313.15	8.76

I. Tuivai - A1 Watershed (No. 3c2f3)

Sub-watershed no.	Mini-Watershed no.	Area of Micro-watershed (in Sq km)						Area of Mini-watershed		Area of Sub-watershed	
		a	b	c	d	e	f	Sq km	%	Sq km	%
3c2f3a	1		6.44	6.51				12.95	0.36	97.81	2.74
	2	6.10	9.60	13.66	7.65			37.02	1.04		
	3	5.79	10.75	10.16	7.97	7.23	5.94	47.84	1.34		
								Total		97.81	2.74

J. Mat - A Watershed (No. 3d1a6)

Sub-watershed no.	Mini-Watershed no.	Area of Micro-watershed (in Sq km)					Area of Mini-watershed		Area of Sub-watershed	
		a	b	c	d	e	Sq km	%	Sq km	%
3d1a6o	1	8.04		77.9	9.73		25.56	0.71	103.42	2.88
	2	6.73	8.32	8.84	10.62		34.51	0.96		
	3	7.93	9.54	5.84	11.21	8.83	43.35	1.21		

K. Statistics of Tlawng,Tuirial,Tuivai and Mat Sub-Catchments

SL.NO	NAME OF SUB-CATCHMENT AND SUB-CATCHMENT NUMBER	AREA OF SUB-CATCHMENT (Sq km)	% OF SUB-CATCHMENT
1	3c2a – Tlawng	541.75	15.15
2	3c2b - Tuirial	1542.19	43.12
3	3c2c – Tuivai_2	163.84	4.58
4	3c2f – Tuivai_1	1225.11	34.26
5	3d1a - Mat	103.42	2.89
	TOTAL	**3576.31**	**100.00**

APPENDIX - III

DESCRIPTION OF SOIL SERIES

The morphological description, soil analysis and interpretative groupings of 14 soil series of Aizawl District, Mizoram are given below. These soils are formed under humid tropical with mean annual rainfall of 3155mm. The pedons described here are all comprise of mixed mineralogy and hyperthermic temperature class:

1. Vervek Series (Map symbol – 1) :

Vervek soil series is a member of loamy skeletal, mixed, Hyperthermic family of Typic Udorthents. They are deep, dark yellowish brown, clay loam, and well drained, strongly acid horizons. It occurs on hill top with a slope of 1 – 10%. The associated soil series is Sialsuk – a Typic Dystrochrepts.

Typifying pedon : Loamy skeletal – mixed forest.

Horizon	Depth (cm)	Descriptions
A1	0 – 11	Dark yellowish brown (10YR 4/4) moist, clay loam, weak sub-angular blocky, 30 – 40% gravels, many fine and medium roots, clear wavy boundary.
AC	11 – 25	Dark yellowish brown (10YR 4/6) moist, clay loam, weak sub-angular blocky, 55% coarse fragments, common fine and medium roots, smooth boundary.
C	25 - 55	Yellowish brown (10YR 5/6) moist, clay loam, weak sub-angular blocky, 80% coarse fragments, para lithic

Use and vegetation : Mostly under mixed forest and abandoned jhum.

Type location : Near Vervek Village, Aizawl District, Mizoram.

No. of profile examined : 4

Interpretative grouping : Land capability sub class : IVe

Soil analysis : Physical Characters-

Horizon	Depth (cm)	Mechanical analysis			Texture
		Sand %	Silt %	Clay %	
A1	0 – 11	42	23	35	Clay loam
AC	11 – 25	43	21	34	Clay loam
C	25 – 55	44	21	35	Clay loam

Chemical Characters-

Horizon	Depth (cm)	pH 1:2	Organic Carbon %	CEC Meq/ 100gm	Exchangeable bases Meq/100gm				B.S. %
					Ca^{++}	Mg^{++}	K^{+}	Na^{+}	
A1	0 – 11	5.45	1.35	26.15	1.5	1.5	0.54	0.35	14.65
AC	11 – 25	5.25	1.10	25.42	1.3	1.1	0.36	0.25	12.62
C	25 – 55	5.12	1.00	25.32	1.1	1.0	0.35	0.22	10.90

2. Sialsuk Series (Map symbol – 1, 10) :

Sialsuk series is a member of loamy skeletal, mixed, hyperthermic family of Typic Dystrochrepts. They are deep to very deep, well drained and have dark brown, clay loam, strongly acid horizon. It occurs mostly on hill top/crest and hill side slopes of more than 50%. One of the associated soil series is Sihphir – a Typic Hapludults.

Typifying pedon : Loamy skeletal – current and abandoned jhum.

Horizon	Depth (cm)	Description
Ap	0 – 14	Dark yellowish brown (10YR 4/3) moist, clay loam, weak sub-angular blocky, many fine and medium roots, clear smooth boundary, 10% coarse fragments.
A1	14 – 35	Dark yellowish brown (10YR 4/4) moist, clay loam, moderate sub-angular blocky, 25 - 35% coarse fragments, many fine and medium roots, clear smooth boundary.
A3	35 - 58	Dark yellowish brown (10YR 4/6) moist, clay loam,

		weak sub-angular blocky, 40% coarse fragments, common fine and medium roots, clear wavy boundary.
B2	58 - 80	Yellowish brown (10YR 5/6) moist, clay loam, weak sub-angular blocky, 50% coarse fragments, common medium roots, gradual smooth boundary.
C	80 - 110	Yellowish brown (10YR 5/6) moist, clay loam, weak sub-angular blocky, 65% coarse fragments, few medium roots.

