Government of Nepal
Ministry of Agriculture, Land Management and Cooperatives

National Land Use Project

Mid Baneshwor, Kathmandu, Nepal

FINAL REPORT

SURYODAYA NAGARPALIKA, ILAM DISTRICT

- Present Land Use
- Soil
- Land Capability
- Risk Layer
- Land Use Zoning
- Cadastral Layer Superimpose
- Gaunpalika/Nagarpalika Profile

PACKAGE-NLUP/CS/QCBS/01/04/2074/075

for

Preparation of Gaunpalika/Nagarpalika Level Land Resource Maps (Present Land Use Map, Soil Map, Land Capability Map, Risk Layer, Land Use Zoning Map, Gaunpalika/Nagarpalika Profile and Superimpose of Cadastral Layers), Database and Reports for F/Y 074/075

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Present Land Use Report

Preparation of Present Land Use Report

Suryodaya Nagarpalika, Ilam District

This document is the output of the project entitled **Preparation of Gaunpalika/Nagarpalika level Land Resource Maps (***Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and Gaunpalika Profile***), Database and Reports (Package-04)** awarded to *PEES Consultant (P) Ltd.* by Government of Nepal, Ministry of Agriculture, Land Management and Cooperatives, National Land Use Project (NLUP) in Fiscal Year 2074-075. The Gaunpalika/Nagarpalika covered under the Package 04 of Ilam District is Rong Gaunpalika and Suryodaya Nagarpalika of Ilam District.

The Gaunpalika areas analysed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the Gaunpalika may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

The consultant is obliged to state that the Imageries, GIS database and other out puts produced for the project is owned by National Land Use Project (NLUP), Mid Baneshwor, Kathmandu. Therefore, the authorization from the NLUP is required for the usage and/or publication of the data in part or whole.

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CHAPTER 1: INTRODUCTION

1.1 Background and Rational

Land is one of the most important natural resources of the earth. Therefore, a country must have adequate information on land, in order to make appropriate or effective decision on land. The sustainable land resource management is required to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wet lands, and loss of fish and wildlife habitat (Anderson, Hardy, Roach, & Witmer, 1976). Therefore, land use data are needed in sustainable land resource management.

Land Cover (LC) is defined as the observed bio/physical cover of the earth's surface (Gregorio & Jansen, 2005). It refers to the type of feature present in the land (but not limited to the land because, the dispute about whether it covers the water area or not is normalized by scientific community, who accept, in practice, water area also under land cover) (FAO, 2005). Land use (LU) relates to the human activity or economic function in a specific piece of land. LU demonstrates the economic activities of an area. It can also be considered as to reflect the degree of human activities directly related to land and making use of its resources or having an impact. LC can describe in terms of biophysical component of a particular area where as LU is a functional unit of the LC. Many of the LU operations lead to the change in LC, which is the consequence of interactions between the natural environment and the human activities. Land use and the land cover (LULC) are the complex mixture of natural and anthropogenic influences and is the composition and characteristics of land surface elements (Cihlar, 2000). Land is a scarce and precious resource and knowledge of the land use/cover has become increasingly important for the national planning of a country.

The land use map is a useful resource to support the decisions of the city planners, economist, and ecologist and for every decision-maker involved in the sustainable development of the territory. In recent years, the technological development in RS and GIS has emerged as a powerful tool in the management and analysis of large volume of spatial and thematic resource data to support land use/resource planning. The digital data obtained from the satellite images are processed, prepared, classified and analyzed by using remote sensing technique to get information for various applications. Currently available satellite imageries with high spatial resolution could be used to derive spatial dataset for land use with good accuracy, more efficiently and in reliable manner. One of the prime pre-requisites for better land use planning is the information on existing spatial and temporal land use patterns. Remote sensing technology has great potential for acquisition of detailed and accurate land use information for management, planning of land use sustainability and sustainable development (Herald et al. 2002). Besides, due to increasing number of remotely sensed data sources, data now can be acquired at multiple times per day, and at spatial scales ranging from 1km to less than 1m resolutions. The computational power to extract meaningful quantitative results from the satellite data has also improved tremendously. These developments in both data access and data processing ability helped Remote Sensing (RS) and Geographic Information System (GIS) to be used widely in land use planning and analysis of land utilization for land use zoning.

Although, the land–use planning for making the best use of the limited land resources is inevitable, yet, except sporadic attempts for the urban areas, Nepal has not practiced land-use planning for the country as a whole. However, several attempts were made for balanced use of country's existing natural resources in the past through different policies and national planning efforts. Land-use planning can be applied at three broad levels: national, district and local. Local level planning is about getting things done on particular areas of land – what shall be done, where and when, and who will be responsible. It requires detail basic information about the land, the people and services at local level. However, Nepal has only regional level data base on land use, land system and land capability which were produced by Land Resource Mapping Project (**LRMP**, 1986). Realizing this fact, the Ministry of Land Reform and Management of Government of Nepal established the **National Land Use Project** (**NLUP**) in 2057/058 fiscal year to generate the necessary data bases on the land resources of the country.

In the first phase, the National Land Use Project of Nepal had initiated several projects at district level and prepared **Land Resource Maps and Database** at 1:50,000 scale for the whole Nepal. It had also prepared same kinds of maps and database for Kirtipur, Lekhnath, Madhyapur Thimi and Bhaktapur municipalities at larger scales. Finally, NLUP was mandated to prepare land resource maps of Nepal for local level planning through outsourcing modality. These digital data base includes Gaunpalika/Nagarpalika level present land use, soil, land capability, risk layers land use zoning, cadastral layers and Gaunpalika/Nagarpalika profile with bio-physical and socio – economic data base.

On the 4th *Baishakh* of 2069, the Government of Nepal has approved the **National Land Use Policy, 2069**. The same policy was modified by the amendment of **National Land Use Policy, 2072.** It has intended to manage land use according to land use zoning policy of the government of Nepal and outlined eleven zones such as ***Agricultural area; Residential area; Commercial area; Industrial area; Mining and Mineral area; Cultural and Archaeological area; River, Lake and Water bodies; Excavation area; Forest area; Public Use area and Others***. The policy has defined the respective zones as per the land characteristics, capability, and requirement of the lands. Further, for the effective implementation of land use zones in the country, the National Land Use Policy, 2072 has clearly directed for an institutional set up of **Land Use Council** at the top to the **District level** and ***Gaunpalika/Nagarpalika* level** at the bottom. It has added further importance to the NLUP projects on preparation of Gaunpalika level maps and database.

In this regards, the National Land Use Project (NLUP) has commissioned PEES Consultant (Pvt.) LTD to conduct the project entitled **Preparation of *Gaunpalika/Nagarpalika* level land resources maps** (Present Land Use Map, Soil Map, Land Capability Map, Land Use Zoning Map, Superimpose of Cadastral Layers and *Gaunpalika/Nagarpalika* Profile), **Data base and Reports** for *Gaunpalika/Nagarpalika* under Package-04 of Ilam District in the fiscal year 2074/075. The Package-04 covers Rong *Gaunpalika and Suryodaya Nagarpalika*.

The rational for the preparation of *Gaunpalika/Nagarpalika* level land use maps by NLUP are:

- Classify land into agricultural area, residential area, commercial area, industrial area, forest area, public use area and other lands as per the policy of the government of Nepal;
- Identification of residential area to provide basic facilities conveniently;
- Classification of agricultural land into maximum comparatively advantageous sub areas on the basis of land characteristics;
- Conservation of the natural resources including forest, shrub, wet lands, hazard prone areas, rivers and rivulets.

1.2 Objective of the Study

The broad objective of National Land Use Project (NLUP), Package-04, (2074/075 fiscal year) is to prepare of *Gaunpalika/Nagarpalika* level **Land Resource Maps** (present land use map, soil map, land capability map, land use zoning map and preparation of profile for land use zoning and cadastral layer superimpose), **Database** and **Reports** for Rong *Gaunpalika and Suryodaya Nagarpalika*.

In order to fulfill the broad objective, the specific objective of the present study is:

I. To prepare Present Land Use Maps at 1:10,000 scales, GIS Database and Reports for the ***Suryodaya Nagarpalika***.

Scope

In order to achieve the above mentioned objectives, the scope of this study includes;

- Perform ortho-rectification of the given satellite image.
- Prepare present Land cover/land use maps in different hierarchical levels
- Design appropriate GIS database.
- Discuss the accuracy, reliability and consistencies of data.
- Prepare reports, describing methodology, existing land use pattern and model of GIS data base.

1.3 Study Area

Suryodaya Nagarpalika, name being the Nepali translation of “Rising Sun” declared Nagarpalika status in 2013 (2070 BS), with the merged of three Village Development Committees (VDCs) namely: Phikkal, Panchakanya and Kanyam. After, the restructuring of local body in 2073 BS, Gorkhey, Pashupatinagar, Sriantu, Samalbung, Laxmipur and Jogmai ward no. 8 and 9 were also merged into the Nagarpalika. It is located in Ilam district, province no 1, approximately 40 km south-east of the district headquarter Ilam. Geographically, it lies in the hill region which is mostly known as Mahabharat range with natural scenery and pleasant weather. Its geographical coordinates are 87°55'59" to 88°10'37" east longitude and 27°0'28" to 26°47'17" north latitude. The Nagarpalika is bordered with India on the east, Ilam Nagarpalika and Mai-Jogmai Gaunpalika on the west, Mai -Jogmai Gaunpalika on the north and Rong Gaunpalika on the south (Figure 1.1). Phikkal is the center of the Nagarpalika. The total area of the Nagarpalika is 22438.57 ha. This is extended north-south 25.29 km and east-west with 24.71 km.

The inhabitants are believed to have been living in this Nagarpalika since ancient time. According to the Population Census of 2011, the total population of this Nagarpalika was 56,707 and the numbers of households were 13,211. This gives an average household size of 4.3 which is lower than the national average (4.88). Administratively, the Nagarpalika has been divided into 14 wards. Ward No. 1 is the largest in terms of population size whereas ward No. 7 is the smallest one.

The Nagarpalika has diversity both in its physical and cultural aspects. It is a business hub of Ilam with beautiful landscapes. Tea, ginger, *Amriso,* cardamom, round chilies (*Akabare Khursani)*, milk and potatoes are the major trade items of this Nagarpalika. The Nagarpalika has grate possibility for the tourism. Kanyam, Pashupatinagar, Phikkal, and Sri Antu are famous for tourist destination sites. Rai, Brahmin, Chhetri and Tamang are major ethnic group inhabited in the Nagarpalika.

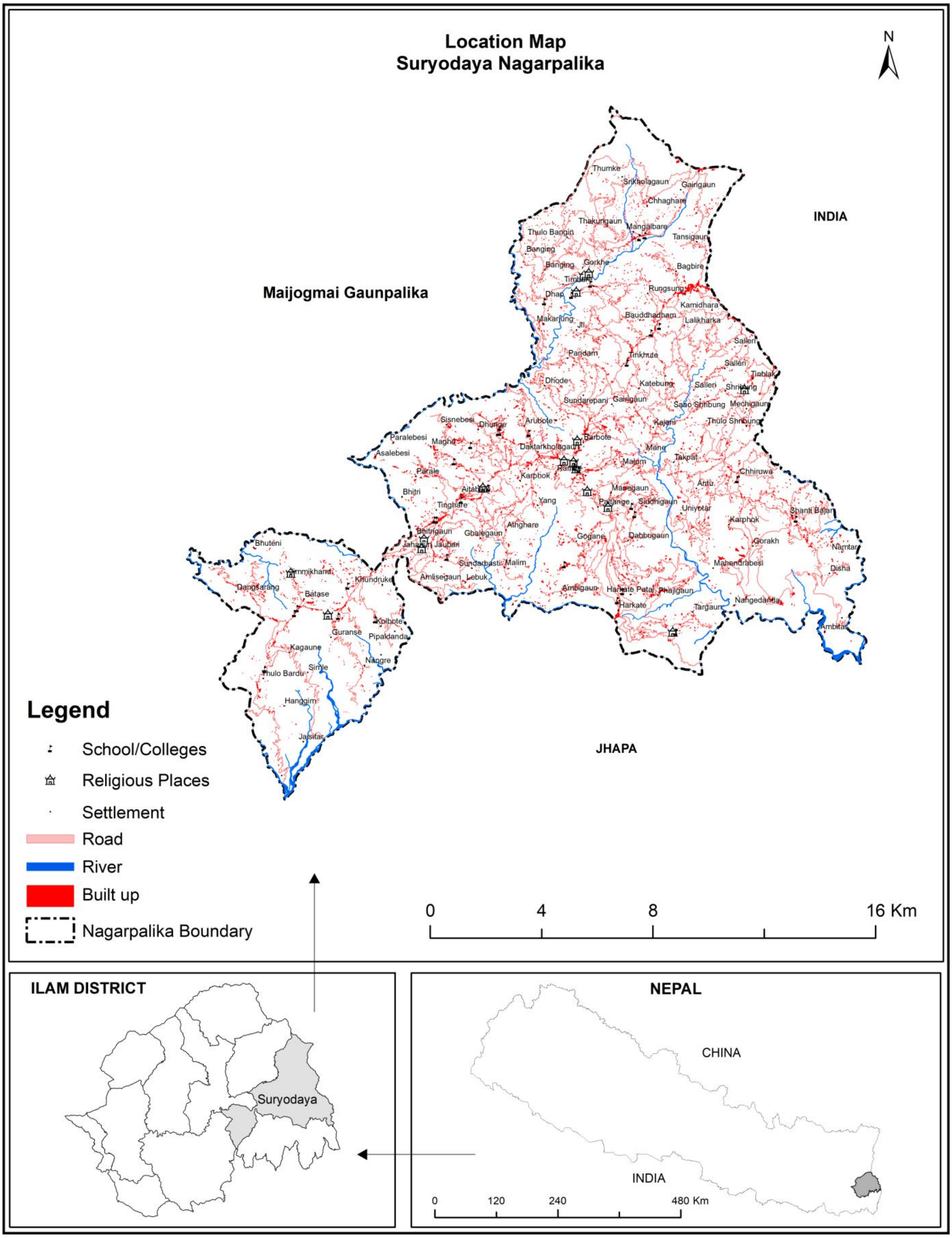


Figure 1.1: Location map of Suryodaya Nagarpalika

CHAPTER 2: CONCEPTUAL BASIS OF LAND USE CLASSIFICATION

2.1 Classification System and Criteria

In almost any classification process, it is rare to find the clearly defined classes that one would like. In determining land cover, it would seem simple to draw the line between land and water until one considers such problems as seasonally wet areas, tidal fiats, or marshes with various kinds of plant cover. Decisions that may seem arbitrary must be made at times, but if the descriptions of categories are complete and guidelines are explained, the inventory process can be repeated. The classification system must allow for the inclusion of all parts of the area under study and should also provide a unit of reference for each land use and land cover type (Anderson, Hardy, Roach, & Witmer, 1976).

There is no one ideal classification of land use and land cover, and it is unlikely that one could ever be developed. There are different perspectives in the classification process, and the process itself tends to be subjective, even when an objective numerical approach is used. There is, in fact, no logical reason to expect that one detailed inventory should be adequate for more than a short time, since land use and land cover patterns change in keeping with demands for natural resources. Each classification is made to suit the needs of the user, and few users will be satisfied with an inventory that does not meet most of their needs. In attempting to develop a classification system for use with remote sensing techniques that will provide a framework to satisfy the needs of the majority of users, certain guidelines of criteria for evaluation must first be established. We have taken the reference of the recently formulated land use policy as guidelines of classification and fit into the model supplied by NLUP.

Land use land cover of an area is largely depend on different factors such as terrain, lithology, soil type, climate, rainfall pattern, socio-cultural practices, relative location etc. land use classification is necessary for the preparation of land use zonation and or for the optimum utilization of a particular land. Classification is an abstract representation of the situation in the field using well-defined diagnostic criteria: the classifiers. It can be defined as: "the ordering or arrangement of objects into groups or sets on the basis of their relationships” (Sokal, 1974). Classification schema describes the systematic framework with the names of the classes and the criteria used to distinguish them, and the relationship between classes. Thus, classification schema requires the definition of class boundaries, which should be clear, precise, possibly quantitative, and based upon objective criteria (Gregorio & Jansen, 2005).

A classification should be:

- Scale independent, meaning that the classes should be applicable at any scale or level of detail; and
- Source independent, implying that it is independent of the means used to collect information, whether it be through satellite imagery, aerial photography, field survey or using a combination of sources.

Classification systems come in two basic formats, hierarchical and non-hierarchical. Most systems are hierarchically structured because such a classification offers more consistency owing to its ability to accommodate different levels of information, starting with structured broad-level classes, which allow further systematic subdivision into more detailed sub-classes. At each level the defined classes are mutually exclusive. At the higher levels of the classification system few diagnostic criteria are used, whereas at the lower levels the number of diagnostic criteria increases. Criteria used at one level of the classification should not be repeated at another lower level (Gregorio & Jansen, 2005).

Classification system can be a priori or a posteriori. In a priori classification system classes are pre-arranged. The use of such a classification assumes that all possible classes can be derived, independent of scale and tools used, from the system. It is the most effective way to produce standardization of classification results among user communities. Posteriori classification system is based upon definition of classes after clustering the field samples that are collected. Since this system depends on the specific area described and is adapted to local conditions, it is unable to define standardized classes.

A land use and land cover classification system which can effectively employ orbital and high-resolution remote sensing image should meet the following criteria (Anderson, Hardy, Roach, & Witmer, 1976). The minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensing image should be at least 85 percent (Jensen, 1996).

- The accuracy of interpretation for the several categories should be approximately equal.
- Repeatable or repetitive results should be obtainable from one interpreter or another and from one time of sensing or another.
- The classification system should be applicable to extensive areas.
- The categorization should permit vegetation and other types of land cover to be used as surrogate for activity.
- The classification system should be suitable for use with remote sensing image obtained at different times of the year.
- Effective use of subcategories that can be obtained from ground surveys or from the use of larger scale or enhanced remote sensing image should be possible.
- Aggregation of categories must be possible.
- Comparison with future land use data should be possible.
- Multiple uses of land should be recognized when possible.

For land use and land cover data needed for planning and management purposes, the accuracy of interpretation at the generalized first and second levels is satisfactory when the interpreter makes the correct interpretation 85 to 90 percent of the time. For regulation of land use activities or for tax assessment purposes, for example, greater accuracy usually will be required. Greater accuracy generally will be attained only at much higher cost.

2.2 Land Use Hierarchy and Description

Land use practice in any region of the country is governed by physiography, lithology/soil, settlement pattern, cultural practices, climatic conditions and socio economic factors. To incorporate diverse land use at the Nagarpalika level, comprehensive model should be adopted while making land use inventory. Hierarchical classification system has been recommended in TOR provided by the National Land Use Project (NLUP). This system provides a great flexibility in terms of application through its hierarchical structure. Priori classification system with land use categories as specified in the specification provided by NLUP should be adopted. This will ensures the standardization among the classification result. Land Use Policy 2072 provides the nomenclature of the Land Use classes. The level 1 categories of the land use are such as ***Agricultural area, Residential area, Commercial area, Industrial area, Mining and Mineral area, Cultural and Archaeological area, Riverine and Lake area, Excavation area, Forest area, Public Use and Open Space area and Others*** as recommended in ToR and specification 2015.

2.2.1 Agricultural

Agricultural land is defined broadly as land used primarily for production of food and fiber. The areas those have been used for agricultural production such as cereals, cash crops, orchards, and so on. Use of land for different agricultural production differs due to physical (e.g. climatic condition, moisture, topography, soil) and social/cultural believes of the particular region. LRMP has broadly categorized cultivated land based on physiograpy of Nepal, namely Tarai, Hill, Mountain and Valley cultivation. Tarai cultivation is further sub divided into Wet land, Dry land and Mix land and Sloping terraces. The Mountain cultivation is further divided into Level terraces, Upland cultivation and Sloppy upland. Similarly, Valley cultivation is divided into Level terraces, Khet land cultivation, Level terraces, Upland/pakho cultivation, Valley slope upland cultivation and Valley riverbeds lower foot slope alluvial fans cultivation (alluvial riverbed fans). The Wetland cultivation is further divided into Low khet land cultivation and Upper khet land cultivation-tari khet. Different cropping pattern is presented in level five, whereas cropping intensity is also presented in subsequent chapter. Based on above information, NLUP has provided hierarchy of agricultural land for this study (in Table 2.1).

Table 2.1: Hierarchy of Agricultural Land Use

Level 1	Level 2	Level 3	Level 4	Level 5 Cropping Pattern	Level 6 Cropping Intensity
				Monsoon- Winter-Dry season	
Agricultural Land Use	**Tarai Cultivation**	▪ **Wet Land Cultivation**	▪ **Low Khet Land Cultivation** (Poorly drained with High bond ----------------- ▪ **Upper Khet Land Cultivation-Tari Khet** (Intermediate land between wet and dry land with well drain soil bonds are lower)	Maize-Oilseeds-m2 Maize-Pulses-m4 Maize-Wheat-m5 Maize - Vegetable-m6 Maize-Millet-m7 Maize-Potato-m8 Maize-Others-m9 Pulses-Fallow-p1 Pulses-Others-p2 Rice-Fallow-r0 Rice-Rice-r1 Rice-Wheat-r2 Rice-Wheat-Pulses-r3 Rice-Oilseed-r4 Rice-Pulses-r5	Intense (75%-100% cultivated) medium(50%-75% cultivated)

<table>
<tr><th rowspan="2">Level 1</th><th rowspan="2">Level 2</th><th rowspan="2">Level 3</th><th rowspan="2">Level 4</th><th>Level 5 Cropping Pattern</th><th rowspan="2">Level 6 Cropping Intensity</th></tr>
<tr><th>Monsoon- Winter-Dry season</th></tr>
<tr><td rowspan="5">Agricultural Land Use</td><td rowspan="2"></td><td>▪ Dry Land Cultivation (Upland Pakho/ Bhith land Cultivation, Drained, smallest bond height)</td><td>Unclassified</td><td rowspan="5">Rice-Rice- Vegetable-r6
Rice-Vegetable-r7
Rice-Potato-r8
Rice-Potato-Vegetable-r9
Rice-Maize-r10
Rice-Vegetable-Vegetable-r11
Rice-Maize-Vegetable-r12
Garlic-Vegetable-v2
Vegetables-Vegetable-v3
Fruit+Potato/Vegetable/Buckwheat-f2
Banana-b2
Tea-t1
Coffee-c1
Cardamom-c2
Amriso-a1
Ginger-g1
Livestock/Cattle/buffalo Farm-l1
Turmeric-t2
Fruits-f4
Rice-Buckwheat-r14
Rice-Wheat-Maize-r15
Bamboo-b3
Pond for Fish farming-p3
Beekeepig-b4
Cotton-c3
Floriculture-f5
Barren Cultivable land-b5
Livestock Grazing area-g2
Maize-Rice-Cereal-m3
Rice-Others-r13
Sugarcane-Sugarcane-s1
Potato-Vegetable Crops-v1
Others-o1
Shrub from non-forest area-s3
Vegetables-Others-v4
Sugarcane-Others-s2
Barley-Buck Wheat-b1
Fruit-Fruit-f1
Fruit-Others-f3
Others-Others-o2
Others-Others-others-o3
Maize-Rice-Fallow-m1</td><td rowspan="5">Light (25%-50% cultivated) Not Applicable

Light-1
Medium-2
Intense-3</td></tr>
<tr><td>▪ Mixed Land Cultivation (Commonly found near River where River have change the course)</td><td>Unclassified</td></tr>
<tr><td rowspan="2">Hill Cultivation</td><td>Level Terraces</td><td>▪ Level Terraces Khet Land Cultivation (level khet land with small bond)

▪ Level Terraces Upland/Pakho Land Cultivation (level upland with no bond)</td></tr>
<tr><td>Slopping Terraces</td><td>▪ Slopping Upland/ Pakho Land Cultivation (cultivated on natural slopes)</td></tr>
<tr><td>Mountain cultivation</td><td>▪ Level Terraces Upland Cultivation
▪ Sloppy Upland</td><td>Unclassified</td></tr>
</table>

Level 1	Level 2	Level 3	Level 4	Level 5 Cropping Pattern Monsoon- Winter-Dry season	Level 6 Cropping Intensity
	Valley Cultivation	▪ **Level Terraces Khet Land Cultivation** (Level khet land with small bond) ▪ **Level Terraces Upland/Pakho Cultivation** (Level upland with small bond)	Unclassified		
	Valley Cultivation	▪ **Valley slope upland/Pakho cultivation** (Cultivated on natural slopes) --------------------- ▪ **Valley Riverbeds(Lower foot slope) Alluvial Fans Cultivation** ▪ (alluvial riverbed fans)	Unclassified		

2.2.2 Forest Use

Area covered by vegetation completely or partially and which does not fall under above mentioned category is forest. It consists of area covered by forest, shrub and grazing land/grassland. It is an area with natural or planted trees along with shrubs and grass where the dominant species are trees of various kinds. The forest land are subdivided into level 2 sub types as per the climatic vegetation zone such as tropical (<1000 m), subtropical (1000-2000/2100m), temperate (2000/2100-3000/3100), sub-alpine (3000/3100-4000/4100) and alpine (4000/4100-4500). Similarly the forest land is further subdivided into level 3 categories by cover type as hardwood, coniferous and mixed. On the basis of crown density, forest is classified as dense, sparse, degraded types. Similarly, according to the forest ownership category or use right, it is classified as private, protected, government managed, community, and leasehold, collaborative and religious. The hierarchy of forest land use is shown in Table 2.2.

Table 2.2: Hierarchy of Forest

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Forest	***Climatic Vegetation Zone:*** **Tropical Forest** (<1000m) **Sub-tropical** (1000-2000/2100m) **Temperate** (2000/2100-3000/3100m) **Sub-alpine** (3000/3100-4000/4100m) **Alpine** (4000/4100-4500m)	***Cover Type*** **Hardwood** **Coniferous** **Mixed**	***Species Type*** As described as below	***Crown Density:*** **Dense** (>70% Crown Density) **Sparse** (40-70% Crown Density) **Degraded** (<40% Crown Density) followed by name of Dominant species (Crown Density/Tree density and Maturity of the forest should be adopted to categorize dense, sparse and degraded forest)	***Maturity Class*** ***Mature*** To over mature-trees have reached at least estimated rotation age of saw timber size **Immature** or small timber size materials **Reproduction** New generation to pole size	***Forest Ownership Category or Use Rights:*** Private Protected Government Managed Community Leasehold Collaborative Religious Others
		Shrub				

Shrub or bush has multiple stems and are usually about 5-6m in height. A large number of plants can be either shrubs or trees depending on their growing conditions. Shrubs are generally found in the gardens, narrow gullies, along the river bank as well as on bare unattended land during rainy season. Shrubs are not categorized into lower levels. Species type forest is shown as below:

- Sal forest
- Pinusroxburghii Forest
- Quercusincana
- Lanuginose Forest
- Quercusdilata Forest
- Quercussemecarpifolia Forest
- Castanopsistribuloides
- Hystrix Forest Quercus lamellose Forest
- Lithocarpuspachyphylla Forest
- Aesculus-juglans-Acer Forest
- Lower Temperate Mixed Broadleaved Forest
- Upper Temperate Mixed Broadleaved Forest
- Tropical Deciduous Riverain Forest
- Rhododendron Forest
- Betulautilis Forest
- Abiesspectabilis Forest
- Tsugadumosa Forest
- Pinusexcelsa Forest
- Abiespindrow Forest
- Cedrusdeodara Forest
- Cupressustorulosa Forest
- Larix Forest
- Tropical Evergreen Forest
- Alnus Woods
- Populus ciliate Woods
- Hippophae Scrub
- Moist Alpine Scrub
- Dry Alpine Scrub
- Juniper wallichiana Forest
- Wetland area
- Rock outcrops/ barren lands
- Sub-tropical Evergreen Forest
- Terminalia Forest
- Dalbergiasissoo-Acacia catechu Forest
- Sub-tropical Deciduous Hill Forest
- Schima-Castonopsis Forest
- Sub-tropical Semi-evergreen Hill Forest
- Other Forest Species

2.2.3 Residential

Residential areas are the built up areas used for housing purposes. Area of sparse residential land use such as farmstead will also be included in this category. This includes annex buildings like cow sheds, garage and farm house etc. This also includes features such as lawn area, well, private path, vegetable farm close to the house etc. The area delineated as residential area by government should also be categorized in this class. Based on density of houses, the residential area is further divided into three categories; dense (> 70%), moderate (40-70%) and sparse (<40%). Similarly, it is also divided in terms of origin of the settlement; old area, newly developed area (unplanned) and planned area such as colony type, parcels plotting area and housing complex etc. (Table 2.3).

Table 2.3: Hierarchy of Residential

Level 1	Level 2	Level 3	Level 4
Residential	Densely Populated Medium Populated Scarcely Populated (The category were devised based on the local condition; based on the density of houses, dense, moderate and or sparse residential unit areas may be used for > 70 %, 40-70% and < 40% categories respectively)	Old Area, Newly Developed Area (Unplanned) Planned Area (Colony Type, Parcels Plotting Area and Housing Complex, etc.)	Residential cluster-r Apartment/Multi-storeys-a Oldage care place-o Hostel-h Dharashram-d Quarters-q Infracture developed area-i Other-x

2.2.4 Commercial

Commercial areas are those used predominantly for the sale of goods and services. It consists of the main building, supporting structure and area that serve for commercial purpose. They are often abutted by, residential, agricultural, or other contrasting uses which help define them. It includes shopping centers, hotels, guest houses, shops, private schools, health centers, radio station, petrol pumps etc. Commercial areas are further classified into service areas and business areas. The service areas include public services whereas Business area includes market area where exchange of goods and services occur. Commercial strip are situated along the highway and access route to the highway in this Nagarpalika (Table 2.4). Phikkal and Pashupatinagar are main economic transaction markets, and are newly emerging urban centers in the study area.

Table 2.4: Hierarchy of Commercial

Level 1	Level 2	Level 3	Level 4
Commercial	Service Areas	Government Service Area(G)	Designated Name
	Business Areas	Market Area with specific categories like Market (M) Hotel (H) Recreation(R) Utility(U) Storage(T) Service (S)	

Commercial Level 4

Market Subcategory		
• Shop • Boutique	• Departmental Store • Retail Business	• Supermarket
Hotel Subcategory		
• Hotel • Guest House • Fast-food	• Restaurant • Bar • Travel Agency	• Other hotel •

Storage Subcategory	
• Storage area/House • Consultancy service area	Business house

Recreation Subcategory	
• Cyber cafe • Cinema Hall • Concert Hall • Theater • Dance Hall • Night Club	• Gaming Hall • Gambling Hall • Exhibition Centre • Gym House • Other Entertaining area
Service Subcategory	
• Bank/Money Exchange • Private Post Office • Private Communication Area • Broadcast Studio • Private school Area • Private Health Service Area • Petrol pump	• Radio Station • Service Centre • TV Station

Utility Subcategory		
• Water Reservoir • Hydropower Area	• Cable Car • Gas Plant	• Oil Storage • Other Storage
Service Subcategory		
• Agriculture Office • CBS • Civil Aviation • Communication • Court • Cultural Office • District Administration Office • Dolidar • Education • Electricity Office • Forestry Office	• Health Office • Irrigation Office • Land Transaction Office • Local Development Office • Mining and Geology • Other • Petroleum • Post Office • Road Office • Soil Conservation	

2.2.5 Industrial Use

Industrial areas are the areas where production of goods occurs. It includes a wide array of land uses from light manufacturing to heavy manufacturing plants. It includes area covered by land, house and shed that are used as workshop or processing and manufacturing industry. It consists of factories such as textile, food, brick, timber, vehicle, brewery etc. It is further sub-divided into small scale industry including cottage industry, medium scale industry and large scale industry (Table 2.5).

Table 2.5: Hierarchy of Public

Level 1	Level 2
Industrial	Small Scale Industry(S) Medium Scale Industry(M) Large Scale Industry(L) Special Economic Zone(E) Industrial Estate(I) Other Industrial Category(O)

2.2.6 Public Use and Open Space

Public use and open space are those which cannot exclude someone to use it under certain terms of condition. Public land used by School, College, Hostel, Well, Parks, Airport, Road, Stadium, Picnic spot and other public service activities are categorized in this class. Public service is further classified on the basis of their functional use into Educational, Security Services, Transportation Infrastructure, Health Service, and Institution. School, Colleges and Universities are placed in Educational class. Police station, Military area and Fire station are categorized in Security services. Transportation Infrastructure includes Road, Trail, Airport, Bus Park, Railway, Ropeway, etc. Hospital, Health Post, Polyclinic etc are included under Health services. Institutional service includes Government and Public institutions. The hierarchy of public services is given below (Table 2.6):

Table 2.6: Hierarchy of Public Use and Open Space

Level 1	Level 2	Level 3
Public Services	Educational	Designated Name
	Security Services	
	Transportation Infrastructure	
	Recreational Facility	
	Health Service	
	Institution	
	Open Area	

Sub-category of Public Use and Open Space at Level 4 is shown as below:

Transportation

- Highway
- Feeder Road
- District Road
- Local Road
- Other Road
- Bus park
- Airport
- Railway
- Car Park
- Port

- Pavement
- Cart Track
- Other

Education

- Primary
- Secondary
- Campus
- University
- Other educational area

Health

- Hospital
- Nursing Home
- Health Centre
- Pharmacy
- Polyclinic
- Other

Institution

- Private Institution
- Public Institution
- NGO
- INGO
- Other Institution

Recreational

- Public Theatre
- Drama House
- Stadium
- Playground
- Open space
- Zoo
- Other

Security Service

- Police Station
- Armed force
- Military Area
- Other Security

2.2.7 Mines and Minerals

Mine and mineral feature includes the construction materials such as sand, cobbles, quartzite, limestone pebbles, boulders, schist, slates etc. Similarly it also includes decorative and dimension materials such as basalt, colored sandstone, granite, and marbles. This category of land use includes fuel mining materials such as coal, hot springs, methane, petroleum and natural gases. It includes aquamarine, beryl, garnets, gem, kyanites, quartz crystal, ruby, sapphire, tourmaline, etc. It also includes metallic minerals such as iron, copper, zinc, lead, cobalt, nickel, gold, silver, tin, tung stone, molybdenum, uranium, lithium, mica, tantalum, bismuth, arsenic, cadmium, chromium, mercury. Titanium, etc. It includes non-metallic materials as clay, dolomite, magnesite, phosphorite, silica, talc, phyllite, etc. The hierarchy of mine and mineral land use is given below (Table 2.7):

Table 2.7: Hierarchy of Mine and Mineral

Level 1	Level 2	Level 3	Level 4	Level 5
Mine and minerals	Metallic Minerals	Iron Copper Zinc Lead Cobalt Nickel Gold Silver Tin Tungsten Molybdenum Uranium Lithium Lepidolite(Mica) Tantalum Bismuth Arsenic Cadmium Chromium Mercury Titanium Other Metallic Minerals	•Licensed •Not-Licensed •Reserved •Banned	•Not Operated So Far •Currently under Operation •Closed •Other Operation status
	Non-metallic Minerals	Clay Dolomite Limestone Magnesite Mica Phosphorite Quartz Silica sand Talc Phyllite Other Non-metallic minearals		
	Construction Minerals (Materials)	Sand Cobbles Flaggy Quartzite Limestone Pebbles Quartzite River Boulders Schist Slates Other Construction Minerals		
	Fuel Minerals	Coal Hot Springs Methane Petroleum Natural Gases Other Fuel Minerals		
	Decorative and Dimension Stones	Basalt Colored sandstone Granites Quartzizes Other Decorative and Dimension Stones		

Level 1	Level 2	Level 3	Level 4	Level 5
	Gemstones	Aquamarine Beryl Garnets Gem Kyanites Quartz Crystels Ruby Sapphire Tourmaline Other Nemstone Minearals		
	Other Minerals			

2.2.8 Cultural and Archaeological Area

Cultural and Archeological land use class cover the cultural site along with archeological place, historical places and religious places. Cultural services include Chowk, Patis, and Bihar etc. Religious places include Temple, Stupa, Monastery, Mosque, Church, etc. Historical Services includes Durbar Square, Gadh, Archeological Site, Heritage etc. The hierarchy of cultural and archeological land use is given below (Table 2.8):

Table 2.8: Hierarchy of Cultural and Archeological

Level 1	Level 2
Historical and Archeological	Heritage Site Durbar Square Gadh Archeological Site Cultural Site Fort Temple Stupa / Monastery Mosque Church Bahal Patis Bihar Other

2.2.9 Riverine and Lake Area

Riverine and lake area categories have the hydrographical feature which includes River, Lakes, Ponds, Canal, Glacier, Snow covered area, wetland, sand, well, spring etc. The hierarchy of riverine, lake and water body Area is given below (Table 2.9):

Table 2.9: Hierarchy of Riverine, Lake and Water bodies

Level 1	Level 2
Riverine and Lake Area	Pond Lake Canal Glacier Snow Area Wetland River Spout

	Well Kulo Sand Other

2.2.10 Excavation Area

Excavation area has mainly construction material area which directly excavated in the industrial purpose. It has included the construction material as cobbles, flaggy quartzite, limestone, pebbles, phylitte, quartzite, river boulders, sands, schist, slates, etc. These excavation areas has further categorized into licensed, not-licensed, reserved and banned. The hierarchy of excavation land use is given below (Table 2.10):

Table 2.10: Hierarchy of Excavation Area

Level 1	Level 2	Level 3
Excavation (Construction Materials) Area	Cobbles Flaggy Quartzite Limestone Pebbles Phylitte Quartzite River Boulders Sands Schist Slates Other Excavation Materials	• Licensed • Not-Licensed • Reserved • Banned

2.2.11 Others Land Use

Others land use includes a type of land that does not belong to the above mentioned categories. Such types of lands are: grass land, orchard, bamboo plantation etc. Grass land is further divided into tropical (<1000m), sub-tropical (1000-2000/2100m), temperate (2000/2100-3000/3100 m), sub-alpine (3000/3100-4000/4100m) and alpine (4000/4100-4500m) which are shown in Table 2.11.

Table 2.11: Hierarchy of Others

Level 1	Level 2	Level 3	Level 4
Others	Grass land	**Climatic Vegetation Zone** Tropical (<1000 m), Sub-tropical (1000-2000/2100 m), Temperate (2000/2100-3000/3100 m) Sub-alpine (3000/3100-4000/4100 m) Alpine (4000/4100-4500 m).	
	Others		

CHAPTER 3: METHODOLOGY

3.1 Data Sources

There are many different sources of information on existing land use and land cover and on changes that are occurring in the landscape. Local planning agencies make use of detailed information generated during ground surveys involving enumeration and observation. Interpretation of large-scale aerial photographs also has been used widely. In some cases, supplementary information is inferred on the basis of utility hookups, building permits, and similar information. Major problems are present in the application and interpretation of the existing data. These include changes in definitions of categories and data collection methods by source agencies, incomplete data coverage, varying data age, and employment of incompatible classification systems. In addition, it is nearly impossible to aggregate the available data because of the differing classification systems used (Anderson et.al, 1976).

The primary data source used for the land use classification in this project is high-resolution 0.5 m WorldView-2 satellite imagery fused with the multi-spectral image of 2 meter spatial resolution of WorldView-2. Various other vector, raster and imagery data sets were used as ancillary data, which enhanced interpretation and classification of land use classes. This chapter describes, in brief, the sources and characteristics of various datasets used for the study.

Both types of data, primary and secondary, were used for the present land analysis. Maps and their related information of Land utilization, Land Capability, Land System, and Topographical Map prepared by Survey Department, Government of Nepal in different years were used as secondary information. Above maps and their reports was gathered and analyzed before interpretation of satellite imagery and field visit. WorldView-2 satellite imagery (MSS and pan bands) dated December 2018 of the project area was used for this project. Primary data (e.g., land use types, cropping pattern, and forest types/management) was collected during the field work through observation and discussion with locals using the structured questionnaires and maps. All data and information obtained from secondary sources related to this theme (land use) were verified during the field work. Major data sources used for this study are as follows.

3.1.1 WorldView-2 Satellite Image

WorldView-2 satellite system is one of the best ground resolution commercial color imaging satellite of the present time. The satellite has extraordinary detail, high accuracy and enhanced stereo imagery for DEM generation. WorldView-2 satellite simultaneously collects panchromatic imagery at 0.41m and multispectral imagery at 1.65m at nadir view. The WorldView-2 image has the stereo capability for the topographical data extraction using rational polynomial coefficient (RPC) file which is provided with the image. The WorldView-2 image was obtained from National Land Use Project (NLUP), Mid Baneshwor, Kathmandu. A sensor characteristic of WorldView-2 is described in Table 3.1 and scene details used in this study are shown in Table 3.2.

Table 3.1: Specification of WorldView-2 Image

Product	Data Detail		
Processing Level	Standard Radiometric Corrected		
Sensor	WorldView- 2		
Product Line	LV2A		
Product Type	Standard		
Image Type	PAN/MSS		
Imaging Mode	Mono		
Image Format	GeoTIFF		
Interpolation Method	Cubic Convolution		
Band/Resolution	Panchromatic	450-800nm	0.46m
	Blue	450-510nm	1.85m
	Green	510-580nm	1.85m
	Red	630-690nm	1.85m
	NIR	770-885nm	1.85m
Satellite Altitude	770 km		
Scan Direction	Reverse		
Dynamic Range	11 bits Per Pixel		
Swath Width	16.4 Km		
Revisit Time	1.1 days (depends upon latitude)		
Map Projection	Universal Transverse Mercator		
Datum	WGS84		
Zone	44N		

Table 3.2: Scene description of WorldView-2 Image

Scene	Acquisition Data	Time (GMT)	Sun Azimuth	Sun Elevation	Collection Azimuth	Collection Elevation	Cloud Cover
057211291090_01_P001	07 Dec 2017	04:54	160.8^0	38.3^0	95.2^0	73.2	0%
057211291100_01_P002	02 Dec 2017	05:10	165.7^0	40.0^0	136.7^0	72	0.5%
057211291100_01_P003	05 Dec 2017	04:53	160.4^0	38.3^0	160.1^0	79.4	0%
057211291100_01_P004	07 Dec 2017	04:54	160.8^0	38.2^0	94.8^0	73	1.1%
057211291100_01_P005	07 Dec 2017	04:54	160.6^0	38.1^0	77.9^0	70.1	2.4%
057211272060_01_P001	14 Nov 2016	05:01	163.0^0	43.4^0	312.2^0	79	0.5%

The WorldView-2 image used in the study area is shown in Figure 3.1.

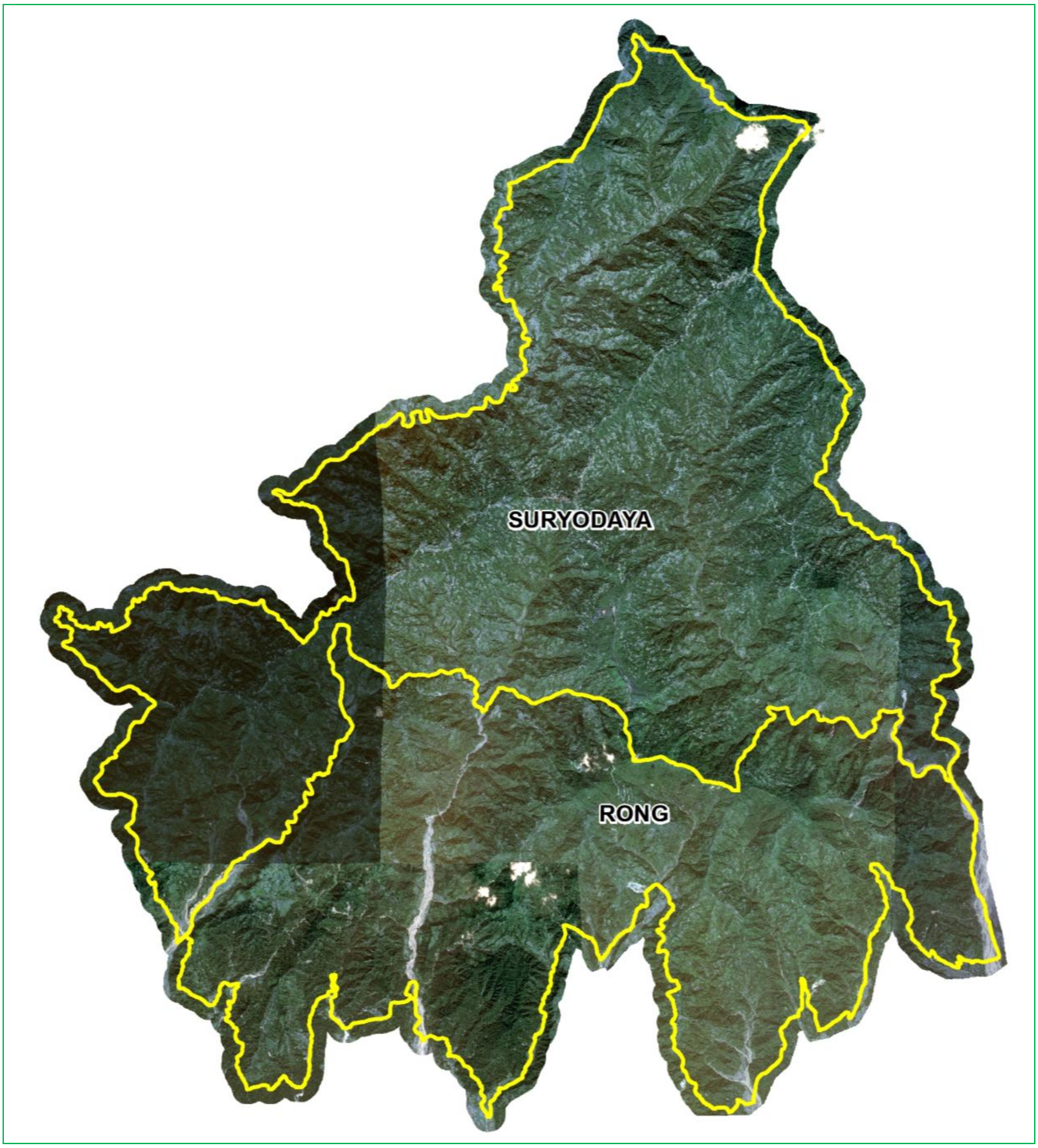


Figure 3.1: WorldView-2 Image of the Study Area

Topographical Map

Topographical Maps of the Study area are covered under 2687-04B, 2687-04D, 2688-01A, 2688-01B,2688-01C, 2688-01D, 2688-05A, 2788-13A and 2788-13B in the scale of 1: 25000 scale with contour interval 20m bearing supplementary contour of interval 10m and in some areas even 5m. These maps are published in 1996 and are compiled from 1: 50000 scale aerial photography of December, 1990 and field verification done in December, 1996. Both hard copy and soft copy covering the 2 project Gaunpalika/Nagarpalika and its surrounding was obtained from Survey Department of Nepal. The Topographical Maps were used for planning process of GCPs collection with DGPS survey and also used for feature extraction of dataset such as drainage network, Gaunpalika/Nagarpalika boundary, location name, etc and additional data for GIS based analysis.

Digital Elevation Model

Digital Elevation Model was prepared from the spot height, contour and river data of Topographic map of study area prepared by Department of Survey. The DEM was created in ArcGIS using topo to raster tool. The DEM was used for the ortho-rectification of the image and to derive information such as slope, aspect, relief intensity surface etc for performing different terrain analysis. The DEM prepared from contours of topographical map is overlaid with Suryodaya Nagarpalika boundary of respective Nagarpalika of this project. The Nagarpalika boundary overlaid in DEM is shown in Figure 3.2.

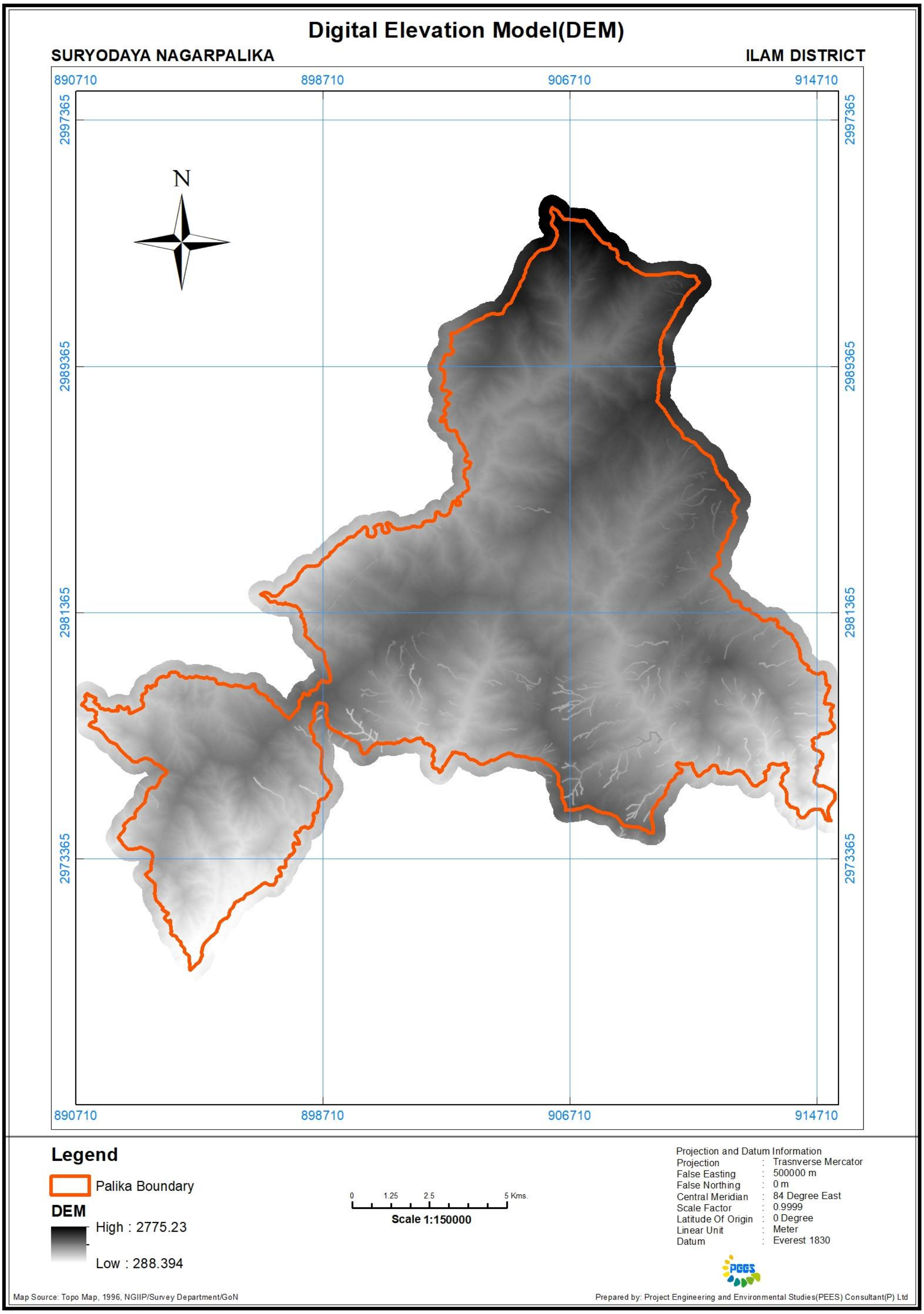


Figure 3.2: DEM of Suryodaya Nagarpalika

LRMP Maps/Reports

Land Utilization, Land System and Land Capability maps and reports prepared by Land Resource Mapping Project (LRMP), 1986 were used as references for getting insights into existing land use classification and zonation system of Nepal. These maps are used to aid the classification process in the study.

Land Use Policy

Land Use Policy (2072) was the main basis for the classification of the land use categories. The policy was reviewed and amended of national land use policy 2069. The major land use categories ascribed by the policy were adopted in classifying the existing land use of the study area.

Key Informants Interview (KII)

Key Informants Interview (KIA) conducted interviewing selected individuals for their knowledge and experience in land use, forests (species and management) and cropping pattern and their related issues. Interviews were qualitative, in-depth, and semi-structured. The interviews were guided by a checklist of topics/issues or open-ended questions.

Formal and Informal Consultation, Discussion and Observation

Formal/informal discussion with Nagarpalika members, local stakeholders and people of different backgrounds and social identities was conducted to identify key actors and agents of the project and to explore the underlying socioeconomic, cultural and bio-physical situation that have shaped the optimum utilization of resources and land use practices. Observation was made for confirm the land use pattern and their practices

Ground Control Point

Differential global positioning system (DGPS) survey was carried out for the collection of ground control points (GCPs) including check points. The DGPS survey for this Package 4 of Suryodaya Nagarpalika and Rong Gaunpalika was carried during 2th Magh, 2074 to 6th Magh, 2074. The survey was done using two numbers COMNAV T300 professional differential global positioning system equipment which has connected with reference points for linking in the national geodetic network and established by the Survey Department. The DGPS stations were established on the locations identifiable in the Worldview 2 imagery as well as on the ground with well distributing covering entire study area and range of elevation. At each GPS station, reading was made for 1hour The DGPS readings were later processed using post processing software to get adjusted co-ordinates of GPS points. Then, these adjusted co-ordinates were transformed into national co-ordinate system. The co-ordinate list of GCPs used in the study is shown in Appendix- 1. The distribution of GCPs point location overlay on WorldView-2 imagery is shown in **Figure 3.3**.

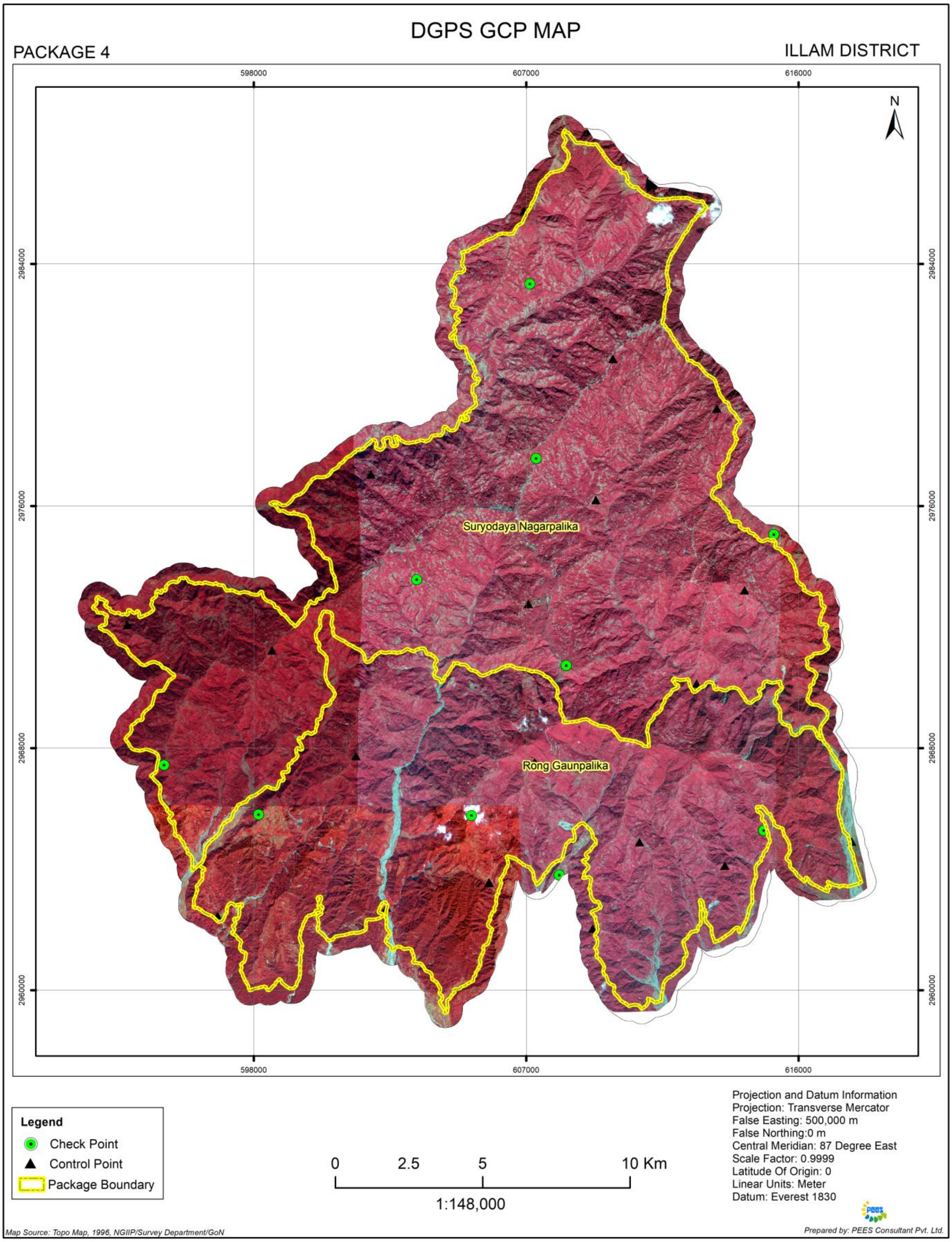


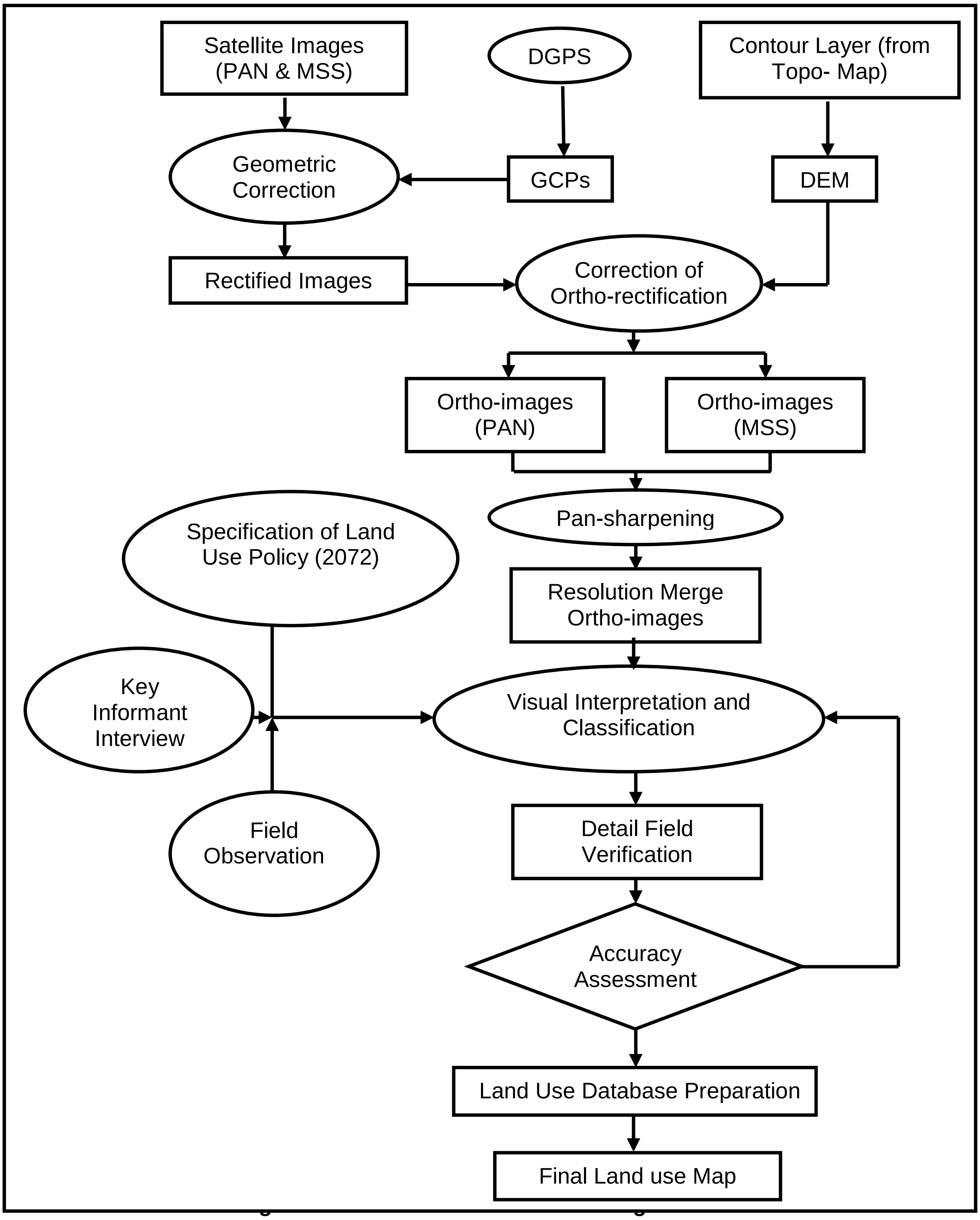
Figure 3.3: Distribution of GCPs locations on Imagery

3.2 Methods Adopted

The specific approaches and methods adopted to generate the Nagarpalika level land use map of the project is explained briefly with the flow diagram in **Figure 3.4.**

The stepwise procedure adopted to generate the land use map of the area is following:

- Geometric Correction and Ortho-rectification
- Pan-sharpening (Image Fusion)
- Visual Image Interpretation and classification
- Detail Field Verification
- Mapping and Accuracy Assessment
- Land Use Geo-database Creation



3.2.1 Ortho-rectification of Satellite Image

For an image taken with high resolution satellite (VHRS) with push broom sensor in which each image line is taken at a different instance of time, i.e. each scan line has its own perspective projection model. On satellite board, there is GPS receivers which are used for determining satellite ephemeris, i.e. camera position with respect to time. Star trackers and gyros on board measure the camera attitude angle (roll, pitch and yaw) as a function of time (Grodecki and Gene, 2003). The sensor camera position and attitude angle most essential to geo-rectification of VHRS optical images. Geometric corrections include correcting for geometric distortions due to sensor-earth geometry variations, and conversion of the data to real world (Tempfli, Bakker, & Kar, 2001). Geometric correction was done to compensate for errors caused by variation in altitude, velocity of sensor platform, rotation of the earth and earth curvature etc.

For the geometric correction of optical images, there are two mathematical approaches commonly used. The first is rigorous sensor model (RSM) which is parametric based on satellite orbital parameters; is used in direct geo-referencing techniques which describes physically the image generation process from the focal plane location of an instrument pixel to an earth surface location in terms of earth coordinate system i.e. this model is established relationship between the point on the image and the correspondent point on the ground (Kaveh and Mazlan, 2011) using model as;

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = kM_a M_b \left[\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} - m \begin{bmatrix} 0 \\ 0 \\ f \end{bmatrix} - \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} \right] \qquad (3.1)$$

The second is rational polynomial functions (RPFs) which are non–parametric or generic or universal sensor models which provide a standardized and easy to use mathematical model to map object coordinates to image column and row values of the original image. Exterior and interior orientation can be implicitly encoded in the form of RPFs using third order polynomials for numerator and denominator. The universal sensor model provides the transformation of object space coordinates to image space coordinates, which is available in standard format for a lot of remote sensing satellite systems (Reinartz.P.et al, 2010) and each of the RPFs for a row and column is given by the ratio of two polynomials of third order with normalized ground coordinate (λ, Φ and h) with 20 coefficients. The advance form of RPF is the rational polynomial co-efficient (RPC) which has universally used for interior and exterior orientation of each satellite images for transformation of image column and row values of the original image to object ground co-ordinates using third order polynomials for numerator and denominator of at least 80 coefficients.

In order to improve the geometric accuracy of the original RPCs, these has to be corrected using GCP collected from ground survey technique of DGPS survey and geometric adjustment has done using least square adjustment with affine transformation for estimate the error occurring between the satellite scene and the reference scene. The corrected image coordinates are computed based on the affine transformation and given by;

$$row = a_0 + a_1 . rpc_r + a_2 . rpc_c$$

$$col = b_0 + b_1 . rpc_r + b_2 . rpc_c \qquad (3.2)$$

Where rpc_r and rpc_c are the originally rational polynomial coefficients provided by satellite image provider or vendors. The RPCs mathematical model are widely used for geo-referencing the images (Lehner et al., 2005).

Ortho-rectified images are the most popular product from high spatial resolution satellite sensors and digital image for the accurate representation of the earth planimetric features or objects as a map (Toutin, 2004). So, it is a map like geometric properties i.e. orthogonal projection with earth reference terrestrial (geographic) coordinate system which preserves the shape of the earth surface and makes the distance measurements possible across the entire image accurately. It is used for the measurements and analysis where a high positional accuracy is required. Nowadays, it is possible to represent the earth surface accurately by DEM, which is useful for environmental planning; monitoring and decision support system and plays an important role in impact of environment and the associated human, cultural, and physical landscape.

Satellite images do not represent the real world features/objects in its actual geometric position due to perspective geometry. The effect of object height, terrain relief, and curvature of the earth, systematic error in aircraft flight or satellite system and object displacements introduces geometric error in the image. Due to the perspective projection of the satellite sensor, scale distortion, effect of the tilt and relief displacement is more prominent in outward direction from the nadir point causes the non-uniform scale over the different part of the image (Schenk, 1999). In ortho-rectification process, oriented image and elevation data are used for differential rectification to transfer perspective projection to orthogonal projection in oriented image and re-sampling process is used for computing the new geometric and radiometric properties of the image of each location after ortho-rectification (Schenk, 1999). Without performing ortho-rectification, the scale of the photograph/image is not constant and uniform over the entire scene as well there is not possibility of accurate measurements of distance and direction. In order to ortho-rectify a transformation model is required which takes into account the various sources of image distortion mainly caused by elevated objects and its relief displacement at the time of photograph/image acquisition. These distortions is eliminated or reduced by ortho-rectification using high quality DEM, but only DEM is not sufficient to eliminate the effect of elevated objects and occlusion caused by it completely.

The present project used geometric correction of satellite images using RPCs mathematical model with RPCs file and GCPs collected with DGPS technique in national co-ordinate system as reference co-ordinate system. Details of Nepalese co-ordinate system of central meridian 87^0 E is as following:

Spheroid	: Everest 1830
Semi-major Axis	: 6377276.345
Semi-minor Axis	: 6356075.413
Inverse Flattering	: 300.8017
Projection	: Modified Universal Transverse Mercator (MUTM)
Origin	: Longitude 87^0 E, Latitude 0^0 N (Equator)
False Co-ordinate	: 500000m Easting, 0m Northing
Scale Factor	: 0.9999 at Central Meridian

Ortho-rectification was done based on geometrically corrected images and DEM generated from topographical contours. Ortho-rectification of seven satellite images were carried in bundle block adjustment in the LPS of Erdas imaging using of these satellite images with its RPC file for interior orientation, GCPs points for exterior orientation and refinement of the geometric position of the satellite images and DEM generated from topographical contours. The minimum and maximum residual errors are ±0.126m and ± 0.982m in Easting and the minimum and maximum residual errors are ±0.108m and ± 0.850m in Northing with the overall root mean square error (RMSE) is ±0.639m.The minimum and maximum residual errors are shown in Appendix-2.

Visualization of different Color Composite

Enhancing of the spatial resolution was carried out by Image fusion of the multi-spectral images among themselves (i.e. generating color composite). In this way, Intensity of panchromatic image is utilized to get the better detail view. As the date and time of the acquisition of these two sets of satellite imagery do not vary that much, we also conducted the image fusion. The process is conducted in the ERDAS Imagine software.

Application of Filters

The original image consisted of spatial disturbance abundantly. To solve this problem, low pass filter was applied to smoothing tool for enhancing the spatial quality of the image.

Cloud Removal

As the image originally given by NLUP was of cloud-free, we did not have to carryout any operation for cloud removal.

Pan-sharpening

Pan-sharpening (resolution merge or image fusion) technique has used to create a high resolution multispectral data set by the fusion process of high resolution panchromatic data with lower resolution multispectral data. Now-a days in image processing several methods of pan-sharpening are used such as Brovey transform, Multiplicative technique, Principal Component Analysis (PCA), Intensity Hue Saturation (IHS) transform, Wavelet transform, Euler's technique, Gram-Schmidt transform etc. For present project, the pan-sharpening was carried using Brovey transform to visually increase contrast in the low and high ends of an image's histogram (i .e. to provide contrast in shadows, water and high reflectance areas such as urban features). Pan-sharpening was done using Multiplicative technique to increase presence of the intensity component and involved in urban or suburban studies, city planning, and utilities routing roads and cultural features (which tend toward high reflection) to be pronounced in the image. Pan-sharpening was done using PCA technique for better spatial and spectral resolution. Similarly, it also used IHS transform for stretching the contrast so that it has approximately the same variance and mean as intensity image and substituted the intensity of image for high resolution image. Pan-sharpening was done with Gram-Schmidt transforms that gives more accurate due to it uses the spectral response function. Pan-sharpening was done using wavelet transform technique to analyze signal in time domain and frequency domain respectively and the multi-resolution analysis is similar with Human Vision System. Pan-sharpening was done using Euler's technique to preserves the spectral characteristics of the lower spatial resolution multispectral images for single-sensor, multi-sensor, and multi-temporal fusion. The requirement for pan-sharpening is that the both images are registered or rectified with an accuracy of 0.25 pixels; otherwise pan-sharpening images may not give the better results. In this study, pan-sharpening was done with Brovey transform technique.

3.2.2 Classification

Initially the radiometrially and geogmetricall rectified satellite Image was classified using the supervised classification method adopting the maximum likelihood classifier algorithm.

Training samples were collected during the field visit, at the time when soil samples were being collected. Samples for the specified thematic classes were fed in the required number to enhance the higher precision of the classified result. The process was conducted using in the ERDAS Imagine software. However, this classification did not render the good result. Theory has already been established in the context of the result of the satellite imagery. Since spectral information based classification renders mixed result, it was found not suitable to directly use as the basis for the land use mapping. Error matrix was generated to see the level of the error in classification. Expert Knowledge is always essential over this result. Hence we only applied the classification over the agricultural area to extrac different level of cropping pattern in the field.

Therefore, multiple image processing techniques were performed to extract the information from the satellite imagery. Subsets of information were extracted from one type of processed product whereas the other subsets were extracted from the other product. Techniques such as Intensity, Hue and Saturation separation, Principal Component Analysis and NDVI calculation were carried out, the product of which were the main inputs for the DRAFT classified result.

3.2.3 Visual Interpretation

Visual interpretation is the process of identification and classification of land cover classification. Most intuitive way to extract information from the satellite imagery is visual image interpretation (Tempfli, Bakker, & Kar, 2001).Visual image interpretation assisted by extensive field visit was used to derive the land use classes from the imagery. The main basis for the land use mapping is the extensive field visit with satellite imagery at 1:5000 scale where different ancillary layers such as NDVI, Image ratio, DEM were used in support while performing this task.

Two extremely important issues must be addressed before undertaking task of image interpretation for delineating land use classes. The criteria to be used to separate the various land use and land cover categories of features occurring in the photographs. For example, in mapping land use the interpreter must fix firmly in mind what specific characteristics determine if an area is residential, commercial, public service or industrial. This was guided by the definition of land use classes defined by Land Use Policy (2072). Interpretation elements such as tone, texture, shape, size, pattern, site and association were used for digitizing, editing and assigning land use classes. The size of an object is one of the most distinguishing characteristics and one of the most important elements of image interpretation. Many natural and man-made features on the ground have very unique shapes that can be referenced in photo and image interpretation. For example, Schools and Colleges can be identified by their peculiar L shape.

Tone of the imagery is important while classifying land cover categories. The tonal variation among different land use is a basis for demarcating land use boundary. Each color is caused by the mixture absorbing some wavelengths of light and reflecting others. We may use color-combining techniques to create color composite images. Knowledge of the bands other than the visible range of spectrum increased the quality of the interpretation. For example Vegetation appears red in standard false color composite. Texture is the characteristic placement and arrangement of repetitions of tones or color in an image. For instance Sugarcane was identified by their peculiar texture. Pattern is the spatial arrangement of objects in the landscape. Site refers to the topographic and geographic location. Some parameters of site are elevation, slope, aspect, type of surface cover, value of the land, adjacency to water etc. We can classify agricultural land into sub classes using these parameters. Association refers to the fact that combination of object makes it possible to infer its function or meaning. School can be identified by using the combination of elements shape and association. Peculiar L- shaped building with associated ground confirms that the object is school.

Vectorization and Coding

The Classified agricultural Raster Polygons were then turned into Vector using the conversion tools. Vector generalisation techniques were carried out to comply with the minimum size of the polygon as specified in the TOR. There was the necessity of assigning codes for the vector output. The database model provided by NLUP was then used to load the data so geneated.

3.2.4 Accuracy Assessment

Validation of classification results is an important process in the classification procedure. It allows users to evaluate the utility of a thematic map for their intended applications using accuracy assessment. Accuracy assessment is a feedback system for checking and evaluating the objectives and the results. It determines the correctness of the classified image. It is a measurement of the argument between a standard that is assumed to be correct and a classified image of unknown quality. If the image classification corresponds closely with the standard, it is said to be accurate (Bhatt, 2008). Classification is not complete until its accuracy is assessed (Lille sand et al., 2008). There are several methods of evaluating the accuracy assessment. In general, one method is compared the classified image to a reference image and a random set of points are generated for the comparison of the classification result with the true information classes in the reference image. A second method is used to perform accuracy assessment involves using a GPS and again a random set of points are generated over the classified image with ground truth has performed by going into the field at the location of each randomly generated point (Bhatt, 2008). These methods are used for sample schema and evaluation process is done with generating confusion matrix and its test statistics with kappa coefficients for the test statistics and kappa index of agreement (KIA) for each category of class.

In this study, validation of classification results were done for the quantification and evaluation of error using confusion matrix (error matrix) which compares the class-by-class based on the training samples with visual interpretation of original images and classification result classes at Level-1. The size of interpretation unit and number of polygons that belong to the unit do not influence the number of points. The total area covered by one legend unit is not taken into account for other legend unit. A total of 315 samples points in study area were taken for confusion matrix generation. The confusion matrix was generated based on the comparison between the classified image and the existing ground using GCPs collected from visual interpretation i.e. the matrix depicts the land cover classification categories versus the field observed land cover type. This matrix was an N x N matrix of “classified” and “observed” cells corresponding to N land cover class. Classification result is given as rows and reference (ground truth) is given as columns for each sample. The diagonal elements in this matrix indicate numbers of sample in which classification results has agreed with the reference data. Off-diagonal elements in each row present the sample that has been misclassified by the classifier at classification process (Bhatt, 2008). These error matrices were evaluated by computing the user accuracy, producer accuracy and overall accuracy which was tested statistically with the KIA (Kappa statistics). The KIA was calculated with the following formula (Congalton 1991).

$$K = \frac{N\sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r}(X_{i+} * X_{+i})}{N^2 - \sum_{i=1}^{r}(X_{i+} * X_{+i})} \tag{3.3}$$

Where:

- r = is the number of rows in the matrix
- X_{ii} = is the number of observations in rows i and column I (along the major diagonal)
- X_{i+} = the marginal total of row i (right of the matrix)
- X_{+I} = the marginal totals of column i (bottom of the matrix)
- N = the total number of observations.

The error matrix/ confusion matrix was generated from 335 sample point as the ground truth point for thematic accuracy assessment. The summary of error matrices of classified images is shown in Appendix-3.The overall accuracy represents the percentage of correctly classified pixels; it is achieved by dividing the number of correct observations by the number of actual observations. The overall accuracies with KIA (kappa statistics) were found 95.87% and 0.94 for the classified objects of the study area.

Table 3.3: Summary of Accuracy Assessment

Land Use/Land Use	Agriculture	Forest	Residential	Commercial	Industrial	Public Services	Mine and Minerals	Cultural and Archeological	Riverine and Lake Area	Other	Total
Agriculture	166	0	1	0	0	1	0	1	0	0	169
Forest	0	44	0	0	0	0	0	0	1	0	45
Residential	0	0	32	2	0	0	0	0	0	0	34
Commercial	0	0	1	8	0	0	0	0	0	0	9
Industrial	0	0	0	0	1	0	0	0	0	0	1
Public Services	0	0	1	0	0	17	0	1	0	0	19
Mine and Minerals	0	0	0	0	0	0	2	0	0	0	2
Cultural and Archeological	0	0	1	0	0	0	0	7	0	0	8
Riverine and Lake Area	0	0	0	0	0	1	0	0	17	0	18
Other	0	1	0	0	0	0	0	0	0	9	10

Total	166	45	36	11	0	19	2	9	18	9	315

Land Use	User's Accuracy (%)	Producer's Accuracy (%)	Commission Error (%)	Omission Error (%)	KIA per Class
Agriculture	98.22	100.00	1.78	0.00	0.96
Forest	97.78	97.78	2.22	2.22	0.97
Residential	94.12	88.89	5.88	11.11	0.93
Commercial	88.89	72.73	11.11	27.27	0.89
Industrial	0.00	100.00	100.00	0.00	1.00
Public Services	89.47	89.47	10.53	10.53	0.89
Mine and Minerals	100.00	100.00	0.00	0.00	1.00
Cultural and Archeological	87.50	77.78	12.50	22.22	0.85
Riverine and Lake Area	94.44	94.44	5.56	5.56	0.94
Other	90.00	100.00	10.00	0.00	0.90

Overall Accuracy = 95.87%
Overall KIA = 0.94

CHAPTER 4: PRESENT LAND USE PATTERN IN SURYODAYA NAGARPALIKA

The chapter describes the present land use pattern of Suryodaya Nagarpalika. General land cover pattern shows that agricultural land dominates land use of this area. This chapter presents land use assessed in different levels of hierarchy.

4.1 Land Use Pattern

General land use of Suryodaya Nagarpalika at first hierarchical level of classification is provided in Table 4.1 and Figure 4.1 below. Out of the designated 11 land use classes, 9 land use classes do exist in the Nagarpalika excepting the Mining and Mineral land use, and Excavation area land use classes. Out of total 22438.57 hectare land, 89% area is covered by agriculture followed by forest with 5.24%. The residential area covers with 2.57% of the Nagarpalika extent. Public services which include transportation, security, health, education etc. cover about 1.81% of the area. The riverine and lake area covers with 1.06% of the Nagarpalika extent. Similarly, under designed other, commercial and industrial area covered 0.11%, 0.02%, and 0.02%. Furthermore, cultural and archeological area covers 0.004% area of the Nagarpalika extent, which has negligible. Spatial distribution of land use patterns in Suryodaya Nagarpalika has also been presented in Map (Appendix 4).

Table 4.1: General land use of Suryodaya Nagarpalika

SN	Description	Area(Ha)	Percentage
1	Agricultural	20008.89	89.17
2	Forest	1176.13	5.24
3	Residential	575.95	2.57
4	Public Use and Open Space	405.79	1.81
5	Riverine and Lake Area	238.89	1.06
6	Other	24.03	0.11
7	Commercial	4.15	0.02
8	Industrial	3.92	0.02
9	Cultural and Archeological	0.81	0.004
10	Mine and Minerals	0.00	0.00
11	Excavation	0.00	0.00
Total		**22438.57**	**100.00**

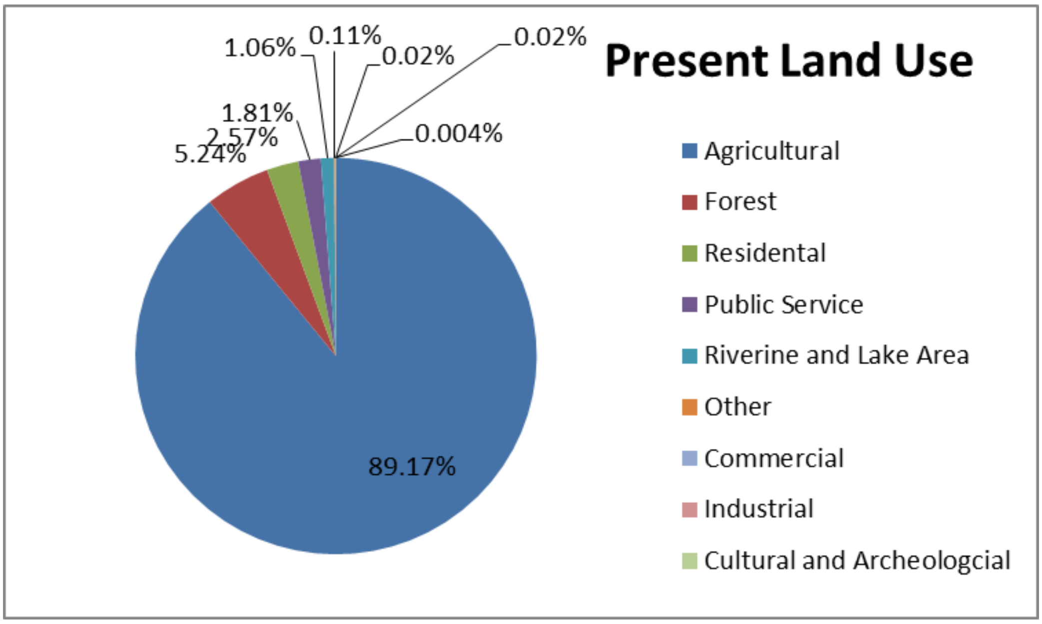


Figure 4.1: Present Land Use of Suryodaya Nagarpalika

4.1.1 Agricultural Land Use

All types of the agricultural land fall under the **Hill Cultivation** at the hierarchy **Level 2**. According to the hierarchical classification **Level 3**, based on the landform and land system the entire agricultural land use pattern of the Nagarpalika has been categorized as **Level Terraces** and **Sloping Terraces**. Further, the agricultural land use pattern of **Level Terraces** cultivation can be categorized into **Level Terraces Khet Land Cultivation** and **Level Terraces Upland/Pakho Land Cultivation** according to the hierarchical classification **Level 4**, based on the cultivation types with availability of water, which is determined either by moisture contain or irrigation facilities. Similarly, **Sloping Terraces** cultivation can be categorized into **Slopping Upland/ Pakho Land Cultivation,** according to the hierarchical classification **Level 4.** Furthermore, according to the **Level 5**, based on the cropping pattern, the agricultural land use pattern in the Nagarpalika is found under **Tea, Shrub for non-forest area, Amriso, Rice-Maize, Rice-Rice, Cardamom, Rice-Wheat, Vegetable-Vegetable, Maize-Vegetable, Maize-Potato, Maize-Others, Maize-Rice-Cereal, Rice-Maize-Vegetable, Coffee, Fruits, Ginger, Rice-Potato, Maize-Millet, Rice-Others, Potato-Vregetable Crops, Livestock/Cattle/Buffalo Farm** and **Floriculture.** Tea is the dominant summer crop. Table 4.2 and Figure 4.2 present the cropping pattern of the Suryodaya Nagarpalika.

Table 4.2: Cropping patterns of the Suryodaya Nagarpalika

SN	Description	Area(Ha)	Percentage
1	Tea	7522.43	37.60
2	Shrub from non-forest area	3881.31	19.40
3	Amriso	2644.48	13.22
4	Rice-Maize	1736.20	8.68
5	Rice-Rice	1575.32	7.87
6	Cardamom	714.31	3.57
7	Rice-Wheat	394.24	1.97
8	Vegetables-Vegetable	356.90	1.78

9	Maize – Vegetable	307.07	1.53
10	Maize-Potato	293.04	1.46
11	Maize-Other	133.91	0.67
12	Maize-Rice-Cereal	101.80	0.51
13	Rice-Maize-Vegetable	97.94	0.49
14	Coffee	85.92	0.43
15	Fruits	53.36	0.27
16	Ginger	52.10	0.26
17	Rice-Potato	26.18	0.13
18	Maize-Millet	15.82	0.08
19	Rice-Others	14.35	0.07
20	Potato-Vegetable Crops	2.14	0.01
21	Livestock/Cattle/buffalo Farm	0.06	0.0003
22	Floriculture	0.01	0.0001
Total		**20008.89**	**100.00**

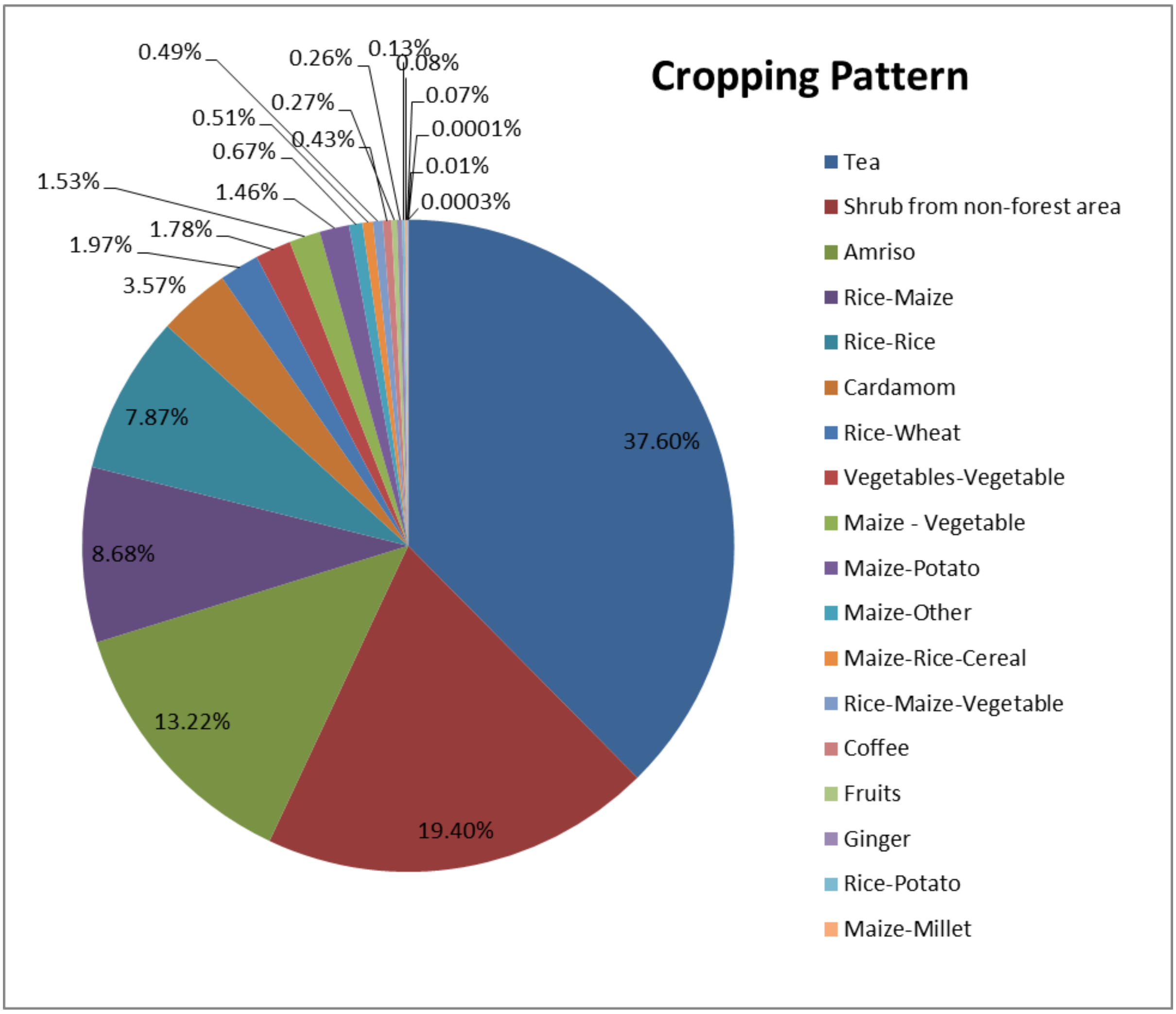


Figure 4.2: Cropping Pattern of Suryodaya Nagarpalika

The Nagarpalika witness 79% of agricultural land having medium cropping intensity where as 20% of arable land of not applicable intensity. Although, Livestock/Cattle/Buffalo Farm land area has not directly related them with cropping intensity, these have been included in the not applicable area.

4.1.2 Forest

DFRS (Department of Forest Research and Survey) report was reviewed and its data has considered as reference for forest area delineation. Suryodaya Nagarpalika possesses Forest area has the second higher coverage of the Nagarpalika extent having 1176 ha with 5% of the extent of Nagarpalika area. The entire forest in the Nagarpalika has the sub-tropical forest in the hierarchical level 2 of the forest classification. The forest area in the Nagarpalika has categorized into hardwood and mixed wood based on species type. The forest area is of hard wood covered mainly **Chilaune, Dhupi** and **salla**.

4.1.3 Residential Use

Suryodaya Nagarpalika has 2.57% residential area. Residential areas of this Nagarpalika is categorized as moderate populated at majority, sparsely populated as moderately and densely populated at minority of the former having 288ha, 165ha and 123 ha respectively. The distribution of these categories has been given in the following Table 4.3 and Figure 4.3. All of the residential area having was residential cluster area.

Table 4.3: Concentration of Residential Area

SN	Description	Area(Ha)	Percentage
1	Moderately Populated	287.73	49.96
2	Sparsely Populated	165.19	28.68
3	Densely Populated	123.02	21.36
Total		575.95	100.00

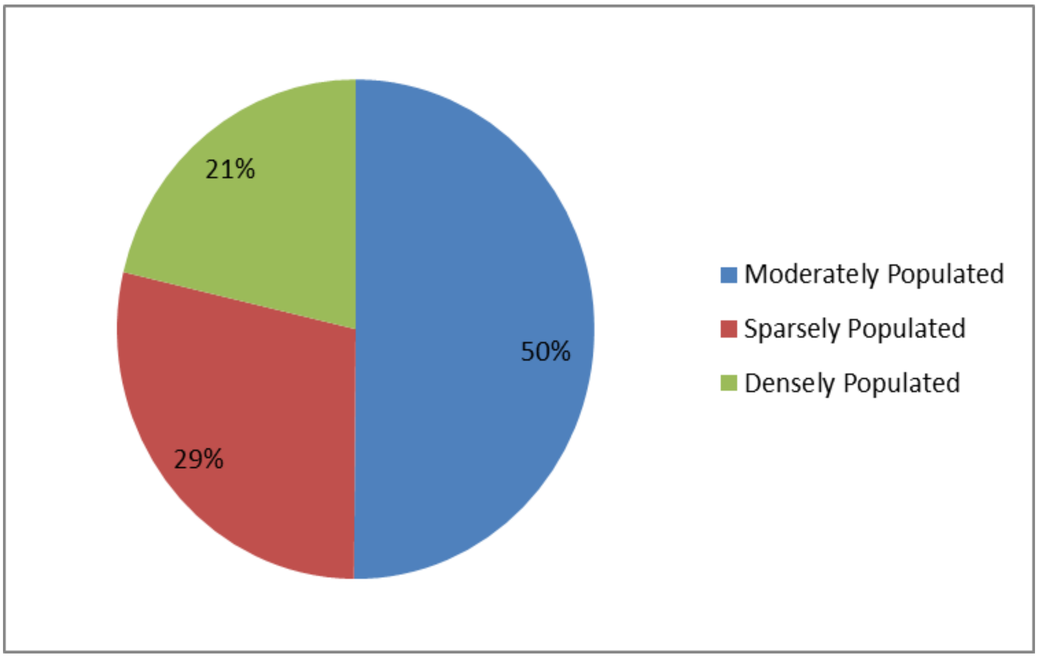


Figure 4.3: Residential Use

4.1.4 Commercial Use

Suryodaya Nagarpalika has 0.02% commercial area having 4.15 ha. Commercial areas of this Nagarpalika are categorized as business area and service area having majority of business area.

4.1.5 Industrial Use

Suryodaya Nagarpalika has 0.02% industrial area having 3.92 ha. Industrial areas in the Nagarpalika are categorized as small scale industry.

4.1.6 Public Use and Open Space

According to the hierarchical Level 2, the public use and open space area in the Suryodaya Nagarpalika has categorized into Transportation Infrastructure area, Institutional area, Educational area, other public area, Recreational area, Utility service area, Security service area and Health service area. Transportation Infrastructure area are different categories of road such as agriculture road, development road and others road in the Nagarpalika. The area covered by each type of the public service is shown in the Table 4.5. According to the table information, the area occupied by the transportation Infrastructure area is the largest, more than 97% the public service area in the Nagarpalika, which is followed by Educational area. Educational services such as school, college; Health services such as health center, health post; Security services, area has police station; Recreational such as playground area. Educational area (1.6%), Institutional area are compromises 1% whereas Other public area (0.47%), Recreational area (0.09%), Utility service area (0.07%), Health services (0.05%), and Security service (0.05%) of the public service area. Detail of the public services area is presented in Table 4.4.

Table 4.4: Public services of Suryodaya Nagarpalika

SN	Description	Area(Ha)	Percentage
1	Transportation Infrastructure	393.86	97.06
2	Educational	6.57	1.62
3	Intuitional Area	3.89	0.96
4	Open Area	0.64	0.16
5	Utility Service Area	0.30	0.07
6	Security Service	0.20	0.05
7	Health Service	0.19	0.05
8	Other Public Use Area	0.14	0.03
Total		**405.79**	**100.00**

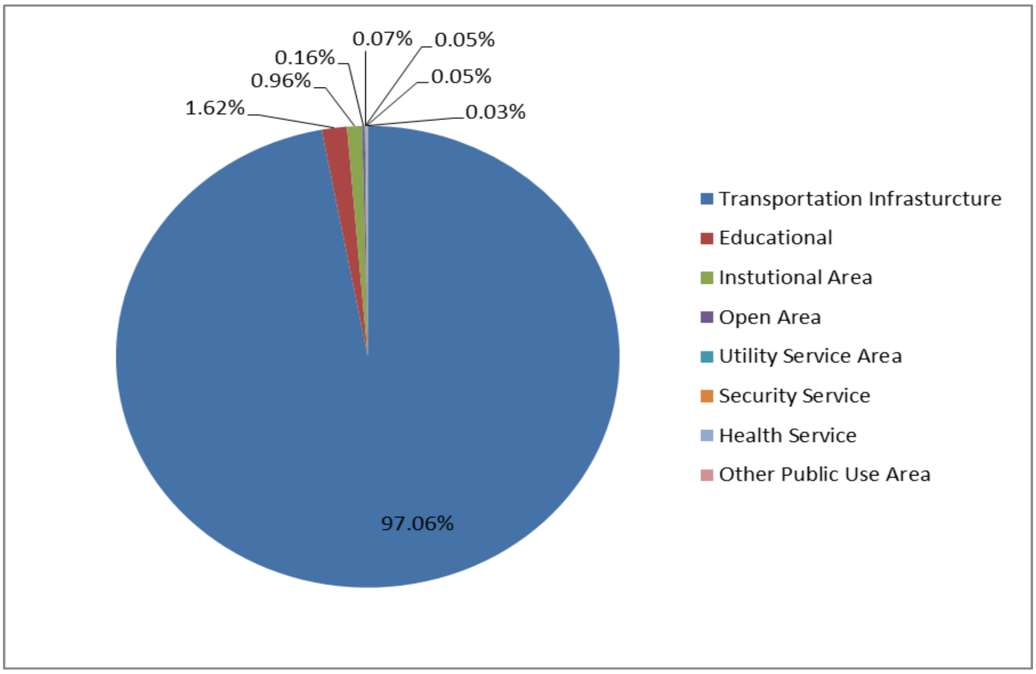


Figure 4.4: Distribution of Public Service

4.1.7 Cultural and Archeological Use

Suryodaya Nagarpalika has 0.004% cultural and archeological area having 0.81ha. Cultural and archeological use of this Nagarpalika is categorized as Temple, Mosque and other and other cultural as well as heritage site area.

4.1.8 Riverine and Lake Area

Suryodaya Nagarpalika has 1.11% riverine and lake area having 250ha. Riverine and Lake Area has categorized at the majority of River followed by other hydrographic features. **River** has mainly having 142ha the highest, which is followed by **other hydrographic features** occupied (79ha), **Sand** (16ha) and **Pond** (2ha). The detail of the Riverine and Lake Area is presented in Table 4.5 and Figure 4.5.

Table 4.5: Riverine and Lake Area Suryodaya Nagarpalika

SN	Description	Area(Ha)	Percentage
1	River	142.06	59.46
2	Other	78.92	33.04
3	Sand	15.51	6.49
4	Pond	2.40	1.01
Total		**238.89**	**100.00**

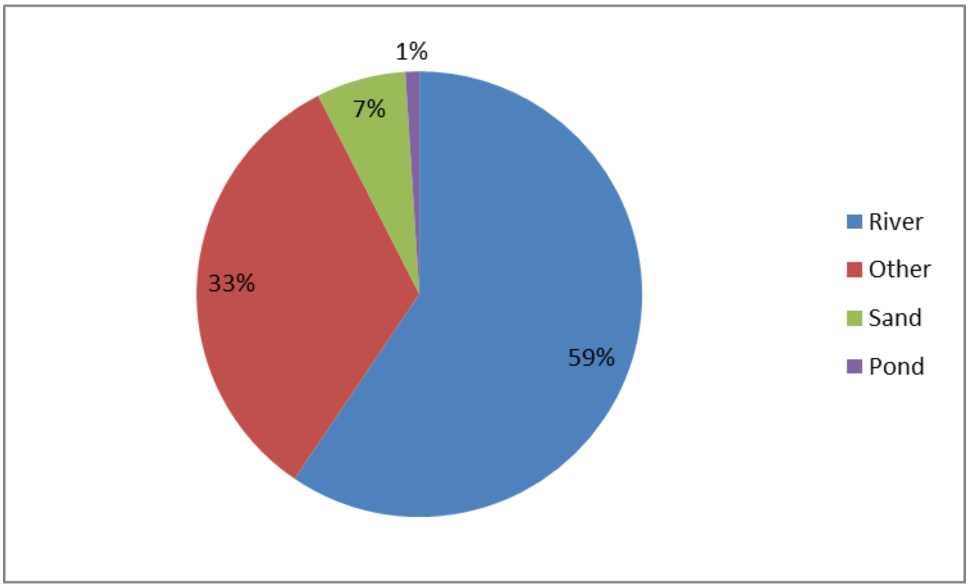


Figure 4.5: Distribution of Riverine and lake Area

4.1.9 Others Area

Other land use area has categorized as others and grazing land. The coverage of other land use area in the Suryodaya Nagarpalika is 24 hectares with 0.11% of the Nagarpalika area.

4.2 Land Use GIS Database

Present Land Use database prepared for this study is strictly followed as Geo-database provided by NLUP for this project as specification (Table 4.6). All data related to land use prepared for this study have been submitted in digital format with this report to NLUP office.

Table 4.6: Database for present land use

Field	Data Type	Description	Remarks
FID	Feature Id	Feature	FID
SHAPE	Geometry	Geometric Object type	SHAPE
ID	Long	Unique Object ID	ID
LEVEL 1	String	Land Use Class	LEVEL 1
LEVEL 2	String	Land Use Class	LEVEL 2
LEVEL 3	String	Land Use Class	LEVEL 3
LEVEL 4	String	Land Use Class	LEVEL 4
LEVEL 5	String	Land Use Class	LEVEL 5
LEVEL 6	String	Land Use Class	LEVEL 6
LEVEL 6	String	Land Use Class	LEVEL 6
AREA	Double	Area in Square meter	AREA
AREA_HA	Double	Area in Hectare	AREA_HA

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The present land use pattern of the Suryodaya Nagarpalika under study was classified using remotely sensed image with the help of ground based information. The classification system has posed in assigning the classes of different level hierarchy in land use. Hierarchical classification system helped in incorporation of complex land use pattern of this Nagarpalika. Priori classification system used in the study attribute to standardization in the land use result among different Nagarpalika. Visual image interpretation incorporated with extensive field visit and use of ancillary data such as LRMP map, slope map, DEM, NDVI was used to generate land use map. For mapping at scale 1:10,000 combinations of different levels are used. The accuracy of the results was assessed and overall accuracy was obtained to be 95.87% with KIA 0.94.

The land use classes yield better accuracy because the classes are designated manually based on ground knowledge and visual interpretation rather than automatic classification. These land use data and map can be used to formulate land use and other plans for the Nagarpalika under study. Further it can also be used for management activities and regulating land use activities in the Nagarpalika.

Out of the designated 11 land use classes, 9 land use classes do exist in the Nagarpalika excepting the Mine and Mineral land use, and Excavation area land use classes. Out of total 22438 hectare land, 89% area is covered by agriculture followed by forest with 5.24%. The residential area covers with 2.57% of the Nagarpalika extent. Public Use and Open Space which include transportation, security, health, education etc. cover about 1.81% of the area. The riverine and lake area covers with 1.06% of the Nagarpalika. Similarly, under designed other, commercial and industrial area covered 0.11%, 0.02%, and 0.02% respectively. Furthermore, cultural and archeological area covers 0.004% area of the Nagarpalika extent, which has negligible.

5.2 Recommendation

Based on the experience of this project following recommendation has been made for future undertaking of similar projects.

- Comprehensive land use database model provided by NLUP facilitated in establishing the physical model very much clear, but the criteria of defining the land use polygon in an objective sense would have been further enhanced the quality and consistency of the work.
- The land use data and map can be used to formulate land use zoning system for controlling land fragmentation, unplanned, and haphazard use of public and government lands. It can be achieved through an interaction and discussions among the planners, stakeholders and decision-makers at national, regional and local levels.

- The databases being built can be valuable for sustainable development of the Nagarpalika with impartial use of resources among the locals for their economic prosperity.

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APPENDICES

Appendix 1: DGPS Coordinates of Control Points in Project Area

S.N.	Easting	Northing	Elevation	Remarks
1	493360.5	2930279	73.15703	GCP_01
2	493976.9	2933056	74.62408	GCP_02
3	496756.5	2935148	74.74872	GCP_03
4	501175.9	2938844	76.65762	GCP_04
5	502933.2	2957207	91.03538	GCP_05
6	504694.7	2960607	93.648	GCP_06
7	505831	2946710	83.0416	GCP_07
8	505916.4	2958186	92.21505	GCP_08
9	507590.5	2948991	84.47271	GCP_09
10	507883.5	2946286	83.11184	GCP_10
11	507926.8	2951139	86.21336	GCP_11
12	509009.9	2930003	71.85285	GCP_12
13	509122.4	2954528	91.21638	GCP_13
14	509338.1	2934144	75.00901	GCP_14
15	510512.3	2951648	87.48605	GCP_15
16	510590.2	2925152	67.57592	GCP_16
17	503430.7	2942466	79.4173	GCP_17
18	499169.1	2938729	75.9904	GCP_18
19	494406.9	2933940	78.5167	GCP_19
20	500765.3	2935028	73.3285	GCP_20
21	504374.8	2939424	77.4103	GCP_21
22	512082.2	2930775	71.7656	GCP_22
23	512465.3	2927133	68.54102	GCP_23
24	512896	2949959	89.34594	GCP_24
25	512947.2	2956475	95.27	GCP_25
26	512947.2	2956475	95.27	GCP_26
27	513015.5	2961278	100.1308	GCP_27
28	513015.5	2961278	100.1308	GCP_28
29	514624.8	2959511	102.5621	GCP_29
30	515526.1	2952180	90.9583	GCP_30
31	515626.1	2969973	271.3349	GCP_31
32	516670.4	2962801	117.3823	GCP_32
33	517079.6	2925494	63.984	GCP_33
34	517381.2	2967866	160.8379	GCP_34
35	517456.1	2922069	67.26569	GCP_35
36	517984.6	2973501	168.7555	GCP_36
37	518321.1	2955400	98.3731	GCP_37
38	518943.3	2958832	110.1606	GCP_38
39	519244.6	2970854	699.347	GCP_39
40	519482.8	2966567	159.4342	GCP_40
41	519898.3	2951848	99.10446	GCP_41

S.N.	Easting	Northing	Elevation	Remarks
42	520118.3	2954136	102.2482	GCP_42
43	520341.9	2956180	105.4581	GCP_43
44	520820.2	2960521	136.8803	GCP_44
45	522682.5	2921801	62.55232	GCP_45
46	522696.7	2953970	110.7812	GCP_46
47	522762.8	2970005	702.349	GCP_47
48	522992.5	2925554	65.42846	GCP_48
49	523043.9	2965837	285.3274	GCP_49
50	523128.2	2956602	117.9133	GCP_50
51	523352.9	2957791	119.5354	GCP_51
52	524228.9	2954219	116.8807	GCP_52
53	524303.1	2955795	122.3695	GCP_53
54	524872	2922355	63.00461	GCP_54
55	525345.5	2924280	65.498	GCP_55
56	526189.4	2955797	132.7399	GCP_56

Appendix 2: Ortho-rectification Error Report

S.N	X_Source	Y_Source	X_ Reference	Y_ Reference	Z_ Reference	X_Residual	Y_Residual	Total Residual	Remarks
1	493183.917	2930522.345	493360.465	2930278.850	73.157	-0.467	-0.246	0.528	Control Point
2	493713.156	2933214.672	493976.946	2933056.451	74.624	0.381	-0.324	0.500	Control Point
3	496506.436	2935060.195	496756.525	2935147.845	74.749	0.227	-0.334	0.404	Check Point
4	500925.981	2938754.683	501175.935	2938844.082	76.658	-0.099	0.227	0.248	Check Point
5	502685.578	2957089.213	502933.222	2957206.651	91.035	-0.008	0.023	0.024	Control Point
6	504445.031	2960484.423	504694.680	2960607.491	93.648	-0.092	-0.189	0.210	Control Point
7	505584.204	2946588.839	505831.025	2946709.569	83.042	0.012	0.015	0.019	Control Point
8	505667.537	2958060.621	505916.405	2958185.744	92.215	0.230	0.494	0.545	Check Point
9	507344.062	2948866.976	507590.515	2948990.970	84.473	-0.212	-0.316	0.381	Check Point
10	507637.021	2946162.928	507883.458	2946285.557	83.112	0.077	0.089	0.118	Control Point
11	507679.647	2951012.881	507926.834	2951138.748	86.213	0.163	0.192	0.252	Control Point
12	508757.664	2930148.222	509009.921	2930002.946	71.853	-0.384	-0.525	0.650	Check Point
13	508874.661	2954401.148	509122.421	2954527.849	91.216	-0.385	-0.803	0.891	Control Point
14	509068.547	2934288.343	509338.125	2934144.250	75.009	-0.520	0.609	0.801	Control Point
15	510264.531	2951520.889	510512.348	2951648.417	87.486	0.215	0.570	0.609	Check Point
16	510339.979	2925304.186	510590.156	2925151.750	67.576	0.445	-0.710	0.838	Control Point
17	503181.011	2942640.146	503430.729	2942465.602	79.417	0.615	0.314	0.690	Control Point
18	499169.127	2938728.629	499169.127	2938728.629	75.990	-0.461	-0.067	0.466	Control Point
19	494406.912	2933939.845	494406.912	2933939.845	78.517	0.421	0.348	0.546	Control Point
20	500765.284	2935028.298	500765.284	2935028.298	73.329	-0.359	-0.614	0.711	Control Point
21	504125.542	2939599.508	504374.839	2939424.347	77.410	0.521	-0.248	0.577	Control Point
22	511820.840	2930917.961	512082.202	2930774.935	71.766	0.404	-0.282	0.493	Control Point
23	512228.501	2927265.807	512465.250	2927133.000	68.541	-0.491	0.039	0.493	Check Point
24	512649.145	2949834.629	512896.021	2949958.518	89.346	-0.125	-0.239	0.270	Control Point
25	512680.083	2956353.139	512947.173	2956474.953	95.270	0.471	0.068	0.476	Check Point
26	512698.034	2956348.757	512947.173	2956474.953	95.270	0.367	0.365	0.518	Check Point
27	512752.699	2961158.504	513015.465	2961277.698	100.131	-0.579	-0.397	0.702	Control Point
28	512765.773	2961154.292	513015.465	2961277.698	100.131	0.117	0.165	0.202	Control Point
29	514362.210	2959391.213	514624.846	2959511.342	102.562	0.013	0.257	0.257	Check Point
30	515257.508	2952059.875	515526.078	2952180.017	90.958	-0.094	-0.181	0.204	Check Point
31	515356.885	2969849.891	515626.110	2969973.156	271.335	0.273	0.178	0.326	Control Point
32	516408.189	2962679.327	516670.388	2962800.648	117.382	-0.040	0.317	0.319	Control Point
33	516817.341	2925633.146	517079.563	2925494.250	63.984	0.094	-0.709	0.715	Check Point
34	517112.398	2967740.081	517381.211	2967865.687	160.838	0.208	0.501	0.542	Check Point

S.N	X_Source	Y_Source	X_ Reference	Y_ Reference	Z_ Reference	X_Residual	Y_Residual	Total Residual	Remarks
35	517208.523	2922200.208	517456.125	2922069.000	67.266	-0.469	0.128	0.486	Control Point
36	517704.824	2973375.041	517984.592	2973501.091	168.756	-0.353	-0.501	0.613	Control Point
37	518055.624	2955279.671	518321.120	2955399.831	98.373	-0.017	-0.812	0.812	Control Point
38	518678.376	2958709.877	518943.344	2958831.841	110.161	0.197	-0.974	0.994	Check Point
39	518968.054	2970728.364	519244.574	2970854.401	699.347	-0.057	-0.314	0.319	Check Point
40	519214.210	2966443.952	519482.794	2966566.955	159.434	-0.265	-0.107	0.286	Check Point
41	519628.239	2951725.725	519898.253	2951848.465	99.104	-0.592	-0.713	0.927	Control Point
42	519848.924	2954007.551	520118.309	2954135.983	102.248	0.428	0.648	0.777	Check Point
43	520073.911	2956054.043	520341.943	2956180.315	105.458	-0.148	0.065	0.162	Check Point
44	520550.743	2960395.116	520820.210	2960521.457	136.880	0.634	0.009	0.634	Control Point
45	522409.195	2921931.229	522682.500	2921800.500	62.552	0.678	-0.077	0.682	Check Point
46	522419.918	2953839.317	522696.652	2953970.268	110.781	0.767	0.279	0.816	Control Point
47	522475.627	2969873.150	522762.819	2970005.464	702.349	0.324	0.482	0.581	Control Point
48	522727.858	2925694.866	522992.531	2925553.500	65.428	-0.756	0.527	0.922	Control Point
49	522763.051	2965704.469	523043.918	2965836.589	285.327	0.038	0.336	0.338	Control Point
50	522861.775	2956491.360	523128.154	2956602.496	117.913	0.052	-0.373	0.377	Check Point
51	523076.237	2957659.352	523352.943	2957791.144	119.535	-0.536	-0.564	0.778	Control Point
52	523961.776	2954109.432	524228.898	2954219.434	116.881	0.007	0.021	0.022	Control Point
53	524035.850	2955683.976	524303.092	2955794.722	122.370	0.009	-0.225	0.225	Check Point
54	524621.147	2922258.238	524871.997	2922355.128	63.005	-0.287	-0.087	0.300	Control Point
55	525094.539	2924180.030	525345.526	2924279.579	65.498	0.167	0.348	0.386	Control Point
56	525920.839	2955685.872	526189.384	2955796.973	132.740	-0.214	0.193	0.288	Control Point
							Total RMSE	**0.546**	

Appendix 3: Accuracy Assessment of Land Use Classification

a) Confusion Matrix and Accuracy

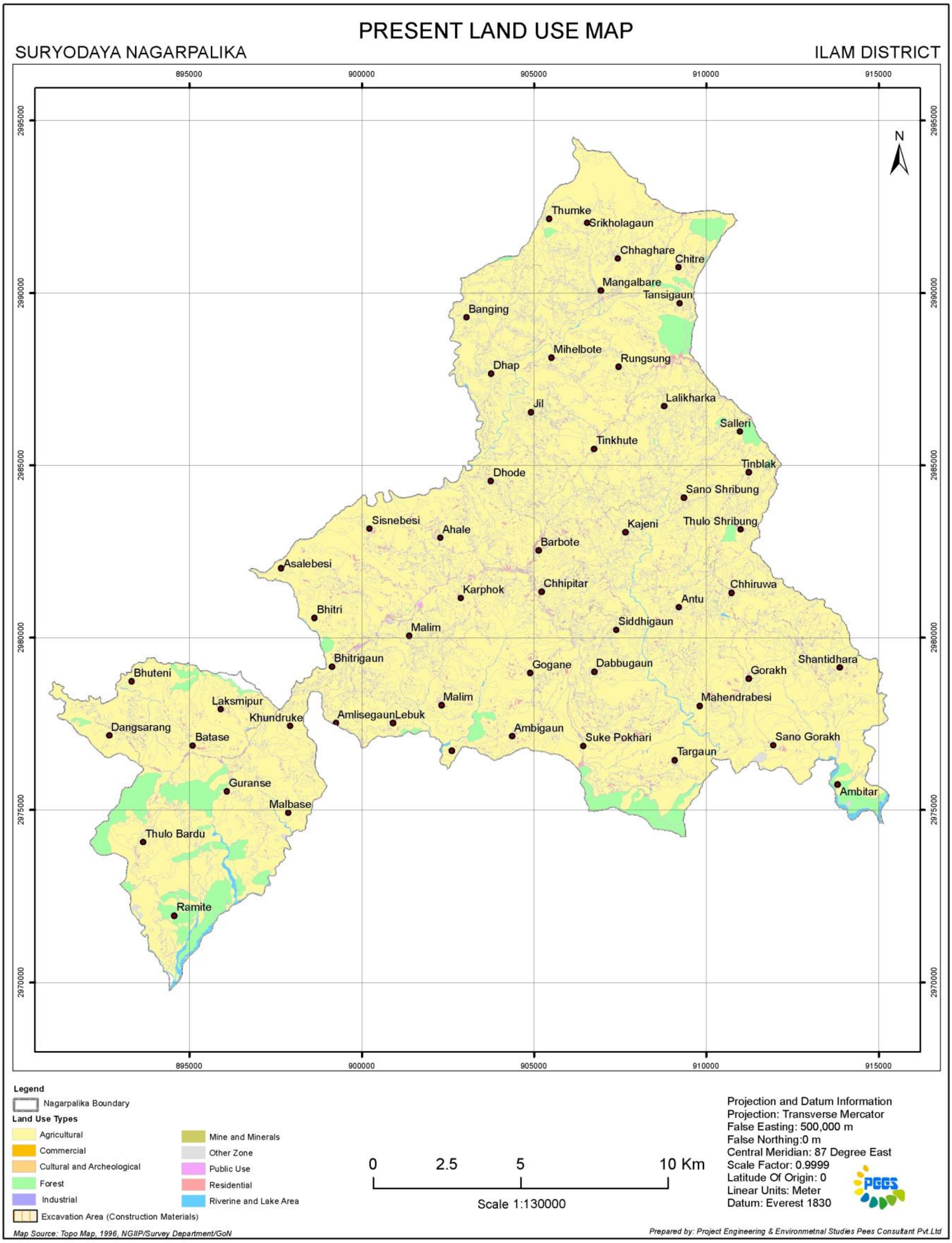
Land Use/Land Use	Agriculture	Forest	Residential	Commercial	Industrial	Public Services	Mine and Minerals	Cultural and Archeological	Riverine and Lake Area	Other	Total
Agriculture	166	0	1	0	0	1	0	1	0	0	169
Forest	0	44	0	0	0	0	0	0	1	0	45
Residential	0	0	32	2	0	0	0	0	0	0	34
Commercial	0	0	1	8	0	0	0	0	0	0	9
Industrial	0	0	0	0	1	0	0	0	0	0	1
Public Services	0	0	1	0	0	17	0	1	0	0	19
Mine and Minerals	0	0	0	0	0	0	2	0	0	0	2
Cultural and Archeological	0	0	1	0	0	0	0	7	0	0	8
Riverine and Lake Area	0	0	0	0	0	1	0	0	17	0	18
Other	0	1	0	0	0	0	0	0	0	9	10
Total	166	45	36	11	0	19	2	9	18	9	315

b.) Accuracy Table

Land Use	User's Accuracy (%)	Producer's Accuracy (%)	Commission Error (%)	Omission Error (%)	KIA per Class
Agriculture	98.22	100.00	1.78	0.00	0.96
Forest	97.78	97.78	2.22	2.22	0.97
Residential	94.12	88.89	5.88	11.11	0.93
Commercial	88.89	72.73	11.11	27.27	0.89
Industrial	0.00	100.00	100.00	0.00	1.00
Public Services	89.47	89.47	10.53	10.53	0.89
Mine and Minerals	100.00	100.00	0.00	0.00	1.00
Cultural and Archeological	87.50	77.78	12.50	22.22	0.85
Riverine and Lake Area	94.44	94.44	5.56	5.56	0.94
Other	90.00	100.00	10.00	0.00	0.90

Overall Accuracy = 95.87%
Overall KIA = 0.94

Appendix 4: Present Land Use Map of Suryodaya Nagarpalika, Ilam



Soil Report

Preparation of Soil Report

Suryodaya Nagarpalika, Ilam District

This document is the output of the project entitled **Preparation of Gaunpalika/Nagarpalika level Land Resource Maps (***Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and Gaunpalika/Nagarpalika Profile***), Database and Reports (Package-04)** awarded to *PEES Consultant (P) Ltd.* by Government of Nepal/Ministry of Agriculture, Land Management and Cooperatives, National Land Use Project (NLUP) in Fiscal Year 2074-075. The Gaunpalika/Nagarpalika covered under the Package 04 of Ilam District is Suryodaya Nagarpalika and Rong Gaunpalika of Ilam District.

Dr. Roshan Man Bajracharya was involved and solely credited for the preparation of maps, data base and reports on Soil theme for the Package 04 of Ilam District.

The Gaunpalika/Nagarpalika areas analysed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the Nagapalika may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

The consultant is obliged to state that the Imageries, GIS database and other out puts produced for the project is owned by National Land Use Project (NLUP), Mid Baneshwor, Kathmandu. Therefore, the authorization from the NLUP is required for the usage and/or publication of the data in part or whole.

ACKNOWLEDGEMENT

The PEES Consultant (P) Ltd. is highly obliged to National Land Use Project (NLUP), for awarding the project **Preparation of Nagarpalika/Gaunpalika level land resource maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and Nagarpalika/Gaunpalika Profile)**, database and reports, Package 4 of Ilam district**. The consultant and the team members would like to extend special thanks to **Mr. Prakash Joshi**, the Project Chief of NLUP, for the positive supports during the project period. Similarly, the consultant and the team members would also like to highly acknowledge the overall supports of **Mr. Sumeer Koirala,** Survey Officer. Likewise, the consultants would like to extend thanks to Mr. Rajan Kumar Phuyal, Account Officer, Survey Officer, Mr. Prakash Dulal, Mr. Karan Singh Rawal, Mr. Dipendra Khadka, Mr. Dharma Raj Dangi, Ms. Bandana Dev, Ms. Radhika Timalsina, Ms. Sarita Gautam and Madhu Maya Bhatta and Ms. Nutan Kumari Yadav for their supports during the project period.

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Executive Summary

A total of 108 soil pits of Suryodaya Nagarpalika were described in the field representing varied micro-topography. They were investigated for each of the representative land type units covering the entire Nagarpalika area. Physical and chemical properties of soil pits were analyzed and linked with spatial entities (soil pits and polygon) based representation of land units and soil mapping units. All individual soil pits were grouped and aggregated into soil mapping units together under different USDA Soil Taxonomy hierarchy as Order, sub-order, great group, sub-group, and family. Different Great Groups, Sub-groups of Alsfisols, Inceptisols, and Entisols occurred in decreasing order of dominancy spatially. Soil nutrient analysis showed that exchangeable potassium of most of soils were high to very high, while available phosphorus was observed to range from low to high levels. Soil total nitrogen and organic matter content range from medium to high indicating that the soils in this municipality were generally of good nutrient status. However, the soil reaction was found to vary from slightly alkaline to highly acidic. Aside from the northern most part of the municipality, most of the other areas were moderately acidic to highly acidic. Hence the main limitations for crop production in this municipality appear to be the acidic nature of most of the soils and steep slopes.

A total of 3 Orders, 5 Sub-orders, 8 Great groups, and 16 Sub-groups were classified based on the soil survey investigation in Suryodaya Nagarpalika of Ilam district. Soil survey and mapping of the Suryodaya Nagarpalika showed that most of the soils found in the area are relatively young with minimum soil profile development. More than 52 percent of the soils were of the order Alfisols, with additional 42.5 percent of the land area of the order Inceptisols. Only less than 4 percent of soils were observed to belong to the order Entisols. The soil map of Suryodaya Nagarpalika of Ilam District was prepared by integrated use of Geo-science technology consisting of RS, GIS and GPS and soil mapping unit identified with landform and land type units.

Most of the land types and soil mapping units fall under moderate to steep slope categories (15- to 30- and 30- to 60-degree slopes). Terrain classification was done to represent micro-relief of the area represented by land type units and land use/land cover. Furthermore, cropping pattern is also considered to differentiate the soil mapping unit. These parameters helped to characterize the unique features of physio-soil relationship. Based on land type, over 90 percent of total geographical area of the Nagarpalika is of sloping mountainous terrain. The present study strongly felt the need of the soil survey and mapping of all the Nagarpalika of Nepal for optimum land use planning and sustainable development of Nagarpalika in future. Since the taxonomical classification is entirely based on some chemical and morphological properties of endopedon (sub-soils) some additional analysis such as texture, organic matter, CEC and pH of the endopedons and CEC of epipedon needs to be analysed. Based on the analysis of nutrient status it can be recommended to supply the appropriate fertilizers as well as appropriate crops as per the suitability of the soil. It is recommended that addition of significant amounts of agricultural lime and organic matter in the form of compost and farmyard manure along with recommended minimal doses of chemical fertilizer to increase the agriculture production for long term sustainability.

CHAPTER 1: INTRODUCTION

1.1 Background and Rationale

Under the Land Use Policy 2072, the National Land Use Project of the Ministry of Agriculture, Land Management and Cooperatives of the Government of Nepal has been mandated to conduct a detailed study to develop land use planning and management zoning for the hill districts of Nepal. Under this project, Project Engineering and Environmental Studies (PEES) Consultants have been given the responsibility to undertake this task for Ilam district, Package -04. The work includes preparation of Gaunpalika/Nagarpalika level land resource database and maps, including present land use, soil, land capability, and land use zoning maps, along with Gaunpalika/Nagarpalika profiles for land use zoning with cadastral layers superimposed.

A prerequisite for sound land use planning and management is the preparation of up to date land resource surveys and soil maps with adequate detail and accuracy. This is best achieved through an integrated approach to land resource planning. An integrated approach to planning the use and management of land resources should involve all stakeholders in the process of decision making on the future of the land, and the identification and evaluation of all biophysical and socio-economic attributes of the land units. This requires the identification and establishment of Land uses (or non-use) of each land unit that is technically appropriate, economically viable, socially acceptable and environmentally non-degrading (Brady, 1996).To this end, soil data and maps are necessary first step in sustainable land use and proper soil and land management decisions.

A soil survey is intended to describe the key features and characteristics of soils in a given area, classify the soils according to a standard system of classification, plot the boundaries of the soil on a map, and make predictions about the behavior of soils under various use and management. The different uses of the soil and how the response of management affects them are taken into careful consideration. The information compiled in a soil survey helps in the development of land-use plans and evaluates as well as predicts the effects of land use on the environment (Brady and Weil, 1996).

Specifically, a soil survey report should cover the following aspects:

1. Mapping of the soils
2. Characterization of the Mapping Units
3. Classification of the Mapping Units
4. Interpretation of soil suitability for various land uses

Sustainable land management requires a detailed study with up to date information on soils, land uses, land forms, climate, and geology. An adequately detailed land and soil survey provides the aforesaid necessary database for effective decision-making. Nepal has been undergoing unmanaged land utilization and urbanization especially encroaching upon the prime agricultural production areas. This has resulted in the loss of valuable agricultural lands and steady degradation of land quality and productivity, which threatens the food security of the nation. Through the Land Use Policy of 2072 B.S., the Ministry of Agriculture

Land Management and Cooperatives, National Land Use Project (NLUP), Government of Nepal has undertaken an initiative to conduct detailed studies including soil survey, land resource mapping and capability classification at present land use at the Gaunpalika/Nagarpalika level. This project also aims to map land capability based on soil and physiographic characteristics as well as prepare land use zoning maps in order to assess and categorize land based on optimal suitability for sustainable management. This initiative aims to produce integrated land resource inventory at municipality level using state-of-the-art remotes sensing and geographical information system (GIS) techniques for sound zoning and land use planning and management.

1.2 Objectives of the Study

The primary objective of the present study is to prepare maps and soil resource database required for zoning and sustainable land use planning of the Nagarpalika/Gaunpalika selected under Package 04 (2074-075 fiscal years) of Ilam district. The area covered under this package is: Suryodaya Nagarpalika and Rong Gaunpalika.

The specific objectives of this study are, however, to prepare a soil map at 1:10,000 scale, GIS database and report for **Suryodaya Nagarpalika** of Ilam district.

Scope of the work

In order to achieve the above mentioned objectives, the following activities were undertaken:

a) Prepare Geological Maps of the Suryodaya Nagarpalika.
b) Prepare Land System Maps for Suryodaya Nagarpalika.
c) Prepare maps of sample pits covering each land unit/land type of the Nagarpalika with coordinate points to be identified in the field.
d) Design appropriate GIS database logically for detailed field survey and lab analysis data.
e) Carry out extensive field survey for field verification of land Use maps and to collect soil samples from the pits and fill up of the soil profile description form.
f) Analyze the physico-chemical characteristics of soils including nutrients based on the field survey as well as laboratory analyses of the soil samples
g) Prepare soil maps from order to family level following United States Department of Agriculture (USDA) Soil Taxonomy system for the Suryodaya Nagarpalika at 1:10000 scales.
h) Discuss the accuracy, reliability and consistencies of data.
i) Prepare reports describing methodology, distribution of different soil types and model of GIS data base.
j) Prepare A4 size Maps of N, P, K, OM, Texture, and pH to append to the soil reports of the Nagarpalika.

1.3 Study Area

Suryodaya Nagarpalika, name being the Nepali translation of "Rising Sun" declared municipality status in 2013 (2070 BS), with the merged of three Village Development Committees (VDCs) namely: Phikkal, Panchakanya and Kanyam. After, the restructuring of local body in 2073 BS, Gorkhey, Pashupatinagar, Sriantu, Samalbung, Laxmipur and Mai-Jogmai ward no. 8 and 9 were also merged into the Nagarpalika. It is located in Ilam district, province No 1, approximately 40 km south-east of the district headquarter Ilam. Geographically, it lies in the hill region which is mostly known as Mahabharat range with natural scenery and pleasant weather. Its geographical coordinates are 87°55'59" - 88°10'37" east longitude and 27°0'28" to 26°47'17" north latitude. The Nagarpalika is bordered with India on the east, Ilam Nagarpalika and Mai-Jogmai Gaunpalika on the west, Mai -Jogmai Gaunpalika on the north and Rong Gaunpalika on the south (Figure 1.1). Phikkal is the center of the Nagarpalika. The total area of the Nagarpalika is 22438.57 ha, which is extended north-south 25.29 km and east-west with 24.71 km.

The inhabitants are believed to have been living in this Nagarpalika since ancient time. According to the Population Census of 2011, the total population of this Nagarpalika was 56,707 and the numbers of households were 13,211. This gives an average household size of 4.3 which is lower than the national average (4.88). Administratively, the Nagarpalika has been divided into 14 wards. Ward 1 is the largest in terms of population size whereas ward 7 is the smallest one.

The Nagarpalika has diversity both in its physical and cultural aspects. It is a business hub of Ilam with beautiful landscapes. Tea, ginger, *Amriso,* cardamom, round chilies (*Akabare Khursani)*, milk and potatoes are the major trade items as well as the Nagarpalika has great possibility for the tourism. Kanyam, Pashupatinagar, Phikkal, and Sri Antu are famous for tourist destination sites. Rai, Brahmin, Chhetri and Tamang are major ethnic group inhabited in the Nagarpalika.

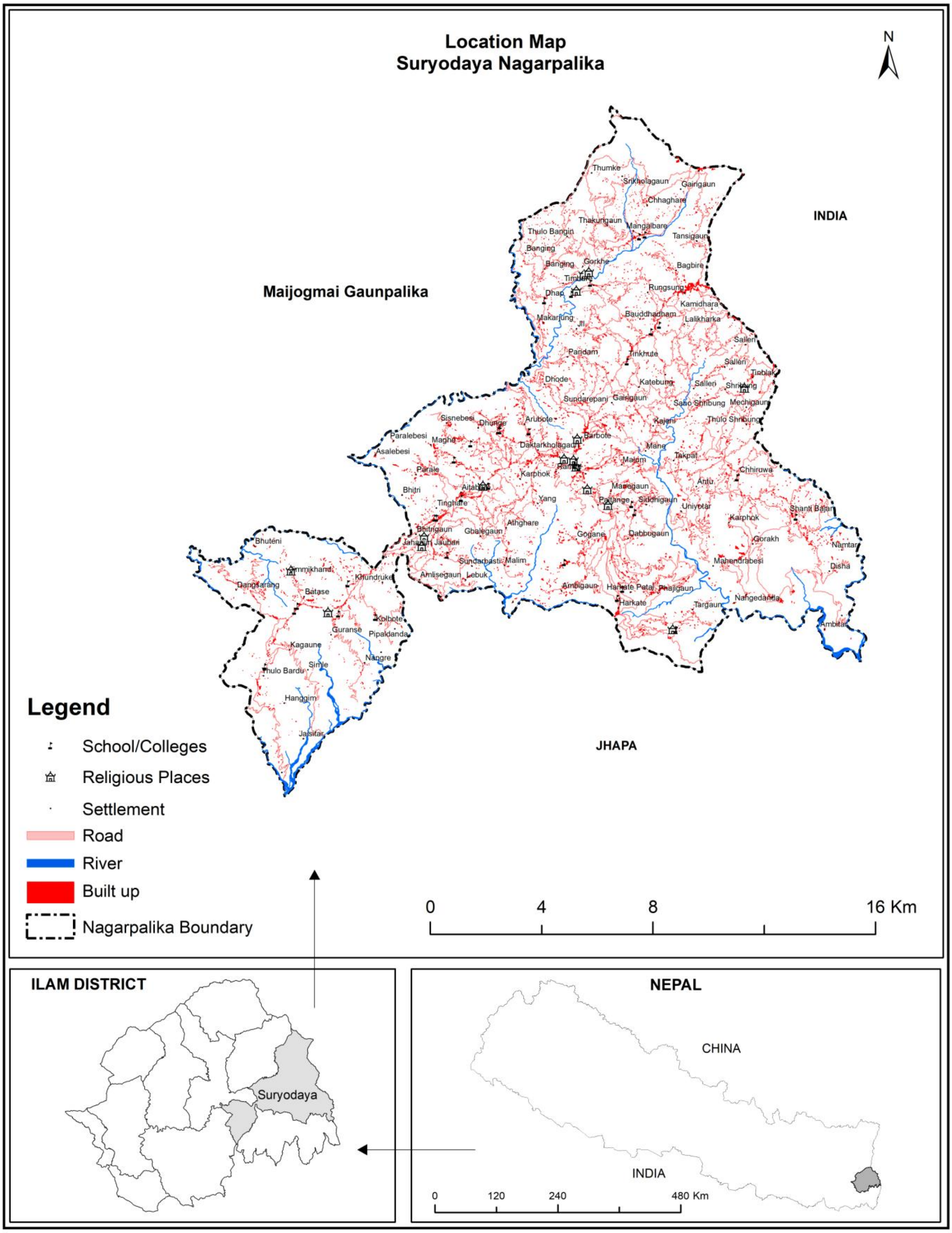

Figure 1.1 Location Map of Suryodaya Nagarpalika

CHAPTER 2:BIO-PHYSICAL FEATURES ASSOCIATED WITH SOIL IN THE STUDY AREA

This chapter provides a brief description of the bio-physical features of the study area, namely the physiographic, geology and environmental characteristics as related with soil types and pedological development. Included are topography, elevation, slope, geology, streams and canals, and, climatic patterns of the area. Soil formation is a complex process governed by the climate, parent material, topography, living organisms and time (Brady, 1974).

2.1 Physiography of the Study Area

The study district of Ilam lies in the Middle Mountains Region of eastern Nepal. Nepal can be divided into eight well defined physiographic units running roughly east-west. Nepal occupies about 800 km of the central sector of the Himalayan arc. From south to north, the Nepal can be divided into eight east- west trending physiographic zones namely: Terai, Siwalik range, Dun valley, Mahabharat Range, the Midlands, Fore Himalaya, Higher Himlaya and Inner and Trans Himalaya valley (Hagen, 1969; Figure 2.1). Each of the above zone has different altitude, topography, climate, soil type, geology and vegetation characteristics.

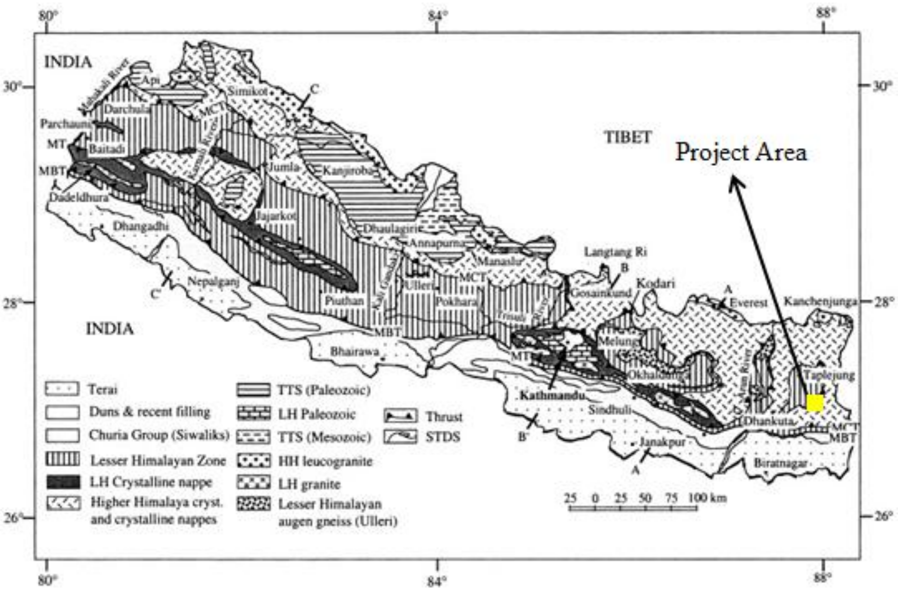

Figure 2.1 Geological division of Nepal (Upreti and Le Fort, 1999) and yellow square represent the project area

The Suryadaya Nagarpalika lies in the Mahabharat range within the Lesser Himalaya that belongs to the Taplejung Window. Some parts of the project area also consist of crystalline rocks that are brought down by the Higher Himalayan Thrust (MCT). Low grade metasediments broadly belonging to Nawakot Complex lying below the crystalline thrust. The Phyllites, representing the lower most units are green to lead gray hard and massive. They are mainly composed of quartz, chlorite, sericite and small crystals of garnet.

2.2 Elevation

Although, major parts of the Ilam district lies in the eastern part of the country within the Middle Mountains Region. The DEM shows the lower parts of Suryodaya Nagarpalika is towards the south and it is about 600m above mean sea level (Figure 2.2). Elevation of the Nagarpalika increases towards north and the west and the highest parts has the elevation of about 2500 amsl.

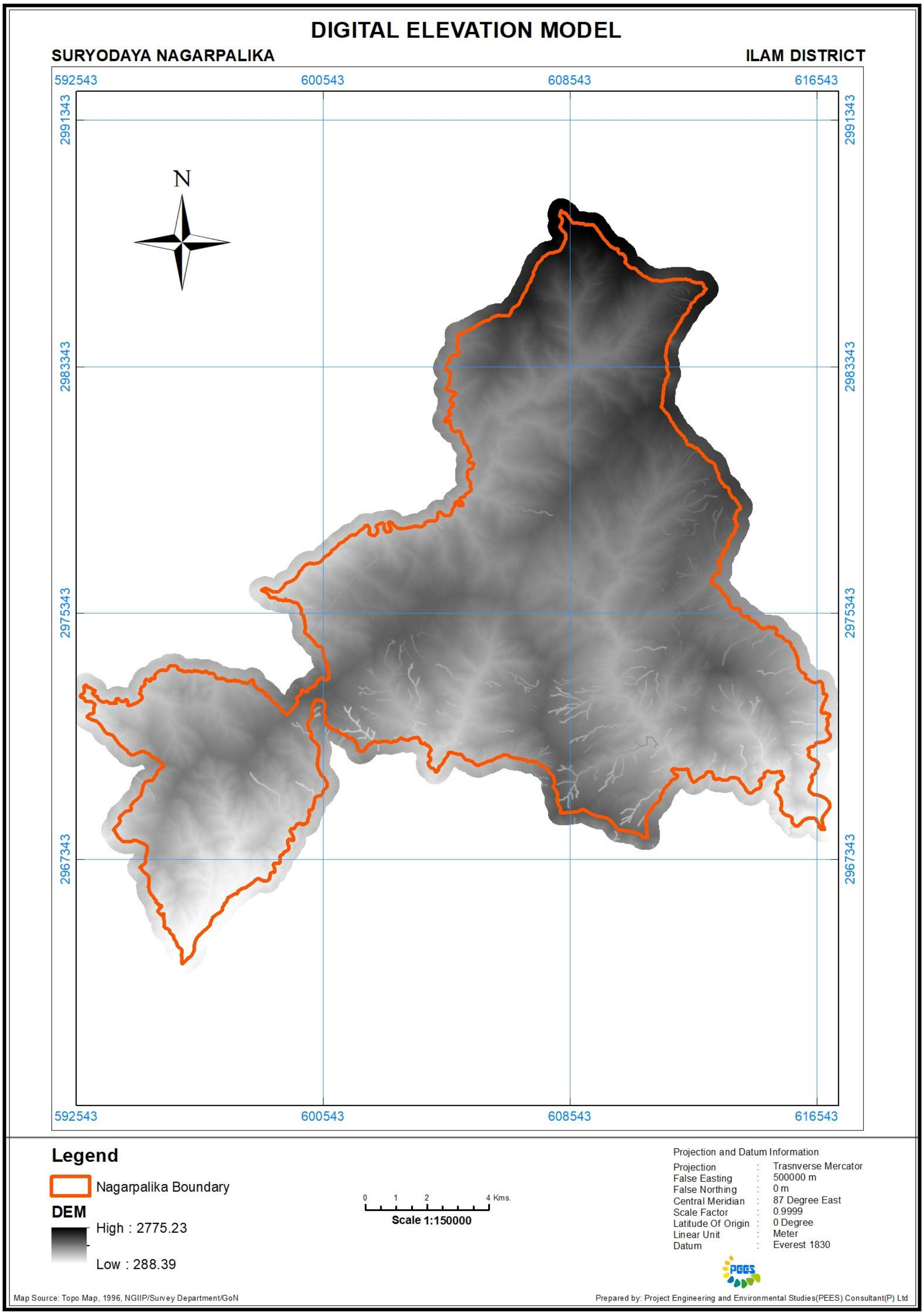

Figure 2.2: DEM of the Suryodaya Nagarpalika

2.3 Slope

The slope of terrain plays a significant role in landform formation and subsequently affects the soil characteristics depending upon varied soil forming factors. Soil surveyors consider the slope variation as a basis for determining runoff, erosion, drainage features, and landscape position. The sloping terrain of project area is considered as fundamental basis for demarcation of landform, land types and land units. The slope controls the surface erosion and land use management and practices. Suryodaya Nagarpalika is predominantly hilly with slopes ranging from nearly level in valleys and ridge-tops to very steep slopes of up to 60 degrees or more (Figure 2.3).

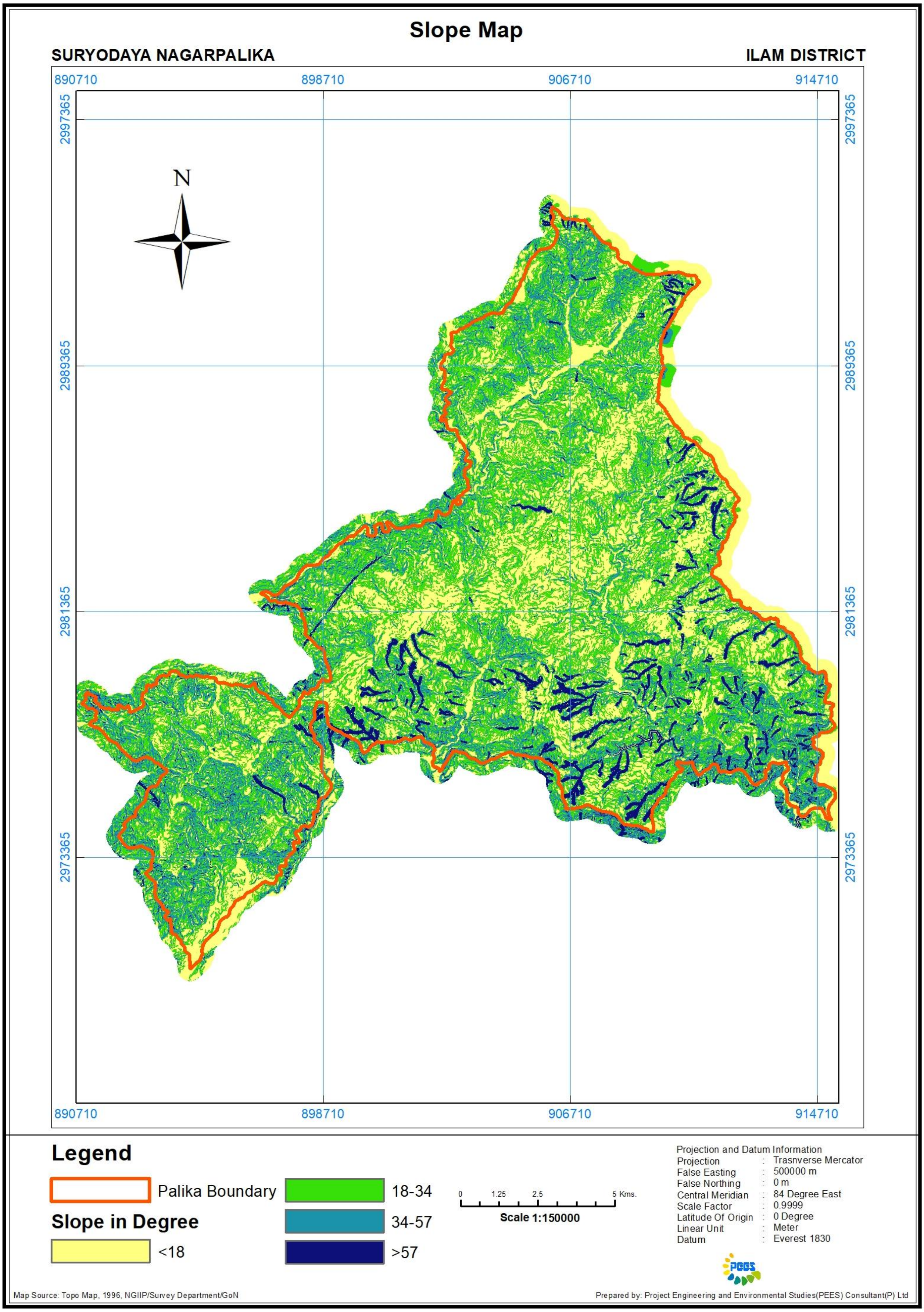

Figure 2.3: Slope Map of the Suryodaya Nagarpalika

2.4. Geology and Geomorphology of the Study Area

The project area lies in Mahabharat zone of Lesser Himalaya has an average width of the 40 km and ranges in elevation is about 1000 -3000 m. It consists of low hills, river valleys, and tectonic basins form the most important physiographic province of Nepal. The zone, in contrast to other physiographic divisions, exhibits a mature landscape. It is drained by a network of large number rivers and streams with predominantly north – south (N-S) and east – west (E-W) trending valleys. The larger rivers with their predominantly N-S course, when reach the northern slope of the Mahabharat ranges, suddenly deflect making right angles bends and flow along E-W direction for a long distance collecting waters of many other N-S flowing rivers and streams on their way. The rivers breach the barrier of the Mahabharat range only at a few places. The major rivers flowing through the Mahabharat have moderate gradient and form extensive Quaternary terraces along their courses. The drainage pattern of the project area is parallel to dendritic in nature. Mayum Khola, Jogmai Khola and Siddhi Khola are the major tributaries forming the drainage pattern in the area.

Suryodaya Nagarpalika lies in the Lesser Himalayan crystalline unit which have been described partly midland-metasediment group and partly as Irkhu Crystalline Nappe (Arbika et al.1973). Crystalline thrust sheet covers a wide area in eastern Nepal and reaches to south upto MBT at some places. Unlike the central and western Nepal, the eastern Nepal Lesser Himalaya including Mahabharat range is widely covered by this thrust sheet. Only along the deeply cut George of Arun and Tamur and in a narrow belt along the frontal part near MBT, the underlying metasediments belonging to Nawakot Complex have been exposed. Lithostratigraphically, the project area comprises the rocks of **1a and 7 classes** (Figure 2.4)**.** Brief description of these rock types are given below.

Class 1a (Recent Deposits) consists of recent and the youngest Pleistocene deposit of unconsolidated sediments. This is the alluvial soil deposited by rivers, rework by water including the river terraces. Such unconsolidated sediments usually found in terai regions and inter-montane valley (duns). In the project area, it also comprises this type of deposition in river terraces of Jogmai Khola, Mayum Khola and Siddhi Khola.

Class 7: Class 7 consists of sediments belong to the Lesser Himalaya of midland metasediments group. It comprises of low to medium grade metamorphic rocks such as phyllite, quartzite, quartz-mica, quartz-schist, schist and some carbonate beds. The age of this sediment is Pre-Cambrian.

Geologically the project area lies in the Taplejung window. Low grade metasediments broadly belonging to Nawakot Complex lying below the crystalline thrust sheet. Upper part of the project area lies in the Taplejung window. Lithological segments divided in the project area represent different lithology such as arenaceous, carbonaceous and argillaceous denoted by 7a, 7b, 7c of the midland metasediments group.

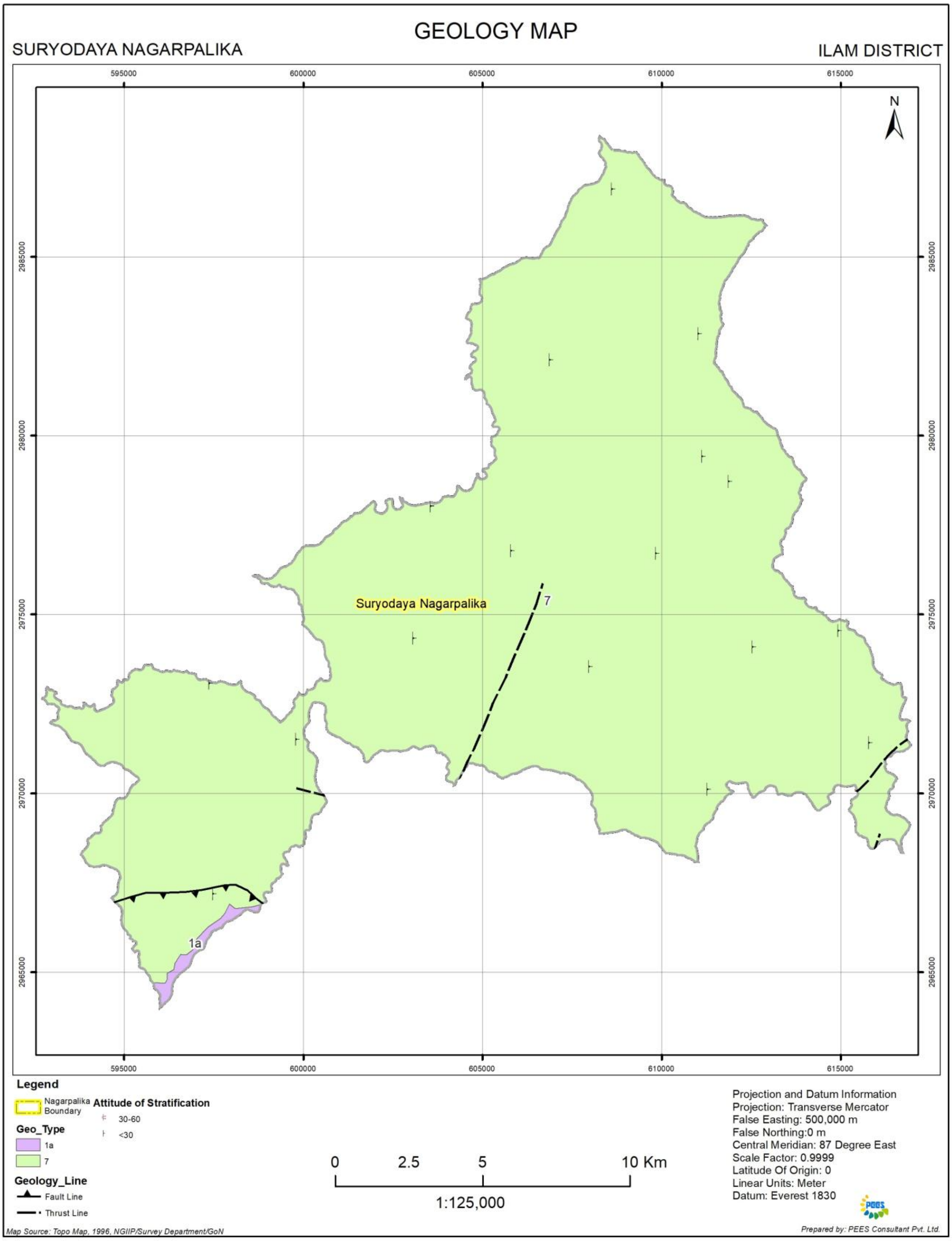

Figure 2.4: Geological map of the Suryodaya Nagarpalika

2.5 Streams and Canals

Suryodaya Nagarpalika is drained by a number of major rivers and streams. These include Mechi Nadi along the eastern border; Sri, Mayum and Rangsung Khola in the northwestern part, Siddhi, Sibrung, Chhiruwa and Antu Khola in the south-eastern part; and Tangting, Sarki, Adheri, Khani and Sakale Khola in the south-western part of the Nagarpalika (Figure 2.5).

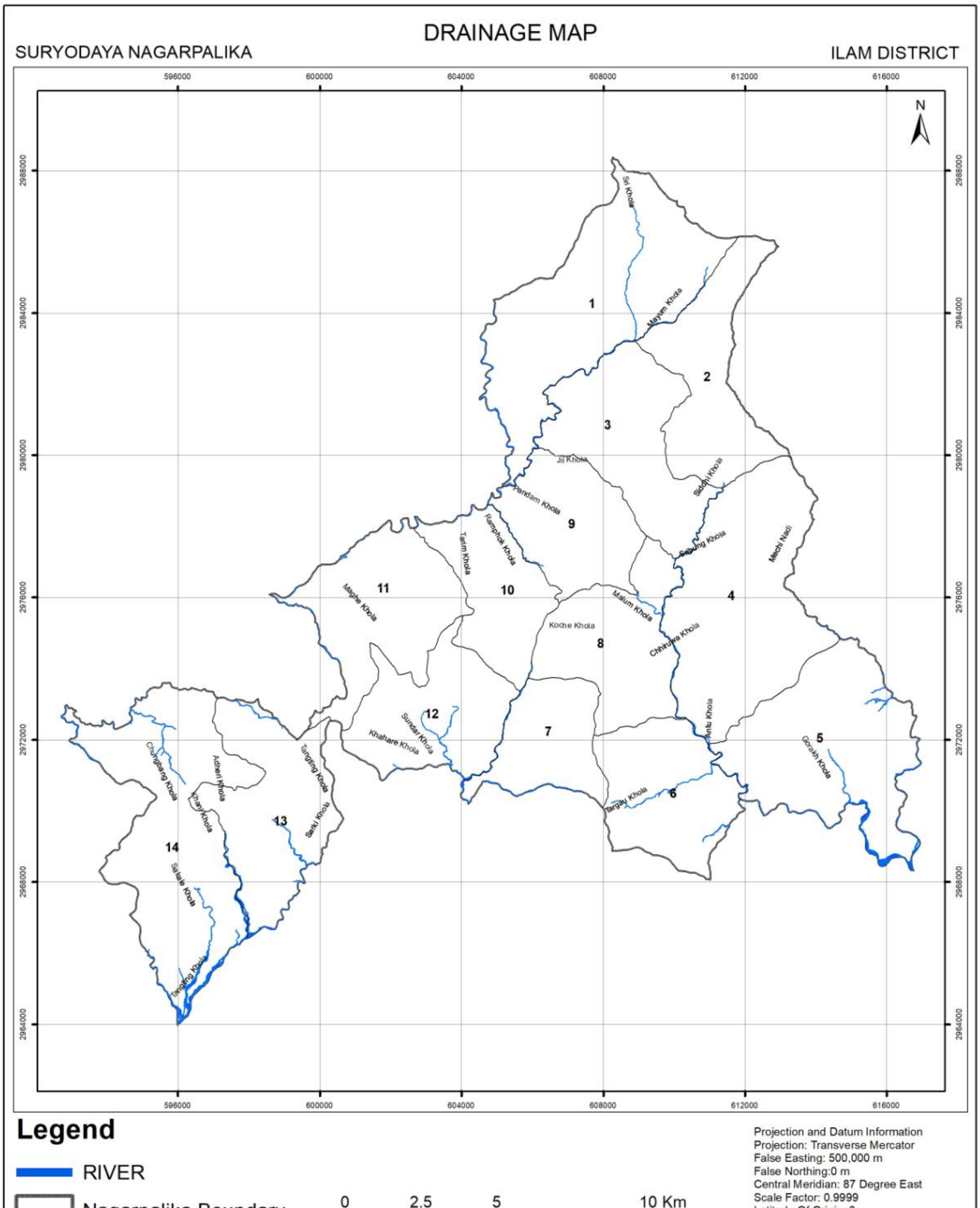

Figure 2.5: Drainage map of Suryodaya Nagarpalika

2.6 Climatic Conditions

Climate is a key soil forming factor that directly and indirectly affects pedogensis. It directly supplies the water and heat energy to react with and weather the parent materials. On the other hand, it also indirectly determines the flora and fauna, which further enhance the weathering and soil formation processes. The energy acts to break down the rocks, leading to the release of minerals in the form of acids and salts (Sehgal, 1990).

The study area has a sub-tropical monsoonal climate with four seasons, namely, winter season (Dec-Feb), pre-monsoon season (Mar-May), monsoon season (Jun - Sept) and post monsoon (Oct-Nov). The winter season is cool with minimal rainfall but generally frost-free, the pre-monsoon is hot with thunder showers, while the rainy season is hot and humid followed by a prolonged dry (post-monsoon) period. The meteorological data from the Kanyam Tea Estate station which is the representative station of climate in the study area.

2.6.1. Temperature

The temperature data indicates that the period from April-August, are the warmest months with the mean maximum temperatures in the range 23 to 25^{0}C), while lowest mean minimum temperatures of 2-3^{0}C occur in the month of January (Figure 2.6). Based on the temperature data, the municipality falls under the mesic temperature regime. In general high mean temperatures are observed during the period from April to September coinciding with the period of monsoon and pre-monsoon rains.

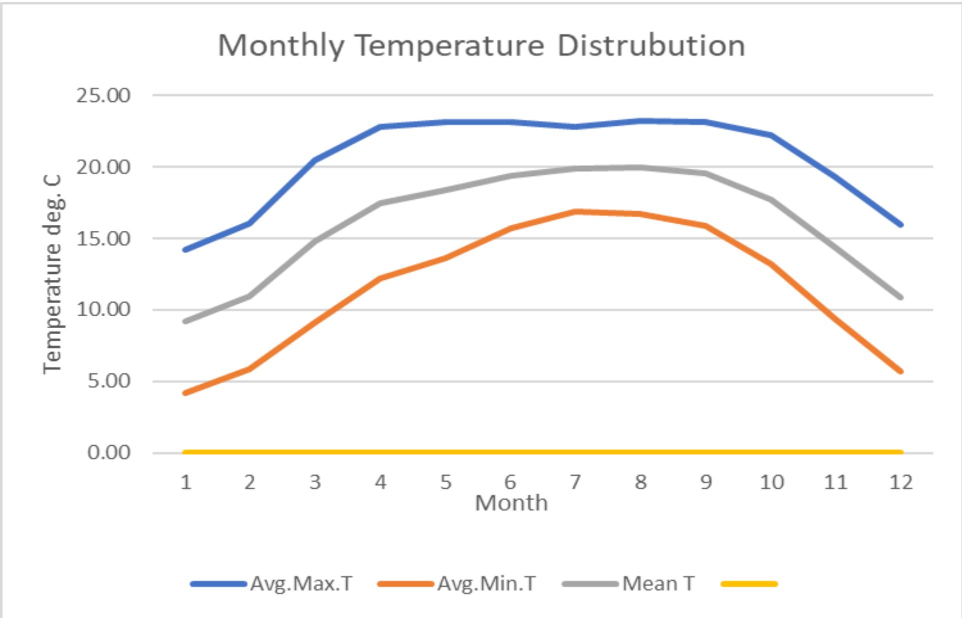

Figure 2.6: Distribution of monthly maximum, minimum and mean temperatures (2007-2016) at Kanyam Tea Estate, Ilam. Source: (DHM, 2017)

2.6.1. Precipitation

The rainfall data shows that the Nagarpalika receives annually on an average about 2500 mm of precipitation on the basis of 10-year weather data (2007-2016). As seen from Figure 2.7, the maximum mean rainfall totals are recorded in the month of July (nearly 750 mm) and minimum rainfall typically occurs in the months of November and December (0 mm). The precipitation data showed that nearly 85% of the rain (about 2140 mm) falls during the four months of the rainy season (June through September).

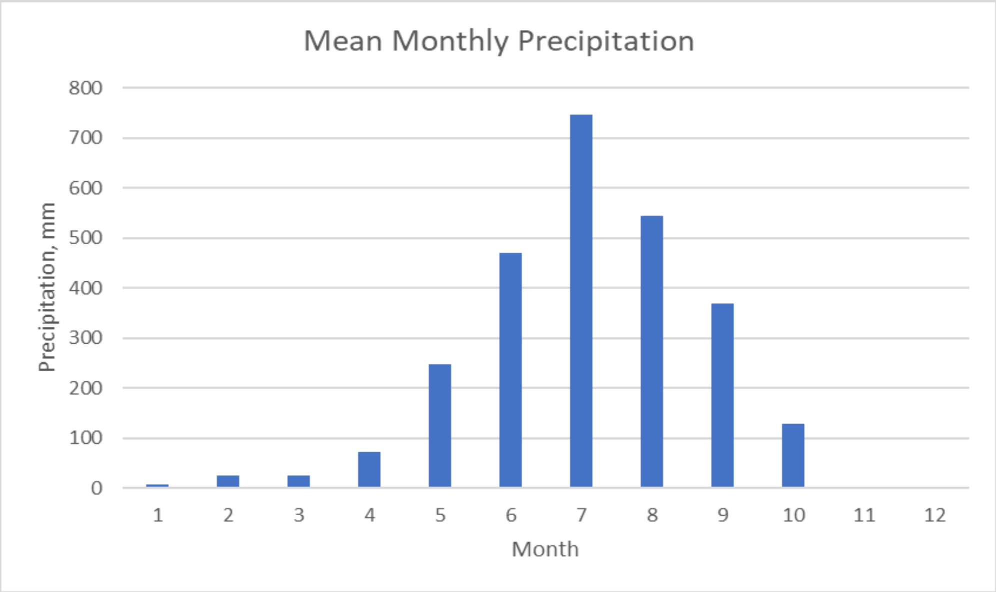

Figure 2.7: Average Monthly Precipitation (2007-2016) at Kanyam Tea Estate. Source: (DHM, 2017).

2.7 Vegetation/ Landuse-Land Cover

Suryoday Nagarpalika has both communities as well as government forests. They have natural forest as well as plantation forests. Sal, Asna, Dhupi Salla,Khotsalla, Chilaune, Katus,Siris and Utis are major forest species. Most of the forests have matured to immature stage. The crown density in most of the community forests belongs to dense i.e. more than 70%, sparse 40 to 70% and the remaining less than 40%. The plantations in the agricultural land are in the form of agroforestry. Some of the models are farmland plantations, homegardens, hertosilviculture, orchards, wood lots, agrosilvopasture and Tea gardens plantations. These are private plantations/forests in agriculture land. All these forests can be categorized in the Tropical, sub tropical to temperate climatic zone having forest type as hard wood, softwood, mixed forests and most of the community forests are supported by Dhupi salla, Utis, Amriso, Amla, *Bakaino*, *Khair*, *Sissoo, Ipil Ipil* and *Khanyu* plantation in the gaps and open areas of community forests.

CHAPTER 3: SOIL SURVEY AND MAPPING METHODS

A Semi-detailed soil survey was conducted in February-March 2018, to delineate and map the existing soil types as baseline data supported by remote sensing technique and geographical information system (GIS) analysis. Seven profiles were described in detail in the field through the excavation of pits within the various land use categories to cover the entire Nagarpalika. The areas were generally homogeneous and dominated by rice-based cropping pattern. At each pit location, soil samples of each horizon collected for laboratory analyses and soil classification. Physical and chemical analyses done at the soil lab using standard techniques, included texture (sand, silt, clay), pH, soil organic matter, total N, available P and exchangeable K.

3.1 Review of Soil Survey Methods

Soil survey methods have evolved from human-drawn maps to aerial ortho-photographs to more recently, high resolution remotely sensed images with the advantage of synoptic view of large areas. The current project has used high resolution satellite imagery for the delineating soil polygons and sampling points.

There are two basic approaches to soil mapping using these satellite data. Satellite data are delivered in digital (softcopy) and imageries (hard copy).

A **Computer aided digital analysis approach:** Digital analysis of remote sensing data utilizing the computers has been developed to meet the requirement of faster analysis and extract information from the large quantities of data based on the utilization of the spectral variations for classification.

B **Visual image interpretation:** Visual interpretation is based on shape, size, tone, shadow, texture, pattern, site and association. This has advantage of being relatively simple and inexpensive. Soil mapping needs identification of a number of elements, which are of major importance for soil survey. They are land type, drainage pattern and drainage condition, vegetation, land use, slope and relief.

In these contexts, soil survey methods based on the visual image interpretation are reviewed here.

3.1.1. General Traversing for Mapping

The surveyor with the interpretation of physiographic-soil relationship on aerial photo or imagery walks briskly along the field by boring a hole at interval depending upon the intensity of mapping and studying soil morphological properties by the *field method* and put these observations on the map.

3.1.2. Grid Survey

The grid survey method is adopted in the pre-selected sample strips to establish correlation between soil and aerial photo/imagery units in the small area. In this method, traverse lines are located along the grid pattern of geo-referenced image and four-five observations are recommended at per hectare of area.

3.1.3. *Free Survey*

The free survey method is adopted for checking and confirming of established soil-physiographic relationship mapping units and inferred soil boundaries demarcated are to be matched with the actual soil properties depending upon indicators and associated features.

3.1.4. *Geo-Statistical Sampling*

In geo-statistical sampling method, systematic sampling of accurate interpolation by krigging producing spatial pattern maps and for accurate estimation of semi-variogram are two primary concerns. A regular grid with square, triangular or hexagonal elements is most often used and placement of sample locations is in the center of each grid cell. Sample spacing for these grid cells should be less than 1/2 of the range for the semi-variogram as a useful tool for modeling spatial structure in a measured soil property.

The methodology adopted for the present soil survey was based on integrated use of visual interpretation and computer aided technology and integrated use of GIS and Remote Sensing techniques. The entire methodology comprises three- tier approach furnished below in detail. The characteristics of present soil survey are expressed as:

Table 3.1: Characteristics of the soil survey

Kinds of soil survey	Kinds of map unit	Kinds of components	Approx. scale	Minimum size delineation
1st order	Mainly consociations and some complexes	Phases of soil series	1:10,000	1 ha

3.2 Desk Study

The digital LRMP maps, land system, land capability and land use at the scale of 1:50,000 and geological Map scale at 1:125,000 and Ilam district, municipality map and Topographic - thematic layers at 1: 25,000 and World View-2 Satellite image at 2 m spatial resolution of MSS provided by National Land Use Project and reports of those maps collected were made available and reviewed in connection with preparation of soil map prior to the field survey. All these layers and satellite images were made compatible for overlay analysis by geo-referencing them in same projection system prescribed by NLUP. Standard false colour composites of the project area at the scale of 1:10000 are produced in A1 size. These imageries sheets were visually interpreted for lithological (parent material) units which are initially delineated based on available geological maps. It is followed by delineation of broad physiographic units based on relief information available in topographical maps. Topographic information, such as relief and slope can also be deduced by interpreting drainage features, drainage density exhibited on imageries. GIS based digital elevation model, relief and hill shade map were produced for the visualization of virtual 3D terrain surface for delineating the land system units that was used for detailed soil survey. The soil mapping units were interpreted and delineated on the imagery with the aid of physiographic-soil relationship such as topography, geology, drainage and land use. The image clearly depicts land system units and upland, lowland and wetland were delineated on the imagery. The physiographic units are further sub-divided based on land use/land cover as revealed in the image.

The land units required for demarcating of soil polygon/mapping unit were determined with the integration of physiography, land system, landform, geology, slope, and land use of Suryodaya Nagarpalika of Ilam district.

a. Soil Mapping Unit

The soil mapping units were demarcated based on the land units that also identified capturing the local topography variation. The description of soil mapping unit and the symbol was formed with the integration of land system, landform, land type and geological map and land use/land cover. The whole Nagarpalika area is divided into two land system units, two land units, two local land types and 5 major land use/land cover types. The major land use/land cover is further subdivided into 4 categories based on minor description of cropping pattern.

b. Soil Sample Pit Design

Soil mapping units derived from Land units were formed and overlaid on Standard False Colour Composite of the project area at the scale of 1:10000. Altogether 108 sample pits were identified in order to represent the soil properties of the Nagarpalika. Soil pits are characterized by geology, land system, slope and land use as mentioned in GIS Database. The Nagarpalika name is coded as **SD** with numerical number of pits as shown in Figure 3.1.

3.3 Field Survey

A preliminary reconnaissance survey was carried out during the pre –field activities to get the insight of ground situation of project area regarding the association of landform and soil. It helped in identification of soil mapping units and designing the soil sample pit collection. Field work was carried out to study the physiography, landform and their associated soils based on the soil pit shown in Figure 3.1. Soil Sample pits covering all the units were dug based on the interpreted soil map, topographical map, Satellite imagery for determination of soil profile.

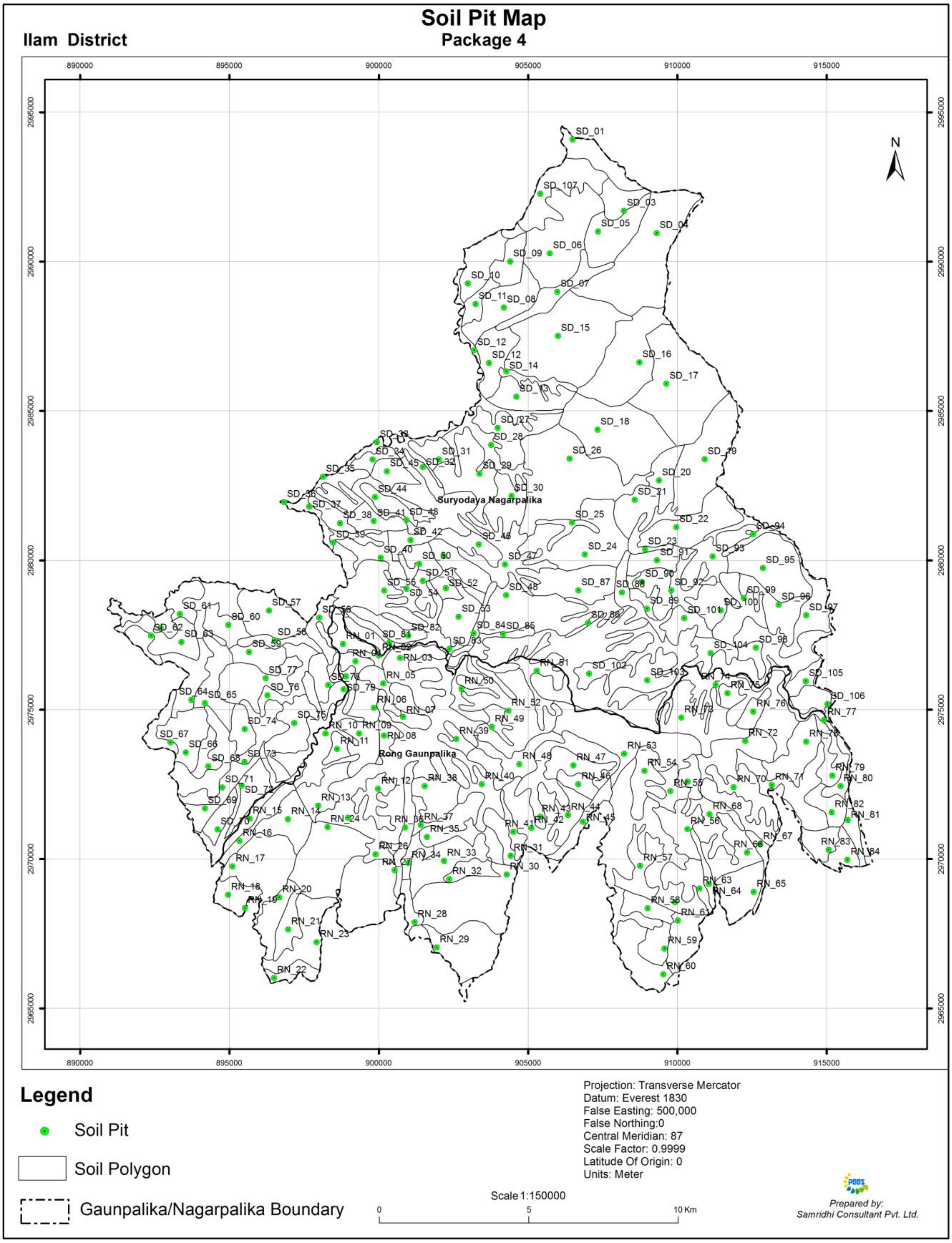

Figure 3.1 Spatial distribution of soil pits in the Suryodaya Nagarpalika

Each of the sample points identified in the base map was visited and pits were manually dug and studied and samples were collected from each horizon based on Soil profile description sheet provided by the NLUP. Various field test, analysis and interpretation for each of the above soil pits were done to study the physical and morphological characteristics of the soils at different horizons. The soil profile description sheet provided by the NLUP includes:

a. Information on site sampled
   Sampled pit number
   Date of observation/sampling
   Surveyor name
   GPS coordinates of sample site location
   Elevation, landform, vegetation, and tentative soil classification

b. General information of soil
   Parent material
   Drainage
   Moisture condition
   Ground water table
   Surface stones or rock outcrop

c. Detail description of individual soil horizon
   Soil horizon
   Depth
   Colour
   Mottling
   Texture
   Structure
   Consistency
   Cutans (clay coatings)
   Cementation/induration/pans
   Porosity
   Roots
   Soil reaction
   Horizon boundary

Soil samples were collected from the top 2-3 horizons for analysis in the soil laboratory. Based on morphological and chemical analysis data soils are classified according to Soil Taxonomy (USDA – NRCS, 2014).

3.4 Laboratory Soil Analysis

Post Field Interpretation

After field work, soil information on soil pits was compiled. Modification in the soil mapping units associated with physiographic units, delineated earlier is made. Soil mapping units with the land type are subsequently translated into soils cape units by incorporating information on soils. Soils cape units are subsequently transferred onto base map of the same scale generated from topographical maps. Beside this, the following major activities were carried out for preparation of soil map.

Spatial Data Analysis: After completing the field study, different thematic layers such as contours, spot height, drainage and municipality and ward, land system and land use were made compatible by transforming into the same projection system (MUTM) adopted by Survey Department. The soil pits location were transferred into base map and vector to raster conversion of line segment were made for preparation of digital surface model required for Digital Terrain Model and Hill shade.

Aspatial Data Analysis: The aspatial data analysis includes the physical and morphological attributes of soil. The information containing in standard soil description form regarding physical and morphological attributes of each soil pit at different horizon level were converted into digital tabular format in order to join with the spatial location of soil pits. All spatial locations of each soil pit were transferred into the base map of same scale geo-referenced base map projected on MUTM parameters.

Laboratory Soil Analysis: The samples collected from the soil pits were transported to the laboratory to analyze selected physical and chemical properties. Top layer or epi-pedon was also examined in the laboratory for the purpose of plant growth fertility assessment whereas sub-surface or endopedons were assessed for classification purpose. The soil samples collected air-dried in the shade, ground, and sieved through a 2mm mesh for analyses. The following methods were used to analyze the physical and chemical properties of the samples:

Table 3.2: Methods adopted in Soil sample tests in laboratory

Soil Sample Tests	Analysis Method
Texture	Soil Hydrometer
pH	1:2 water suspension
Organic Matter content	Modified Walkley and Black
Available Phosphorous (P2O5)	Modified Olson Bi-carbonate
Available Potassium (K2O)	Flame photometric method extraction with Ammonium Acetate
Total Nitrogen(N)	Microjeldahl

Soil Mapping: Based on shape, size, tonal variation and color variation and relative height, the landform and land types of the project area were identified on satellite imagery and Digital Terrain Model. The color variation ranging from light to dark represents the soil difference identifying dry soil differentiated from wet soil. Soil association as the universally accepted for soil mapping was adopted in orders to correlate the soil pit and soil mapping units because these two spatial entities are geometrically different. More than one soil pit are enclosed by soil mapping. Thus classifications were made based on soil association. Based on morphological and chemical analysis data soils are classified according to Soil Taxonomy (USDA – NRCS, 2014).

CHAPTER 4: LAND SYSTEM, LAND FORM AND LAND TYPE

4.1 Background

There is a strong interaction between landform, topography their influence on soil formation. Soil and their horizons differ from one another, depending on how and when they formed. Physiography includes relief and topography representing geo-morphologically distinct units and difference in elevation of the land surface, respectively. Even though, topography is considered as passive factor of soil formation, it significantly influences climate, vegetation and organism of an area as a genetic factor. It affects soil formation, the thickness of soil profile determining the nature of its position on landscape. Slope and aspect affect the moisture and temperature ranges of the soil. Steep soils may be eroded and lose their topsoil as they form. Thus, they may be thinner than the more nearly level soils that receive deposits from areas upslope. Deeper, darker colored soils may be expected on the bottom land. Many studies have proven the close relationship between soil properties and topography (FAO, 1976; 1990; 2007).

This study adopts soil landform relationship approach. It is based on the physiographic-soil relationship approach assuming the physiographic controlled landform as the basic spatial and structural entities of forming soil mapping units (Table 4.1). Physiography in study area is further divided into land system according to recurrent pattern of landforms, geology and slope and arable agriculture limits and then land units based on map able land surface significantly from some user oriented point of view for delineation (LRMP 1986). Within the land units, land types were delineated based on position, slope, direction, drainage of landscape features which is especially important for local level project design (Carson 1985). The soil properties within the land types further subdivided based on the cropping pattern were determined by detailed field soil survey. These observations were further studied on *Soil Association* for classification. Digital Terrain Model (DTA) is employed for delineation of landform, land units and land types for detailed soil survey at local level planning.

4.2 Land system/Land form

Suryodaya Nagarpalika falls within the Middle Mountain physiographic region and is located in the north-central part of the Ilam district. The Nagarpalika is mountainous and has land systems 9, 11 and 12, namely, river channels, alluvial plains and fans, ancient river terraces, and moderately to very steep mountainous terrain (LRMP, 1986). Physiography is further subdivided into landforms basically defined by the position of land surface within landscape and it is characterized by slope and its direction, elevation, rock exposure and soil type. The Nagarpalika was found to be heterogeneous with nearly 98% of the area falling within two land systems (Land System 11 and 12). The land system types are given in Table 4.1.

Table 4.1 Land System/ land type units of Suryodaya Nagarpalika

Land System/ land Units	Area in ha	Percentage	Descriptions
9a	140.56	0.63	Alluvial plains and fans; river channel
9b	74.94	0.33	Alluvial plains and fans; alluvial plains (river/stream flood plains)
9c	241.14	1.07	Alluvial plains and fans; alluvial fans (sloping

			depositional areas)
11	13756.42	61.31	Moderately to steeply sloping mountainous terrain
12	8225.51	36.66	Steep to very steeply sloping mountainous terrain

4.3 Land Units / Land Types

Landform affects soil formation and its profile development in association with the steepness of land and slope direction. The slope classes are required for land type classification. The majority of slopes of study area were found to be in 15-30 and 30-60° or S4 and S5 categories. The classified slopes are presented in table 4.2.

Table 4.2: Slope classes and symbol

Slope description	Slope (in degrees)	Symbol
Flat or nearly flat	<1	S1
Gently sloping	1-3	S2
Moderate slopes	3-15	S3
Moderately steep	15-30	S4
Steep slopes	30-60	S5
Very steep slopes	>60	S6

The texture of soil depends upon the relative proportions of the different soil particles size fractions, namely, sand, silt and clay. The soil texture of the top layer or surface horizon is used for land system classification, soil suitability and classification of soil at family level. The main textural classes found in the municipality were: loamy sand (LS), sandy loam (SL), silt loam (SiL), and sandy clay loam (SCL).

4.3.1 Description of Individual Land Type Units

The land units defined by LRMP are further subdivided based on local field situation associated with the different agriculture terraces. Altogether 9 land units were identified in the project area associated with the local micro-relief variations. The spatial extent covered by the project area is depicted in table 4.3. The data showed that more than 89 percent of the land fell under agricultural land use and another 5.24 percent of the area was under forest. About 5 percent of the land area has been developed as residential, commercial, industrial, and public service areas. And about 1 percent of the area is covered by water bodies, namely, rivers, streams and lakes.

Table 4.3 Land Use Types of Suryodaya Nagarpalika

Sn.	Description	Area(ha)	Percentage
1	Agricultural	20008.89	89.17
2	Forest	1176.13	5.24
3	Residential	575.95	2.57
4	Public Use and Open Space	405.79	1.81
5	Riverine and Lake Area	238.89	1.06
6	Other	24.03	0.11
7	Commercial	4.15	0.02
8	Industrial	3.92	0.02
9	Cultural and Archeological	0.81	0.004
10	Mine and Minerals	0.00	0.00
11	Excavation	0.00	0.00
Total		**22438.57**	**100.00**

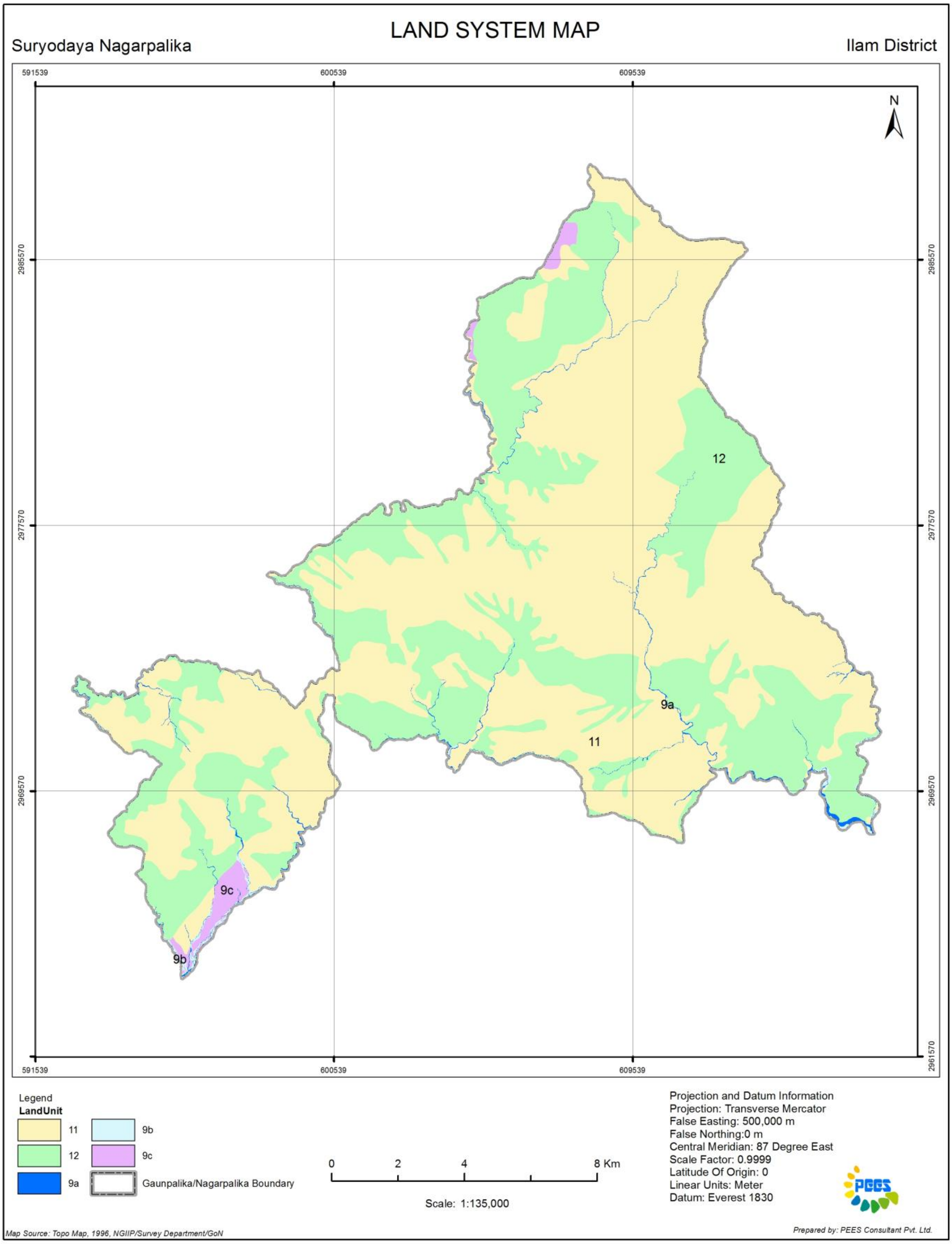

Figure 4.1: Land System map of the Suryodaya Nagarpalika

CHAPTER 5: SOIL CLASSIFICATION SCHEME

Classification is the systematic and scientific categorization of things for detailed study, establishing relationships, enhancing understanding and ease of communication. Soil classification helps to foster global communications about soils among soil scientists, and all people concerned with the management of land and the conservation of the soil resources. Through such systems we can take advantage of research and experience at one location to predict the behavior of similarly classified soil at another location.

Soil classification is the grouping of soils into categories based on morphology and formation factors. Soil classification is itself a dynamic subject related to the structure of the classification system itself, to the definition of each class, as well as in the application of the system. Soil classification is done from both the perspective of pedogenesis and soil morphology. Pedogenesis approach includes the study of the soil evolution and their distribution in the nature. Soil morphology is the field study of various soil horizons and the description of the kind and arrangement of the horizons (Buol, et al., 1997; 2011).

There are a number of soil classification systems in use in different parts of the world. Broadly, two classification systems have adopted worldwide.

1 FAO- World Reference Base for Soil Resources- involving a practical classification system used to inventory and describe the world's resources
2 USDA Soil Taxonomy System (USDA 1985; 1999; 2014)

The comprehensive soil classification, called Soil Taxonomy (Soil Survey Staff, 1985), classifies soil as a natural body and has two other major features that make it most useful. First, the system is based on soil properties that are easily verified by others. This lessens the likelihood of controversy over the classification of a given soil, which can occur when scientists deal with systems based on soil genesis or presumed genesis. The second significant feature of Soil Taxonomy is the unique nomenclature used, which gives a definite connotation of the major characteristics of the soils in question. Consideration is given to the nomenclature used after brief reference is made to the major criteria for the system – soil properties.

Soil Taxonomy is based on the properties of soils as they are found today. Although one of the objectives of the system is to group soils similar in genesis, the specific criteria used to place soils in these groups are those of soil properties. In so doing, soil genesis is not ignored. Since soil properties often are related directly to soil genesis, it is difficult to emphasize soil properties without at least indirectly emphasizing soil genesis as well. Examples of the soil properties used in the system are: moisture, temperature, colour, texture, and structure of the soil. Chemical and mineral properties such as the contents of organic matter, clay, iron and aluminum oxides, silicate clays, salt, the pH, the percentage base saturation, and soil depth are other important criteria for soil classification (Buol et al., 2011).

Differences between horizons generally reflect the type and intensity of processes that have caused changes in the soil. Ideally, we should always be striving in our descriptions to maintain a link between process and morphology. In many soils, these differences are expressed by horizonation that lies approximately parallel to the land surface, which in turn reflects vertical partitioning in the type and intensity of the various processes that influence soil development.

5.1 Soil Diagnostic Horizons

Horizonation is described in terms of master horizons, subordinate distinctions within master horizons, diagnostic horizons and transitional horizons.

a. Master Horizons

Master horizons (major horizons) are designated by capital letters, such as O, A, E, B, C, and R. The description of master horizons is given in table 5.1.

Table 5.1: Master horizons

Oi / Oe	Loose leaves and organic debris, largely not decomposed
Oa /Oe	Organic debris, partially decomposed
A	A dark colour horizon of mixed mineral and organic matter
E	A light coloured horizon of maximum eluviation
EB	Transitional to C but more like E than B
BE	Transitional to B but more like B than E
B	Maximum accumulation of silicate clay mineral or of sesquioxides and organic matter
BC	Transitional to C but more like B than C
C	Weathered parent material
R	Rock beneath the soil

b. Subordinate Distinctions within Master Horizons

Lower case letters are used to designate specific features within master horizons. Highly decomposed organic material, as 'a' is used only with the O master horizon. The rubbed fiber contents < 17 % of the volume.