Use and vegetation : Mostly under current and abandoned jhum.

Type location : Near Sialsuk Village, Aizawl District, Mizoram.

No. of profile examined : 14

Interpretative grouping : Land capability sub class : IVe & VIIe

Soil analysis : Physical characters-

Horizon	**Depth (cm)**	**Mechanical analysis**			**Texture**
		Sand %	**Silt %**	**Clay %**	
Ap	0 – 14	42	19	39	Clay loam
A1	14 – 35	41	22	37	Clay loam
A3	35 – 58	42	23	35	Clay loam
B2	58 – 80	42	24	34	Clay loam
C	80 – 110	44	25	31	Clay loam

Chemical characters-

Horizon	**Depth (cm)**	**pH 1:2**	**Organic Carbon %**	**CEC Meq/ 100gm**	**Exchangeable bases Meq/100gm**				**B.S. %**
					Ca^{++}	**Mg^{++}**	**K^{+}**	**Na^{+}**	
Ap	0 – 14	5.15	1.55	7.886	0.6	4.6	0.144	0.148	56.22
A1	14 – 35	5.25	1.46	6.052	0.11	3.4	0.086	0.158	50.37
A3	35 – 58	5.12	1.24	5.836	0.3	2.1	0.072	0.154	45.07
B2	58 – 80	5.07	0.95	6.895	0.3	2.5	0.118	0.197	45.04
C	80– 110	5.03	0.87	6.195	0.2	2.6	0.094	0.178	49.00

3. Aibawk Series (Map symbol – 2, 3)

Aibawk soil series is a member of fine loamy, mixed, hyperthermic family of Typic Dystrochrepts. They are very deep, dark yellowish brown, clay loam and well drained, very strongly acidic horizons. It occurs on hill side slope of less than 50%. The associated soil series is Thingsulthliah – a Typic Hapludults.

Typifying pedon: Fine loamy – current and abandoned jhum.

Horizon	Depth (cm)	Descriptions
A_p	0 – 15	Dark yellowish brown (10YR 4/4) moist, clay loam, weak sub-angular blocky, 4% coarse fragments, many fine and medium roots, clear smooth boundary.
A1	15 – 35	Dark yellowish brown (10YR 4/5) moist, clay loam, weak sub-angular blocky, 6% coarse fragments, many fine and medium roots, gradual smooth boundary.
A3	35 - 58	Yellowish brown (10YR 5/6) moist, clay loam, weak sub-angular blocky, 12% coarse fragments, common fine and many medium roots, clear smooth boundary.
B2	58 - 88	Strong brown (7.5YR 4/6) moist, clay loam, weak sub-angular blocky, 15% coarse fragments, few fine and common medium roots, gradual smooth boundary.
C	88 - 115	Strong brown (7.5YR 5/6) moist, clay loam, weak sub-angular blocky, 20% coarse fragments, few medium roots.

Use and vegetation : Mostly under current and abandoned jhum.

Type location : Near Aibawk Village, Aizawl District, Mizoram.

No. of profile examined : 9

Interpretative grouping : Land capability sub class : IIIe & IVe

Soil analysis : Physical Characters-

Horizon	Depth (cm)	Mechanical analysis			Texture
		Sand %	Silt %	Clay %	
Ap	0 – 15	40	21	39	Clay loam

A1	15 – 35	41	21	36	Clay loam
A3	35 – 58	39	22	39	Clay loam
B2	58 – 88	38	25	37	Clay loam
C	88 – 115	37	22	40	Clay loam

Chemical Characters-

Horizon	**Depth (cm)**	**pH 1:2**	**Organic Carbon %**	**CEC Meq/ 100gm**	**Exchangeable bases Meq/100gm**				**B.S. %**
					Ca^{++}	**Mg^{++}**	**K^{+}**	**Na^{+}**	
Ap	0 – 15	4.88	1.24	9.58	0.5	3.9	0.116	0.14	48.26
A1	15 – 35	4.72	1.15	9.86	0.3	3.7	0.119	0.13	42.77
A3	35 – 58	4.71	0.95	9.72	0.5	2.3	0.115	0.19	32.56
B2	58 – 88	4.60	0.72	10.94	0.4	3.1	0.116	0.17	32.68
C	88– 115	4.56	0.54	10.74	0.5	3.1	0.106	0.12	35.80

4. Darlawn Series (Map symbol – 6,7, 11,13) :

Darlawn series is a member of loamy skeletal, mixed, hyperthermic family of Umbric Dystrochrepts. They are very deep, dark brown to yellowish brown, clay loam to clay, well drained, strongly acidic to very strongly acidic horizons. It occurs on hill side slope of more than 25%. The associated soil series is Tawizo – a Humic Hapludults.

Typifying pedon: Loamy skeletal – mixed forest and abandoned Jhum.

Horizon	**Depth (cm)**	**Descriptions**
A1	0 – 16	Dark brown (10YR 3/3) moist, clay loam, weak sub-angular blocky, 12% coarse fragments, many fine and medium roots, clear smooth boundary.
A3	16 – 38	Dark brown (10YR 4/3) moist, clay loam, weak sub-angular blocky, 30% coarse fragments, many fine and medium roots, gradual smooth boundary.
B2	38 - 62	Dark yellowish brown (10YR 4/5) moist, sandy clay, weak

		sub-angular blocky, 40% coarse fragments, few fine and common medium roots, gradual smooth boundary.
B3	62 - 91	Yellowish brown (10YR 5/5) moist, clay, weak sub-angular blocky, 50% coarse fragments, common medium roots, gradual smooth boundary.
C	91 - 126	Yellowish brown (10YR 5/6) moist, clay, moderate sub-angular blocky, 70% coarse fragments, few medium roots.