The following information is collected for assembling standard profile descriptions:

i. Horizon boundary characteristics
ii. Color
iii. Texture
iv. Rock Fragments
v. Structure
vi. Consistence
vii. Roots
viii. pH, effervescence
ix. Special features such as coatings, nodules, and concretions

c. Diagnostic Horizons of Soil

Diagnostic soil horizons are found in the surface or the subsurface (Table 5.2). The diagnostic surface horizons are called epi-pedons (from the Greek words epi meaning over and pedon meaning soil). The epi-pedons includes the upper part of the soil darkened by organic matter, the upper alluvial horizons, or both. It may include part of the B horizon if the latter is significantly darkened by organic matter. Seven epi-pedons are recognized as follows:

Table 5.2: Major Features of Diagnostic Horizons of Soil Taxonomy

Surface Horizon (Epipedons)	
Mollic	Thick, dark colored, high base saturation, strong structure
Umbric	Same as Mollic except low base saturation
Ochric	Light colored, low organic content, may be hard and massive when dry
Histic	Very high in organic content, wet during some part of year
Anthropic	Man-modified Mollic-like horizon, high in available P
Plaggen	Man-made sod-like horizon created by years of manuring
Melanic	Thick black horizon rich in organic matter usually associated with aluminum-humus complex
Subsurface Horizons (Endopedon)	
Argillic	Silicate clay accumulation
Natric	Argillic, high in sodium, columnar or prismatic structure
Spodic	Organic matter, Fe and Al oxides accumulation
Cambic	Changed or altered by physical movement or by chemical reactions
Agric	Organic and clay accumulation just below plow layer resulting from cultivation
Oxic‘	Highly weathered, primarily mixture of Fe, Al oxides and non-sticky-type silicate
Duripan	Hard pan, strongly cemented by silica
Fragipan	Brittle pan, usually loamy textured, weakly cemented
Albic	Light colored, clay and Fe and Al oxides mostly removed
Calcic	Accumulation of CaCO3 or CaCO3.MgCO3
Gypsic	Accumulation of gypsum
Salic	Accumulation of salts
Kandic	Accumulation of low activity clays
Petrocalcic	Cemented calcic horizon
Petrogypsic	Cemented gypsic horizon
Placic	Thin pan cemented with iron alone or with manganese or organic matter
Sombric	Organic matter accumulation
Sulfuric	Highly acid with Jarosite mottles

d. Transitional Horizons

Transitional horizons are layers of the soil between two master horizons. There are two types of transitional horizons as the first letter indicating the dominant master horizon and the second letter indicating subordinate characteristics.

Separate components of two master horizons are recognizable in the horizon and at least one of the component materials is surrounded by the others. The designation is by two capital letters with a slash in between. The first letter designates the material of greatest volume in the transitional horizon such as A/B, B/A, E/B or B/E. For example, an AB horizon indicates a transitional horizon between the A and B horizon, but one that is more like the A horizon than the B horizon. An AB or BA designation can be used as a surface horizon if the master A horizon is believed to have been removed by erosion.

5.2 Local Classification System

It is known that local farmers are considered as best engineers because of the fact that they know everything and they have local knowledge derived from their ancestors and historical practices. Local classification helps the farmers to know the soil properties benefited to agriculture. Ethnopedology is another branch of soil science dealing with the indigenous knowledge of local people regarding soil naming and management in Nepalese society, local farmers use to naming the soil base on color, texture and fertility of top soil.

Table 5.3: Local names of soil textures used by the local communities.

Sand	Baluwa
Loam	Domat
Silt	Pango
Clay	Chimato
Sandy soil	Balutemato
Loamy soil	Chimatalomato
Silty clay loam	Pangochemtodomat

5.3 USDA Soil Taxonomy System

The six categories in the U.S. System of Soil Taxonomy are in decreasing rank, order, sub-order, great group, sub-group, family, and series. These categories are briefly explained and defined below:

Order

The order category is based largely on soil-forming processes as indicated by the presence or absence of major diagnostic horizons. A given order includes soil whose properties suggest that they are not too dissimilar in their genesis. For example, many soils that developed under grassland vegetation have the same general sequence of horizons and are characterized by a thick, dark epipedon (surface horizon) high in metallic cations. Soils with these properties are thought to have been formed by the same general genetic process and are included in the same order, Mollisols. There are twelve soil orders in Soil Taxonomy (Table 5.4).

Sub-order

The suborders are subdivisions of orders that emphasize properties that suggest genetic homogeneity. Thus, wetness, climate environment, and vegetation, which help determine the nature of the genetic process, help determine the suborder in which a given soil is found.

Great Group

Diagnostic horizons are the primary bases for differentiating the great groups in a given suborder. Soils in a given great group have the same kind and arrangement of these horizons.

Subgroup

The subgroups are subdivisions of the great groups. The central concept of a great group makes up one subgroup (Type). Other subgroups may have characteristics that are integrates between those of the central concept and soils of other orders, suborders, or great groups.

Family

In the family category are found soils with a subgroup having similar physical and chemical properties affecting their response to management and especially to the penetration of plant roots (e.g., soil-water-air relationships). Differences in texture, mineralogy, temperature, and soil depth are primary bases for family differentiation.

Series

The series category is the most specific unit of the classification system. It is a subdivision of the family, and its differentiating characteristics are based primarily on the kind and arrangement of horizons. Conceptually, it includes only one polypedon; however, in the field, aggregates of polypedons and associated inclusions are included in the soil series mapping units (Buol et al. 2011).

Table 5.4: Soil orders and their major characteristics

Formative element			Major characteristics
Name	Derivation	Pronunciation	
Entisols	Nonsense symbol	Recent	Little profile development, ochric epipedon is common
Inceptisols	L. inceptum, beginning	Inception	Embryonic soils with few diagnostic features, ochric or umbric epipedon; cambic horizon
Mollisols	L. mollis, soft	Mollify	Mollicepipedon, high base saturation, dark soils, some with argillic or natric horizons
Alfisols	Nonsense symbol	Pedalfer	Argillic or natric horizon; high to medium saturation
Ultisols	L. ultimus, last	Ultimate	Argillic horizon, low base saturation; highly weathered
Oxisols	Fr. Oxide, oxide	Oxide	Oxic horizon, no argillic horizon, highly weathered
Vertisols	L. verto, turn	Invert	High in swelling clays; deep cracks when soil dry
Aridisols	L. aridus, dry	Arid	Dry soil, ochricepipedon, sometimes argillic or natric horizon
Spodosols	Gk. Spodos, wood ash	Podzol; odd	Spodic horizon commonly with Fe, Al, and humus accumulation
Histosols	Gk, Histos, tissue	Histology	Peat or bog; >30% organic matter
Andisols	Modified from Ando	Andesite	From volcanic ejecta, dominated by allophane or Al-humic complexes
Gelisols	Gk. Gelid , meaning very cold	Crysols	Permafrost within 100 cm
Aridisols	L. aridus, dry	Arid	Dry soil, ochricepipedon, sometimes argillic or natric horizon
Spodosols	Gk. Spodos, wood ash	Podzol; odd	Spodic horizon commonly with Fe, Al, and humus accumulation

5.4 World Reference Base for Soil Resource (FAO)

There are many soil classification systems - French, South African, Australian, Canadian, Russian, and still others. Some of these are limited mostly to soils of that country and do not attempt a comprehensive coverage of world soils. None of them are equated simply to terms in any other classification. The Food and Agricultural Organization (FAO) of the United Nations has prepared a world map with described classification units (FAO, 1990, 2007). The FAO world soils are given in Table 3 with approximate comparisons to the USDA system (1999). This comparison provides an acquaintance with taxonomic names and approximate relationships of the systems.

The FAO soil classification system is worldwide, but it is not a system of units grouped into higher categories. The units are designed as the legend of a soil map of the world. The soil map has about 5000 units. These units relate most closely to great groups in the US system. The FAO system uses the US system of diagnostic horizons, although they are sometimes more simplified in definition.

Comparisons of the United States and FAO Classification System

A tabulation of the FAO system is given as the basis for comparing the systems: FAO and the USDA system (Table 5.5). These comparisons are only approximate because the systems are very different. The great group of the USDA system is most accurately related to the first sub-unit level of the FAO system. The meanings of most of the FAO sub-unit names and adjectives are identifiable from the formative elements given in Table 5.5. A few terms not given in the table are as follows:

Orthic : central concept of that soil
Calcaric : shallow to lime (2 cm – 25 cm)
Gelic : permafrost within 200 cm
Gleyic : hydromorphic (anaerobic)
Luvic : leached, clay moved downward
Solodic : < 6% Na in the CEC
Takyric : clay texture, massive crust, dry
Thionic : sulfuric material or horizon
Vertic: Vertisol-likeproperties

Table 5.5: A comparison of the FAO and the U.S. Systems of Soil Classification

FAO System and Name Meanings	USDA System (1999)
ACRISOLS Latin acris = very acidic, low base status. Subunits: Orthic, Ferric, Humic, Plinthic	ULTISOLS Hapl-ults Pale-ults Hum-ults Plinth-ults
ANDOSOLS Japanese an = black, do = soil. Subunits: Ochric, Mollic, Humic, Vitric	ANDISOLS Several suborders and great groups
ARENOSOLS Latin arena = sand. Subunits: Cambic, Luvic, Ferralic, Albic	Psamments. Several subgroups
CAMBISOLS Latin cambiare = change Subunits: Eutric, Dystric, Humic, Gleyic, Golic, Calcic, Chromic, Vertic, Ferralic	INCEPTISOLS Many Ochrepts
CHERNOZEMS Russian chern = black, zemlja = earth. Subunits: Haplic, Calcic, Luvic, Glossic	MOLLISOLS Several Borolls OXISOLS Most suborders
FERRALSOLS Latin ferrum = iron and aluminum.	Fluvents

FAO System and Name Meanings	USDA System (1999)
Subunits: Orthic, Xanthic, Rhodic, Hemic, Acric, Plinthic	
GELOSOLS Greek gelid = very cold, permafrost in part	Gelisols
GLEYSOLS Russian gJey = mucky soil mass. Subunits: Eutric, Calcaric, Dystric, Mollic, Humic, Plinthic, Gelic	Aquents, Aquepts, Aquolls
GREYZEMS English grey and Russian zemlja = earth. Subunits: Orthic, Gleyic	MOLLISOLS Borolls, Aquolla
HISTOSOLS Greek histos = tissue. Subunits: Eutric, Dystric, Gelic	HISTOSOLS
KASTANOZEMS Latin castanea = Chestnut, Russian zemlja = earth. Subunits: Haplic, Calcic, Luvic	MOLLISOLS Ustolls, Borolls
LITHOSOLSGreek lithos = stone shallow to rock. Subunits: none	Lithic subgroups
LUVISOLS Latin Juo = to wash, Iliuvial clay layer. Subunits: Orthic, Chromic, Calcic, Vertic, Ferric, Albic, Plinthic, Gleyic Brown Wooded, Acid Brown Forest soils	ALFISOLS Many suborders
NITOSOLS Latin nitidus = shiny, shiny ped surfaces. Sub-units: Eutric, Dystric, Humic	Paleudalfs, many Udults, Tropohumults
PHAEOZEMS Greek phaios = dusky, Russian zemlja = earth. Subunits: Haplic, Calcaric, Luvic, Gleyic	Udolls and Aquolls
PLANOSOLS Latin planus = flat, level, poorly drained. Sub-units: Eutric, Dystric, Mollic, Humic, Solodic, Gelic	Pale-alfs, Albaquults, Aqualfs, Albolls
PODZOLS Russian pod = under, zola = ash, white layer. Sub-units: Orthic, Leptic, Ferric, Humic, Placic, Gleyic	SPODOSOLS Orthods, Humods, Aquods
PODZOLUVISOLS From Podzol and Luvisol. Sub-units: Eutric, Dystric, Gleyic	MOLLISOLS Udalfs, Boralfs, Aqualfs
RANKERS Austrian rank = steep slope, shallow soils. No Sub-units	Lithic Haplumbrepts
REGOSOLS Greek rhegos = blanket, thin soil. Sub-units: Eutric, Calcaric, Dystric, Gelic	Orthents, Psamments
RENDZINAS Polish rzedzic = noise, stoney soil. No Sub-units	Rendolls
SOLONETZ Russian sol = salt, affected by salt. Sub-units: Orthic, Mollic, Gleyic	Salids
SOLONETZ Russian sol = salt, affected by salt. Sub-units: Orthic, Mollic, Gleyic	Natr-alfsNadurargids
VERTISOLS Latin verto = turn, self-mixing. Sub-units: Pellic, Chromic	VERTISOLS Pell-erts Chrom—erts
XEROSOLS Greek xeros = dry areas. Sub-units: Haplic, Calcic. Gypsic, Luvic	ARIDISOLS CalcidsGypsids –argids
YERMOSOLS Spanish yermo = desert areas.	ARIDISOLS Cambids

FAO System and Name Meanings	USDA System (1999)
Sub-units: Haplic, Calcic	Argids
ACRISOLS Latin acris = very acidic, low base status. Subunits:Orthic, Ferric, Humic, Plinthic	ULTISOLS Hapl-ults Pale-ults Hum-ultsPnth-liults
ANDOSOLS Japanese an = black, do = soil. Subunits: Ochric, Mollic, Humic, Vitric	ANDISOLSSeveral suborders and great groups
ARENOSOLS Latin arena = sand. Subunits Cambic, Luvic, Ferralic, Albic: CAMBISOL Latin Cambiare=Charge Subunits: Eutric, Dystric, Humic, Gleyic, Golic, Calcic, Chromic, Vertic, Ferralic	Psamments Several subgroups.
CHERNOZEMS Russian chern = black, zemlja = earth. Subunits: Haplic, Calcic, Luvic	INCEPTISOLS Many Ochrepts
GlossicFERRALSOLS Latin ferrum = iron and aluminum. Subunits: Orthic, Xanthic, Rhodic, Hemic, Acric, Plinthic	MOLLISOLS Several Borolls OXISOLS
FLUVISOLS Latin fluvius = river (alluvial deposits). Subunits: Eutric, Calcaric, Dystric, Thionic	Most suborders Fluvents
GELOSOLS Greek gelid = very cold, permafrost in part of the profile	Gelisols
GLEYSOLS Russian gJey = mucky soil mass. Subunits: Eutric, Calcaric, Dystric, Mollic, Humic, Plinthic, Gelic	Aquents, Aquepts, Aquolls MOLLISOLS Borolls, Aquolla
Aquents, Aquepts, Aquolls MOLLISOLS Borolls, Aquolla	HISTOSOLS MOLLISOLS Ustolls, Borolls Lithic subgroups
HISTOSOLS Greekhistos=tissue,Subunits:Eutric, Dystric,Geli	ALFISOLS Many suborders Paleudalfs, many Udults, Tropohumults Udolls and Aquolls
LITHOSOLS Greek lithos = stone shallow to rock. Subunits: none	Pale-alfs,Albaquults,Aqualfs, Albolls
LUVISOLS Latin Juo = to wash, Iliuvial clay layer. Subunits: Orthic, Chromic, Calcic, Vertic, Ferric, Albic, Plinthic, Gleyic Brown Wooded, Acid Brown Forest soils	SPODOSOLS Orthods, Humods, Aquods

5.5 Rating of Soil Fertility Status and Crop Suitability

Crop suitability has been defined as specific cultivate of crop types based on the requirement of different crops for agriculture and soil attribute pertaining in soil mapping units defined. It has been done for various crops considering for a single clearly defined, reasonably homogenous purpose or practice and suitable appraisal for a list of crops or other activities.

The requirements (natural, social, economic and technological, etc.) of the particular crop/activity needs to be known or alternatively what soil/site attributes adversely influence the crop. In order to identify and to delineate land with the desirable attributes but without the undesirable ones, a number of classes are determined according to degrees of suitability as below:

Highly suitable (S1) – land having no limitation to sustainable application of a given use or only minor limitations will not significantly reduce benefits

Moderately suitable (S2) – land having limitations in which aggregate are moderately severe for sustained application of a given use or increase inputs to the extent that overall benefit to be gained.

Marginally suitable (S3) – land having limitations to sustained application of a given use or increase required inputs, marginally justified; costly rice in Mustang; sub divisions of S2 and S3

Not Suitable (N1) – indicates that the land is not suitability for a defined use in its present condition, without major improvements. A not suitable classification may be modified through improved management and conservation practices, or recommended to a different use.

Permanently not suitable (N2) – refers to the suitability, for a defined use, of land units in their condition at some future date, after specified major improvements have been completed where necessary.

Suitability analysis based on soil nutrient status

The soil suitability analysis in the present case has been performed based the soil nutrients derived from chemical properties of soil pits based on soil lab test. Soil fertility status analysis can be performed based on the soil test results.

5.5.1 Crop Requirements

The soil suitability analysis is done based on the major soil nutrient available on the ground investigated from soil survey and requirement criteria of the different on the optimum condition. In general the range of pH required for the cultivation of crops, fruits, and vegetables is taken as 5.5 to 7.5 with optimum at 6.5.

5.5.2 Rating of Soil Nutrients

Soil fertility status assessment is derived from soil parameters related to top-soil rooting depth, workability (soil texture), soil drainage (permeability), alkalinity and acidity, content of organic matters, nitrogen, available phosphorus and, available potassium. Soil fertility status based on chemical properties of soil and their rating is presented in the tables below:

Table 5.6: Soil Depth Rating

Soil Root Depth		
>200	Very Deep	High Suitability
100-200	Deep	
50-100	Moderately Deep	
25-50	Shallow	
<25	Very Shallow	Low Suitability

Table 5.7: Workability Rating

Soil Texture (Workability)		
(Loam)	Good	High Suitability
SiL (Silt Loam)	Good	
SL (Sandy Loam)	Good	
SiL + L (Silt Loam + Loam)	Good	
CL (Clay Loam)	Moderate	
CL + L/SiL (Clay Loam + Loam over Silt Loam)	Moderate	

SiCL (Silty Clay Loam)	Moderate	
SiL + SiCL (Silt Loam + Silty Clay Loam)	Moderate	
SiCL + SCL (Silty Clay Loam + Sandy Clay Loam)	Moderate	
SiC (Silty Clay)	Fair	
SC + SiC (Sandy Clay + Silty Clay)	Fair	
C (Clay)	Poor	Low Suitability

Table 5.8: Drainage Rating

Soil drainage	
Well drained	High Suitability
Moderately well drained	
Somewhat poorly drained	
Somewhat excessively drained	
Poorly drained	
Excessively drained	
Very poorly drained	
Very excessively drained	Low Suitability

Table 5.9: Alkalinity and Acidity Rating

Soil Alkalinity & Acidity		
< 5.0	Very Strongly acidic	Low Suitability
5.1– 5.5	Strongly acidic	
5.6 – 6.0	Moderate acidic	
6.0 – 6.5	Slightly acidic	High Suitability
6.6 – 7.3	Neutral	Most Suitable
7.4 – 7.8	Slightly alkaline	High Suitability
7.9 – 8.4	Moderate alkaline	
8.5 – 9.0	Strongly alkaline	
>=9	Very Strongly alkaline	Low Suitability

Table 5.10: Organic Matter Content Rating

Organic Matter (%)		
>5	High	High Suitability
2.5 – 5	Medium	
<2	Low	Low Suitability

Source: DOA & NARC

Table 5.11: Total Nitrogen Rating

Total Nitrogen (%)		
>0.2	High	High Suitability
0.11 –0.2	Medium	
< 0.1	Low	Low Suitability

Table 5.12: Available Phosphorous Rating

Available P_2O_5(kg/ha)		
>55	High	High Suitability
31 – 55	Medium	
< 30	Low	Low Suitability

Table 5.13: Available Potassium Rating

Available K_2O (kg/ha)		
>280	High	High Suitability
110 – 280	Medium	
<110	Low	Low Suitability

Based on the above rating tables, the soils of Suryodaya Nagarpalika had mostly soils of medium to high organic matter with near neutral to strongly acidic reaction. The nutrient status of the soils ranged from low to high with respect to total N and available P, while exchangeable K ranged from high to very high. The main limitation for these soils in terms of productivity appears to be highly acidic nature of most of the soils and high sand contents of many of the soils which could lead to excessive drainage and low moisture retention causing water stress to crops. The Figures in Appendices 1 through 6 provides maps of the distribution of nutrients, organic matter and soil pH across the Nagarpalika.

CHAPTER 6: SOIL OF SURYODAYA NAGARPALIKA

The soil classification system in Nepal has adopted USDA Soil taxonomy (USDA-NRCS, 2014). The system should permit easy translation into other taxonomic systems also (World Reference Base, FAO).

6.1 Soil Types

Soil types can be delineated based on order, sub order, great group and sub group as well as family and series, the latter being particularly locally specific. The present study has incorporated both classification systems to devise the Nagarpalika level soil type of the area.

6.1.1. Soil types from order to sub-group level

Soils of Suryodaya Nagarpalika of Ilam district are classified based on the information of soil derived from soil pits and soil mapping unit level (Figure 6.1). This soil classification is based on the Great Soil Groups of Soil Taxonomy (USDA) with LRMP (1986) report due to the fact that the FAO soil classification is not a system of units grouped into higher categories, even though the system is spread worldwide. But these units relate most closely to Great Groups in the US system. In this system, the soils are grouped according to Soil Orders, Sub-Orders, Great Groups, Sub-Groups, Family and Series. The soils could not be classified to the family or series level due to insufficiently detailed information. Table 6.1 presents Soil Taxonomy classification to the Sub-Group level for the predominant soils of Suryodaya Nagarpalika.

Table 6.1: Soil Taxonomy Classification of Suryodaya Nagarpalika

Sample Identification No.	Sand %	Silt %	Clay%	Soil Texture	Soil Classification
SD 1	74.4	17.6	8	SL	Typic Haplumbrept
SD 3	47.4	34.6	18	L	Arenic Eutrochrept
SD 4	75.4	18.6	6	SL	Lithic Dystrochrept
SD 5	37.4	42.6	20	L	Typic Eutrochrept
SD 6	67.4	21.6	11	SL	Arenic Eutrochrept
SD 7	73.4	16.6	10	SL	Arenic Haplustalf
SD 8	41.4	46.6	12	L	Typic Haplumbrept
SD 9	53.4	31.6	15	SL	Typic Haplumbrept
SD 10	43.4	40.6	16	L	Typic Eutrochrept
SD 11	50.4	31.6	18	L	Typic Eutrochrept
SD 12 - a	57.4	30.6	12	SL	Arenic Hapludalf
SD 12- b	53.4	24.6	22	SCL	Typic Hapludalf
SD 13	57.4	32.6	10	SL	Arenic Hapludalf
SD 14	67.4	23.6	9	SL	Arenic Haplustalf
SD 15	41.4	44.6	14	L	Typic Hapludalf
SD 16	63.4	24.6	12	SL	Arenic Hapludalf
SD 17	67.4	21.6	11	SL	Arenic Haplustalf
SD 18	59.4	24.6	16	SL	Arenic Eutrochrept
SD 19	43.4	38.6	18	L	Typic Eutrochrept
SD 20	61.4	26.6	12	SL	Arenic Eutrochrept

SD 21	75.4	18.6	6	SL	Arenic Eutrochrept
SD 22	61.4	24.6	14	SL	Arenic Eutrochrept
SD 23	71.4	20.6	8	SL	Arenic Haplustalf
SD 24	55.4	26.6	18	SL	Arenic Haplustalf
SD 25	76.4	17.6	6	LS	Arenic Haplustalf
SD 26	63.4	24.6	12	SL	Arenic Haplustalf
SD 27	65.4	16.6	18	SL	Arenic Haplustalf
SD 28	55.4	32.6	12	SL	Psammentic Hapludalf
SD 29	55.4	34.6	10	SL	Psammentic Hapludalf
SD 30	56.4	29.6	14	SL	Psammentic Hapludalf
SD 31	73.4	18.6	8	SL	Psammentic Hapludalf
SD 32	55.4	30.6	14	SL	Psammentic Hapludalf
SD 34	65.4	24.6	10	SL	Psammentic Hapludalf
SD 35	53.4	36.6	10	SL	Typic Ustifluvent
SD 36	65.4	26.6	8	SL	Typic Ustifluvent
SD 37	49.4	36.6	14	L	Typic Haplumbrept
SD 38	57.4	32.6	10	SL	Arenic Haplustalf
SD 39	53.4	26.6	20	SCL	Udic Ustochrept
SD 40	67.4	20.6	12	SL	Udic Ustochrept
SD 41	31.4	36.6	32	CL	Typic Agrudalf
SD 42	57.4	32.6	10	SL	Udic Ustochrept
SD 43	30.4	36.6	32	CL	Udic Ustochrept
SD 44	51.4	27.6	21	SCL	Psammentic Hapludalf
SD 45	55.4	36.6	8	SL	Psammentic Hapludalf
SD 46	57.4	30.6	12	SL	Psammentic Hapludalf
SD 47	57.4	33.6	9	SL	Lithic Dystrochrept
SD 48	56.4	31.6	12	SL	Typic Agrudalf
SD 49	49.4	36.6	14	L	Typic Dystrochrept
SD 50	50.4	33.6	16	L	Typic Dystrochrept
SD 51	43.4	36.6	20	L	Lithic Dystrochrept
SD 52	49.4	36.6	14	L	Typic Agrudalf
SD 53	67.4	23.6	9	SL	Arenic Hapludalf
SD 54	69.4	22.6	8	SL	Arenic Hapludalf
SD 55	66.4	26	7.6	SL	Typic Ustochrept
SD 56	70.4	23	6.6	SL	Typic Ustochrept
SD 57	63.4	29	7.6	SL	Typic Ustochrept
SD 58	47.4	34	18.6	L	Typic Ustochrept
SD 59	73.4	16	10.6	SL	Typic Ustochrept
SD 60	55.4	31	13.6	SL	Arenic Haplustalf
SD 61 a	71.4	18	10.6	SL	Arenic Haplustalf
SD 61 b	61.4	26	12.6	SL	Arenic Haplustalf
SD 62	75.4	15	9.6	SL	Arenic Haplustalf
SD 63	75.4	16	8.6	SL	Arenic Haplustalf
SD 64	63.4	20	16.6	SL	Arenic Haplustalf
SD 65	69.4	14	16.6	SL	Arenic Haplustalf
SD 66	58.4	27	14.6	SL	Arenic Haplustalf

SD 67	61.4	27	11.6	SL	Arenic Haplustalf
SD 68	53.4	35	11.6	SL	Typic Haplustalf
SD 69	45.4	42	12.6	L	Typic Haplustalf
SD 70	37.4	45	17.6	L	Typic Haplustalf
SD 71	53.4	34	12.6	SL	Typic Ustifluvent
SD 72	35.4	44	20.6	L	Typic Ustifluvent
SD 73	50.4	35	14.6	SCL	Typic Ustifluvent
SD 74	69.4	10	20.6	SCL	Typic Ustochrept
SD 75	51.4	40	8.6	L	Typic Hapludalf
SD 76	61.4	18	20.6	SCL	Arenic Hapludalf
SD 77	59.4	32	8.6	SL	Arenic Eutrochrept
SD 78	67.4	19	13.6	SL	Lithic Hapludalf
SD 79	53.4	38	8.6	SL	Lithic Hapludalf
SD 80	45.4	40	14.6	L	Typic Hapludalf
SD 81	37.4	48	14.6	L	Typic Hapludalf
SD 82	53.4	20	26.6	SCL	Typic Hapludalf
SD 83	61.4	28	10.6	SL	Lithic Hapludalf
SD 84	69.4	24	6.6	SL	Arenic Hapludalf
SD 85	43.4	50	6.6	SiL	Typic Hapludalf
SD 88	45.4	44	10.6	L	Typic Eutrochrept
SD 89	63.4	26	10.6	SL	Arenic Ustochrept
SD 90	55.4	36	8.6	SL	Arenic Haplustalf
SD 91	59.4	32	8.6	SL	Arenic Haplustalf
SD 92	71.4	18	10.6	SL	Arenic Haplustalf
SD 93	61.4	32	6.6	SL	Arenic Eutrochrept
SD 94	59.4	30	10.6	SL	Udic Ustochrept
SD 95	57.4	30	12.6	SL	Arenic Haplustalf
SD 96	75.4	16	8.6	SL	Arenic Haplustalf
SD 97	51.4	44	4.6	L	Udic Ustochrept
SD 98	63.4	24	12.6	SL	Lithic Haplustalf
SD 99	45.4	46	8.6	L	Udic Ustochrept
SD 100	69.4	6	24.6	SCL	Arenic Haplustalf
SD 101	69.4	20	10.6	SL	Arenic Haplustalf
SD 104	69.4	14	16.6	SL	Arenic Eutrochrept
SD 107	65.4	26	8.6	SL	Arenic Eutrochrept
SD 102	53.4	26	20.6	SCL	Typic Dystrochrept
SD 103	55.4	28	16.6	SL	Arenic Haplustalf
SD 105	77.4	10	12.6	SL	Typic Ustifluvent
SD 106	69.4	24	6.6	SL	Typic Ustifluvent
SD 86	63.4	26	10.6	SL	Arenic Haplustalf
SD 87	55.4	36	8.6	SL	Arenic Haplustalf

Source: Soil Lab Report & Soil Survey, 2018

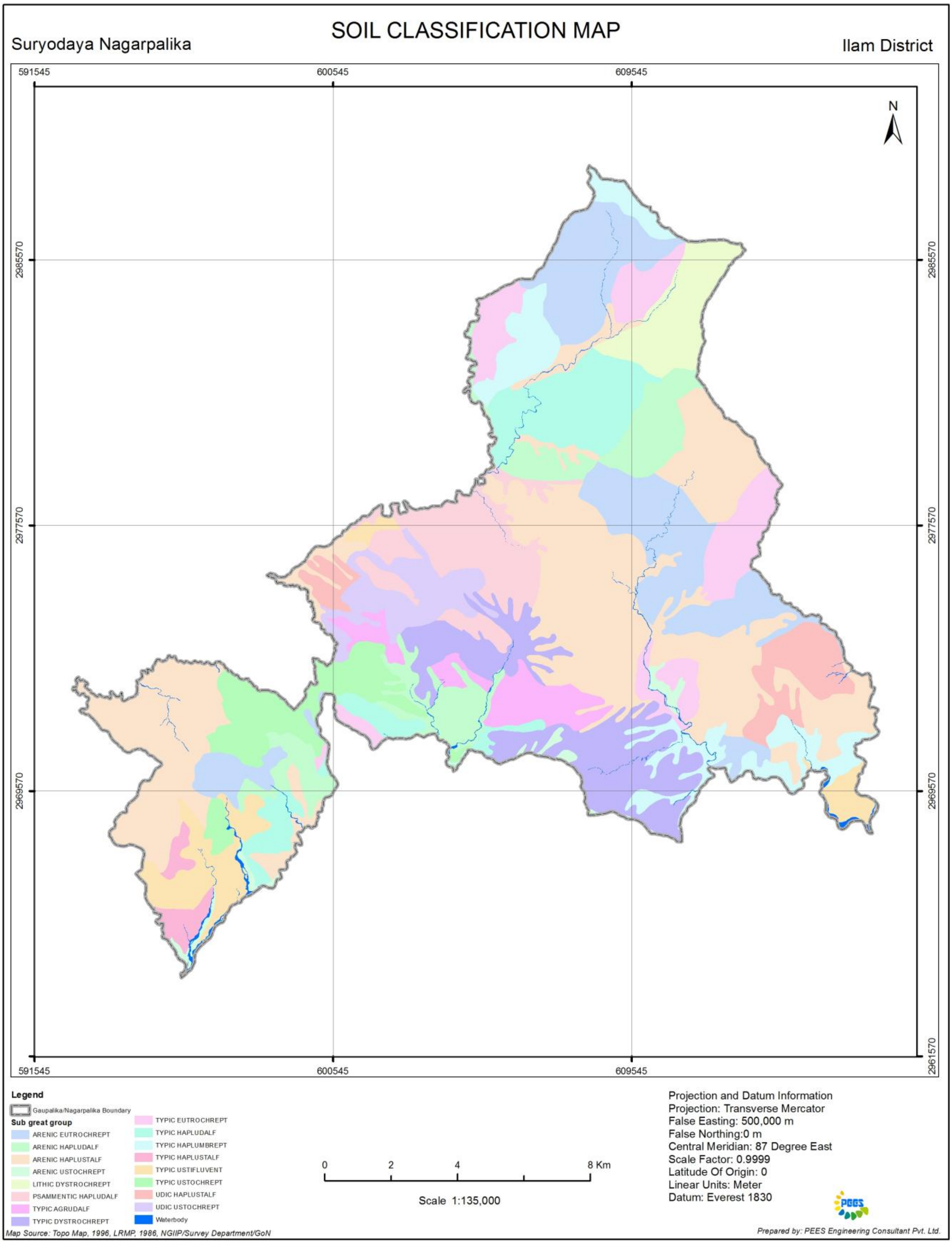

Figure 6.1: Distribution of soil Sub-groups of the Suryodaya Nagarpalika

Table 6.2. Area coverage of different soil sub-groups in the Suryodaya Nagarpalika

Order	Sub order	Great group	Sub great group	Area (Ha)	Percentage
ALFISOL	UDALF	AGRUDALF	TYPIC AGRUDALF	648.73	2.89
		HAPLUDALF	ARENIC HAPLUDALF	1502.10	6.69
			PSAMMENTIC HAPLUDALF	1294.87	5.77
			TYPIC HAPLUDALF	1473.01	6.56
	USTALF	HAPLUSTALF	ARENIC HAPLUSTALF	5889.08	26.25
			TYPIC HAPLUSTALF	220.65	0.98
			UDIC HAPLUSTALF	745.08	3.32
ENTISOL	FLUVENT	USTIFLUVENT	TYPIC USTIFLUVENT	856.87	3.82
INCEPTISOL	OCHREPT	DYSTROCHREPT	LITHIC DYSTROCHREPT	755.44	3.37
			TYPIC DYSTROCHREPT	1670.89	7.45
		EUTROCHREPT	ARENIC EUTROCHREPT	2712.41	12.09
			TYPIC EUTROCHREPT	1339.13	5.97
		USTOCHREPT	ARENIC USTOCHREPT	190.84	0.85
			TYPIC USTOCHREPT	1006.69	4.49
			UDIC USTOCHREPT	719.25	3.21
	UMBREPT	HAPLUMBREPT	TYPIC HAPLUMBREPT	1188.86	5.30
Water body				224.66	1.00
Total				**22438.57**	**100.00**

Suryodaya Nagarpalika forms a hilly area with considerable micro-variability in soil conditions. The soils were mostly young soil (at higher elevations) and moderately well-developed soils in the lower slopes and valleys. Physical properties such as texture were observed to be mainly sandy loam, loam and clay loam with some loamy sands along river or stream banks. The soils were mostly strongly acidic to near neutral in reaction. Soil fertility status was found to be of mostly medium with moderate to high OM content, medium total N and available P, while exchangeable K mostly high to very high.

Although a total of 3 Orders, 5 Sub-orders, 8 Great groups, and 16 Sub-groups were classified based on the soil survey investigation in Suryodaya Nagarpalika of Ilam district. The predominant soil orders making up most of the total land area were: Alfisols (52.46 percent) and Inceptisols (42.54 percent), while Entisols only covered less than 4 percent of the land area as shown in Figure 6.1 and Table 6.2. The soils are mostly sandy loam to loam in texture, strongly acidic to near neutral in pH, low to medium in P_2O_5, high to very high in K_2O and generally medium to high in other nutrients and organic matter. A detailed description of all the classified levels is provided below.

Order Alfisols

Alfisols are well developed soils with moderately leached profiles that have a high clay accumulation (argilllic diagnostic horizon) in the subsurface layers. These soils are stable and have good potential for agriculture production. The soils were observed to have low to medium level nutrient levels with high phosphorus content in this municipality. Only one Suborder Ustalfs and one Great group Haplustalfs are reported in this Nagarpalika.

Sub-order Ustalfs: Alfisols that have an Ustic soil moisture regime. These soils are mostly greyish brown to yellowish brown colour and found in warm humid climates. These soils in the study area were found to be near neutral to strongly acidic in soil pH. They have warm rainy season followed by a short winter and prolonged dry season.

Great Group Haplustalfs: These soils have well-developed profiles with clay accumulation in the subsurface layers, and an Ustic moisture regime. Clay coatings are observed indicating argillic diagnostic subsurface horizons.

Sub-group Typic Haplustalfs: These soils retain the central concept of Haplustalfs with the Typic subgroup having soils that are moderately deep or deep are freely drained and slightly alkaline to neutral in reaction.

Sub-group Arenic Haplustalfs: These soils are are moderately deep or deep to hard rock, freely drained and strongly acidic to neutral soil but differed from the Typic sub-group in that they had higher sand contents and were excessively drained in some cases.

Sub-Order Udalfs: Alfisols that have an Udic soil moisture regime. These soils are mostly dark greyish brown to dark yellowish brown colour and found in warm humid climates. These soils in the study area were found to be near neutral to strongly acidic in soil pH. They have warm rainy season followed by a short mild winter and prolonged dry season.

Great Group Agrudalfs: These are Alfisols having an “agric” sub-surface diagnostic horizon indicative of prolonged cultivation over centuries. These soils in the study area ranged from slightly to strongly acidic and have been under traditional agriculture for generations.

Great Group Hapludalfs: These soils are Alfisols that have a Udic moisture regime. They are mostly dark greyish brown to dark yellowish brown colour and found in warm humid climates. They have little development with weak features like structure, consistence, colour and boundary distinctions. These soils in the study area were found to be slightly to strongly acidic in soil pH.

Sub-group Arenic Hapludafs: These are Hapludafs with a sandy surface horizon. They also have minimal development with weak features like structure, consistence, colour and boundary distinctions. These soils in the study area were found to be moderately to strongly acidic in soil pH.

Sub-group Psammentic Hapludalfs: These soils are similar to Arenic Hapludalfs but have sandy textures throughout the profile. These soils in the study area were found to be moderately to strongly acidic in soil pH.

Soil Order: Entisols

Entisols are very young soils with little profile development on fresh alluvial deposits or on actively eroding rocks. The bulk of the soil is of relatively unchanged parent materials such as sand or rock fragments. It has only one sub-order found in this municipality that is given below. These soils occupy less than 4 percent of the total land area. They are sandy loam to loamy sand in texture, pH moderately alkaline, medium in P_2O_5, high in K_2O and medium to high in other nutrients and organic matter. The soil sub-order, great group and subgroup are detailed below.

Sub order Fluvents: These are Entisols that do not have a lithic or paralithic content with in 25cm of the soil surface and mainly located along the river course in depositional areas.

Small percent of the area (<3 %) are found in this sub order. These soils are coarse textured and affected by flooding during monsoon season.

Great Group Ustifluvents are Fluvents that have an Ustic soil moisture regime. The Ustifluvents soils are also called alluvial soil. They are slightly alkaline in reaction with low organic matter and nutrient status.

Sub-group Typic Ustifluvents: The soils are light coloured being greyish brown to yellowish grey in colour. They occur on are nearly level flood plain and most of the area are irrigated and cultivated. They make up only a small portion of the land found in the municipality mainly found adjacent to rivers and streams.

Soil Order: Inceptisols

The *Inceptisols* is the most extensive soil type found in Suryodaya Nagarpalika of Ilam district covering about percent of the area. This soil order also represents the dominant order at the national level in Nepal (LRMP 1986). Only one Sub-order Ochrepts, was observed along with the main Great Group of Ustochrepts. The main differentiating criteria used are soil moisture regime, diagnostic horizon and soil colour (hue, value and chroma) and base saturation level. They are silty clay or clay in texture, pH is strongly acidic to alkaline, low to medium level in P_2O_5, very low to very high in K_2O and mostly low in total nitrogen and organic matter content. These soils are mostly suitable for rice- based crop production.

Sub-order Ochrepts: Ochric epipedon is characterized by light colour (moist values greater than 4), comparatively low organic content and low base saturation. They tend to be hard and massive when it is dry. Under this sub-order the Great Group Ustocrepts were identified. Rice based intensive cropping pattern is dominant on this soil in the study area.

Great Group Ustochrept: Ustochrepts great group in this Nagarpalika are characterized by an ochric epipedon with moderately to strongly acidic soil pH, a mesic soil temperature regime and an Ustic soil moisture regime. It has two sub groups, namely, *Typic, and Arenic Ustocrepts*.

Sub-group Arenic Ustochrepts: These soils are similar to Typic Ustrochrepts with low soil profile development, neutral to alkaline, and have low nutrient content with an Ochric epipedon. The main difference in these soils is a high sand content and rapidly to excessively drained profile.

Sub-group Udic Ustochrepts: These are soils similar to Arenic Ustochrepts but have a moisture regime between that of ustic and udic. They typically occur on north and north-east facing slopes where the soil moisture is higher.

Great Group Dystrochrepts: These are soils with an Ochric epipedon and many features similar to Ustochrepts. The main distinction of these soils is a generally low fertility status and low organic matter. The soils in this category found in the study area have mesic temperature regime and slightly to strongly acidic reaction. Two sub-groups are found in the study area, namely, *Typic* and *Lithic Dystrochrepts*.

Sub-group Lithic Dystrochrepts: These soils are Dystrochrepts that have a shallow soil profile. Most of these soils have thickness of less than 50 cm. The thin layer of soil contributes to their low fertility and marginal suitability for crop cultivation.

Great Group Eutrochrepts: These are soils with an Ochric epipedon and features similar to Ustochrepts and Dystrochrepts. The main distinction of these soils is a higher fertility status and organic matter content than Dystrochrepts. The soils in this category found in the study area have mesic temperature regime and moderately to strongly acidic reaction. Two sub-groups are found in the study area, namely, Typic and *Lithic Eutrochrepts*.

Sub-group Arenic Eutrochrepts: These soils are Eutrochrepts that have a sandy surface horizon and fairly deep soil profiles. They are generally young soils with weak profile development but generally good fertility status.

Sub-Order Umbrepts: These are Inceptisols that have an Umbric epipedon. They are dark in colour due to high organic matter content, particularly in the surface soil layers. In the study area, these soils tend to occur in cooler, north or northeast facing slopes.

Great Group Haplumbrepts: These soils are Umbrepts that have minimal development and weak profile features such as structure, consistence, colour and boundary distinctions. They are generally dark coloured soils with high organic matter and nutrient status.

Sub-group Typic Haplumbrepts: These are Haplumbrepts that reflect the typical features of such types of soils as described above. In the study area, these soils had near neutral to strongly acidic pH with moderate to deep profiles.

6.1.2. Soil types based on family level

Soil family is the descriptive presentation of soil properties relating to plant growth or engineering purpose such as mineralogical class, soil temperature class, pH, soil texture, permeability, thickness of horizon, structure, consistency etc. In the present context, soil temperature is used as descriptive criteria of soil family.The study area, Suryodaya Nagarpalika falls in the Mesic soil temperature regime of sub-tropical climatic condition. Mesic soil temperature regime means that the mean annual soil temperature at 50 cm (control section) is between 8 and 15 degrees Celsius. Table 6.1 is presents the soil classifications found in the study municipality to the sub-group level, which indicates the soil order, sub-order, great group and sub-group of each soil type found in the study area.

6.1.3. Detailed soil profile descriptions

Some examples of the field survey and detailed soil profile descriptions derived from the field work are given below. Soil property data for each pit is given in the tables below.

Soil Pit No.: SD_30

Surveyor	:	R. Bhattarai
Location	:	Phikkal Bazaar
Coordinates	:	N 2976206; E 606579
Local Climate	:	Sub-tropical, monsoon
Bedrock type	:	Schist, quartzite
Parent material	:	Colluvial rocks and debris
Rock outcrop	:	Nil
Landform/slope position	:	back slope

Slope/Aspect	:	20-25 degrees; Northeast
Drainage	:	Well drained
Land use	:	Fallow, vegetables
Vegetation	:	weeds
Cropping pattern	:	Potato, vegetables
Irrigation availability	:	nil
Erosional signs	:	Slight rill
Other features	:	Sandy soil, Ochric epipedon

Ap --	0-20 cm; Yellowish brown (10YR 5/6) dry; Sandy loam, weak fine subangular blocky, soft; acidic, few fine roots; smooth clear boundary.
B --	20-60 cm; Light brown (7.5YR 6/4) Sandy loam, weak fine subangular blocky, soft; common fine interstitial pores; wavy cl ear boundary.
C --	60+ cm; weathered schist and quartzite rocks (parent material)

Classification: ***sandy mixed mesic Psammentic Hapludalf***

Sample Index	Soil Property	Observed Value
SD_30	Soil pH	5.65
	Organic matter	4.35 %
	Total N	0.22 %
	Available P	30.75 mg/kg
	Exchangeable K	844.2 mg/kg
	Textural Class	Loamy sand

Soil Pit No.: SD_40

Surveyor	:	D. Ghimire
Location	:	Tinghare
Coordinates	:	N 2974146; E 601905
Local Climate	:	Sub-tropical, monsoon
Bedrock type	:	Gneiss, quartzite, schist
Parent material	:	Weathered quartzite, gneiss and schist
Rock outcrop	:	Nil
Landform/slope position	:	Back slope
Slope/Aspect	:	
Drainage	:	Well drained
Land use	:	Forest
Vegetation	:	Mixed forest
Cropping pattern	:	Nil
Irrigation availability	:	N/A

Erosional signs	: Nil
Other features	: moderately deep, sandy soil

A --	0-22 cm; Dark yellowish brown (10YR 4/4) Sandy loam, weak medium sub-angular blocky, friable; 5% gravel, strongly acidic, common fine roots; wavy gradual boundary.
B --	22-60 cm; Brownish yellow (10YR 6/6) Sandy clay loam, moderate medium sub-angular blocky, firm; few fine interstitial pores; few fine-medium roots, wavy clear boundary.
C --	60+ cm; Yellowish brown (10YR 5/8) Sandy clay loam, weathered quartzite, gneiss and schist parent material.

Classification: ***coarse mixed mesic Udic Ustochrept***

Sample Index	Soil Property	Observed Value
SD_40	Soil pH	5.39
	Organic matter	2.29 %
	Total N	0.16 %
	Available P	19.1 mg/kg
	Exchangeable K	281.4 mg/kg
	Textural Class	Sandy loam

Soil Pit No.: SD_41

Surveyor	: S. Pandey
Location	: Aitabare
Coordinates	: N 2974718; E 602889
Local Climate	: Sub-tropical, monsoon
Bedrock type	: Schist, quartzite
Parent material	: Weathered quartzite and schist
Rock outcrop	: Nil
Landform/slope position	: Shoulder
Slope/Aspect	: 15-20 deg.; northeast
Drainage	: Somewhat poorly drained
Land use	: Horticulture
Vegetation	: Fruit trees
Cropping pattern	: Permaculture
Irrigation availability	: N/A
Erosional signs	: Slight sheet erosion
Other features	: Moderately deep, medium clay content

Ap --	0-20 cm; Brown (7.5YR 5/4) Sandy clay loam, weak coarse sub-angular blocky, hard; common fine roots; wavy clear boundary.
Bt1 --	20-32 cm; Brown (7.5YR 4/4) Clay loam, weak coarse sub-angular blocky, hard; few medium roots; very fine interstitial pores; wavy clear boundary.

Bt2 --	32+ cm; Reddish yellow (7.5YR 6/8) Clay loam, moderate coarse sub-angular blocky, very hard; wavy gradual boundary.

Classification: ***loamy mixed mesic Typic Agrudalf***

Sample Index	Soil Property	Observed Value
SU_41	Soil pH	5.36
	Organic matter	4.46 %
	Total N	0.22 %
	Available P	46.52 mg/kg
	Exchangeable K	536 mg/kg
	Textural Class	Sandy clay loam

Soil Pit No.: SD_56

Surveyor	:	S. Kafle
Location	:	Bhalukhop
Coordinates	:	N 2972097; E 599473
Local Climate	:	Sub-tropical, monsoon
Bedrock type	:	Schist, phyllite
Parent material	:	Weathered schist and phyllite
Rock outcrop	:	Nil
Landform/slope position	:	Back slope
Slope/Aspect	:	10-15 degrees; Southwest
Drainage	:	Well drained
Land use	:	Tea cultivation
Vegetation	:	Tea plants
Cropping pattern	:	Tea permaculture
Irrigation availability	:	N/A
Erosional signs	:	Rill erosion visible
Other features	:	Moderately deep, sandy soil

Ap --	0-18 cm; Dark yellowish brown (10YR 4/4) Sandy loam, weak fine granular, friable; 5% gravel, strongly acidic, many fine roots; smooth gradual boundary.
B --	18-58 cm; Dark yellowish brown (10YR 4/4) Sandy loam, weak fine sub-angular blocky, friable; few fine-medium roots, wavy gradual boundary.
C --	60+ cm; Yellowish brown (10YR 5/4) Sandy clay loam, weathered phyllite and schist parent material.

Classification: ***coarse-loamy mixed mesic Typic Ustochrept***

Sample Index	Soil Property	Observed Value
SD_56	Soil pH	5.44
	Organic matter	3.04 %
	Total N	0.15 %
	Available P	30.1 mg/kg
	Exchangeable K	375.2 mg/kg
	Textural Class	Sandy loam

6.2 Soil GIS Database(Geo-database)

Soil GIS database was prepared at two levels: Soil Pit and Soil Mapping Unit. Soil Mapping Units were formed or delineated based on integration of Land System, Landform and Land units along with micro relief variation in relation to physico-chemical soil characteristics. Individual pit level information was aggregated at soil mapping units because it contains multi-pits or pedons. Soil Pit contains site characteristics including physical attribute and also soil profile at horizon level information. It also includes physical and chemical properties or attribute of soil. Soil horizon level information was contained in soil pit.

The soil GIS database is stored and maintained as related to geo-database linking shape file to its attribute in attribute table. The soil GIS Database contains soil unit GIS database, soil pits GIS database including soil profile horizon information. Furthermore, it contains soil chemical (lab) test database table. GIS "shape" files and "dbf” are also maintained for comprehensive use.

CHAPTER 7: CONCLUSIONS

7.1 Conclusions

Soil survey and mapping of the Suryodaya Nagarpalika showed that most of the soils found in the area are relatively young with minimum soil profile development. More than 52 percent of the soils were of the order Alfisols, with additional 42.54 percent of the land area of the order Inceptisols. Only about 4 percent of soils were observed to belong to the order Entisols. The soil map of Suryodaya Nagarpalika of Ilam District was prepared by integrated use of Geo-science technology consisting of RS, GIS and GPS and soil mapping unit identified with landform and land type units.

Most of the land types and soil mapping units fell under moderate to steep slope categories (15 to 30 and 30- to 60-degree slopes). Terrain classification was done to represent micro-relief of the area represented by land type units and land use/land cover. Furthermore, cropping pattern is also considered to differentiate the soil mapping unit. These parameters helped to characterize the unique features of physio-soil relationship. Based on land type, over 90 percent of total geographical area of the Nagarpalika is of sloping mountainous terrain.

A total of 108 soil pits were described in the field representing varied micro-topography. They were investigated for each of the representative land type units covering the entire Nagarpalika area. Physical and chemical properties of soil pits are analyzed and linked with spatial entities (soil pits and polygon) based representation of land units and soil mapping units. All individual soil pits were grouped and aggregated into soil mapping units together under different USDA Soil Taxonomy hierarchy as Order, sub-order, great group, sub-group, and family. Different Great Groups, Sub-groups of Alsfisols, Inceptisols, and Entisols occurred in decreasing order of dominancy spatially. Soil nutrient analysis showed that exchangeable potassium of most of soils were high to very high, while available phosphorus was observed to range from low to high levels. Soil total nitrogen and organic matter content range from medium to high indicating that the soils in this municipality were generally of good nutrient status. However, the soil reaction was found to vary from slightly alkaline to highly acidic. Aside from the northern most part of the municipality, most of the other areas were moderately acidic to highly acidic. Hence the main limitation for crop production in this municipality appears to be the acidic nature of most of the soils.

7.2 Recommendations

The integration of 3S (RS, GIS & GPS) technology in soil survey was found to be satisfactory. The use of methodology adopted for this study is essential for digital soil mapping required for sustainable land use planning. The present study strongly felt the need of the soil survey and mapping of all the Nagarpalika of Nepal for optimum land use planning and sustainable development of municipalities in future. Since the taxonomical classification is entirely based on some chemical and morphological properties of endopedon (sub-soils) some additional analysis such as texture, organic matter, CEC and pH of the endopedons and CEC of epipedon needs to be analysed. Based on the analysis of nutrient status it can be recommended to supply the appropriate fertilizers as well as appropriate crops as per the suitability of the soil. It is recommended that addition of significant amounts of agricultural lime and organic matter in the form of compost and farmyard manure along with recommended minimal doses of chemical fertilizer to increase the agriculture production for long term sustainability.

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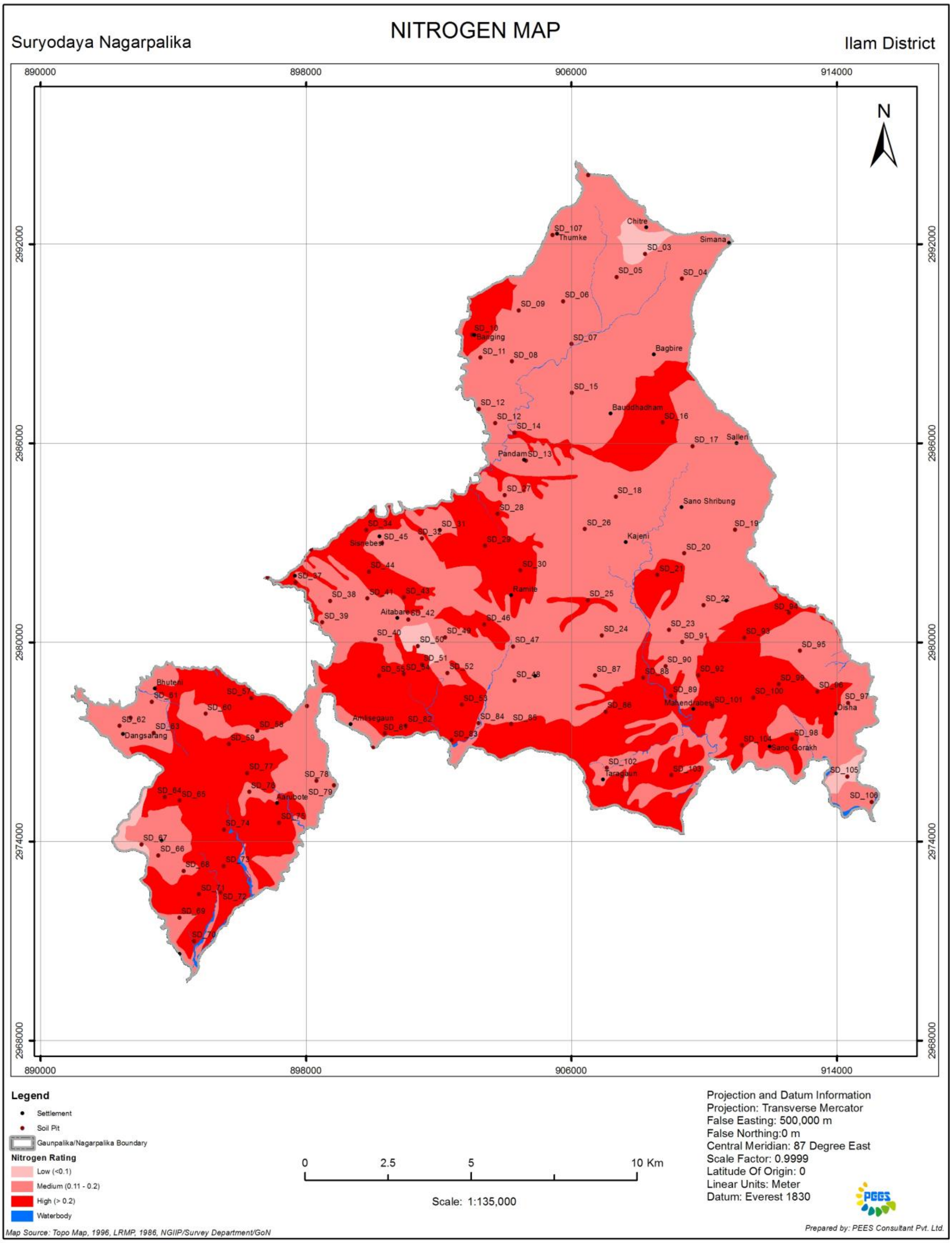
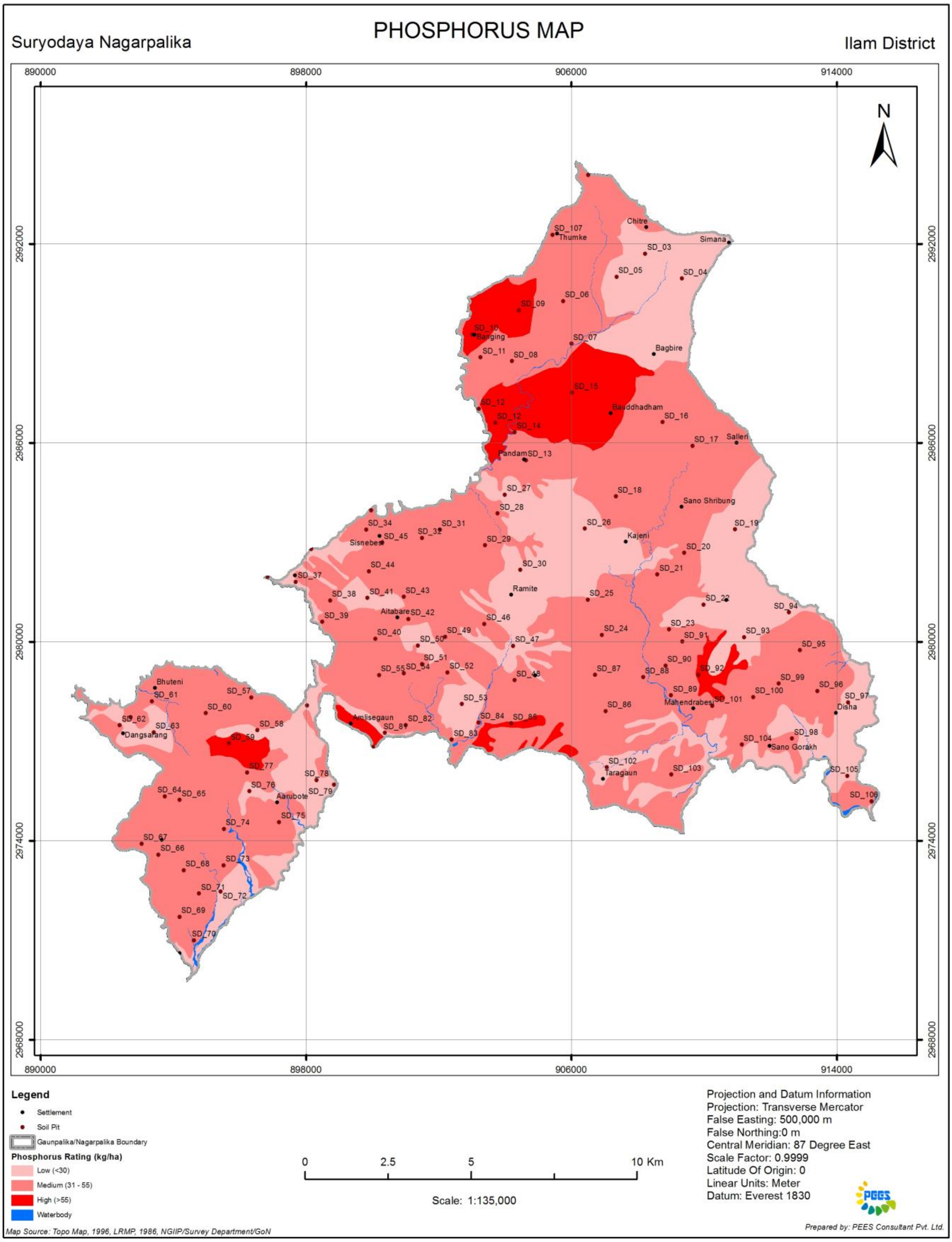
APPENDICES

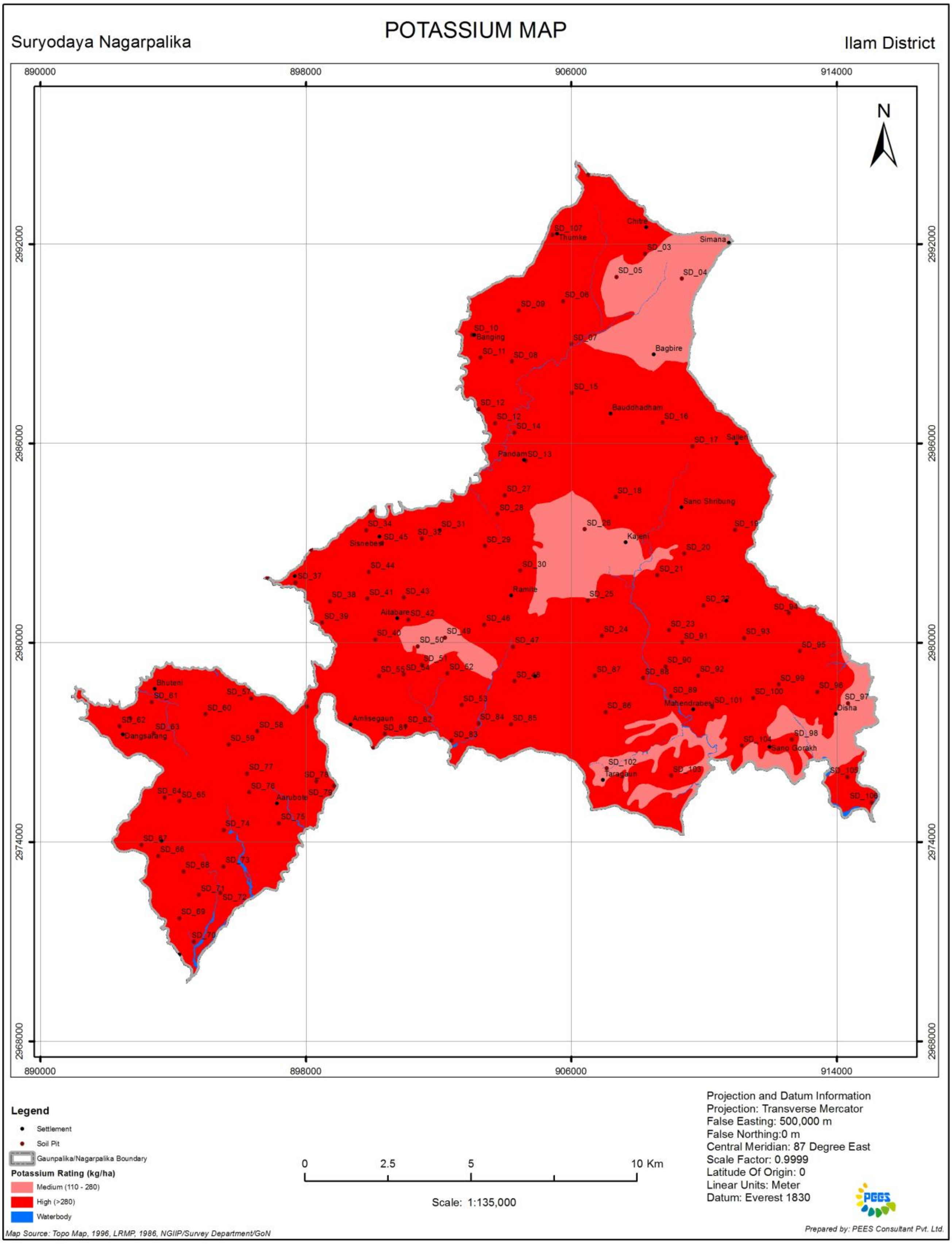
Appendix 1: Nitrogen content in the Suryodaya Nagarpalika



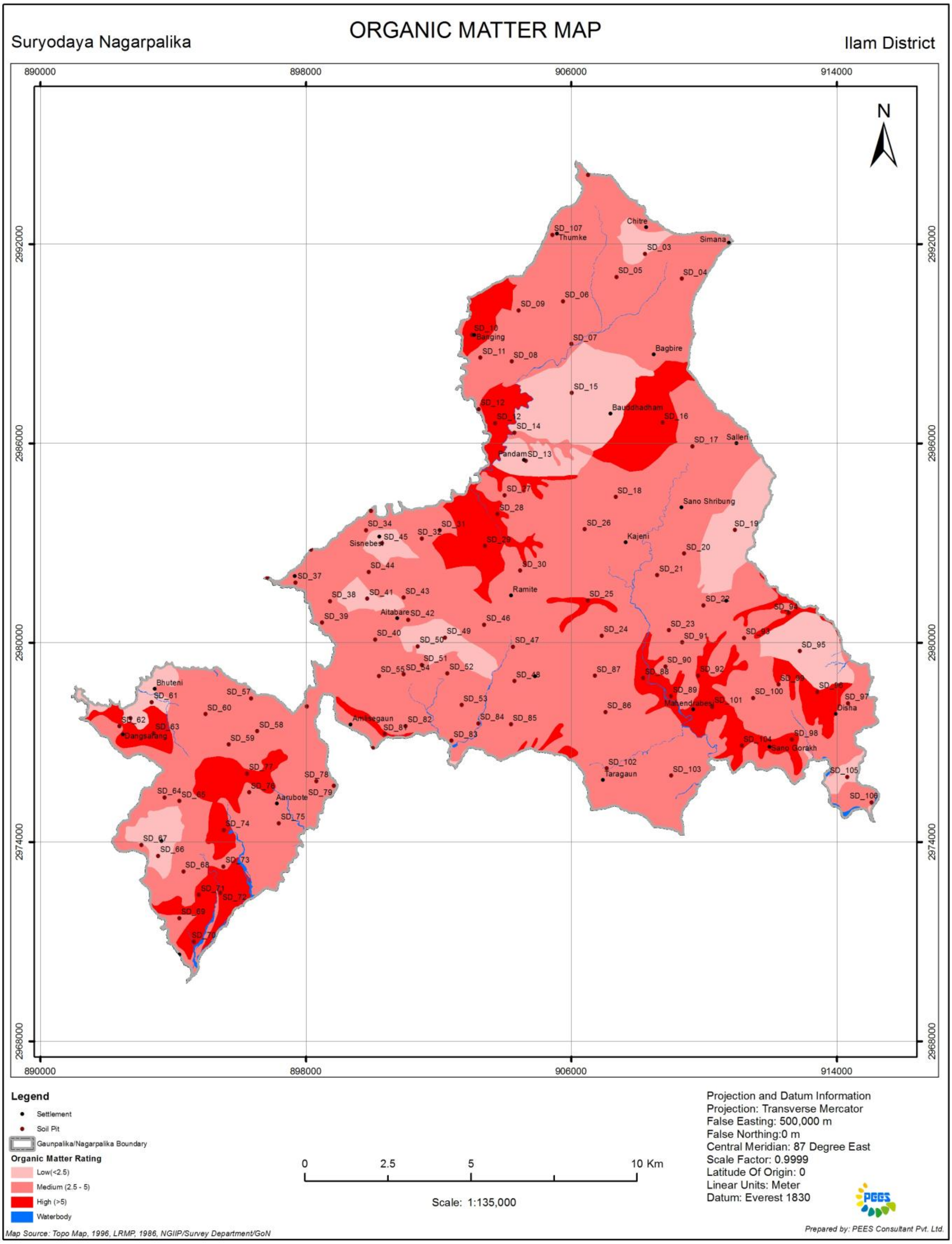
Appendix 2: Phosphorus content in the Suryodaya Nagarpalika



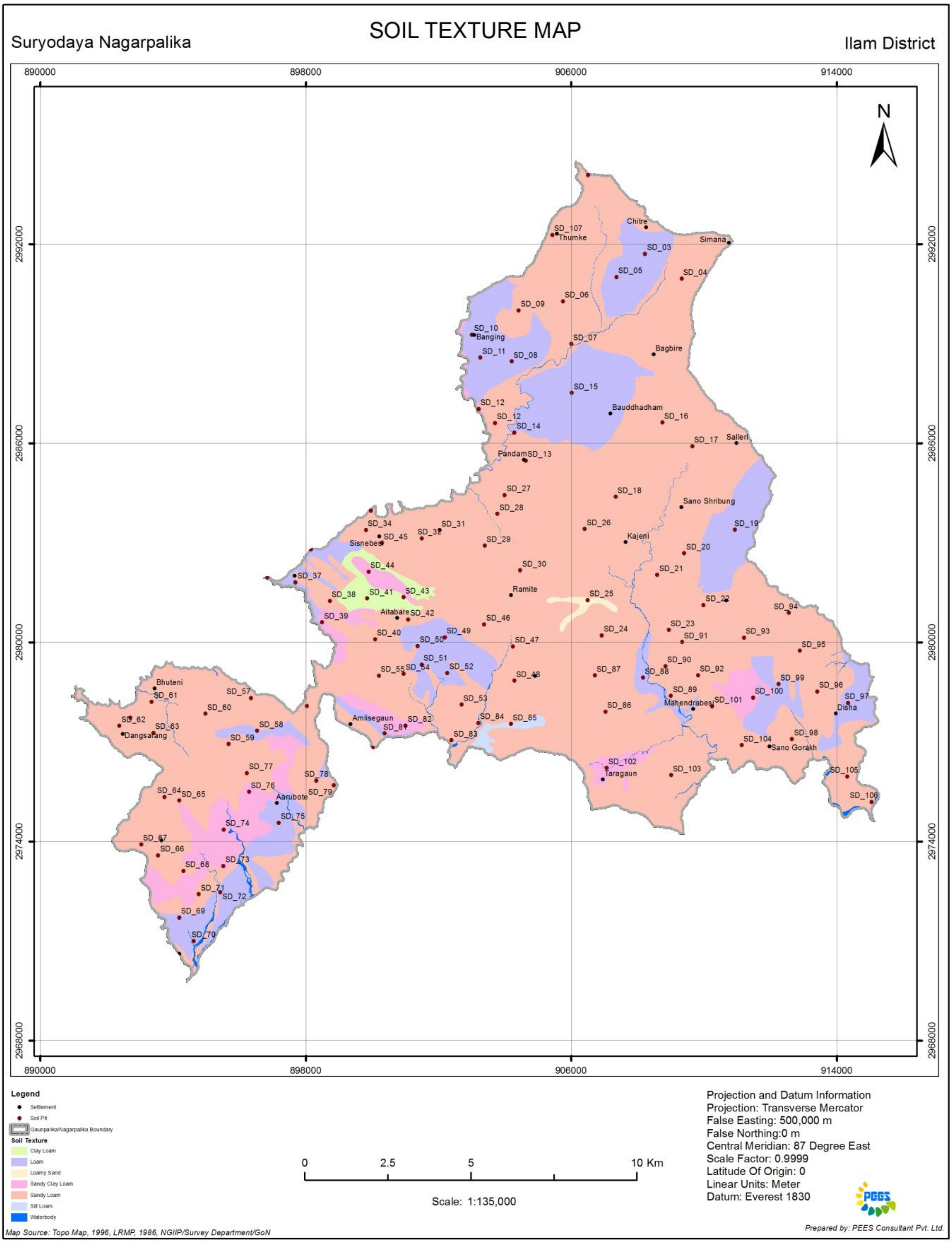
Appendix 3: Potassium content in the Suryodaya Nagarpalika



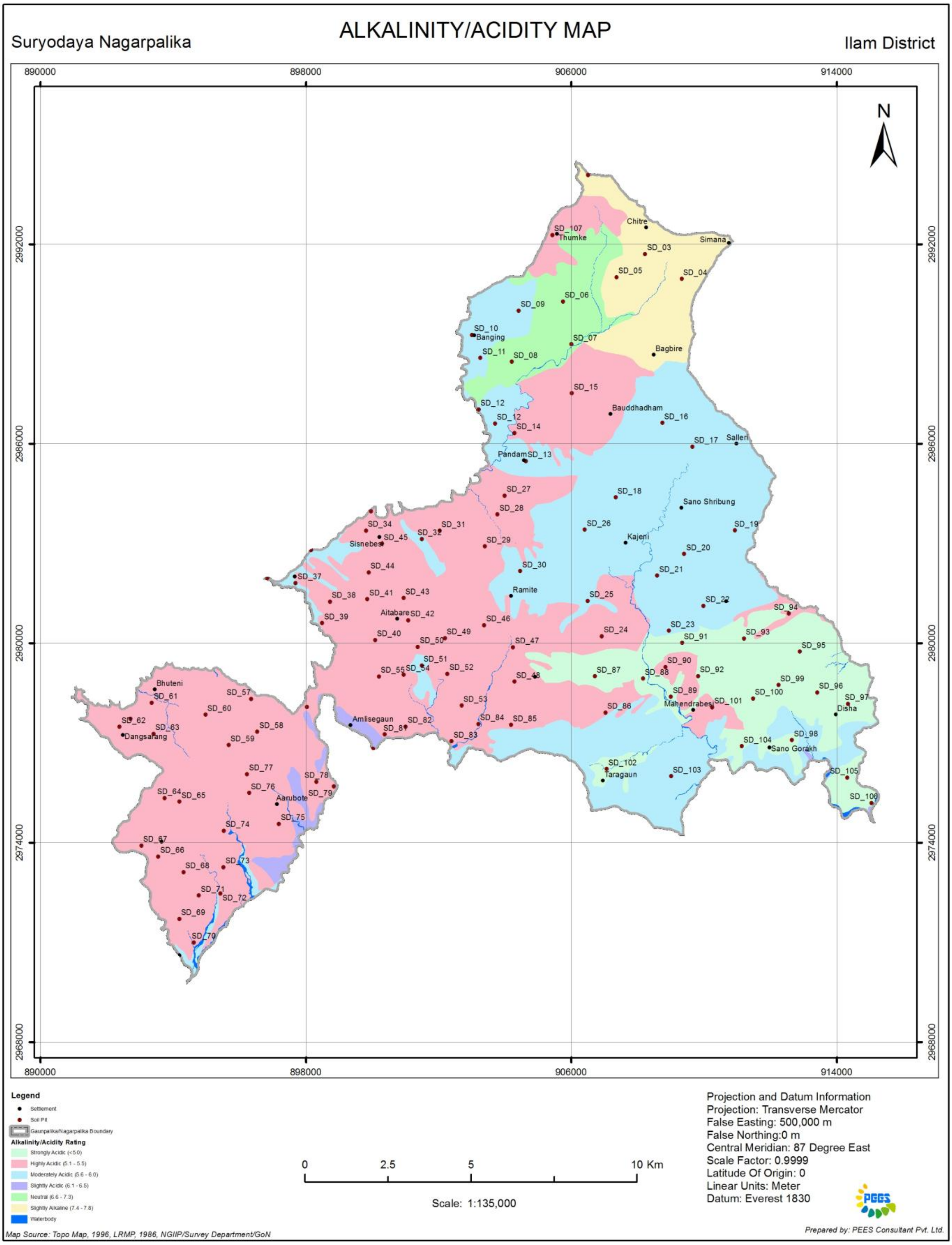
Appendix 4: Organic matter content in the Suryodaya Nagarpalika



Appendix 5: Texture content in the Suryodaya Nagarpalika



Appendix 6: pH content in the Suryoadaya Nagarpalika



Land Capability Report

Preparation of Land Capability Report Suryodaya Nagarpalika Ilam District

This document is the output of the project entitled **Preparation of Gaunpalika/Nagarpalika level Land Resource Maps (***Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and Gaunpalika/Nagarpalika Profile***), Database and Reports (Package-04)** awarded to *PEES Consultant (P) Ltd.* by Government of Nepal/Ministry of Agriculture, Land Management and Cooperatives, National Land Use Project (NLUP) in Fiscal Year 2074-075.The Nagarpalika/Gaunpalika covered under the Package 04 of Ilam District are: Suryodaya Nagarpalika and Rong Gaunpalika.

The Nagarpalika/Gaunpalika areas analysed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the Nagarpalika/Gaunpalika may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

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Executive Summary

Suryodaya Nagarpalika covers a total land area of 22,438.57 ha (of which about 89 percent is cultivated and only 5.24 percent is forest) and has a population of 56,707 inhabitants. It consists mainly of lands with moderate to steeply slopes ranging from 5 to 60 degree slopes, with elevations ranging from about 700 m to 2500 m amsl or msl. Also, much of the land area has moderately deep soil formed on active and recent colluvial deposits and weathered schist, phyllite, quartzite and gneiss parent material. The majority of the land is categorized in Classes III land capability class with some minor areas categorized as I and II capability classes. About 37 percent of the land is non-arable being settlement areas, forested areas or very steep sloping land (30 to 60 degree slopes).

More than 61 percent of the land in the Nagarpalika fell under capability class III. These lands are generally suited to upland rain-fed agriculture; however, terracing is mandatory due to typically steep slopes (5-30 degrees). Moreover, some of these soils have additional limitations due to soil acidity and shallow soil depth. Therefore, liming and soil water management is recommended for optimum production. Other categories, namely, I Ah, II Au, II Ah and II Bh, while better suited to agriculture, make up only a small portion of the land area. Therefore, in order to achieve high yields for economic crop production, adequate soil stabilization measures and fertility management, including addition of sufficient amounts of lime and farmyard manure, are required.

Since the Nagarpalika has mostly moderately to steeply sloping lands, they require adequate conservation measures, including, terracing, proper drainage of excess runoff and other soil stabilization measures, to achieve economic production. Also, as many of the soils are highly acidic addition of adequate amounts of agricultural lime is recommended. Other steeply sloping areas are not recommended for traditional agriculture but, they may be suitable for controlled livestock grazing, horticultural crops and agroforestry systems implemented with proper soil conservation and stabilization measures.

Other steeply sloping areas are not recommended for traditional agriculture; however, these lands may be suitable for controlled livestock grazing, horticultural crops and agroforestry systems implemented with proper soil conservation and stabilization measures. Such a diversified cropping system with incorporation of livestock rearing would also enhance the resilience of local communities to the impacts of climate change.

CHAPTER 1 : INTRODUCTION

1.1 Background and Rationale

Land has been defined as “a delineable area of the earth’s terrestrial surface, encompassing all attributes of the biosphere immediately above or below the surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps), near surface sedimentary layers and associated groundwater reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity” (UN, 1995). Land has many functions, such as, production, hydrologic, climate regulative, biotic function, living space, connectivity, etc., which are all vital for the survival and well-being of human and other terrestrial communities. As human populations explode and over-exploitation of land-based resources is increasing, there is an urgent need for proper planning and policy formulation regarding land use. Planning and evaluation is an essential function of rational use of available natural resources for overall development of the nation. Land use planning is the systematic assessment of land and water potential and alternatives for land use considering economic and social conditions in order to select and adopt the best land use options.

The FAO (1976) framework defined land evaluation as “the process of the assessment of land performance when the land is used for specified purposes. It involves the execution and interpretation of surveys and studies of landforms, soil, climate, vegetation and other aspects of land in order to identify and compare promising kinds of land use in terms applicable to the objectives of the evaluation. To be of value in planning, the range of land uses considered should be limited to those relevant within the physical, economic and social context of the area considered, and the comparisons should incorporate economic considerations.”

Nepal has, in recent decades, undergone rapid population growth, urbanization and demographic shifts. The ever-growing demand for food is no longer met through domestic production; rather the nation has become increasingly dependent on imports. Although the majority of Nepalese people are heavily dependent upon land resources for their livelihoods and sustenance, sub-optimal utilization of these resources, a shortage of farm labour due to out-migration, and unsustainable practices are leading to productivity decline and land degradation. Hence, sound land-use planning supported by land capability classification is neededfor sustainable land management in Nepal.

Modern technologies such as remote sensing (RS) and Geographic Information Systems (GIS) offer real time spatial and temporal data on land resource which could be used efficiently to prepare digital database. These spatial databases together with data on different land use characteristics can be collected fromthe field survey even at Nagarpalika level and information derived could be used for developing decision making support systems (DSS). Land can be classified according to its present use and suitability for specific crops under the existing forms of management, its capability for producing crops or combinations of crops under optimum management. A good knowledge of the land capability and suitability combined with good understanding of the soil characteristics and management aspects are essential for more productive and sustainable use of land resources.

In view of the above factors, the Ministry of Agriculture, Land Management and Cooperatives of GoN established the NLUP in 2057/058 fiscal year to generate the necessary databases on the land resources of the country. In the first phase, the NLUP initiated several projects at district level and prepared Land Resource Maps and Database at 1:50,000 scale for the whole nation. Recently, NLUP has been mandated to prepare land resource maps at Gaunpalika/Nagarpalika level for local level planning.

In the above context, Project Engineering and Environmental Studies (PEES) Consultants have been given the responsibility to undertake this task for Ilam district, Package-04. The work includes preparation of Gaunpalika/Nagarpalika level land resource database and maps, including present land use, soil, land capability, risk and land use zoning maps, along with profiles for land use zoning with cadastral layers superimposed. For this task, two local bodies of Ilam district have been selected. These include: Suryodaya Nagarpalika and Rong Gaunpalika. The mandate for the preparation of Nagarpalika level land capability maps by NLUP are:

a) Identification of the residential and other non-agricultural areas according to the capability of land.
b) Promotion of agricultural productivity as per land capability in comparatively advantageous sub-areas.
c) Conservation of natural resources including forest, shrub, rivers and rivulets and wetland in agricultural/non-agricultural areas.

1.2 Objectives and Scope of the Study

The general objective of this project is to prepare Gaunpalika/Nagarpalika level land resource maps (Present Land Use Map. Soil Map, Land Capability Map, Risk Map, Land Use Zoning Map, Gaunpalika/Nagarpalika Profile for Land Use zoning and Superimpose of Cadastral Layers), database and reports.

The specific objective of the project is to prepare Land Capability Maps at 1:10,000 scales, GIS database and Reports for **Suryodaya Nagarpalika**

Scope of the Work: In order to achieve the above mentioned objective, the scope of work includes the following activities:

a) Study the existing relevant maps, documents and database of the project area.
b) Prepare land capability maps for the selected Nagarpalika at 1:10,000 scales by analyzing relevant data, maps, field samples and information of soil laboratory test analysis.
c) Design appropriate GIS database.
d) Discuss the accuracy, reliability and consistencies of data.
e) Prepare reports while describing methodology, existing land capability types and model of GIS database.

1.3 The Study Area

Suryodaya Nagarpalika, name being the Nepali translation of “Rising Sun” declared Nagarpalika status in 2013 (2070 BS), with the merged of three Village Development Committees (VDCs) namely: Phikkal, Panchakanya and Kanyam. After, the restructuring of local body in 2073 BS, Gorkhey, Pashupatinagar, Sriantu, Samalbung, Laxmipur and Jogmai ward no. 8 and 9 were also merged into the Nagarpalika. It is located in Ilam district, province no. 1, approximately 40 km south-east of the district headquarter Ilam. Geographically, it lies in the hill region which is mostly known as Mahabharat range with natural scenery and pleasant weather. Its geographical coordinates are 87°55'59" - 88°10'37" east longitude and 27°0'28" to 26°47'17" north latitude. The Nagarpalika is bordered with India on the east, Ilam Nagarpalika and Maijogmai Gaunpalika on the west, Maijogmai Gaunpalika on the north and Rong Gaunpalika on the south (Figure 1.1). Phikkal is the center of the Nagarpalika. The total area of the Nagarpalika is 22438.57ha. This is extended north-south 25.29 km and east-west with 24.71 km.

The inhabitants are believed to have been living in this Nagarpalika since ancient time. According to the Population Census of 2011, the total population of this Nagarpalika was 56,707 and the numbers of households were 13,211. This gives an average household size of 4.3 which is lower than the national average (4.88). Administratively, the Nagarpalika has been divided into 14 wards. Ward 1 is the largest in terms of population size whereas ward 7 is the smallest one.

The Nagarpalika has diversity both in its physical and cultural aspects. It is a business hub of Ilam with beautiful landscapes. Tea, ginger, *Amriso,* cardamom, round chilies (*Akabare Khursani)*, milk and potatoes are the major trade items of this Nagarpalika. The Nagarpalika has great possibility for the tourism. Kanyam, Pashupatinagar, Phikkal, and Sri Antu are famous for tourist destination sites. Rai, Brahmin, Chhetri and Tamang are major ethnic group inhabited in the Nagarpalika.

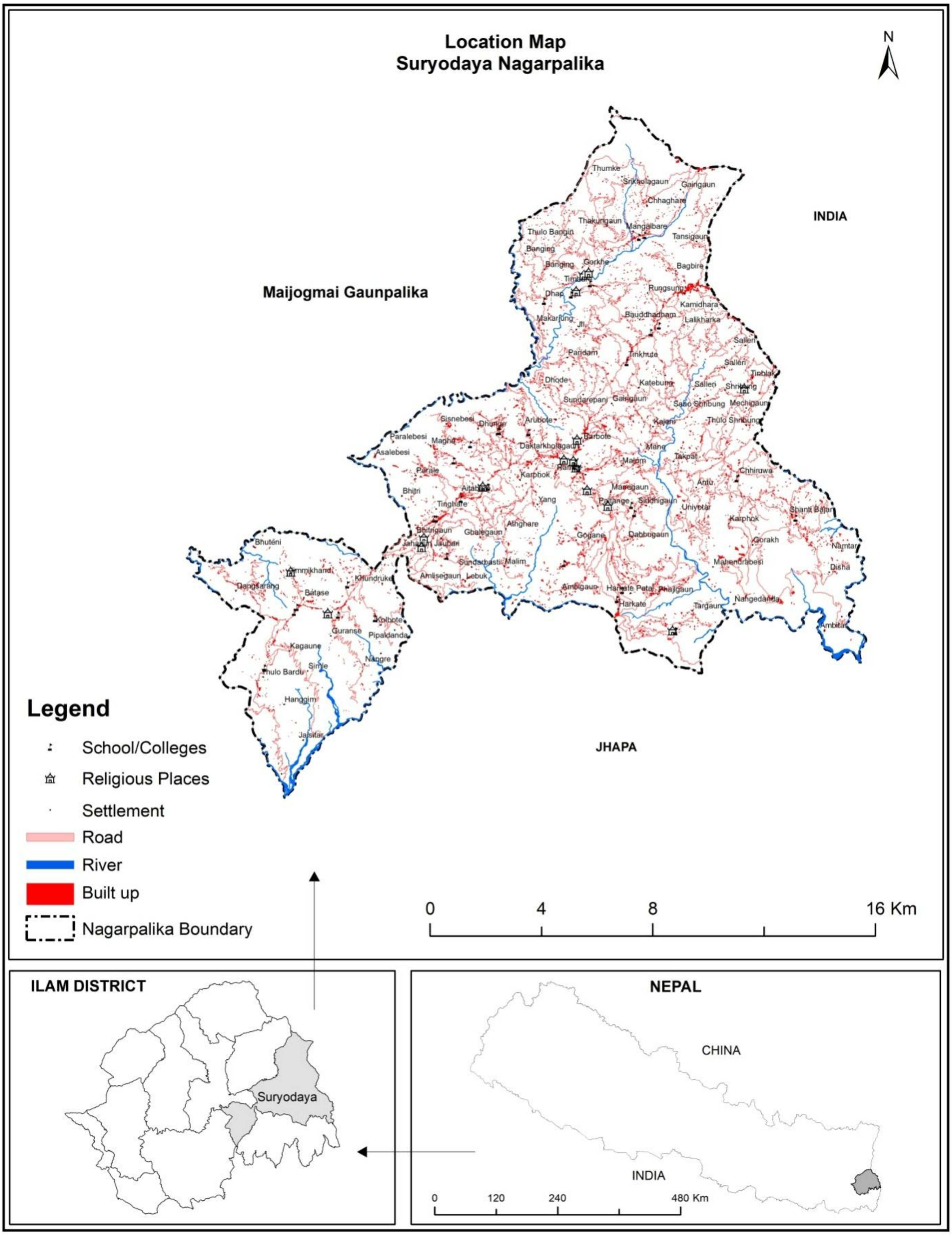

Figure 1.1.Location Map of Suryodaya Nagarpalika

CHAPTER 2: CONCEPTUAL BASIS OF LAND CAPABILITY CLASSIFICATION

Evaluation of land for capability assessment involves the categorization of the land on the basis of its ability to support a range of uses such as agriculture, pastures, settlements, etc., on a sustainable basis without degradation of the resources. It was put forth and developed by the United States Department of Agriculture and has been used in identifying appropriate land uses and required management forsustaining long-term productivity. Land capability classification takes into account geology, soils, slope, climate, erosion hazards and land management practices. It also takes into account stoniness, flooding, salinity and drainage conditions of the land. It grades the land for broad scale agricultural uses.

Land capability grading at Gaunpalika/Nagarpalika level requires assessment of land for various uses considering land suitability, limiting factors for the specified uses, and required management measures to conserve the land resource for optimal productivity. This chapter gives a framework for land capability classification at Nagarpalika level. It includes, review of land capability determinations as established by LRMP (1986), land capability classes, irrigation suitability classes, irrigation suitability sub-class, land capability sub-classes, land capability sub-divisions, framework for Nagarpalika level land capability classifications and land capability classification hierarchy.

2.1 Review of Land Capability according to LRMP

Land capability assessment is an interpretive and somewhat subjective system for evaluating a suite of resource information. It provides a ranking of the ability of an area to support a range of agricultural activities on a sustainable basis. The foundation of land classification lies in land resource inventories, starting with major geological surveys during the nineteenth century. The development of land capability schemes during the 1930s in the USA marks the beginning of the second major development in the subject, but the widespread adoption of land capability schemes only began after 1960 (Davidson, 1992). The assessment of land capability involves an evaluation of the degree of limitations posed by permanent or semi-permanent attributes of land to one or more land uses.

The Soil Conservation Service of the US Department of Agriculture refined the technique and it is referred to as the USDA method. Integral to the assessment procedure is an evaluation of soil erosion hazard, wetness, soil and climatic limitations. Land capability assessment isbased on a broader range of characteristics than soil properties. Information on slope angle, climate, flood, and erosion risk as well as on soil properties are required (Davidson, 1992). Land capability could be the land to sustain a specified land use without insignificant onsite or offsite degradation or damage of land resources (US Department of Agriculture & State Planning Commission, 1989). Generally, the land capability classifications refer to the grading the ability of land. The US Department of Agriculture has been using Land capability widely since the 1950s to assess the appropriate use of various type of land for agriculture usages in identifying land uses and management practices that can minimize soil erosion, especially induced by rainfall (Brady & Well, 2002).

Land capability assessment is, therefore, based on the permanent biophysical features of the land (including climate). Land capability assessment is different from land suitability assessment which, in addition to the biophysical features, takes into account economic, social and/ or political factors in evaluating the best use of a particular area of land for various usages, drainage, sewage disposal of land (Grose, 1999).

The FAO Framework of Land Evaluation is most widely used for assessing the suitability of soils for various kinds of Land Utilization Types (LUTs). Land Suitability may be defined as "the fitness of a given type of land for a specified kind of land use" (FAO, 1983). Suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land use. Suitability is assessed for each relevant use and each land unit is identified in the study for the optimum economic benefit.

Land capability classification at Gaunpalika/Nagarpalika level requires assessment of each individual physiographic land unit for agricultural land use as in the case of present study area. At the level 1, land capability classification needs to be made for degree of suitability, nature of dominant limiting factors considering management and conservation requirements to tackle the limitations in order to conserve land resources for best economic productivity. This chapter gives a conceptual basis for the land capability assessment on which the classifications are done at Nagarpalika level.

During 1980-1985, 266 Land Capability Maps were produced by the Land Resource mapping Project covering the entire country. LRMP defines land capability classifications as "a specialized evaluation of the land resource based on interpretative classification considering the slope stability, irrigation, flood hazards etc." (Carson, 1986).The LRMP Land Capability classification is based on observable biophysical characteristics as delineated by land system, local climatic conditions and empirically derived assessment of existing and potential land use. Landis grouped into seven classes and five sub-divisions according to their potential, limitations and hazards for different sustainable uses. Land suitability for agriculture and forestry uses are emphasized; thus the class arrangements shows decreasing suitability or opportunities for use, as well as, decreasing intensity of use.

In this system, seven classes are assigned, according to the order of use possibilitiesthat each class offers. For example, Class I land has little or no limitations for agriculture or forestry uses. The categorization of classes is influenced by the land system and soil units. The sub-classes of land capability are based on distinct temperature regimes according to elevation zones. The subclasses are categorized into five climatic regime groups, viz., sub-tropical, warm temperature, cool temperature, alpine, and arctic. These sub-classes are further differentiated to represent major moisture regime zones, which are arid, semi-arid, sub-humid, humid, and per-humid. Each land capability unit for Class I and Class II is further designated with irrigation suitability. The United States Bureau of Reclamation land classification framework, modified for local conditions, is applied to determine the irrigation suitability classification. Irrigation suitability classes are further sub-classified on the basis of deficiencies in the soil, topography or drainage conditions, which reflect the arability of land. Figure 2.1 shows the LRMP Land Capability classification scheme. A brief description of land capability classes are presented in subsequent subsections.