Use and vegetation : Mostly under mixed forest and Old abandoned Jhum.

Type location : Near Darlawn Village, Aizawl District, Mizoram.

No. of profile examined : 15

Interpretative grouping : Land capability sub class : IVe & VIe

Soil analysis : Physical characters-

Horizon	**Depth (cm)**	**Mechanical analysis**			**Texture**
		Sand %	**Silt %**	**Clay %**	
A1	0 – 16	42	19	39	Clay loam
A3	16 – 38	40	20	40	Clay loam
B2	38 – 62	44	13	43	Sandy clay
B3	62 – 91	41	12	47	Clay
C	91 – 126	39	13	48	Clay

Chemical Characters-

Horizon	**Depth (cm)**	**pH 1:2**	**Organic Carbon %**	**CEC Meg/ 100gm**	**Exchangeable bases Meq/100gm**				**B.S. %**
					Ca^{++}	**Mg^{++}**	**K^{+}**	**Na^{+}**	
A1	0 – 16	5.35	1.22	5.06	0.7	1.9	0.24	0.14	63.08
A3	16 – 38	5.24	1.11	6.19	0.6	2.6	0.21	0.14	58.96
B2	38 – 62	5.12	1.08	4.62	0.6	0.9	0.19	0.15	34.18
B3	62 – 91	5.04	0.78	5.52	0.6	1.0	0.32	0.17	42.37
C	91 – 126	5.01	0.61	4.60	0.8	0.8	0.23	0.14	43.50

5. Suangpuilawn Series (Map symbol – 4, 5, 8,9,12,13) :

Suangpuilawn series is a member of fine loamy, mixed, hyperthermic family of Umbric Dystrochrepts. They are very deep, dark brown to yellowish brown, sandy clay loam to clay, well drained, medium acidic to very strongly acidic horizons. It occurs on hill side slope of various slope categories. The associated soil series is Tawizo – a Humic Hapludults.

Typifying pedon : Fine loamy – Mixed forest and Bamboo forest.

Horizon	Depth (cm)	Descriptions
A11	0 – 13	Dark brown (10YR 3/3) moist, sandy clay loam, weak sub-angular blocky, 2% coarse fragments, many fine and medium roots, clear smooth boundary.
A12	13 – 36	Dark brown (10YR 4/3) moist, sandy clay loam, weak sub-angular blocky, 4% coarse fragments, many fine and medium roots, gradual smooth boundary.
A3	36 – 56	Dark yellowish brown (10YR 4/4) moist, sandy clay loam, weak sub-angular blocky, 5% coarse fragments, few fine and many medium roots, clear smooth boundary.
B2	56 – 86	Dark Yellowish brown (10YR 4/6) moist, sandy clay loam, weak sub-angular blocky, 10% coarse fragments, few medium roots, clear smooth boundary.
B3	86 – 112	Yellowish brown (10YR 5/4) moist, sandy clay loam, weak sub-angular blocky, 20% coarse fragments, few medium roots.
C	112-134	Strong brown (7.5YR4/6) moist, clay, medium sub angular blocky, 35% coarse fragments, sticky and plastic.

Use and vegetation : Mostly under mixed forest and bamboo forest.

Type location : Near Suangpuilawn Village, Aizawl District, Mizoram.

No. of profile examined : 17

Interpretative grouping : Land capability sub class : IIIe & VIe

Soil analysis : Physical characters-

Horizon	Depth	Mechanical analysis	Texture

	(cm)	Sand %	Silt %	Clay %	
A11	0 – 13	47	24	29	Sandy clay loam
A12	13 – 36	46	24	30	Sandy clay loam
A3	36 – 56	42	22	36	Clay loam
B2	56 – 86	40	20	40	Clay loam
B3	86 – 112	40	18	42	Clay loam
C	112-134	34	17	49	Clay

Chemical Characters-

Horiz-on	Depth (cm)	pH 1:2	Organic Carbon %	CEC Meq/ 100gm	Exchangeable bases Meq/100gm				B.S. %
					Ca^{++}	Mg^{++}	K^{+}	Na^{+}	
A11	0 – 13	5.87	1.62	7.67	1.1	2.1	0.09	0.15	53.94
A12	13 – 36	5.72	1.56	7.82	1.0	2.1	0.13	0.18	45.56
A3	36 – 56	5.35	1.24	5.64	0.4	1.1	0.12	0.21	39.03
B2	56 – 86	5.08	0.88	4.92	0.6	0.9	0.10	0.16	34.35
B3	86 – 112	4.84	0.72	4.54	0.4	0.8	0.12	0.17	30.93
C	112-134	4.65	0.52	4.72	0.2	0.6	0.13	0.19	24.54

6. Tuivawl Series (Map symbol – 14):

Tuikual series is a member of fine loamy, mixed, hyperthermic family of Fluventic Dystrochrepts. They are very deep, dark brown to dark yellowish brown, clay loam surface and clay loam sub - surface, poorly drained, very strongly acidic horizons. It occurs on flood plains of valleys. The associated soil series is Saitual – a Fluventic Umbric Dystrochrepts.

Typifying pedon : Fine loamy – mostly cultivated.