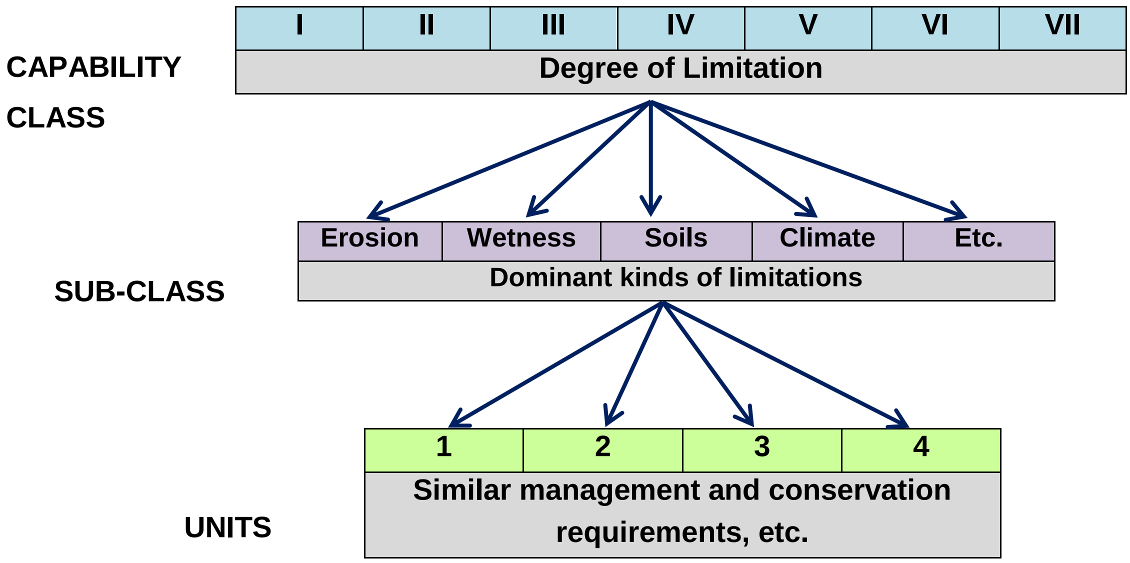

Figure 2.1: Levels of a generic land capability classification system

2.1.1 Land Capability Classes

Land Capability classes are derived from the Land System Map Units. There are seven land classes grouped on the basis of similar geophysical characteristics, reflecting management option (NLUP, 2007). A diagrammatic representation of the land capability classification scheme is shown in Figure 2.2. Descriptions of each of seven classes are provided below.

LAND CAPABILITY CLASS						
Class I	**Class II**	**Class III**	**Class IV**	**Class V**	**Class VI**	**Class VII**

Elevation, m	Climate Type	Soil Temperature Regime	Mean Annual Temperature, ºC
4500+	Alpine	Pergelic	<3
3000-4000	Sub-Alpine	Cryic-Frigid	3-10
2000-3000	Cool Temperate	Mesic	10-15
1000-2000	Warm Temperate	Thermic	15-20
0 - 1000	Sub-Tropical	Hyper-thermic	20-24

Sub-Division (Moisture Regime)
Arid (a)
Semi-Arid (s)
Sub-Humid (u)
Humid (h)
Per-Humid (p)

Deficiency Sub-Class
Soil (s)
Topography (t)
Drainage (d)

Irrigation Sub-Class
Class 1
Class 2
Class 1R
Class 2R
Class 5
Class 6

Figure 2.2: Land capability scheme of the LRMP

Class I

Land in this class is characterized as the nearly level (<1 degree slope) and deep soil stratum. This type of land has very few limitations for arable agriculture. River bank cutting is rampant; however, mass wasting does not pose any significant problems. Stability of the land is not considerably affected due to engineering works. Sporadic flooding occurs in the Terai region, depositing large amount of sediment; but these depositional areas are quickly reclaimed. When flood deposited heavy sediments and debris the capability class may be lowered that is based on the depth and types of debris deposited. By using traditional, intermediate as well as modern farming practices class I lands are cultivated. To minimize the effects of flooding and subsequent mass wasting, erosion mitigation measures and river embankment control works are required.

Surface drainage pattern and soil moisture affect the land use capability class. Well to moderately well drain lands are suitable for a wide range of usages including annual cropping, perennial cropping, and grazing and forestry uses during the monsoon period. Poorly drained areas with high water tables included in class I lands during the monsoon, are highly suitable for rice production. In class I lands, during the dry season, where irrigation water is available, wide range of crops can be grown in various temperature regimes. Moderately well and imperfectly drained areas having sufficient subsoil moisture are producing wheat and other winter crops in dry season, where irrigation water is not available. The dominant land system units associated with are 1d, 2c, 2d, 3a, 4c, 5a, 6a, 9b, 13b in class I land. Other land system units associated are 3c, 5c, 6c, 10a, 10b and 13d and about 13.7% of total land of Nepal consists of class I type land.

Class II

Class II lands are characterized as gentle slope (1-5 degrees) and soil layer is deep and well to moderately well drain. No limitations exist in this class for agriculture, however, terracing and contouring many be required to control soil erosion and suitable provisions are needed for controlling surface runoff and drainage waters. The main hazard often occurring is debris flow though lands are usually reclaimable. Due to soil characteristics and surface gradient, gully erosion is major concern. Using traditional, intermediate or modern farming techniques these lands can be successfully cultivated by considering above factors and implementing appropriate mitigation measures.

Surface and subsurface irrigation is generally adequate for a wide range of uses including annual cropping, perennial cropping, pasture and forestry during monsoon season. In the areas where the climate is favorable and irrigation water is available, paddy rice may be grown even on coarser textured soil. Class II land is dominant with land system units associated with 3b, 3c, 5b, 5c, 6c, 9c, 10a, 13c and 13d. Other land system units associated are 2d, 3b, 3d and 5d and about 3.2% of total land of the country is occupied by this land capability class.

Class III

This type of land is characterized by moderate to steep (5-30 degrees) slopes. Soils are well drained and more than 50cm deep. These lands only occur in climatically arable regions. Soil erosion occurs constantly due to mass wasting, landslides, slumps, and debris flowsas well as river bank undercutting. There are few limitations in this class of land for forest management for fodder, fuel wood, or timber production. Grazing is restricted due to heavy physical damage to soil by livestock overgrazing. When land is used for agriculture, terracing is compulsory to control erosion. Class III land is generally cultivated using terraces based on traditional farming practices. However, intermediate farming practices can be adopted for better crop production. Fertility of cultivated land is maintained by fodder, forest litter collection and grazing on non-cropped area in the traditional farming methods as in-situ maturing.

Mostly, large area of Class III land is available for forestry usages for fodder and fuel wood collection. In terrace farming the irrigation water in leveled bench terraces is extensively used wherever irrigation facility is available. To prevent slope failure and soil erosion in terrace farming a new irrigation system should be developed or modify the cascade system of irrigation .Land system units dominantly associated with this class are 7, 11 and 14a. Significant land system units 12, 13c and 14b are also prevalent in this class and about 15.2 percent of the total land in the country consists of Class III land.

Class IV

Class IV lands are characterized by soils more than 20cm deep and well to imperfectly drained lands which are too steep (>30ºslopes) to be economically terraced and cultivated, too cold to be cultivated, or prone to gully erosion and flooding. These lands are best suited for all pasture and forestry related uses provided that good, permanent vegetation cover is maintained to minimize erosion. Mass wasting is a serious and constant hazard problem for any type of land use in this class.

Major areas of class IV land is presently forested which can be used for fuel wood, fodder, forage, litter, medicinal plants and timber production. Degradation of forest due to overgrazing is the main problem in this land class. So grazing must be strictly controlled or prohibited altogether in sensitive areas. Sustainable forest management must be given special attention for forest usages, location and design of access roads and maintenance of ground cover. The dominant units of land system associated to this class are 3d, 5d, 12, 14b and 15a. Other significant land system units are 1c, 1d, 43b, 6d, 7,8,11, 14a, and 15b. About 25.8 percent of the total land of Nepal is occupied by this class.

Class V

Class V lands are characterized by soils more than 20cm deep and slopes less than 30 degrees. These lands are too frequently flooded, too cold or too dry to support any vegetation cover. However, these lands are very suitable for pasture development provided that the stocking rates are carefully controlled. Alpine regions above 3000 m, the natural steppe country in the shadow of the Himalayas and active flooding alluvial plains are the major Class V lands in Nepal. This land occupies about 4.1 percent of the total land of the country. The dominant land system units are 1c, 13a, 16a, 16b, 16c, and 16d and other significant units are 1b and 15a. Major parts of Class V lands are flood plains which are subjected to frequent inundation throughout the country. More intensive land uses occur on floods plains and it precludes any other more intensively used land. Coarse grasses native to this land provide for fodder, wildlife habitat and construction materials. Above 3000 meters, alpine pastures are generally found, often along the crest of mountain ridges. The major limitations to production are cold and wetness in this land. The steppe country is the natural habitat of class V land which is used for tourism and recreation (mountaineering and trekking) due to scenic beauty and High Mountain peaks for climbing.

Class VI

These lands are characterized by steep slope (40–50 degrees), severe gully erosion with less than 20cm soil depth and considered to have severe limitations for food and fiber production. To minimize the risk of erosion hazard on this land vegetation cover should be maintained. The degraded areas are difficult or sometimes impossible to reclaim due to steep slope as well as low soil temperature which restricts the speed of regeneration of any type of vegetation. Lands are best suited for controlled extraction of fuel wood or timber, watershed protection and wildlife habitat conservations and tourism due to their environmental sensitivity. The dominant land system units are 6d, 8, 15b and 17a. Approximately 18.3 percent of the total land of Nepal falls in this class.

Class VII

These lands are characterized by exposed rock and ice in very steeply sloping mountainous terrain. Outcrop rocks or vegetation is virtually absent in this class. The Class VII lands are best suited for the tourism and recreation (mountaineering and trekking) due to scenic beauty and High Mountain peaks for climbing. The land system units are 17b. 18.3 percent of the total land of Nepal falls in this class.

2.1.2 Irrigation Suitability Class

Irrigation suitability classes are based on systematic appraisal of soils and their designations by categories on the basis of similar physical characteristics and land use opportunities under irrigation. The classification follows the USBR land classification framework modified to suite the local conditions of Nepal. The entire Terai region, Dun valleys and lands under Class I and Class II capability are classified according to their suitability for irrigation. A brief description of each of the irrigation classes is presented below.

Class 1 Diversified Crop –Arable

The lands highly suitable for irrigated farming and capable of producing sustained and relatively high yields of climatically suited upland crops as well as paddy are classified in Class I.

Class 2 Diversified Crops –Arable

These lands are ranked lower than Class I in production capacity but moderately to fairly suitable for irrigated farming. The narrow ranges of diversified crops are adapted to these lands. There are some limitations in soil, which can be corrected and others may not. In this class, the land productivity is limited compared to class I.

Class 1R Wet Land Paddy-Arable

These lands are capable of producing sustained and high yields of paddy at reasonable cost and highly suitable for paddy production under irrigated conditions.

Class 2R Wet Land Paddy-Arable

These lands are ranked lower than Class 2R in productivity or more costly to farm and land is moderately to fairly suitable for paddy production under irrigation. The soil deficiencies can be ameliorated. These lands may possess poor drainage characteristics that affect winter crop production.

Class 5 Non-Arable

Class 5 lands are tentatively classified as non-arable and generally subjected to seasonal inundation. In this report lands under settlements, industries and other non-agricultural uses are included in this section.

Class 6 Non-Arable

Land included in this class is considered as non-arable because of their failure to meet the minimum requirements for the other classes of land. Generally, soil of this class land is very shallow or impervious to root or water. The lands are characterized by extremely coarse texture surfaces, low water retaining capacity, overflow and run-off channels, permanent waste and slumps. The land is non-arable also due to complex topography.

2.1.3 Irrigation Suitability Sub-Class

The above mentioned irrigation suitability classes are further sub-divided based on the limitations or deficiency in soil, topography or drainage or the combinations of any of these two. These irrigation suitability rating sub-classes are shown in Table 2.1

Table 2.1 Irrigation suitability rating for sub-classes

Major deficiency types for irrigation	Map symbol
Soil deficiency	S
Topographic deficiency	T
Drainage deficiency	D

2.1.4 Land Capability Sub-Class

The land capability classes described above are further classified into sub-classes on the basis of distinct climatic regimes with their altitudinal ranges. The vegetation line is regarded to be at 5000 m as the temperature decreases an increase in elevation above the sea level (Seinfeld and Pandis, 2012). At an altitude of about 5000 m, at mid-latitudes, the mean air and soil temperature becomes near 0ºC, hence, beyond this elevation permafrost exists. Likewise, natural vegetation changes at approximately every 1000 m elevation difference. At lower altitudes, the natural vegetation is dominated by Sal forest (below 1000 m), whereas, Pine forest occurs dominantly between 1000 to 2000 m, Quircus forest between 2000 to 3000 m, and Betula forest between 3000 to 4000 multitudes' (see Figure 2.3).

Above 4000 m there is no forest vegetation, hence, the tree line is regarded to occur at an elevation of about 4000 m (depending upon latitude). Between 4000 and 4500 m open (sparse) shrub and grass vegetation is found and above it up to 5000 m Tundra vegetation is available. In the case of crop cultivation, 1000 m is the limit for double-cropping of rice. Rice generally does not grow beyond 2000 m except Jumli Marshy of Jumla Valley, and likewise, 3000 m is the limit for maize cultivation. Above 3000 m there are only limited valleys where maize, buckwheat, oats and potato can be cultivated. Crop production stops at the limit of forest vegetation where open meadow is available and livestock can successfully be reared.

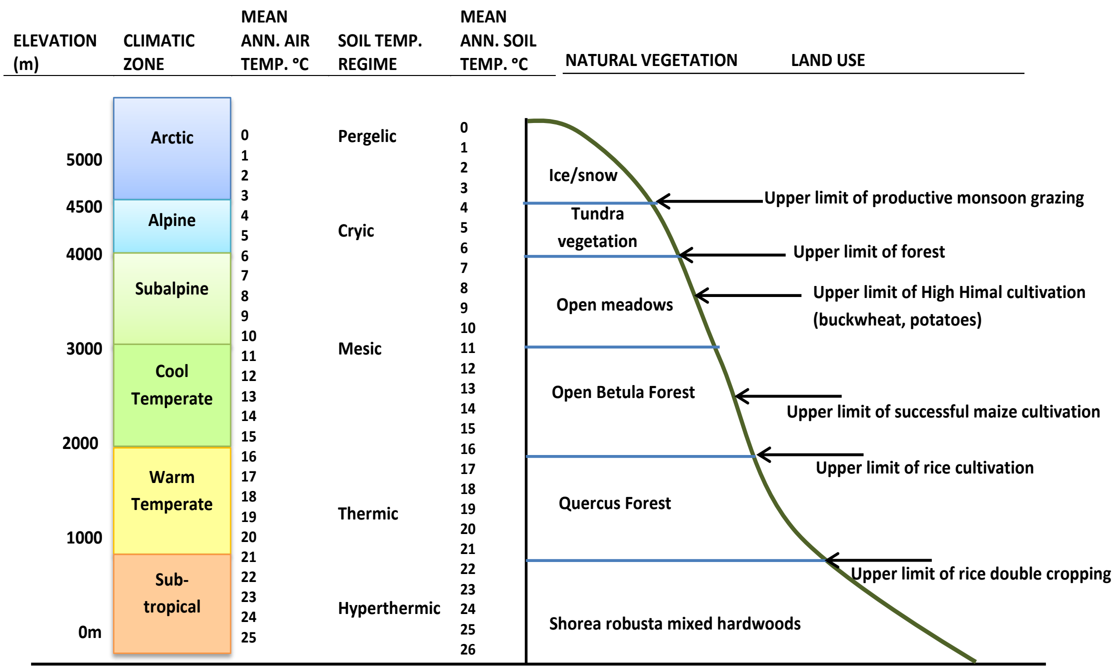

Figure 2.3: The relation among altitude, climate, vegetation and agriculture (Adapted from LRMP, 1986).

2.1.5 Land Capability Sub-Divisions

Besides categorization of capability classes based on climatic regimes, a sub-division based on the mean annual precipitation in combination with mean annual temperature is also made. The capability sub- divisions of moisture regimes are: Arid, Semiarid, Sub-humid, Humid, and Perhumid as shown in Fig. 2.2 above.

2.2 Framework for Nagarpalika Level Land Capability Classification

Land capability classification at Gaunpalika/Nagarpalika level at large scale follows the basic principle of LRMP land capability. The LRMP land capability classification is further elaborated to highlight specific management limitation pertaining to the soil for sustainable agricultural uses in particular land unit. This system has been widely used in US Department of Agriculture & State Planning Commission in 1989 (Grose, 1999) and is adapted to suite the context of present study and the context of agricultural soil management in Nepal as a whole.

The salient features of this classifications system are as follows:

a. It follows LRMP Land Capability Classifications System

b. Classifications rating is done for geomorphological land unit i.e. land system land type unit considering soil characteristics, topography, climate, geology and geomorphology.

c. The classification system contains three tiers viz. class, subclass, and unit.

d. Unlike LRMP Land Capability, in which site specific deficiencies are assigned to the arable land units only (classes 2, 2R, and 5 for Class I and Class II), this system assigns deficiency categories to all the land capability units including (III,IV,V,VI,VII) to highlight specific management limitations in each capability classes and the associated land type units.

e. Climatic parameters viz. climatic regimes and moisture are associated with the capability class itself rather than differentiating them as sub-class and sub-division respectively as in LRMP Land Capability. The reason for this is that the climatic and moisture regimes do not vary significantly at all within a small area/region as Gaunpalika/Nagarpalika, which is the current extent of the study.

2.3 Land Capability Classification Hierarchy

Land Capability is classified into three hierarchical levels viz. capability class, sub-class and unit. Capability Class gives an indication of the general degree of limitations to use; sub-class identifies the dominant kind of limitation and unit differentiates between lands with similar management and conservation requirements as well as productivity characteristics. The hierarchical levels are shown in Table 2.4.

Table 2.4: Land Capability Hierarchy (adopted from Grose, 1999)

Class						
I	II	III	IV	V	VI	VII
Degree of limitations						

↓

Sub-Class			
Soil	Topography	Erosion	Wetness
Dominant limitation			

↓

Unit					
1	2	3	4	5	Etc.
Similar management requirement					

The land capability classification system can be used and applied at various scales by mapping at the class, sub-class and unit levels.

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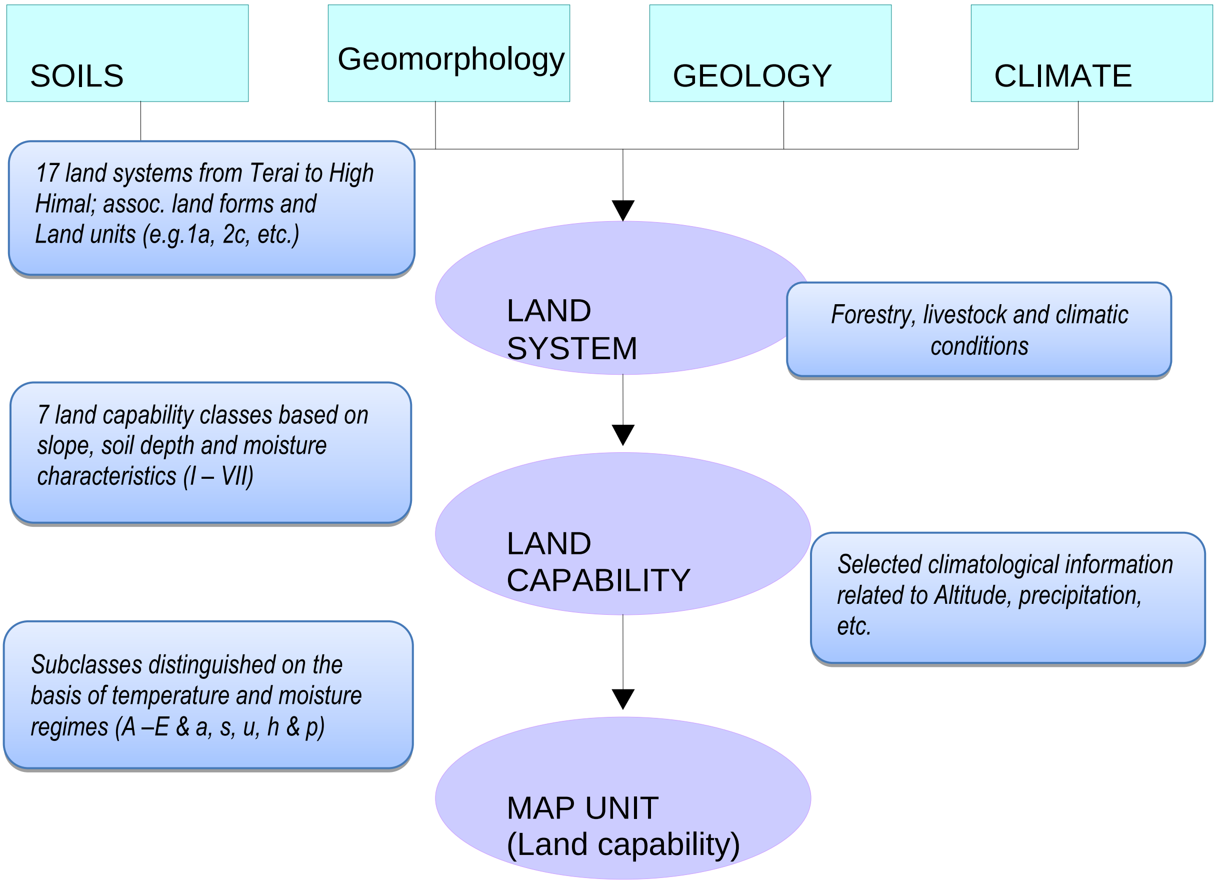

Figure 2.4: Determination of land capability classes and map units in the LRMP classification scheme (adapted from LRMP, 1986).

2.3.1 Capability Class

The land capability class comprises seven classes ranked in order of increasing degree of limitation and in decreasing order of adaptability for agricultural use. Class I land is identified as the best suited land and it can produce wider range of crops and pastures at higher levels of production with lower costs and/or with less management requirements and/or less risk of damage compared to any other classes of land. Class II is superior to Classes III to VII but inferior to Class I.

A range of land may occur in any one capability class, but it is often possible to identify good or bad quality land within the same class of land. Class I to III, are considered as capable of supporting cropping activities on sustainable basis. Class IV is suited for forestry. Class V is suited for grazing pastures and fodder collection. Class VI has severe limitation and considered fragile and suitable for rough seasonal grazing only. Class VII land comprises of rock and snow cover with severe management limitations which cannot be corrected. The description of each capability class is presented in brief as below.

Capability classes associated with plain and terraced cultivation viz. Class I and II are further designated with the irrigation suitability as similar to LRMP irrigation suitability ratings for arability viz. Class 1, Class 2, Class 1R, Class 2R, Class 5, and Class 6.

Class I

Class I consists of lands with very few or no physical limitations to use. These lands are suitable for wide range of cropping, grazing or forestry. These land are leveled to nearly leveled (<1^o slope) and soils are deep.

Class II

Class II consists of land with very few physical limitations to use. Terracing or contouring is necessary to control soil erosion when used for diversified agricultural crops and ground cover maintenance is required for forestry and grazing use. These lands are gently sloping (1^o–5^o slope) and soils are deep.

Class III

Class III consists of land with moderate limitations that limit the choice of crops or reduce productivity in comparison to Class I and Class II lands. These lands need careful management and conservation for optimum productivity and uses for agriculture. These lands are slopping to moderately steep (5^o-30^o slope) with soils 50-100 cm deep and moderately well to well drained. Terracing is compulsory to control erosion when used for agriculture. There are few limitations to traditional forest use provided adequate ground cover is maintained.

Class IV

Class IV consists of lands with moderately severe limitations that limit the choice of crops and/or require very careful management practices. These lands are either too steep to be terraced and cultivated (>30^o slope) or lie above the altitude limit of agriculture. These lands also include relatively flat to gentle slopping lands with shallow soil depths (>20 cm) and well to imperfectly drained. These lands are suitable for forestry uses and require permanent vegetative cover in the slopes to minimize erosion.

Class V

Class V consists of lands with severe limitations that restrict its use for agriculture and forestry. The lands having less than 30^o slope, soils more than 20 cm deep and in alpine above tree line or are frequently flooded river plains are included in this class. These lands do not support tree growth but have few limitations when used for fodder collection or grazing.

Class VI

Class VI consists of lands with very severe limitations that restrict its use to rough grazing, forestry and recreation. These lands include areas with 40^o to 50^o slope or gentler slopes with soils less than 20 cm deep. These lands are considered as fragile because of extreme erosion hazard and/or poor regeneration potential.

Class VII

Class VII lands consist of rock and perpetual snow and have severe limitations that cannot be rectified.

2.3.2 Sub-Class

Within each class it may be possible to identify a number of limitations which restrict their agricultural use. Limitations may be defined as physical factors or constraints that affect the adaptability of the land and determine its capability for long-term sustainable agricultural production. Where limitations are found a class may also be assigned a subclass code indicating the nature of the dominant limitations or hazards that exists. Sub-class is equivalent to LRMP Land Capability's irrigation suitability subclasses but is assigned to all capability classes whether they are arable or not. Thus, the sub-classes can further be categorized enabling to discriminate good and bad land within each individual capability class. In general sub-class represents management deficiency and its dominant factor. Deficiency factors may be more than one, thus indicating complex or severe management limitations. These deficiency factors are related to soil, topography, erosion and wetness.

2.3.3 Unit

Unit helps to differentiate between similar areas that have different management or conservation requirements. They may also be used to separate areas that have slightly different productivity characteristics. This is done by specifically indicating a combination of the factors. These factors pertain to one or more of the capability sub-classes related to soil, topography, erosion susceptibility and wetness. The units are represented by codes associated with each individual deficiency type as presented below.

Deficiencies due to soil characteristics may arise from shallow soil depth, plant nutrient availability, workability (related to texture, e.g., high clay soils are difficult to till), drainage (tendency to be water-logged or excessively dry), permeability (water movement through high clay soils tends to be very slow), and soil reaction (acidity or alkalinity). The map symbols for these deficiencies are shown in Table 2.2.

Table 2.2: Unit codes for sub-class soil deficiencies

Type of Soil Deficiency	Map Symbol
Soil depth	s1
Plant nutrient availability	s2
Workability	s3
Drainage	s4
Permeability	s5
Acidic nature	s6
Alkaline nature	s7

Likewise deficiencies due to topography arise from the steepness of the slope or the presence of surface dissection by channels formed by runoff water. These deficiencies and corresponding map symbols are indicated in Table 2.3 below.

Table 2.3: Unit codes for sub-class topographic deficiencies

Type of Topographic Deficiency	Map Symbol
Steep slopes	t1
Surface channel dissection	t2

CHAPTER 3: METHODOLOGY

Land capability map of Suryodaya Nagarpalika was prepared by analyzing the existing data, maps, field samples and information of lab test using GIS. Nagarpalika level map attempts to identify and carry out classification of agricultural land for lucrative (profitable) crop production within the Nagarpalika; identify and classify land for non-agricultural purpose; and prepare GIS inventory of current land capability data based on the spatial analysis of soil and terrain parameters, arability class and deficiency type and sub-type unit using GIS tool. A multi-criteria evaluation rule was developed to classify land units based on soil parameter, fertility, erosion susceptibility, terrain constraints and surface drainage (wetness). The details of the methodology are discussed in the following sections:

3.1 Methodological Framework

In general, the approach or methodology includes following steps:

a) Formulation of multi-criteria weighted rules for soil, topography, erosion and drainage parameters
b) Evaluation of rules and ratings from best suited to least suited (high to low)
c) GIS based attribute query and spatial analysis of rated parameters
d) Classification and designation of suitable land capability class to land type land units
e) Classification and designation of deficiency sub-classes and units to land capability classes
f) Final land capability map preparation with GIS database creation and use.

3.2 Land Capability Evaluation Criteria

The following criteria are used to derive land capability classification:

Major soil properties that characterize soil fertility include organic matter, soil pH, drainage class; permeability (based on soil texture as explained by USDA, 2016) and NPK are given certain numerical points. These properties are pooled and multiplied by the values obtained and weighted average is then taken to evaluate soil fertility. In other words, it involves multi-criteria analysis which is detailed below:

Multi-Criteria Analysis

Muti-criteria analysis (MCA) is a decision support tool which facilitates selection of the most suitable option among a range of alternatives. The basis for a decision is known as a criterion. In MCA, an attempt is made to combine a set of criteria to achieve a single composite index for a decision according to a specific objective. Decisions need to be made about which areas are the most suitable for specific land use type development. In this analysis, criteria, or factors affecting capacity for crop production, include edaphic factors such as soil depth, drainage condition, permeability and soil fertility factors like pH, Organic matter and total Nitrogen (N) available Phosphorus (P_2O_5) and available Potassium (K_2O).

Land capability maps were generated from the MCA process in which parameter weight was derived from the expert knowledge given in table 3.1. Since the land that we evaluate falls on flat plain of Terai and no erosional class is mentioned. Since N is a mobile element and keeps mineralizing continuously, it is rated with the lowest weighted average.

Table 3.1: Parameters used and weight age factors for MCA

S.No.	Parameters	Weight age factor
1	Soil depth	4
2	pH	3
3	OM	3
4	Drainage (Texture)	3
5	K_2O	2
6	P_2O_5	2
7	Nitrogen	1

Source: DOA & NARC

Weighted Composite Score

Weighted Composite Score (WCS) is a systematic procedure for developing factor weights required for preparing capability map (Table 3.1). The weights assigned to different factors were obtained by subjective to expert judgment. The larger the weight, the more important is the criterion in the overall capability class. In developing the weights, an individual factor were ranked as low, medium, and high and very high weight are assigned as 1, 2, 3 and 4 respectively as given below. Factors or criteria were rated according to the following 4-point scale. Weighted Composite Score (WCS) was employed based on parameter weight and individual weighted value as 4, 3, 2 and 1 corresponding to very high, high, medium and low rank of the concerned factor, respectively. The final value of weighted composite score (WCS) for each soil mapping unit was calculated by summing all individual factors value obtained by multiplying individual factor weight rank value with their corresponding weight of parameters. The equation of calculation of WCS is given below:

Weighted Composite Score (WCS) = Soil depth weightage value*4+ pH weightage*3+ Drainage weightage value*3+ OM weightage value*3+ K_2O weightage value*2+ P_2O_5 weightage value*2 + Nitrogen weightage value*1

Total fertility level is 58 and minimum is 18 and hence 45-58 is high 36-44 as medium and below 36 is low fertility.

i. Soil Fertility Status and Crop Suitability Rating

Crop suitability has been defined as the attributes of the land/soil and the crops that enable cultivation of the crop based on the nutritional, water and temperature requirements. It has been done for various crops considering for a single clearly defined, reasonably homogenous purpose or practice and suitable appraisal for a list of crops or other activities.

The requirements (natural, social, economic and technological, etc.) of the particular crop needs to be known or alternatively what soil/site attributes adversely influence the crop. To identify and to delineate land attributes in terms of the favorable and limiting factors, of classes are determined according to degrees of suitability as below:

Highly suitable (S1) – land having no limitation to sustainable application of a given use or only minor limitations will not significantly reduce benefits

Moderately suitable (S2) – land having limitations in which aggregate are moderately severe for sustained application of a given use or increase inputs to the extent that overall benefit to be gained.

Marginally suitable (S3) – land having limitations to sustained application of a given use or increase required inputs, marginally justified; costly rice in Mustang; sub divisions of S2 and S3

Not Suitable (N1) – indicates that the land is not suitability for a defined use in its present condition, without major improvements. A not suitability classification may be used for a specified purpose with improved management practices or special measures put in place, or may be recommended to a different use.

Permanently not suitable (N2) – refers to the suitability, for a defined use, of land units in their condition at some future date, after specified major improvements have been completed where necessary.

Suitability analysis based on soil nutrient status

The soil suitability analysis in the present case has been performed based the soil nutrients derived from chemical properties of soil pits based on soil lab test. Soil fertility status analysis can be performed based on the soil test results.

Crop Requirements

The soil suitability analysis is done based on the major soil nutrient available on the ground investigated from soil survey and requirement criteria of the different on the optimum condition. In general the range of pH required for the cultivation of crops, fruits, and vegetables is taken as 5.5 to 7.5 with optimum at 6.5.

Rating of Soil Nutrients

Soil fertility status assessment is derived from soil parameters related to total nitrogen, available phosphorus and, available potassium. Soil fertility status based on chemical properties of soil and their rating is presented in the tables below.

Table 3.2: Soil fertility rating based on plant available nutrients

Fertility value range	Deficiency rating	Suitability	Map symbol
<18	Very high deficiency	Very low suitability	f1
19-35	High deficiency	Low suitability	f2
35-46	Medium deficiency	Moderate suitability	f3
>46	Low deficiency	High suitability	f4

Source: DOA & NARC

Other soil deficiency criteria are based on top-soil rooting depth, workability (soil texture), soil drainage (permeability), alkalinity and acidity, content of organic matter content as shown in the tables below.

Table 3.3: Soil Depth Rating

Soil Root Depth	Depth Category	Suitability	Map symbol
>54	Deep	High suitability	**s4**
36-54	Moderately Deep		**s3**
18-36	Shallow		**s2**
<18	Very Shallow	Low suitability	**s1**

Source: DOA & NARC

Table 3.4: Workability Rating

Soil Texture (Workability)	Rating	Suitability
L (Loam)	Good	High Suitability
SiL (Silt Loam)	Good	
SL (Sandy Loam)	Good	
SiL+L(Silt Loam + Loam)	Good	
CL (Clay Loam)	Moderate	
CL+L/SiL (Clay Loam + Loam	Moderate	
SiCL (Silty Clay Loam)	Moderate	

Sil+SiCL (Silt Loam + Silty	Moderate	
SiCL+ SL (Silty Clay Loam +	Moderate	
SiC (Silty Clay)	Fair	
LS + SC (Loamy sand + Silty	Fair	
C (Clay)	Poor	Low Suitability

Source: DOA & NARC

Table 3.5: Drainage Rating

Soil drainage category	Suitability
Well drained	High Suitability
Moderately well drained	
Somewhat poorly drained	
Somewhat excessively drained	
Poorly drained	
Excessively drained	
Very poorly drained	
Very excessively drained	Low Suitability

Source: DOA & NARC

Table 3.6: Alkalinity and Acidity Rating

Soil Reaction	Rating	Suitability
< 5.0	Very Strongly acidic	Low Suitability
5.1– 5.5	Strongly acidic	
5.6 – 6.0	Moderate acidic	
6.0 – 6.5	Slightly acidic	High Suitability
6.6 – 7.3	Neutral	Most Suitable
7.4 – 7.8	Slightly alkaline	High Suitability
7.9 – 8.4	Moderate alkaline	
8.5 – 9.0	Strongly alkaline	
>=9	Very Strongly alkaline	Low Suitability

Source: DOA & NARC

Table 3.7: Organic Matter Content Rating

Organic Matter (%)	Rating	Suitability
>5	High	High Suitability
2.5 – 5	Medium	
<2	Low	Low Suitability

Source: DOA & NARC

Table 3.8: Total Nitrogen Rating

Total Nitrogen (%)	Rating	Suitability
>0.2	High	High Suitability
0.11 –0.2	Medium	
< 0.1	Low	Low Suitability

Source: DOA & NARC

Table 3.9: Available Phosphorous Rating

Available P_2O_5(kg/ha)	Rating	Suitability
>55	High	High Suitability
31 – 55	Medium	
< 30	Low	Low Suitability

Source: DOA & NARC

Table 3.10: Available Potassium Rating

Available K_2O (kg/ha)	Rating	Suitability
>280	High	High Suitability
110 – 280	Medium	
<110	Low	Low Suitability

Source: DOA & NARC

Topographic Criteria

The topographic criteria for land classification refer to management limitations arising from the topography of the terrain. Such limitations are due to the steepness of the slopes which affect the sustainable use of land. Land having these topographic problems requires careful management with terracing and maintaining vegetation cover to mitigate soil degradation.

Table 3.13: Topography Deficiency (Criteria for slope evaluation)

Description	Dominant Slope (º)	Suitability	Map symbol
Flat to gently sloping	<3	High Suitability	**t1**
Gentle to moderately Steep slopes	3-15	Medium Suitability	**t2**
Steep slopes	15-30	Low Suitability	**t3**
Very steep slopes	>30	Not Suitable	**t4**

Source: DOA & NARC

Irregular surface topography and surface dissection is another form of topographic limitation. The surface dissection may be due to the recent gulling or past-multi-terrace effect of surface erosion. Dissected topography increases difficulty in surface water conveyance for irrigation as well as causes severe erosion (especially gully erosion) due to concentrated run-off in this type of terrain.

Erosion Susceptibility Criteria

Erosion susceptibility criteria affect the potential of soil loss resulting from water erosion. The susceptibility rating of different types of erosion is given in the following Table 3.14.

Table 3.14: Soil Erosion Susceptibility

Type of soil erosion	Erosion susceptibility	Suitability	Map symbol
Sheet erosion	Low	High Suitability	**e1**
Rill erosion	Medium		**e2**
Rill/Gully erosion	High		**e3**
Soil slumps / Mass movements	Very high	Low Suitability	**e4**

Source: DOA & NARC

Surface Drainage Criteria

Surface drainage (wetness) criteria pertain to the drainage condition of surface. Frequent flooding resulting in land inundation, water logging and high water table are the general problems affecting the productivity and use of land.

Table 3.15: Drainage Deficiencies

Drainage Deficiency (Wetness)	*Symbol*
Water Logging	Dw
Flooding	Df
High Water Table	Dwt

Source: DOA & NARC

3.3 Land Capability Assessment Method

Land capability of land unit (i.e. land system land type/soil mapping unit) is evaluated based on above mentioned criteria and rating of the land unit is designated with appropriate land capability class along with its specific management limitations.

Figure 3.1 below shows the general approach for classification and designation of land capability class to a land unit.

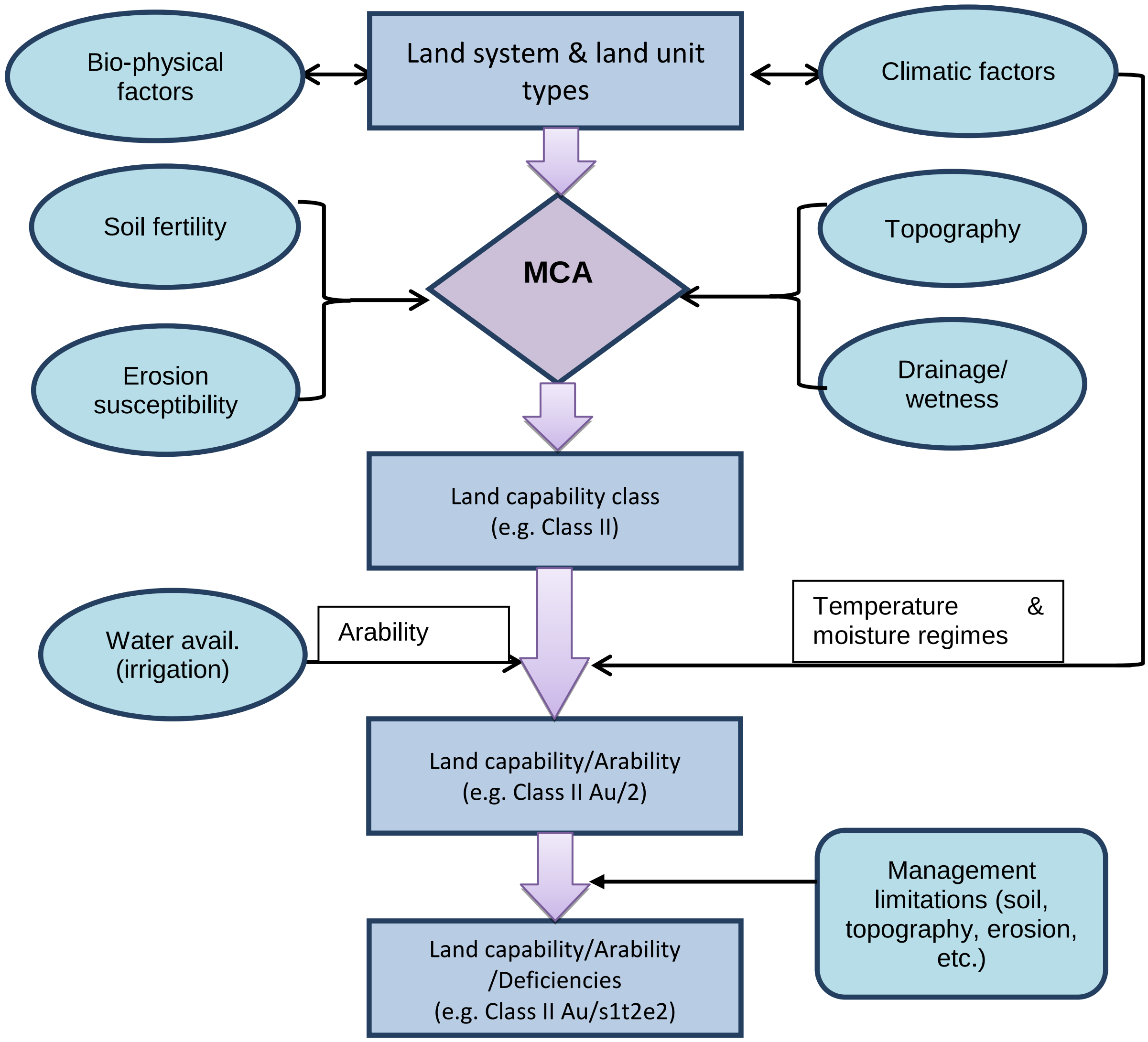

Figure 3.1: Flow chart showing multi-criteria assessment for land capability classification

CHAPTER 4: LAND CAPABILITY OF SURYODAYA NAGARPALIKA

As described in the methodology section, land capability classification is carried out on the basis of established criteria of land system, geology, soil quality, deficiencies, arability, climatic and soil moisture conditions. This chapter presents the results of land capability classification framework applied to Suryodaya Nagarpalika of Ilam District.

4.1 Capability Classes

Soil quality rating was determined on the basis of soil pH, organic matter, main nutrients nitrogen, phosphorus, and potassium as indicated in the previous chapter. The weighted composite scores (WCS) for the sampled soils of Suryodaya Nagarpalika were in the range between 40 and 68. Thus the soils of this Nagarpalika ranged from medium to very high fertility, but were generally variable depending on landscape position, elevation and soil depth. Nonetheless, most of the lands in this area were of moderate to good quality for agriculture, the main limitations being soil reaction (pH) and depth.

Table 4.1: Quality rating based on soil properties and weighted composite scores

Sample identification	pH	OM	N	P	K	depth	drainage	WCS
SD-1	3	3	2	3	4	3	3	55
SD-3	3	1	1	2	3	3	4	47
SD-4	3	3	2	2	3	2	3	47
SD-5	3	2	2	1	3	3	4	49
SD-6	3	3	2	3	4	3	3	55
SD-7	4	3	3	3	4	2	3	55
SD-8	4	3	2	3	4	2	4	57
SD-9	2	3	2	4	4	3	3	54
SD-10	3	4	3	4	4	4	4	68
SD-11	2	3	2	3	4	3	4	55
SD-12	3	4	2	4	4	2	3	56
SD-12	2	2	2	3	2	3	2	42
SD-13	2	2	2	3	4	3	3	49
SD-14	1	3	2	3	4	3	3	49
SD-15	1	2	3	4	4	4	4	56
SD-16	2	4	2	3	4	3	3	55
SD-17	2	3	3	3	4	3	3	53
SD-18	2	3	2	3	4	3	3	52
SD-19	2	2	2	1	3	3	4	46
SD-20	2	3	2	3	4	3	3	52
SD-21	2	3	2	2	4	3	3	50
SD-22	2	2	3	1	3	3	3	44
SD-23	2	2	2	3	4	3	3	49
SD-24	1	3	2	3	4	4	3	53

SD-25	2	4	3	3	4	3	1	50
SD-26	2	3	2	2	3	3	3	48
SD-27	2	3	2	2	4	4	3	54
SD-28	1	4	3	3	4	3	3	53
SD-29	1	4	4	3	4	3	3	54
SD-30	2	3	3	3	4	3	3	53
SD-31	1	3	2	3	4	3	3	49
SD-32	2	3	2	3	4	3	3	52
SD-43	2	3	3	3	4	3	3	53
SD-34	1	3	2	3	4	3	3	49
SD-35	2	3	3	3	4	3	3	53
SD-36	1	3	2	3	4	2	4	48
SD-37	1	3	2	3	4	3	3	49
SD-38	1	3	2	3	4	3	2	46
SD-39	1	3	2	1	4	2	3	41
SD-40	1	3	2	3	4	2	2	42
SD-41	1	4	2	3	4	3	3	52
SD-42	1	4	3	4	4	4	2	56
SD-44	1	4	3	4	4	4	2	56
SD-45	1	2	3	4	2	4	3	49
SD-46	1	3	3	3	4	3	3	50
SD-47	1	3	2	3	4	3	3	49
SD-48	1	2	2	3	4	3	3	46
SD-49	1	2	2	3	3	3	4	47
SD-50	1	1	1	1	3	3	4	39
SD-51	1	3	3	3	4	3	4	53
SD-52	1	3	2	3	4	3	4	52
SD-53	1	3	3	3	4	3	3	50
SD-54	1	3	3	3	4	3	3	50
SD-55	1	3	3	3	4	3	3	50
SD-56	1	3	2	3	4	3	3	49
SD-57	1	3	3	3	4	3	3	50
SD-58	1	3	2	3	4	2	4	48
SD-59	1	3	2	4	4	3	3	51
SD-60	1	3	2	3	4	3	3	49
SD-61	1	2	2	3	4	3	3	46
SD-61	1	2	2	3	4	3	3	46
SD-62	1	3	2	3	4	3	3	49
SD-63	2	4	2	3	4	2	3	51
SD-64	1	3	4	3	4	2	3	47
SD-65	1	3	3	3	4	3	3	50
SD-66	1	2	2	3	4	3	3	46
SD-67	1	3	1	3	4	3	3	48
SD-68	1	3	2	3	4	3	3	49
SD-69	1	3	2	3	4	3	4	52
SD-70	1	4	4	3	4	4	4	61
SD-71	1	4	3	3	4	2	3	49

SD-72	1	4	4	3	4	3	4	57
SD-73	1	3	3	3	4	3	2	47
SD-74	1	4	4	3	4	4	2	55
SD-75	1	3	3	3	4	2	4	49
SD-76	1	3	2	2	4	4	2	48
SD-77	1	4	3	3	4	3	3	53
SD-78	1	3	2	2	4	3	3	47
SD-79	1	3	2	2	4	2	3	43
SD-80	1	3	2	3	4	3	4	52
SD-81	1	4	3	3	4	3	4	56
SD-82	1	3	3	3	4	3	2	47
SD-83	1	3	3	3	4	3	3	50
SD-84	1	3	2	3	4	3	3	49
SD-85	1	3	3	4	4	3	4	55
SD-88	1	3	3	3	4	3	4	53
SD-89	1	3	2	3	3	4	3	51
SD-90	1	4	4	3	4	3	3	54
SD-91	1	4	4	3	3	3	3	52
SD-92	1	3	3	3	4	3	3	50
SD-93	1	3	2	3	3	3	3	47
SD-94	1	4	2	3	4	3	3	52
SD-95	1	3	3	3	4	3	3	50
SD-96	1	4	3	4	4	3	3	55
SD-97	1	2	3	1	3	3	4	44
SD-98	1	4	2	1	4	3	3	48
SD-99	1	3	3	3	4	3	4	53
SD-100	1	4	4	3	4	4	2	55
SD-101	1	3	4	3	4	3	3	51
SD-104	1	3	4	3	4	3	3	51
SD-107	1	4	4	3	4	2	3	50
SD-102	1	3	3	1	3	3	2	41
SD-103	1	2	2	1	3	3	3	40
SD-105	1	4	4	3	4	2	3	50
SD-106	1	2	2	3	4	3	3	46
SD-86	1	2	2	3	4	3	3	46
SD-87	1	3	3	3	4	3	3	50

The capability classification in Suryodaya Nagarpalika of Ilam District was done on the basis of slope, soil rooting depth, soil attributes and other major limitations for crop cultivation (Table 4.1, Figure 4.1). Most of the land area of this Nagarpalika has moderate to steeply sloping topography and moderately deep soil. Based on the standard criteria of land capability classification, the land area of this Nagarpalika fell mostly in Classes III, with the remaining areas falling under the Class II, and non-arable categories. This Nagarpalika has a total land area of about 22,438.57 ha of land and slopes range from nearly flat (1 degree) to about 60 degree slopes. The land in Classes I, II and III are generally suited to upland crops with some limitations for agriculture and other uses.

Table 4.2: Land Capability Classes of Suryodaya Nagarpalika

S.N	Land Capability Class	Area in ha.	Percentage
1	IIIBh	12863.73	57.33
2	Non-arable (Forest &Built-up)	6857.21	30.56
3	IIICp	711.20	3.17
4	VICp	552.74	2.46
5	IIBh/2st	510.64	2.28
6	IVCp	384.88	1.72
7	IIIAu	198.09	0.88
8	IVAh	170.24	0.76
9	IIAu/2st	104.67	0.47
10	IVBh	47.84	0.21
11	IAh/1	35.67	0.16
12	VIAh	1.05	0.005
13	IVAu	0.25	0.001
14	IIAh/2	0.21	0.001
15	IIAh/2st	0.09	0.00
16	IIIAh	0.05	0.0002
Grand Total		**22438.57**	**100**

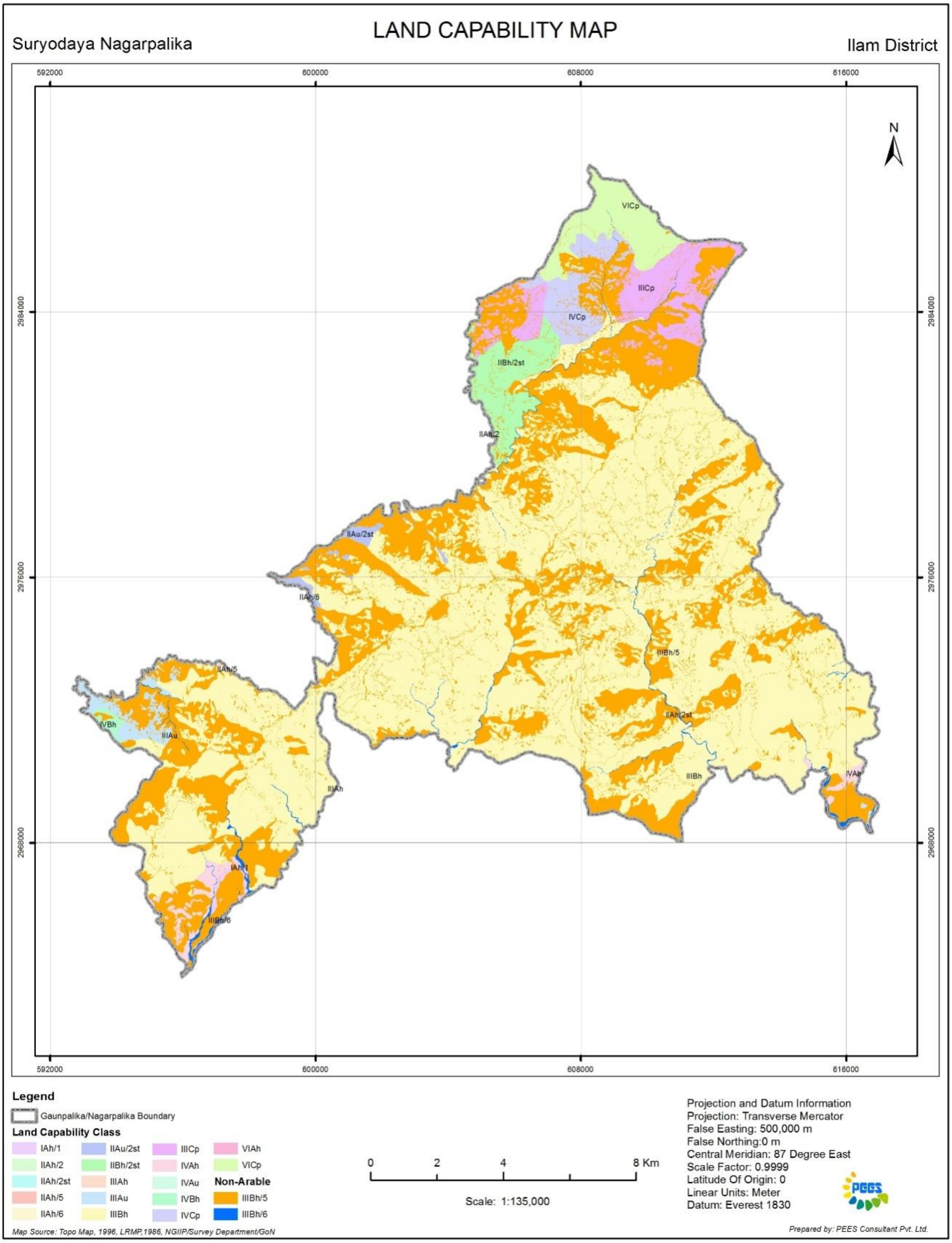

Figure 4.1: Land capability map of Suryodaya Nagarpalika

The dominant category of land in Suryodaya Nagarpalika is of capability class III, which makes up more than 61.38 percent of the area. These lands are generally suited to upland rain-fed agriculture, however, terracing is mandatory due to typically steep slopes (15-30 degrees).They require adequate conservation measures, including, terracing, proper drainage of excess runoff and other soil stabilization measures, to achieve economic production. Moreover, the main sub-classes in this category, i.e., III Bh and III Cp have additional limitations due to soil acidity and shallow soil depth in some areas. Therefore, these lands also require liming and soil water management for optimum production. Other categories, namely, I Ah, II Au, II Ah and II Bh, while better suited to agriculture, make up only a small portion of the land area (<3 percent).

About 31 percent of the land in Suryodaya Nagarpalika falls under forested or built-up areas and in the non-arable capability classesIV and VI. The forest and non-arable categoriesmay be recommended for community management and controlled livestock grazing.

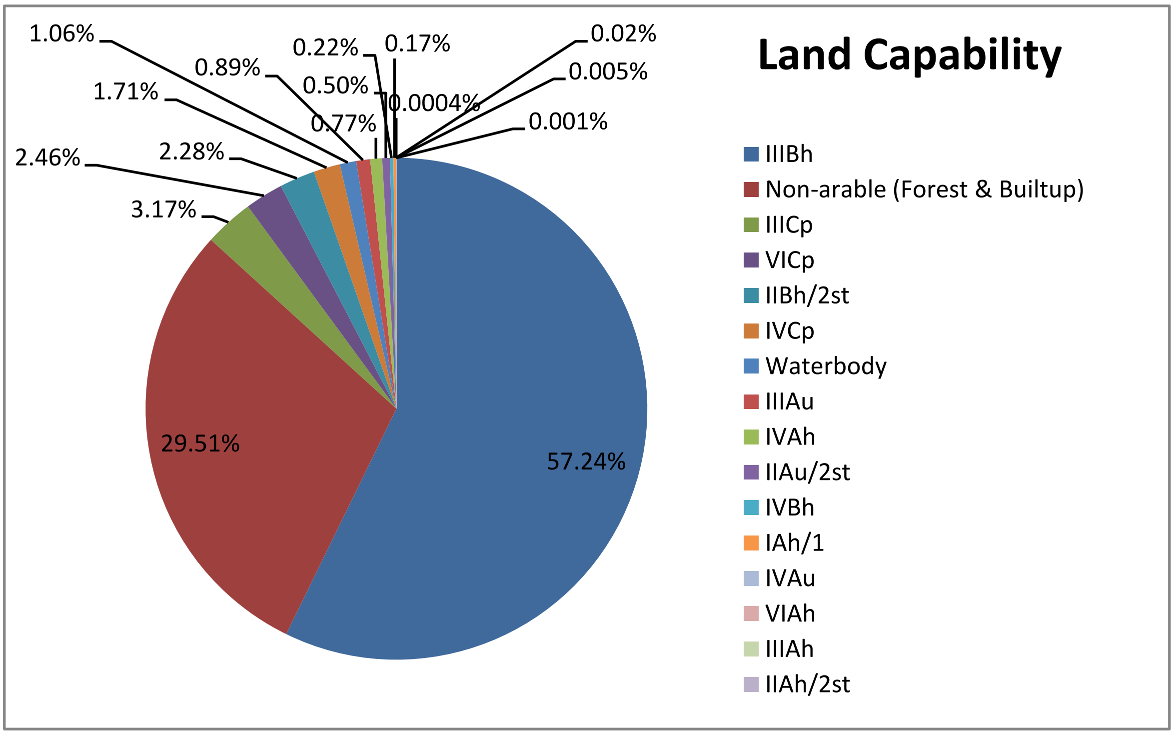

Figure 4.2: Land capability classes in Suryodaya Nagarpalika.

4.2 Land Capability GIS Database

The land capability GIS data is stored in data model provided by the NLUP office.

CHAPTER 5: CONCLUSIONS

5.1 Conclusions

Suryodaya Nagarpalika consists of mostly moderate to steeply sloping lands (5-30 degree slopes) ranging from about 700 m to 2500 m elevation. Also much of the land area has moderately deep soil formed on active and recent colluvial deposits and weathered schist, phyllite, quartzite and gneiss parent material. The majority of the land is categorized in Classes III land capability class with some minor areas categorized as I and II capability classes. About 31 percent of the land is non-arable being settlement areas, forested areas or very steep sloping land (30-60 degree slopes).

More than 61 percent of the land in the Nagarpalika was of capability class III.These lands are generally suited to upland rain-fed agriculture; however, terracing is mandatory due to typically steep slopes (5-30 degrees). Moreover, some of these soils have additional limitations due to soil acidity and shallow soil depth. Therefore, liming and soil water management is recommended for optimum production. Other categories, namely, I Ah, II Au, II Ah and II Bh, while better suited to agriculture, make up only a small portion of the land area. Therefore, in order to achieve high yields for economic crop production, adequate soil stabilization measures and fertility management, including addition of sufficient amounts of lime and farmyard manure, are required.

5.2 Recommendations

As the Nagarpalika has mostly sloping lands of 5 to 30 degree slopes, they require adequate conservation measures, including, terracing, proper drainage of excess runoff and other soil stabilization measures, to achieve economic production.Also, as many of the soils are highly acidic addition of adequate amounts of agricultural lime is recommended.Other steeply sloping areas are not recommended for traditional agriculture, however, these lands may be suitable for controlled livestock grazing, horticultural crops and agroforestry systems implemented with proper soil conservation and stabilization measures.

Other steeply sloping areas are not recommended for traditional agriculture, however, these lands may be suitable for controlled livestock grazing, horticultural crops and agroforestry systems implemented with proper soil conservation and stabilization measures. Such a diversified cropping system with incorporation of livestock rearing would also enhance the resilience of local communities to the impacts of climate change.

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Risk Report

Preparation of Risk Layer Report

Suryodaya Nagarpalika, Ilam District

This document is the output of the project entitled **Preparation of Nagarpalika/Gaunpalika level Land Resource Maps (***Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps, Cadastral Layer Superimpose and Nagarpalika/Gaunpalika Profile***), Database and Reports (Package-04)** awarded to *PEES Consultant (P) Ltd.* by Government of Nepal/Ministry of Agriculture, Land Management and Cooperatives, National Land Use Project (NLUP) in Fiscal Year 2074-075.The area covered under the Package 04 of Ilam District are: Suryodaya Nagarpalika and Rong Gaunpalika.

The Nagarpalika/Gaunpalika areas analysed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the Nagarpalika/Gaunpalika may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

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CHAPTER 1: INTRODUCTION

1.1 Background and Rationale

Hazard is simply means as a condition of a potential harm. It poses a level of threat to life and properties and/or local environment. It is commonly defined as ‘the potential to cause harm’; whereas the term ‘risk’ is generally used to described ‘chance of disaster. However, it is commonly defined as ‘the combination of the probability or frequency of occurrence of a defined hazard and the magnitude of the consequences of occurrence’ (Royal Society 1992, cited in EEA 2011). Generally, in many environmental literature, the term ‘hazard’ and ‘risk’ used simultaneously to describe those activities which are threats to human lives properties and the surrounding environment. The analysis of risk-hazard will increase the level of awareness and knowledge for decision makers. It also provides a picture of the risk and vulnerability that may exist in our society, which supports to make threat mitigation plan or safety preparedness plan.

Land use planning is a tool to reduce potential risk from natural or manmade hazards. Man-Made Hazards are the events caused by humans and occur in or close to human settlements whereas natural hazard refers to all atmospheric, hydrologic and geologic phenomena that have potential to affect human beings, their structures, and/or activities adversely (Burton, Kates and White, 1978). Land use planning without due consideration these hazards/risks are not effective. Mainstreaming disaster risk reduction in land use planning can systematically reduce impact of specific hazard. There exist diversities in risk type such as fire, flood, landslide, seismic, industrial etc. The government of Nepal has enacted the Land Use Policy 2072. The policy has encouraged to make different land use zones (see Land Use Policy- 8-1) through the analysis of geology, capacity and suitability of land; present land use and/or as per necessary. Land use policy 2072 (policy 13) has also focused on the development of land use planning information system through the preparation of land use/land resources maps, land capability maps, hazards maps and generated database. The policy assumed that the preparation of land use zoning through the analysis of hazard risk will be more suitable to secure people’s lives and properties and conducted related activities. Therefore, the main objective of this study is to investigate the risk factor associated with the land use planning.

1.2 Objectives of the Study

Disaster risk layer is considered as key components for the preparation of land use zoning maps and database. For this purpose fire, flood, landslide, soil erosion, industrial and seismic hazards are taken into consideration. Depending on the nature of disaster their inputs, objective, scope, method and output varies. Therefore, the general objective of this study is to identify the risk events potentially caused by flood, landslide, soil erosion, earthquake, fire and industry within the study areas; and prepare a risk map at 1:10,000 scale and GIS database which is required for preparation land use zoning of **Suryodaya Nagarpalika** of Ilam District (Package-04) (fiscal year 2074/75).

1.3 Study Area

Suryodaya Nagarpalika, name being the Nepali translation of “Rising Sun” declared Nagarpalika status in 2013 (2070 BS), with the merged of three Village Development Committees (VDCs) namely: Phikkal, Panchakanya and Kanyam. After, the restructuring of local body in 2073 BS, Gorkhey, Pashupatinagar, Sriantu, Samalbung, Laxmipur and Jogmai ward no. 8 and 9 were also merged into the Nagarpalika. It is located in Ilam district, province no. 1, approximately 40 km south-east of the district headquarter Ilam. Geographically, it lies in the hill region which is mostly known as Mahabharat range with natural scenery and pleasant weather. Its geographical coordinates are 87°55'59" to 88°10'37" east longitude and 27°0'28" to 26°47'17" north latitude. The Nagarpalika is bordered with India on the east, Ilam Nagarpalika and Maijogmai Gaunpalika on the west, Mai-Jogmai Gaunpalika on the north and Rong Gaunpalika on the south (Figure 1.1). Phikkal is the center of the Nagarpalika. The total area of the Nagarpalika is 22438.57 ha. which is extended north-south 25.29 km and east-west with 24.71 km.

The inhabitants are believed to have been living in this Nagarpalika since ancient time. According to the Population Census of 2011, the total population of this Nagarpalika was 56,707 and the numbers of households were 13,211. This gives an average household size of 4.3 which was lower than the national average (4.88). Administratively, the Nagarpalika has been divided into 14 wards. Ward 1 is the largest in terms of population size whereas ward 7 is the smallest one.

The Nagarpalika has diversity both in its physical and cultural aspects. It is a business hub of Ilam with beautiful landscapes. Tea, ginger, Amriso, cardamom, round chilies (Akabare Khursani), milk and potatoes are the major trade items of this Nagarpalika. The Nagarpalika has grate possibility for the tourism. Kanyam, Pashupatinagar, Phikkal, and Sri Antu are famous for tourist destination sites. Rai, Brahmin, Chhetri and Tamang are major ethnic group inhabited in the Nagarpalika.

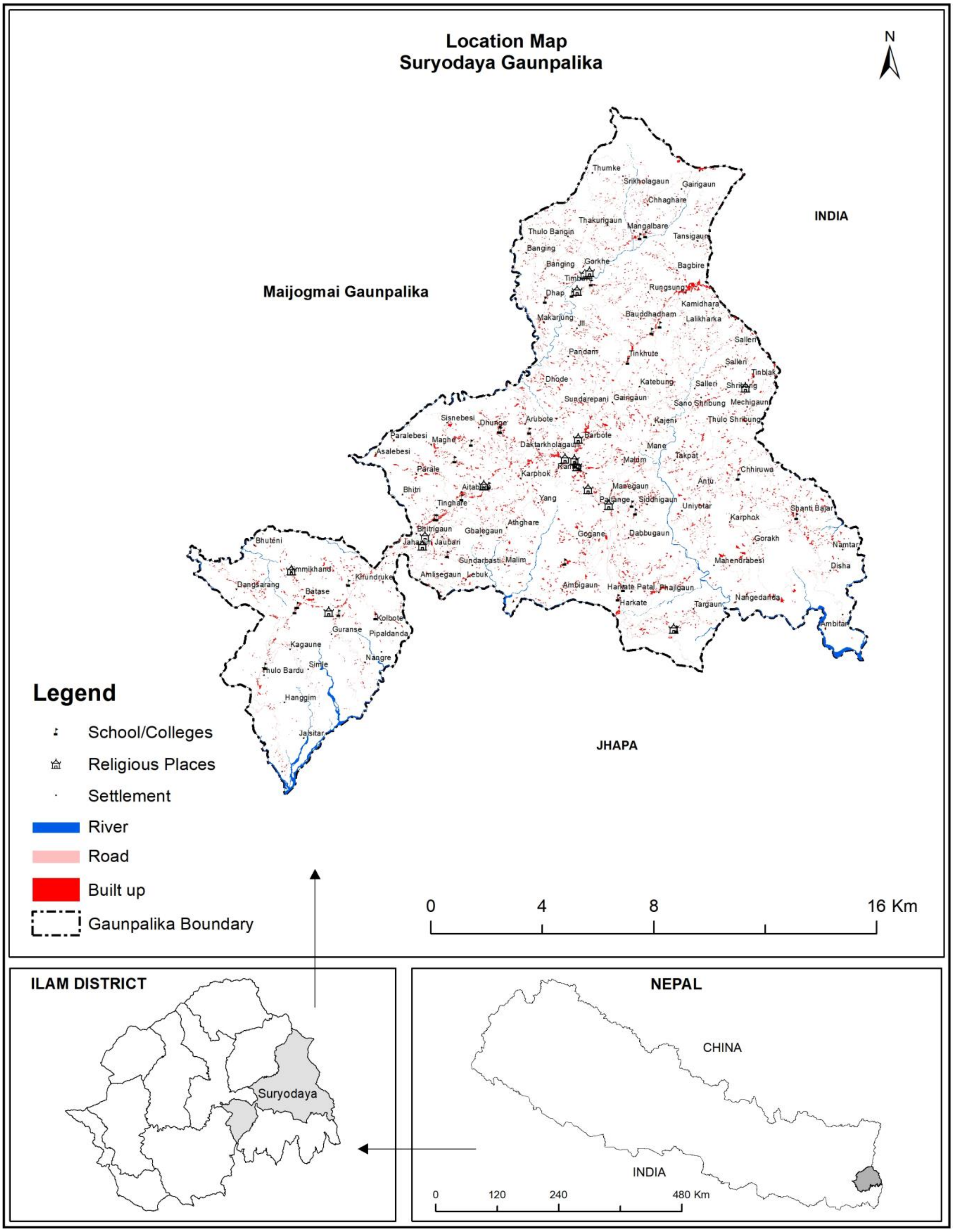


Figure 1.1: Location of Suryodaya Nagarpalika, Ilam District

CHAPTER 2: CONCEPTUAL BASIS OF RISK MAPPING

2.1 Risk and its relation to Land Use Zoning

Planning has the greatest chance to reduce risk, and land use planning process should aim to reduce the risks associated with populations exposed to disaster. Land-use planning is considered one of the best practices for the disaster risk management, by which a community can consider disaster risks and their spatial distribution, steer more sustainable land development and use, and reduce the vulnerability of poor people who are often settled on degraded sites with significant risks and constraints (Roy and Ferland, 2015). Recently in many countries, integration of disaster risk into spatial planning has been largely emphasized. Spatial planning requires hazard information, and hazard information is needed by planners to decide which areas should be prohibited for future development due to excessive risks or to allocate land for potential uses on the basis of hazard intensity or recurrence interval. In this context, land use planning is recognized not only as a key for achieving sustainable development but also as a tool to mitigate risks, generated due to natural and manmade disaster. Greiving and Fleischhauer (2006) discussed various aspects of the integration between risk and spatial planning; and Fleischhauer et al. (2006) have identified four possible roles of spatial planning in risk management namely;

- Keeping areas free of future development that are; a) hazard pone, particularly with history of occurrence of disaster events, b) needed to lower the effects of hazardous event (e.g. flood retention basins), and c) needed to enhance effectiveness of disaster response (e.g. evacuation routes etc).
- Differentiated decisions on land use – allocating land for different uses based on hazard intensity, frequency or other hazard criteria. For instance flood prone areas may be used for agriculture purposes and may be forbidden for residential or siting of critical buildings, avoiding construction on steep slopes but encouraging forestation on those areas etc.
- Regulating land use by legally binding status – for instance regulating building density in earthquake prone areas, recommended roof types for buildings in the hurricane belt, or prohibition of basements in flood prone areas.
- Hazard modification - spatial planning can contribute in reduction of hazard potential of some of the natural hazards such as floods. This can be achieved by influencing intensity and frequency of a hazard.

(Source: Spatial planning and Hazard Data Requirements, ACE-EU Natural Disaster Risk Reduction Programme. Retrieved from www.charim.net/methodology/71 .)

Population, buildings and infrastructure, economic activities, public services utilities, other infrastructures and environmental values in the area potentially affected by the hazard are deemed as elements at risk. The assets at risk from disaster can be enormous and include private housing, transport and public service infrastructure, commercial and industrial enterprises, and agricultural land. FAO's Guidelines for Land Use Planning (1989, 1993) make it clear that in the long run, land use must be economically viable and socially acceptable, and that one major goal of development planning is to make an efficient and productive use of the land. In this context, hazard and risk factor must be analyzed while preparing land use planning/zoning. Land use zoning refers to the division of land into homogeneous areas and their ranking according to degrees of actual or potential hazard or risk or applicability of certain hazard-related regulations; and modern land use planning has also emphasized to environmental component, and in this respect it is often restrictive in the kind of land uses permitted (Verheye, 2009).

2.2 Relation of vulnerability and hazard with Risk

Hazard: Hazard is a prime component of risk. It is a condition for causing an undesirable consequence, which expressed as the probability of a potentially damaging event of a certain magnitude occurring within a certain period of time. Hazards depend on site-specific and seasonal climatic conditions. For example, the description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the probability of their occurrence within a given period of time.

The initiating causes of a hazard may be either an external (e.g. earthquake, flood or human agency) or an internal (defective element of the system e.g. an embankment breach) with the potential to initiate a failure mode. Hazards are also classified as either of natural origin (e.g. excessive rainfalls, floods) or of man-made and technological nature (e.g. sabotage, deforestation, industrial site of chemical waste). Regarding hazard identification and estimation, two approaches can be identified based on the ANCOLD Guidelines (2003) and the ISDR principles (2004):

a. Traditional deterministic approach: a first level estimation of the potential adverse consequences, if the hazard occurs, in order to classify the system under threat, identify the necessity or not of further investigation. This approach is also the most comprehensive way of estimating man-induced and /or technological hazards, e.g. a forest fire hazard that cannot be captured by a probability distribution.

b. Probabilistic approach: it is based on the theory of probability and regards hazard estimation as the estimation of the probability of occurrence of a particular natural event with an estimated frequency within a given period of time. It can be applied on hazards of natural origin and it represents a very common method used in most flood plain delineation studies when the potential for loss of life is considered negligible in terms of historical floods. The probabilistic approach tends to assume that events in the future are predictable based on the experience of the past.

Vulnerability: One of the best-known definitions of vulnerability was formulated by the International Strategy for Disaster Reduction (ISDR, 2004), which regards it as "a set of conditions and processes resulting from physical, social, environmental and economical factors, which increase the susceptibility of a community to the impact of hazards". A basic consensus has emerged, that the concept of vulnerability addresses a double structure consisting of an external side (exposure) (Bohle, 2001), and also that vulnerability is:

- Multi-dimensional and differential (varies across physical space and among and within social groups).

- Scale-dependent (with respect to time, space and units of analysis, such as individual, household, region, system).
- Dynamic (characteristics and driving forces of vulnerability change over time, certainly exceeding that time of the extreme event itself).

The vulnerability function could be treated as a function between 0 and 1. However, the most appropriate approaches for the case of vulnerability of the society and the cultural heritage are thought to be qualitative. A vulnerability analysis in the event of a hazard like flood considers the population and structures at risk within the affected area. In the start of the analysis, a reference level of the system's vulnerability should be determined that usually refers to existing flood protection systems of the affected area. The vulnerability analysis evaluates the potential costs of disaster event in terms of damages to buildings, crops, roads, bridges and critical infrastructure etc.

Risk is defined as the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions (UN-ISDR, 2009, EC, 2011 cited in Westen, n.d). Risk can presented conceptually with the following basic equation.

Risk = Hazard * Vulnerability * Amount of elements-at-risk

The equation given above is not only a conceptual one, but can also be actually calculated with spatial data in a GIS to quantify risk from geomorphological hazards. The way in which the amount of elements-at-risk are characterized (e.g. as number of buildings, number of people, economic value) also defines the way in which the risk is presented.

The relationship between risk, hazard and vulnerability has been presented in figure 2.1

Figure 2.1: Factors of Disaster

2.3 Risk types and their Descriptions

Depending upon the types of factor causing an area to expose into vulnerability and hazard associated with it, risk can be classified into various categories. However, for the land use mapping process, risk factors have been specified related to the following event: Flood, Landslide, Soil erosion, Fire, Earthquake (Seismic event) and Industrial hazard.

Flood

A **flood** is an overflow of water. It usually occurs in rivers when the flow rate exceeds the capacity of the river channel. Moving water has awesome destructive power when a river overflows its banks. Country like Nepal, there is high potentiality of flash flood (rapid flooding event), erosion and inundation particularly during the monsoon season. Nepal has more than 6000 rivers and rivulets (Manandhar, 2010). These rivers and rivulets support irrigated agriculture and other livelihoods, but also wreak havoc in valleys and in the terai when they overflow (Dixit, 2010). This phenomenon occurs mainly in Monsoon. Intense monsoon rainfall causes flooding in many rivers of Nepal. The frequency of flood and scale of damage have increased in the terai and inner terai regions of Nepal. Thousands of people are affected by flood every year in Nepal during the monsoon season. Altogether, water induced disasters cause an average annual loss of 309 lives and affect 27654 families (Asia et al., 2009). MOHA (2013) reported loss of 4079 lives and affected 181961 households in 2012 due to floods in Nepal.

According to EU Directive (COM, 2006) for flood management, "flood risk" is the likelihood of a flood event together with the actual damage to human health and life, the environment and economic activity associated with that flood event. In this context flood risk can be considered as the actual threat, in other words the real source of flood hazard to the affected areas. The quantification of flood risk results either in monetary units or in loss of life units, if the losses are measurable, or in qualitative terms (e.g. allocation in classes) in the case of intangible damages (social, environment, cultural) to the affected areas. In general, risk as a concept incorporates the concepts of hazard {H} (initiating event of failure modes) and vulnerability {V} (specific space/time conditions). Mathematically, it is expressed risk (R) as a functional relationship of hazard (H) and vulnerability (V); $R = \{H\} \times \{V\}$.

Flood in Nepal: Flood occurs repeatedly in low plains of Nepal causing loss of lives and properties. Nepal has more than 6000 rivers and rivulets (Manandhar, 2010). Major sources of water are Glaciers Rivers, lakes, rainfall, ponds, groundwater etc. Intensity of rainfall with average 1700 mm annually contributes to surface water flow in average annually of approximately 224.7 billion m^3or in terms of flow rate; it is 7,125 m^3/sec (Bajracharya and Mool *et al*., 2009). It further adds that Nepal suffers from frequent water induced disaster like flood, landslide, erosion, debris flows, glacial lake outburst, drought and epidemic. This phenomenon occurs mainly in Monsoon. Intense monsoon rainfall causes flooding in many rivers of Nepal Altogether, water induced disasters causes average annual loss of 309 lives and affects 27654 families (Baracharya and Mool *et al*., 2009).

Landslide

Landslides are a form of erosion and are an important process in the shaping and reshaping landscapes and landforms. Landslide hazard is frequent phenomenon is Nepal due to several reasons including tectonic activities, uncontrolled and unsafe development, heavy precipitation and environmental degradation. However it is observed that rainfall induced landslides is most prevalent in the hills and mountainous districts. In Nepal, high susceptibility zone of landslide are identified in the areas of high intensity rainfall and earthquake hazard.

Landslide susceptible area of varying degree, potential landslides may be of varying likelihood of occurrence based on management practices and protection measures in the area

Fire

Fire is common event every year in Nepal, particularly in the settlements of Terai and forests in hills region of Nepal. Government of Nepal has given less priority in managing settlement and/or forest fire due to limited resources. It is common in Terai during the dry, stormy season between April and June when temperatures exceed 35°C, houses in the region are wooden and have thatched roofs, they are extremely vulnerable to incendiary lighting strikes, suffers from numerous fire outbreaks mainly during the process of cooking. In the winter, the major cause of fires is the short circuiting of electrical appliances, particularly heaters. In urban and other areas, houses are built in close proximity; these too are vulnerable, as fires easily leap from one house to the next. This fires cause great loss of life and property and can have a devastating impact on local economies.

Very few fires are naturally caused in Nepal (NBS, 2002). Karkee (1991) observed that 40% of forest fires in the mid-hills are caused by accidents while 60% are started deliberately e.g. Shifting cultivation, forest encroachment. In settlement areas, due to negligence while cooking, firing is common house and shelter. Faulty wiring and electrical equipment, candles, home heating and cooking, children activities, flammable liquids (fuels, solvents, adhesives, paints, and other raw materials – can ignite or explode if stored improperly) and careless smoking were the main sources of firing in houses and settlements areas.

In an industrial area the fires occur when hazardous materials such as petrochemicals spill or leak and subsequently explode, technology fails, vehicles collide, and factories catch on fire. Within minutes, an entire industrial area can be aflame and billions of rupees of property swallowed up. They also take lives and destroy the environment.

Earthquake (Seismic event)

Earthquake or seismic event is the sudden shaking of the earth surface. Its magnitude is measured by Richter scale ranges between 0-9. An earthquake of magnitude above 7 is considered as a big earthquake. The Himalaya seismicity owes its origin to the continued northward movement of Indian plate after the continental collision between Indian plate and Eurasian plate. The magnitude, recurrence and the mechanism of continental collision depend upon the geometry and plate velocity of Indian plate in relation to southern Tibet (Eurasian Plate). Recent studies also suggest that the convergence rate is about 20 mm /

year and the Indian plate is sub-horizontal below the Sub- Himalaya and the Lesser Himalaya. The result of micro seismic investigation, geodetic monitoring and morphotectonic study of the Central Nepal has depicted that the more frequent medium sized earthquakes of 6 to 7 magnitude are confined either to flat decollment beneath the Lesser Himalaya or the upper part of the middle crustal ramp. The ramp is occurring at about 15 km depth below the foothills of the Higher Himalaya in the south of MCT surface exposures. Big events of magnitude greater than eight are nucleated near the ramp flat transition and rupture the whole ramp-flat system up to the blind thrust (MBT) of the Sub-Himalaya (Pandey et. al., 1995). According to Bajracharya (1994), Nepal has been divided into five seismic zones (Zone1, Zone 2, Zone 3, Zone 4, Zone 5) with relation to the seismic hazard (Low, Moderate and High). The study area falls in the seismic medium hazard area (Seismic zone 3) of the Nepal Himalaya.

The Richter scale shows the how big earthquake is, and their hazardous impacts are decided on the basis of quantum of damage or loss of lives and properties. An earthquake becomes a hazard when it strikes in the urban area or the highly populated areas. Loss lives and properties, damage infrastructure and other man made structure, slope failure, decreasing underground water table, drought etc. are direct impacts of the seismic event.

Industrial Hazards

The adverse impacts caused by industrial pollution and expansion within the zone needs to be identified and assessed to conserve the environment, living organism, as well as the biodiversity of the region for promoting the sustainable development of the surrounding communities in a deliberate and tactful way. The major risk area has to be identified so that the proper planning for settlement and other development activities can be done in planned and sustainable way followed by land use planning. The areas nearer to the industries are in high risk in all aspect such as health, environmental, water ecology, agricultural productivity etc.

The risks from the industries in Suryodaya Nagarpalika are minimally negative in nature, for long-term duration and low in magnitude as none of the industries are of large scale. As stated above, the majority of the small scale industries are agro based. The agro based industries generate effluents and solid wastes that need to be disposed in an environmentally acceptable manner. However, there is a marginal risk of air pollution and water contamination from wastewater generated by those industries as the industrial discharges end up in surface water, causing a risk on flora and fauna, as well as on human beings, who use the surface water.

CHAPTER 3: METHODOLOGY

3.1 Flood Risk

In natural stream, when quantity of water increased sufficiently, it is said to be flood. Flood is a natural event of rising water level in a stream, lake, reservoir or coastal region (Friesecke, 2004). Flood is too much water in the '*wrong*' place (Singh et al., 2014). A flood is caused by heavy rainfall during short period of time that causes river/oceans to over flow. Flood can happen very quickly when heavy rain falls over a short period of time. Such type of flood is called flash flood, which can occur with little or no warning. This can cause huge damage of human life. The flooding can be worst if storms, 'spring tides' and low atmospheric pressure occur at a time. Floods can distribute large amounts of water and suspended sediment over vast areas, restocking valuable soil nutrients ruining crops, destroying agricultural land and buildings and drowning farm animals (Singh et al., 2014).

Natural hazard due to flood events is a part of nature that is always existed. Floods are climatological phenomena, which are influenced by geology, geomorphology, relief, soil, and vegetation conditions. Meteorological and hydrological processes can produce flash floods or more predictable, slow developing floods causing riverside floods. In some cases, floods are invited by the failure of dam and landslides. Mitigation and non-structural measures are found to be more effective and long-term solution for the river water related problems. The local flood protection measures create negative effect in both upstream and downstream. Therefore, whole river basin should be taken into account. Flood plain should be identified before assigning any land use in such area (UN/ECE, 2003). The identification of flood plain can be performed by delineating flood hazard areas on the map. This can be helpful to keep away the building development in immediate flood risk areas.

Mathematical Method of Flood Risk

According to the EU directive for flood management (COM, 2006), "flood risk" is the likelihood of a flood event together with the actual damage to human health and life, the environment and economic activity associated with that flood event. In this context flood risk can be considered as the actual threat. The flood risk effects can be measured either in monetary terms or in loss of life terms, or in qualitative terms (*e.g.* allocation in classes) in the case of intangible damages (social, environment, cultural) to the affected areas. In general, risk as a concept incorporates the concepts of hazard {H} (initiating event of failure modes) and vulnerability {V} (specific space/time conditions). It is customary to express risk (R) as a functional relationship of hazard (H) and vulnerability (V).

$$\{R\} = \{H\} ☼ \{V\}$$

Where, the symbol ☼ represents a complex function incorporating the interaction of hazard (H) and vulnerability (V). Consequently, in mathematical terms it can be expressed as:

$$R = \{H\} \times \{V\}$$

Since vulnerability is a dimensionless quantity (Villagran, 2006) and therefore, risk can be measured in the same units as hazard. In quantitative terms, annualized risk can be estimated as the product of probability of occurrence of the hazardous phenomenon and the actual consequence, combined over all scenarios. According to the method of estimating average (annualized) hazard, the expected value of flood risk can be calculated as follows:

$$E(X) = \int^{\infty} x \,.\, V(x).\ f(x)dx$$

Where *X* is the actual flood damage caused by the flood hazardous phenomenon, *f(x)* is the probability density function (*pdf*) that describes the phenomenon and *V(x)* is the vulnerability of the system towards the corresponding magnitude of the phenomenon. While estimating the flood risk, it involves major restrictions such as:

- It can be applied only on hazards of natural origin due to probabilistic analysis
- As it abides to a general methodological framework , it is highly case specific
- It is highly dependable on expert's judgment

3.1.1 Data

Data for the flood risk assessment can be classified into various groups as follows:

- Land use and land cover
- Elevation data (such as spot height, contour, digital elevation model, etc.)
- Hydrologic parameters (such as catchment area, cross-sectional at defined interval, river bank lines, flow path geometry, stream centre line, etc.)
- Discharge at strategic points
- Soil type and flood plain property (such as manning's constant, river boundary delineation, etc)

The data on those aspects stated above were collected during the field visit done.

3.1.2 General Approach and Methodology Framework

In Nepal, there are various methodological frameworks in practice for flood modeling. It is generally accepted that *the flood risk management framework* should be mainly oriented towards non-structural measures (e.g. land use planning, flood warning systems, evacuation plans, insurance policy). They are mainly driven by the need of cultural heritage protection and also by the socioeconomic conditions of the area concerned. In this context, the methodological framework adopted for the flood risk assessment in this study is shown in Figure 3.1.

In the context of flood risk, the concepts of hazard, vulnerability and risk have been extensively used in various disciplines with a different meaning, impeding cross-disciplinary cooperation for facing hazardous events. Flood, a common natural hazard, has also hard to find the unique definitions and assessment procedures. In this study, it is used a comprehensive way for defining and assessing flood risk and vulnerability in the flood-prone areas. The suggested methodology follows a three-step assessment approach:

i. Annualized hazard incorporating both probabilities of occurrence and the anticipated potential damages
ii. Vulnerability (exposure and coping capacity) in the flood- prone areas, and

iii. Annualized flood risk (estimated on annual basis).

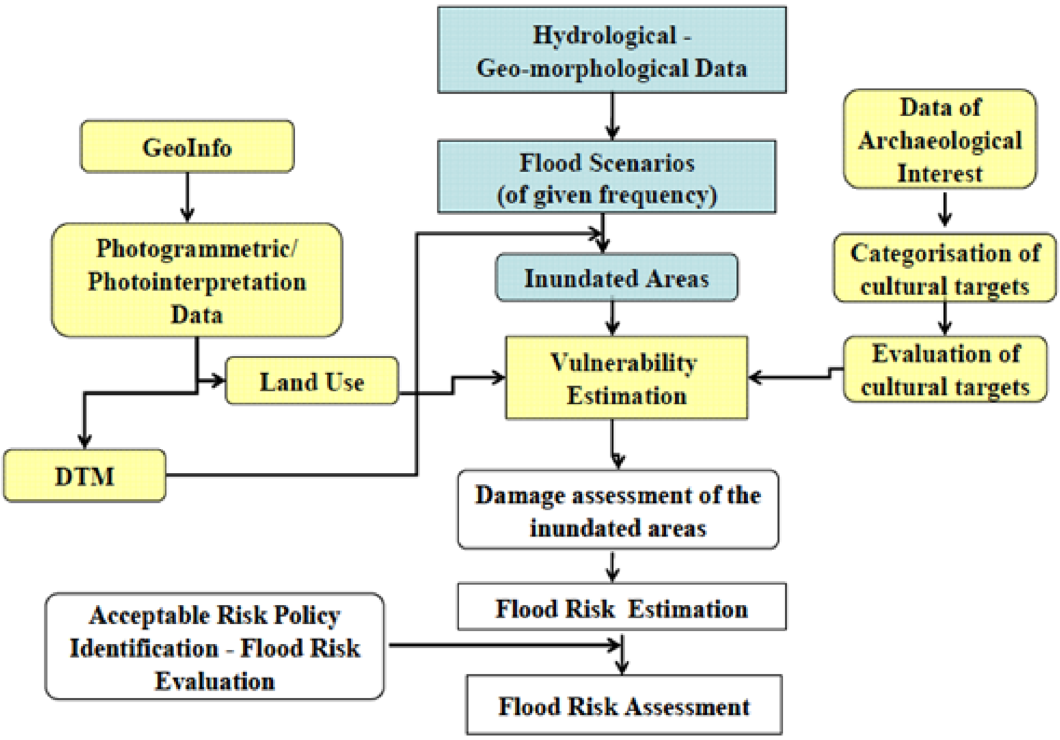


Figure 3.1: Methodological framework for flood risk assessment

The methodology aims to assist water managers and stakeholders in devising rational flood protecting strategies. To apply the methodology, terms such as flood plain, flood hazard map, flood modeling etc are defined with data sources in the following sub-sub sections.

i. Flood plain

The land that lies next to the river or along the river side during normal river flow and submerged during the flood is called as 'flood plain' (Shahiriparsa & Vuatalevu, 2013).

ii. Flood hazard mapping

Flood hazard mapping (FHM) refers to the map that provides information on inundation like predicted inundation, inundation depth etc. This also includes the evacuation routes graphically in understandable format. Flood hazard mapping is an example of non-structural measures for minimizing risk (Konecny *et al*., 2003). FHM includes the information on historical as well as potential future flood events. This can be the basis for determining land use control, flood proofing of constructions and flood awareness and preparedness. FHM provides information on type of flood, the flood extent, water depths or water level, flow velocity or the relevant water flow direction (Prinos, 2009). Flood hazard mapping should be considered before any investments or implementation of development projects.

iii. Flood modeling

It is an engineering tool that provides accurate information regarding flood profile. The governing factor for causing flood are rainfall, run off, catchment characteristics and return period (Singh et. al, 2014). The main input data for calculating flood hazard maps is the occurrence probability and the amount of high water discharge in rivers (Prinos, 2008). Flood discharge calculation is a prominent task for designers of hydraulic structures and river training works. This task is difficult to be adopted as Nepal lacks sufficient hydrological information (Rijal, 2014). To carry out the calculation of flood flow, different approaches can be adopted based on site condition and available data. There are various methods adopted for calculating flood discharges. They are such as rational method, empirical formula (modified Dicken's formula), water and energy commission secretariat (WECS) approach, flood - frequency method, etc. Brief introductions of these methods are given in following sub-sections.

Rational method

The rational method is applied for the peak flow calculation of smaller basin that responds to storms, as it is simple and requires limited data. In this method it is assumed that intensities of rainfall and infiltration are uniformly distributed in time and space. To apply the rational method, the scientific community suggested that the smallest basin area should be 25 km^2 (Hua, Liang, & Yu, 2003).

Empirical formula

The empirical formula (Modified dickens formula) has been derived for the first time for Northern India. The formula uses the catchment area as a single parameter affecting the flood peak and other factors are constant based on the specific region. This formula is applicable in the region from which the formula has been developed and then is applied to other areas that at best can give rough estimates (Subramanya, 2006). Even though, northern India and southern part of Nepal have similar catchment, it is not opted to apply the empirical formula for current study because of the data limitation.

Flood frequency analysis

The flood frequency method is the statistical method of flood frequency analysis. The method needs a large-scale data (a minimum of 30 years) to get the accurate result. In case of the data records with less than ten years, flood frequency analysis should not be adopted (Subramanya, 2006).

WECS method

The WECS method (DHM, 1990) is the unique method for Nepal and found to be accurate comparing others. In this method, the whole country is considered as single hydrological region. As per flood records, low flows, long-term flows and high flood flows sub regions are divided. The method is first developed jointly by the Water and Energy Commission Secretariat (WECS) and Department of Hydrology and Meteorology of Nepal in 1982. Later it is modified and came up in improved form in 1990. The World Meteorological Organization (WMO), Water and Energy Resource Development Project (WERDP) and WECS/NEA Institutional Support Programme (WISP) are major partners to develop this method. The following equations are used for flood flow of any river having catchment area ‘A’ below 3000.

$$Q_2 = 1.8767\ (A+1)^{0.8783}$$

$$Q_{100} = 14.63\ (A+1)^{0.7342}$$

Where, the subscript 2 and 100 stand for the return periods in number of years.