Horizon	Depth(cm)	Descriptions
Ap	0 – 14	Dark Yellowish brown (10YR 4/4) moist, sandy clay loam, weak sub-angular blocky, many fine and medium roots, clear smooth boundary.
A1	14 – 38	Dark yellowish brown (10YR 4/5) moist, sandy clay loam, weak sub-angular blocky, common fine and many medium

		roots, gradual smooth boundary.
A3	38 – 61	Dark yellowish brown (10YR 4/6) moist, clay loam, weak sub-angular blocky, common medium roots, clear smooth boundary.
B2	61 – 82	Yellowish brown (10YR 5/4) moist, sandy clay, weak sub-angular blocky, few medium roots, gradual smooth boundary.
B3	82-108	Yellowish brown (10YR 5/6) moist, clay, medium sub-angular blocky.

Use and vegetation : Mostly under cultivation.

Type location : Near Tuivawl River, Aizawl District, Mizoram.

No. of profile examined : 6

Interpretative grouping : Land capability sub class : IIe

Soil analysis : Physical characters-

Horizon	**Depth (cm)**	**Mechanical analysis**			**Texture**
		Sand %	**Silt %**	**Clay %**	
Ap	0 – 14	52	19	29	Sandy clay loam
A1	14 – 38	52	18	30	Sandy clay loam
A3	38 – 61	44	20	36	Clay loam
B2	61 – 82	45	16	39	Sandy clay
B3	82-108	35	20	45	Clay

Chemical characters-

Horizon	**Depth (cm)**	**pH 1:2**	**Organic Carbon %**	**CEC Meq/ 100gm**	**Exchangeable bases Meq/100gm**				**B.S. %**
					Ca^{++}	**Mg^{++}**	**K^{+}**	**Na^{+}**	
Ap	0 – 14	4.82	0.99	6.01	0.6	1.8	0.12	0.19	45.16
A1	14 – 38	4.75	0.77	5.39	0.4	1.4	0.09	0.20	38.82
A3	38 – 61	4.70	0.48	4.38	0.2	1.0	0.08	0.19	33.83
B2	61 – 82	4.61	0.41	4.04	0.2	0.9	0.01	0.13	30.84
B3	82-108	4.55	0.38	3.29	0.1	0.8	0.07	0.12	25.47

7. Saitual Series (Map symbol – 14) :

Saitual series is a member of fine loamy, mixed, hyperthermic family of Fluventic Umbric Dystrochrepts. They are very deep, dark brown to dark yellowish brown, sandy clay loam surface and clay loam sub-surface, poorly drained, strongly acidic horizons. It occurs on flood plains and narrow valleys. The associated soil series is Tuivawl – a Fluventic Dystrochrepts.

Typifying pedon : Fine loamy – mostly cultivated and fallow land.

Horizon	Depth (cm)	Descriptions
Ap	0 – 12	Dark brown (10YR 3/3) moist, sandy clay loam, weak sub-angular blocky, many fine and medium roots, clear smooth boundary, 5% coarse fragments.
A1	12 – 30	Dark brown (10YR 4/3) moist, sandy clay loam, weak sub-angular blocky, many fine and medium roots, gradual smooth boundary, 6% coarse fragments.
A3	30 – 48	Dark yellowish brown (10YR 4/4) moist, sandy clay loam, weak sub-angular blocky, few fine and common medium roots, gradual smooth boundary, 8% coarse fragments.
B1	48 – 71	Dark yellowish brown (10YR 4/6) moist, clay loam, weak sub-angular blocky, common medium roots, clear smooth boundary, 10% coarse fragments.
B3	71 –105	Dark brown (7.5YR 4/4) moist, clay loam, weak sub-angular blocky, few medium roots, 30% coarse fragments.

Use and vegetation : Mostly under cultivation.

Type location : Near Saitual Town, Aizawl District, Mizoram.

No. of profile examined : 8

Interpretative grouping : Land capability sub class : IIe

Soil analysis : Physical Characters-

Horizon	Depth (cm)	Mechanical analysis			Texture
		Sand %	Silt %	Clay %	
Ap	0 – 12	53	19	28	Sandy clay loam

A1	12 – 30	50	20	30	Sandy clay loam
A3	30 – 48	50	18	32	Sandy clay loam
B1	48 – 71	41	22	37	Clay loam
B3	71- 105	40	22	38	Clay loam

Chemical characters:

Horizon	**Depth (cm)**	**pH 1:2**	**Organic Carbon %**	**CEC Meq/ 100gm**	**Exchangeable bases Meq/100gm**				**B.S. %**
					Ca^{++}	**Mg^{++}**	**K^{+}**	**Na^{+}**	
Ap	0 – 12	5.48	1.12	4.89	0.6	1.1	0.18	0.18	44.07
A1	12 – 30	5.42	1.05	3.36	0.6	0.9	0.11	0.12	43.87
A3	30 – 48	5.25	0.95	3.06	0.4	0.6	0.14	0.14	34.18
B1	48 – 71	5.23	0.88	2.68	0.2	0.2	0.09	0.18	29.71
B3	71 – 105	5.18	0.67	2.74	0.2	0.2	0.06	0.11	21.22

8. Tuirini Series (Map symbol – 14) :

Tuirini series is a member of fine loamy, mixed, hyperthermic family of Aquic Dystrochrepts. They are very deep, yellowish brown to brownish yellow, mottles of low chroma, clay loam surface and sandy clay loam sub-surface, poorly drained, medium acidic to strongly acidic horizons. It occurs on flood plains of narrow valleys. The associated soil series is Tuivawl – a Fluventic Dystrochrepts.

Typifying pedon : Fine loamy – mostly cultivated.