The flows for any other return period 'R' is then given by:

$$Q_R = exp\ (\ln Q_2 + 3\ \sigma)$$

Therefore, comparing the merits and de-merits of all the methods and their suitability, WECS/DHM method is found to be appropriate for this study. By using this method, the flood discharge for the return period of 2 years and 100 years have been calculated and analysed.

iv. Manning's roughness coefficient (n)

The Manning's roughness coefficient, *n*, is commonly used to represent flow resistance (Phillips & Tadayon, 2006). The friction parameters have been selected from the guidance of the standard hydrological textbook by visual judgment.

v. Computer Applications used for flood modeling

Computer application software such as GIS, HEC GEO-RAS, and HEC RAS has been used to develop the flood plain map in this study.

vi. Geographic Information System (GIS)

GIS is computer based system for mapping and analyzing spatial data. GIS is considered revolutionary new technology, which increases ability to make decision and solve problems. GIS differs from other information system as it integrates common data base operations like query and statistical analysis, unique visualization and geographic analysis benefits offered by maps. This is helpful for explaining events, predicting outcomes and planning strategies. The careful analysis of spatial data using GIS can provide detail information on problem like pollution, deforestation, natural disasters and suggest the way to address them. GIS comprises five components i.e. hardware, software, data, people, and methods (Joerin & Musy, 2000).

vii. HEC-GeoRas

HEC-GeoRas is an extension for ArcGIS. This extension allows users with limited GIS experience to create an HEC-RAS import file containing geometric attribute data from an existing digital terrain model (DTM) and complementary data sets. Water surface profile results may also be processed to visualize inundation depths and boundaries (Ackerman, 2011). HEC-GeoRAS is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS using a graphical user interface (GUI).

viii. HEC-RAS

HEC-RAS is numerical analysis software. It is a computer program that models the hydraulics of water flow through natural rivers and other channels (Prinos, 2008). "It is an integrated package of hydraulic analysis programs, in which the user interacts with the system through the use of a Graphical User Interface (GUI)" (Brunner, 2010). This provides the details of flood profiles. This software is easily available and has precise calibration accuracy (Kute *et al.*, 2014). This is the major part of the modeling where flood simulation is done. This program is one-dimensional, which means the flow is considered to be uniform from point to point upstream to downstream. It includes numerous data entry capabilities, hydraulic analysis components, data storage and management capabilities, and graphing and reporting capabilities (Prinos, 2008). HEC-RAS system is the composition of four one-dimensional river analysis components viz. steady flow water surface profile computations, unsteady flow simulation, movable boundary sediment transport computations, water quality analysis (Brunner, 2010). In HEC-RAS, we can see the two major water surface profile facilities: *a*) Steady flow water surface profile, and *b*) Unsteady flow water surface profile.

ix. Steady Flow water surface profile

This component of modeling system is intended to calculate water surface profiles. The system can handle a single river reach, a dendrite system, or a full network of channels. The component is capable of modeling subcritical, supercritical, and a mixed flow regime water surface profiles. The basic computational procedure is based on the solution of the one-dimensional energy equation. Friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head) are used for the evaluation of Energy loss while momentum equation is applied in situations where the water surface profile is rapidly varied. These situations include mixed flow regime calculations i.e., hydraulic jumps, hydraulics of bridges, and evaluating profiles at river confluences (stream junctions). The steady flow system is designed for application in flood plain management and flood insurance studies to evaluate floodway encroachments (Brunner, 2010).

x. Unsteady Flow water surface profile

This component is capable of simulating one-dimensional unsteady flow through full network of open channels. This component gives the design value for subcritical flow regime. However, new releases of the model give the mixed flow regime (subcritical, supercritical, hydraulic jumps, and drawdown). Special features of this component include: Dam break analysis; levee breaching and overtopping; Pumping stations; navigation dam operations; pressurized pipe systems, and sediment analysis (Brunner, 2010).

Upon discussion with NLUP authorities, it was found that that the study should also aim to evaluate land use plan from disaster (flood) management perspective for which requires the evaluation of flood way encroachment. From the experience knowledge, it is concluded that, steady flow analysis is designed to evaluate flood way encroachment. Therefore, in this study, steady flow analysis has been used for the flood simulation as required for the project. It has to keep noticed that; due to the lack of unsteady flow data, this study is limited to choose steady flow analysis.

3.1.3 Methods

In order to obtain the objectives defined in TOR regarding flood risk, spatial and non-spatial data were collected. Both qualitative and quantitative approaches were adopted for data generation. The primary sets of data were acquired using the method of interview with the people of residing in the flood prone areas and government officials. The secondary data were collected from the National Land Use Project. The census of 2011 was obtained from website of CBS of Nepal (www.cbs.gov.np). A short description of data collection and processing is given in the following sub-sections.

i. Data Collection

Data collection is the systematic gathering of information necessary is this study. The information can be of people, objects or phenomena. Haphazard collection of data may create difficulty in answering the set question in a conclusive way (Chaleunvong, 2013). So, the method applied for collecting data is both qualitative and quantitative, which are such as available information, observation, interviewing face to face, written questionnaire, etc. The primary data was obtained using the method of interview with the people residing in flood prone area to get responses to the frequency of occurrence of flood and the methods they adopted to cope with. In addition, more information was collected through the questionnaire being administered to the local people. Non-probability, purposive sampling was used with the sample size of twelve questions.

ii. Data Analysis

- ***Conversation with local people***

From the information obtained through interview with local people, it is known that flood was not frequent in most of the study area, Package-04 (Suryodaya Nagarpalika and Rong Gaunpalika). However, there were some floods: on 2044, 2042, 2061 and 2072 BS in Jil khola (minor flood problems in ward no. 9 of Suryodaya Nagarpalika); Chhiruwa Khola (minor flood problems in ward no. 6 of Suryodaya Nagarpalika); Mechi river (some flood effects in ward no. 5 of Suryodaya Nagarpalika and eastern part of ward no. 6 of Rong gaunpalika); Goyang Khola and Biring Khola (minor problems of ward no. 1, 2 4, 13 &14 of Rong Gaunpalika). The main problems due to flooding are: River bank cutting and landslides which was verified during the time of field visits. The drainage network map under Package 04 (Rong Gaunpalika and Suryodaya Nagarpalika) is shown in figure 3.2.

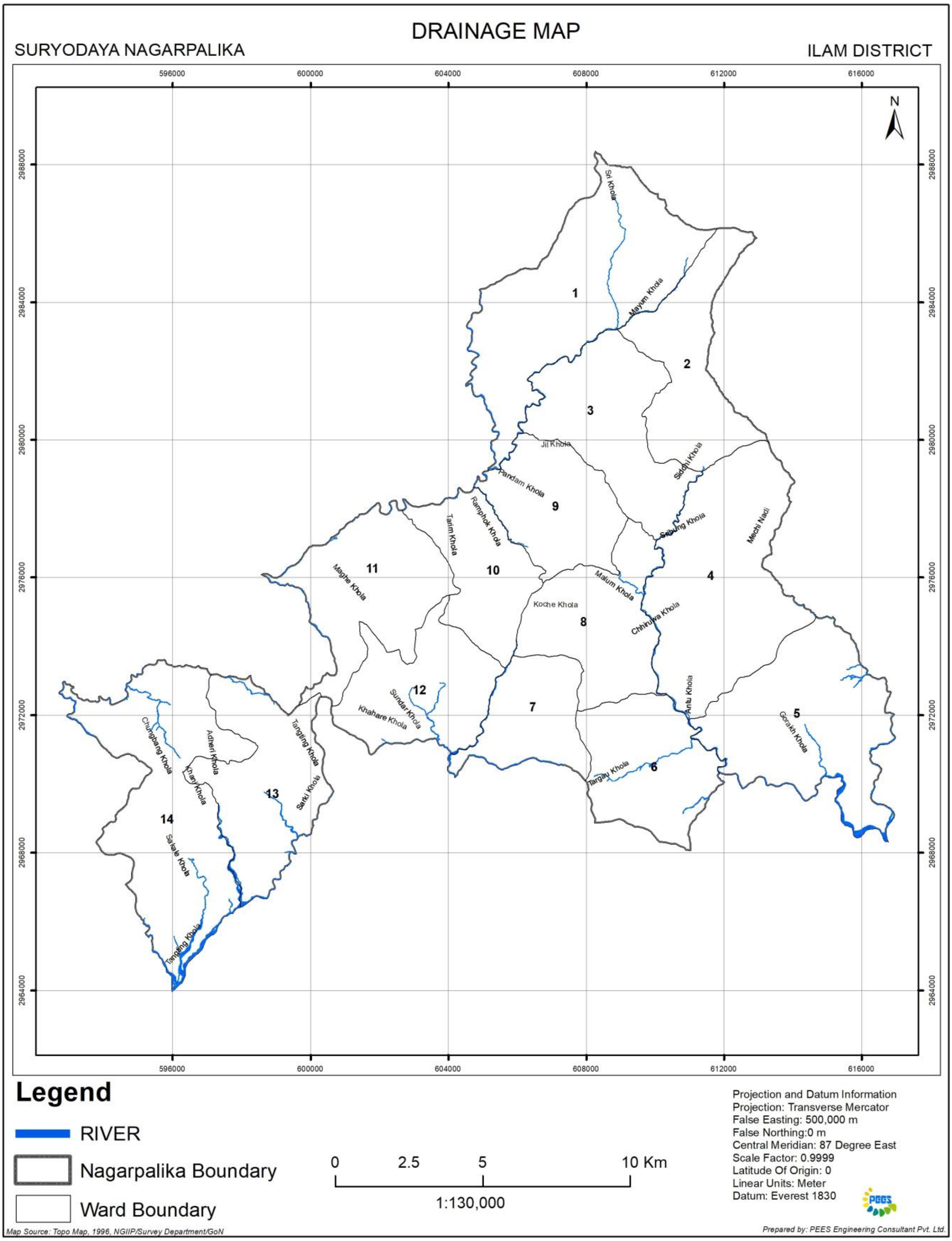


Figure 3.2: Drainage network Map of Package -04, Ilam District

- ***Analysis of Watershed area***

While analyzing flood hazard and risk areas for Package 04 project (Suryodaya Nagarpalika and Rong Gaunpalika), following rivers were digitized from the WorldView-2 image. The names are: Mechi khola, Sakale khola, Jogmati khola, Mayum Khola, Biring Khola, Siddhi khola, Thule khola, Tanting Khola, Tri 1 and Tri 4. Digital elevation model was prepared by using contour and station point from the topographic maps published by the Survey Department of Nepal. Water discharge for return period 100 years was calculated with the determination of watershed area for flow direction and flow accumulation. The process adopted in this study is shown in the Figure 3.3.

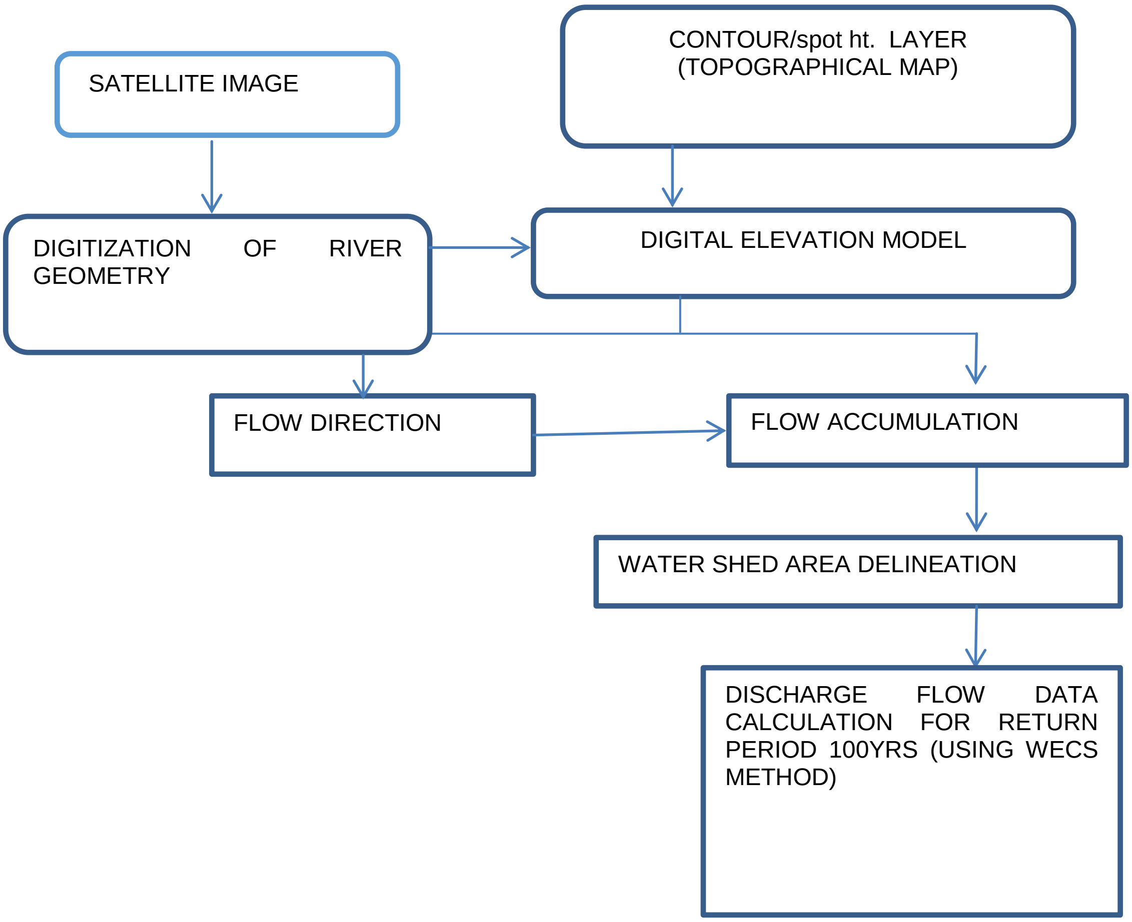


Figure 3.3: DEM processing and Discharge calculation

Calculated flow discharge for the given catchment area of return period 100 years is given in Table 3.1.

Table 3.1: Discharge calculation for given Return Periods 100 years

River Name	Chainage (Km+m)	Catchment Area (Km^2)	Discharge (m^3/sec)
Mechi Khola	15+892	8.19	174.57
Mechi Khola	5+405	39.25	320.54
Mechi Khola	5+203	119.28	592.65
Mechi Khola	3+994	121.03	597.89
Mechi Khola	2+001	126.30	613.52

River Name	Chainage (Km+m)	Catchment Area (Km²)	Discharge (m³/sec)
Mechi Khola	0+211	133.21	633.90
Sakale	1+996	4.51	80.00
Sakale	0+147	1.27	104.00
Tri 1	3+426	5.64	58.75
Tri 1	0+126	6.63	90.00
Jogmai	18+090	34.86	250.00
Jogmai	10+343	97.29	450.00
Jogmai	0+11	139.88	570.00
Mayum	11+885	0.50	50.00
Mayum	7+984	21.82	175.00
Mayum	0+32	41.94	250.00
Biring Khola	15+419	9.25	80.78
Biring Khola	0+55	68.21	350.00
Siddhi Khola	22+245	16.82	215.00
Siddhi Khola	0+113	85.749	430.00
Thule Khola	6+754	4.52	58.00
Thule Khola	4+189	7.90	90.00
Thule Khola	0+25.	12.33	130.00
Tri 4	7+068	3.52	44.29
Tri 4	0+33	7.56	82.00
Tanting	10+342	1.80	50.00
Tanting	6+987	10.39	103.00
Tanting	3+478	19.40	201.00
Tanting	0+975	27.61	291.00
Tanting	0+20	32.36	345.00

iii. Pre-Processing in GIS environment

RAS layers (Stream centerline, river banks, flow path centerlines and cross sections) were created which was later followed by layer setup and finally RAS-GIS import file was created. The file then processed by the HEC-GeoRAS layer.

iv. HEC-RAS Processing

The file created in HEC-Geo RAS was imported in Geometric Data Editor interface in HEC-RAS. The study flow analysis was preceded by using the flood discharge for return periodic 100 years, which was obtained from WECS/DHM method. Reach boundary conditions were defined as critical depth for both upstream and downstream. Manning's constant for left and right bank was set as 0.04 while 0.035 for centre of channel. It was judged by field observation. Mixed flow analysis is done. Then the generated data is exported in GIS format. The process in block diagram form is shown in Figures 3.4.

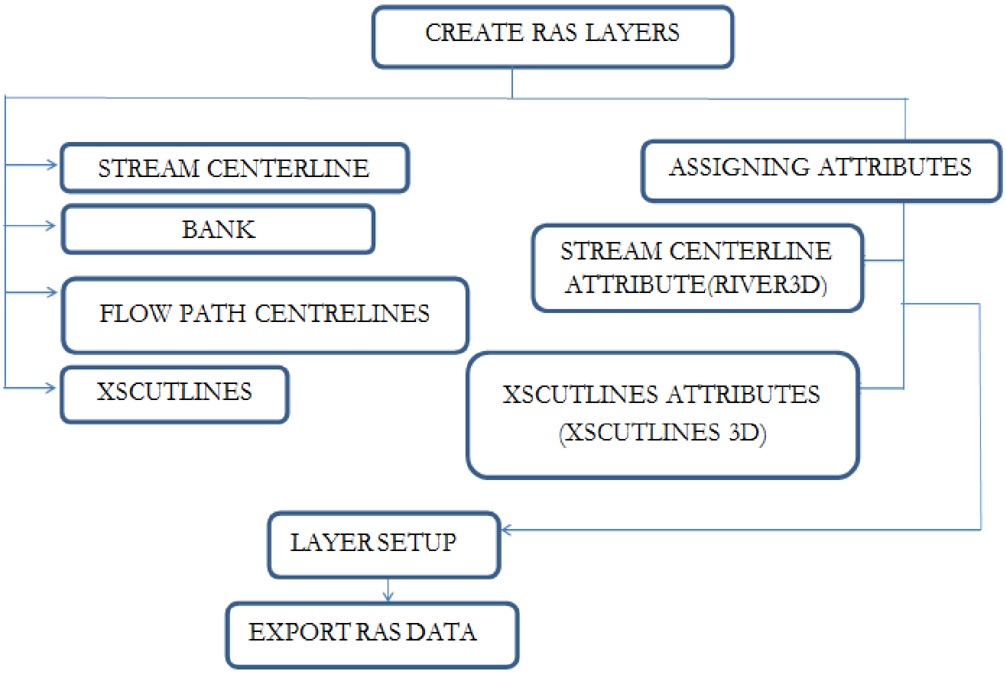


Figure 3.4: HEC-GeoRAS processing

Each of the rivers has its own water surface profiles and they are different in nature. For example, Thule Khola water surface profile is shown in Figure 3.5.

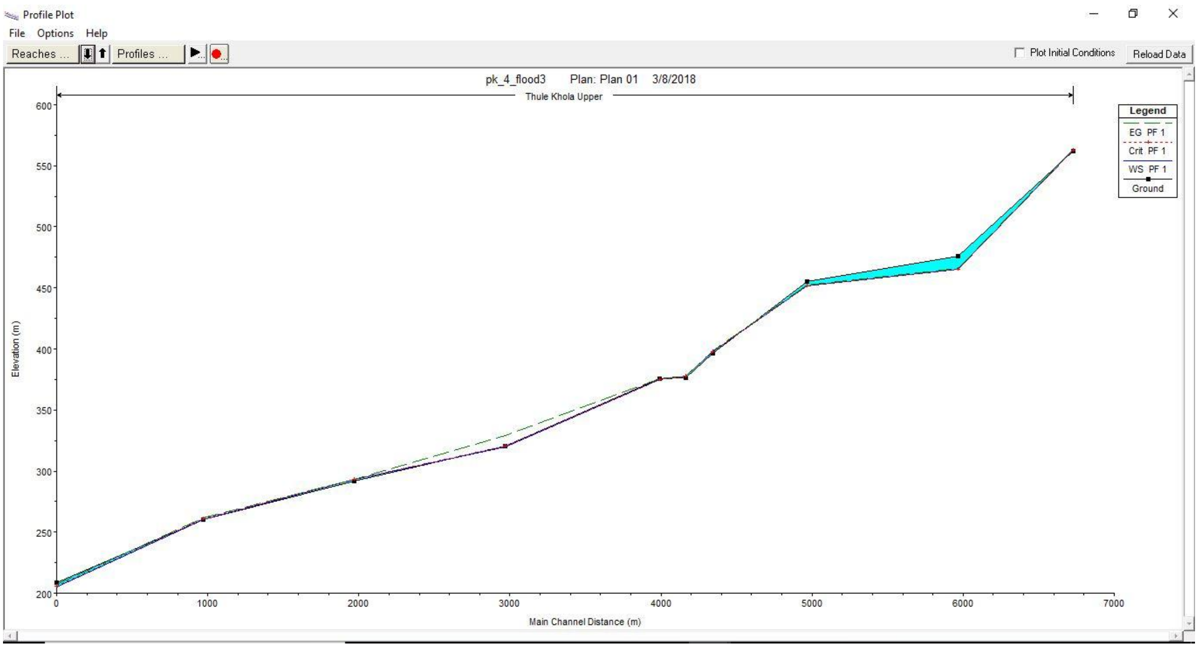


Figure 3.5: Water Surface Profile of Thule Khola for 100 years floods

iv. HEC GEO RAS Post Processing

In this phase inundation mapping was performed with the generation of water surface which was later followed by flood plain delineation. The process involved is given in Figure 3.6.

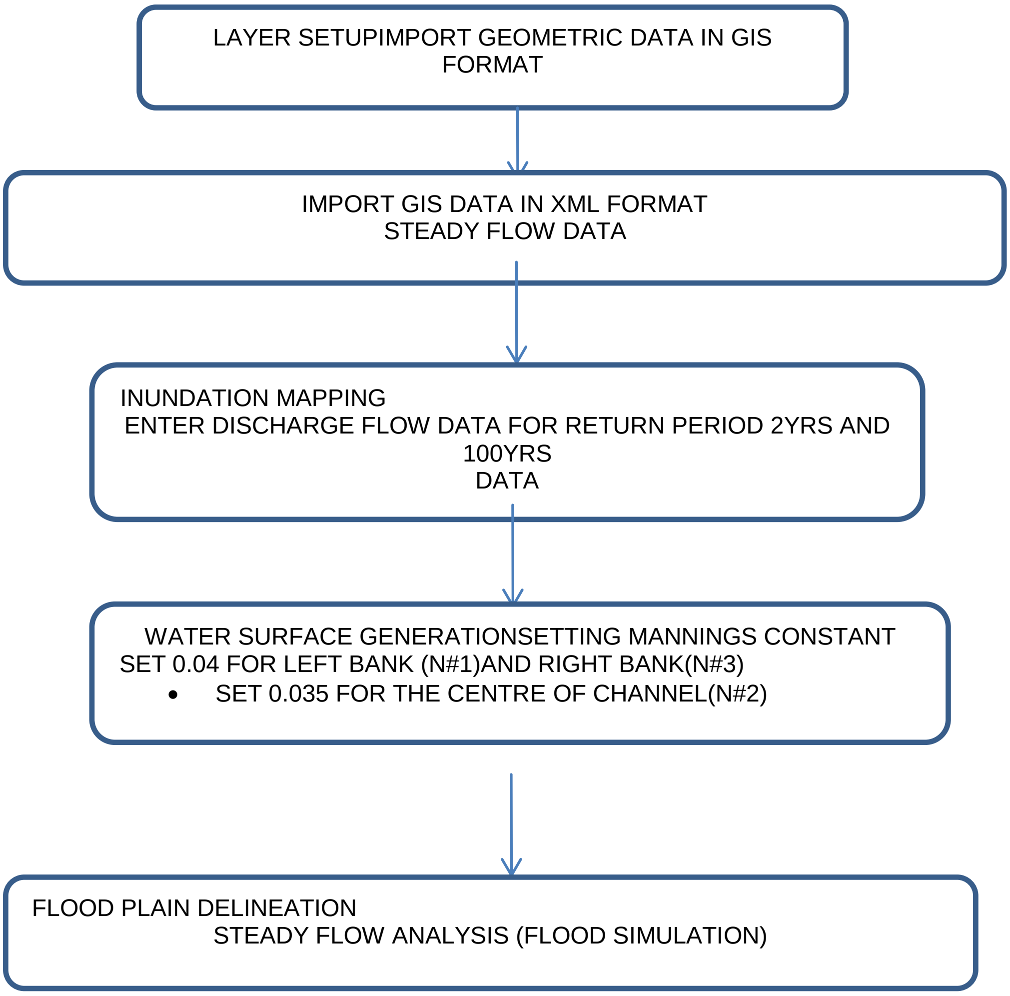


Figure 3.6: HEC-GEO RAS post processing

3.1.4 Result

Flood hazard map was prepared by overlaying land use map with flood area polygon for return period of 100 years. This has given clear picture of possible flood that can affect land use of the area. The assessment has been done for period which is represented in given map shown at the end of this section.

Preparing flood Hazard Map

There are major rivers are: Mechi khola, Sakale khola, Jogmati khola, Mayum Khola, Biring Khola, Siddhi khola, Thule khola, Tanting Khola, Tri 1 and Tri 4. The major problems due to floods are bank cutting and landslides in nearby banks.

Flood hazard map was prepared by overlaying land use map with flood area polygon for return period 100 years. This has given clear picture of possible flood inundation that can affect land use in Suryodaya Nagarpalika, which is presented in Table 3.2, and Figure 3.7.

Table 3.2: 100 year Return Period Flood Prone Area in Suryodaya Nagarpalika

Suryodaya Nagarpalika					
Land use Type	**High**	**Medium**	**Low**	**No Risk**	**Grand Total**
Agriculture	333.68	25.79	111.71	15725.63	16196.82
Commercial	0.10	0.00	0.08	4.01	4.18
Cultural and Archeological	0.12	0	0.002	0.69	0.81
Forest	186.20	9.82	49.70	4749.47	4995.19
Riverine and Lake Area	140.14	7.18	44.59	42.47	234.37
Industrial	0.00	0.00	0.00	3.92	3.92
Other	0.29	0.01	0.62	23.11	24.03
Public	4.62	0.35	1.47	398.78	405.23
Residential	3.55	0.36	1.10	569.00	574.01
Grand Total	**668.70**	**43.51**	**209.27**	**21517.08**	**22438.57**

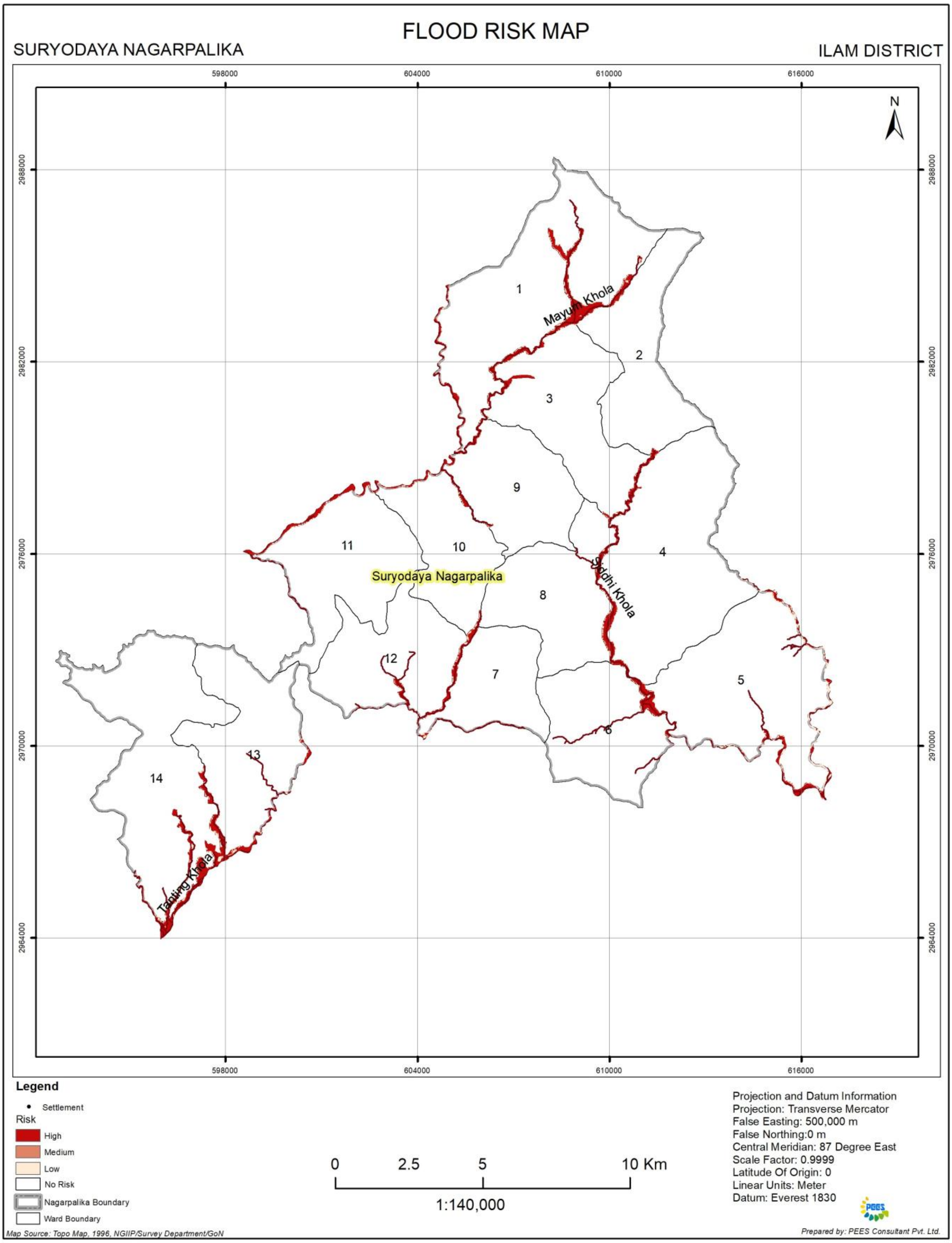
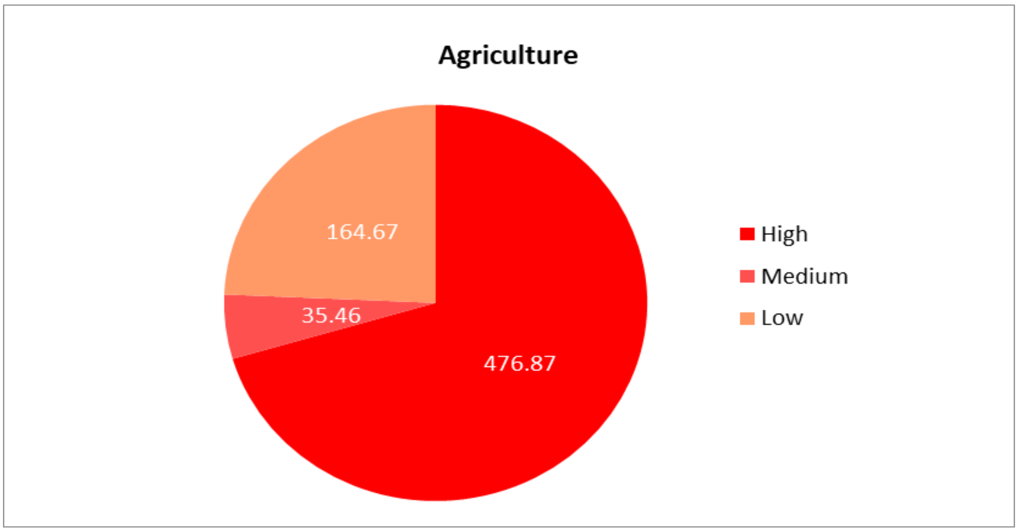


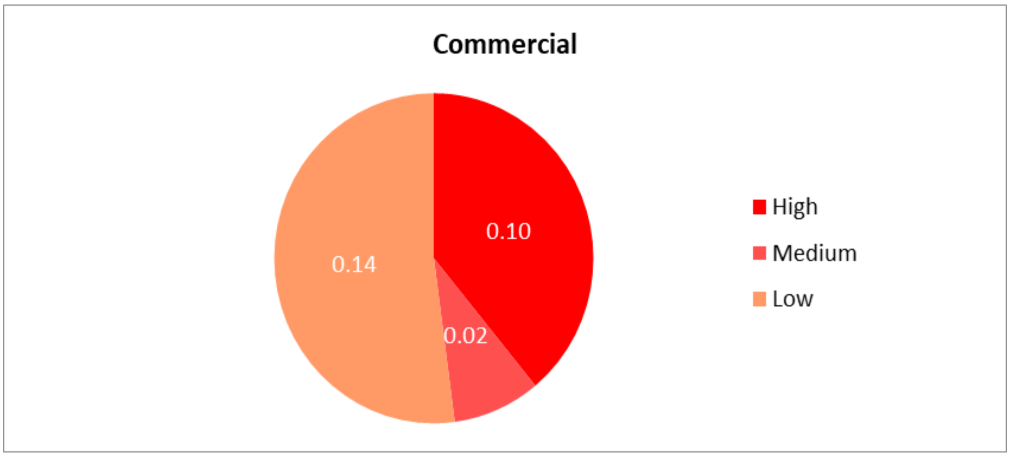
Figure 3.7: Flood Risk Map of Suryodaya Nagarpalika, Ilam

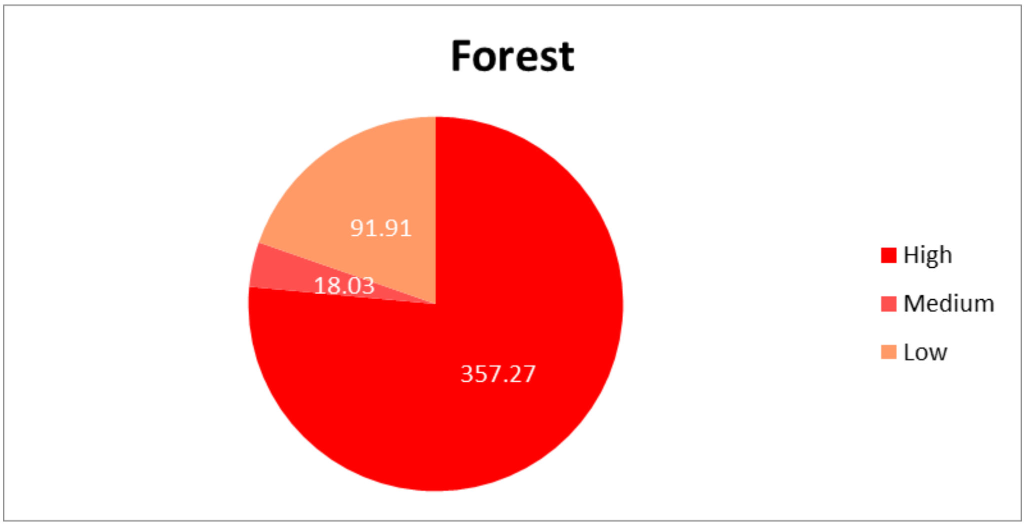
__Flood depth for 100 year return period__

From experience, it shows that there is possibility of occurrence of flood, affecting the nearby areas of the river and streams, because of bank cutting and landsides takes place. This may destroy the agricultural land. It is necessary to make conservation of agricultural land from entering the floods. In addition at present the people of the nearby areas of the rivers are found suffering from water logging problem during the summer rainfall season. From observations it seems that Mechi khola, Sakale khola, Jogmati khola, Mayum Khola, Biring Khola, Siddhi khola, Thule khola, Tanling Khola, Tri 1 and Tri 4 Rivers are the most flood prone river.

According to flood assessment for return period 100 years, It is found that the flood depth is greater than 1.5 m cover, .56 % of residential area, 1.02% of public use area, 1.86% of agriculture area, 1.89% of commercial area, 7.78% of cultural and archeological area, 3.35% of forest area, around 40% of riverine and lake area, around 2% f other area. It shows that major areas are riverine parts where, as per Hindu rituals, many temples are situated. The graphical representation of major lands for the return period 100 years are shown in Figure 3.8.







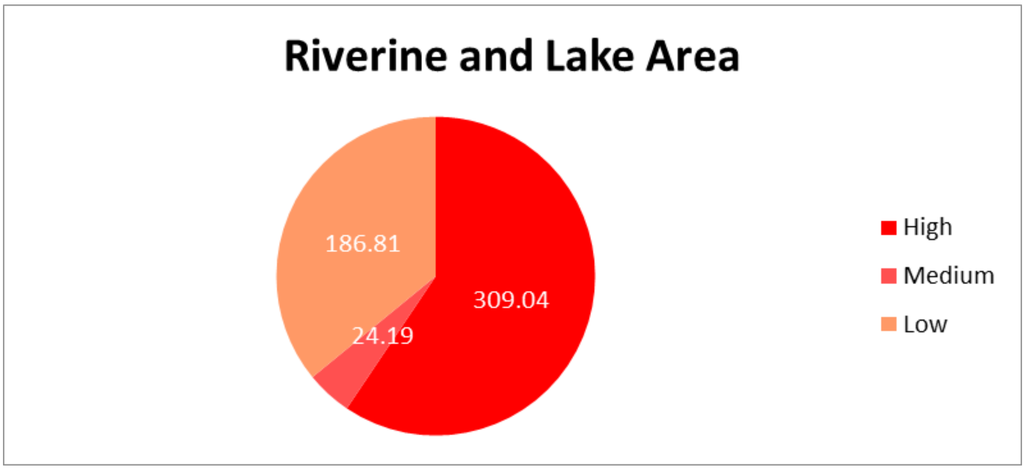


Figure 3.8: Flood Depth for return period 100 years package 04 (Hectares)

3.1.5 Discussion

It is found that the settlements near by the high flood risk areas as shown in Figure 3.7 are more prone to flood. The people in such area are at risk of flood hazard so these people need to be shifted from such flood risk area to the area free of flood. It is also suggested to take immediate action against mitigating flood hazard by undertaking river training or embankment or levee construction along the rivers having flood potential.

Major flood had occurred on 2044, 2042, 2061 and 2072 BS in Jil khola (minor flood problems in ward no. 9 of Suryodaya Nagarpalika); Chhiruwa Khola (minor flood problems in ward no. 6 of Suryodaya Nagarpalika); Mechi river (some flood effects in ward no. 5 of Suryodaya Nagarpalika and eastern part of ward no. 6 of Rong gaunpalika); Goyang Khola and Biring Khola (minor problems of ward no. 1, 2 4, 13 &14 of Rong Gaunpalika). The main problems due to flooding are: River bank cutting and landslides which was verified during the time of field visits. The probability of entering floods of these rivers usually is in the months of June, July, August and September. From interview with the local peoples, it is noticed that many agricultural lands have been converted to river bank due to bank cutting and landslide problems. According to the local people, flooding can be minimized with the construction of Gabion works along the rivers.

3.2 Fire Risk

Land Use and Fire Hazard

The overall impact of land use change on drivers of fire risk is often specific to the location, ecosystem, land use system, and underlying climate of a particular place, and thus it can be difficult to generalize across multiple systems, although some general trends have emerged. Fire risk can drive land use change by creating the need for alternative vegetation management activities, such as type converting flammable fuels and landscape planning. Land use change can in turn impact fire risk by impacting fuel loads and ignitions. Combined, these impacts interact on the landscape and thus inform both future land use change decisions and future fire risk (Figure3.9). Low density housing can lead to increased fuel loads if houses are not designed with flame resistant materials. But if plant vegetation or natural ecosystem nears their homes, there is low chance of firing. Alternatively, small scale fuel treatments associated with increased housing density can decrease fuel loads, although different ownership types may be more or less likely to manage fuels. Increased land use intensity can result in decreased fuel loads, as is the case in dense cities where most buildings are built from non-flammable concrete and steel (Van Butsic, Maggi Kelly and Max A. Moritz; 2015).

Each year Nepal experiences fire hazard in different areas of the country. The fire hazards take place in both built-up areas as well as forests. Fire hazards can take place in many places, however, so far as the ecological regions are concerned the Terai belts experienced it more and vulnerable as well. In the hilly regions, particularly during the dry, stormy season between April and June when temperatures are higher, wooden houses in clustered settlements are vulnerable to fire risk. This fires cause great loss of life and property and can have a devastating impact on local economies. Likewise, the forest fire occurs every year in Nepal, particularly in the forests of Terai and Churia hills.

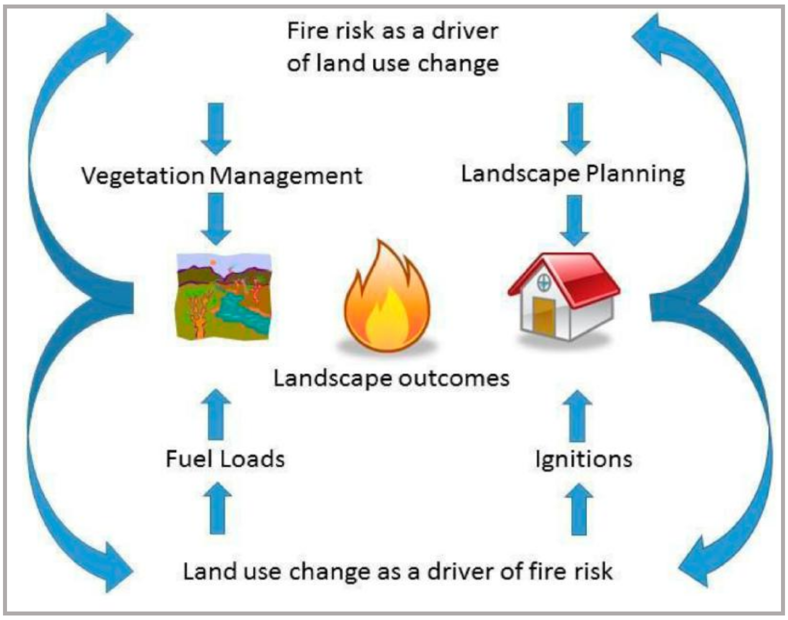


Figure 3.9: Conceptual model of interactions between land use changes and fire risk

(*Source: Van Butsic, Maggi Kelly and Max A. Moritz (2015). Land Use and Wildfire: A Review of Local Interactions and Teleconnections; Department of Environmental Science, Policy and Management. University of California Berkeley, Berkeley, CA 94720, USA).*

3.2.1 Data

The identification of fire risk areas is a difficult process. However, attempts can be made to identify the risk areas based on the past occurrences (hot spots), buffer analysis in ArcGIS, a survey of building materials and observation of building density, and socioeconomic status of the residents, etc. The present analysis has tried to evaluate the fire risk areas by collecting data through buffer analysis in ArcGIS, consultation with local communities as well as field observation.

3.2.2 General Approach and Methodology Framework

General Approach: The general approach for the data collection of fire risk layer is as follows:

i. For Forest:
   - Identification of forest area, forest type and its categorization with current management status
   - Identifying nearby settlement areas, their categorization and adjacency to the forest area,
   - Identification of fire risk with a holistic approach, taking fire risk entities into consideration
   - Identification and delineation of fire risk area.

ii. For settlement areas.
   - Identification and categorization of settlement (clustered, moderately clustered, scattered)
   - Locating nearby industries, petrochemical stations and other factors that relate to fire risk
   - Identification of high-risk settlement areas by identifying entities of fire risk
   - Identification of fire risk with a holistic approach, taking fire risk entities into consideration
   - Identification and delineation of fire risk area.

Methodological Frameworks

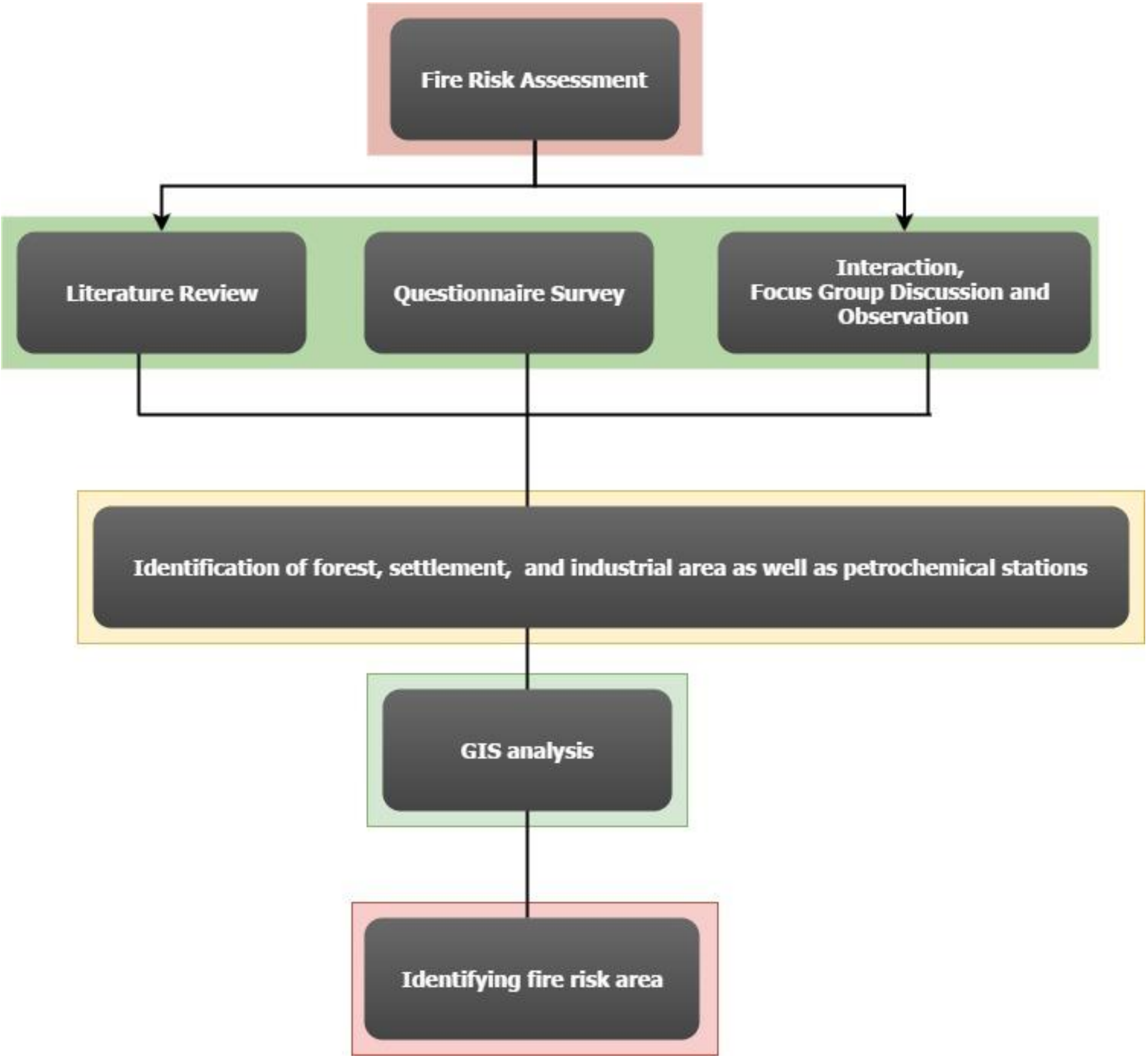


Figure 3.10: Fire Risk Mapping: A Methodological Framework

3.2.3 Methods

The following methods were adopted for the collection

Literature Review

The relevant information was collected from available secondary literature in the form of books, reports, and maps; topographic maps, land use maps, aerial photographs, and cadastral survey maps, etc. information on the coverage of the study areas have been drawn from various web pages.

Field Investigation

A detailed field study was conducted in Nagarpalika by a multidisciplinary team, which comprised of a risk expert, environmentalist, geographer, forestry experts, agricultural scientists, biologist, and sociologists. During the visits, baseline information on forest, settlement, industries and petrochemical stations was taken to incorporate a holistic approach to risk analysis of the Nagarpalika.

Questionnaires Survey and Focus group discussion

The data were gathered through a household survey with questionnaires to obtain information on fire risk of the project area. Extensive consultation with government representatives at various levels, experts and professionals, local communities and industrial stockholders was also undertaken.

Focus group discussions were held at Phikkal, Pashupatinagar, Malim, Laxmipur of the Nagarpalika to interact with local people and stakeholders to collect information on fire risk of the Gaunpalika. Direct observation (walkover survey) was done to collect information on fire risk entities.

GIS analysis

Buffer analysis, a spatial analytical technique for assessing proximity within a certain distance of fire risk areas, was used for the purpose of evaluating fire risk areas of the Nagarpalika. In this method, a buffer is drawn at a pre-defined distance to create the various block groups. These groups are identified that are within or intersect with the area in the buffer, and information about the settlements in these block groups was used to estimate the characteristics of the population inside the buffer and the risks inherent due to the fire hazard.

3.2.4 Result

Apart from the built-up areas, the risk of forest fire is very high during the hot-dry season in hilly areas. Suryodaya Nagarpalika has community-managed forest areas nearby and the risk of a forest fire as well.

In rural parts of Suryodaya Nagarpalika, there have been practices of using fire by farmers for burning crop residue, and for converting forest to agricultural land. Because fire removes the organic matter and provides an ash bed, which facilitates the growth of grasses, local people set fire to gather ash, which is locally used as manure, the activity which is sometimes blamed for fire in settlements.

The Nagarpalika is at a reasonable risk of fire in the settlement area too due to the practice of constructing houses using thatch/straw for roofing (ward number 1 has 92/1848 households; ward numbers 2 and 3 have 25/1980 households; ward number 4 & 5 have 87/2185 households; ward numbers 6-12 have 221/6317 households; ward numbers 13 and 14 have 310/2035 households;) clustered settlement in market areas, unmonitored children’s activities, careless smoking, and negligence in cooking. The risk of fire is mainly likely to outbreak during the windy and the dry season e.g. Chaitra & Baisakh. During the field observation, people reported that occasional fire breakouts had affected the Nagarpalika in the past. It has been found that the Suryodaya Nagarpalika has had three major fire incidents with an estimated loss of property valuing NRs 12500000 in the past. Figure 3.11 shows the forest fire risk map of Suryodaya Nagarpalika.

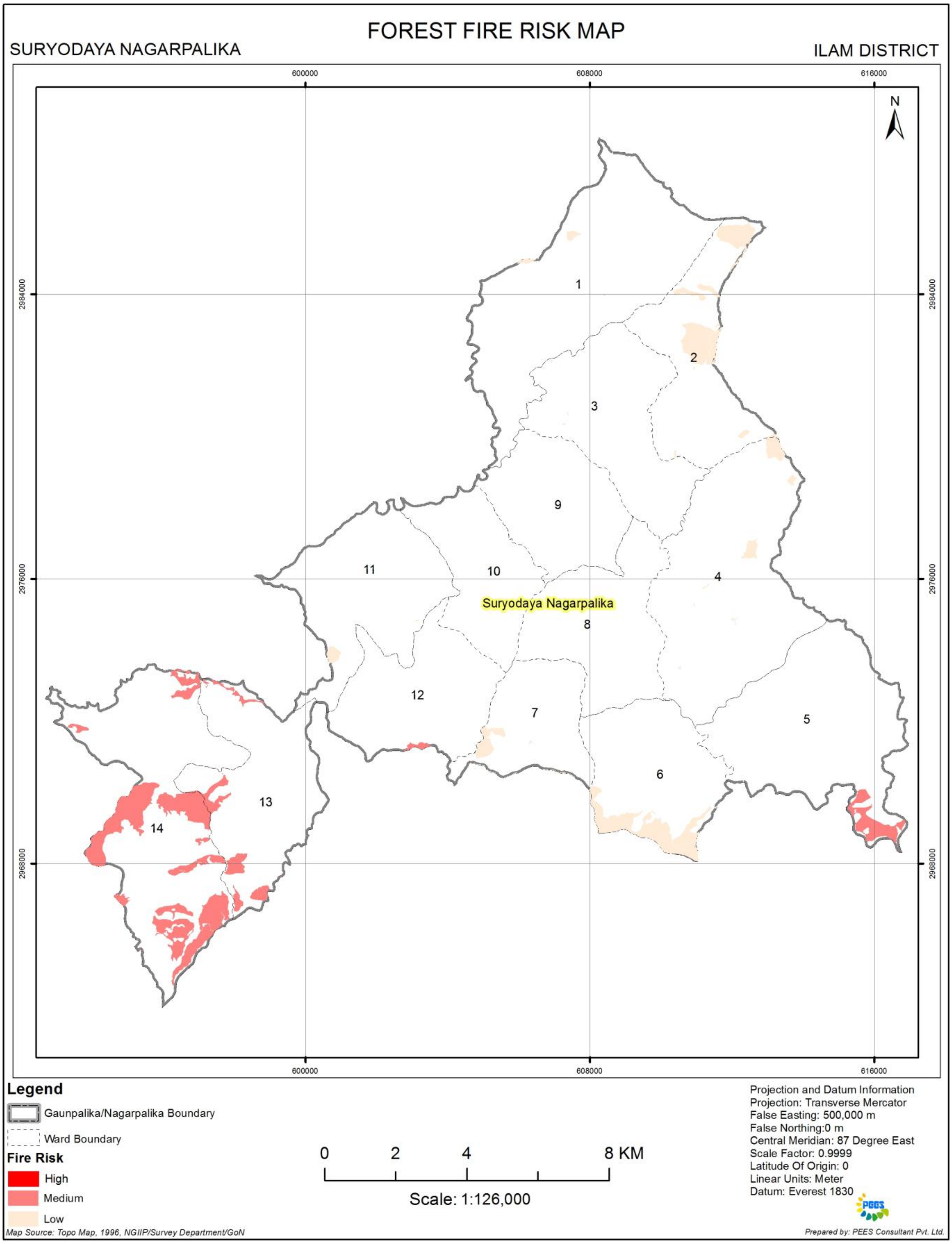


Figure 3.11: Forest Fire Risk Map of Suryodaya Nagarpalika

The lack of equipment and skilled manpower such as trained firefighters poses serious challenges in Suryodaya Nagarpalika. Furthermore, the difficult topography of the hill settlements makes it difficult for the authorities to bring a raging fire under control quickly. The clustered settlements in the market areas and building materials further worsen the risks. Because a significant number of houses in the market areas in Suryodaya Nagarpalika are built in clusters with thatch and timber with no fire protection. Negligent handling also could lead to an outbreak of a major fire. Similarly, haphazard construction of houses without complying construction code and fire safety measure invariably puts such property at great risk.

The marginalized and poor community has inhabited the area. The lack of education, slash and burn cultivation, burning of agricultural residues, the clustered settlement made up of thatch and straw houses, and negligent fire handling practices among the people in these wards of the Nagarpalika potentially contributes to the fire risk in the area.

3.2.5 Discussion

In the study area, the presence of a number of houses with thatch or straw roof; burning of agricultural wastes; unmonitored children's activities, careless smoking, and negligence in cooking could contribute to the risk of fire. The tile/slate buildings are also at risk to fire because of the faulty electrical wiring and equipment, and LPG gas, however, the risk is low compared to houses made of wood and a thatched roof. With the presence of the tea industries and petrochemical stations in the Nagarpalika, the Nagarpalika has fire risk inherent in such businesses.

Petrochemical sources and stations are always at high risks; therefore should be kept far from the settlement area. Similarly, the areas resided by poor people are always in the high risk of fire. Therefore, fire preparedness activities should be carried out in marginalized communities, which include communication of messages through television, radio, folk songs, drills, posters, pamphlets, and hoarding boards, etc.

To tackle the fire risk, the government should allocate sufficient budget and other necessary assistance to Suryodaya Nagarpalika. Such assistance may include buying modern fire engines and training firefighters. With the rapid urbanization in Suryodaya Nagarpalika, property constructed face high risks of fires, especially during the dry, humid seasons. Awareness about fire safety should also be disseminated to the locals in clustered settlements while enforcing the house construction code strictly.

The study finds a need to discourage the practice of burning agricultural residue and encourage mass awareness to people about careful handling of the fire to reduce the risk of fire in the settlement area.

3.3 Land Slide Risk

Landslides are a form of erosion and are an important process in the shaping and reshaping landscapes and landforms. Landslides re-distribute soil and sediments in a process which can be extremely rapid or very slow. Landslide hazard, defined as the annual probability of occurrence of a potentially destructive landslide event. Landslide hazard is frequent phenomenon is Nepal due to several reasons including tectonic activities, uncontrolled and unsafe development, heavy precipitation and environmental degradation. However it is observed that rainfall induced landslides is most prevalent in the hills and mountainous districts. In view of rapid development in hills and mountains in the country, it has become imperative to review, identify and analyze landslide prone areas and their causative factors. In Nepal, high susceptibility zone of landslide are identified in the areas of high intensity rainfall and earthquake hazard. Earthquake induced hazard are distributed in centre (hill) zone of Nepal, which is largely dependent on Pick Ground Acceleration (PGA) values. For example, in Palpa more than 20% of geographical areas are prone to high landslides triggered by high intensity rainfall and earthquake whereas in Kaski one third of the areas will be in high landslide susceptible zone as per 500 years earthquake return period assessment.

Landslide susceptibility refers to the classification, area spatial distribution of potential landslide occurrence area. Landslide susceptibility zoning refers to the division of land into homogeneous area or domain and their ranking according to degree of potential landslide susceptibility, hazard or risk. Landslide inventory, susceptibility and hazard zoning for local areas for preliminary level risk zoning and the advance stages of planning for larger engineering structures are carried out at 5000 to 2500 scale covering are from 10 to 1000 square km (Fell et. al., 2005).

3.3.1 Data

Landslides are the result of triggering natural factors mainly extreme precipitation, rainfall intensity and seismicity and susceptibility factors dominantly, slope, lithology, soil moisture and land cover and land use. Peak of monsoon usually correlate with high landslide events in Nepal due to high precipitation. Data on the importance of earthquake triggered vs. precipitation triggered in terms of fatalities may not be easily available. However, it is known that in some cases, a significant share of the earthquake fatalities are killed by earthquake triggered landslides. All relevant spatial data at available geographical coverage and format are collected, compiled and processed in GIS platform for the analysis purpose.

Data collected for land use resource mapping and topographical, soil and geology data are used for landslide susceptibility analysis. Data and source of data are detailed below:

- Land cover land use (present land use, Satellite image Worldview-2, 2018)
- Elevation and Slope (from DEM, Satellite image Worldview-2, 2018)
- River network: Drainage density (Present land use, Satellite image Worldview-2, 2018 & Topographical sheets, 1995-97)
- Geology: Fault and lineament, Lithology and Rock type (DoMG, 2009)
- Soil (Land system, SOTER 2009), and
- Rainfall/ precipitation zone (DHM, 2007-2017).

3.3.2 General Approach and Methodology Framework

Landslide susceptibility assessments are based on different methods. Some common landslide susceptibility mapping methods are: Geomorphologic mapping, inventories, Statistical modeling, index based Heuristic analysis and Process based mapping and analysis. The current landslide susceptibility is based on process based mapping. The overall methodology applied is presented in Figure 3.12 and the approach followed for landslide mapping includes:

- Inventory of existing landslides from satellite image
- Verification of landslides in the field
- Mapping areas susceptible to landslide based on integration of scientific methodology and field landslide data characteristics.

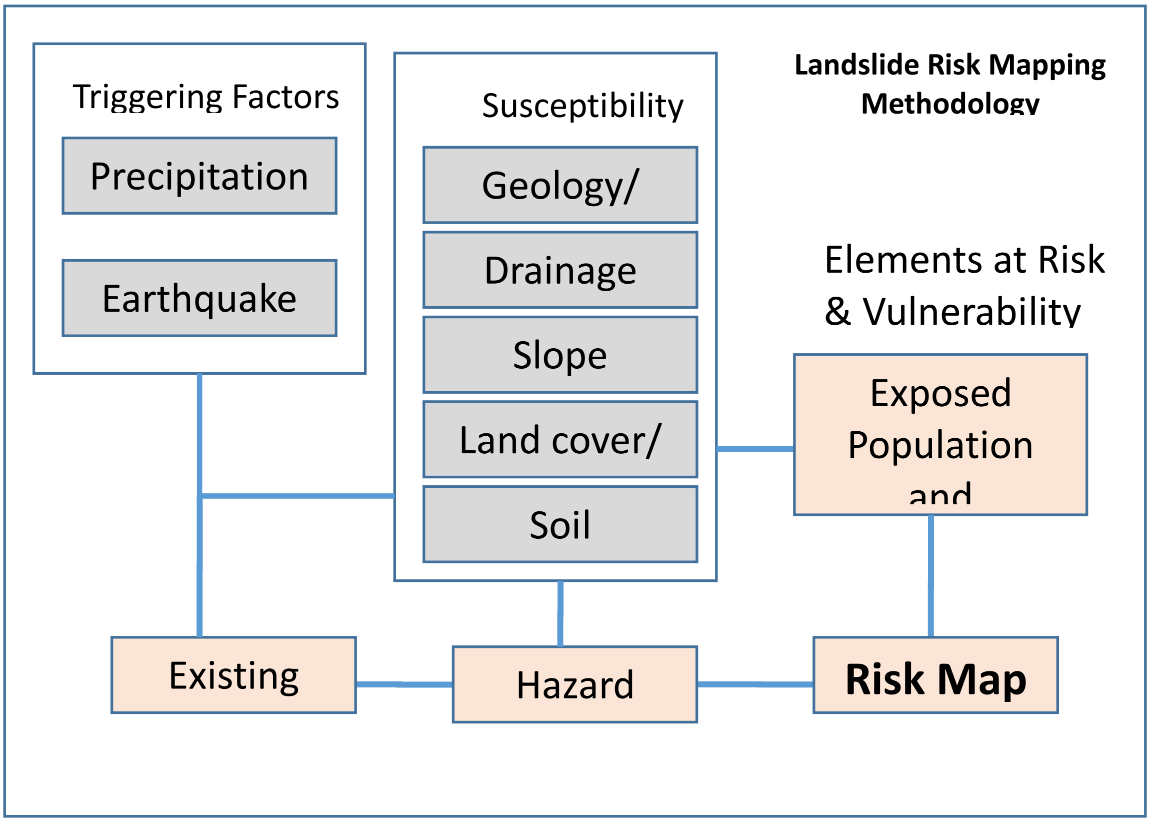


Figure 3.12: Landslide risk mapping methodology

3.3.3 Methods

Landslide susceptibility zoning with existing landslide data integration provides quantitative measure on landslide distribution with the assumption of continuous landslide density in space. Landslide susceptibility zoning usually involves developing an inventory of landslides which have occurred in the past together with an assessment of the areas with a potential to experience land sliding in the future, but with no assessment of the frequency (annual probability) of the occurrence of landslides (AGS, 2007).

Landslide susceptibility zoning is carried out in a GIS-based system with multi criteria analysis, MCA using number of spatial data layers so that the zoning can be readily be applied for land use planning and can be up-dated as more information becomes available. Standard processing and conversion methods are adopted in this analysis to minimize data error and methodology is devised accordingly. Landslide susceptibility mapping was carried out based on Nepal hazard assessment methodology(MoHA, 2011) and weights are assigned as specified in landslide hazard zonation mapping in mountainous terrain guideline (Bureau of Indian standards, 1998) combining triggering factors (mainly extreme precipitation and seismicity) and susceptibility factors (slope, lithology, and soil moisture). The following formula was used for weighted spatial analysis using MCA:

Landslide Susceptibility Ranking (LSR),

LSR= Σ (Pc_{rn} +Eq_{rn}) + (Ge_{rn} + Dd_{rn} + Lu_{rn} +Slp_{rn} +$So_{rn)}$..….......**(Equation 1)**

where, rn = Rank, of *Pc*= Precipitation, Eq = Fault and Lineaments, Ge = Geology, Dd = Drainage density, Lu = Land use/Land cover, *Slp*=Slope and So = Soil texture

Based on landslide inventory, geology, topography and geomorphology, soil and land cover/ land use, and using equation 1, weighted value are calculated. Rank 1 to 3 are assigned for each triggering factor and high to low susceptibility rank were summed and final rank grouped as high medium and low through Jenk's natural break method. Higher the rank (i.e. value 1) higher the landslide susceptibility (High) and vice-versa.

3.3.4 Result

The landslide mapping of package 04 is carried out using susceptibility methodology outlined under methodology by using overlay analysis in GIS environment. As more than 56 percent of the project area have slope greater than 20 degree and lies in higher rainfall zone, landslide susceptibility is found in more than 33 percent area. Table 3.3 details the area under different landslide susceptibility zones and Figure 3.13 shows the distribution of landslide susceptible area in the project area. Among total landslide susceptible area, 5 percent area is under high susceptibility zone covering more than 400 hectare while 58 percent area has medium susceptibility of landslide occurrence. The south western and northern part of the project area is highly vulnerable to landslide susceptibility whereas middle part has relatively lower susceptibility. Forest area is relatively lower with only 12 percent coverage while more than 56 percent of the area is above 20 degree slope indicating vulnerability to landslides. Settlement and road infrastructure distribution is dispersed to all over the project area and hence landslide vulnerability of settlement and infrastructure is also variable.

Table 3.3: Landslide Susceptible Area of Suryodaya Nagarpalika

Sn.	Susceptibility	Area Ha	Percent
1	High	404.65	5.32
2	Medium	4426.76	58.14
3	Low	2781.92	36.54
	Total	**7613.331**	**100.00**

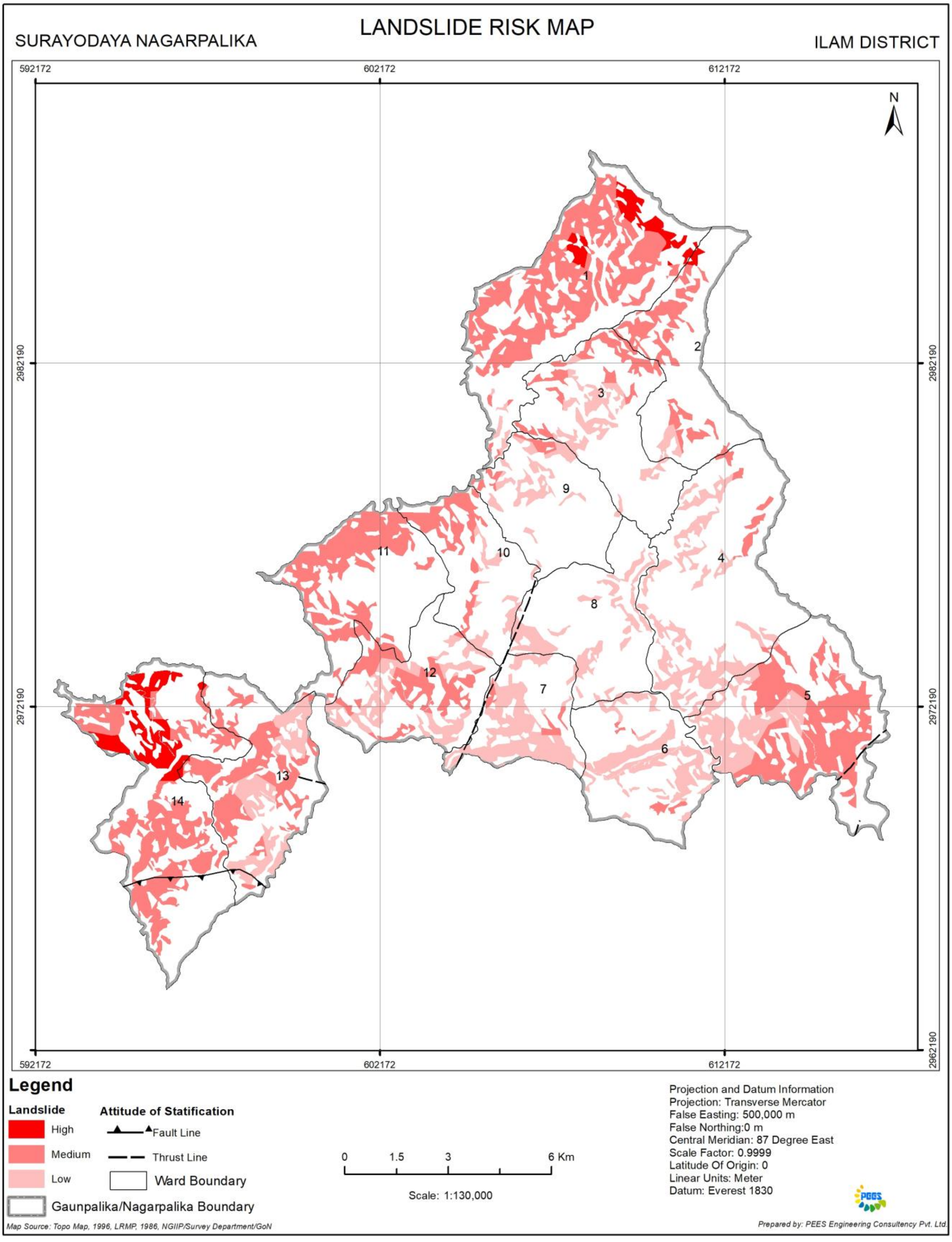


Figure 3.13: Landslide Susceptible Map of Suryodaya Nagarpalika

3.3.5 Discussion

Landslide susceptibility zoning is based on assumption of continuous landslide density in space. Hence while land use planning and zoning, factors which minimizes landslide risks could be excluded such as in plain area and forest cover in relatively lower slopes of 15 to 20 degree. Similarly in identified landslide susceptible area of varying degree, potential landslides may be of varying likelihood of occurrence based on management practices and protection measures in the area. South-western and northern part of the project area are most vulnerable to landslides because of weak geology, hence proper management strategies and protection measures should be implemented for agriculture practices, settlement and infrastructure development.

The assessment of landslide susceptibility based on Multi criteria analysis in GIS environment indicate that there is a close relationship between slope, land cover land use and geology and landslide susceptibility. Beside, infrastructure construction mostly road construction in higher slope area with weak geology is another major factor along roadside landslide occurrence. A study by DWIDP in 2003 also reported that transport infrastructure in Nepal is heavily affected by landslide incidences every year. A field survey conducted in 2003 in arterial routes of Nepal, it was found that small- to medium-scale roadside landslides very often occur as partial landslips within existing large-scale landslides in the area. Therefore, considering greater and effective serviceability of existing transport infrastructure, better planning of newer transportation routes, and safe land-use planning, it is very important to understand the distribution pattern of large-scale landslides so as to mitigate the risk of future infrastructure damage and economic losses.

Landslide record reveals that road and human settlement slopes are more vulnerable to landslides than ordinary natural slopes. This suggests that there is significant influence of human intervention, particularly in terms of road slope cutting, land development, agricultural practices, etc., on the occurrence of landslides and related failures in Nepal (Bhandary et. al., 2012).

Nepal hazard risk assessment report 2011 states Slope, lithology, soil moisture, and precipitation are controlling factors for landslide hazard, while earthquake and rainfall are triggering factors. The report also highlights the paucity of data on the importance of earthquake triggered vs. precipitation triggered in terms of fatalities may not be easily available. High severity zone areas are relatively governed by specific lithology condition and slope degree. Based on analysis, more than 20 % of geographical areas are prone to high landslides triggered by high intensity rainfall. Landslides typically occur in hilly areas and primarily affects the road sector. At the national scale, the damage caused by landslides is negligible in comparison to that caused by earthquakes, floods and droughts. These three disasters (earthquakes, floods and droughts) impact large geographical areas, covering almost all parts of the topography of Nepal.

An approach is required to integrate hazard maps developed by different organizations at suitable scale and used for disaster resilient development. The hazard risk map of particular area should be revised from time to time after major, extreme precipitation, and earthquake and major development infrastructure which may have affected.

3.4 Seismic Risk

Nepal lies within the seismic hazards zones of the world. The Himalaya seismicity, in general, owes its origin to the continued northward movement of Indian plate after the continental collision between Indian plate and Eurasian Plate. The magnitude, recurrence and the mechanism of continental collision depend upon the geometry and plate velocity of Indian plate in relation to southern Tibet (Eurasian Plate). Recent result suggests that the convergence rate is about 20 mm/ year and the Indian plate is sub-horizontal below the sun-Himalaya and the Lesser Himalaya.

3.4.1 Data

The analyzed data has been taken from the secondary sources. The data has been produced by a maps of epicenter of the Earthquake in Nepal Himalaya, Probabilistic seismic hazard assessment map of the Nepal Himalaya (Figure 3.14, Pandey et al. 2002), and seismic zonation of map the Nepal Himalaya (Figure 3.15, National Society for Earthquake Technology-Nepal (NSET) (Figure 3.16).

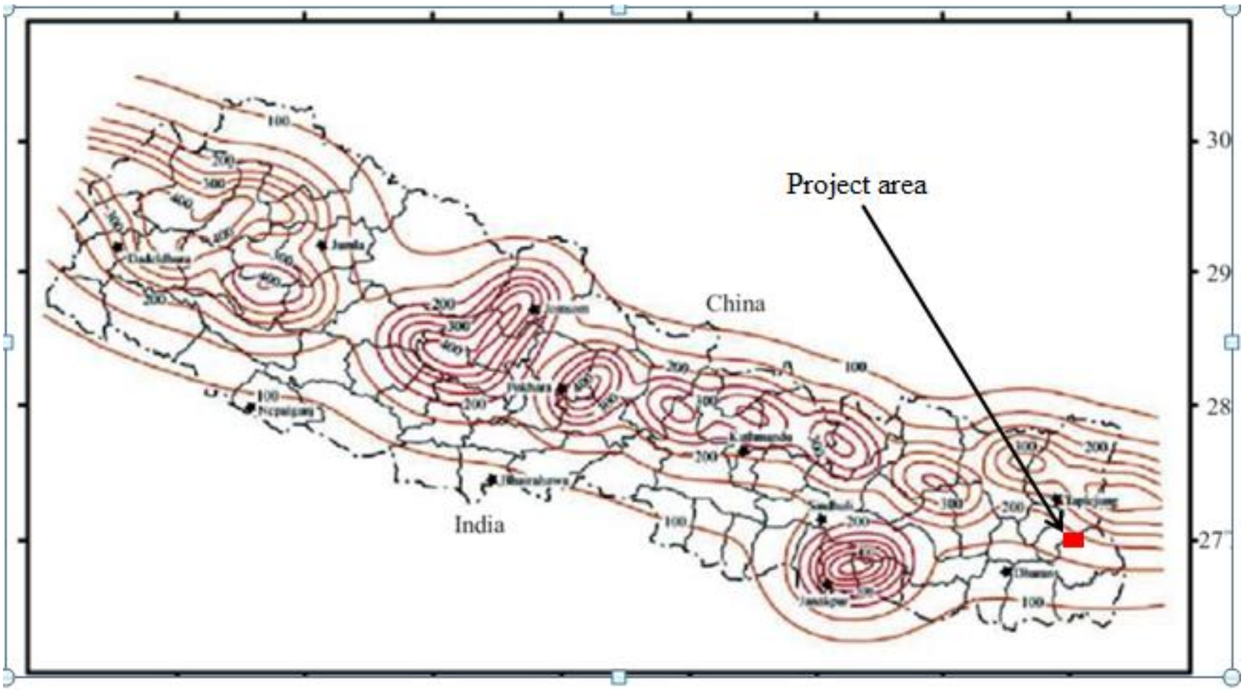


Figure 3.14: Seismic-hazard map of Nepal, (Pandey et al.2002)

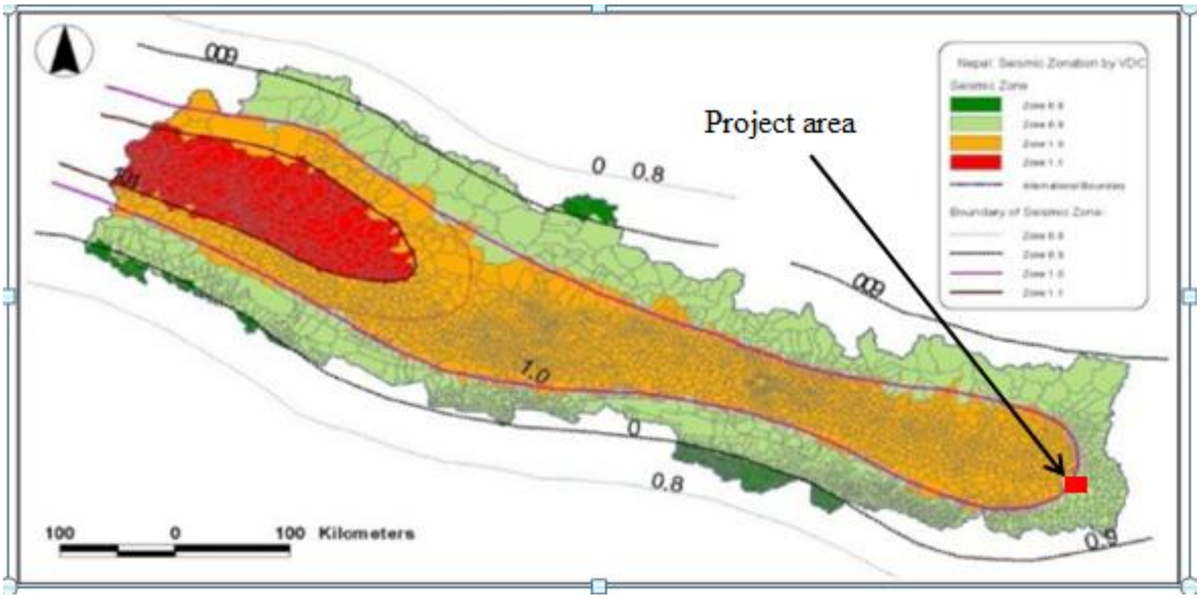


Figure 3.15: Seismic zoning map of Nepal with the lowest governance unit in different seismic zones

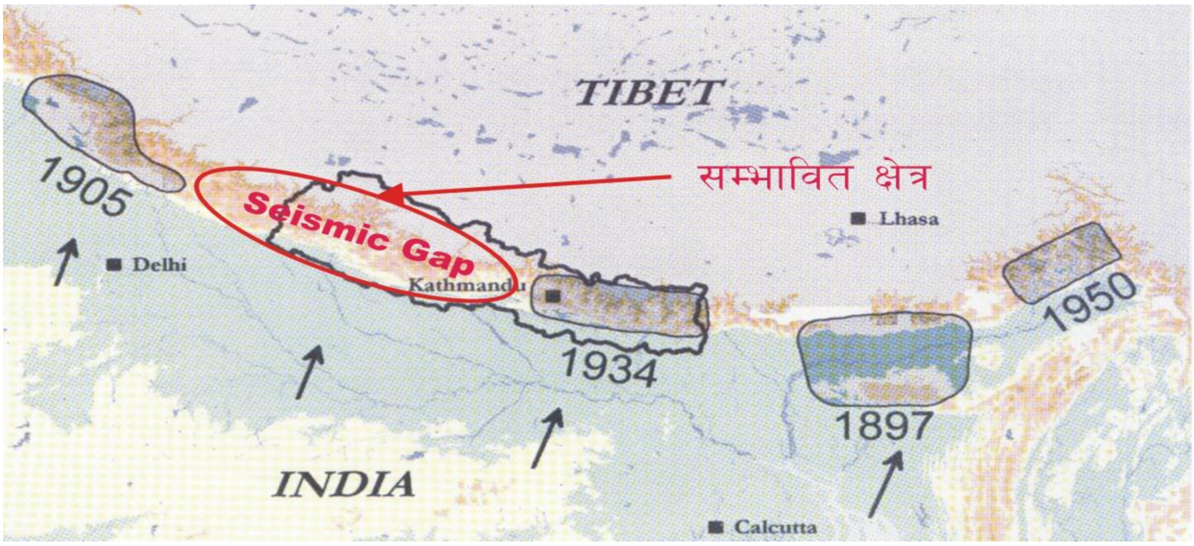


Figure 3.16: Map shows that the present area lies in the seismic gap of the region.

3.4.2 General Approach and Methodology Framework

The seismicity deals with the preliminary investigation of maximum credible earthquake and seismic coefficient of the project area. The result of micro seismic investigation, geodetic monitoring and morpho-tectonic study of the central Nepal has depicted that the more frequent medium sized earthquakes of 6 to 7 magnitudes are confined either to flat decollment beneath the lesser Himalaya or the Upper part of the Middle crustal ramp. The ramp is occurring at about 15 km depth below the foothills of the Higher Himalaya in the South of MCT surface exposures. Beg events of magnitude greater than eight are nucleated near the ramp flat transition and rupture the whole ramp-flat system up to the blind thrust (MBT) of the Sub- Himalaya (Pandey et al. 1995)

Preliminary seismic hazard assessment of the country using Gamble's third asymptotic extremes with the instrumental seismicity database of ISC is carried out by Bajracharya

(1994) for different return periods 50, 100, 200, and 300 years, Attenuation model with mean value of McGuire and Oliveira is used for Horizontal acceleration.

Return period (years)	Peak horizontal acceleration (g)
50	0.10
100	0.15
200	0.20
300	0.25

Several seismicity studies have been carried out for the various projects in the country during the engineering design phase and seismic design coefficient have been derived for the project. There are several methods to convert the maximum acceleration of the earthquake motion into the design seismic coefficient. Generally three methods are commonly used to establish the seismic coefficient. These are:

i. Simplest method
ii. Empirical Method
iii. Dynamic analysis method using dynamic model

The effective design seismic coefficient is determined by using the simplest method, the following equation:

$A_{eff} = R^{*} A_{max}/980$

Where A_{eff} is effective design seismic coefficient

R= Reduction factor (empirical value R=0.50-0.65)

The result obtained from this method is found to be similar in the recent studies carried out by using the dynamic analysis and the static analysis. Therefore, this method is considered to be the most common method to establish the design seismic coefficient at present.

The third method is the dynamic analysis method using the dynamic model. This method is considered to be the most reasonable method at present. However, to apply this method parameters like the design input motion, the soil structure model, the properties of the rock materials have to be known, and therefore, it means that a detailed study is required to use this method. Therefore, the empirical method is considered to be the best to establish the design seismic coefficient for this level of the study.

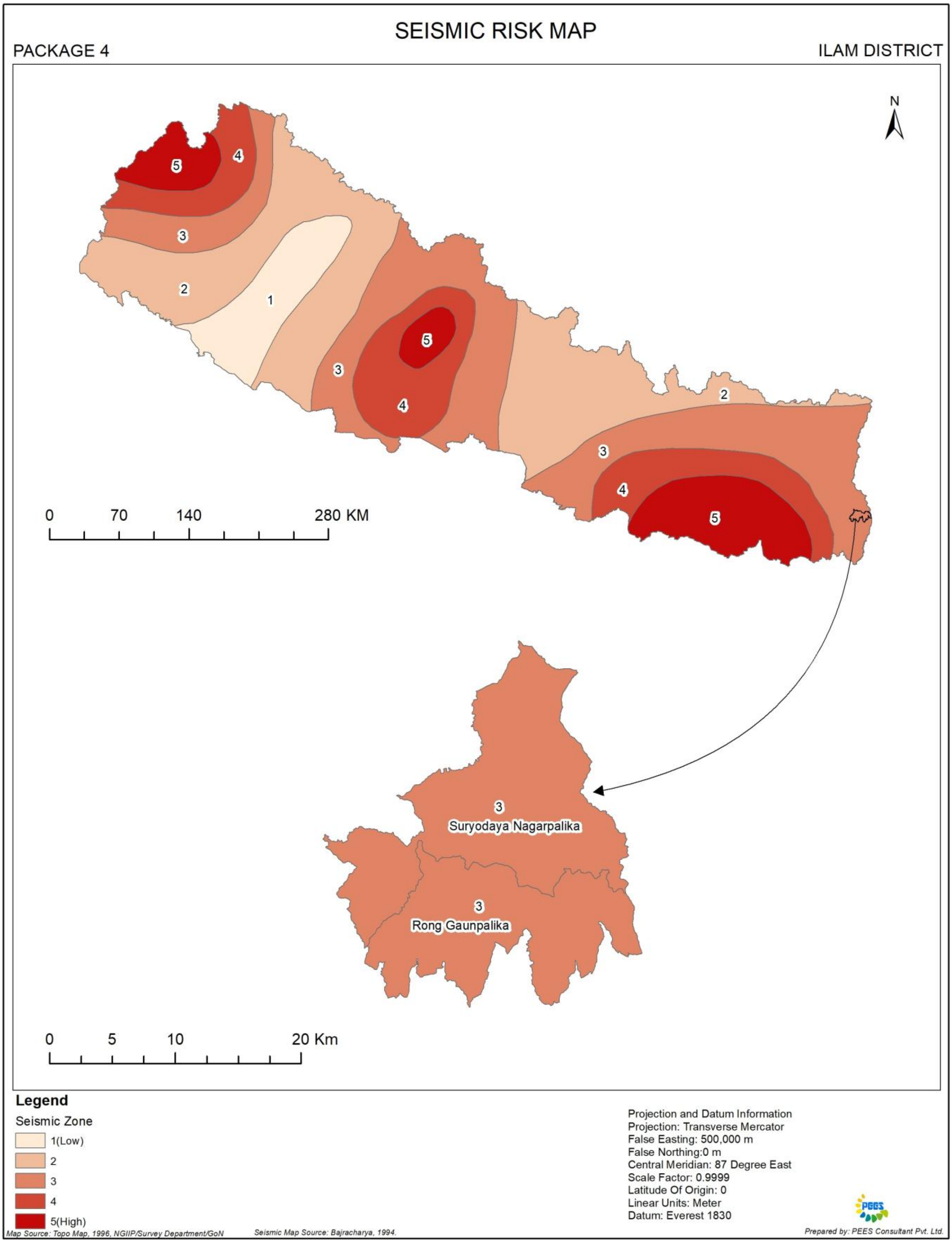


Figure 3.17: Seismic Risk map of Nepal showing the project area (Bajracharya 1994)

3.4.3 Method

The effective design seismic coefficient is determined by using the simplest method, the following equation:

$A_{eff} = R^{*}A_{max}/980$

Where A_{eff} is effective design seismic coefficient

R= Reduction factor (empirical value R=0.50-0.65)

Maximum acceleration A_{max}= 200 gal according to seismic hazard map of Nepal

The result obtained from this method is found to be similar in the recent studies carried out by using the dynamic analysis and the static analysis. Therefore, this method is considered to be the most common method to establish the design seismic coefficient at present.

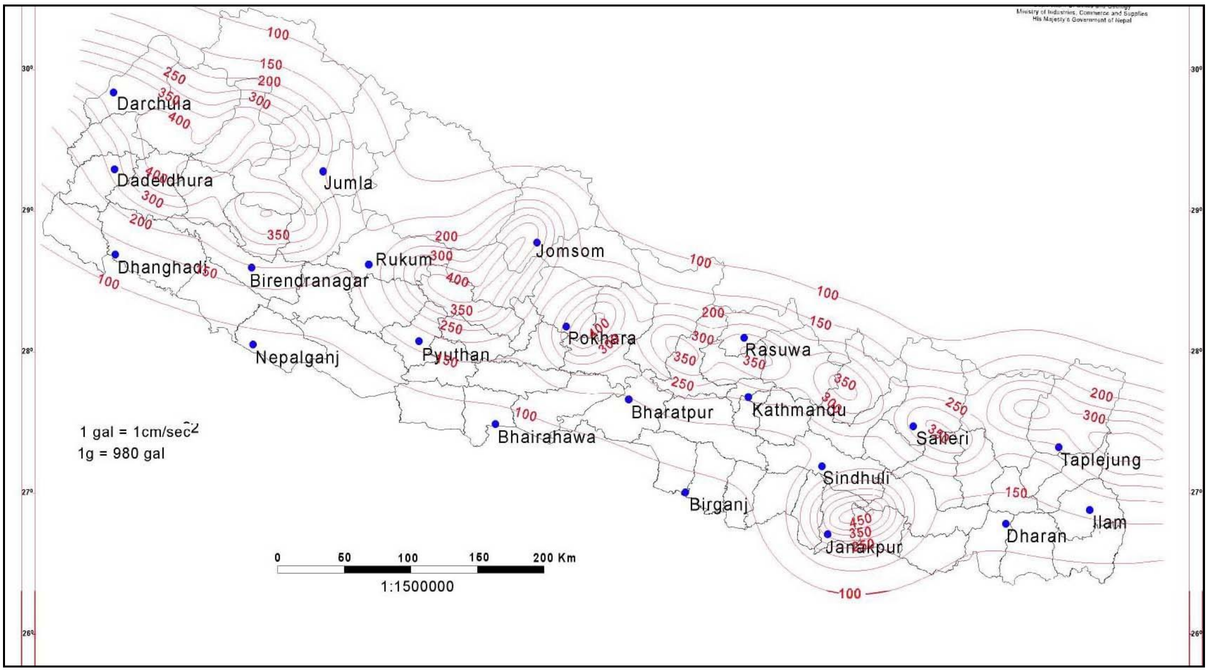


Figure 3.18: Probabilistic Seismic Hazard Assessment Map of the Nepal Himalaya

3.4.4 Results

The result obtained from this method is found to be similar in the recent studies carried out by using the dynamic analysis and the static analysis. Therefore, this method is considered to be the most common method to establish the design seismic coefficient at present. The calculated effective design coefficient of Suryodaya Nagarpalika area is considered as 0.117.

3.4.5 Discussion

The Suryodaya Nagarpalika lies in the eastern part of Nepal which is comparatively less vulnerable in terms of seismic activities in comparison to other parts of Nepal. However, the project area is bounded by the MCT forming the tectonic window certainly have threats of seismic activities in future. This shows that a due consideration is required before planning the large scale projects like hydropower development, tunnel construction, reservoir development, highway construction, large irrigation projects and landslide mitigation techniques. That’s why geotechnical considerations are the must before starting any kind of development activities in the area.

3.5 Industrial Risk

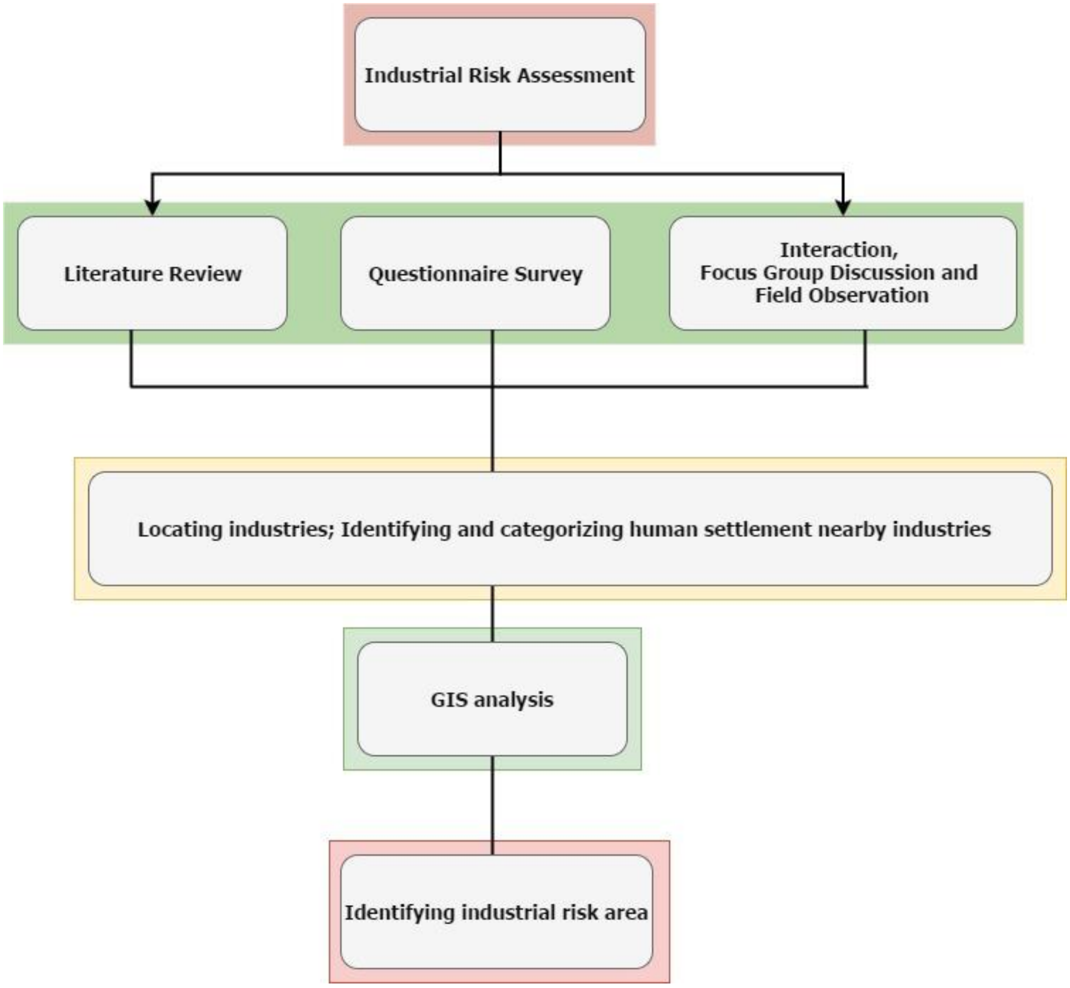
3.5.1 Data

Attempts have been made to identify the risk areas based on the location of industries, human settlements, buffer analysis in ArcGIS, survey of building materials and observation of building density, and socioeconomic status of the residents, etc. The present study has identified the industrial risk areas by collecting data through literature review, GIS analysis, consultation with local communities and field observation.