Horizon	**Depth (cm)**	**Descriptions**
Ap	0 – 13	Yellowish brown (10YR 5/4) moist, clay loam, moderate medium sub-angular blocky, many fine and medium roots, sticky and plastic, clear smooth boundary.
A1	13 – 28	Yellowish brown (10YR 5/6) moist, clay loam, weak medium sub-angular blocky, many fine and medium roots, sticky and plastic, clear smooth boundary, 3% coarse fragments.
A3	28 – 56	Yellowish brown (10YR 5/8) moist, clay loam, moderate medium sub-angular blocky, few fine and common medium roots, sticky and plastic, clear smooth boundary, 5% coarse

		fragments.
B2	56 – 82	Brownish yellow (10YR 6/5) moist, sandy clay loam, weak sub-angular blocky, few medium roots, gradual smooth boundary, 10% coarse fragments.
B3	82–112	Brownish yellow (10YR 5/6) moist, sandy clay loam, weak sub-angular blocky, few medium roots, 20% coarse fragments.
C	112 -125	Brownish yellow (10YR 6/6) moist, clay loam, weak sub-angular blocky, few medium roots, 40% coarse fragments.

Use and vegetation : Mostly under cultivation and Abandoned Jhum

Type location : Near Tuirini river, Aizawl District, Mizoram.

No. of profile examined : 7

Interpretative grouping : Land capability sub class : IIe

Soil analysis : Physical characters-

Horizon	**Depth (cm)**	**Mechanical analysis**			**Texture**
		Sand %	**Silt %**	**Clay %**	
Ap	0 – 13	41	19	40	Clay loam
A1	13 – 28	43	20	37	Clay loam
A3	28 – 56	44	19	37	Sandy clay loam
B2	56 – 82	46	18	36	Sandy clay loam
B3	82–112	48	20	32	Sandy clay loam
C	112 - 125	50	19	31	Sandy clay loam

Chemical Characters-

Horizon	**Depth (cm)**	**pH 1:2**	**Organic Carbon %**	**CEC Meq/ 100gm**	**Exchangeable bases Meq/100gm**				**B.S. %**
					Ca^{++}	**Mg^{++}**	**K^{+}**	**Na^{+}**	
Ap	0 – 13	6.08	1.44	7.79	1.1	2.9	0.09	0.19	40.79
A1	13 – 28	5.45	1.24	6.35	0.8	2.6	0.07	0.16	43.62
A3	28 – 56	5.38	1.08	6.77	0.6	2.5	0.08	0.22	44.92
B2	56 – 82	5.31	0.76	5.89	0.4	1.8	0.06	0.28	47.34
B3	82–112	5.22	0.65	4.27	0.4	0.9	0.14	0.27	50.42
C	112 - 125	5.11	0.62	5.66	0.6	1.1	0.22	0.21	51.22

9. Aizawl Series (Map symbol – 5) :

Aizawl series is a member of clayey, mixed, hyperthermic family of Typic Dystrochrepts. They are very deep, dark yellowish brown surface and strong brown sub-surface, clay loam surface and clay sub-surface, well drained, strongly acidic to very strongly acidic horizons. It occurs on hill side slopes of less than 50%. The associated soil series is Suangpuilawn – a Umbric Dystrochrepts.

Typifying pedon : Clayey – Abandoned jhum and mixed forest.

Horizon	Depth (cm)	Descriptions
Ap	0 – 14	Dark yellowish brown (10YR 4/4) moist, clay loam, weak sub-angular blocky, many fine and medium roots, sticky and plastic, clear smooth boundary, 3% coarse fragments.
A1	14 – 34	Dark yellowish brown (10YR 4/6) moist, clay loam, weak sub-angular blocky, common fine and many medium roots, clear smooth boundary, 5% coarse fragments.
A3	34 - 49	Yellowish brown (10YR 5/4) moist, clay loam, weak sub-angular blocky, common medium roots, 8% coarse fragments, clear smooth boundary.
B2	49 - 72	Yellowish brown (10YR 5/6) moist, clay, moderate medium sub-angular blocky, few medium roots, sticky and plastics, gradual smooth boundary, 12% coarse fragments.
B3	72 - 102	Dark brown (7.5YR 4/4) moist, clay, moderate medium sub-angular blocky, 15% coarse fragments, sticky and plastic.
C	102 - 128	Strong brown (7.5YR 5/6) moist, clay, moderate medium sub-angular blocky, sticky and plastic, 25% coarse fragments.

Use and vegetation : Abandoned jhum and mixed forest.

Type location : Near Maubawk village, Aizawl, Mizoram.

No. of profile examined : 6

Interpretative grouping : Land capability sub class : IIIe

Soil analysis : Physical characters-

Horizon	Depth	Mechanical analysis	Texture

	(cm)	Sand %	Silt %	Clay %	
Ap	0 – 14	43	19	38	Clay loam
A1	14 – 34	40	20	40	Clay loam
A3	34 - 49	40	19	41	Clay loam
B2	49 - 72	34	21	45	Clay
B3	72 - 102	32	18	50	Clay
C	102 - 128	31	17	52	Clay

Chemical characters-

Horizon	Depth (cm)	pH 1:2	Organic Carbon %	CEC Meq/ 100gm	Exchangeable bases Meq/100gm				B.S. %
					Ca^{++}	Mg^{++}	K^{+}	Na^{+}	
Ap	0 – 14	5.44	1.68	5.66	0.6	1.6	0.31	0.18	48.80
A1	14 – 34	5.40	1.55	4.85	0.4	1.4	0.26	0.15	52.66
A3	34 - 49	5.26	0.92	3.75	0.2	1.2	0.17	0.12	38.96
B2	49 - 72	5.11	0.78	3.13	0.2	0.8	0.11	0.14	42.62
B3	72 - 102	4.98	0.59	2.90	0.1	0.6	0.12	0.12	39.15
C	102 -128	4.92	0.51	2.28	0.1	0.4	0.15	0.11	43.01

10. Sihphir Series (Map symbol – 3, 10) :

Sihphir series is a member of fine loamy, mixed, hyperthermic, Typic Hapludults. They are deep to very deep, well drained and have dark yellowish brown to strong brown, sandy clay loam to clay, medium acidic to strongly acidic horizon. It occurs on hill side slopes of various catagories. One of the associated soil series is Aibawk – a Typic Dystrochrepts.

Typifying pedon: Fine loamy – Current jhum.

Horizon	Depth (cm)	Descriptions
A1	0 – 12	Dark yellowish brown (10YR 4/4) moist, sandy clay loam, weak medium sub-angular blocky, many fine and medium roots, clear smooth boundary.

B21t	12 – 28	Dark yellowish brown (10YR 4/6) moist, sandy clay loam, weak medium sub-angular blocky, many medium roots and common fine roots, clear smooth boundary, patchy thin cutans.
B22t	28 – 62	Yellowish brown (10YR 5/4) moist, clay, moderate medium sub-angular blocky, many medium and few fine roots, patchy thin cutans, clear smooth boundary.
B23t	62 – 84	Yellowish brown (10YR 5/5) moist, clay, moderate medium, sub-angular blocky, few medium roots, 5% coarse fragments, patchy thin cutans, clear smooth boundary.
B3	84–118	Yellowish brown (10YR 5/6) moist, clay, moderate medium, sub-angular blocky, few medium roots, 10% coarse fragments.

Use and vegetation : Current jhum.

Type location : Near Sihphir village, Aizawl, Mizoram.

No. of profile examined : 12

Interpretative grouping : Land capability sub class : IVe & VIIes

Soil analysis : Physical characters-

Horizon	**Depth (cm)**	**Mechanical analysis**			**Texture**
		Sand %	**Silt %**	**Clay %**	
A1	0 – 12	46	21	33	Sandy clay loam
B21t	12 – 28	45	20	35	Sandy clay loam
B22t	28 – 62	37	21	42	Clay
B23t	62 – 84	36	20	44	Clay
B3	84–118	35	19	46	Clay

Chemical characters-

Horizon	**Depth (cm)**	**pH 1:2**	**Organic Carbon %**	**CEC Meq/ 100gm**	**Exchangeable base Meq/100gm**				**B.S. %**
					Ca^{++}	**Mg^{++}**	**K^{+}**	**Na^{+}**	
A1	0 – 12	5.84	2.14	12.71	2.1	2.9	0.25	0.21	42.94
B21t	12 – 28	5.67	1.76	10.93	1.4	2.6	0.22	0.17	34.78
B22t	28 – 62	5.46	1.42	8.54	0.6	1.0	0.15	0.17	27.27
B23t	62 – 84	5.25	0.94	8.18	0.4	1.0	0.13	0.11	23.62

B3	84–118	5.21	0.81	7.11	0.2	1.0	0.11	0.14	23.36

11. Thingsulthliah Series (Map symbol – 1, 6, 7, 9, 11, 12) :

Thingsulthliah series is a member of loamy skeletal, mixed, hyperthermic family of Typic Hapludults. They are deep to very deep, dark yellowish brown to brownish yellow, sandy clay loam to clay, well drained, strongly acidic horizons. It occurs on hill top and hill side slopes of various slope categories. The associated soil series is Chalfilh – a Humic Hapludults.

Typifying pedon : Loamy skeletal –abandoned jhum and Mixed forest.

Horizon	Depth (cm)	Descriptions
A1	0 – 14	Dark yellowish brown (10YR 4/4) moist, sandy clay loam, weak medium sub-angular blocky, many fine and medium roots, 15% coarse fragments, clear smooth boundary.
B1t	14 – 38	Dark yellowish brown (10YR 4/5) moist, sandy clay loam, medium sub-angular blocky, common fine and many medium roots, 35% coarse fragments, patchy thin cutans, clear smooth boundary.
B2t	38 – 72	Dark yellowish brown (10YR 4/6) moist, clay loam, weak medium sub-angular blocky, common medium roots, 40% coarse fragments, patchy thin cutans, clear smooth boundary.
B3	72 – 96	Yellowish brown (10YR 5/6) moist, clay loam, weak medium sub-angular blocky, few medium roots, 45% coarse fragments, clear smooth boundary.
C	96–125	Brownish yellow (10YR 6/6) moist, clay, moderate medium sub-angular blocky, 50% coarse fragments.

Use and vegetation : Abandoned jhum and mixed forest.

Type location : Near Thingsulthliah village, Aizawl District, Mizoram.