3.5.2 General Approach and Methodology Framework

General Approach: The general approaches for the industrial risk layer data collection are as follows:

- Location of industries nearby the human settlements and river bodies that may relate to industrial risk
- Identification and categorization of settlement patterns such as clustered, moderately clustered, and scattered
- Identification of high-risk settlement areas by identifying entities of industrial risk
- Identification of industrial risk with a holistic approach, taking various risk entities into consideration
- Identification and delineation of the industrial risk area



3.5.3 Methods

The following methods were adopted for the gathering of data and information related to industrial risk:

Literature Review

The relevant information was collected from available literature in the form of books, reports, and maps of topography, land use, cadastral survey, and aerial photographs. Further information was also acquired from various websites.

Field Investigation

A detailed field study was conducted in the Nagarpalika by a multidisciplinary team, which comprised risk expert, environmentalist, geographer, forestry expert, agriculturalist, biologist, and socio-economist. During the visits, information on the basic components of human settlements, industries, forest, petrochemical stations, etc was collected that has been used to establish baseline data and used for the industrial analysis of the Nagarpalika.

Questionnaires Survey and Informal discussion

The data on the industrial risk of the project Nagarpalika were gathered through household surveys with questionnaires. Extensive consultation with government representatives at various levels, experts and professionals, local communities and industrial stakeholders was also carried out.

Informal discussions were held in the Nagarpalika to interact with its local people and industrial stakeholders to collect information on the industrial risk of the Nagarpalika. Direct observation (walkover survey) was carried out to gather information about industrial risk entities.

GIS analysis

The GIS functions including the buffer analysis and spatial analytical technique for assessing proximity (within a certain distance) of industrial areas from the location of human settlements were used for the purpose of evaluating industrial risk areas of the Nagarpalika. In this method, a buffer zone has been defined at a pre-defined distance to create the various block groups. These buffer zones were used to describe the characteristics of the population inside each zone and the risks inherent due to the industrial location.

3.5.4 Result

There are few industries in Suryodaya Nagarpalika mostly related to tea processing. According to the latest available industrial statistics report (2072/2073) published by Ministry of Industry, there is one major tea processing industry named Phikkal Tea and Coffee Private Limited in Suryodaya Nagarpalika with a production capacity of 75 metric tons of CCT Tea, 275 metric tons of Orthodox Tea, and 20 metric tons of Coffee employing 60 workers. Except for this large-scale industry in the Nagarpalika, other industries have medium production capacity and use coal and wood as fuels to operate. They operate about 8 hours a day, generating a smoke thereby affecting the surrounding environment and settlements. The Nagarpalika has a solid waste problem, as the current solid waste disposal practice is to dump the waste into random lands. With growing number of population and the Nagarpalika inability to tackle the garbage management issue, there has been an increase in the production of garbage and other solid waste.

3.5.5 Discussion

Although the pollution caused by the industries in the Nagarpalika creates a nuisance to the residents who feel uncomfortable, risks from the industries are moderately negative in nature, for the long-term duration and low in magnitude as the majority of industries are agro-based. The agro-based industries generate effluents and solid wastes that need to be disposed of in an environmentally acceptable manner. In concurrence with the regulatory requirements, the industries need to adopt a sustainable approach to the waste management. The effluents generated by agro-based industries are biodegradable and non-toxic and treated by physical, chemical and biological processes. With the application of appropriate technologies, it is possible to minimize the pollution and also to recover the water and other useful materials from the waste streams.

Therefore, there is a medium risk of air pollution and water contamination from wastewater generated by those industries as the industrial discharges end up in surface water causing a risk on flora and fauna, as well as on human beings, who use the river water.

The best way to reduce the industrial risk would be a land use planning and zoning. Industries need to abide by the environmental rules and regulations and other statutory provisions of the Government of Nepal. The discharges from the industries need to meet the requirements of quality standards as set up by the Government of Nepal. To assure the public and concerned stakeholders about the minimization of industrial risk, the Government of Nepal needs to initiate an effective monitoring system and its thorough implementation.

CHAPTER 4: RISK IN THE STUDY AREA

4.1 Existing Risk in the Study Area

Flooding and Landslide are main risk observed in the Suryodaya Nagarpalika (package-04), Ilam district. Area under Suryodaya Nagarpalika falls in the Mid-hills and Siwalik zone that is characterized by of unconsolidated sediments of the Siwalik and the hills. Floods are not frequent in the Nagarpalika; however, there is a chance of entering flood in the area along the Tangting khola, Khani khola, Antu khola, Siddhi khola, Mayum khola (Figure 4.1). The main problems due to flooding are: River bank cutting, degradation of agricultural lands etc. There were some floods: on 2044, 2042, 2061, 2068 and 2072 BS in Jil khola (minor flood problems in ward no. 9 of Suryodaya Nagarpalika); Chhiruwa Khola (minor flood problems in ward no. 6 of Suryodaya Nagarpalika); Mechi river (some flood effects in ward no. 5 of Suryodaya Nagarpalika and eastern part of ward no. 6 of Rong gaunpalika); Goyang Khola and Biring Khola (minor problems of ward no. 1, 2 4, 13 &14 of Rong Gaunpalika). In 2068 floods in Shiddhi Khola, 14 people lost their life due to landslides in Rong Gaunpalika, ward no. 9. The main problems due to flooding are: River bank cutting and landslides which was verified during the time of field visits.

More than 56 percent of the project area have slope greater than 20 degree and lies in higher rainfall zone, landslide susceptibility is found in more than 33 percent area. Among total landslide susceptible area, 5 percent area is under high susceptibility zone covering more than 400 hectare while 58 percent area has medium susceptibility of landslide occurrence. The south western and northern part of the project area is highly vulnerable to landslide susceptibility whereas middle part has relatively lower susceptibility. Forest area is relatively lower with only 12 percent coverage while more than 56 percent of the area is above 20 degree slope indicating vulnerability to landslides. Settlement and road infrastructure distribution is dispersed to all over the project area and hence landslide vulnerability of settlement and infrastructure is also variable.

As per them, many agricultural lands have been converted to river bank due to bank cutting, which was verified during the time of field visits.

Apart from the built-up areas, the risk of **forest fire** is very high during the hot-dry season in hilly areas particularly at the Siwalik region. However, Suryodaya Nagarpalika has mostly community-managed forest; therefore, risk of a forest fire could be low.

The area under package 4 does not have any large-scale industries. Most of the industries in the Nagarpalika are agro-based, tea processing; therefore, their impacts on human seems low.

Besides above, there are other natural and anthropogenic factors that produce risk and/or hazard. Drought, hailstone and wind, agricultural diseases and pest are other risks in the study area but their extent and intensity is relatively low.

4.2 Potential Risk in the Study Area

Flood and landslide are most occurring and potential risks in the study area. South-west, south-eastern and north-eastern parts of the Nagarpalika are basically prone to landslide, these areas are also affected by flooding and river bank erosion as well. Both flood and landslide hazard may affect to the river bank area and erodes the banks, therefore, it may affect to the settlements as well as cultivated land and infrastructure particularly during the monsoon period. Many landslide and flood hazard can be seen along the Tangting khola, Khani khola, Siddhi khola, Gorkhe and Mayum khola. In terms of seismic hazards, according to Bajracharya (1994), the Nagarpalika area falls in the seismic medium hazard zone (seismic zone 3) of the Nepal Himalaya. Agriculture diseases and pest, heat wave, hailstone, frost etc. are also potential risk in the study area but their extent and magnitude is relatively low and in the local level.

4.3 Risk Data Model

The risk developed for Risk data is shown in Table 4.1.

Table 4.1: Risk Data Model

Field	Data Type	Description	Remarks
OBJECT ID	Object	Feature	
SHAPE	Polygon Geometry	Geometric Object type	
RISK ID	Short	Unique Object ID	
RISK Type	Text	1. Flood Risk	
		2. Fire Risk	
		3. Landslide Risk	
		4. Seismic Risk	
		5. Industrial Risk	
RISK LEVEL	Text	High	
		Medium	
		Low	
NAGARPALIKA	Text	Nagarpalika Name	
DISTRICT	Text	District Name	
REMARKS	Text	Any remarks regarding the feature	
SHAPE LENGTH	Double	Meter	
SHAPE AREA	Double	Area in m^2	

4.4 Risk GIS Database

The attribute of risk in the feature database is shown in 4.2. With this geo-database, the risk maps were generated.

Table 4.2: Risk GIS Database

S.N.	Description	Level 1	Level 2	Nagarpalika	District	Remarks
1	Fire	Fire	High Medium Low	Name of Nagarpalika	Name of District	
2	Flood	Flood	High Medium Low	Name of Nagarpalika	Name of District	
3	Landslide	Landslide	High Medium Low	Name of Nagarpalika	Name of District	
4	Seismic	Seismic	High Medium Low	Name of Nagarpalika	Name of District	
5	Industrial	Industrial	High Medium Low	Name of Nagarpalika	Name of District	
6	Other	Other	High Medium Low	Name of Nagarpalika	Name of District	

CHAPTER 5: CONCLUSIONS

5.1 Conclusions

Land use zoning is an essential planning tool for successful and systematic disaster risk reduction. It can reduce the vulnerability of people and infrastructure identifying appropriate locations for settlement and construction by applying adequate building standards during implementation of plan. Flood, landslide, fire, industrial and earthquake are major events that expose into vulnerability and hazard associated with risk. Among others, landslide and flood risks are high in the Nagarpalika as compared with other risks/hazards. South-western and northern part of the Nagarpalika area are most vulnerable to flood and landslides because of weak geology, hence proper management strategies and protection measures should be implemented for agriculture practices, settlement and infrastructure development.

5.2 Recommendation

Based on the present experience of the project, the following recommendations are made for future undertaking of similar projects:

- Settlements developed along the bank of Mayum khola, Chhiruwa khola, Srikhola, Tangting khola, Gorkhe khola are more prone to floods and bank cutting. Therefore, immediate action is needed to take against flood and bank cutting such as river training or embankment or levee construction to protect the agriculture land and settlements from the flood. Additional study is needed for the analyses and forecasting of flood risk.
- Integration of hazard maps developed by different organizations at suitable scale is required, and used for disaster resilient development policy. And that hazard risk map (of particular area) should be revised from time to time after major, extreme precipitation, and earthquake and major development infrastructure which may have affected.
- Fire preparedness activities most be carried out, which includes spreading messages through television, radio, street drama, video, folk songs, drills, posters, pamphlets, and hoarding boards to reduce the risk of firing.
- The seismicity factor should be considered in the detail engineering design.
- The risk layer maps and database may be useful for land use planners and environmentalist for the development intervention. Therefore, it could also be useful for preparation of environmental planning, policies and strategies to the Nagarpalika.

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Land Use Zoning Report

Preparation of Land Use Zoning Suryodaya Nagarpalika of Ilam District

This document is the output of the project entitled **Preparation of Nagarpalika/Gaunpalika level Land Resource Maps (***Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps, Cadastral Layer Superimpose and Nagarpalika/Gaunpalika Profile***), Database and Reports (Package-04)** awarded to *PEES Consultant (P) Ltd.* by Government of Nepal/Ministry of Agriculture, Land Management and Cooperatives, National Land Use Project (NLUP) in Fiscal Year 2074-075.The area covered under the Package 4of Ilam District are: Suryodaya Nagarpalika and Rong Gaunpalika.

The Nagarpalika/Gaunpalika areas analysed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the Nagarpalika/Gaunpalika may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

The consultant is obliged to state that the Imageries, GIS database and other out puts produced for the project is owned by National Land Use Project (NLUP), Mid Baneshwor, Kathmandu. Therefore, the authorization from the NLUP is required for the usage and/or publication of the data in part or whole.

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CHAPTER 1:INTRODUCTION

1.1. Background and Rationale

Land is a unique resource limited in supply but endless in the variety of its uses. It is a basis of socio economic development of every country. For sustainable development of society, this resource should be wisely managed. Many countries around the world are nowadays paying their utmost attention to various land management issues for sustainable socio economic development and environmental management. One of the most effective and widely used land management instruments is to develop land use strategy from the long term perspective which will provide basis for controlling land use changes through the adoption of land use zoning and regulations. It is the land which has preserved the proof of human achievement and failure. But never in the history of mankind has land been such a crucial issue as today. The land issue has developed in the context of explosive urbanization that has taken place as a result of mankind's great achievement in the fields of science and technology (Chhetri, 1986).

Hence, land use is one of the priority sectors of Government of Nepal (GoN) which can be visualized from the different official documents. Most of these documents have mentioned on short term policies and in some cases it succeeded with partial implementation of the policy as well.To address the land use sector, the eighth fifth year plan first time has identified a long term program. The ninth fifth year plan has focused for sustainable development of land and natural resources for preservation and extension of ecological sectors (Ninth Plan, 1998).This plan has identified the need of the formulation of land use plan based on the land form, climate, soil etc. as well as in agricultural production, environment preservation and other facilities,sectoral development and increase the public awareness on importance and role of land use plan. In the same way, the tenth fifth year plan focused to the formulation and activation of land use policy to discourage the use of arable land to other non-agricultural purposes and creation of national geographic information database related with land resource maps. However, it is necessary to devise a proper land based planned land use map to correlate in the actual ground. In this context, the superimposed of cadastral maps on the land use zoning maps are necessary for implementing the land use policy.

In Nepal, with the high population growth accompanied by rapid urbanization the country is experiencing at present, land management issues have reached critical stage at both national and local level. The highly fertile agricultural land is getting urbanized haphazardly especially in and around the fast growing urbanizing areas and market centers all along the transport corridors from east to west and south to north. In many places, agricultural lands have been left unused and abandoned. The available land is also not being used on its optimum level. Crop production is not in accordance with the suitability and capability of the land in many areas. Rampant encroachment of public and forest land especially in the Terai areas have resulted in haphazard and uncontrolled growth of squatter settlements contributing to the declining level of the ecological balance. Similarly widely scattered unplanned and haphazard subdivision of fertile agriculture land as building plots in areas adjacent to major and minor road network in most terrain districts is taking place everywhere also indicate that there is no control mechanism or instrument to regulate such activities. In many places, especially in the hilly and mountainous land, uncontrolled and rampant human activities have contributed to the accelerated pace of natural disasters such as landslides and flooding. Consequently, Nepal is subjected to serious threat of facing problems related to food security and hunger in future. Similarly, unplanned settlement and unhealthy habitat, lack of basic infrastructure and services, natural disaster, and environmental degradation are other serious challenges already faced by the country. If these issues and problems are not addressed in time, it may invite a major disaster for the country from the perspective of food security and hunger, health risks due to environmental degradation and other unforeseen natural calamities.

Land use planning is a decision – making process that “facilitates the allocation of land to the uses that provide the greatest sustainable benefits”. It is based on the socio-economic conditionsandexpected developments of the population in and around a natural land unit. These are matched through a multiple goal analysis and assessment of the intrinsic value of the various environmental and natural resources of the land units. In the simplest planning situation, that of new land settlement as land units can be allocated to specific uses. Settlers are then brought in, and at least initially, required to practice those uses (GTZ, 1995).Far more commonly now-a-days, the land is already settled and is being cultivated, grazed, etc., so the purpose of the plan is to help solve problems of existing land use systems. In this situation, land use cannot be simply “allocated”. New land use types can be recommended for specific areas, through extension services and through provision of inputs and services. Decisions on land allocation or land use recommendation for completing uses begin with a set of policy guidelines, for example – a minimum acceptable production of staple foods and fuel wood, the preferred location within range of existing services and a limited amount of development capital. Sometimes, it is helped to set out the options in a goals achievement matrix and rank them according to chosen criteria. For the increasingly complex tasks of selecting sites for development projects, allocating land among several land uses, development policies on land use as well as allocating resources, hundreds of individual land units and many alternative land uses may have to be considered. The decision-maker must take into account a variety of practical considerations, including-

- the expressed preference of the local people
- the interest of minority group
- mitigation of national policies
- some constraints such as land tenure, availability of source of data as inputs
- the maintenance of environmental standards
- practicability for its potential implementing agencies
- Costs and the availability of funding.

At this point, the decision-maker can appraise the overall situation and, if dissatisfied with the achievement of any particular policy guideline, can adjust the weighting of the criteria or introduce new ones. With the aid of a computer, a new land use pattern and its suitability scores can be produced quickly and, perhaps over several iterations between the decision-makers and the decision support system, an optimum solution may be arrived at. In this context, the system can be used to arrive at set of optimum land development prescriptions keeping in view the physical, natural, environmental and socio-economic characteristics of the planning area. It operates on a pre-captured land development criterion based on four parameters representing the physical,natural and environmental conditions. These include; present land useland cover, slope, soilcharacteristics including soil texture, soil nutrients and soil depth, ground water prospects derived from hydro-geomorphology (Gupta, 2006).The system also provides a mechanism for evaluating the impact of proposed development actions. Good land use decisions can be arrived at without the assistance of a computerized decision support system. The procedure is the same whether a computer is used or not, but the computer package enables the decision maker to take account of much more information and to learn from predicted consequences of alternative decisions.

Multi-disciplinary natural resources teams are required to make GIS/LIS systems an effective tool in support of land use planning. This will include physical geographers, agronomists and climate-soil-crop modelers, geo-statisticians, computer programmers, economists and social scientists to ensure that the system and its products are transparent to the occasional users, such as policy-makers and stakeholders at every level. There remain a number of technical and organizational limitations to the effective utilization of GIS technology, especially in the smaller developing countries (Sombroek and Antoine, 1994). Four important constraints are : (I) the inadequate analysis of real-life problems as they occur in complex land management and sustainability issues at the household level, and as they involve the integration of biophysical, socioeconomic and political considerations in a truly holistic manner; (ii) the limitation in data availability and data quality at all scales, especially those that require substantial ground truthing; (iii) the lack of common data exchange formats and protocol; and (iv) the inadequate communication means between computer systems, data suppliers and users due, for instance, to poor local telephone networks.

To cope with these challenges, available land resources need to be managed appropriately and in a planned and systematic manner. Land use zoning is the tools for getting optimum benefit from scarce land resource. Sustainable socio-economic development of a country is highly dependent on the proper use and utilization of resources available and its monitoring. Therefore, a comprehensive land use plan is of utmost importance in the national development process. To this end Government of Nepal has identified land use zoning as an important step to design a detailed land use plan and policy. In this context, the Ministry of Agriculture, Land Management and Cooperative, has taken the initiative by formulating National Land Use Policy, 2072 which has been adopted by the Government of Nepal. This policy is to be implemented through the preparation of land use zoning maps and the necessary regulatory framework to enforce the land use strategy. In order to implement this policy the Ministry of Land Reform and Management, has initiated the National Land Use Project to prepare land use zoning maps of Nepal in different level such as district and Gaunpalika/Nagarpalikalevel.

Land-use zoning can be applied at three broad levels: national, district and local.However, it requires detail basic information about the land, the people and services at local level. However, Nepal has only regional level data base on land use, land system and land capability which were produced by Land Resource Mapping Project (**LRMP**, 1986). Realizing this fact, the Ministry of Agriculture, Land Management and CooperativeGovernment of Nepal established the **National Land Use Project** (**NLUP**) in 2057/058 fiscal year to generate the necessary data bases on the land resources of the country.

In the first phase, the National Land Use Project of Nepal had initiated several projects at district level and prepared **Land Resource Maps and Database** at 1:50,000 scale for the whole Nepal. It had also prepared maps and database for Kirtipur, Lekhnath, Madhyapur Thimi and Bhaktapur municipalities at larger scales. Finally, NLUP was mandated to prepare land resource maps of Gaunpalika/Nagarpalikaof Nepal for local level planning through outsourcing modality. These digital data base includes Gaunpalika/Nagarpalika level present land use, soil, land capability, land use zoning, cadastral layers and Gaunpalika/Nagarpalikaprofile with bio-physical and socio – economic data base.

On the 4th *Baishakh* of 2069, the Government of Nepal has approved the **National Land Use Policy, 2069**.National Land Use policy, 2069 has been modified by the amendment in 2072 and introduced **Land Use Policy, 2072.** It has intended to manage land use according to land use zoning policy of the government of Nepal and outlined eleven zones such as ***Agricultural zone, Forest zone, Residential zone, Commercial zone, Industrial zone,Public Use zone, Mining and Mineral zone, Cultural and Archaeological zone, Riverine andLake area, Excavation zone and Others***. The policy has defined the respective zones as per the land characteristics, capability and requirement of the lands. Further, for the effective implementation of land use zones in the country, the Land Use Policy, 2072 has clearly directed for an institutional set up of **Land Use Council** at the top to the **District level** and **Gaunpalika/Nagarpalikalevel** at the bottom. It has added further importance to the NLUP projects on preparation of Gaunpalika/Nagarpalika level maps, database and reports.

In the context stated above, the PEES Consultant (Pvt.) LTDhas been commissioned to pursue the project (**Preparation of Gaunpalika/Nagarpalikalevel land resource maps, databases and reports**)Package 04 of Ilam district by National Land Use Project (NLUP) office, Kathmandu. The Suryodaya Nagarpalika and Rong Gaunpalika has covered under the project area (Total 2local bodies) of Package 04.

The study is based on following conceptual aspects:

- Classification of the land into Agricultural zone, Forest zone, Residential zone, Commercial zone, Industrial zone, Public Use zone, Mining and Mineral zone, Cultural and Archaeological zone, Riverine and Lake area zone, Excavation zone and Othersas per necessity as mentioned in the National Land Use Policy 2072 of the Government of Nepal.
- Identifying and demarcating areas for potential residential, commercial, industrial and public use to support sustainable urban development
- Classifying agricultural land into comparatively advantageous sub areas on the basis of quality of land, suitability and capability of land to increase the productivity
- Proper conservation of natural resources including forests, shrubs, rivers and rivulets and swampy lands for environmental protection

1.2. Objectives of the Study

The main objective of the study is:

To prepare land use zoning maps, GIS database and reports of **Suryodaya Nagarpalika** of Ilam district of Nepal.

The specific objectives of this study are:

- To prepare land use map of **Suryodaya Nagarpalika** on the basis of existing land use including land cover, suitability and capability of the land by using available data sources in GIS.
- To prepare appropriate GIS database of proposed land use zoning.
- To prepare land use zoning map at 1:10,000 scale clearly showing different zones and sub-zones in accordance with the Government's Land Use Policy 2072.
- To prepare detailed report containing conceptual basis and methodology, criteria of land use zoning, distribution of different land use zones and data models of GIS database.

Scope

The scope of this project work is as follows:

- Study of the existing relevant maps, documents, and database of the project area
- Preparation of land use zoning maps of the Suryodaya Nagarpalika at 1:10000 scale based on existing land use and field survey with clear demarcation of different zones and sub zones as per the Government's Land Use Policy 2072
- Designing appropriate GIS database on land use zoning for the selected Suryodaya Nagarpalika Assuring accuracy, reliability and consistency of data
- Preparation of detailed reports, describing methodology, criteria and distribution of different land use zones and sub zones with GIS data models and databases.

1.3. Study Area

Suryodaya Nagarpalika, name being the Nepali translation of “Rising Sun” declared municipality status in 2013 (2070 BS), with the merged of three Village Development Committees (VDCs) namely: Phikkal, Panchakanya and Kanyam. After, the restructuring of local body in 2073 BS, Gorkhey, Pashupatinagar, Sriantu, Samalbung, Laxmipur and Jogmai ward no. 8 and 9 were also merged into the municipality. It is located in Ilam district, province no. 1, approximately 40 km south-east of the district headquarter Ilam. Geographically, it lies in the hill region which is mostly known as Mahabharat range with natural scenery and pleasant weather. Its geographical coordinates are 87°55'59" to 88°10'37" east longitude and 27°0'28" to 26°47'17" north latitude. The Nagarpalika is bordered with India on the east, Ilam Nagarpalika and Maijogmai Gaunpalika on the west, Mai-Jogmai Gaunpalika on the north and Rong Gaunpalika on the south (Figure 1.1). Phikkal is the center of the Nagarpalika. The total area of the Nagarpalika is 22438.57ha.Which is extended north-south 25.29 km and east-west with 24.71 km?

The inhabitants are believed to have been living in this Nagarpalika since ancient time. According to the Population Census of 2011, the total population of this Nagarpalika was 56,707 and the number of households were 13,211. This gives an average household size of 4.3 which is lower than the national average (4.88). Administratively, the Nagarpalika has been divided into 14 wards. Ward 1 is the largest in terms of population size whereas ward 7 is the smallest one.

The Nagarpalika has diversity both in its physical and cultural aspects. It is a business hub of Ilam with beautiful landscapes. Tea, ginger, *Amriso,* cardamom, round chilies (*Akabare Khursani)*, milk and potatoes are the major trade items of this Nagarpalika. The Nagarpalika has great possibility for the tourism. Kanyam, Pashupatinagar, Phikkal, and Sri Antu are famous for tourist destination sites. Rai, Brahmin, Chhetri and Tamang are major ethnic group inhabited in the Nagarpalika.

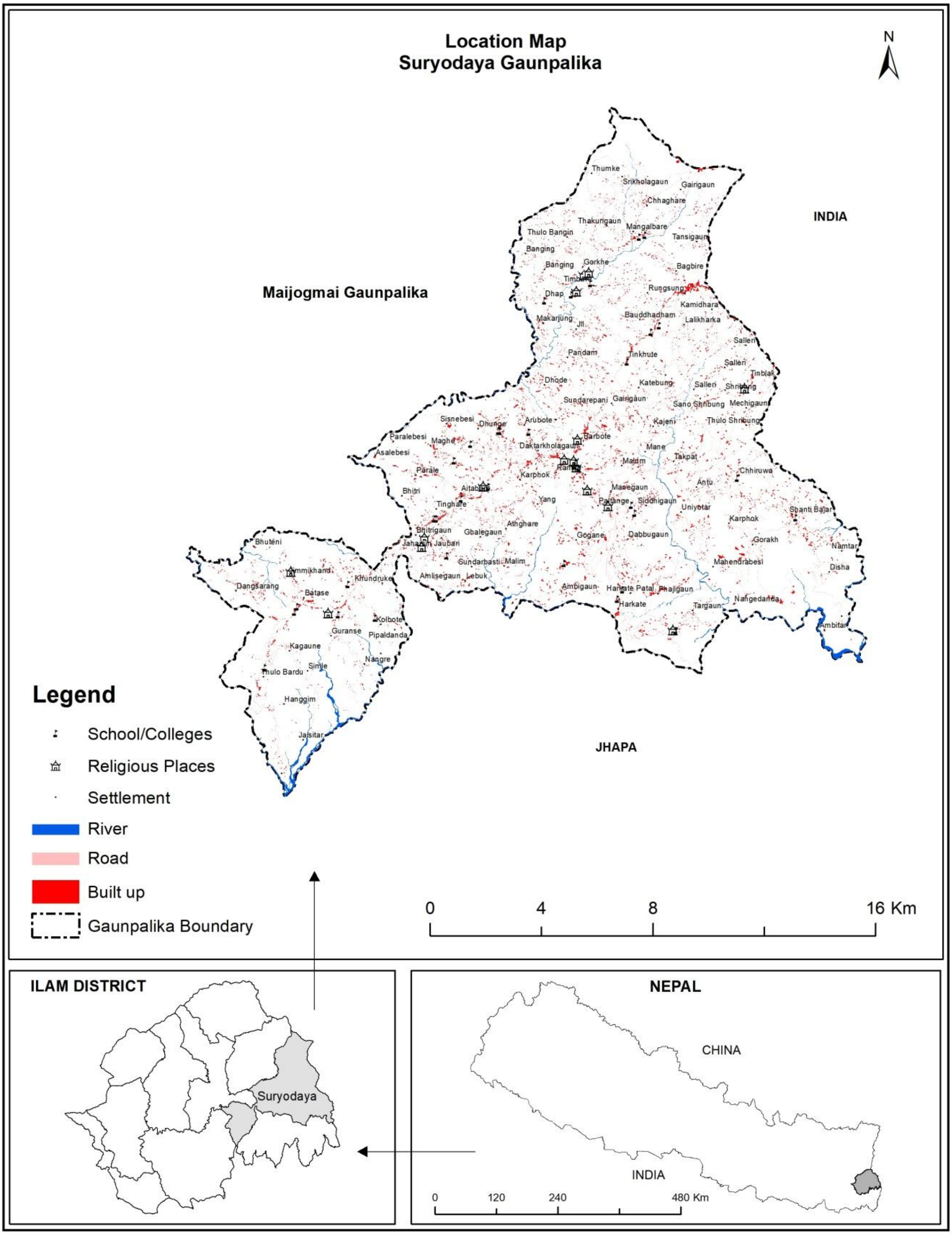


Figure 1.1 Location map of Suryodaya Nagarpalika

CHAPTER 2: CONCEPTUAL BASIS OF LAND USE ZONING

This chapter describes the conceptual idea and principles of land use planning, its parameters and criteria used for land use zoning in the study area.

2.1. Land Use Zoning - Principles and Criteria

Land use planning in the context of development cooperation is defined as an iterativeprocess based on the dialogue among all stakeholders. It also implies the initiation and monitoring of measures to realize the agreed land uses (GTZ, 1995). It is one of the tools that can help to meet them as it focuses on negotiating future land and resource uses by all relevant stakeholders. It has enforced for achieving food security, mitigating and adapting to climate change, protecting biodiversity while at the same time initiating economic growth, protecting people from natural disasters, preventing and settling land conflicts or initiating to construct the basic need of infrastructure development.

Land use planning has developed from a rather top-down planning by experts outside theexisting institutions towards a participatory planning which is integrated into nationalinstitutions and is increasingly linked to financial planning. Regional differences are, however, quite significant. Depending on the conditions, land use planning can be more or less complex, ranging from the simple inclusion of spatial aspects into local development planning to comprehensive spatial planning approaches at different levels. The land use planning, which consists of fixing space for different purposes in national, regional and local framework, has been used as part of the national development policy in a number of countries, for example: United Kingdom, the Netherlands, Denmark and some other European countries. The most important policies adopted for land use control and management by many of these countries are:

- Long term national and regional land use planning including environmental conservation
- Special land use controls in areas where development need to be either regulated and/or discouraged
- Positive land use control directing and promoting development
- Land pooling/land adjustment schemes (reshaping theparcel of land in a given area)
- Expropriation and compensation

Land Use Plan is formulated to provide policy guidance and assistance in the decision making process relative to land use and land development issues affecting the community. For effective implementation of land use zoning, land use plan is prepared with the intention to identify, illustrate and express preferences for use of land in the area based on physical features and constraints, the characteristic of areas and neighborhoods, site suitability for particular types of land use activities, economy and availability of public services and infrastructure.

A Land Use Map is a graphic representation of physical uses of land. These land use maps are highly visible within most community plans, often showing both current land use and plans for future land use. Land Use Maps identify land uses by category. These typically include Residential, Industrial, Commercial, Natural Areas, Agricultural, and Civic uses. Land

Use maps can be either very broad or very detailed depending on the context or need behind creating the map. The land use map is an important tool for identifying existing conditions and provides basis for future development vision for the community.

The following guideline principles has essential for land use planning(Wehrmann, 2011):

- Legal bindingness;
- Institutional anchorage;
- Vertical and horizontal integration;
- Subsidiary;
- Iteration;
- Simplicity;
- Transparency;
- Adaptation to national, regional and local conditions;
- Recognition of local knowledge;
- Inclusiveness;
- Participation;
- Dialogue;
- Spatial orientation;
- Inter-linkage with financial planning;
- Orientation towards implementation;
- Aiming at sustainability and capacity development.

Land use zoning is the classification of land use as per the development of real state of that area. In Land use zoning process, the segregation of land use into different areas for each type of use such as agricultural, vegetation (forest), industrial, residential and recreational. The process by which lands are evaluated and assessed to become a basis for decisions involving land disposition and utilization is termed as land use zoning. Land use zoning regulation and restriction are used by local governmental development plan to control and direct the development of property within their boundaries(Wafaie, 2008). It is controlling the food security, improvement of environment and sustainable development of land. Land use zones separate one set of land uses from another based on the optimum and sustainable use of resources. For this purpose, it is necessary to identify the proper zone of the proper individual parcel. Land zoning of a parcel of land where all surrounding parcels are zoned for a different use in particular where the zoning creates a use that is compatible with surrounding land uses.

A Zoning Map is a graphic depiction of an area with defined boundaries for which a certain set of standards or regulations have been formulated and adopted by a governmental agency with the authority to administer, manage and regulate land and land uses. The zoning map typically provides predictability to the residents and development community as to what type of land uses may be expected in the future which would be permitted within each Gaunpalika/Nagarpalika/District. In zoning map land is divided into zones in accordance with the zoning code which describes the land use regulations of each particular zone category. A typical zone will have a set of regulations for permitted land uses.

Land use zoning is assessed based on the suitability of sustainable use for a given purpose. Land use zoning differs from land capability classification in a sense that land capability is general classification of land based on arability and productivity of soil without degradation or offsite effects of farming whereas land use zoning is suitability classification of land for various land use purposes.

The concept of land use zoning is adopted to achieve the following objectives:

- To provide for a mixture and variety of land uses in appropriate locations throughout the study area
- To identify prime land areas suitable for agricultural crop production.
- To identify and set aside land areas for future industrial growth and development.
- To create stable, attractive, safe residential neighborhoods which contain a range of supportive commercial, institutional, and public facilities
- To promote stable and functional commercial centers based on site suitability and compatibility with adjacent land uses.
- To provide for the appropriate location and distribution of public facilities such as parks and schools throughout the community.
- To promote rehabilitation and improvement of the living environment in older neighborhoods and areas characterized by conflicting patterns of land use.
- To promote land use activities appropriate and compatible to the features and characteristics of the natural landscape.
- To support, maintain and promote consistency between the Land Use Plan and current land use pattern.
- To provide for the adequate transitioning and buffering between residential uses and industrial and commercial uses.
- To promote growth in areas adjacent to existing urban development so that public services and facilities may be provided efficiently and economically.

In this particular project, the land use zoning is carried out by adopting the following concept:

- Classification of land into Agricultural area, Residential area, Commercial area, Industrial area, Mining and Mineral area, Cultural and Archaeological area, River, Lake and Water bodies area, Excavation area, Forest area, Public Use area and Others.
- Identifying areas for potential residential, commercial, industrial and public utility keeping balanced environment.
- Classifying agricultural land into comparatively advantageous sub-areas on the basis of quality of land, land capability, and irrigation facilities to increase productivity.
- Proper conservation of natural resources including forest, shrub, rivers and rivulets and swampy land etc.
- Proper determine the Mining and Mineral area and Excavation area considering the environment impact and social impact.
- Public service area mainly open area should be identified for the use during hazard.
- In hazard prone area, forest and public service area should be proposed.

For this project, the database on land capability, risk and present land use classification were reviewed carefully. Similarly, the TOR provided by NLUP is taken as reference for categorizing the various land use zones.

For land use zoning, thefollowingcriteria havebeen undertaken which is described as follows:

- The zoning of the Gaunpalika/Nagarpalikashould not contradict with the essence of the Land Use Policy, 2072.
- Sufficient land area should be zoned at appropriate locations throughout the study area (Gaunpalika/Nagarpalika) to accommodate the expected growth in population and other development needs of the Gaunpalika/Nagarpalikawithin the time frame of the Plan.
- Zoning should be designed to promote particular uses in appropriate locations, to minimize conflicting land uses and to protect environmental resources both natural and man-made. Further, zoning should be used as a tool for shaping the future development of the area and not solely reflect existing land uses.
- Development should be encouraged in already established urban, semi-urban and peri-urban centers and the development and/or redevelopment of underutilized land in these areas should be promoted with a view to consolidating and adding vitality to existing urban and semi urban centers to ensure efficient use of the land.
- Existing forest area should be kept constant.

Based on the above criteria, the following guidelines havebeen considered for land use zoning:

1. Agricultural Area

a. Most of the agricultural areas are kept intact but it is almost impossible to retain all areas as some of the newly proposed residential, commercial, industrial and public use areas are proposed on the agricultural land. It is essential to address the needs of housing, marketing, employments, public utility development and other economic activities besides agriculture for the growing population. Therefore, the agricultural areas may be slightly decreased. However, we need to retain the mostly arable agricultural land and marginally capable lands should be used for infrastructure development.

b. Within the agricultural land, the area of comparative advantage can be identified on the basis of land capability, land system, temperature, irrigation and drainage system, and other physical, chemical parameters of soil. Extensive discussions are carried with agriculture experts and their opinion is taken to further sub classification of agricultural land.

2. Forest Area

a. Existing forests areas are kept intact

b. New forests or plantation are proposed mainly on the basis of the following criteria:

i. Barren lands, Wetlands, Abandoned lands
ii. Slopping land, watershed, high mountains
iii. Flood and erosion prone river banks
iv. Other lands of marginal utilization
v. Sides of roads, canals etc, if possible
vi. Near or around Industrial areas to make natural protection from pollution
vii. On the land under high or medium hazard risk
viii. Other suitable areas for agroforestry or timber production etc.

3. Residential Area:

a. The existing residential area is kept intact if they are risk free or at low risk. Generally the settlements in the local area or villages are established on the basis of inherent indigenous knowledge, they are generally safe and the infrastructures are already available in many of the areas. Therefore these settlements are kept intact.

b. Keeping the local population growth and flow of internal migration to the area in mind and looking at the rate of built-up development in the area during last 10 years, some new settlements are proposed. Some of the criteria to identify appropriate land for new settlements are:

i. The land should be free from or at low hazard risk as much as possible
ii. The area should be in the neighborhood of the existing settlement, if possible
iii. Availability of road and infrastructures if possible
iv. Not in the flood plain of any river
v. Within Geologically stable areas
vi. Not in the vicinity of dense forests and industrial areas as much as possible
vii. The land should be of marginal utilization, i.e. the land should be unprofitable for agricultural crop production

4. Commercial Area

a. The existing commercial area is kept intact as they are already established according to the necessity of the local people in or near residential areas.

b. For the future planning, the land is allocated for the new commercial and business areas including government institution on the basis of the following criteria:

i. The land should be free from or at low hazard risk as much as possible
ii. The areas should be in the neighborhood of residential area, number of household and population should be considered
iii. Availability of road and infrastructures if possible
iv. Not in the flood plain of any river
v. Within Geologically stable areas
vi. Not in the vicinity of dense forests
vii. The land should be of marginal utilization, i.e. the land should be less capable for agricultural crop production

5. **Industrial Area**

   a. Most of the existing industries in the rural area are small and agriculture based. The impacts of these industries on human activities are not much prominent. Therefore, the existing small industries are kept intact. Most of the heavy industries are already either far from settlement or they are managed in such a way that the impactsare less on the human activities. In case of industries found affecting human life will be recommended to relocate.

   b. For the proposed industrial areas, the following criteria are chosen:

      i. The land should be free from or at low hazard risk as much as possible
      ii. It should be in the neighborhood of existing industrial area (if it is already suitable)
      iii. It should not be in the vicinity of residential and commercial area but within the approachable distance from market and settlements with infrastructures
      iv. Accessibility of roads if possible
      v. Not in the vicinity of rivers, ponds or any other water sources and dense forest
      vi. The land should be of marginal utilization, i.e. the land should be less capable for agricultural crop production
      vii. Geologically stable
      viii. Not in the international boundary but can be in the bordering area of two or more administrative units (Gaunpalika /Nagarpalika/Districts) so that there would be opportunity to share benefits of the resources of both administrative units

6. **Public Use zone**

   a. Existing public utility and open areas are kept intact

   b. Some of the new public use areas such as Health, Education, open area etc are proposed on the vicinity of existing and proposed residential/commercial/industrial areas wherever appropriate.

   c. Mostly, these types of service areas are located on the basis of the necessity and requirement of the local people. Therefore, this zone is suggested to be planned after discussion with local community using participatory approach.

   d. Mine and Minerals Zone

   e. Existing Mining and Quarrying areas as defined and described by Land use Policy 2072

   f. Identified and prescribed areas as potential Mining and Quarrying area in future

7. **Cultural and Archaeological Zone**

   a. Existing religious, cultural, archeological areas as defined and described by Land use Policy 2072

b. Area defined as cultural heritage by their master plans

8. Riverine and Lake Zone

a. Existing rivers and water bodies as defined and described by Land use Policy 2072

9. Excavation Zone

a. Existing areas as defined by Land Use Policy 2072

b. Areas prescribed and allocated by the national/local government for such use

c. Areas found appropriate from expert's study for such use in future

10. Other Zones prescribed as required

a. As per the prescription of experts and decision of the government

2.2. Land Use Zones and their Descriptions

The Land Use Policy, 2072has identified the following elevation land use zones:

Agricultural Zone

The agricultural zone covers the area where there is a presence of agro products (food grains, cash crops, horticulture, etc.), animal husbandry, fisheries, agro and forest products or orchards in a private land. It also indicates a region prescribed by the government as an agricultural zone.

Forest Zone

Forest zone covers an areas being covered with public, community, leasehold forests in part or entirety, national parks, wildlife reserves, conservation areas, bushes, shrubs, all types of jungles and places designated by the government as a forest regardless of whether there are trees or not. This term also infers an area nominated by the government for the expansion of forests or green areas, in a definite geographical region.

Residential Zone

Residential zone covers the land used by people for shelter or housing and also includes animal shed, food container, garage, stable, well, tap, orchard, backyard, courtyard or land with any other use whether joined with the house or separate. Residential zone also denotes a collective housing or apartment built by a business company or institution, and also to a specific land declared by the government for housing purposes.

Commercial Zone

Commercial zone covers the land occupied by or allocated for shops, hotels, exhibition stalls, petrol pumps, warehouses, health and information facilities, commodities trade centre, an organization providing any literary, scientific or technical service or advice, fair venues, discos, clubs, swimming pools, cinema halls opened for business purposes, entertainment joints or any other building meant for commercial use. It also includes a commercial building built in a trade zone by a business company or institution and the land occupied by the same. Moreover, it also covers an area declared by the government to develop a city for market expansion and commercial use in a definite geographical region.

Industrial Zone

Industrial zone covers the land occupied by or allocated for any workshop, goods manufacturing industry, the associated buildings and sheds. It also denotes an industrial corridor, industrial village, cluster, special export zone and special economic zone declared by the government for industrial promotion in a definite geographical region.

Public Use Zone

Public use/service covers land occupied by schools, colleges, vocational educational centers, academic institutions including the universities, security agencies, health centers, health posts, private or community hospitals, telecom, drinking water, government agencies involved in providing electricity or other energy, community buildings, libraries, old age homes, child protection homes, other buildings, sheds, platforms erected for public use. It also includes the hills, meadows, cliffs, mountains, snow covered areas, pastures. Public use zone also denotes playgrounds, parks, stadiums, grounds, platforms, picnic spots, open places having no special use, district roads, rural roads, bus parks, airports, cargo areas, dry ports, railways, ropeways, waterways, cable cars, electricity transmission lines, ports and the places designated as public utilities zone by the government or prevailing laws.

Mine and Minerals Zone

Mining and minerals zone covers a land being used for mining, production or processing of minerals or area declared by the government as a mining and quarrying zone definite geographical region. It also includes any area where mineral deposit is discovered or a mine is operational, where industries for mining, production, processing and purification of minerals are being located as well as the associated buildings, sheds as the land being used for the operation of such industries as well.

Cultural and Archaeological Zone

Cultural and archaeological zone covers the forts, palaces, buildings, temples, shrines, mosques, monasteries, *Manes*, with a historical and archaeological significance as well as other pilgrimage sites and places of worship. Cultural and archaeological zone also implies an area declared by the government as a historical, cultural, religious and archaeological place in a definite geographical region.

Riverine and Lake Zone

Riverine and lake zone covers an area where rivers, rivulets, streams, canals, lakes, ponds, long-holding swamps or wetlands are existent.

Excavation Area (Construction Materials) Zone

Excavation Area (Construction Materials) zone covers the area designated for quarrying, production or processing of stones, pebbles and sand as per the determined standards, or any other place designated by the government as an aggregate quarrying zone (stones, pebbles and sand) in a definite geographical region.

Other Zone prescribed as required

Other zone prescribed to the areas that do not fall under any of the above land use zones but which need to be mentioned as an exclusive land use zone. This term also implies an area with mixed characteristics where the residential and business zones have merged so seamlessly that they cannot be bifurcated as is seen now in various cities, towns, highway areas. This zone shall be applied only for regulating settlements and market areas that have been since the past.

The present study has strictly followed the guidelines of the National Land Use Policy 2072 and devised the zones and sub zones within the study area as shown in the table 2.1.

Table 2.1: Land use zoning scheme of the study area

Class	Zone	Zone Type	Code	Sub zone	Description	Remarks
1	Zone 1	Agricultural Zone	AGR	Zone 1A	Cereal crop production area	
				Zone 1B	Cash crop area	
				Zone 1C	Horticultural area	
				Zone 1D	Animal husbandry area	
				Zone 1E	Fish farming area	
				Zone 1F	Agro forestry area	
2	Zone 2	Residential Zone	RES	Zone 2A	Existing residential zone	
				Zone 2B	Potential area for residential zone	
3	Zone 3	Commercial Zone	COM	Zone3A	Governmental institutions and service areas	
				Zone 3B	Business area	
4	Zone 4	Industrial Zone	IND	Zone 4A	Areas under industrial use	
				Zone 4B	Potential area for Industrial zone	
5	Zone 5	Forest Zone	FOR	Zone 5A	Existing forest	
				Zone 5B	Potential area for forest including barren lands, wet lands etc.	
6	Zone 6	Public UseZone	PUB	Zone 6A	Areas under roads, railways, bus parks, airport and land fill site etc.	
				Zone 6C	Picnic spots, playing grounds and stadiums etc.	
				Zone 6E	Public health/education/library, police station, fire station, telephone /electricity areas etc.	
				Zone 6F	Grazing Land	
				Zone 6G	Public Institution Area	
				Zone 6H	Open Area	
7	Zone 7	Other area	OTH	Zone 7	as per requirement	if necessary
8	Zone 8	Mine and Minerals Zone	MIN	Zone 8A	Existing Mines and mineral area	
				Zone 8B	Potential areas for Mines and mineral	
9	Zone 9	Cultural and Archeological	CULARCH	Zone 9A	Existing cultural and archeological area	

Class	Zone	Zone Type	Code	Sub zone	Description	Remarks
		Zone		Zone 8B	Potential cultural and archeological areas	
10	Zone 10	Riverine and Lake zone	HYD	Zone 10A	Existing rivers and riverine area	
				Zone 10B	Potential hydrographic areas	
11	Zone 11	Excavation Zone	EXC	Zone 11A	Existing quarrying and excavation area	
				Zone 11B	Potential areas for quarrying and excavation	

Source: NLUP Policy, 2072

CHAPTER 3: METHODOLOGY

This chapter deals with the data used and method adopted for land use zoning and preparation land use zone maps.

3.1. Data

Various data sources are used in this land use zoning. They are asfollows:

- Ortho-rectified Very High Resolution Satellite Image Worldview-2
- Present Land Use Map, Soil Map, Land System map and Land Capability Map prepared under the present project
- Digital Land Utilization, Land System, Geological and Land Capability maps and reports prepared by Land Resource Mapping Project (LRMP, 1986)
- Digital Topographical Datasets
- GIS vector data (shape file) of mainly land capability, land system, present land use, Administrative boundary (Gaunpalika/Nagarpalika, Ward).
- Socio-economic data and village profile
- Hazard Data such as Seismicity data, Flood Inundation data, Industrial Risk data, etc.

3.2. General Approach and Methodology Framework

The TOR has been quite clear and unambiguous about the objective and scope of work for the study. In this study, the delineation of an area to be covered by a land use zoning can be made on the basis of administrative boundaries asGaunpalika/Nagarpalika. The data to be incorporated into the databases are available in the form of maps, statistics and tables, though these have often been compiled at different formats and scale. Such spatial inconsistencies have made their integration for the decision-making process of resource management difficult and time-consuming, especially if the basic landscape-ecological units were not taken as a starting point. With the continuous developments of computer hardware and software, and their availability at fair prices by national, district or municipal planning entities, this condition is improving dramatically. In particular, the development of Land Information Systems (LIS) (Meyerinck et al., 1988) and Geographic Information Systems (GIS) software has enabled the available geo-referenced databases to be harnessed with relative ease into multiple-layer digital form. Each thematic layer is analogous to a map, but it can be both displayed and printed separately, and overlaid to produce a multi-theme map at any scale or orientation.

Government of Nepal has enacted the Land Use Policy 2072. According to the policy the overall land mass of nation shall be divided into the various 11 land use zones as mentioned above. These zones shall be further sub divided into sub-zones as required. Since earthquakes, landslides of devastating nature and other natural calamities negatively affect more than one land use zones, the risk prone areas shall be identified and such risk spots shall be marked in the land use maps to avoid the development of settlements, townships, and infrastructure in risk zone.

The primary bases of land use zoning are as follows:

The basis of land composition, capability and appropriateness

The indicator of geographical and geological land composition, capability and appropriateness shall be the primary basis for determining land use zoning.

The basis of current land use

The land use zone for a particular area shall be determined on the basis of current land use of that same area, if it is in accordance with its land composition, capability, and appropriateness.

The basis of necessity

In case the state has to use any particular land for a use other than it is directed for public good and development of physical infrastructure, then the land use zone shall be assigned in a manner so as to facilitate its utilization as per the need.

The land use zones in urban areas may be determined through micro zoning to their relative sensitivities. Thezoning map is prepared keeping the objective of the policy in mind. Therefore, the following main principles are adopted:

- Agricultural land should be kept intact as much as possible
- Forest cover should not be decreased, but can be increased.
- Wetlands should be preserved.
- Natural disasters risks areas should be avoided.
- Appropriate housing and residential areas should be identified for planned settlement
- Appropriate land should be allocated to commercial, business and industrial areas for economic activities.
- Area of comparative advantage should be identified within agricultural crop production.

To achieve the aforementioned objectives, the following basis is taken for land use zoning:

- Existing land use
- Capability and suitability of the land
- Socio economic data
- Potential risk areas
- Expert's opinion
- Subjective analysis

3.3. Methods

The specific method used for the land use zoning is shown on the following schematic diagram (Figure 3.1):

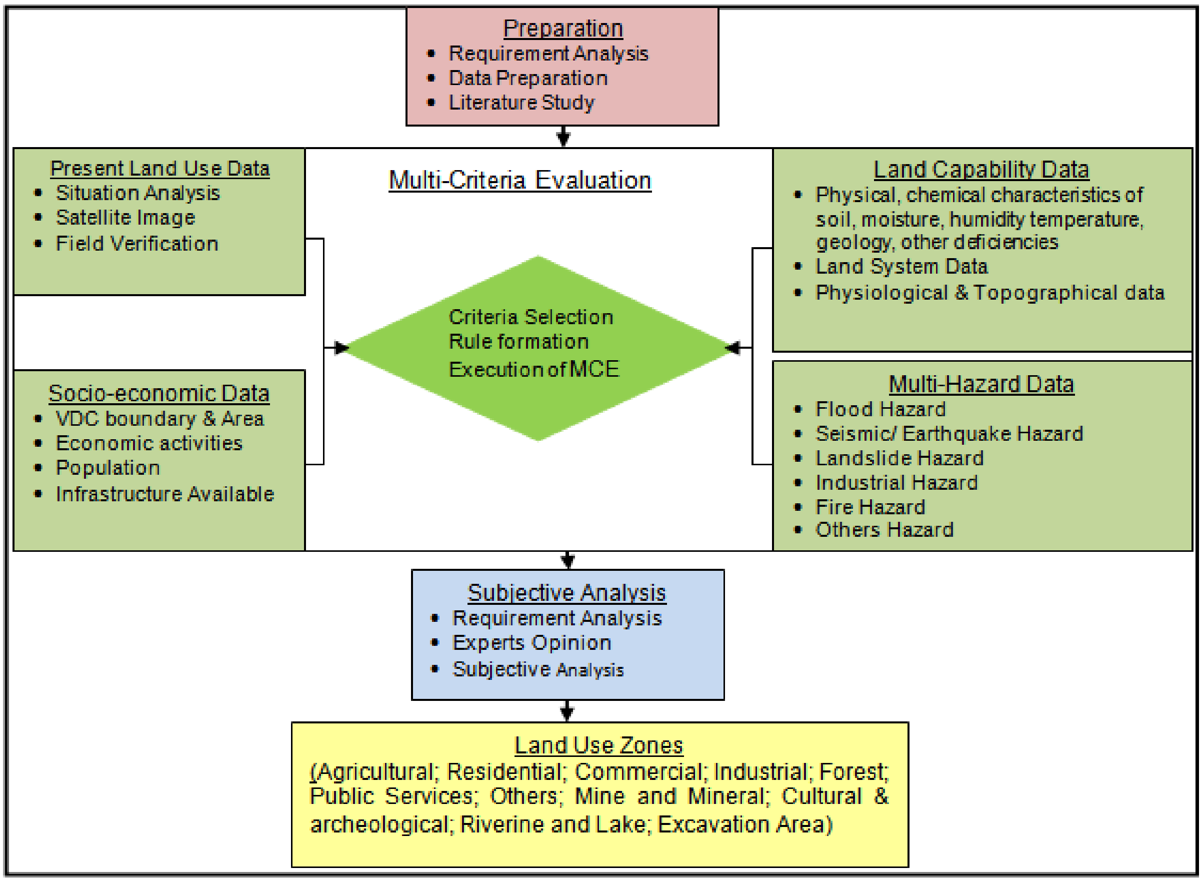


Figure 3.1: Work Flow Diagram of Land Use Zoning

Preparation

In this stage, literature review, requirement analysis and database preparation of different criteria map for land use zoning were carried out for the determination of proper land use classes. The exercise is also idea generation for the land use planning for future use of land.

a. Multi-criteria Analysis

Land use zoning is carried out mainly by using GIS based spatial analysis using multiple criteria analysis on several available data sets. Either GIS vector data (shape file) or raster data of mainly land capability, land system, present land use or socio economic data was used as a factor maps. A general rule has developed by using multiple criteria on the basis of expert knowledge by focus group discussion with stakeholders or Analytical Hierarchy Process (AHP) using pair wise comparison for land use zoning. These criteria were used to identify a suitable land use zone; and to identify a potential area for future land use. These data files comprised the various parameters like soil characteristics, land form, land type, arability, slope, drainage system, topography, existing land use, crop patterns, population density, existing and potential risk parameters used for land use zoning. A simple rule base was developed by using multiple criteria on the basis of expert knowledge for classification of land use zone. These criteria were used to identify a suitable zone for a particular type of land use zone. This is a scientific process and individual judgments cannot be made while applying the process. The suitability of certain use is judged by the software based on the provided criteria.

For example, to identify the potential residential area zone the following criteria were used:

- Not in a risk areas
- Not in highly land productive agricultural land
- Within slopping terrace of $28^0$and lesser.

Similarly, to identify a potential area for future industrial use the following criteria were used:

- Within a certain distance from road network
- In close proximity to existing industries
- Lower population density and less residential
- Not of much importance from agricultural crop production point of view e.g. dry land
- Not within a certain distance from forest, wetland, water body

These kinds of multiple criteria are evaluated and suitable land for particular use is identified with the help of GIS software.

b. Subjective Analysis

Subjective analysis with logical inference was applied for land use zoning with consultation with the thematic experts, and focal group discussion stakeholder to modify the land use zone as extracted from multi-criteria evaluation/analysis. It was carried out on the basis of requirement and expert's opinion. As an example, although, if a small piece of land is found suitable for agricultural use but it surrounded by residential area, then it is placed in the residential area. Similarly, if the land is found suitable for agricultural area but it is in the flood plain of the river and high risk of flooding, then it can be used for forest and plantation to control the flood. Apart from these kind of criteria formed on the basis of expert knowledge, some subjective analysis and logical interference was also applied for land use zoning.

For example,

- The bed of a stream should not be used for agricultural but it can be used for forest plantation or grass land (though it can be very suitable for rice crop production).
- If a small unit of a land use zone (e.g. Zone 5 with forest) was found surrounded by some other land use zone (e.g. Zone 7 with others), then the later zone was merged to the former.

3.4. Results

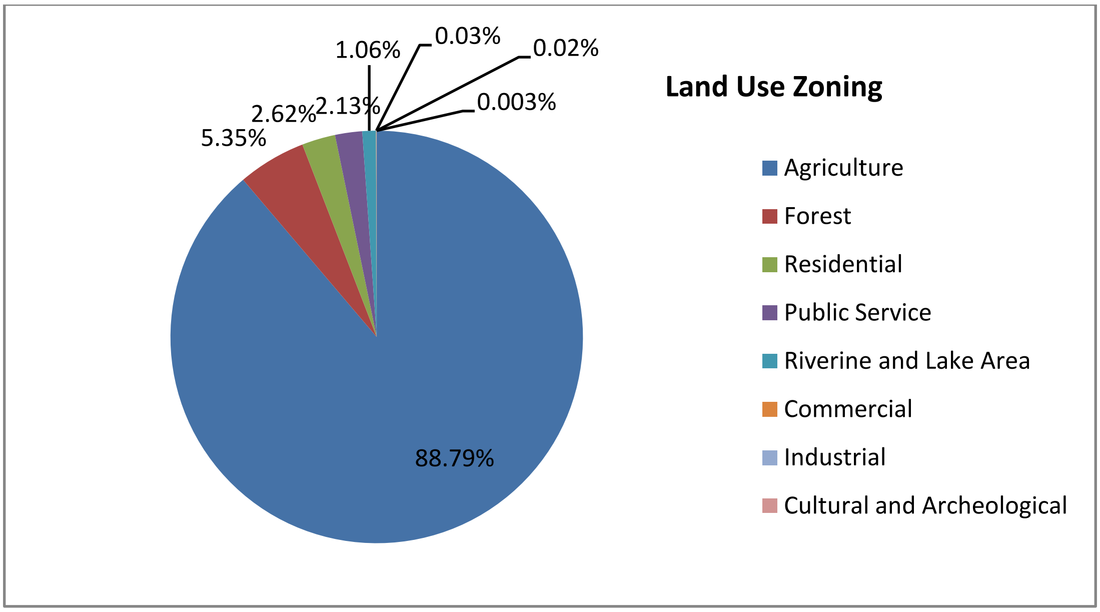
The method described in the previous chapter is applied and GIS analysis is performed on the various steps for land use zoning. The Land Use Zones identified in this Suryodaya Nagarpalika after GIS analysis are summarized on the following table:

Table 3.1: Land use zones of the study area

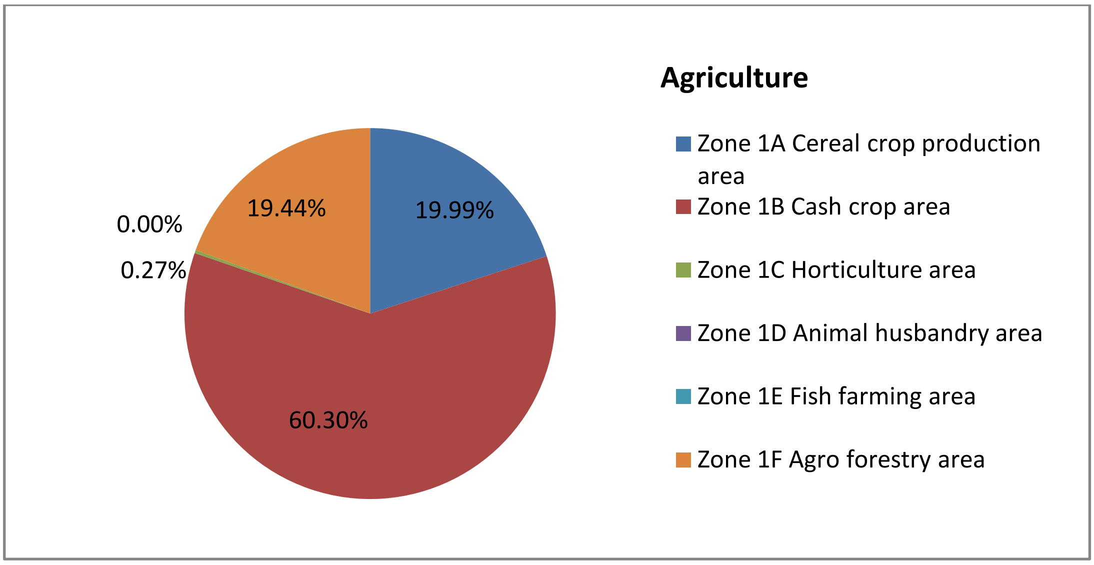
Class	Zone	Zone Type	Code	Sub zone	Description	Area of sub zone type (Ha)	% of individual zone	Area of zone type (Ha)	% of total area
1	Zone 1	Agricultural	AGR	Zone 1A	Cereal crop production area	1756.21	18.66	**9411.41**	60.93
				Zone 1B	Cash crop area	4835.30	51.38		
				Zone 1C	Horticulture area	92.38	0.98		
				Zone 1D	Animal husbandry area	0.00	0.00		
				Zone 1E	Fish farming area	0.00	0.00		
				Zone 1F	Agro forestry area	2349.57	24.97		
				Zone 1G	Other Agricultural Area	377.93	4.02		
2	Zone 2	Residential	RES	Zone 2A	Existing residential zone	134.10	93.92	**142.78**	0.92
				Zone 2B	Potential area for residential zone	8.68	6.08		
3	Zone 3	Commercial	COM	Zone3 A	Governmental institutions and service areas	0.76	57.34	**1.32**	0.01
				Zone 3B	Business area	0.56	42.66		
4	Zone 4	Industrial	IND	Zone 4A	Areas under industrial use	0.09	100.00	0.09	0.00
				Zone 4B	Potential area for Industrial zone	0.00	0.00		
5	Zone 5	Forest	FOR	Zone 5A	Existing forest	5056.22	98.51	**5132.91**	33.23
				Zone 5B	Potential area for forest including barren lands, wet lands etc.	76.69	1.49		
6	Zone 6	Public Use and Open Space	PUB	Zone 6A	Areas under roads, railways, bus parks, airport and land fill site etc.	198.19	96.06	**206.32**	1.34
				Zone 6C	Recreation, picnic spot	3.80	1.84		
				Zone 6E	Health, education etc institutions	3.65	1.77		
				Zone 6F	Grazing land		0.00		
				Zone 6G	Public Institution Area	0.24	0.11		

Class	Zone	Zone Type	Code	Sub zone	Description	Area of sub zone type (Ha)	% of individual zone	Area of zone type (Ha)	% of total area
				Zone 6H	Open spaces	0.43	0.21		
7	Zone 7	Other area	OTH	Zone 7	as per requirement	0.00	0.00	0.00	0.00
8	Zone 8	Mine and Minerals area	MIN	Zone 8A	Existing Mines and mineral area	0.75	100.00	**0.75**	0.00
				Zone 8B	Potential areas for Mines and mineral	0.00	0.00		
9	Zone 9	Cultural and Archeological	CULARCH	Zone 9A	Existing cultural and archeological area	0.71	100.00	**0.71**	0.00
				Zone 9B	Potential cultural and archeological areas	0.00	0.00		
10	Zone 10	Riverine and Lake area	HYD	Zone 10A	Existing rivers and riverine area	551.04	100.00	**551.04**	3.57
				Zone 10B	Potential hydrographic areas	0.00	0.00		
11	Zone 11	Excavation area	EXC	Zone 11A	Existing quarrying and excavation area	0.00	0.00	0.00	0.00
				Zone 11B	Potential areas for quarrying and excavation	0.00	0.00		
Total						**15447.33**		**15447.33**	**100.00**

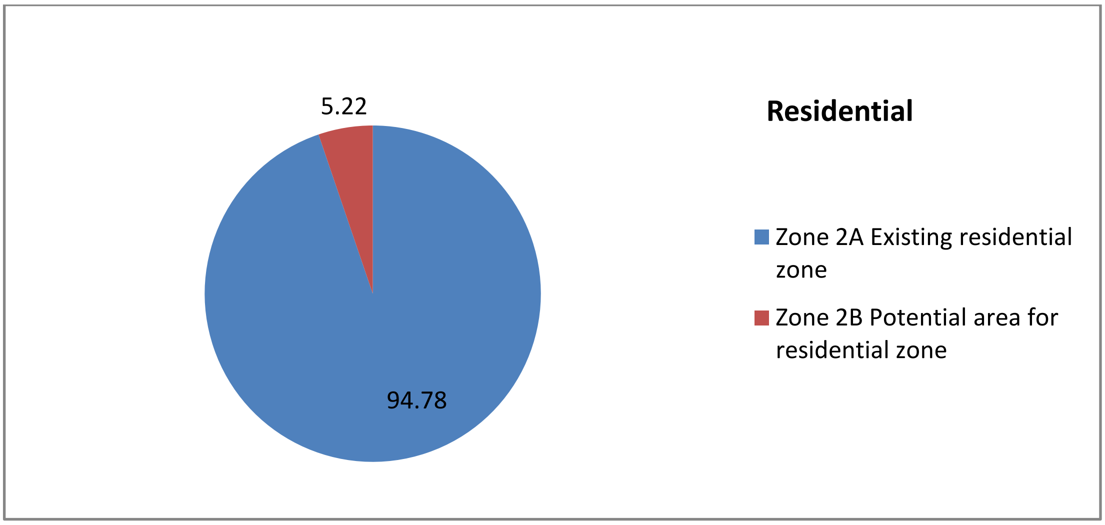
In this Suryodaya Nagarpalika, the agriculture zone was proposed for almost89% areas of the Nagarpalika followed by forestzone with about5% of the Nagarpalika extent.Similarly, theresidential, Public service area, riverine& lake area, and commercial land zone with 3%, 2%, 1% and 0.3% respectively of the Nagarpalika extent. The industrialand cultural& archeological zone has in small extent. The mines and mineral zone, excavation area and other zone do not exist however, some river banks are being used to excavate sands and stones informally.



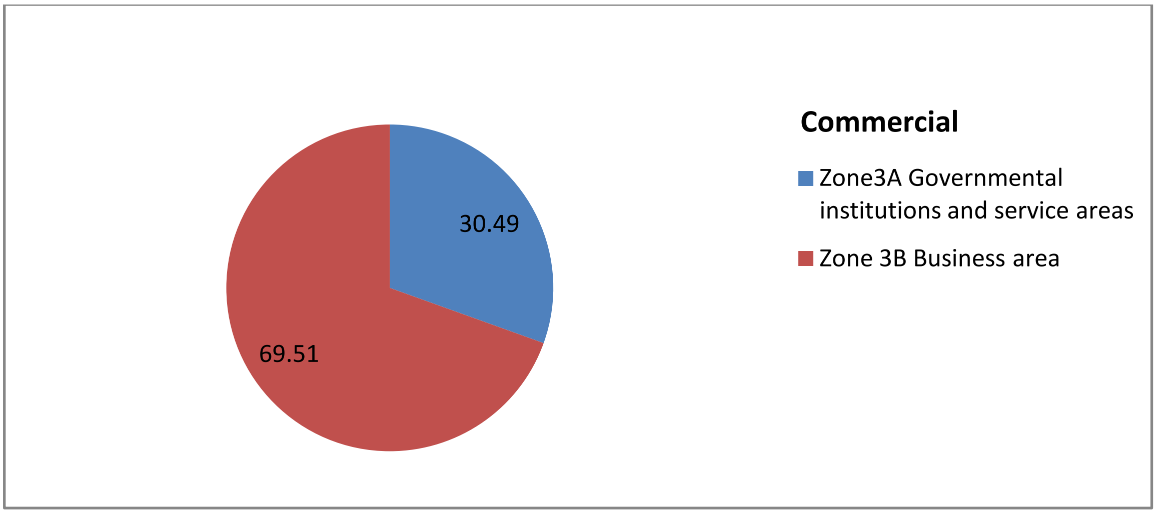
Land Use Zoning
1.06%
0.03%
0.02%
0.003%
2.62%
2.13%
5.35%
88.79%
Agriculture
Forest
Residential
Public Service
Riverine and Lake Area
Commercial
Industrial
Cultural and Archeological

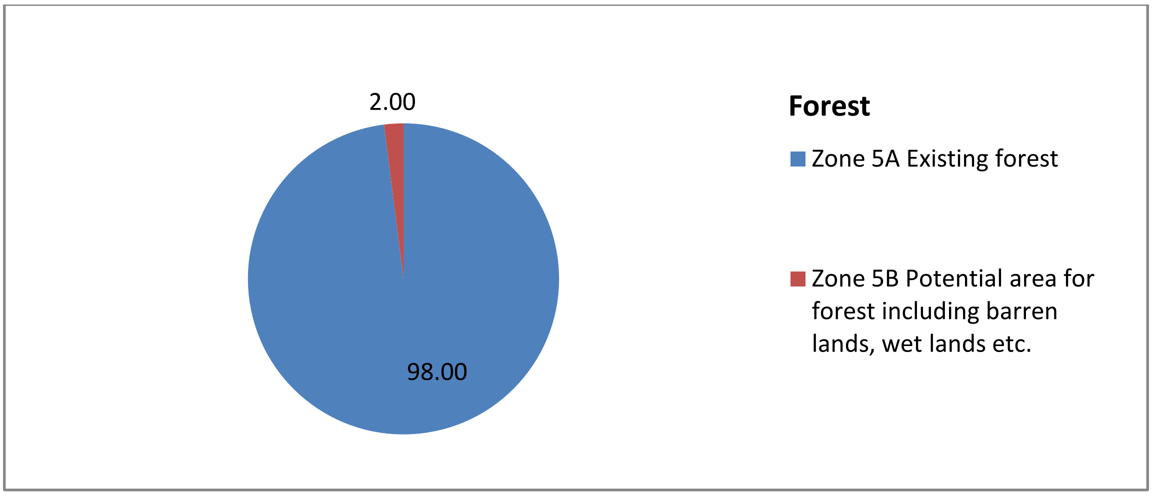


Agriculture
0.00%
0.27%
19.44%
19.99%
60.30%
Zone 1A Cereal crop production area
Zone 1B Cash crop area
Zone 1C Horticulture area
Zone 1D Animal husbandry area
Zone 1E Fish farming area
Zone 1F Agro forestry area



5.22
94.78
Residential
Zone 2A Existing residential zone
Zone 2B Potential area for residential zone





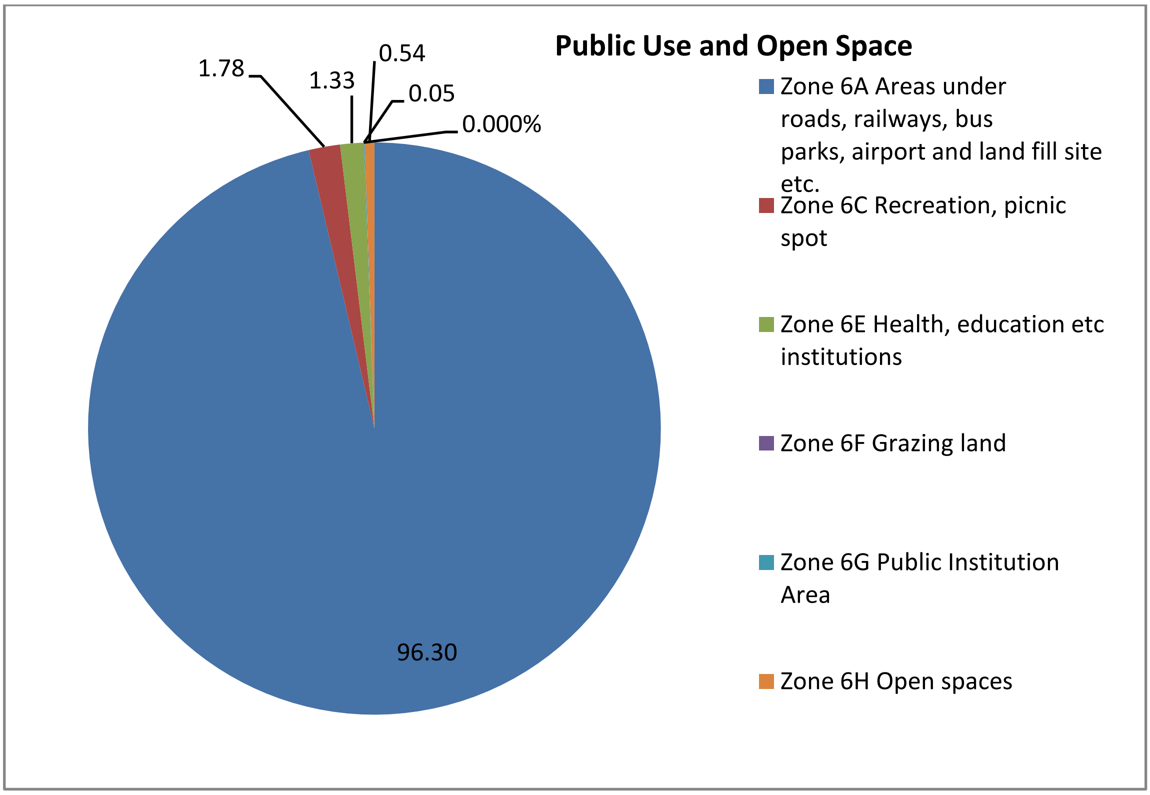


Figure 3.2: Details of Land Use Zoning of Suryodaya Nagarpalika

3.5. Discussion

In the present zoning, areas under agriculturezone aredominant followed by forest, residential, publicuse and open space area andriverine &lake area. Phikkal, Pashupatinagar are newly emerging urban centers in the Ilam district. Industrial areaand Cultural and archeological areas are not in significant scale. The, Mines and mineral sites, Excavation area andundersigned other land use site do not exists however, some river banks are being used to excavate sands ad stones informally, which is not mentioned here in this study.

The decrease in agricultural area is due to the allocation of new sites and areas for residential, commercialand industrial use together withthe proposefor new forest within the high risk of landslide, flood, bank cutting, erosion and flooding. Most of the agriculture land in the Nagarpalika has land capability of class III which has used for major agriculture production. To allocate agricultural land for new residential and commercial area, land capability data were analyzed and suitability analysis was done. Land of marginal utilization with low capability of agricultural production is allocated for residential, commercial and industrialarea as far as possible.In exception case, only residential and commercial area was allocated at high fertile arable land.Mainly, residential area was allocated at the surrounding residential and infrastructure developed area. Open area and greenery area will be not purposed separately, it will be included in purposed residential area which will be planned separately in physical development plan and land use plan by local authority. Similarly, the commercial area was allocated at the main core business area in existing residential extent and high possible of economic activities along major road junction, highly development of available commercial infrastructure.

According to the CBS data, the rate of population growth is almost 0.78 in this area. It has been observed that the present settlement has been developed gradually in last 40 years. But in last 10 years, the rate of urbanization is increasing moderately. The main reason behind this is internal migration from the hilly region to this area, foreign employment, increasing social trend to small family. Therefore, significant growth can be seen in the residential zoning because of the high population growth.

This area is moderately urbanizing in hill area mostly along the Mechi Highway and with high economic and commercial activities. There are many growing markets e.g. Phikkal and Pashupatinagar where commercial activities take place. These areas have a mixed type of use of residential and commercial purpose. This is the reason why the commercial area is shown relatively higher in proportion. Many new commercial and business area are proposed for future use.

Although most of the land is used in the agricultural activities, but the optimum utilization of land is not observed in the Nagarpalika. Most of the fertile land has been left uncultivated and barren after harvesting rice. The main reason behind this is pointed as lack of irrigation facility and working labor. The other reason is high cost of fertilizers, seeds and other production requirements. The benefit in comparison of investment is very low and therefore people do not adopt agriculture as primary occupation. This could be a very serious problem for food security in future and therefore the Government should identify appropriate solution to address the problem.

Regarding the agricultural crops, cereal crop is dominant agricultural production along with cash crops and horticulture in this area. Rice and wheat are the main cereal crops whereas tea, vegetable, oilseeds, corn etc are the major cash crops. Remarkable numbers of people have shown their interest to plant tea, Amriso, cardamom and other horticulture;and fish farming, animal husbandry is almost negligible.

Public use areas are not proposed explicitly. The reason behind this is the local need of people should be decided well by the local people. So it would be better to leave it for the local planer and local institutions. However, the residential area is allocated more than the population growth rate to accommodate future need of developing public use area as well.

The area is mostly safe for human settlement. As the area is hill risk of landslide occurs but flood doesn’t exist. Because of various rivers and streams, risk of flooding, inundation and bank cutting exist, but it is also not much severe. But many houses are made of woods and other inflammable material, therefore, the risk of fire outburst exists in some areas.

CHAPTER 4: LAND USE ZONES OF THE STUDY AREA

4.1. Risk Areas within the study area

There is no much risk for human activities in this area. The most prominent risk observes in this area is because of flood in rainy season. There are several rivers and stream which may cause destruction of human life and their livelihood. As the study area is in Hilly area, the risk of landslide is present but doesn't the risk of flood. However, bank cutting and erosion of fertile land has been observed.

To identify such flood prone area and the extent of flood, flood modeling has been carried out. The flood prone area has been classified as high, medium and low risk areas for flooding. The high and medium risky area has not been allocated to those land use zones which may have higher human interactions such as residential, commercial and industrial area. These areas are proposed to forest and plantation to reduce the impact of flood and low casualty of human livelihood in case of such event in future. The area with low flood risk is allocated for agricultural activity as it has.

Similarly, the other risk in the study area is air pollution created by industries, mainly the brick factories. The other risk in the area is because of fire spreading in summer by forest fire. In some rural settlement, some houses are made of wood and other combustible materials. These houses are in cluster and attached to each other. Further, many of the households used to store fuel woods, straw and other inflammable material inside or adjoining to houses for daily use. In this situation, if one of the house or surrounding catches fire accidently, there is a huge risk of spreading fire all over the settlement.

The detailed description of risk and risk prone area in the study area is separately described and delineated in risk study.

4.2. Analysis of Present Land Use and Potential Land use Zone

The change in present land use and potential land use zone is described in Table 4.1

Table 4.1: Comparison of Present land use and Land use zoning

S. N.	Description	Land Use Area (ha)	Percentage	Land Use Zone Area (ha)	Percentage	Change (ha)	Rate of Change (ha)
1	Forest	1176.13	5.24	1200.121	5.35	23.99	2.04
2	Agriculture	20008.89	89.17	19922.33	88.79	-86.56	-0.43
3	Riverine and Lake Area	238.89	1.06	238.8946	1.06	0.00	0.00
4	Residential	575.95	2.57	587.9132	2.62	11.96	2.08
5	Public Use and Open Space	405.79	1.81	476.8792	2.13	71.09	17.52
6	Other	24.03	0.11	0.00	0.00	-24.03	-100.00
7	Commercial	4.15	0.02	7.820726	0.03	3.67	88.63
8	Cultural and Archeological	0.81	0.00	0.75676	0.003	-0.05	-6.52
9	Industrial	3.92	0.02	3.848456	0.02	-0.08	-1.93
	Grand Total	**22438.57**	**100.00**	**22438.57**	**100.00**	**0.00**	

Source: Field Survey -2018

In the present zoning, areas under agriculture zone are dominant followed by forestarea, residentialarea, public use and open space area, riverine &lake area; and. Commercial area is also remarkable as this Nagarpalika has fast growing peri-urban area. The Industrial andCultural and archeological areas are not in significant scale. Mines and mineral sites, Excavation area and undersigned other land use site do not exists however, some river banks are being used to excavate sands ad stones informally, which is not mentioned here in this study.

The decrease in agricultural area is due to the allocation of new sites and areas for residential, commercialandpublic use and openspace areause together withthe proposefor new forest within the high risk of landslide, bank cutting, erosion and flooding. Most of the agriculture land in the Nagarpalikahas land capability of class I which has used for major agriculture production. To allocate agricultural land for new residential and commercial area, land capability data were analyzed and suitability analysis was done. Land of marginal utilization with low capability of agricultural production is allocated for residential, commercial and industrialarea as far as possible.In exception case, only residential and commercial area was allocated at high fertile arable land. Mainly, residential area was allocated at the surrounding residential and infrastructure developed area. Open area and greenery area will be not purposed separately, it will be included in purposed residential area which will be planned separately in physical development plan and land use plan by local authority. Similarly, the commercial area was allocated at the main core business area in existing residential extent and high possible of economic activities along major road junction, highly development of available commercial infrastructure.

4.3. Analysis of Safe settlement areas and Open Areas

Existing settlement in the area are mostly safe. However, some settlements or individual houses lies in the flood prone area and within the risk of industrial pollution. In this study, this area which has under potential hazard has been shown in the risk map.

According to the CBS data, the rate of population growth is almost 0.78 in this area. It has been observed that the present settlement has been developed gradually in last 40 years. But in last 10 years, the rate of urbanization is increasing rapidly. The main reason behind this is internal migration from the hillyregion to this area, foreign employment, increasing social trend to small family. Therefore, significant growth can be seen in the residential zoning although the rate of population growth is not so much high. This area is moderately urbanization with high economic and commercial activities. There are growing markets where commercial activities take place. These areas have a mixed type of use of residential and commercial purpose. This is the reason why the commercial area is shown relatively higher in proportion. Some new commercial and business area are proposed for future use.

The potential residential areas for future settlement are proposed after thorough study of possible hazards in the area. New settlements are not proposed in flood prone area, area under industrial pollution and other risk. Therefore, the residential and commercial areas are almost at minimum risk. Because of the limitation of available techniques, the seismic hazard and its occurrences cannot be studied and couldn't be considered for proposing new settlement. However, geological stability is studied and considered.

4.4. Land Use Zone in the study area

The following land use zones are identified in this study area (in Table 4.2):

Table 4.2: Land use zone in the study area

S.N.	Description	Land Use Zone (ha)	Percentage
1	Agriculture	19922.33	88.79
2	Forest	1200.12	5.35
3	Residential	587.91	2.62
4	Public Service	476.88	2.13
5	Riverine and Lake Area	238.89	1.06
6	Commercial	7.82	0.03
7	Industrial	3.85	0.02
8	Cultural and Archeological	0.76	0.003
	Grand Total	**22438.57**	**100.00**

Source: Field Survey, 2018

The Excavation area, Mine and Mineral and the Other Zone are not identified in this area. The detailed description of land use zone in the study area has been provided in section 3.3.

4.5. Land Use Zoning GIS Database

The following database schema is used for preparation of GIS database (in Table 4.3):

Table 4.3: Database schema used for land use zoning

Field	Data Type	Description	Remarks
FID	Feature Id	Feature	
SHAPE	Geometry	Geometric Object type	
ID	Integer	Unique Object ID	
ZONE NO	String	Zone No	
ZONE TYPE	String	Zone type	
SUB ZONE TYPE	String	Subzone Type	
GAUNPALIKA/NAGARPALIKA	String	Gaunpalika/Nagarpalika Name	
DISTRICT	String	District Name	

CHAPTER 5: CONCLUSIONS

5.1. Conclusions

This Suryodaya Nagarpalika has the domination ofagriculture zone followed by the forest zone. Agricultural areas aremainly suitable for cereal crop production, along with cash crop and horticulture. Urbanization is increasing day by day hence the agricultural land is being used in this purpose moderately. Commercial activities are also increasing. Some existing industrial activities are occurring and chance of industrialization but difficult in topography, so industrial area has not proposed. Most of the fertile land has not been utilized as per its capacity because of various management reasons which could be a serious problem in future. This location is safe in general for residential purpose.

5.2. Recommendation

- Zoning criteria are subjective, which may lead to ambiguous zoning and inconsistency amongst different consultants.
- The land use in this Nagarpalikais still not deteriorated so far. Therefore, land use planning should be started on the basis of this study as soon as possible
- The implementation should be initiated through local government to address the local needs. Some of the local needs and aspiration could not be judged by this study as it lacks participation of the local people in each and every step. For example, the present exercise suggest for a health post in this Nagarpalika. However, the actual location should be ultimately finalized by the local people on the basis of available land and other circumstances.
- It is suggested to develop a micro zoning by the local government on the basis of this report/maps/database/document for further implementation.

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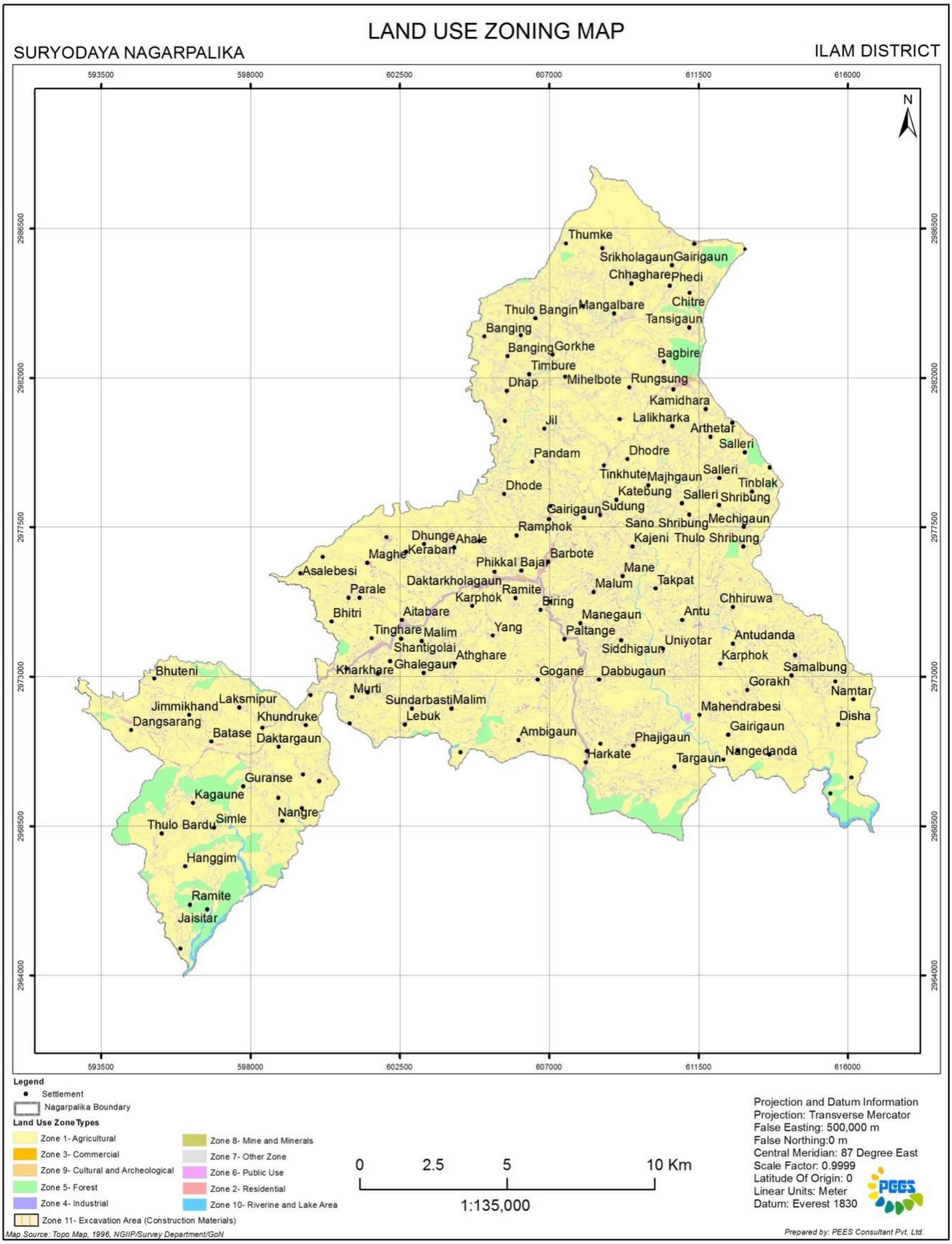
APPENDIX

Land Use Zoning Map of Suryodaya Nagarpalika



CADASTRAL SUPERIMPOSE REPORT

Preparation of Cadastral Superimpose Report
Suryodaya Nagarpalika, Ilam District

This document is the output of the project entitled **Preparation of Nagarpalika/Gaunpalika level Land Resource Maps (***Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps, Cadastral Layer Superimpose and Gaunpalika/Nagarpalika Profile***), Database and Reports (Package-4)** awarded to *PEES Consultant (P) Ltd.* by Government of Nepal/Ministry of Land Reform and Management, National Land Use Project (NLUP) in Fiscal Year 2074-075. The municipalities covered under the Package 04 of Ilam District are Rong Gaunpalika and Suryodaya Municipality of Ilam District.

The Gaunpalika areas analyzed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the Gaunpalika may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

ACKNOWLEDGEMENT

The PEES Consultant (P) Ltd. is highly obliged to National Land Use Project (NLUP), for awarding the project **Preparation of Nagarpalika/Gaunpalika level land resource maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and Nagarpalika/Gaunpalika Profile)**, database and reports, Package 4 of Ilam district**. The consultant and the team members would like to extend special thanks to **Mr. Prakash Joshi**, the Project Chief of NLUP, for the positive supports during the project period. Similarly, the consultant and the team members would also like to highly acknowledge the overall supports of **Mr. Sumeer Koirala,** Survey Officer. Likewise, the consultants would like to extend thanks to Mr. Rajan Kumar Phuyal, Account Officer, Survey Officer, Mr. Prakash Dulal, Mr. Karan Singh Rawal, Mr. Dipendra Khadka, Mr. Dharma Raj Dangi, Ms. Bandana Dev, Ms. Radhika Timalsina, Ms. Sarita Gautam and Madhu Maya Bhatta and Ms. Nutan Kumari Yadav for their supports during the project period.

The consultant and team members would like to thank the local people, members of the different political parties and staffs of the Nagarpalika/Gaunpalika and local institutions of Rong and Suryodaya Nagarpalika/Gaunpalika of Ilam District (Total 2 Nagarpalika/Gaunpalika) for providing their valuable time to the study team in discussing different aspects of the project. Without their support this work could not have been completed.

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List of Abbreviations

DGPS	Differential Global Positioning System
DEM	Digital Elevation Model
DOLIA	Department of Land Information and Archive
GCP	Ground Control Point
GIS	Geographical Information System
GoN	Government of Nepal
Ha	Area in hectare
Hqs	Headquarters
LRMP	Land Resources Mapping Project
MoLRM	Ministry of Land Reform and Management
MSS	Multispectral Scanner
NLUP	National Land Use Project
RS	Remote Sensing
Km	Kilometer
m	Meter
mm	Millimeter
RMSE	Root Mean Square Error

CHAPTER 1: INTRODUCTION

1.1. Background and Rationale

Background

Land is one of the important and precious natural resources of the earth surface. The demands for arable land, grazing, forestry, wildlife, tourism and urban development are greater than the land resources available. Hence, land use planning for making the best use of the limited land resources is inevitable. Land use planning is the systematic assessment of land and water potential, alternatives for land use and economic and social conditions in order to select and adopt the best land–use options (FAO, 1993).

The Government of Nepal has adopted the National Land Use Policy Baishak, 2069 B.S. with a vision to achieve sustainable social, economic and environmental development through optimum use of land and land resources. For this purpose it has assigned a goal to classify the whole land of the country in different classes (agricultural, residential, commercial, industrial, forests, public use and other designated) based upon the landscape characteristics, quality of soil, capacity, capability and needs. It has emphasized to prepare and implement a hierarchical land use plan within 10 years for the land use planning and implementation in the municipalities, districts and urbanizing Gaunpalika together with areas adjoining to major roads within 5 years. For this purpose a Land Use Management Department has been proposed, and the National Land Use Project will continue to carry out this function until such Department will be established.

Land use planning refers to a branch of public policy that encompasses various disciplines that seek to order and regulate the use of land. The Canadian Institute of Planners defines land use planning as:

“Land use planning means the scientific, aesthetic, and orderly disposition of land, resources, facilities and services with a view to securing the physical, economic and social efficiency, health and well-being of urban and rural communities” (CIP 2000).

Land use planning is a key function which includes long-range land use policy, growth management, capital budgeting and regulatory or implementation of planning process (Wehrmann, 2011). It generally involves zoning of appropriate types and forms of land uses, as well as infrastructure and open space planning directed at the efficient utilization of land in order to provide benefits to the broader population, the economy and the environment. Land use planning is an important aspect of regional planning, which also encompasses social and economic concerns. Except sporadic attempts for the urban areas (GoN, 2002), Nepal has not practiced land-use planning for the country as a whole, although attempts were made for balanced use of Country’s existing natural resources in the past through different policies and national planning efforts. The National Land Use Policy Baishak, 2069 B.S. envisages land-use planning to be applied at three broad levels: national, district and local Authority as Gaunpalika/Nagarpalika. Local level planning is about a detailed outline of getting things done on particular areas of land – what shall be done, where and when, and who will be responsible. It requires detail basic information about the land, the people and services at local level. The available data base on land use, land system and land capability produced by Land Resource Mapping Project (LRMP, 1986) could be useful as reference material for national and regional or district level planning. However, we need very detailed information for local level planning at the Gaunpalika/Nagarpalika level. Use of present day geo-information technology like satellite remote sensing (RS) and the Geographic Information System (GIS) can be helpful in acquiring spatial/temporal data, and preparing different thematic digital data base like current land use at this level. These spatial databases together with data on different land characteristics collected from the field survey and secondary sources are used to prepare land use zoning maps at local Gaunpalika/Nagarpalika level.