No. of profile examined :18

Interpretative grouping : Land capability sub class : IIIe, IVe & VIIe

Soil analysis : Physical characters-

Horizon	Depth (cm)	Mechanical analysis			Texture
		Sand %	Silt %	Clay %	
A1	0 – 14	48	20	32	Sandy clay loam
B1t	14 – 38	46	19	35	Sandy clay loam
B2t	38 – 72	45	17	38	Clay loam
B3	72 – 96	42	18	40	Clay loam
C	96–125	37	18	45	Clay

Chemical characters-

Horizon	Depth (cm)	pH 1:2	Organic Carbon %	CEC Meq/ 100gm	Exchangeable bases Meq/100gm				B.S. %
					Ca^{++}	Mg^{++}	K^{+}	Na^{+}	
A1	0 – 14	5.65	1.44	10.91	1.4	2.6	0.26	0.14	42.27
B1t	14 – 38	5.54	1.25	9.80	1.6	1.8	0.18	0.17	33.72
B2t	38 – 72	5.46	1.08	9.74	1.6	1.4	0.14	0.15	33.31
B3	72 – 96	5.32	0.82	8.58	0.8	0.9	0.12	0.11	24.77
C	96–125	5.21	0.74	7.87	0.6	1.0	0.11	0.18	24.19

12. Khawlian Series (Map symbol – 2, ,4) :

Khawlian series is a member of clayey, mixed, hyperthermic family of Typic Hapludults. They are very deep, dark brown to dark yellowish brown, clay loam surface and clay sub-surface, well drained, strongly acidic to very strongly acidic horizons. It occurs on hill side slopes of less than 25%. The associated soil series is Aibawk– a Typic Dystrochrepts.

Typifying pedon: Clayey – Current Jhum and Bamboo forest.

Horizon	Depth (cm)	Descriptions
A1	0 – 14	Dark yellowish brown (10YR 4/4) moist, sandy clay, weak medium sub-angular blocky, many fine and medium roots, sticky and plastic, clear smooth boundary.
B1t	14 – 38	Dark yellowish brown (10YR 4/5) moist, light clay, moderate

		medium sub-angular blocky, many fine and medium roots, sticky and plastic, patchy thin cutans, clear smooth boundary.
B21t	38 – 61	Dark yellowish brown (10YR 4/6) moist, light clay, moderate medium sub-angular blocky, few fine and common medium roots, sticky and plastic, patchy thin cutans, clear smooth boundary, 8% coarse fragments.
B22t	61– 82	Yellowish brown (10YR 5/6) moist, clay, medium sub-angular blocky, few medium roots, sticky and plastics, patchy thin cutans, clear smooth boundary, 12% coarse fragments.
B3	82–105	Strong brown (7.5YR 4/6) moist, clay, medium sub-angular blocky, sticky and plastics, 25% coarse fragments.
C	105-126	Strong brown (7.5YR 4/6) moist, clay, medium sub-angular blocky, sticky and plastics, 40% coarse fragments.

Use and vegetation : Bamboo and mixed forest.

Type location : Near Tuivamit village, Aizawl, Mizoram.

No. of profile examined : 8

Interpretative grouping : Land capability sub class : IIIe

Soil analysis : Physical characters-

Horizon	**Depth (cm)**	**Mechanical analysis**			**Texture**
		Sand %	**Silt %**	**Clay %**	
A1	0 – 14	46	11	43	Sandy clay
B1t	14 – 38	45	13	42	Sandy clay
B21t	38 – 61	38	16	46	Light clay
B22t	61 – 82	35	17	48	Clay
B3	82–105	31	19	50	Clay
C	105-126	27	20	53	Clay

Chemical characters-

Horizon	**Depth (cm)**	**pH 1:2**	**Organic Carbon %**	**CEC Meq/ 100gm**	**Exchangeable bases Meq/100gm**				**B.S. %**
					Ca^{++}	Mg^{++}	K^{+}	Na^{+}	
A1	0 – 14	5.21	1.94	8.07	1.1	2.7	0.24	0.12	51.69

B1t	14 – 38	4.92	1.58	7.99	1.0	1.2	0.16	0.16	33.67
B21t	38 – 61	4.82	1.32	7.16	1.2	0.6	0.16	0.18	31.60
B22t	61 – 82	4.71	0.92	6.32	0.6	0.8	0.14	0.13	27.22
B3	82–105	4.65	0.65	5.18	0.4	0.6	0.08	0.10	22.85
C	105-126	4.61	0.51	5.17	0.2	0.4	0.07	0.12	15.73

13. Chalfilh Series (Map symbol – 4, 5, 7, 9, 11) :

College Veng series is a member of fine loamy, mixed, hyperthermic family of Humic Hapludults. They are very deep, well drained and have dark brown to dark yellowish brown, clay in texture, very strongly acidic horizon. It occurs mostly on hillside slopes of various slope categories. One of the associated soil series is Suangpuilawn – a Umbric Dystrochrepts.

Typifying pedon: Fine Loamy – mixed forest.

Horizon	Depth (cm)	Description
A1	0 – 15	Dark brown (10YR 3/3) moist, clay, moderate medium sub-angular blocky, many fine and medium roots, 3% coarse fragments, clear smooth boundary.
B1t	15 – 37	Dark yellowish brown (10YR 4/4) moist, clay, moderate medium sub-angular blocky, common fine and medium roots, 7% coarse fragments, patchy thin cutans, clear smooth boundary.
B21t	37 – 67	Dark yellowish brown (10YR 4/5) moist, clay, moderate medium sub-angular blocky, common medium roots, 10% coarse fragments, patchy thin cutans, clear smooth boundary.
B22t	67 – 92	Dark yellowish brown (10YR 4/6) moist, clay, moderate medium sub-angular blocky, few medium roots, 16% coarse fragments, patchy thin cutans, clear smooth boundary.
B3	92–127	Dark yellowish brown (10YR 4/6) moist, sandy clay loam, moderate medium sub-angular blocky, few medium roots, 20% coarse fragments.