Sustainable land use planning requires recognition of the limitations of the biosphere and the need for a balance of social, cultural and economic uses within these natural limitations (Chalifour, 2007). Land use planning is fundamentally related to sustainability planning, which integrates five dimensions of sustainability: social, cultural, environmental, economic, and governance. When implementing at the bottom level administrative level, local people has involved in land use planning process towards sustainability. Sustainability initiatives that make economic sense today and that logically move the community towards a future of social inclusiveness, cultural vibrancy, environmental stewardship and strong governance practices. Practical aspects of sustainability planning include (among others) growth management, housing choice and affordability, and inter-jurisdictional coordination. The land use practice has a direct impact on environment, ecology and other socio-economic factors.

Land use planning can be applied at three broad levels: national, district and local. Local level planning is about getting things done on particular areas of land – what shall be done, where and when, and who will be responsible. It requires detail basic information about the land, the people and services at local level. Except sporadic attempts for the urban areas (GoN, 2002), Nepal has not practiced land use planning for the country as a whole, although attempts were made for balanced use of country's existing natural resources in the past through different policies and national planning efforts.

Nepal has only regional level database on land use, land system and land capability which were produced by Land Resource Mapping Project (**LRMP**, 1986). Realizing this fact, the Ministry of Land Reform and Management, Government of Nepal established the **National Land Use Project** (**NLUP**) in 2057/058 fiscal year to generate the necessary database on the land resources of the country. In the first phase, the National Land Use Project of Nepal had initiated several projects at district level and prepared **Land Resource Maps and Database** at 1:50,000 scale for the whole Nepal. It had also prepared same kinds of maps and database for Kirtipur, Lekhnath, Madhyapur Thimi and Bhaktapur municipalities at larger scales. Finally, NLUP was mandated to prepare land resource maps of VDC/Municipality (now Gaunpalika/Nagarpalika) of Nepal for local level planning through outsourcing modality. Up to 2068/069 fiscal years, NLUP has completed preparation of land resource maps and database for all VDCs/Municipality of Chitwan and Nawalparasi district and one VDC/Municipality each for Kavre (Panchkhal) and Tanahu (Anbu Khaireni) District as well. These digital databases include VDC/Municipality level present land use, soil, land capability, land use zoning, cadastral layers and VDC/Municipality profile with bio-physical and socio-economic database.

On the 4th Baishakh of 2069, the Government of Nepal has approved the National Land Use Policy, 2069. Recently, this policy was modified by amendment in 2072 and introduced Land Use Policy, 2072. It has intended to manage land use according to land use zoning policy of the government of Nepal and outlined eleven zones such as **Agricultural area, Residential area, Commercial area, Industrial area, Mining and Mineral area, Cultural and Archaeological area, Riverine and Lake area, Excavation area, Forest area, Public Use area and Others**. The policy has defined the respective zones as per the land characteristics, capability and requirement of the lands. Further, for the effective implementation of land use zones in the country, the Land Use Policy, 2072 has clearly directed for an institutional set up of Land Use Council at the top to the District level and Gaunpalika/Nagarpalika level at the bottom. It has added further importance to the NLUP projects on preparation of Gaunpalika/Nagarpalika level maps and database.

In the context stated above, the NLUP in the Fiscal Year 2074-075 has commissioned PEES Engineering Consultant P. Ltd to carry out the project entitled "Preparation of Gaunpalika/Nagarpalika level land resource maps (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and Gaunpalika/Nagarpalika Profile), database and reports" for Package 04 of Ilam District. The Gaunpalika/Nagarpalika covered under the Package 04 is Suryodaya Nagarpalika and Rong Gaunpalika of Ilam District.

Rational of the Study

The rationale for the preparation of Gaunpalika/Nagarpalika level superimposition of cadastral maps on land use and land use zoning maps by NLUP are to identify individual parcels according to present land use and proposed land use. For all land related decision making, land ownership and land tenure information provides essential ingredient. The implementation of land use plan cannot succeed without the active and positive support of the individual land owners. Therefore, the main rationale of superimposition of cadastral maps on land use and land use zoning maps is to support in the formulation and implementation of land use plans and land use zoning policy within the Gaunpalika/Nagarpalika.

More specifically, this information is necessary for the following:

- Delineation of land parcels according to land use zoning viz. Agricultural area, Residential area, Commercial area, Industrial area, Mining and Mineral area, Cultural and Archaeological area, River, Lake and Water bodies area, Excavation area, Forest area, Public Use area and Others.
- Classification of land parcels for the purpose of non-agricultural land uses.
- Delineation of the areas for conservation of forest, shrubs/herbs, river, wetlands for achieving environmental balance.
- Sub-classification of agricultural land parcels into optimum production sub-areas based on soil characteristics, land capability, irrigated and potential irrigable areas to increase the productivity of the land.

- Preparation of Gaunpalika/Nagarpalika level data base and maps using GIS for the implementation of Gaunpalika/Nagarpalika land use plan.
- Management of land resources on the basis of land characteristics as well as the conceived policy of the government.

Objective and Scope of the Study

1.2. Objectives

The broad objective of National Land Use Project (2074/075) is to prepare Gaunpalika/Nagarpalika Level Land Resource Maps, Database and Reports for Package 04 of Ilam District of Nepal. The specific objective of the present study is to prepare maps of Cadastral Layer Superimpose on Land Use Zone Map, GIS database and Reports for the **Suryodaya Nagarpalika** of Ilam district at 1:10,000 scales.

Scope of the Study

Scope of this study includes the following activities:

- Collect and prepare cadastral geo-database from existing cadastral map.
- Collect land use zoning maps and present land use maps at 1:10,000 scale
- Overlay of cadastral layer on present land use and land use zoning and prepare cadastral superimposed map at 1:10,000 scale.
- Classify the cadastral parcels according to present land use and land use zoning.
- Maintain GIS database on cadastral parcels with zoning characteristics and current land use as per the specification provided by NLUP.
- Analyze the accuracy, reliability and consistencies of data, and
- Report describing methodology, distribution of cadastral layers as per land use zones and present land use, and model of GIS database.

1.3. Study Area

Suryodaya Nagarpalika, name being the Nepali translation of “Rising Sun” declared municipality status in 2013 (2070 BS), with the merged of three Village Development Committees (VDCs) namely: Phikkal, Panchakanya and Kanyam. After, the restructuring of local body in 2073 BS, Gorkhey, Pashupatinagar, Sriantu, Samalbung, Laxmipur and Jogmai ward no. 8 and 9 were also merged into the municipality. It is located in Ilam district, province no. 1, approximately 40 km south-east of the district headquarter Ilam. Geographically, it lies in the hill region which is mostly known as Mahabharat range with natural scenery and pleasant weather. Its geographical coordinates are 87°55'59" to 88°10'37" east longitude and 27°0'28" to 26°47'17" north latitude. The Municipality is bordered with India on the east, Ilam Nagarpalika and Maijogmai Gaunpalika on the west, Maijogmai Gaunpalika on the north and Rong Gaunpalika on the south (Figure 1.1). Phikkal is the center of the Nagarpalika. The total area of the Nagarpalika is 22438.57 ha. This is extended north-south 25.29 km and east-west with 24.71 km.

The inhabitants are believed to have been living in this Nagarpalika since ancient time. According to the Population Census of 2011, the total population of this Nagarpalika was 56,707 and the numbers of households were 13,211. This gives an average household size of 4.3 which is lower than the national average (4.88). Administratively, the Nagarpalika has been divided into 14 wards. Ward 1 is the largest in terms of population size whereas ward 7 is the smallest one.

The Nagarpalika has diversity both in its physical and cultural aspects. It is a business hub of Ilam with beautiful landscapes. Tea, ginger, *Amriso,* cardamom, round chilies (*Akabare Khursani)*, milk and potatoes are the major trade items of this Nagarpalika. The Nagarpalika has grate possibility for the tourism. Kanyam, Pashupatinagar, Phikkal, and Sri Antu are famous for tourist destination sites. Rai, Brahmin, Chhetri and Tamang are major ethnic group inhabited in the Nagarpalika.

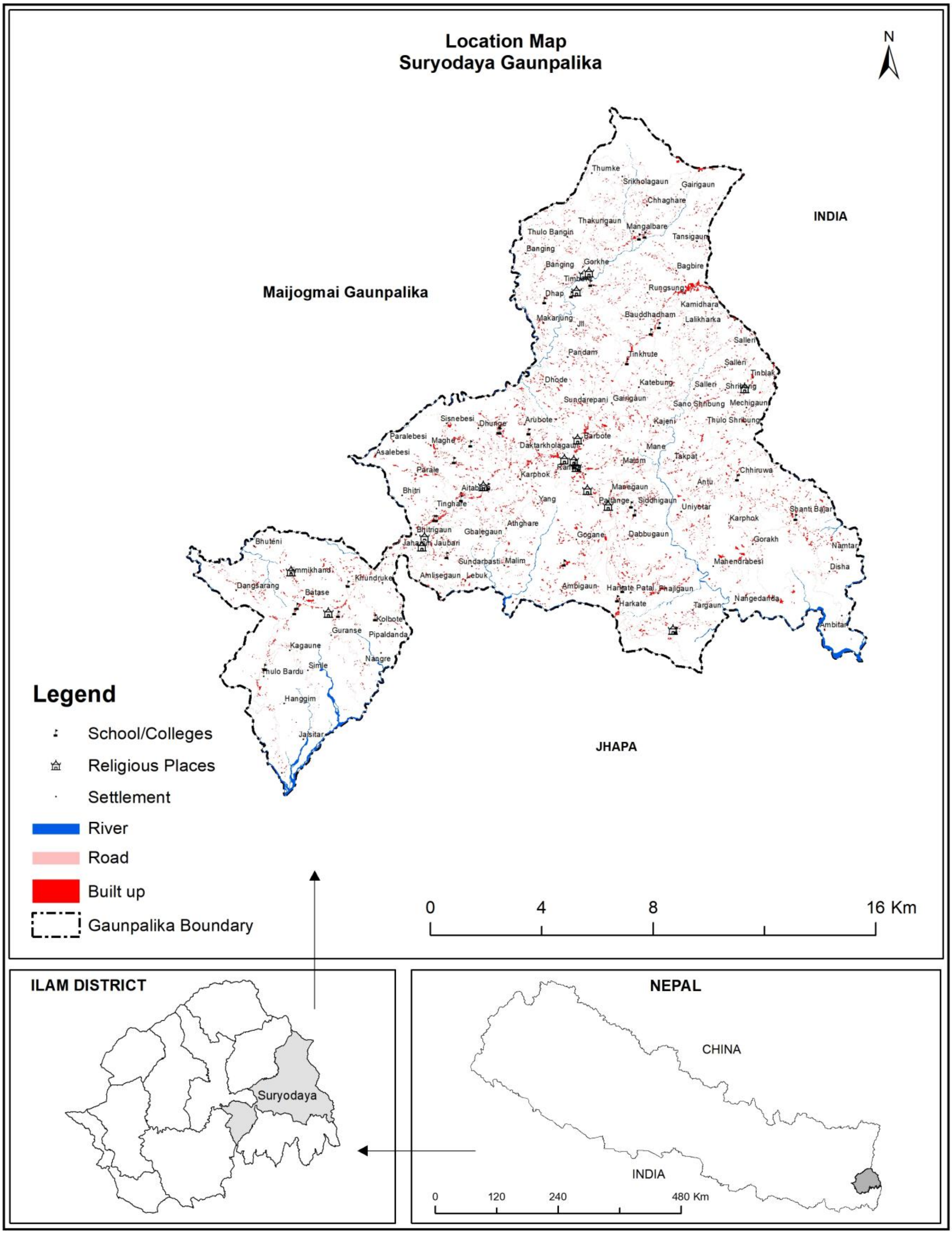

Figure 1.1 Location Map of Suryodaya Nagarpalika

CHAPTER 2: CONCEPTUAL BASIS OF SUPERIMPOSE OF CADASTRAL LAYER

This chapter describes the conceptual basis behind the superimposing of cadastral layer on land use zoning map.

2.1. Concepts

The superimposing of the land use zoning in cadastral layer is useful for implementation the national land use policy at the local level (Gaunpalika/Nagarpalika) of the country. This will provide information regarding the proposed land use directly in relation with the land owner, its tenant, current land use and the shape and size of the individual parcel. It will subsequently relate the concerned land owner with the country wide property information. Therefore, the local governments can develop a comprehensive plan and administer the land use regulations as per the standards for planning set by national government. A local comprehensive plan of cadastral layer guides a community's land use, conservation of natural resources, economic development, and related public services. For this, it needs several databases: with a cadastral layer as base information together with the existing land use and a land use zoning layer.

Cadastral map is defined as "the outlines of the property and the parcel identifier normally are shown on large scale maps, which together with registers, may show for each separate property the nature, size, value and legal rights associated with the parcel" (Dooley,1985). The cadastral map should be defined as the outline of parcels or pieces of land which constitute the units of the land recorded whatever the purpose of the land may be. Generally, cadastral maps are prepared based on the ground survey either with plane table or total station, and/or interpretation of ortho-photo prepared from stereo pairs of aerial photograph or high resolution satellite imageries. The cadastral map at all times should show the real situation, shape and size of each and every individual land parcel within the area with complete accuracy and adequacy. Cadastral maps are dynamic; they must reflect the changes in the cadastral framework arising from land development and land fragmentation.

In Nepal, a systematic cadastral survey was carried since B.S. 2021 using the plane tabling techniques at the scales of 1:2400 and 1:4800 in the beginning, but later shifted to 1:2500, 1:1250 and 1:500 depending upon the size and density of the parcels. The district survey offices maintain the mutations of each parcel upon fragmentation due to transactions. Though the accuracy of plane tabling survey cannot be considered too high, it is more than enough here since the superimposition is carried out at the 1:10,000 scales. The digital data provided by NLUP is from the digitization of the existing up to date maps from the DOLIA at the date of digitization. Though with the passage of time some of the parcels may have been outdated at the time of implementation, the parcel history available at the Survey Office may be linked to update such information when needed.

Land use maps are those types of map which provide information about current and or proposed land use of any area. There are a number of different applications for such maps, and in many nations, land use maps are prepared by several government agencies, for a variety of reasons. Individual groups and organizations can also generate maps with land use information. Often, such maps are publicly available, so that people who are interested in land use trends can access them.

One form of land use map is a zoning map. Zoning maps are used to mark out areas designated for specific types of land use, so that people developing land know which kinds of uses are allowed by land use regulations in a particular area. The creation of zoning maps is a part of the overall process of community planning, in which communities decide how they want to develop their land and vicinity in the future. Zoning decisions can include things like setting aside green space, isolating industrial land, and so forth. Another type of land use map is a map which shows utilization. Utilization maps are often used in zoning decisions to determine whether or not zoning changes need to be made. Utilization land use maps show how land is being used, and may also indicate historic utilization information, and provide information about how long land has been developed. Utilization maps can be very detailed and tremendously useful. They can highlight a variety of activities, including farming, mining, residential use, light industrial area, heavy industrial area, waste storage, and so forth so that people get a clear visual impression of how land in a particular area covered by the map is being used. Utilization land use maps can also be important from a development perspective because they provide data about historical use; land used for a tannery, for example, might not be a great place for a residential development.

Land use maps, records, and archives are maintained by competent authorities as a coherent record. Researchers who want to study land use or the history of a region can access these archives, as can developers who want to know more about their land use options, and government officials who monitor land use. These maps can become important in zoning and property disputes, as people may be able to use them to prove or argue their case.

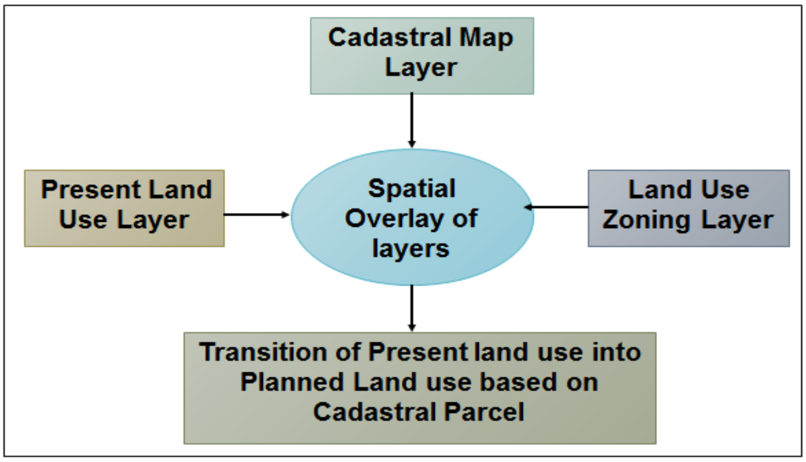

Figure 2.1: Spatial Function Related to Spatial Databases

2.2. Spatial Function related to Spatial Database

The overlay process of two spatial data layers (cadastral and zoning map) having same reference system facilitates to prepare a composite map and data bases (Figure 2.1). It leads to generate a new set of polygons that explain the relations between the two inputs of spatial data (land use zone class and parcel id). The overlay of seamless cadastral map layer and present land use map provides information on which parcel belongs to which present land use. Similarly, the overlay of cadastral layer over proposed zoning map provides information on proposed use of the particular parcel. The overlay function provides information on the proposed change of parcel wise use, and also provides a summary on the overall change in land use anticipated upon the implementation of the land use zoning.

2.3. Attribute Data Management

The connections between graphical and alphanumerical database is based on the use of a GIS internal table as a linkage with other tables in external databases. These data are usually managed by a relational database management system (RDBMS). The procedures are based in the connection of each graphical element to a line of column of the alphanumerical table containing its attributes. The attribute table used for superimposing land use zoning map on cadastral layers are prepared and managed in GIS environment.

CHAPTER 3: METHODOLOGY

Superimposing cadastral parcels on the land use and land use zoning enable land use classification and zoning at parcel level required for micro planning of land based resources in the smallest unit of administrative division i.e. Gaunpalika/Nagarpalika level. For the preparation of the cadastral layer to be superimposed on land use and land use zoning maps of the project areas, the following methodological approach was adopted. The method adapted to superimpose cadastral parcel on land use zoning map for the prescribed Suryodaya Nagarpalika area is shown in Figure 3.1.

3.1. Acquisition of Cadastral Maps

The original source of cadastral data for the Suryodaya Nagarpalika of Ilam district was the Survey Office who maintains the original cadastral maps and records, and those cadastral maps were digitalized by DOLIA and stored as sheet wise geo-database. This was made available to the project/ NLUP for this exercise. NLUP has provided digital copies of island cadastral maps in vector format together with the attribute database. The data thus obtained were not synchronized with national reference frame. The data were based on the digitization of related cadastral maps available with the Survey Office and current to the date of digitization by DOLIA.

The present land use and land use zoning maps for the study area were prepared by PEES Engineering Consultant (P) Ltd. under the separate components of the project as per the TOR. The land use zoning map of the Nagarpalika is based on the categories of Land Use Policy, 2072 of Government of Nepal.

3.2. Scanning

Although a digital cadastral database was made available in compatible data format by NLUP, some digital cadastral maps were missing. Therefore, the consultant visited the District Survey Office, Ilam and collected the Ammonia Print of the missing cadastral maps. These collected ammonia print of cadastral maps were scanned in 300dpi with large format scanner with high radiometric quality.

3.3. Geo-referencing of Cadastral Data

As sheet wise free-sheet digital cadastral database was available for the project there was necessity of geo-rectification. The geo-rectification process makes the cadastral maps geometrically oriented and corrected to ground scale as well as to the national reference frame. The geo-rectification of free sheets of digital cadastral database and scanned cadastral images was carried out with the help of ortho-rectified satellite image of the project area. Geo-referencing is the process of aligning cadastral parcel maps on to the geometrically oriented and corrected to ground scale and in terms of national reference frame. As the cadastral vector data obtained from NLUP were not geo-referenced in national reference frame, the following method was applied. The details of ortho-rectification are given in Land Use Report.

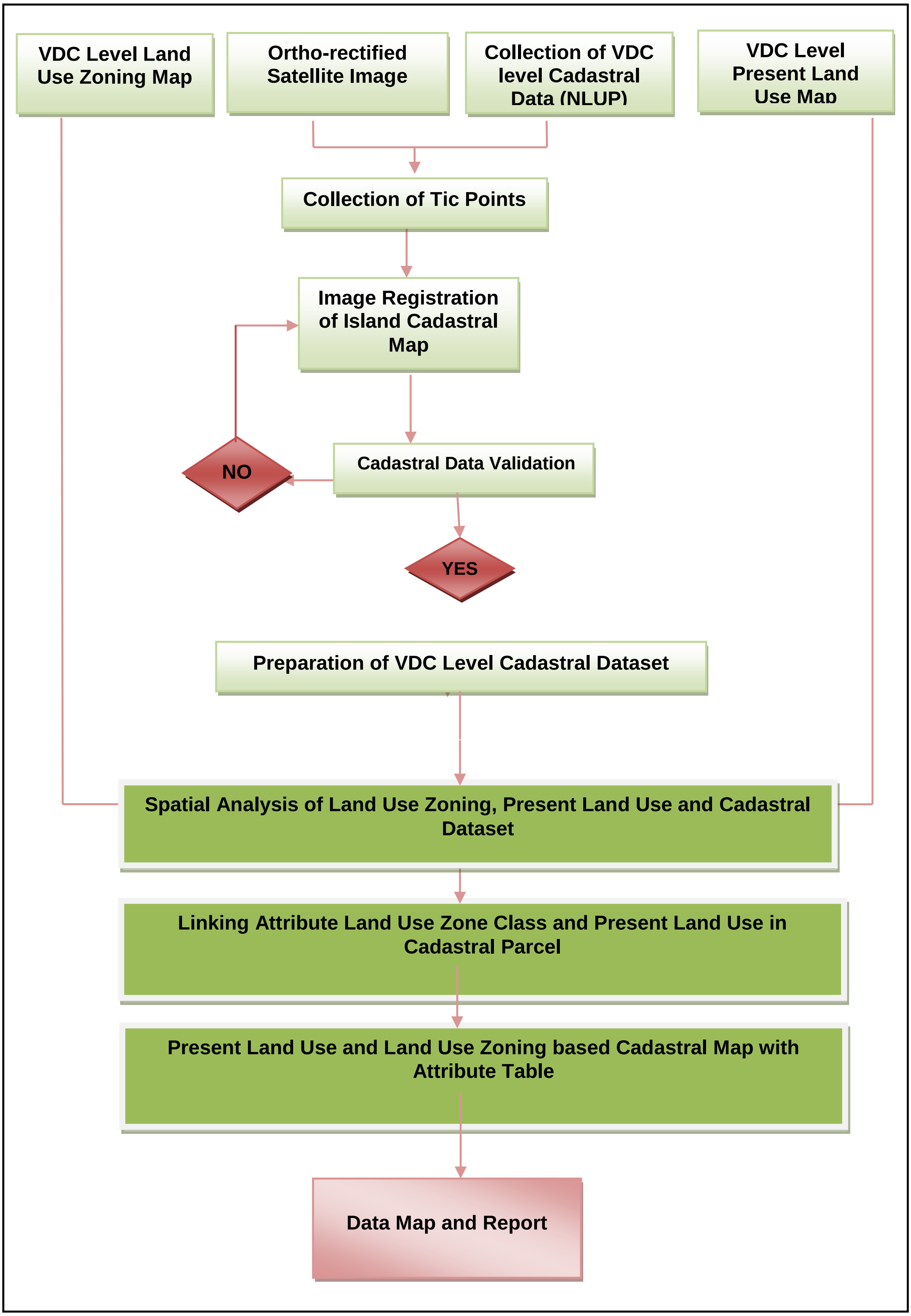

Figure 3.1: Schematic Diagram of Methods Adopted

- A team of surveyors visited project areas for carrying out survey of Tic Points

The geo-referencing was carried out matching the sharply identifiable common points (Tic Points) in the cadastral map and the ortho-rectified image map. Geo-correction of vector layer of cadastral data need Tic Points at least on the four corners of the map sheet, however, to maintain the accuracy, and ensure even distribution of errors, 16 to 20 Tic Points in one cadastral map sheet were used for geo-referencing. A 3rd degree polynomial transformation was applied for rectification of the vector layer of cadastral dataset after assigning the required Tic Points. Due to larger errors in source data, mainly due to the method of plane tabling using limited local controls, some of the cadastral maps still were not free of overlapping and gap errors even after affine rectification. However, this has limited consequence due to the scale of end product (1:10,000). Moreover, the gaps and overlaps occurred in the margin of separate cadastral map sheets which were generally road, stream, and jungle/unsurveyed public land in some other cases. Accuracy of individual cadastral map sheet transformation has been assessed and an error report has been generated.

Details of national reference system coordinate used are presented in table 3.1.

Table 3.1: Projection Parameters Adopted

Projection	**Modified Universal Transverse Mercator**
Spheroid	**Everest 1830 (Adjustment 1937)**
Semi-Major axis	**a=6377276.345m**
Semi-Minor axis	**b=6356075.413**
1/f	**300.8017**
Central Meridian	**87^{o} E, 0^{o} N**
False Coordinate	**500,000 m E, 0 m N**
Scale Factor at Central Meridian	**0.9999**

Some of the constraints the consultant faced during the rectification process are listed below:-

- Very difficult to find easily identifiable ground control points corresponding to the distinct features
- Adjacent sheets are difficult to match and create problem to get seamless mosaics even after polynomial, similarity transformation or triangulation.

Geo-referencing and matching with the ortho-rectified images provides a common geodetic framework for all related maps and therefore; provide a common basis for overlay and other GIS operation functions.

3.4. Digitization and Preparation of Digital data

Scanned cadastral maps were digitized to convert analogue format into digital format of cadastral datasets. These datasets were stored as sheet-wise cadastral geo-database in .gdb format. These geo-database has used for preparation of seamless cadastral database of Ward or Gaunpalika/Nagarpalika. The complete digital vector cadastral data set is shown in Figure 3.2.

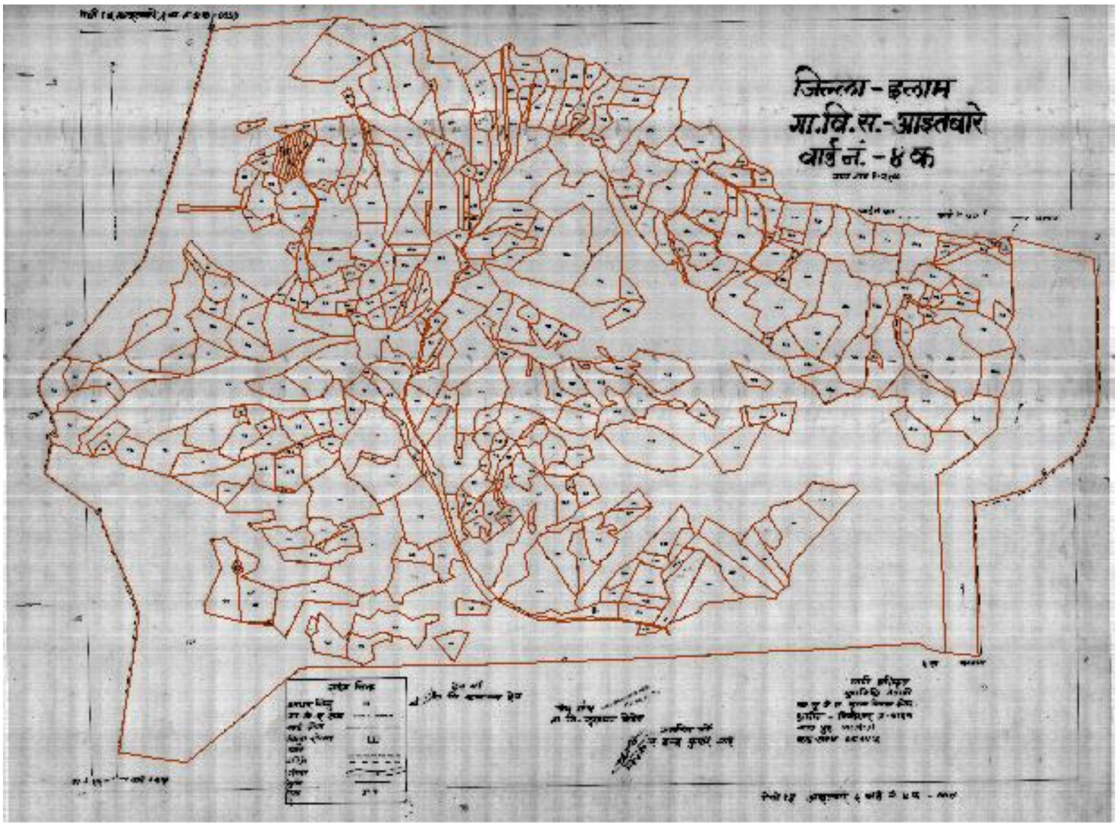

Figure 3.2: Vector Cadastral Layer overlaid on Scan Image

The transformed cadastral vector layer overlaid on ortho-rectified satellite image is shown in Figure 3.3.

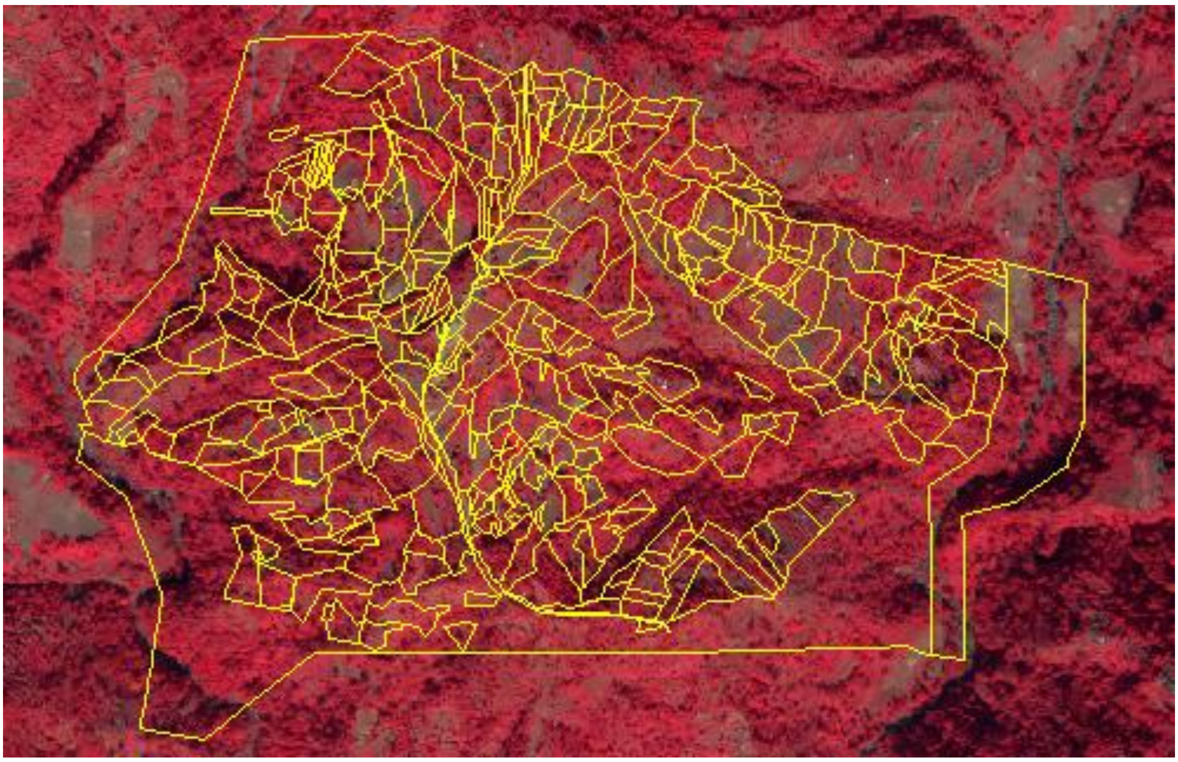

Figure 3.3: Vector Cadastral Layer overlaid on Ortho-rectified Satellite Image

3.5. Preparation of Nagarpalika level Seamless Cadastral Dataset

A ward level and subsequently Nagarpalika level seamless cadastral datasets was prepared by spatial analysis process of merging of different geo-reference cadastral map sheets in GIS environment. An error of overlapping and gap between individual cadastral map sheets was noticed during the spatial merging process; however, those errors were eliminated with building topology within the permissible limit of threshold already assigned. In extreme cases as already explained such gaps or overlaps were assigned at the margin of free sheets falling in river or other un-surveyed areas.

3.6. Superimpose of Nagarpalika Level Seamless Cadastral Dataset on Land Use Zoning Map

Spatial Analysis of land use zoning map and cadastral dataset was carried out by overlaying Nagarpalika level land use zoning map on cadastral datasets of the same area and level using spatial analysis function in GIS environment. This was possible since all datasets were on the same geo-reference frame. During overlay process, caution was taken to maintain different topology functions viz.

- Topology function must not overlap
- Topology function must not intersect
- Topology function must not contained

3.7. Spatial Linking Attribute of Land Use Zoning and Present Land Use with Cadastral Parcel

Land use zoning map is linked with seamless cadastral datasets by the process of querying in the attribute table of Nagarpalika level cadastral datasets and land use zoning class datasets. Geographic objects in a vector map were linked to one or more tables. A link defines driver database to be used. Each parcel category number in a geometry file corresponds to a row in the attribute table. The practical use of this system is that it allows placement of thematically distinct but topologically related objects on a single map. Further, the table can be linked to subsequent layers.

CHAPTER 4: CHARACTERISTICS OF THE SUPERIMPOSE OF CADASTRAL PARCEL

The chapter four illustrates some analysis of the superimposition of cadastral maps over the present land use and the land use zoning map. Some details on the suitable conversion upon comparison of zoning map with the present land use with respected to surveyed cadastral plans are as well provided. Some analysis of the superimposition of cadastral maps over the present land use and the land use zoning map is provided here. Some details on the suitable conversion upon comparison of zoning map with the present land use with respected to surveyed cadastral plans are as well provided. Cadastral Survey in Ilam district was carried out during 2024-2028 B.S. Due to lack of a land use zoning regulations the parcel size and use have undergone random conversions over the years. Similarly, due to the lack of strict regularizations on maintenance of public and government land some changes have undergone in their uses as well. Accuracy of the original plane table survey should as well be considered while assessing on the figures on the database, however, this will have limited implications on the scale of the map 1:10,000. However, the Suryodaya Nagarpalika had 55167 land parcels and area covered in the survey was 18410 ha.

4.1. Cadastral Parcel Superimpose on Present Land Use

Table 4.1 shows the present characteristics of cadastral parcels that falls in Suryodaya Nagarpalika of Ilam district of Nepal. In the cadastral area of the Nagarpalika, out of the designated 11 classes, nine land use classes do exist excepting the Excavation area, and Mining and Mineral area land use classes. It is significant that there are only 3 land parcels for undersigned other land use class. The predominant land use was the agriculture land use that covers with a total of 16818 ha (91%) having 48616 land parcels out of the total 55167 land parcels in the Nagarpalika. The coverage of the residential land parcels covered 571 ha (3.1%) having 3811 land parcels. The coverage of the forest land parcels covered 570 ha (3.1%) having 717 land parcels. Similarly, the public service land parcels is significant of about 333 ha (1.8%) having 1634 land parcels. The coverage of the hydrographic feature such as riverine and lake area land parcels covered 102 ha (0.55%) having 291 land parcels. About 0.003% (0.51ha) area fall on the cultural and archeological land use class, which is as well significant. The distribution of land parcel on present land use is shown in Figure 4.1.

Table 4.1: Parcel Characteristics of Present Land Use

Present Land Use	No. of Parcel	Area (ha)	Percentage
Agriculture	48616	16817.64	91.35
Residential	3811	570.71	3.10
Forest	717	569.57	3.09
Public Use	1634	333.29	1.81
Riverine & Lake	291	102.16	0.55
Industrial	22	7.32	0.04
Commercial	67	7.01	0.04
Others	3	1.86	0.01
Cultural & Archeological	6	0.51	0.003
Grand Total	**55167**	**18410.06**	**100.00**

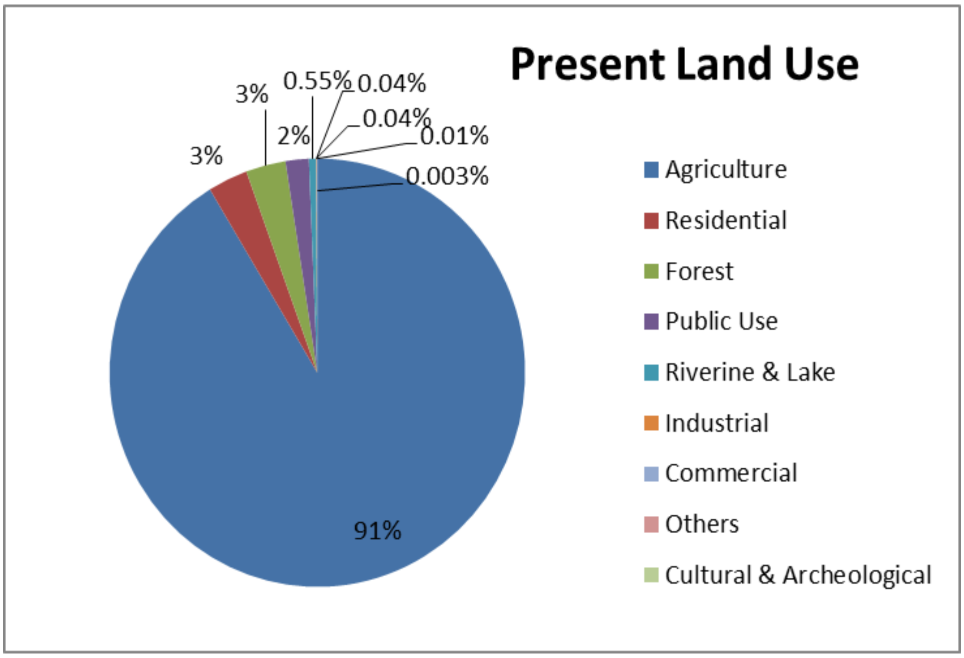

Figure 4.1: Distribution of Cadastral Parcel on Present Land Use

4.2. Cadastral Parcel Superimpose on Land Use Zoning

Table 4.2 shows the characteristics of cadastral parcels superimposition on Land Use Zoning for the Suryodaya Nagarpalika of Ilam district of Nepal. The land use zoning shows a restructuring on the existing land use. In the cadastral area of the Nagarpalika, out of the designated 11 classes, zoning for eight classes is made thus avoiding the Excavation area, Mining and Mineral area and undersigned other land use classes. Agriculture land parcels are reduced from 16818 ha to 16755 ha a significant loss of 0.4% in terms of areal extent whereas agriculture land parcels is reduced from 48616 to 47889 land parcels. The significant change in the existing agriculture land use land parcels allocation has converted into residential, commercial and public use land use classes. Prominent change of Residential land parcels has increased by 23 ha and increased by 214 land parcels. Commercial land parcels has increased by 2 ha and increased by 116 land parcels. There is marginal increase in public service land parcels by 41 ha. The distribution of cadastral parcel in land use zoning classes is shown in Figure 4.2.

Table 4.2: Parcel Characteristics of Land Use Zoning

S.N.	Land Use Zoning	No. of Parcel	Area (ha)	Percentage
1	Agriculture	47889	16754.56	91.01
2	Commercial	183	9.19	0.05
3	Cultural & Archeological	6	0.51	0.00
4	Forest	714	571.32	3.10
5	Industrial	16	7.25	0.04
6	Public Use	2471	370.61	2.01
7	Residential	3597	594.47	3.23
8	Riverine & Lake	291	102.16	0.555
	Grand Total	**55167**	**18410.06**	**100.00**

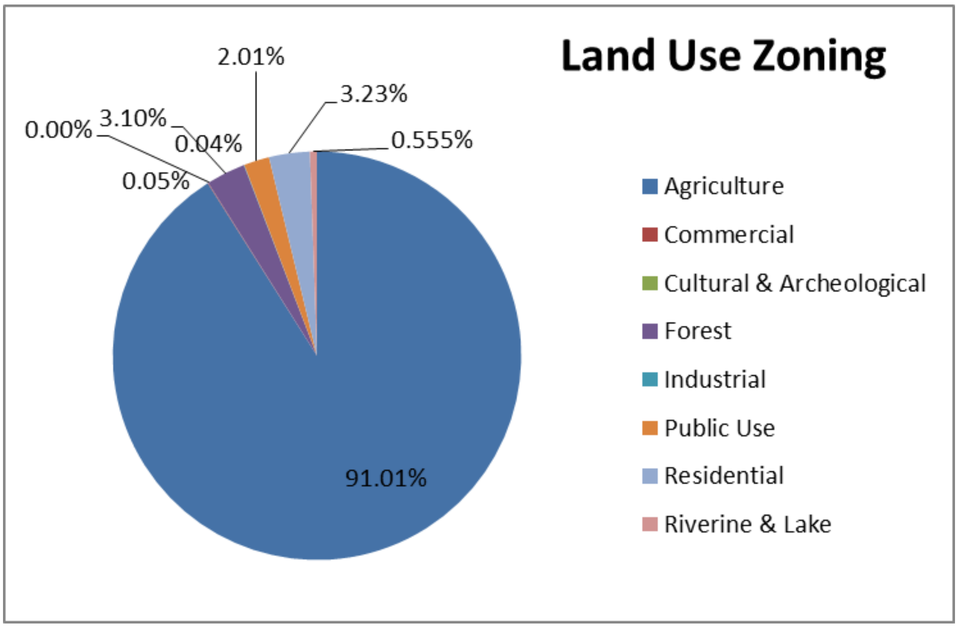

Figure 4.2: Distribution of Cadastral Parcel on Land Use Zoning

Parcel characteristics: This could be assessed from the superimposition of present land use and proposed land use given in the land use zoning maps. The parcel characteristics could be analyzed with this superimposition. Table 4.3 gives the details.

Table 4.3: Parcel Characteristics of Present Land Use Land Use Zoning Superimposition

S.N.	Conversion	No. of Parcel	Area (ha)	Percentage
1	Agriculture/Agriculture	47884	16754.35	91.01
2	Forest/Forest	711	569.46	3.09
3	Residential/Residential	3220	556.36	3.02
4	Public Use/Public Use	1634	333.29	1.81
5	Riverine & Lake/Riverine & Lake	291	102.16	0.55
6	Agriculture/Residential	377	38.10	0.21
7	Agriculture/Public Use	324	24.55	0.13
8	Residential/Public Use	501	12.59	0.07
9	Industrial/Industrial	16	7.25	0.04
10	Commercial/Commercial	67	7.01	0.04
11	Others/Forest	3	1.86	0.01
12	Residential/Commercial	85	1.55	0.01
13	Agriculture/Commercial	31	0.63	0.003
14	Cultural & Archeological/Cultural & Archeological	6	0.51	0.003
15	Residential/Agriculture	5	0.21	0.001
16	Forest/Public Use	6	0.11	0.001
17	Industrial/Public Use	6	0.07	0.0004
	Grand Total	**55167**	**18410.06**	**100.00**

Out of the total 18410 ha of land parcel currently 18330 ha remains constant and 80 ha of the total cadastral land parcel area were converted into the residential, commercial and public service land use classes. The new characteristics of the Nagarpalika is now more homogeneously structured, and looks to be restructured with sufficient allocation for industrial and commercial use, preserving in the same time the parcels and areas under forest and public use.

CHAPTER 5: CONCLUSIONS

5.1. Conclusions

Due to the involvement of many stakeholders directly and indirectly the land use planning and management is a cross-sectoral issue. Therefore, a single measure may have very little impact in reducing demand for land. To reach a sustainable level of land use, a wide variety of instruments, including fiscal, economic, regulatory and planning tools, must be used in combination. Furthermore, the activities, strategies and instruments must involve the relevant stakeholders, such as representatives from the administration (national, regional and local level) and the different disciplines (regional versus urban planning, nature conservation and environment protection, economy and traffic) in order to efficiently achieve a sustainable level of land use. Even more important would be the involvement of the local bodies, the local people and the local user groups, which has been very much emphasized in the Land Use Policy 2072, and its implementation directives, 2069.

The present exercise is fruitful and it produced required maps, data base and reports on the theme, which will be helpful in providing technical reference for implementing land use plan at the local level. Such a database will certainly help the concerned authorities to think of the ongoing practices on the lands, the finite resources of the country. It will further help to develop plan for the local areas and implement accordingly. In this sense, the exercise can be regarded as the milestone for the planners and authorities working within the area.

5.2. Recommendations

The study team has observed that the digital cadastral databases provided by through NLUP are not adequately accurate. During field work, ortho-rectification and geo-referencing, some under and overlapping and mismatch with the ground reality could be seen. Therefore, it is recommended that the parcel wise data could be used for reference only and the boundary adjudication of proposed land use zoning should be implemented cautiously.

It is highly recommended that the land use zoning implementation on the ground has to be confirmed through local consultation, for which these technical maps and data should be used as important reference.

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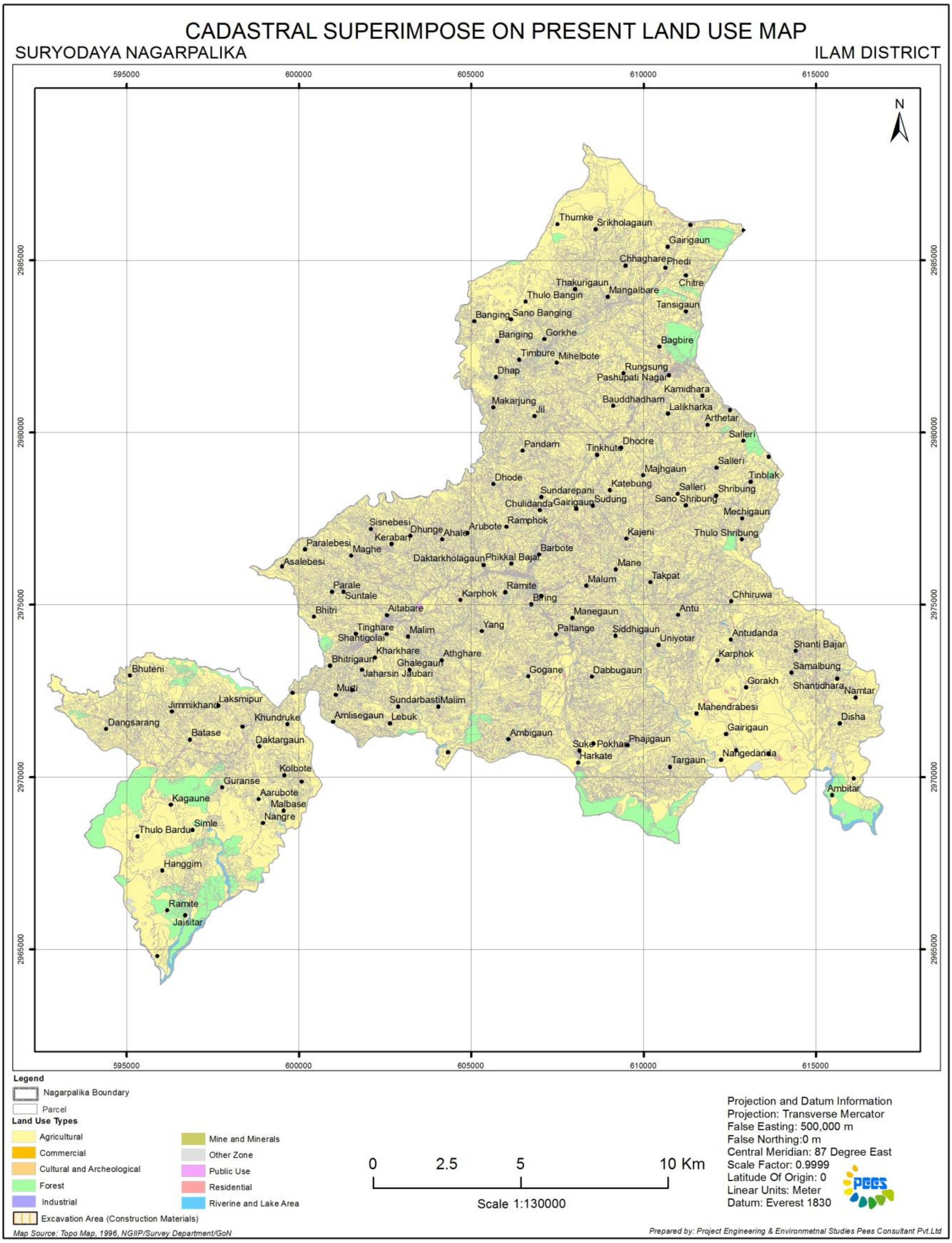
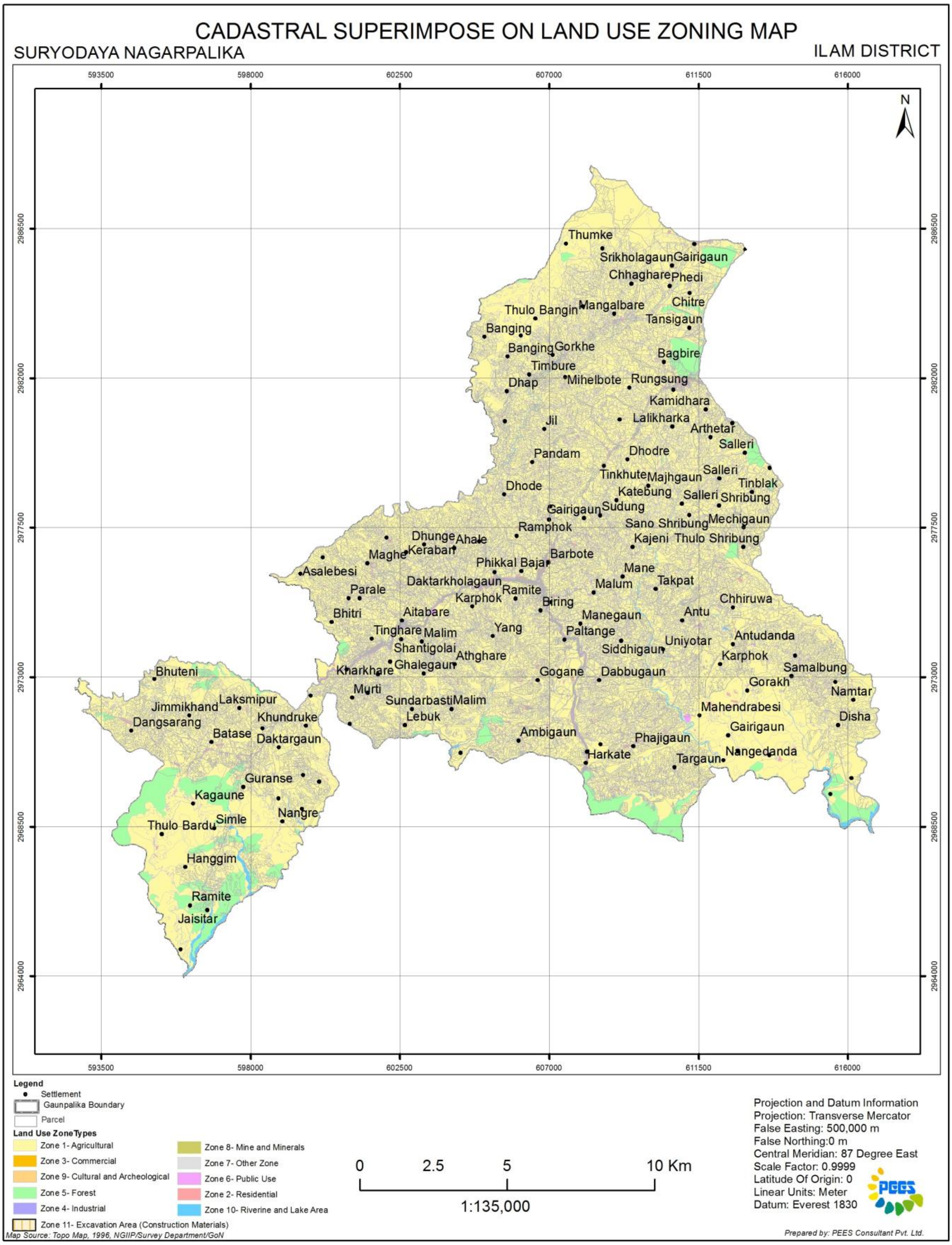
APPENDICES

Appendix 1: Cadastral Superimpose on Present Land use Map



Appendix 2: Cadastral Superimpose on zoning map



Nagarpalika Profile

Preparation of Nagarpalika Profile
Suryodaya Nagarpalika, Ilam District

This document is the output of the project entitled **Preparation of Gaunpalika level Land Resource Maps (**Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps, Cadastral Layer Superimpose and Gaunpalika Profile**), Database and Reports (Package-04)** awarded to PEES Consultant (P) Ltd. by Government of Nepal/Ministry of Agriculture, Land Management and Cooperative, National Land Use Project (NLUP) in Fiscal Year 2074-075. The Nagarpalika/Gaunpalika covered under the Package 04 of Ilam District is Rong Gaunpalika and Suryodaya Nagarpalika of Ilam District.

The Nagarpalika/Gaunpalika areas analysed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the Nagarpalika/Gaunpalika may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

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The PEES Consultant (P) Ltd. is highly obliged to National Land Use Project (NLUP), for awarding the project **Preparation of Nagarpalika/Gaunpalika level land resource maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and Nagarpalika/Gaunpalika Profile)**, database and reports, Package 4 of Ilam district**. The consultant and the team members would like to extend special thanks to **Mr. Prakash Joshi**, the Project Chief of NLUP, for the positive supports during the project period. Similarly, the consultant and the team members would also like to highly acknowledge the overall supports of **Mr. Sumeer Koirala,** Chief Survey Officer. Likewise, the consultants would like to extend thanks to Mr. Rajan Kumar Phuyal, Account Officer, Survey Officer, Mr. Prakash Dulal, Mr. Karan Singh Rawal, Mr. Dipendra Khadka, Mr. Dharma Raj Dangi, Ms. Bandana Dev, Ms. Radhika Timalsina, Ms. Sarita Gautam and Madhu Maya Bhatta and Ms. Nutan Kumari Yadav for their supports during the project period.

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CHAPTER 1: SURYODAYA NAGARPALIKA– AN OVERVIEW

1.1 Naming and Origin

Suryodaya Nagarpalika, name being the Nepali translation of "Rising Sun" declared municipality status in 2013 (2070 BS), with the merged of three Village Development Committees (VDCs) namely: Phikkal, Panchakanya and Kanyam. After, the restructuring of local body in 2073 BS, Gorkhey, Pashupatinagar, Sriantu, Samalbung, Laxmipur and Jogmai ward no. 8 and 9 were also merged into the municipality. There are 14 wards in this Nagarpalika. It has three transit points with India including Pashupatinagar, Chhabise and Manebhanjang. Sriantu is famous for sunrise view in the morning.

1.2 Location

Suryodaya Nagarpalika is located in Ilam district, province no.1; approximately 40 km southeast of district headquarter of Ilam. Geographically, it is located between 87°55'59" to 88°10'37" east longitude and 27°0'28" to 26°47'18" north latitude. Suryodaya Nagarpalika lies on the eastern part of the Ilam district bordering with India at the east, Maijogmai Gaunpalika and Ilam Nagarpalika at the north, Rong Gaunpalika at the south and Mai Nagarpalika at the west (Figure 1.1).The Nagarpalika is extended north-south about 25.29 km and east-west about 25km.

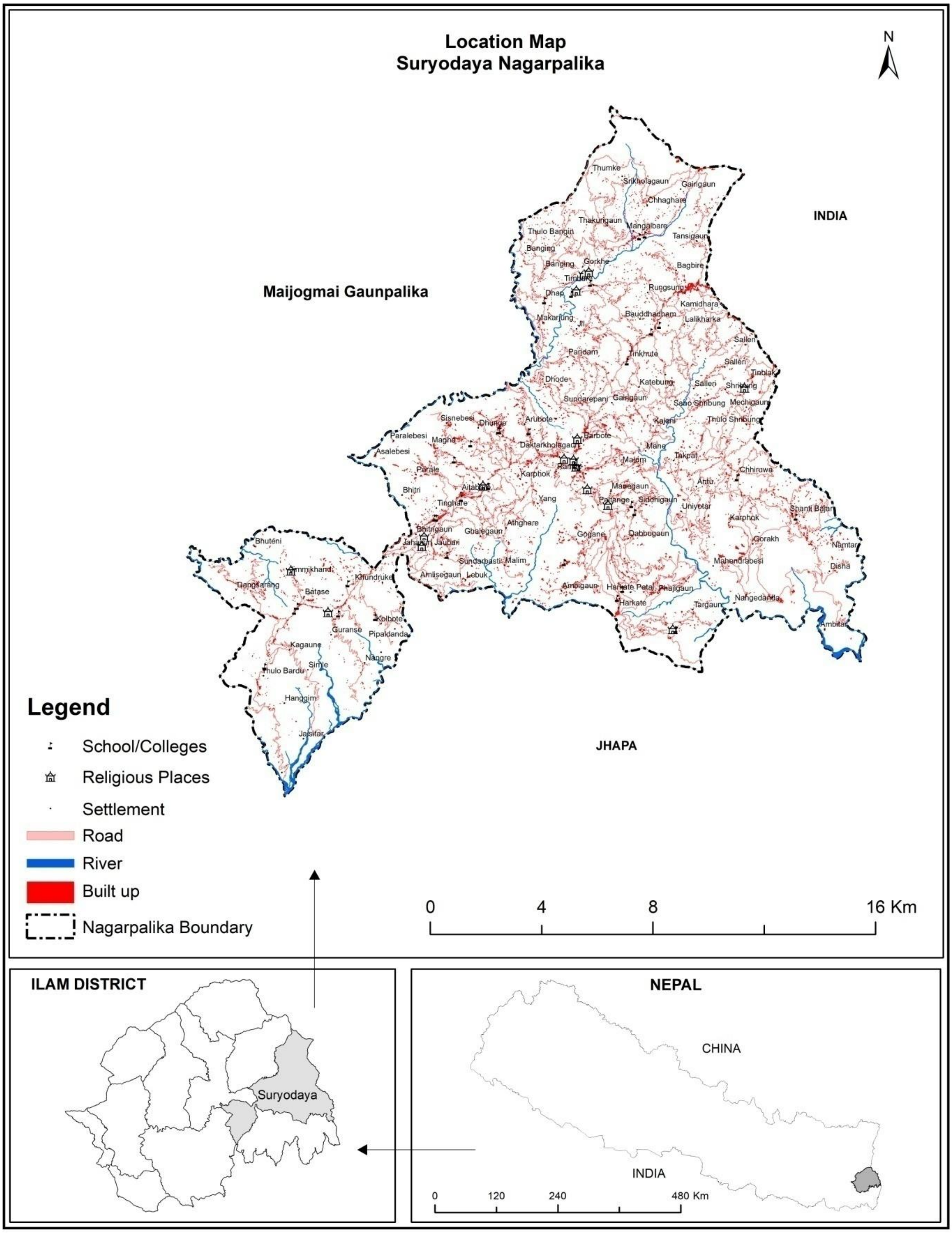

Figure 1.1: Location Map of Suryodaya Nagarpalika

1.3 Settlements and Administrative Units

Suryodaya Nagarpalika has been divided into 14 wards. According to the CBS 2011, the total population of this Nagarpalika was 56, 707 and the numbers of households were 13,211. This gives an average household size of 4.29which is lower than the national average of 4.88. Of the total population, 51% were female and 49% were male population. Ward 1 of the Nagarpalika was the largest population size whereas ward 7was recorded the smallest one. Main settlements and their population size by wards have been presented in Table 1.1.

Table 1.1: Main Settlements with their Households by Ward, Suryodaya Nagarpalika

Ward No.	Settlements	No. of Households
1	Gorkhe, Manethayank	1228
2	Pasupatinagar	1076
3	Baudha Dham, tikhute	904
4	Shree Antu	1167
5	Samalbung, Kajigaun	1018
6	Kanyam, Harkate, Targaun	666
7	Kanyam, Gogune	539
8	Kanyam, Paltange, Shidhigaun	970
9	Phikal, Barbote, Ramfoka	962
10	Phikal, Aale, Arubote, Yang, Nayachok	1269
11	Panchakanya, Kalapani, Karfok,	803
12	Panchakanya, Tinghare, Jarsing Gaun, Aetabare	1108
13	Suryodaya, Laxmipur	622
14	Laxmipur	879
Total		**13211**

Source: Suryodaya Nagarpalika, 2018

CHAPTER 2: PHYSICAL SETTINGS

2.1 Physiography of the project area

Nepal occupies about 800 km of the central sector of the Himalayan arc. From south to north, the Nepal can be divided into eight east- west trending physiographic zones namely: Terai, Siwalik range, Dun valley, Mahabharat Range, the Midlands, Fore Himalaya, Higher Himlaya and Inner and Trans Himalaya valley (Hagen, 1969; Figure 2.1). Each of the above zone has different altitude, topography, climate, soil type, geology and vegetation characteristics.

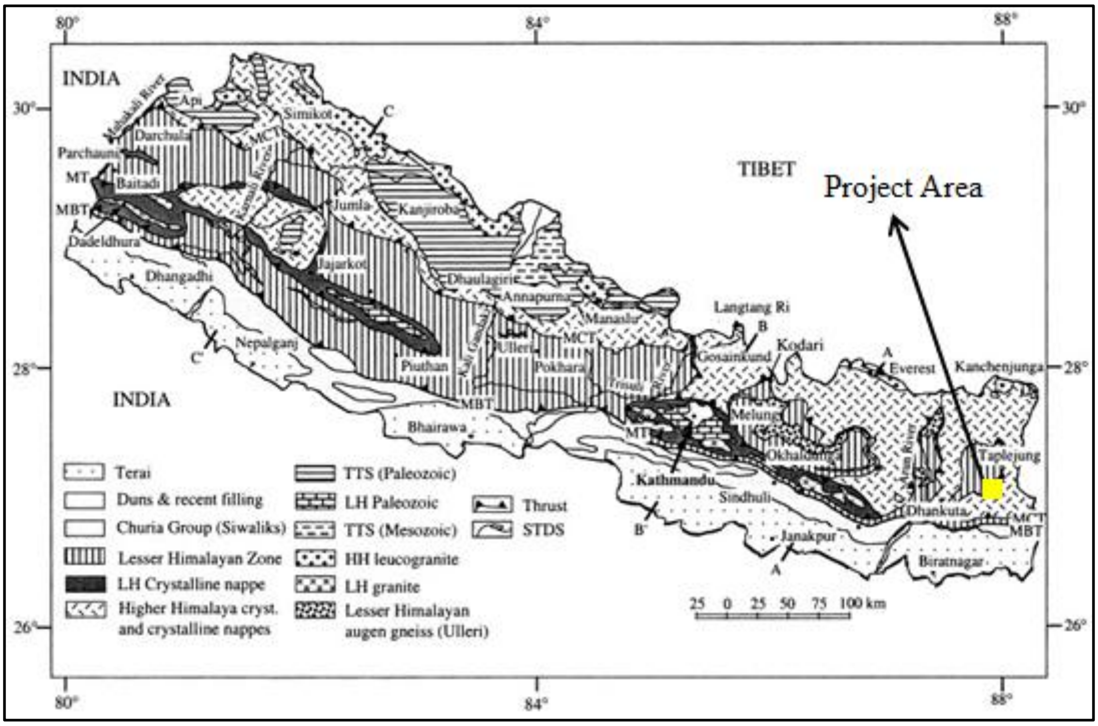

Figure 2.1: Physiography division of Nepal and yellow circle represented the project area

The Suryodaya Nagarpalika lies in the Mahabharat range within the Lesser Himalaya that belongs to the Taplejung Window. Some parts of the project area also consist of crystalline rocks that are brought down by the Higher Himalayan Thrust (MCT). Low grade meta sediments broadly belonging to Nawakot Complex lying below the crystalline thrust. The Phyllites, representing the lower most units are green to lead gray hard and massive. They are mainly composed of quartz, chlorite, sericite and small crystals of garnet.

2.2 Geomorphology

The project area lies in Mahabharat zone of Lesser Himalaya has an average width of the 40 km and ranges in elevation is about 1000 -3000 m. It consists of low hills, river valleys, and tectonic basins form the most important physiographic province of Nepal. The zone, in contrast to other physiographic divisions, exhibits a mature landscape. It is drained by a network of large number rivers and streams with predominantly north – south (N-S) and east – west (E-W) trending valleys. The larger rivers with their predominantly N-S course, when reach the northern slope of the Mahabharat ranges, suddenly deflect making right angles bends and flow along E-W direction for a long distance collecting waters of many other N-S flowing rivers and streams on their way. The rivers breach the barrier of the Mahabharat range only at a few places. The major rivers flowing through the Mahabharat have moderate gradient and form extensive Quaternary terraces along their courses. The drainage pattern of the project area is parallel to dendritic in nature. Tangting, Khani, Antu, Chhiruwa, Siddhi, Gorkhe, Srikhola and Mayum Khola are the major tributaries forming the drainage pattern in the area.

2.3 Geology

Suryodaya Nagarpalika lies in the Lesser Himalayan crystalline unit which have been described partly midland-meta sediment group and partly as Irkhu Crystalline Nappe (Arbika et al.1973). Crystalline thrust sheet covers a wide area in eastern Nepal and reaches to south upto MBT at some places. Unlike the central and western Nepal, the eastern Nepal Lesser Himalaya including Mahabharat range is widely covered by this thrust sheet. Only along the deeply cut George of Arun and Tamur and in a narrow belt along the frontal part near MBT, the underlying meta sediments belonging to Nawakot Complex have been exposed. Lithostratigraphically, the project area comprises the rocks of **1 a and 7 classes** (Figure 2.2). Brief description of these rock types are given below.

Class 1a (Recent Deposits) consists of recent and the youngest Pleistocene deposit of unconsolidated sediments. This is the alluvial soil deposited by rivers, rework by water including the river terraces. Such unconsolidated sediments usually found in terai regions and inter-montane valley (duns). In the project area, it also comprises this type of deposition in river terraces of Jagmai Khola, Mayim Khola and Siddi Khola.

Class 7: Class 7 consists of sediments belong to the Lesser Himalaya of midland meta sediments group. It comprises of low to medium grade metamorphic rocks such as phyllite, quartzite, quartz-mica, quartz-schist, schist and some carbonate beds. The age of this sediment is Pre-Cambrian.

Geologically the project area lies in the Taplejung window. Low grade meta sediments broadly belonging to Nawakot Complex lying below the crystalline thrust sheet. Upper part of the project area lies in the Taplejung window. Lithological segments divided in the project area represent different lithology such as arenaceous, carbonaceous and argillaceous denoted by 7a, 7b, 7c of the midland meta sediments group.

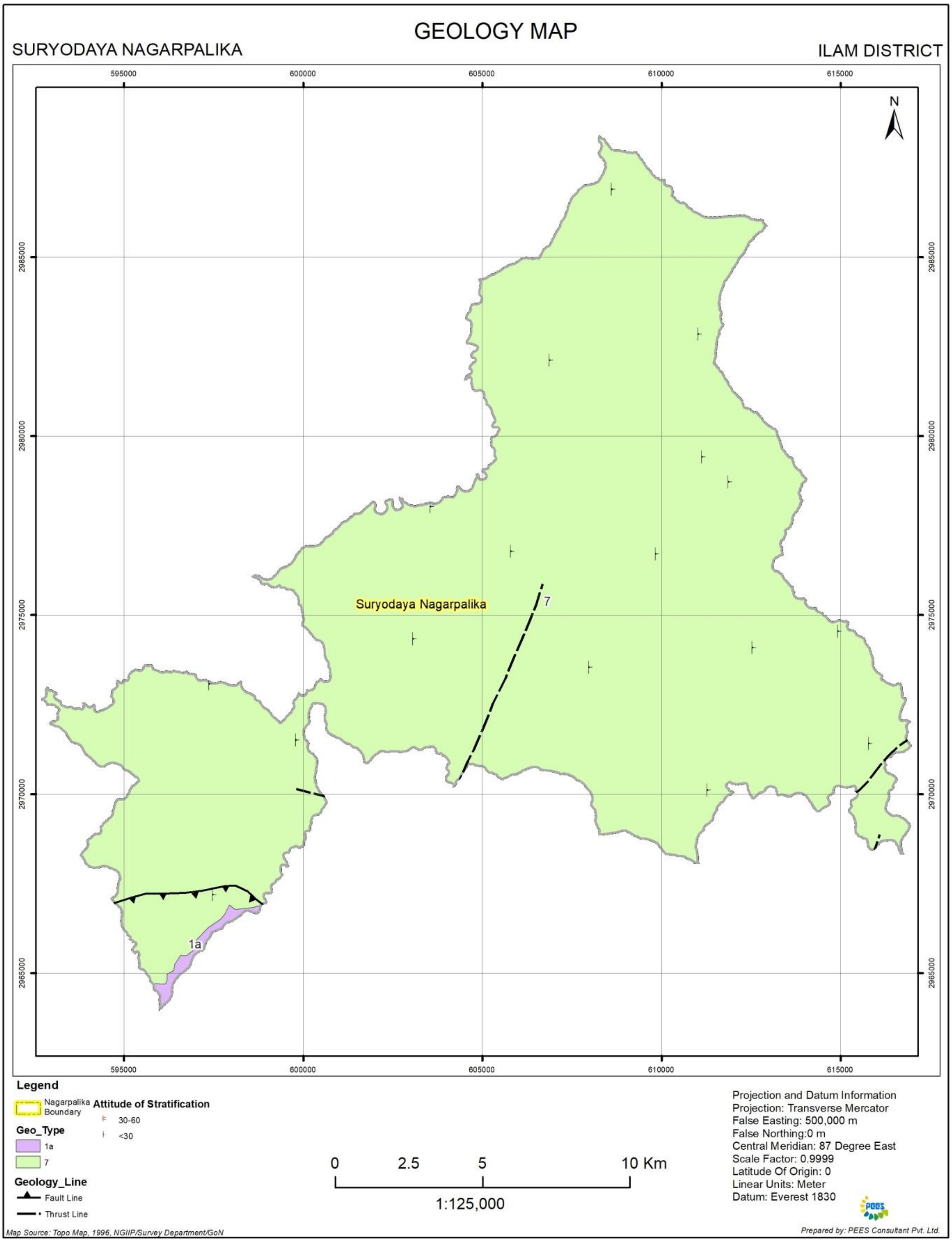

Figure 2.2: Geology Map of Suryodaya Nagarpalika

According to the regional geological map of eastern Nepal prepared by the Department of Mines and Geology (DMG, 1984), the project area comprises of the Seti Formation, Ulleri Formation, Middle Siwalik and Sarung Khola Formation with the intrusion of pegmatites(Figure 2.3). The detail description of above mentioned formation is as follow:

Seti Formation (St): The most of the land of the Suryodaya Nagarpalika is occupied by the Seti Formation. It is enclosed within the Naudanda Formation. The Formation is characterizes by the greenish, grey phyllites, Quartzite gritty phyllite with minor conglomeratic layer. Basic intrusions were noted in the Seti Formation. The general trend of foliation is 40/50 and 60/30.

Ulleri Formation (Ul): The Ulleri Formation is characterizes by the feldspathic schists with augen gneisses. The intrusions of granite are also noted in the Ulleri Formation. It lies in southern region of the project area. Banded gneiss, augen gneiss, mica gneiss are some of the varieties of gneiss in the study area.

Middle Siwalik (Ms): The Middle Siwalik is comprised of the medium to coarse grained, friable arkostic sandstone and fine to medium grained hard massive grey sandstone, inter-bedded with green to greenish, grey clays, grey shales and thin bands of pseudo conglomerates and mudstones plant and animal fossils are present in clays and shales. This type of rock was found in the southernmost part of the Suryodaya Nagarpalika. The beds are dipping towards the NE and the dip of bedding plane ranges from 20^0 to 60^0. The age of this Siwalik is considered Pleistocene to Middle Miocene.

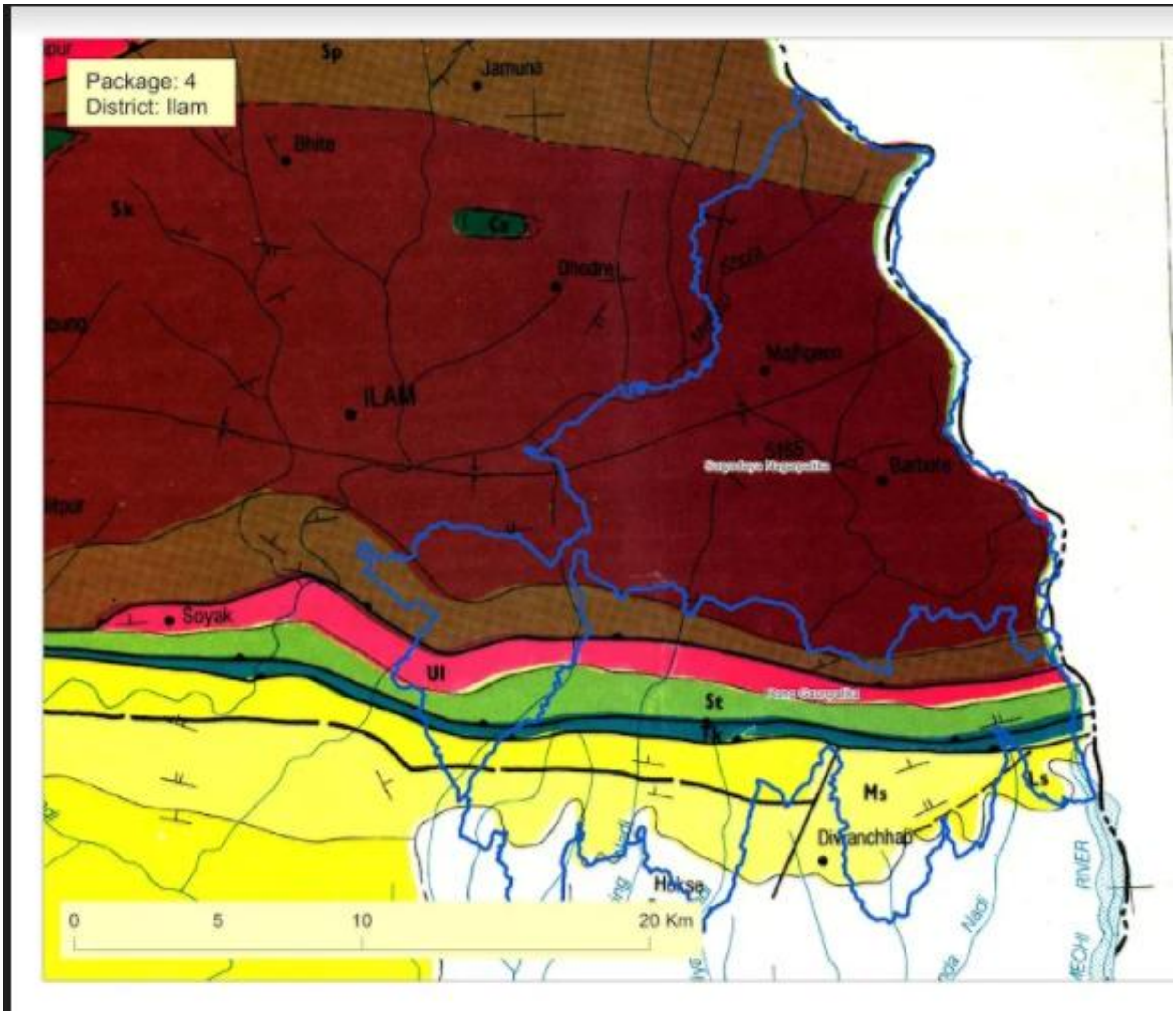

Figure 2.3: Regional geological map of Eastern Nepal prepared by DMG (1987) showing the project location

Sarung Khola Formation (Sk): Sarung Khola Formation is the largely distributed formation in the project area. The characterization of this formation is fine texture, dark grey to greenish white quart biotite schists, quartz feldspar biotite schists, occasionally garnetiferous interbedded with quartzites and micaceous quartzites with intrusions of pegmatites Cs-calc. It also consists of silicate rocks and marble bands.

Geological Description

Geologically, the project area lies in the Lesser Himalaya however the Higher Crystalline rocks are common because of the thrust sheet that overlies the Lesser Himalayanmetasediments and reach upto the MBT as a continuous thrust sheet. East of Dharan, these high grade crystalline rocks nearly come in direct contact with the Churia Group along MBT. The two large tectonic windows i.e. Arun and Taplejung Windows along the Arun and Tamur river valleys respectively, expose the low grade metasediments that tectonically lie below the thrust sheets. When the upper lithology of Higher Crystalline rocks are washed out due to erosion the low grade metasediments are exposed. This resembles that one is looking from the window of Higher Crystalline rocks into the Low grade mentasediments of Lesser Himalaya. In this way the tectonic demarcation of the Eastern region is difficult. It can only be applied in the geographical sense.

Meta sediments of Nawakot complex are also exposed in the Lower Arun and Tamur section of eastern Nepal and a narrow band to the north of MBT. However, so far no detailed and systematic study of the stratigraphy of these rocks has been worked out. Bordet (1961) described the geology of the area north of Dharan. Maskey (1987, 2043) did a brief stratigraphic study of this area and correlated these rocks with the Nawakot complex rocks of Central Nepal.

Geological Structures

According to the map prepared by the Survey Department of the ministry of Land Reform government of Nepal, there are different types of geological structures like faults, folds etc. Suryodaya Nagarpalika consists of longitudinal thrusts i.e. Main Central Thrust (MCT), Main Boundary Thrust (MBT) and Main Fronta Thrust (MFT) in the southern part. The area lies in the part of Arun and Taplejung Window circling the area by the MCT. Apart from this, Suryodaya Nagarpalika consists of a syncline fold as the major geological structure extending from Salleri in the north-east to Jimikhand in the south east. The general trend of the bed is 170˚/35˚ in the north of syncline and 350˚/40˚ in the south. Another major structure include a thrust separating geological formation of Class 2b from Class 7a,c.

Natural Hazards and Environment (Geo-Hazards)

Nepal is located in a geographic region prone to natural disasters. Loss of lives and property are a regular phenomenon, and the number of such events is on the rise due to natural as well as man-made causes. Among the main reasons for natural disasters in Suryodaya Nagarpalika are active tectonic and geomorphic processes, young and fragile geology, variable climatic conditions, unplanned settlement, increasing population, weak economic condition and low literacy rate. Suryodaya Nagarpalika is therefore geologically found to be vulnerable to various types of natural disasters such as flood, landslide, fire, epidemic, earthquake, windstorm, and downwards-movement through gravity.

i. There is syncline fold whose axial line is passes through the NE to SW direction. The topography and rocks are fragile in nature, so there are possibilities of mass-movement and erosion.
ii. The slope and nature of topography varies place to place. In some place there is very steep slope with a lot of gullies. The area has the several possibilities of rock fall and landslide.

2.4 Drainage/Hydrology

Mechi River is flowing at the eastern border side of the Nagarpalika. Srikhola, Mayum, Rangsung, Ramphok khola are flowing at the northern side of the Nagarpalika, whereas Siddhi khola, Targau, Sundar, Gorkhe, Malum, Chhiruwa, Antu are flowing at the southeastern; and Chhingbang, Adheri, Khani, Sakale, Tangting, Sundar and Maghe khola are flowing at the western part of the Suryodaya Nagarpalika. All these rivers are small streams and rivulets passes through this Nagarpalika (Figure 2.4).

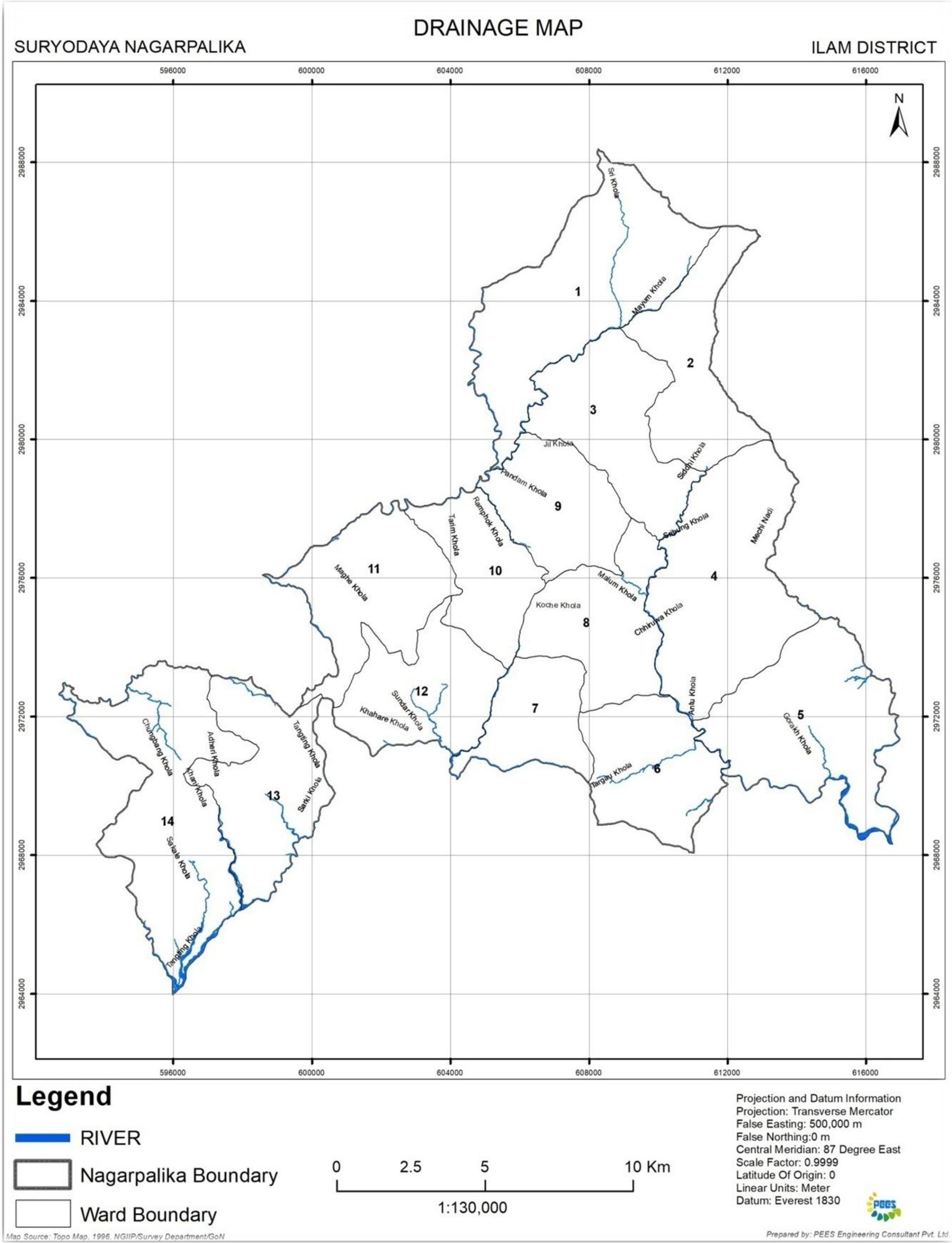

Figure 2.4: Drainage Map of Suryodaya Nagarpalika

2.5 Terrain

2.5.1 Elevation

The elevation ranges from 288.39 to 2775.23 meter above mean sea level. The elevation of the Suryodaya Nagarpalika is shown in figure 2.5.

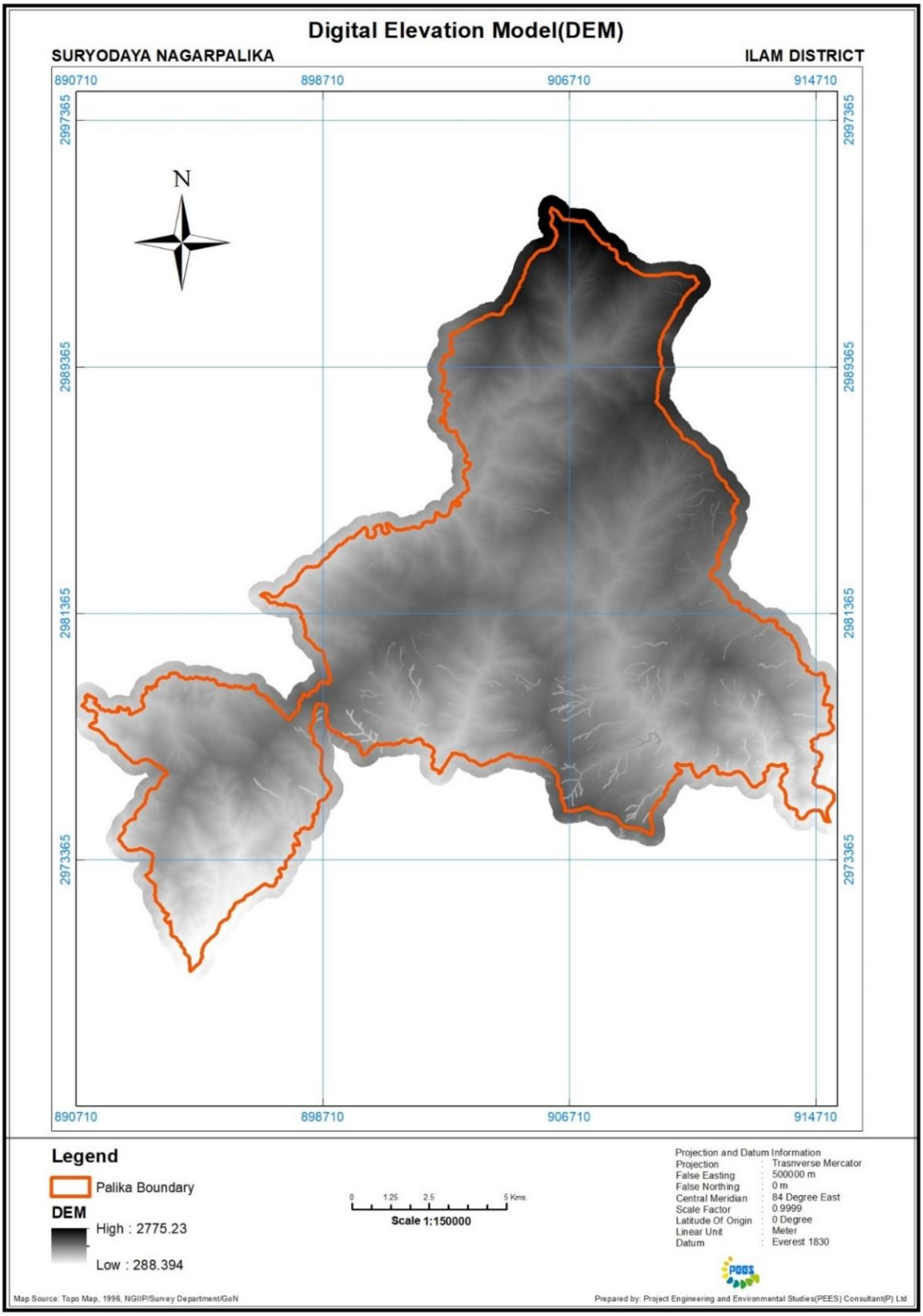

Figure 2.5: DEM of Suryodaya Nagarpalika

2.5.2 Slope

Slope plays a significant role in landform formation. Basically, the slope is associated with the surface erosion and land use practices and management. The slope of the study area ranges from less than 18° to 34° and it is predominated by 18° slope in the hill region that covers more than 85% of the total geographical area of the Suryodaya Nagarpalika. The slope map of the Nagarpalika is shown in figure 2.6.

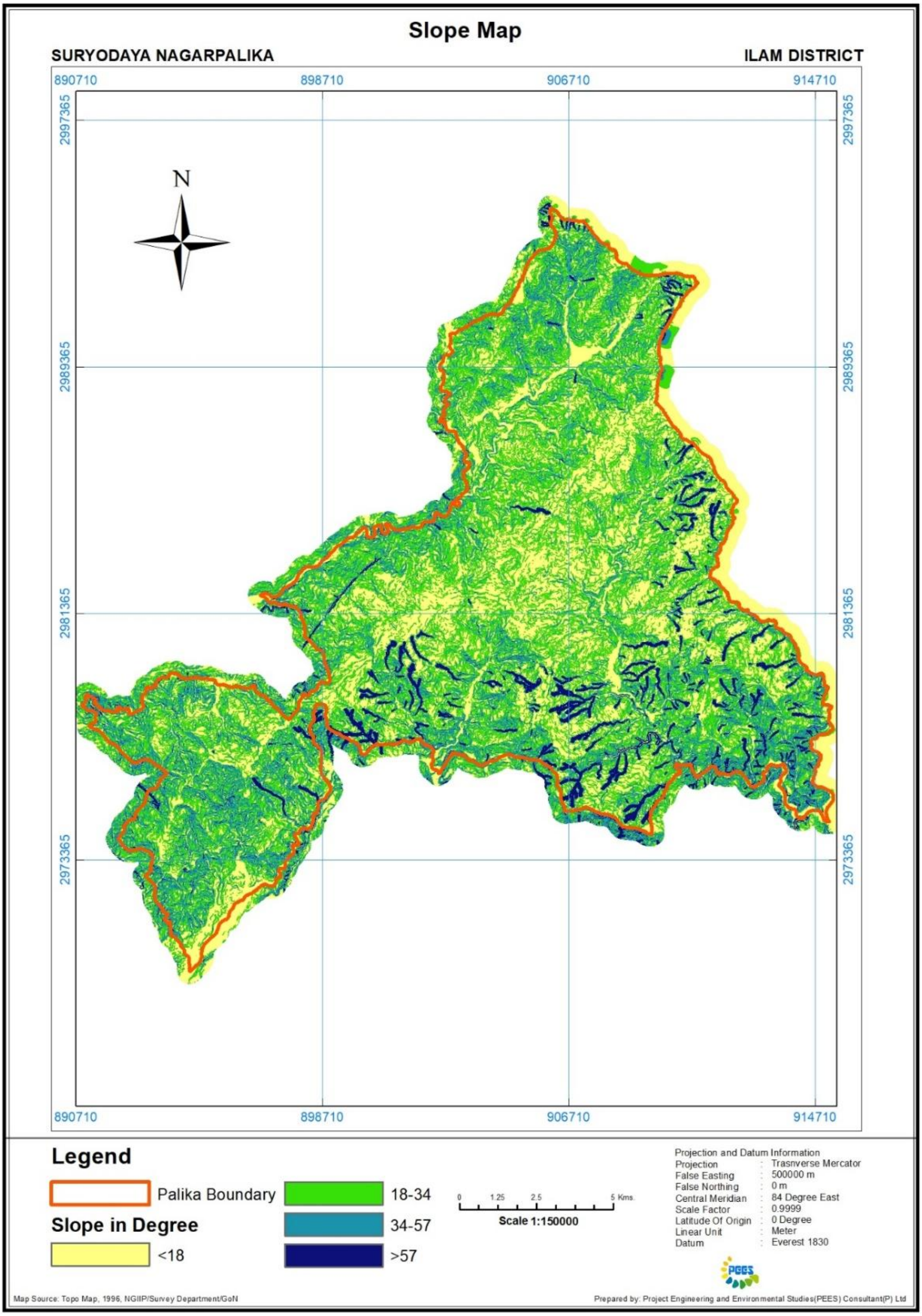

Figure 2.6: Slope Gradient, Suryodaya Nagarpalika

2.6 Climate

Climate is one of the major factors influence to soil formation. Directly it affects the soil by supplying water and heat to react with parent material whereas indirectly it through flora and fauna furnishes a source of energy in the formation of organic matter.

2.6.1 Temperature

Climate of the Suryodaya Nagarpalika is sub-tropical and temperate monsoon types. The climate has three distinct seasons. Dry summer season begins from the month of March when the sun starts to move northward from the equator. It lasts till the middle of July during which the mean monthly minimum temperature reaches up to 16.8^0 C (Table 2.1) and mean monthly maximum temperature reaches up to 23.2^{0}C (Table 2.2). Rainy season starts from the month of July and ends in September. Generally, the winter season begins from the month of October and lasts till February as the sun moves southward from the equator.