Use and vegetation : Mixed forest and Bamboo forest.

Type location : Near Chalfilh , Aizawl District, Mizoram.

No. of profile examined : 17

Interpretative grouping : Land capability sub class : IVe & VIe

Soil analysis : Physical characters-

Horizon	Depth (cm)	Mechanical analysis			Texture
		Sand %	Silt %	Clay %	
A1	0 – 15	34	19	47	Clay
B1t	15 – 36	36	19	45	Clay
B21t	36 – 67	37	17	46	Clay
B22t	67 – 92	31	18	51	Clay
B3	92–127	49	22	29	Sandy clay loam

Chemical characters-

Horizon	Depth (cm)	pH 1:2	Organic Carbon %	CEC Meq/ 100gm	Exchangeable bases Meq/100gm				B.S. %
					Ca^{++}	Mg^{++}	K^{+}	Na^{+}	
A1	0 – 15	4.96	1.67	8.63	1.2	1.6	0.11	0.12	35.15
B1t	15 – 36	4.82	1.15	9.15	0.8	2.1	0.08	0.14	34.42
B21t	36 – 67	4.76	0.92	8.51	0.6	1.3	0.06	0.12	29.52
B22t	67 – 92	4.67	0.72	8.53	0.6	1.4	0.17	0.14	27.39
B3	92–127	4.63	0.56	7.93	0.6	1.3	0.05	0.16	26.94

14. Tawizo Series (Map symbol – 8, 12, 13) :

Tawizo series is a member of loamy skeletal, mixed, hyperthermic family of Humic Hapludults. They are very deep, dark brown to yellowish red, clay loam to clay, well drained, very strongly acidic horizons. It occurs on hill side slopes of more than 25% slope. The associated soil series is Suangpuilawn – an Umbric Dystrochrepts.

Typifying pedon : Loamy skeletal – Bamboo and mixed forest.

Horizon	Depth (cm)	Descriptions
A1	0 – 14	Dark brown (10YR 3/3) moist, clay loam, weak medium sub-angular blocky, many fine and medium roots, sticky and plastic, 20% coarse fragments, clear smooth boundary.
B21t	14 – 34	Dark yellowish brown (10YR 4/4) moist, clay loam, moderate medium sub-angular blocky, many fine and medium roots, sticky and plastic, 35% coarse fragments, patchy thin cutans, clear smooth boundary.
B22t	34 – 61	Dark yellowish brown (10YR 4/6) moist, light clay, moderate medium sub-angular blocky, few fine and common medium roots, sticky and plastic, 40% coarse fragments, patchy thin cutans, clear smooth boundary.
B3	61 – 98	Strong Brown (7.5YR 4/6) moist, clay, moderate medium sub-angular blocky, few medium roots, sticky and plastics, 45% coarse fragments, clear smooth boundary.
C	98 –130	Strong Brown (7.5YR 5/6) moist, clay, moderate medium sub-angular blocky, sticky and plastics, 55% coarse fragments.

Use and vegetation : Abandoned jhum and mixed forest.

Type location : Near Durtlang village, Aizawl, Mizoram.

No. of profile examined : 14

Interpretative grouping : Land capability sub class : IVe & Vie

Soil analysis : Physical characters-

Horizon	Depth (cm)	Mechanical analysis			*Texture*
		Sand %	Silt %	Clay %	
A1	0 – 14	37	24	39	Clay loam
B21t	14 – 34	39	22	39	Clay loam
B22t	34 – 61	38	20	42	Light clay
B3	61 – 98	35	19	46	Clay
C	98 –130	33	18	49	Clay

Chemical characters-

Horizon	**Depth (cm)**	**pH 1:2**	**Organic Carbon %**	**CEC Meq/ 100gm**	**Exchangeable bases Meq/100gm**				**B.S. %**
					Ca^{++}	**Mg^{++}**	**K^{+}**	**Na^{+}**	
A1	0 – 14	4.92	1.18	6.07	0.4	1.6	0.19	0.17	39.04
B21t	14 – 34	4.84	1.11	6.42	0.4	1.4	0.12	0.18	29.97
B22t	34 – 61	4.67	0.86	7.61	0.6	1.2	0.14	0.28	31.70
B3	61 – 98	4.62	0.72	6.81	0.6	0.8	0.16	0.17	25.16
C	98 –130	4.61	0.65	5.60	0.4	0.4	0.11	0.14	23.29

BIO DATA

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1.	M.Sc.(SD)	Sikkim Manipal University	2005	Sustainable Developments	**I**	69.50%
2.	PG.Dip.(RS)	Indian Institute of Remote Sensing	1988	Remote Sensing	**Distinction**	
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7. PAPER PUBLISHED

1. **Lalnunsiama Colney** and B.P.Nautiyal (2013). Distribution of exchangeable bases for suitability of Land use planning in soils of Aizawl district, Mizoram. *Journal of Environment and Ecology.* **31(1A)** : 302 – 305.

2. **Lalnunsiama Colney** and B.P.Nautiyal (2013). Characterization and Evaluation of Soils of Aizawl District, Mizoram, India using Remote Sensing and GIS Techniques, *Journal of Geomatics.* **7(1)***: 83 - 91*

3. Lungmuana and **Lalnunsiama Colney** (2011). Soil testing – an important tool for assessing soil health and quality. *Science Vision.* **11(4)**: 214 – 217.

4. Published many other articles and research paper in local journals (in local dialect) and gave lecture in different workshops and seminars relating to Remote Sensing and GIS applications.