Table 2.1: Mean Monthly Minimum Temperature (0C), the Kanyam Tea Station

Months	Years										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
Jan	4.9	5.4	5.2	5.2	4.3	3	3	3	4	DNA	4.22
Feb	5.4	5.5	6.7	5.6	6.3	5.7	6.3	2.9	5.3	8.7	5.84
Mar	7.9	9.5	8	9.8	9.4	8.6	9.1	6.4	10.5	11.9	9.11
Apr	13.1	12.7	11.4	12.6	11.9	11.7	10.6	9.9	12.2	15.6	12.17
May	15.4	13.6	11.5	13.5	13.8	14	12.3	12	14.9	15.2	13.62
Jun	16.1	17.1	13.5	15	15.2	15.8	14.7	14.4	17.6	17.5	15.69
Jul	16.9	18.2	18.5	16.4	15.8	15.8	15.2	16.4	18	17.7	16.89
Aug	17.2	17.6	17.9	16.5	15.8	15.8	14.6	15.9	17.9	18.1	16.73
Sep	16.3	16.4	16.9	15.7	15	15	14.3	14.9	17.4	17.1	15.90
Oct	13.5	13.6	14.4	14	11.8	11.9	11.4	11.8	14.7	15.1	13.22
Nov	9.7	9.7	9.6	9.5	9.1	7.8	7.2	8.3	11.2	11.4	9.35
Dec	6.4	6.9	6.7	5.8	5.9	4.7	3	5.1	6.8	DNA	5.70

Source: Department of Hydrology and Meteorology

Table 2.2 shows the mean monthly maximum temperature of ten-year period. The monthly minimum temperature ranges from 3°C in the month of January, 2012-2014 to 24.9°C in the month of May, 2012. The average monthly minimum temperature is highest in Jul 16.8°C and lowest in January 4.22°C.

Table 2.2: Maximum Temperature in ^{0}C

Month	Years										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
Jan	13.8	13	14.9	15.4	12	12.6	15	15.3	16.1	DNA	14.23
Feb	13.5	13.6	17	15.6	15.3	17.2	18.4	15.9	16.8	17.4	16.07
Mar	18.3	18.9	21	21.3	20.9	20.3	20.8	20.8	21	21.2	20.45
Apr	21.9	22.3	22.2	23.7	22.4	22.8	22	24.5	21.4	24.5	22.77
May	23.6	22.2	22.6	22.7	22.3	24.9	22.1	24.1	23.9	23.2	23.16
Jun	23.1	22.1	23.7	22.5	22.6	23.6	22.8	24.1	23.4	23.5	23.14
Jul	23.8	21.9	22.8	22.4	22.2	22.3	23.3	23.6	23.8	22.2	22.83
Aug	23.6	22.4	23.1	DNA	22.7	24	22.7	22.9	23.3	24.3	23.22
Sep	22.1	23.3	23.3	DNA	23	22.9	23.9	23.5	23.2	23.2	23.16
Oct	21.3	23.1	21.1	DNA	21.4	21.9	22.3	23.3	22.3	23.3	22.22
Nov	18	19.6	18.2	DNA	18.8	19.9	19.9	19.4	19.8	20.3	19.32
Dec	15.2	16.2	14.5	DNA	16.8	16.6	15.4	17.5	15.8	DNA	16.00

Source: Department of Hydrology and Meteorology

Note: DNA= Data Not Available

Figure 2.7 shows the mean monthly maximum temperature of ten-year period. The monthly maximum temperature ranges from 14.23°C in the month of January to 24.5°C in the month of Jul, 23.83 The Mean minimum monthly temperatures is highest in Jul 16.89°C and lowest in January 4.22°C.

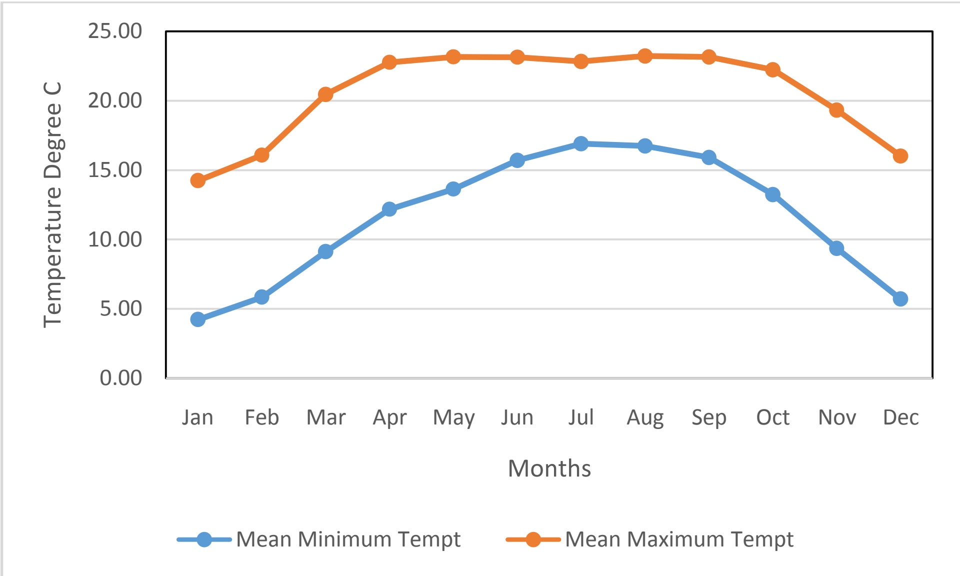

Figure 2.7: Distribution of Monthly Minimum and Maximum Temperature, 2007-2016

Figure 2.7shows that mean monthly minimum temperature recorded from 2007 to 2016 being high in July and gradually declining through August, November to December when temperature remains the lowest. There is similar trend of mean monthly maximum temperature as with the mean monthly minimum temperature trend. The trend is that the mean monthly maximum temperature begins to rise in the month of May till the month of October and then declines gradually.

2.6.2 Rainfall

The trend line of monthly mean rainfall for ten years during 2007 to 2016 at Kanyam Tea Station is shown in figure 2.8. The monthly average rainfall ranges from 0.82 mm in the month of December to 746.82 mm in the month of July. The trend line of mean monthly rainfall is below 25 mm in first three months (November, December and January) and it rises up steeply until July and falls down sharply in October.

Table 2.3: Rainfall in mm. (Kanyam Tea Station Mean from Ten Years, 2007-2016)

Month	Year										Mean
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Jan	0	24.4	0	0	8.8	11.8	12.2	0	10.8	DNA	7.56
Feb	168.4	3.4	0	2.8	19	4	29	10	16.6	0	25.32
Mar	28.8	61.4	14.2	0	32	2	16.2	22	44.4	30	25.10
Apr	54	53.9	110.4	67.6	88.5	106.8	112.2	6.6	117	6.8	72.38
May	268.2	354	483.4	245.4	136.4	122.8	379.6	107.4	136.6	238.2	247.20
Jun	602.4	590.3	228.5	543.6	520.4	465.2	461.2	370	492.8	424.7	469.91
Jul	980	575.4	657.2	949.7	783.5	613.8	634.3	586.8	602	1085.5	746.82
Aug	455.8	867.5	881.5	620.2	557.7	284	400	613.6	501	256.2	543.75
Sep	516.6	188	178.8	404.8	380.8	379.8	206.4	373	605.2	451.3	368.47
Oct	78	57.6	306.1	178.2	83.4	67.6	154.8	53.6	49	267	129.53
Nov	0	1	0	0	15.8	0	0	0	2.6	DNA	2.16
Dec	0	5.2	2.2	0	0	0	0	0	0	DNA	0.82
Yearly Mean	262.7	231.8	238.5	251.0	218.9	171.5	200.5	178.6	214.8	306.6	219.9

Source: Department of Hydrology and Meteorology, 2018.

Note: NA= Not Available

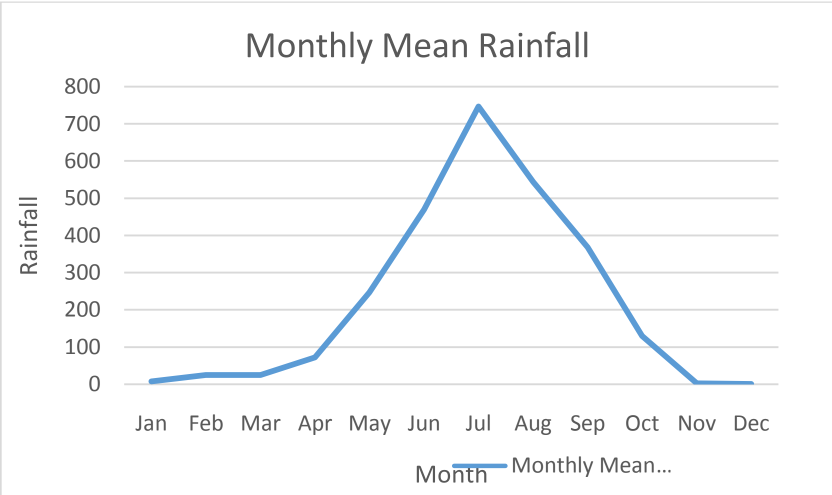

Figure 2.8: Monthly Mean Rainfall Pattern (2007-2016)

2.7 Forest and Biodiversity

Suryodaya Nagarpalika has both communities as well as government forests. They are natural as well as plantation forests dominated by Sal, Asna, Dhupi Salla, Khot salla, Chilaune, Katus, Siris and Utis species. Most of the forests have matured to immature stage. The crown density in most of the community forests belongs to dense i.e. more than 70%, sparse 40 to 70% and the remaining less than 40%. The plantations in the agricultural land are in the form of agro forestry. Some of the models are farmland plantations, homegardens, hertosilviculture, orchards, wood lots, agro-silvopasture and Tea gardens plantations. These are private plantations/forests in agriculture land. All these forests can be categorized in the Tropical, sub-tropical to temperate climatic zone having forest type as hard wood, softwood, mixed forests and most of the community forests are supported by Dhupi salla, Utis, Amriso, Amla, *Bakaino*, *Khair*, *Sissoo, Ipil Ipil* and *Khanyu* plantation in the gaps and open areas of community forests. Total areas of the community forest handed over of forest user group are 6746.12 ha.

The following are the plants, NTFPs and wild animals' biodiversity in these forests.

Plant biodiversity: The plant biodiversity within the area covers Sal (*Shorea robusta*), Karma(*Adina cordifolia*), Asna(*Terminalia tomentosa*), Kusum(*Schleichera trijuga*),Chilaune(*Schima wallichaii*), Utis(*Alnus nepalensis*), Dhupi (*Cupressus torulosa*), Khotesalla(*Pinus roxburghii*), Supari(*Erica nut*),Siris (*Albegia Species*), Banjhi(*Quercus leucotrichophora)*, Sissoo(*Dalbergia sissoo*), Satisal(*Dalbergia latifolia*), Malato(*Macranga pustulata*), Khair(*Acacia catechu*), Asna(*Terminalia tomentosa*), Bot-dhangero(*Largestromia parviflora*) , Laliguransh(*Rhododendron species*), Harro (*Terminalia chebula*), Barro(*Terminalia bellerica*), Jamun(*Syzygium cumini*), Amla(*Phylanthus oficilansis*) , Bel(*Aegle marmelos*), Simal(*Bombax cieba*), Bans (*Bamboo*), Arjun(*Terminalia arjuna*), Masala(*Eucalyptus camaldulensis*), Dabdabe(*Garuga pinnata*), Bair(*Ziziphus jujuba*) , Mahuwa(*Madhuca indica*), Mainkanda(*Xeromphis spinosa*), Siris(*Albigia Species*), Bayer (*Zizyphus mauritiana*), Lathikath(*Cornus oblonga*)and , Sadan/Padan (*Desmodium oojenense*),Gayo (*Bridelia retusa*), Banmara (*Eupatorium adenophorum*), Tuni (*Toona ciliata*), Kutmero(*Litcea monepetala*) ,Badhar(*Artocarpus lakoocha*),Koiralo(*Bahiniya variegata*),Khanyu(*Ficus semicordata*),Tanki(*Bahuniya purpuriya*),Ipip Ipil*(Lecanea lacocephala*),Bakaino(*Melia azaderacta*),Dudhilo(*Holerhena antidecetrica*),Nibharo/Nimaro(*Ficus auriculata*),Bar(*Ficus bengalensis*) ,Thotne (*Persicaria chinessis*), ,Bedulo,Gogan, Khasru (*Quarcus species*),Ratnaulo, Musure katus(*Castonopsis tribuloides*), Khiro (*Sapium insigne*),Guyeli, Ritha(*Sapindus mukorossi*) ,Mango (*Mangifera indica*) ,Kali kath(*Myrsine semiserrata*), Lati kath(*Cornus oblonga*) ,Bhalmilo, Khaluk ,Srikhand(*Santum album*) ,Sami(*Ficus benjamina*), Amba*(Psidium guajava*) etc.

NTFPs: Babiyo(Eulolіopsis binata), Amriso(*Thysanolaena latifolia*), Jethi madhu, Kaulo(Percea odoratissima), Bayer(Ziziphus mauritiana),Marcha(Senerio cappa), Sajiwan(Jatropha curcus) , Sisnu(Urtica dioica), Sugandhwall(Valeriana jatamansi),Sugandhakokila(Cinnamomum glaucescsense),Kurilo(Sparagus afficinalis) Tarul (Dioscorea bulbifera), Bel(Aegle marmelos), Jamun(Syzygium cumini), Harro (Terminalia chebula), Barro(Terminalia bellerica), Amala (Phyllanthus emblica), Shikakai(Acacia rugata), Ritha(Sapindus mukorosi), Karaunda, Tanki(Bahunia purpuria) , Satawari (Asparagus racemosa), Sarpagandha (Rauvolfia serpentina), Pudina (Mentha arvensis), Bhorla (Bauhinia vablii), Gurjo (Tinospora sinensis), Pipla (Piper longum),Pipli, Ghodtapre (Centella asiatica),Batule pate(Cissampelos pareira), Tejpat (Cinamomum tamela), Bans (Bamboosa species), Siudi, Amphi, Thaune, Lokta(Daphne bholua), Allo(Girardinia diversifolia), Syanu ko lahara, Neem(Azadirachta indica), Charchare, Panilahara, Chutro(Berberis aristata), Bhamkilo, Sirudhap, Marul singo, Nagejhar, Bhimsen pate, Makhmali, Kus(Desmostachya bipinnata), Nigalo(Bambusa species), Lute jhar, Pani amla, Lapsi(Choerospondias axillaris), Dhaturo(Datura stramonium), Jatamasi(Nardostachys jatamansi) etc.

Wild animals: Some wild mammals, birds and reptiles are Red panda (*Ailurus fulgens*), Bandel (*Sus scrofa*), Bankukoor (*Cuon alpinus*), Elephant(*Elephus maxima*), Fox (*Vulpes montana*),Bandar(*Macaca mulutta*), Langur (*Prosbytus entellus*), Jungle Cat (*Felis chus*), Bwaso/ Wolf(*Canis lupus*), Dumsi (*Hystrix indica*), Chittal(*Axix axix*) , Ratuwa deer (*Mutianus mutijac*),Jackle (*Canis aurens indicus*), Leopard(*Panthera uncia*) , Kharayo (*Lepus ruficaudatus*), Crow (*Corvus splendense*), woodpecker (*Sitta frontalis*),Kalij (

Lophura leucomelana), Dhukur (*Streptopeli chinensis*),Garud (*Ciconia episcopus*), Owl (*Tyto alba*), Tithee(*Sterna hirundo*),Dove (*Chalcophaps indica*), Mayur (*Pavo cristatus*),Myana (*Acridotheres tristis*), ,Vulture(*Turgos calvus*),Large bat (*Pteropus giganteus*), Nyauree musso(*Herpestes auropunctus*), Tortoise(*Testudo elongate*), Common Rat Snake (*Ptyas mucosus*), Common garden Lizard (*Calotes versicolor*) ,Wasp(*Polytes olivacus*) Kalij(*Lophura leucomelana*), Luiche/Red Jungle Fowl(*Gallus gallus*), Fruit eating bat(*Pteropus giganteus*),Gray hornbill(*Tokhus birostris*) etc.

2.8 Natural Hazards and Environment

Classification of the land use and land cover in the study area has been assessed by interpretation of the topographic map, GIS technique, and field visits. The spatial distribution patterns of settlements in Suryodaya Nagarpalika consist of scattered form in the agricultural village areas, agglomerated form along the Mechi Highway, and tended to be clustered in the inner core areas of the villages with motorable road access, which is composed mostly of a residential area.

Topographically, Suryodaya Nagarpalika has a hilly terrain. The project areas have a sub-tropical climate with a maximum temperature of 24°C and mean monthly temperature of 3.6° C, and with an annual rainfall, 2814 mm (1998) (DHM, 2017) Maximum precipitation occurs in the months of May to September, and the minimum in November and December.

Suryodaya Nagarpalika is largely affected by flood and landslide. Water-induced disasters resulting from severe cut banks, landslides and debris flows are common in this area. There are a number of shallow to deep-seated landslides developed due to toe cutting by the Siddha Khola, SundarKhola, and Yang Khola.

Erosion has been taking place in Suryodaya Nagarpalika especially in the ward number 14 (Laxmipur). The major factors that contribute to mass movements in the area are afragile geological condition, prolonged and high-intensity rainfall, and various anthropogenic factors. The weak rocks undergo extensive weathering and erosion process, thereby producing heavy loads of sediments to the gullies and to the rivers in the area. In addition, the scenario is worse due to deforestation, which removes the surface cover thereby increasing the soil erosion. Formation of gullies plays an active role in the erosion of the rock and soil. The presence of numerous gullies and resulting erosion, give rise to the formation of badlands topography. It is mainly taking place on a south facing hill slope in Suryodaya Nagarpalika.

Suryodaya Nagarpalika is prone to landslides because of thepresence of the Main Boundary Thrust and poor surface drainage. The late monsoon precipitation in 1994 collapsed 63 meters of the blacktopped Mechi Highway within Suryodaya Nagarpalika section. The landslide was induced due to geological as well as chemically contaminated groundwater. As a prominent fault line is passing in many sections of Suryodaya Nagarpalika, landslide occurrence will be likely to occur in future. Therefore, a series of check dams, surface drainage, and plantation, to control the landslide is recommended in those vulnerable sections.

There are three primary types of forest in the area, namely Shorearobusta (sal); Acacia catechu (khayar)-Dalbergiasissoo (sisau), other riverine forests and grasslands.

The Shorearobusta forest is dominated by the Shorearobusta species with common associates of Terminaliatomentosa (Asna), Adina cordifofia (karma), Anogeissuslatifolia (bud dhayera), Lagerstroemia parvifolia (botdhaiyero), Dilleniapentagyna (Tantari), Syzygiumcumini (jamun) and Semecarpusanacardium (bhalayo). The acacia catechu-dalbergiasissoo forest is found on newly deposited alluvium, often gravelly along streams and rivers. The other riverine forest consists of tropical evergreen forest dominated by syzygiumcumini (black plum) tropical deciduous forest usually dominated by Bombaxceiba (simal), Holopteliaintegrifolia (cheptepagro) and Trewianudiflora (pindar) species. Medicinal plants of significance are Sikakai (Acacia concinna), Assuro (Adhetodavasica), Tulasi (Ocimum sanctum), Kureelo (Asparagus racemosus), Harro (Terminaliacheberia), Barro (Terminaliafelerica) and Amala (Emblicaofficinalis), etc.

Deteriorating water quality, unsanitary condition and lack of personal hygiene are often blamed for the prevalence of water-borne diseases. Diseases like diarrhea and dysentery are the most common in the Nagarpalika and other diseases like skin irritation; infection and coughing etc. are also common. Besides tuberculosis, encephalitis and malnutrition were reported during field observation. Lack of medicines and technical health workers at the local area, it has become very difficult for local. For major treatment, people have to travel to the headquarter or to India (Siliguri).

The Nagarpalika office is the authority to handle solid waste problems in an organized way. However, few individual households and health centers dispose of their own solid wastes separately in an unorganized manner. To keep the commercial area clean, a sweeper is hired on a monthly basis to collect, sweep and dispose of the waste products. The solid waste disposal site has been defined in a location of ward number 10, however, occasionally wastes are dumped randomly in the jungle and along the highway. Besides, there is a lack of segregation of medical infectious waste produced by local health centers from domestic, non-infectious waste. This practice can be hazardous or potentially harmful to the community because when medical wastes are mixed with domestic wastes, the combined wastes also become infectious as there is the presence of dangerous chemicals, pharmaceuticals, radioactivity in medical wastes.

The air quality observed was good and the Nagarpalika does not have major sources of noise nuisance. Although, noise and dust emission during vehicular movement in the existing road is a natural phenomenon and it is more significant during dry and festival season. Some educational and offices close to road alignment have noise disturbance to some extent during transportation services. Likewise, water quality seems to be good. There is no defecation problem around the drinking water sources along the road alignment. However, during the monsoon season, the water will be slightly polluted.

Tea plantation in Suryodaya Nagarpalika stands out in its peculiar form. The significant land has been utilized for tea plantation as Tea plantation tends to have higher return compared to other crop cultivated by farmers. Tea plantation also empowers women as it generates good employment opportunities for women. During field visits, people referred that more than 60 percent of the workers employed in the tea industry are women. Few farmers are also involved in organic tea farming who use farmyard manure and locally available botanical pesticides. As there is a high demand for organic tea in the international market, fallow land in Suryodaya Nagarpalika could be utilized for the tea plantation with minimal environmental effects.

CHAPTER 3: SOIL AND LAND CHARACTERISTICS

3.1 Land System and Soil Characteristics

The land system and soil characteristic of the Suryodaya Nagarpalika is described in the following sections.

3.1.1 Land System

Suryodaya Nagarpalika falls within the Middle Mountain physiographic region and is located in the north-central part of the Ilam district. The Nagarpalika is mountainous and has land systems 9, 10, 11 and 12, namely, river channels, alluvial plains and fans, ancient river terraces, and moderately to very steep mountainous terrain (LRMP,1986). Physiography is further subdivided into landforms basically defined by the position of land surface within landscape and it is characterized by slope and its direction, elevation, rock exposure and soil type. The Nagarpalika was found to be heterogeneous with nearly 95% of the area falling within two land systems. The land system types are given in Table 3.1; figure 3.1.

Table 3.1: Land type units of Suryodaya Nagarpalika

Land System/ Land units	Area (In ha.)	Percentage	Descriptions
9a	148.52	0.66	Alluvial plains and fans; river channel
9b	81.47	0.36	Alluvial plains and fans; alluvial plains (river/stream flood plains)
9c	242.75	1.08	Alluvial plains and fans; alluvial fans (sloping depositional areas)
11	13752.79	61.21	Moderately to steeply sloping mountainous terrain
12	8241.65	36.68	Steep to very steeply sloping mountainous terrain

Source: NLUP, 2018

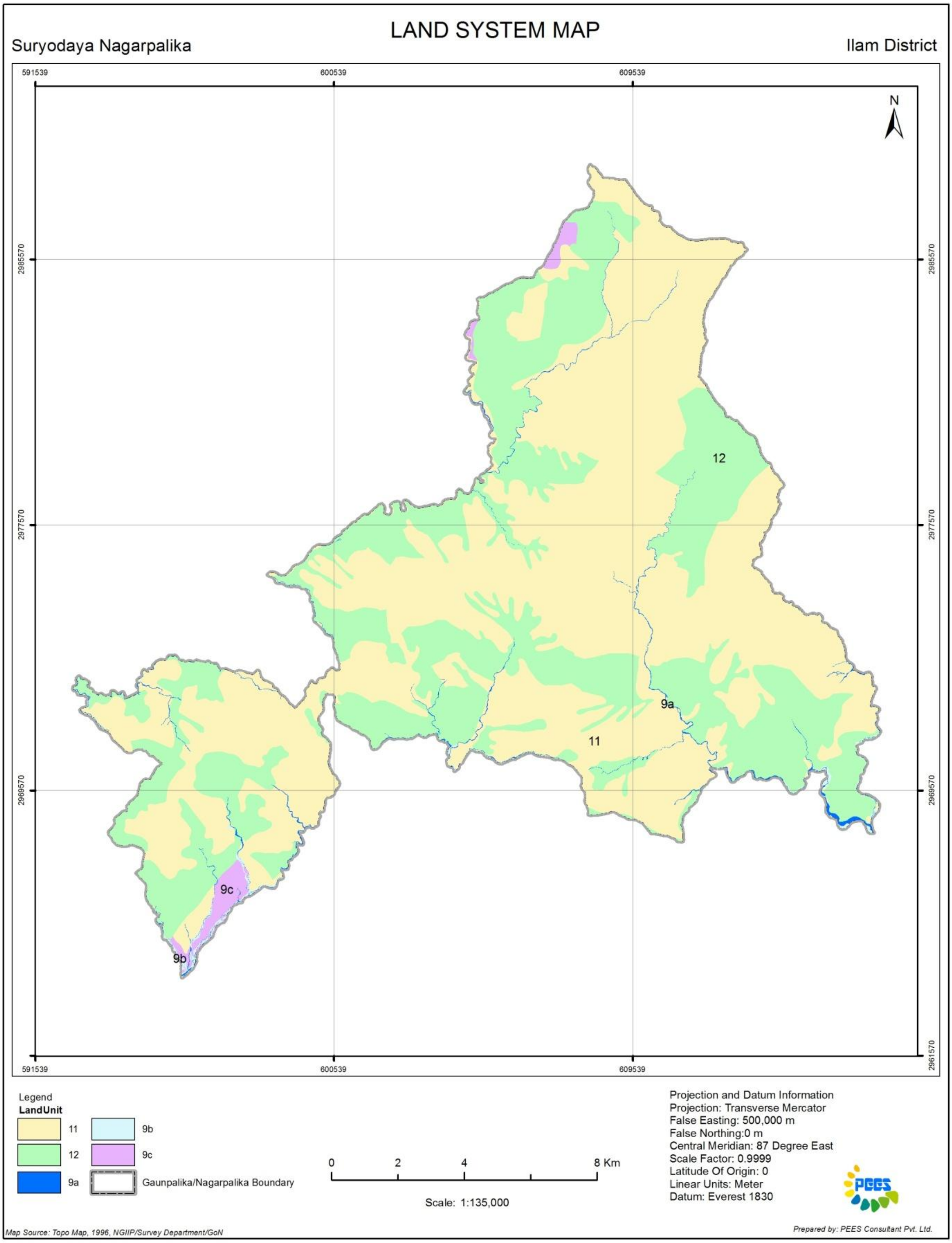

Figure 3.1: Land System Map of Suryodaya Nagarpalika

3.1.2 Soil Characteristics

The soil classification system in Nepal has adopted USDA Soil taxonomy (USDA-NRCS, 2014). The system should permit easy translation into other taxonomic systems also (World Reference Base, FAO). Soil types can be delineated based on order, sub order, great group and sub group as well as family and series, the latter being particularly locally specific.

Soil types from order to sub-group level

Suryodaya Nagarpalika forms a hilly area with considerable micro-variability in soil conditions. The soils were mostly young soil (at higher elevations) and moderately well-developed soils in the lower slopes and valleys. Physical properties such as texture were observed to be mainly sandy loam, loam and clay loam with some loamy sands along river or stream banks. The soils were mostly strongly acidic to near neutral in reaction. Soil fertility status was found to be of mostly medium with moderate to high OM content, medium total N and available P, while exchangeable K mostly high to very high. Table 3.2 is presents the soil classifications found in the study municipality to the sub-group level, which indicates the soil order, sub-order, great group and sub-group of each soil type found in the study area.

Table 3.2: Area coverage of different soil sub-groups in the Nagarpalika

Order	Sub order	Great group	Sub great group	Area (Ha)	Percentage
ALFISOL	UDALF	AGRUDALF	TYPIC AGRUDALF	648.73	2.887
		HAPLUDALF	ARENIC HAPLUDALF	1530.50	6.812
			PSAMMENTIC HAPLUDALF	1302.11	5.796
			TYPIC HAPLUDALF	1732.20	7.710
	USTALF	HAPLUSTALF	ARENIC HAPLUSTALF	6080.42	27.064
			TYPIC HAPLUSTALF	250.01	1.113
			UDIC HAPLUSTALF	745.08	3.316
ENTISOL	FLUVENT	USTIFLUVENT	TYPIC USTIFLUVENT	871.78	3.880
INCEPTISOL	OCHREPT	DYSTROCHREPT	LITHIC DYSTROCHREPT	755.44	3.362
			TYPIC DYSTROCHREPT	1953.55	8.695
		EUTROCHREPT	ARENIC EUTROCHREPT	2739.56	12.194
			TYPIC EUTROCHREPT	1257.71	5.598
		USTOCHREPT	ARENIC USTOCHREPT	59.20	0.264
			TYPIC USTOCHREPT	1009.25	4.492
			UDIC USTOCHREPT	718.24	3.197
	UMBREPT	HAPLUMBREPT	TYPIC HAPLUMBREPT	573.11	2.551
Water body				240.29	1.070
Total				**22467.18**	**100.000**

Source: Soil Survey, 2018

Although a total of 3 Orders, 5 Sub-orders, 8 Great groups, and 14 Sub-groups were classified based on the soil survey investigation in Suryodaya Nagarpalika of Ilam district (Figure 3.2) the predominant soil orders making up most of the total land area were Inceptisols (about 40 percent) and Alfisols (about 52 percent), while Entisols only covered less than 4 percent of the land area as shown in Figure 6.1 and Table 6.2. The soils are mostly sandy loam to loam in texture, strongly acidic to near neutral in pH, low to medium in

P_2O_5, high to very high in $K_2O$and generally medium to high in other nutrients and organic matter.

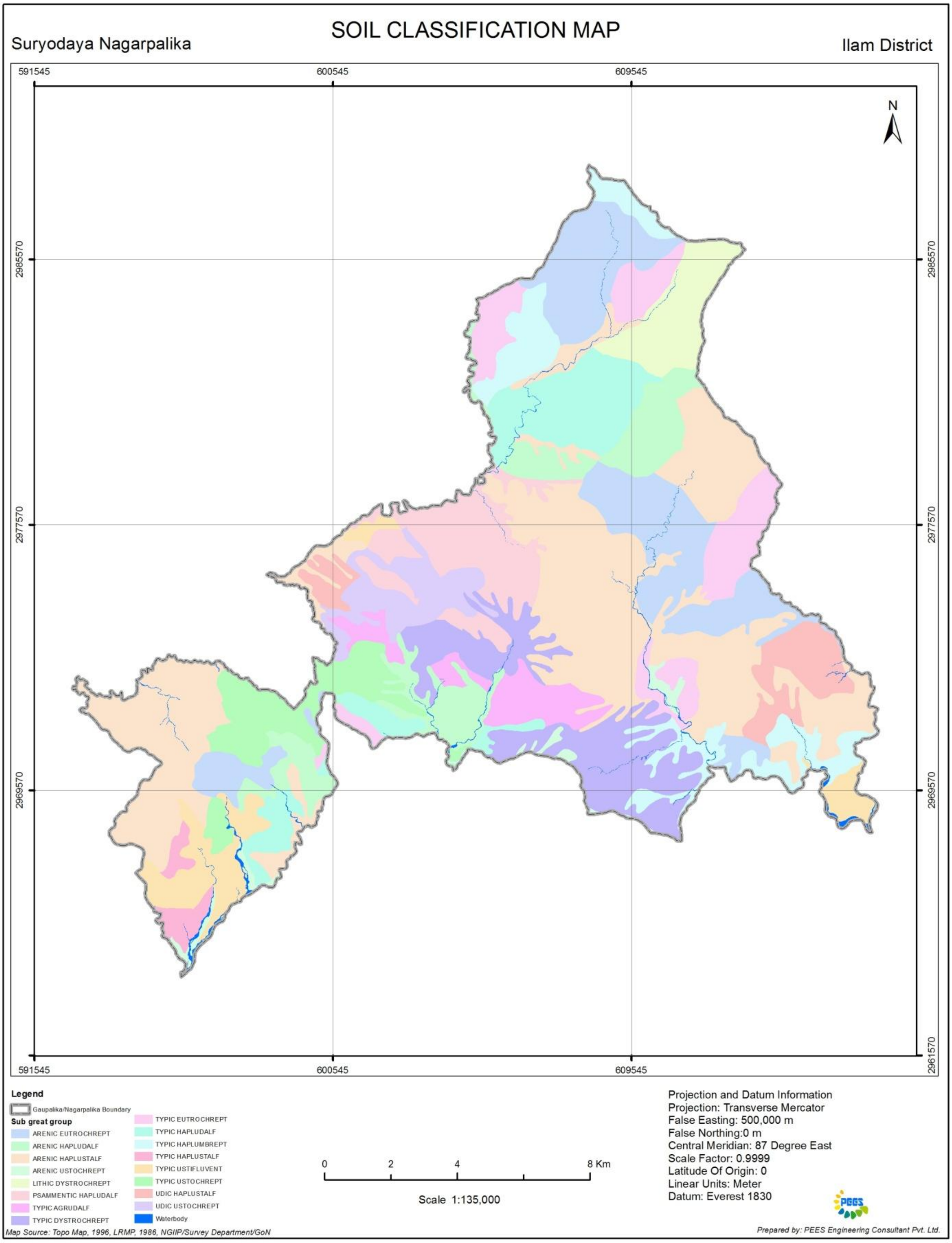

Figure 3.2: Soil Map of the Suryodaya Nagarpalika

Soil types based on family level

Soil family is the descriptive presentation of soil properties relating to plant growth or engineering purpose such as mineralogical class, soil temperature class, pH, soil texture, permeability, thickness of horizon, structure, consistency etc. In the present context, soil temperature is used as descriptive criteria of soil family. The study area, Suryodaya Nagarpalika falls in the Mesic soil temperature regime of sub-tropical climatic condition. Mesic soil temperature regime means that the mean annual soil temperature at 50 cm (control section) is between 8 and 15 degrees Celsius.

3.2 Land Capability

Most of the land area of this Nagarpalika has moderate to steeply sloping topography and moderately deep soil. Based on the standard criteria of land capability classification, the land area of this Nagarpalika fell mostly in Classes III, with the remaining areas falling under the Class II, and non-arable categories (Table 3.3; Figure 3.3).This Nagarpalika has a total land area of about 22,467 ha of land and slopes range from nearly flat (1 degree)to about 60 degree slopes. The land in Classes I, II and III are generally suited to upland crops with some limitations for agriculture and other uses.

Table 3.3: Land Capability Classes of Suryodaya Nagarpalika

S.N.	Land Capability Classes	Area (ha)	Percentage
1	IIIBh	12860.92	57.24
2	Non-arable (Forest & Built-up)	6630.17	29.51
3	IIICp	711.20	3.17
4	VICp	552.74	2.46
5	IIBh/2st	513.00	2.28
6	IVCp	384.88	1.71
7	Water body	237.63	1.06
8	IIIAu	200.37	0.89
9	IVAh	172.29	0.77
10	IIAu/2st	112.22	0.50
11	IVBh	48.83	0.22
12	IAh/1	37.09	0.17
13	IVAu	4.43	0.02
14	VIAh	1.05	0.005
15	IIIAh	0.26	0.001
16	IIAh/2st	0.09	0.0004
	Grand Total	**22438.57**	**100.00**

Source: NLUP, 2018a

The dominant category of land in Suryodaya Nagarpalika is of capability class III, which makes up more than 57 percent of the area. Sub-classes in this category, i.e., III Bh and III Cp have additional limitations due to soil acidity and shallow soil depth in some areas. Other categories, namely, I Ah, II Au, II Ah and II Bh, while better suited to agriculture, make up only a small portion of the land area (<3 percent). About 37 percent of the land in Suryodaya Nagarpalika falls under forested or built-up areas and in the non-arable capability classes IV and VI.

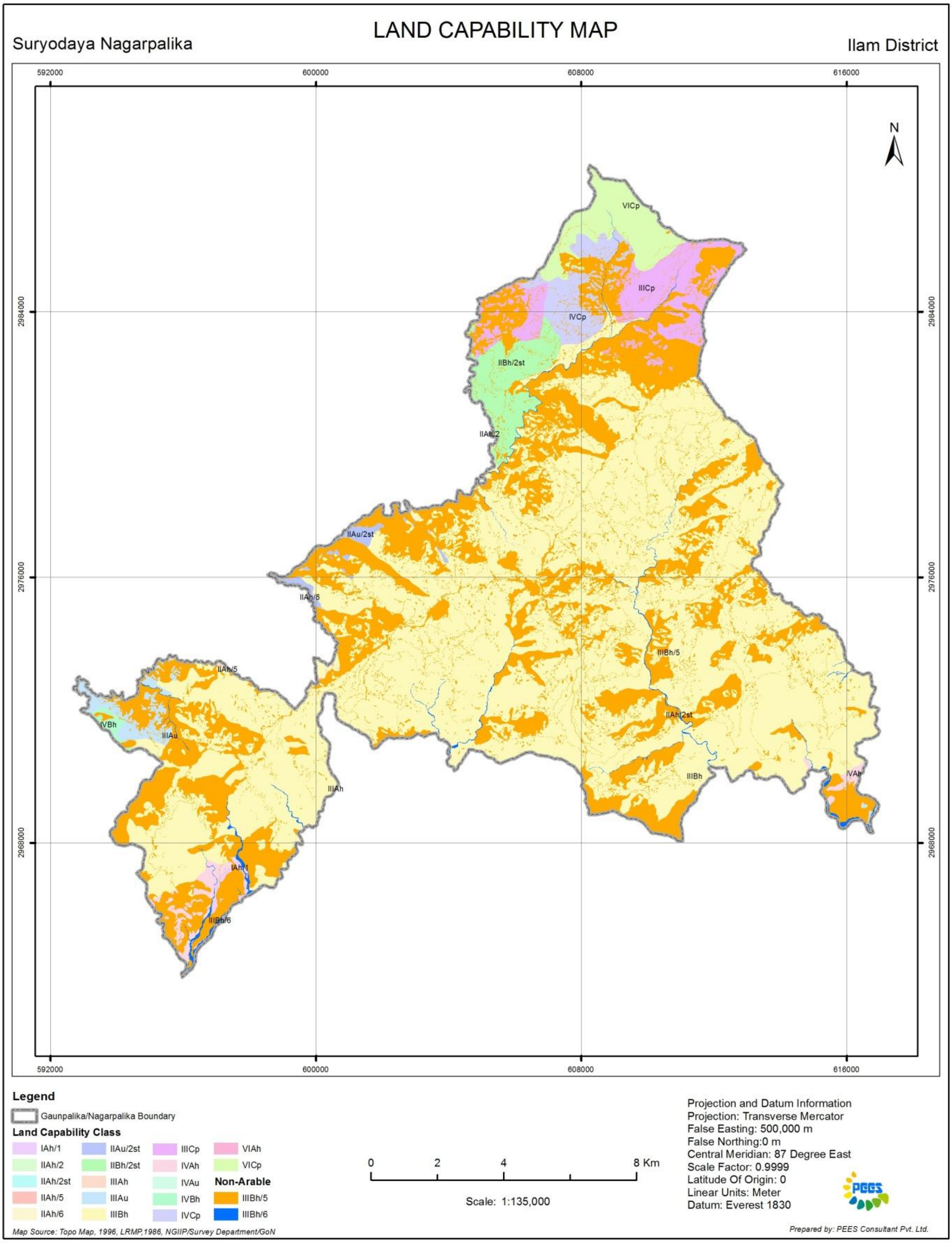

Figure 3.3: Land capability map of Suryodaya Nagarpalika

3.3 Present Land Use

Out of the designated 11 land use classes, 9 land use classes do exist in the Nagarpalika excepting the Mining and Mineral land use, and Excavation area land use classes. Out of total 22438 hectare land, 69% area is covered by agriculture followed by forest with 25.15%. The residential area covers with 2.57% of the Nagarpalika extent. Public Use and Open Space which include transportation, security, health, education etc. cover about 1.83% of the area. The riverine and lake area covers with 1.11% of the Nagarpalika extent. Similarly, under designed other, commercial and industrial area covered 0.11%, 0.02%, and 0.02%. Furthermore, cultural and archeological area covers 0.004% area of the Nagarpalika extent, which has negligible (Table 3.4).

Table 3.4: General land use of Suryodaya Nagarpalika

S.N.	Land Use Types	Area (ha)	Percentage
1	Agriculture	15523.49	69.18
2	Forest	5644.14	25.15
3	Residential	576.36	2.57
4	Public Service	411.65	1.83
5	Riverine and Lake Area	249.56	1.11
6	Other	24.03	0.11
7	Commercial	4.18	0.02
8	Industrial	3.92	0.02
9	Cultural and Archeological	0.81	0.00
Total		**22438.57**	**100.00**

Source: Field Survey 2018

3.4 Agriculture Pattern

All types of the agricultural land fall under the Hill Cultivation at the hierarchy Level 2. According to the hierarchical classification Level 3, based on the landform and land system the entire agricultural land use pattern of the Nagarpalika has been categorized as Level Terraces and Sloping Terraces. Further, the agricultural land use pattern of Level Terraces cultivation can be categorized into Level Terraces Khet Land Cultivation and Level Terraces Upland/Pakho Land Cultivation according to the hierarchical classification Level 4, based on the cultivation types with availability of water, which is determined either by moisture contain or irrigation facilities. Similarly, Sloping Terraces cultivation can be categorized into Slopping Upland/ Pakho Land Cultivation, according to the hierarchical classification Level 4. Furthermore, according to the Level 5, based on the cropping pattern, the agricultural land use pattern in the Nagarpalika is found under Tea, Amriso, Rice-Maize, Rice-Rice, Cardamom, Rice-Wheat, Vegetable-Vegetable, Maize-Vegetable, Maize-Potato, Maize-Others, Maize-Rice-Cereal, Rice-Maize-Vegetable, Coffee, Fruits, Ginger, Rice-Potato, Maize-Millet, Rice-Others, Potato-Vegetable Crops, Livestock/Cattle/Buffalo Farm and Floriculture. Tea is the dominant summer crop (Table 3.5).

Table 3.5: Cropping pattern of the Suryodaya Nagarpalika

S.N.	Description	Area (ha)	Percentage
1	Tea	7101.35	45.75
2	Amriso	2557.72	16.48
3	Rice-Maize	1716.32	11.06
4	Rice-Rice	1585.80	10.22
5	Cardamom	699.72	4.51
6	Rice-Wheat	370.68	2.39
7	Vegetables-Vegetable	356.90	2.30
8	Maize – Vegetable	307.07	1.98
9	Maize-Potato	244.37	1.57
10	Maize-Others	133.91	0.86
11	Maize-Rice-Cereal	101.80	0.66
12	Rice-Maize-Vegetable	97.94	0.63
13	Coffee	85.92	0.55
14	Fruits	53.36	0.34
15	Ginger	52.10	0.34
16	Rice-Potato	26.18	0.17
17	Maize-Millet	15.82	0.10
18	Rice-Others	14.35	0.09
19	Potato-Vegetable Crops	2.14	0.01
20	Livestock/Cattle/buffalo Farm	0.03	0.0002
21	Floriculture	0.01	0.0001
Grand Total		**15523.49**	**100.00**

Source: NLUP, 2018b

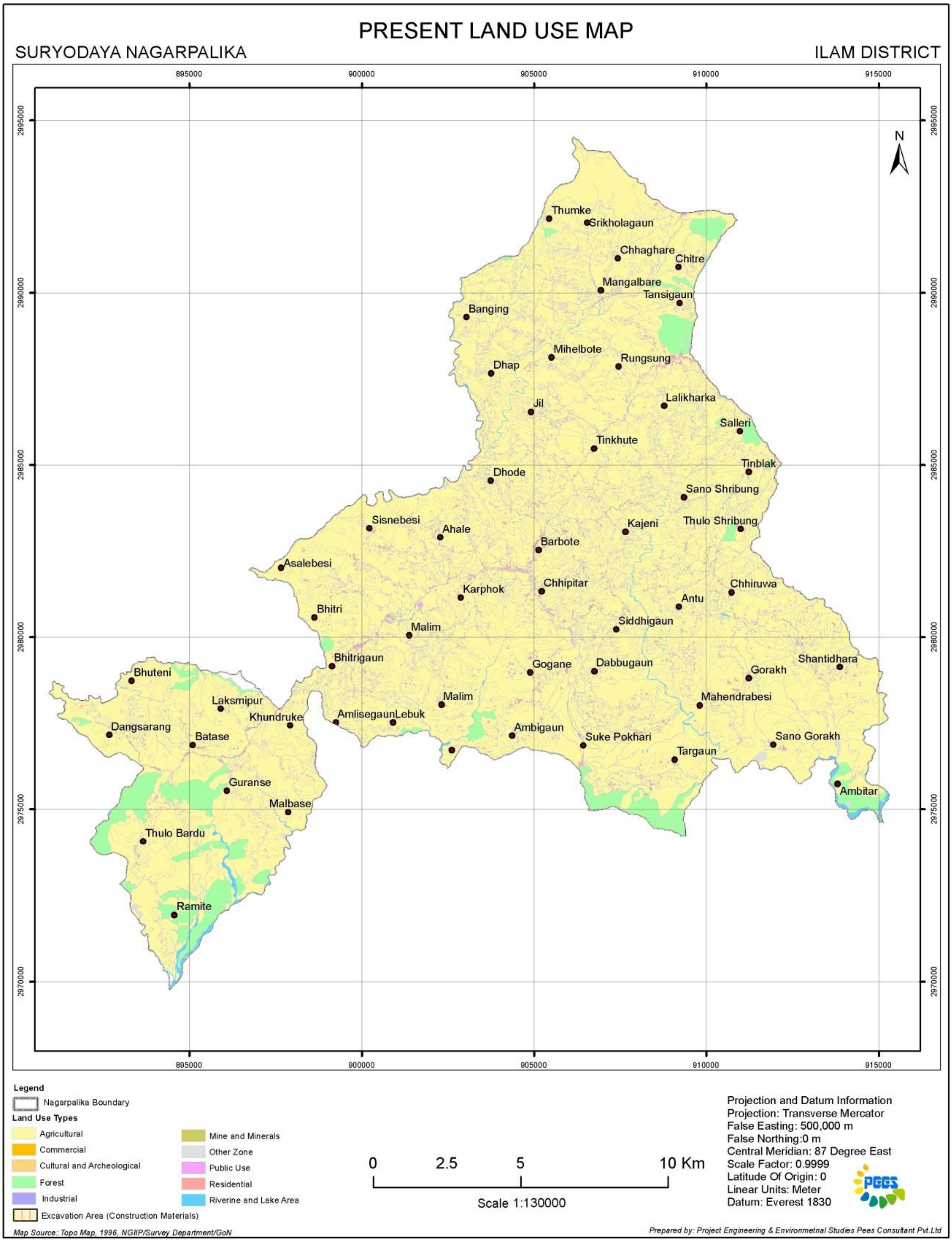

Figure 3.4: Present Land use Pattern of Suryodaya Nagarpalika

3.5 Land Use Zones

Agriculture zone is dominant followed by forest area, residential area and public service area. Commercial area is also remarkable as the Nagarpalika has growing fast in Ilam district. Phikkal and Pashhupatinagar are business centers and growing rapidly in the Nagarpalika. The Industrial and Cultural and archeological areas are not in significant scale. Mines and mineral sites, Excavation area and undersigned other land use site do not exists however, some river banks are being used to excavate sands and stones informally by the local people.

The decrease in agricultural area is due to the allocation of new sites and areas for residential, commercial and public use and open space use together with the propose for new forest within the high risk of landslide, bank cutting, erosion and flooding. Residential and commercial area was allocated at high fertile arable land. Commercial area was allocated at the main core business area in existing residential extent and high possible of economic activities along major road junction, highly development of available commercial infrastructure. The Excavation area, Mine and Mineral and the Other Zone are not identified in this area. Table 3.6 shows the land use zones in Suryodaya Nagarpalika.

Table 3.6: Land use zone in the study area

S.N.	Description	Area (ha)	Percentage
1	Agriculture	15492.95	69.05
2	Forest	5626.79	25.08
3	Residential	586.47	2.61
4	Public Use	474.81	2.12
5	Riverine & Lake Area	245.44	1.09
6	Commercial	7.07	0.03
7	Industrial	3.85	0.02
8	Cultural & Archeological	0.76	0.003
	Grand Total	**22438.14**	**100.00**

Source: NLUP, 2018c

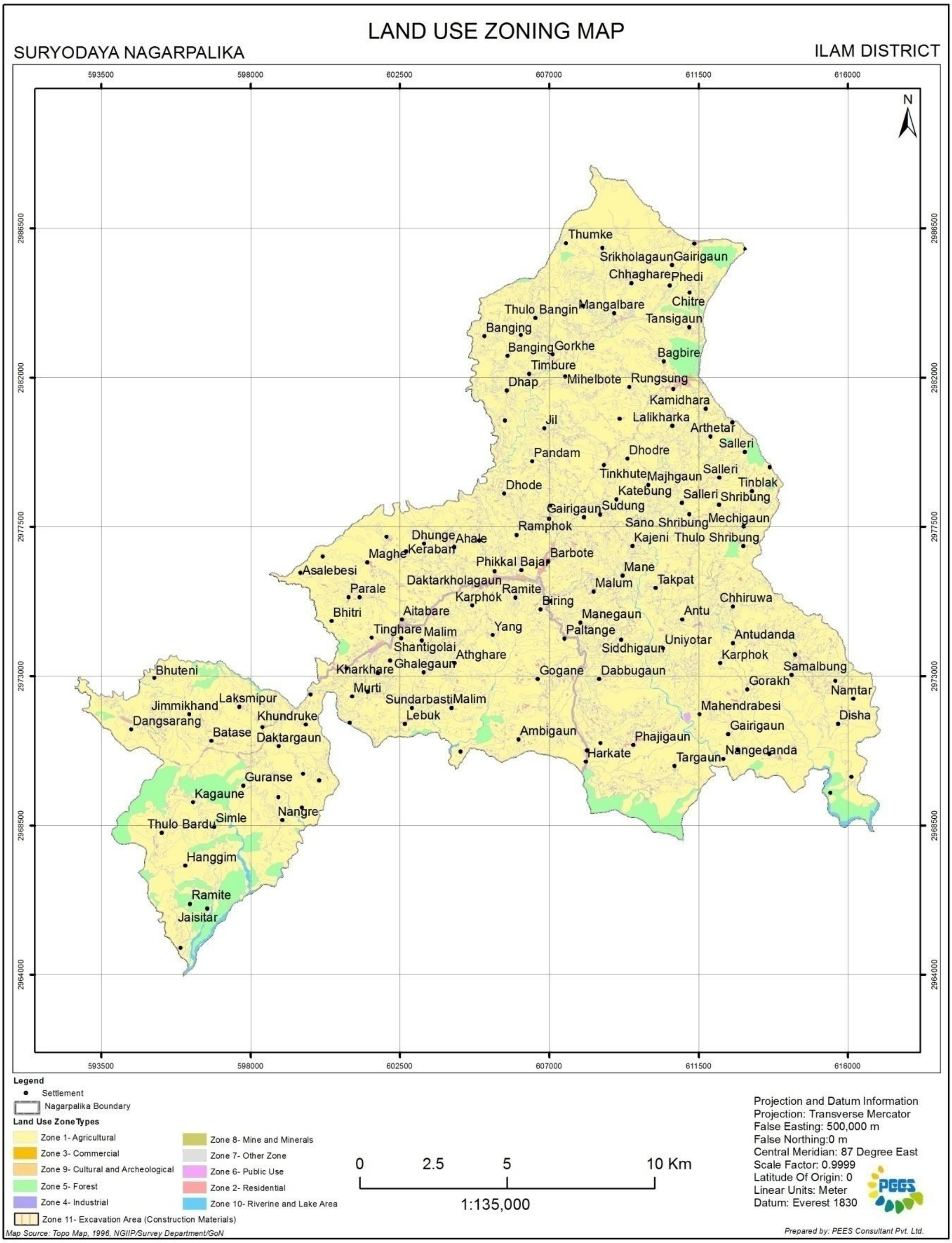

Figure 3.5: Land Use Zoning Map of the Nagarpalika

3.6 Cadastral Data

Cadastral Survey in Ilam district was carried out during 2024-2028 B.S. Due to lack of a land use zoning regulations the parcel size and use have undergone random conversions over the years. Suryodaya Nagarpalika had 43055 land parcels and area covered in the survey was 19524 ha.

Cadastral Parcel Superimpose on Present Land Use

In the cadastral area of the Suryodaya Nagarpalika, out of the designated 11 classes, eight land use classes do exist excepting the Excavation area, and Mining and Mineral area land use classes. It is significant that there are only 3 land parcels for undersigned other land use class. The predominant land use was the agriculture land use that covers with a total of 13954 ha (71%) having 29647 land parcels out of the total 43055 land parcels in the Nagarpalika. The coverage of the forest land parcels covered 4495 ha (23%) having 9018 land parcels. The coverage of the residential land parcels covered 569 ha (2.9%) having 2914 land parcels. Similarly, the public use and open space parcels are significant of about 365 ha (1.9%) having 1234 land parcels. The coverage of the hydrographic feature such as riverine and lake area land parcels covered 125 ha (0.6%) having 177 land parcels. About 0.003% (0.51ha) area fall on the cultural and archeological land use class, which is as well significant (Table 3.7)? The distribution of land parcel on present land use is shown in Figure 3.6.

Table 3.7: Parcel Characteristics of Present Land Use

S.N.	Present Land Use	No. of Parcel	Area (ha)	Percentage
1	Agriculture	29647	13953.50	71.47
2	Forest	9018	4495.34	23.02
3	Residential	2914	569.16	2.92
4	Public Use	1234	364.54	1.87
5	Riverine & Lake	177	124.72	0.64
6	Industrial	16	7.39	0.04
7	Commercial	42	7.08	0.04
8	Others	3	1.86	0.01
9	Cultural & Archeological	4	0.51	0.003
	Grand Total	**43055**	**19524.09**	**100.00**

Source: NLUP, 2018d

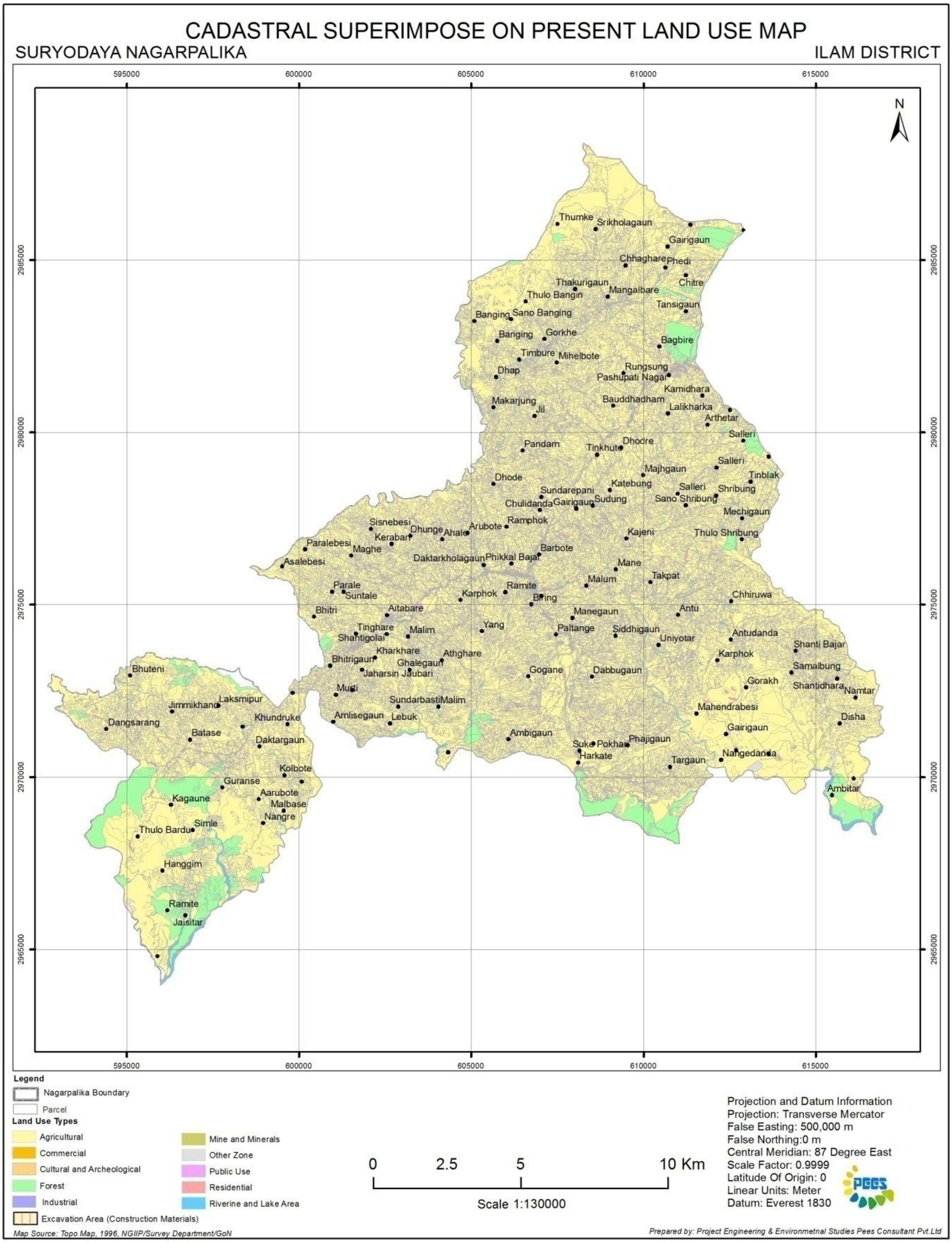

Figure 3.6: Cadastral Parcel Superimpose on Present Land Use

Cadastral Parcel Superimpose on Land Use Zoning

In the cadastral area of the Nagarpalika, out of the designated 11 classes, zoning for eight classes is made thus avoiding the Excavation area, Mining and Mineral area and undersigned other land use classes. Agriculture land parcels are reduced from 13954 ha to 13891 ha a significant loss of 0.5% in terms of areal extent whereas agriculture land parcels are reduced from 29647 to 29104 land parcels. The significant change in the existing agriculture land use land parcels allocation has converted into residential, commercial andpublic use land use classes. Prominent change of Residential land parcels has increased by 22 ha and increased by 71 land parcels. Commercial land parcels have increased by 2 ha and increased by 73 land parcels. There is marginal increase in public service land parcels by 44 ha. The distribution of cadastral parcel in land use zoning classes is shown in Table 3.8 and Figure 3.6.

Table 3.8: Parcel Characteristics of Land Use Zoning

S.N.	Land Use Zoning	No. of Parcel	Area (ha)	Percentage
1	Agriculture	29104	13891.32	71.15
2	Forest	8975	4491.14	23.00
3	Residential	2843	591.74	3.03
4	Public Use	1824	408.03	2.09
5	Riverine & Lake	177	124.72	0.64
6	Commercial	115	9.32	0.05
7	Industrial	13	7.32	0.04
8	Cultural & Archeological	4	0.51	0.00
	Grand Total	**43055**	**19524.09**	**100.00**

Source: NLUP, 2018d

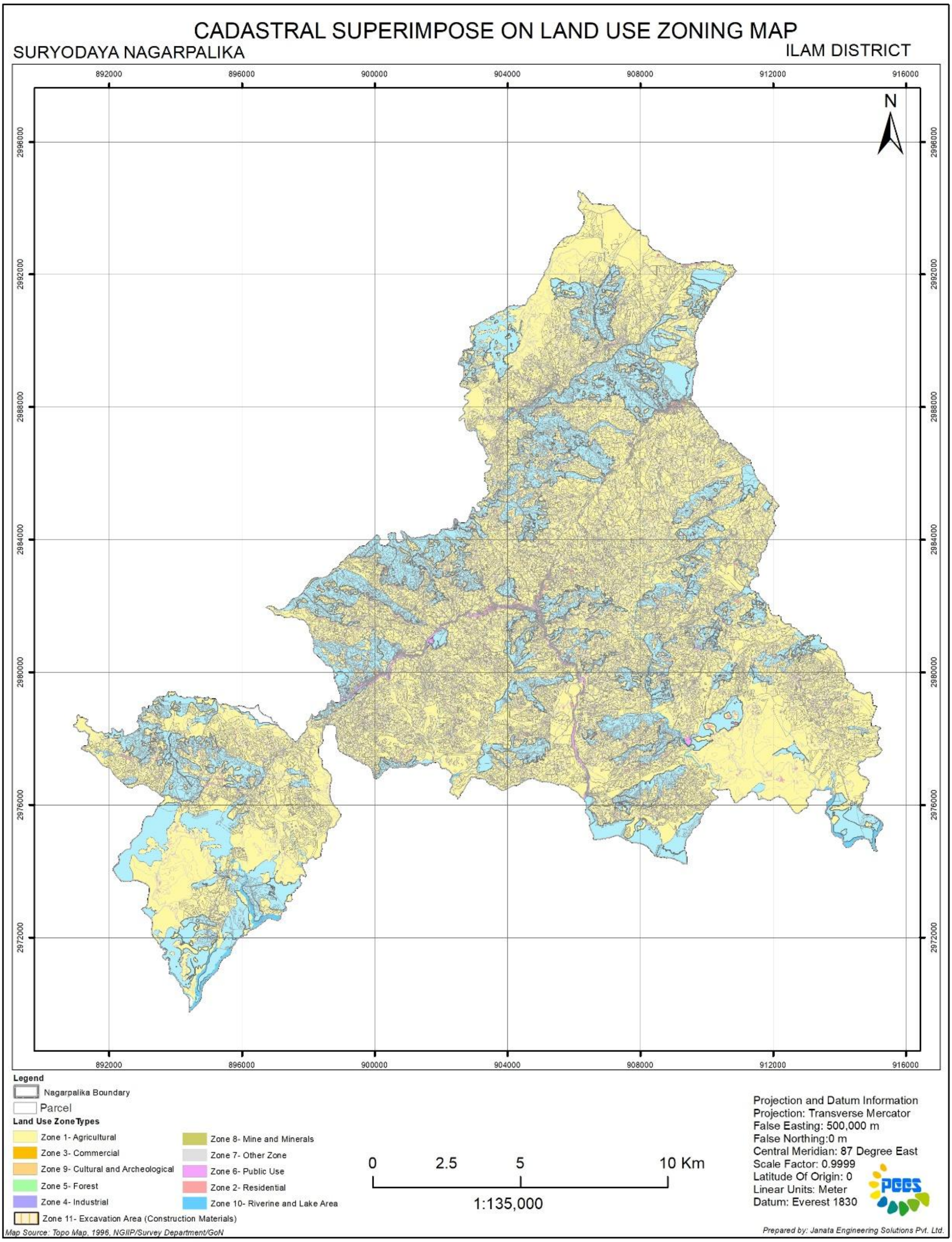

Figure 3.7: Cadastral Parcel Superimpose on Land Use Zoning

CHAPTER 4: SOCIO-ECONOMIC SETTINGS

4.1 Socio-economic settings

This chapter deals with socio-economic settings of Suryodaya Nagarpalika. In so doing, it deals with social attributes and economic phenomena such as employment and occupation, industries, remittance, present income sources and its potential opportunities.

4.1.1 Population distribution and density

According to the National Population Census, 2011, the total population of this Nagarpalika was 56,707 and the numbers of households were 13,211. This gives an average household size of 4.29, which was higher than the national average of 4.88. Of the total population, female and male populations were recorded 51% and 49% respectively. Ward 1 of the Nagarpalika was recorded the largest population size (5,358), whereas Ward 7 with a total population of 2,322 was the smallest one (Table 4.1). The total area of the Suryodaya Nagarpalika is 22438.57ha. Population density of the Nagarpalika has been calculated 252 people per square km.

Table 4.1: Population and Household by Wards and Sex

Ward No.	Households	Male	Percentage	Female	Percentage	Total
1	1228	2640	9.47	2718	9.42	5358
2	1076	2103	7.55	2200	7.63	4303
3	904	1939	6.96	2029	7.04	3968
4	1167	2447	8.78	2534	8.79	4981
5	1018	2170	7.79	2127	7.38	4297
6	666	1391	4.99	1446	5.01	2837
7	539	1169	4.19	1153	4.00	2322
8	970	2029	7.28	2068	7.17	4097
9	962	2056	7.38	2162	7.50	4218
10	1269	2519	9.04	2561	8.88	5080
11	944	2034	7.30	2163	7.50	4197
12	967	2093	7.51	2196	7.61	4289
13	622	1372	4.92	1403	4.86	2775
14	879	1905	6.84	2080	7.21	3,985
Total	**13,211**	**27,867**	**100**	**28,840**	**100**	**56,707**

Source: National Population and Housing Census 2011(Village Development committee)

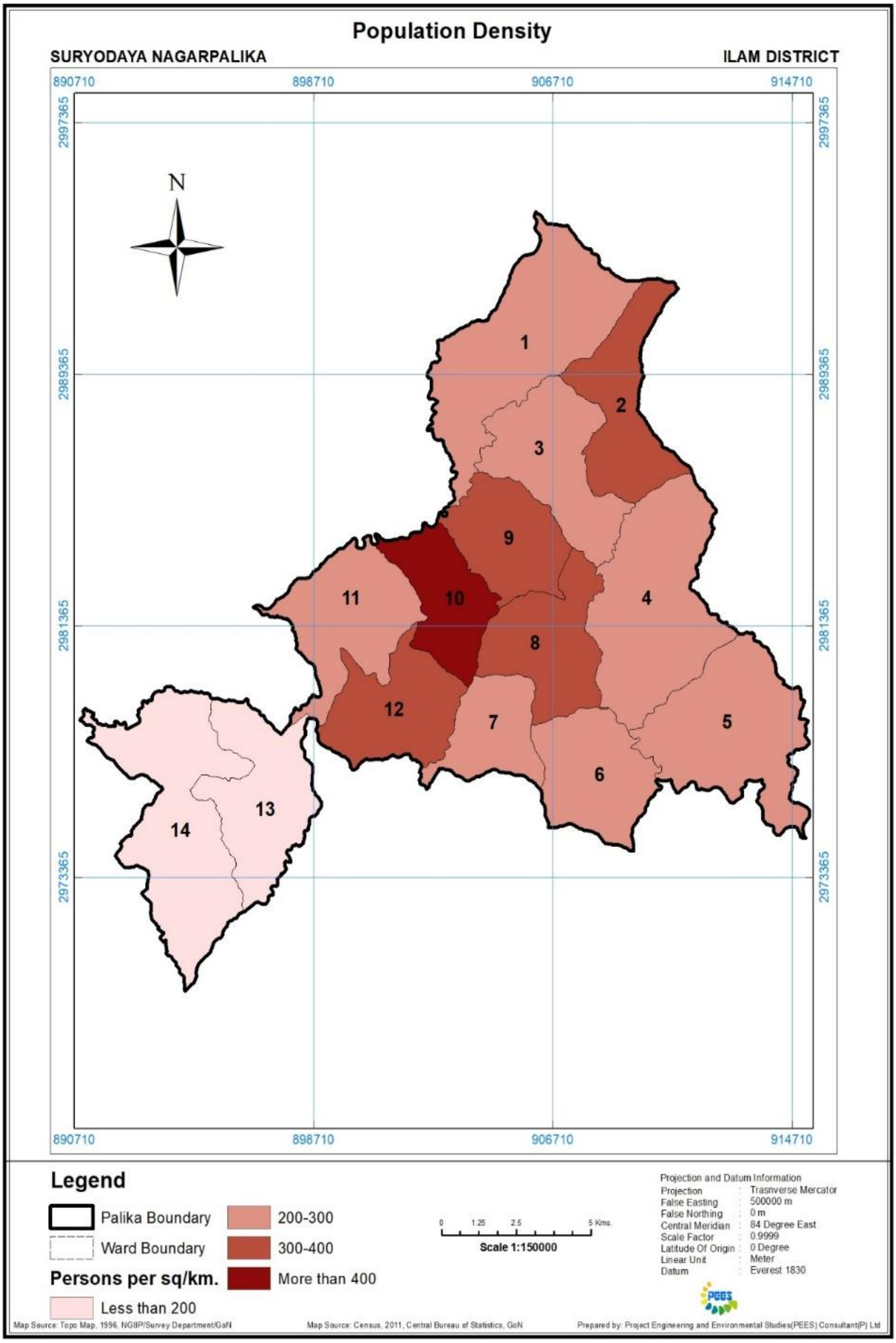

Figure 4.1: Population Density Map of Suryodaya Nagarpalika

4.1.2 Population by Caste/ Ethnicity

Caste and ethnicity are the major component of social structure. Suryodaya Nagarpalika is inhabited by people from diverse ethnic backgrounds including Adibasi-Janajati (Rai, Limbu, Magar, Newar, Gurung, Tamang, Kumal etc), Dalit (Kami, Sarki, Damai) etc), and other ethnic group (Brahman, Chhetri, Thakuri, Sanyasi etc). The detail of different castes and their corresponding population size is presented in the Table 4.2.

Table 4.2: Population of the Suryodaya Nagarpalika by Caste/Ethnicity

Caste/Ethnicity	Total Population	Percentage
Rai	15393	27.14
Brahman	9789	17.26
Chhetri	7378	13.01
Tamang	6460	11.39
Limbu	3231	5.70
Newar	2767	4.88
Magar	1989	3.51
Others	9700	17.11
Total	**56707**	**100.00**

Source: National Population and Housing Census 2011(Village Development committee)

Table 4.2 shows that, Rai (27.14%) and Brahmin (Hill) (17.26%) are main ethnic groups inhabited in the Nagarpalika followed by the Chhetri (13.01%) and the Tamang (11.39%).Khawas, Thakuri, Gharti/Bhujel, Sanyasi/Dashanami, Sunuwar, Magar, Sherpa, Lepcha, Thami, Sarki etc are also recorded in the Nagarpalika with their small population size.

4.1.3 Literacy Status

About 83.2% populations of age 5years and above are literate. They can read and write. About 88.9% males and 78.4% female of age above 5 years and above are literate in the Nagarpalika (Table 4.3). Similarly, about 35.5% population of age 5 years and above have passed primary level of education while about 15.2% population have passed secondary level of education and additional 9.6% have passed SLC or equivalent in the Nagarpalika (Table 4.4).

Table 4.3 Population aged 5 years and above by literacy status and sex in Suryodaya Nagarpalika

Description	Total Population	Population who			Literacy rate %
		Can read & write	can read only	can't read &write	
Both Sex	55109	44916	986	9171	83.2
Male	26998	23384	477	3122	88.9
Female	28111	21532	509	6049	78.4

Source: National Population and Housing Census 2011(Village Development Committee/Municipality) 2012.

Table 4.4 Population aged 5 years and above by educational attainment (level passed) and sex in Suryodaya Nagarpalika.

	Total	Population that have completed the educational level of							Non-formal education	Level not stated
		Beginner	Primary (1-5)	L.secondary (6 -8)	Secondary (9 -10)	S.L.C. & equiv.	Intermediate & equiv.	Graduate & Above		
Both Sex	45196	650	16050	10284	6861	4360	2061	730	3433	569
Male	23535	339	8657	5201	3378	2161	1126	478	1742	298
Female	21661	311	7393	5083	3483	2199	935	252	1691	271

Source: National Population and Housing Census 2011(Village Development Committee/Municipality) 2012.

Several educational institutions are established in the Suryodaya Nagarpalika. There are 56 pre-primary and 14 secondary schools(District Education Office Ilam, 2074), and several private boarding schools established in the Nagarpalika area which indicates that people have good access to education facilities.

4.1.4 Population by religion

According to the Nagarpalika Office record (2073), the Hindus are the dominant religious group, accounting for about 80%, follows by Kirat, Buddhist and Christian (Table 4.5).

Table 4.5: Population by Religion in Suryodaya Nagarpalika

Religions	Population
Hinduism	80
Kirat	11
Buddhist	7
Christian	2
Total	100.00

Source: Suryodaya Nagarpalika, 2018

4.2 Economic Settings

Economy is one of the most important components of the people to make their livelihood better. There are different income sources in this Suryodaya Nagarpalika. Major income sources are remittance, public and private services, agriculture, labour work, livestock and business. Growing cash crops is becoming common among the Nagarpalika farmers, as the local communities are involved in cash crops farming. Some of the local agriculture products, particularly Tea, ginger, Amriso, cardamom, Akabare Khursani and vegetables are exported to Budhabare and Birtamode (Jhapa) and Mirik, Sukha Pokhari and Darjaling (India); and sometimes Kathmandu Valley as well. There is increasing trend of the people being involved in cash crop farming. Besides agriculture, some households run their own business and services for their livelihood.

4.2.1 Agriculture

4.2.1.1 Food Production

Area and ecosystem and total geographical area of this Nagarpalika is 22438.75 hectors, however the total cultivated land in 200 KM^2 (20,000 hectors). The total cultivated land under horticulture is 25KM^2(2500 hectors) and rest area is under other agronomical crops. The irrigated area 20% and unirrigated area is 80%. Irrigated area throughout the year is only 13% and rest 7% is seasonally irrigated only. 90% area is sloppy land i.e. terrace and only 10% area is leveled field called tar. Soil of leveled field is fine textured and fertile with high water holding capacity. But soil of terraces is coarse textured, light soil with poor fertility and less water holding capacity. Source of irrigation management is generally personal or individual.

Table 4.6: Productivity of major cereal and cash crops

S.N.	Crop	Productivity	(Ton / ha)
		Irrigated	Unirrigated
1	Rice	3.38	2.86
2	Wheat	3.90	2.30
3	Maize	3.40	2.85
4	Potato	14.66	11.96
5	Ginger	-	14.22
6	Cardamom	-	0.36
7	Tea	-	1.08
8	Akabare Khursani	-	3.68

Source: DADO, Ilam 2074.

Table 4.7: Crop Calendar

S.N.	Crop	Planting Time	Harvesting Time
1.	Rice	Jaisth - Asadh	Ashoj – Mansir
2.	Wheat	Kartik, Mansir, Poush	Chaitra-Baisakh
3.	Maize	Falgun - Chaitra	Baisakh – Jestha
4.	Potato (Winter)	Ashoj – Mangsir	Poush – Falgun
5.	Potato (Rainy)	Poush – Falgun	Asadh – Shrawan
6.	Rainy season Vegetable	Magh- Jesth	Asadh – Shrawan
7.	Winter Season Vegetable	Shrawan – Mangsir	Kartik – Falgun
8.	Ginger	Falgun – Baisakh	Kartik – Poush
9.	Tori *Sarson*	Ashoj – Kartik	Magh – Flagun
10.	Pea	Shrawan – Kartik	Ashojh – Magh
11.	Akbare Khursani (Red Round Chili)	Magh – Falgun	Jestha – Shrawan

Source: DADO, Ilam 2074.

Crops and Cropping System: Agronomical crops grown are rice maize, wheat, mustard and millet. Vegetable crops grown are *Ishkush*, tomato, potato, cauliflower, radish, cabbage, cucurbits. Cropping system under irrigated condition are rice-fallow-rice, rice-wheat-maize, rice-potato-maize, rice-wheat-fallow, rice-vegetable-vegetable, rice-lentil-fallow. Cropping system under partially irrigated area is rice-wheat-fallow, maize-wheat-fallow, rice-maize-fallow, rice-potato-fallow. Cropping system under unirrigated area is millet-wheat-fallow, millet-potato-fallow, millet-mustard-fallow, maize-mustard-fallow, and maize-vegetable-fallow.

Table 4.8: Cropping System and Cropping Intensity

Khet Land (Low Land)		Pakho Land (Upland)	
Cropping system	**Cropping Intensity (%)**	**Cropping system**	**Cropping Intensity**
Rice-Wheat Maize	300	Maize - millet-fallow	200
Rice-fallow-Maize	200	Maize-potato	200
Rice-potato-maize	300	Maize millet-tori	300
Rice-lentil-fallow	200	ginger -fallow	100
		Maize-millet-potato	300
		Maize-pulse-fallow	200
		Maize-Vegetable	200

Source: DADO, Ilam 2074.

Cropping Pattern and Cropping Intensity: In rainy season, most of the area is under rice followed by maize, millet and legume crops like black gram, soybean. In winter season 15% area is under wheat, 10% area is under winter maize 5% area under mustard and 10% area under potato. In spring season, most of area is under vegetable like cucurbits and other.

4.2.1.2 Production of High value Crops

Suryodaya Nagarpalika is famous for tea and other five high value crops - Aalu (potato), Alaichi (cardamom), Aduwaa (ginger), Akabare khursani (red round chilly) and Amliso. These are the high value crops grown in the Nagarpalika. Potato, ginger, cardamom, red round chilly and amliso are exported to Siliguri and Darjeeling in India whereas Tea is exported to foreign countries.

Existing Management Practice, Productivity and Income Level: The present crop management practice is very traditional, poor and old resulting into subsistence, uneconomical and non-profitable in terms of income level. There is severe deficit of quality seed of improved variety of different crops in different season, irrigation facility, availability of various inputs like organic manure and inorganic fertilizer, use of plant protection chemicals like insecticide, fungicide, herbicide, and growth substance. Apart from deficit of inputs, there is lack of technical knowledge about use of manures and fertilizers and plant protection chemicals. The prevailing productivity of rice, wheat, maize, lentil, mustard, potato, vegetables and fruits and cash crops is low and poor. The present productivity of rice is 2 to 2.5 ton per hector maize 3 to 3.5 ton per hector, wheat 1 to 1.5 ton per hector, lentil 500 – 600 kg per hector, mustard 400 to 500 kg per hector. Productivity of vegetable, fruit and cash crop is low and poor as compared to potential yield i.e. possible maximum yield. With scientific method of crop production, productivity of rice can be raised to 7.5 to 8 ton per hector, wheat 5 to 6 ton per hector, maize 8 to 10 ton per hector, mustard 2 ton per hector, lentil 2.5 ton per hector.

Recommendation for Obtaining Maximum Yield: The existing present poor productivity of various crops can be tripled or increased many folds with the supply or availability of quality seed of improved variety of various crops and vegetable, irrigation facility optimum quantity of manures and fertilizers use, use of plant protection chemicals. For the cultivation of rice, wheat, maize, mustard, vegetables and fruits under irrigated condition 2 KG potash, 4 KG DAP and 6 KG urea along with 500 KG FYM per ropani should be applied, urea should be applied in various splits. One fourth urea should be applied as basal dose in the beginning and remaining at 20 days interval. If sufficient FYM is not available, biopower or zyme available in the market can be used at the rate of 1 kg per ropani but for unirrigated condition for the cultivation of rice, maize, wheat, mustard, vegetable and fruits, 1KG potash, 2KG DAP and 3 KG urea along with 500 KG FYM or biopower 1 KG per ropani should be applied. For the cultivation of legume crops either pulses, vegetables and fruits 1.5 kg potash, 3 KG DAP and 500 KG FYM or 1 KG biopower per ropani should be used under irrigated condition. But under unirrigated condition above dose should be reduced by 50%.

4.2.1.3 Livestock farming

Livestock is an important component of the farming system in Suryodaya Nagarpalika. Livestock is reared as an indispensable to the farming system and hence both livestock and crop farming are practiced as an integrated farming system. People use to rear cattle like cows and buffaloes for the purpose of milk and ghee, and they rear goat, pig and hen for the purpose of meat. Milk and ghee are one of the main sources of family income of the local people. The manure produced from the livestock farming is used for agricultural purpose. According to the Nagarpalika sources, there were altogether 1, 92,200 livestock heads (Table 4.9). . In general, number of livestock owned per household is 1 cow, 1 buffalo, 1 goat and 1 pig. Management level of livestock is very old and traditional far away from modern livestock management. Therefore, productivity and income from livestock is very low.

Table 4.9: Types of Livestock, Suryodaya Nagarpalika

Livestock	Total
S/he Cow	40000
S/he Buffalo	8000
Goat	66000
Pig	13000
Hen	65000
Duck	200
Total	**192200**

Source: Suryodaya Nagarpalika, 2018

4.2.1.4 Fish Farming

There are two fish ponds and area of fish pond is 0.25 hectors. In rivers Asala fish is available. Management level of fish farming is suboptimal and hence, productivity income is not satisfactory.

4.3 Employment/Occupation

Agriculture is the main source of income and employment of the people living in the Nagarpalika. About 70% population is depends on agricultural and livestock. Apart from this, 10% population is engaged in service sector and about 9% are run their own business and industry (Table 4.10).

Table 4.10: Occupational Information (15-59 age groups)

Occupations	House hold Numbers	Percentage
Agriculture & Livestock	9248	70
Services	1322	10
Business/ Industry	1190	9
Others	1451	11
Total	**13211**	**100**

Source: Suryodaya Nagarpalika, 2018

4.4 Industry

Suryodaya Nagarpalika is famous for tea farming. There are altogether 30 tea industries and 18 *Chhurpi*(hard cheese)industries. In addition, there are some small scale industries such asoil mills/rice mills. Tea and Chhurpi industry are the main source of income which are also exported to the third countries as well.

4.5 Remittance

Based on interaction with Nagarpalika office personnel and local informants, it was found that many youths of this Nagarpalika are engaged in foreign employment. Most of them went to Malaysia, Dubai, Saudi Arabia and Qatar. Therefore, remittance has played a significance role for improving living conditions of the families whose members are employed in abroad. About 23% of the total population is estimated to work outside the country, and average annual income is estimated at NRs 396,000,000.

4.6 Sources of Income

There are different sources of income such as agriculture, livestock, remittance, labor work, services, business etc. According to the Suryodaya Nagarpalika 2018, remittance is the largest source of income, which is followed by agriculture/livestock, business, service, wage labor and others (Table 4.11).

Table 4.11: Major source income of Suryodaya Nagarpalika

Types	Income in NRs	Percentage
Agriculture/Livestock	70000000	13.54
Services	15000000	2.91
Business/ Industry	20000000	3.86
Remittances	396000000	76.59
Labor	7500000	1.46`
Other	8500000	1.64
Total	**517000000**	**100.00**

Source: Suryodaya Nagarpalika, 2018

4.7 Potential Income Opportunities

Commercial farming can be the best possible to generate income opportunities of the local people of the Nagarpalika. Geographically, Suryodaya Nagarpalika has uneven land features and beautiful landscape. In addition, the climate is also suitable for extensive agriculture and livestock farming. Different cash crops can be grown extensively, as some farmers have already began vegetable farming as cash crops. The farmers can also be attracted to large-scale farming of livestock including poultry, improved varieties of goats, cows and buffaloes. Cash crops stand first as the potential income opportunities in this Nagarpalika. Cash crops of this area include ginger (Aduwa), Amisha, Cardamom (Elaichi), Olan (milk), Orthodox tea and Bamboo handicraft. Cardamom and tea are produced in large scale which are playing major role in improving economic condition of this area (Suryodaya Nagarpalika 2074). Similarly, milk products and bamboo handicrafts are also getting popularity and expanding their market in and out of the country. Connectivity and accessibility by means of road network across the municipality and to major trunk road (Mechi highway) and market places are being crucial factors to increase the production of cash crops and livestock farming. Upgrade these roads would link farmer to market throughout the year. Industries relied on these potential products would be created, offering employment opportunities to local.

CHAPTER 5: INFRASTRUCTURE AND SERVICES

In this chapter, infrastructure and services of Suryodaya Nagarpalika has been discussed. It includes road, electricity, health facility, communication, financial and educational institutions that is indispensable for human being.

5.1 Road

Road is an important network to facilitate economic activities. The Nagarpalika is well connected by roads and transportation. There is 37 km of black-topped, 40 km of gravel and 140 km of earthen road recorded in the area (Suryodaya Nagarpalika,2074).Ward no. 2, 3, 4, 6,7, 8, 9, 10, 11, and 12 are connected by blacktopped road, and other wards are connected by gravel and earthen roads. Mechi highway, which connects Terai (Jhapa district) to mountain region (Ilam, Panchathar and Taplejung districts) passes through this Nagarpalika. There are two concrete bridges, two suspension bridges, and 10 other local bridges recorded in the Nagarpalika.

5.2 Health

There is only one government Ayubedh hospital at Panchakanya which is providing health facilities to people. In addition, 2 primary health centers located at Pashupatinagar and Phikkal, 3 health centers (Sriantu, Kanyam and Malim), 3 health posts (Laxmipur, Malim and Panchakanya), 10 private clinics, 3 private hospitals and 50 pharmacies are recorded in the Nagarpalika. Similarly, 7 Homeopathic and 2 Ayurvedic clinics and 33 Gaunghar clinics are also recorded in the Nagarpalika. In case of serious injury and some fatal cases, people usually go to Birtamod, Bhadrapur, Illam, Biratnagar, Dharan, Bharatpur and Kathmandu; and some are go to Siliguri (India) as well.

Table 5.1: Distribution of Health Institutions in Suryodaya Nagarpalika

Ward No	Health Post	Ward no/location
2	Pashupatinagar Primary Health Center	Suryodaya-2,Pashupatinagar
4	ShreeAntu Health Center	Suryodaya-4,ShreeAntu
5	Samalbung Health Post	Suryodaya-5,Samalbung
7	Kanyam Health Center	Suryodaya-7,Kanyam
8	Phikkal Primary Health Center	Suryodaya-8,Phikkal
11	Panchakanya Health Post	Suryodaya-11, Panchakanya
12	Mechi Anchal Ayurbedh Hospital Aeibare	Suryodaya-12, Panchakanya
14	Laxmipur Health Post	Suryodaya-14, Laxmipur
15	Nagar Health Center Malim	Suryodaya-15, Phikkal

Source: District Health Office Ilam 2074

5.3 Drinking Water

There has been good supply of private water taps in all wards of the Nagarpalika (Suryodaya Nagarpalika 2074).There are altogether 1800 private water taps and 1000 of public water taps. There are altogether 300 rivers-streams-rivulets, and 63 wells.

5.4 Electricity

Electricity is main source of energy, lightning and cooking. About 82% household are using electricity facility, 38% are using solar, 45%are using biogas and 98% are using firewood (Suryodaya Nagarpalika, 2074). Almost all wards are connected by electricity.

5.5 Education

The education is the first step in leading individuals and society towards creative thinking and development. It plays a vital role for the development of the community and the economy. There are 56 basic primary schools and 14 secondary schools in the Nagarpalika. The primary schools are reported in all wards, and secondary schools are recorded only in wards no. 6, 8, and 9.

Table 5.2: Distribution of Educational Institutions

S.N.	Descriptions	Community School	Institutional Schools	Total
1	Primary School	45	12	57
2	Pre- Secondary School	9	10	19
3	Secondary School	7	11	18
4	Higher Secondary School	8	1	9
5	Campus		1	1
6	Gumba	1		1
7	Technical Base School	1		1
8	Community Learning Center	3		3
9	Child Development Center	58		58
10	Resource Center	2		2

Source: Suryodaya Nagarpaika, 2074.

Table 5.3: Colleges and Higher Education Institutions in Suryodaya Nagarpalika

S.N	Name	Address	Programme	Num. of Student
1	Karfok Multiple Campus	Panchakanya	Education/Humanities/ Management	174
2	Krishnashram Secondary	Kanyam	Education/Humanities/ Management	111
3	Himalaya Secondary	Gorkhe	Education/Humanities/ Management	68
4	Karfok BidhaMandir Secondary	Panchakanya	Education/Humanities/ Management	73
5	Bauddhadham Secondary	Pashupatinagar	Education/Humanities/ Management	83
6	Phikkal Secondary	Phikkal	Education/Humanities/ Management	303
7	Jyoti Secondary	Laxmipur	Education/Humanities/ Management	45
8	Saraswoti Secondary	Laxmipur	Education/Humanities/ Management	144
9	Janak Secondary	Shree Antu	Education/Humanities/ Management	139
10	Averland Academy	Phikkal	Humanities/ Management	10
	Total			**1150**

Source: Suryodaya Nagarpalika, 2074

5.6 Financial Institution

Financial institution is important to provide economic services to people. Banks, local cooperatives and micro finances are established and expanding their services in the rural areas of the Nagarpalika. There are five commercial banks namely: Agricultural Development Bank, Excel Developmental Bank, Rastriya Banijya Bank, Global Bank and Siddhartha Bank. *Chap Dugdha Sahakari Sastha, Neelkamal Bachat Sahakari Sastha, Sadhubesi Chiya Sahakari Sastha, Camelia Dugdha Sahakari Sastha, Anamol Krishi Sahakari Satha and Nava Akata Krishi Sahakari Sastha* are also established and working in the Nagarpalika. Similarly, development banks namely: Swolamba Development Bank, Sahara Bikash Bank, Nirdhan Utthan Bank and Excel Bank are also expanding their services in the area. These banks and financial institutions are providing loan and saving-credit facilities to the local people with the interest rate varies among the various institutions; the interest rate ranges 12-17%to the banks, 20 -25% to the cooperatives and 6-14% interest rate to the micro-finances (Suryodaya Nagarpalika 2074).

CHAPTER 6: HERITAGE, CULTURE AND TOURISM

6.1 Heritage

Nepal is the Hindu country. It is rich in culture heritages. There are 30 temples in this Nagarpalika. These temples are related to Hindu people. Hindu people perform worship regularly in the temples. There are famous temples, stupas and churches in Suryodaya Nagarpalika. Actually, this is the Nagarpalika where Hindus, Buddhists and Christians are residing. There are 14 stupas and 7 churches were recorded in the Nagarpalika.

6.2 Culture

Nepal has diversity according to caste/ethnic group and culture. There are more than 100 castes/ethnic groups all over Nepal. These different castes and ethnic groups have their own customs and traditions. Generally, people following different religions have different cultures. Hindus are the dominant religious group living here. They have their own rites and rituals. Suryodaya Nagarpalika is no exception. There is mainly Hindu Pahadi in the Nagarpalika. Hindu Pahadi people celebrate different festivals like Dashain, Tihar, Teej, Maghe Sakranti, Janai Purnima, Nag panchami, Shivratri, Chaite Dashain, and Holi etc. Buddists mostly celebrate Losar, Dashain and Tihar. Similarly, Christain people also celebrate Christmas day and New Year.

6.3 Tourism

Geographically, it lies in the hill region which is mostly known as Mahabharat range with natural scenery and pleasant weather. The Nagarpalika has great possibility for the promotion of tourism. Ilam district itself is a very beautiful place with many touristic attractions. Suryodaya Nagarpalika hosts many tourist destination places such as Kanyam tea garden, Phikkal, Karfook, Pashupatinagar, Sriantu and other beautiful landscape and panoramic views. **Kanyam** is 5 KM south of Phikkal Bazar and is easily accessible on the Mechi highway. It is famous for beautiful landscape and tea gardens and pleasant weather. **Phikkal** is a business hub of Ilam district, and central of Suryodaya Nagarpalika, located along the Mechi Highway. The legendary sunrise view spot of **Sri Antu** is located on the eastern side of Ilam and situated at an altitude of 1818m from the mean sea level. The major attractions of the area are the panoramic sunrise view, antu pokhari, sungava farming and the lepcha culture and traditions. Home stays have also been begun in the area. **Pashupatinagar** is a border town, and a main entry point to Nepal from Mirik/Darjelling (India).

CHAPTER7: RISK IN THE STUDY AREA AND SAFE AREAS FOR SETTLEMENT

7.1 Flood Risk

A **flood** is an overflow of water. It usually occurs in rivers when the flow rate exceeds the capacity of the river channel. Moving water has awesome destructive power when a river overflows its banks. Country like Nepal, there is high potentiality of flash flood (rapid flooding event), erosion and inundation particularly during the monsoon season. Nepal has more than 6000 rivers and rivulets (Manandhar, 2010). These rivers and rivulets support irrigated agriculture and other livelihoods, but also wreak havoc in valleys and in the terai when they overflow (Dixit, 2010). This phenomenon occurs mainly in Monsoon. Intense monsoon rainfall causes flooding in many rivers of Nepal. The frequency of flood and scale of damage have increased in the terai and inner terai regions of Nepal. Thousands of people are affected by flood every year in Nepal during the monsoon season. Altogether, water induced disasters cause an average annual loss of 309 lives and affect 27654 families (Asia et al., 2009). MOHA (2013) reported loss of 4079 lives and affected 181961 households in 2012 due to floods in Nepal.

From the information obtained through interview with local people, it is known that flood was not frequent in most of the study area (suryodaya Nagarpalika). However, there were some major floods in the previous years in Tangting khola, Khani khola, Antu khola, Siddhi khola, Mayum khola. The main problems due to flooding are: River bank cutting, degradation of agricultural lands etc. As per them, many agricultural lands have been converted to river bank due to bank cutting, which was verified during the time of field visits. Table7.1 shows that the possible flood that can affect land use of the Nagarpalika. Figure7.1 shows the potential food prone area in the Nagarpalika.

Table 7.1: Flood Prone Area in Suryodaya Nagarpalika

Land Use Types	Ares (in ha.)				Grand Total
	High	Medium	Low	No Risk	
SURYODAYA	672.83	43.59	209.40	21512.75	22438.57
AGR	307.74	22.69	106.61	15086.86	15523.90
COM	0.10	0.00	0.08	4.01	4.18
CULARCH	0.12		0.00	0.69	0.81
FOR	198.57	10.97	53.11	5364.37	5627.02
Forest	5.80	0.27	0.55	10.49	17.11
HYD	149.76	8.74	45.77	45.30	249.56
IND	0.00	0.00	0.00	3.92	3.92
OTH	0.29	0.01	0.62	23.11	24.03
PUB	6.90	0.55	1.56	402.64	411.65
RES	3.55	0.36	1.10	571.35	576.36
Grand Total	**672.83**	**43.59**	**209.40**	**21512.75**	**22438.57**

Source: NLUP, 2018.

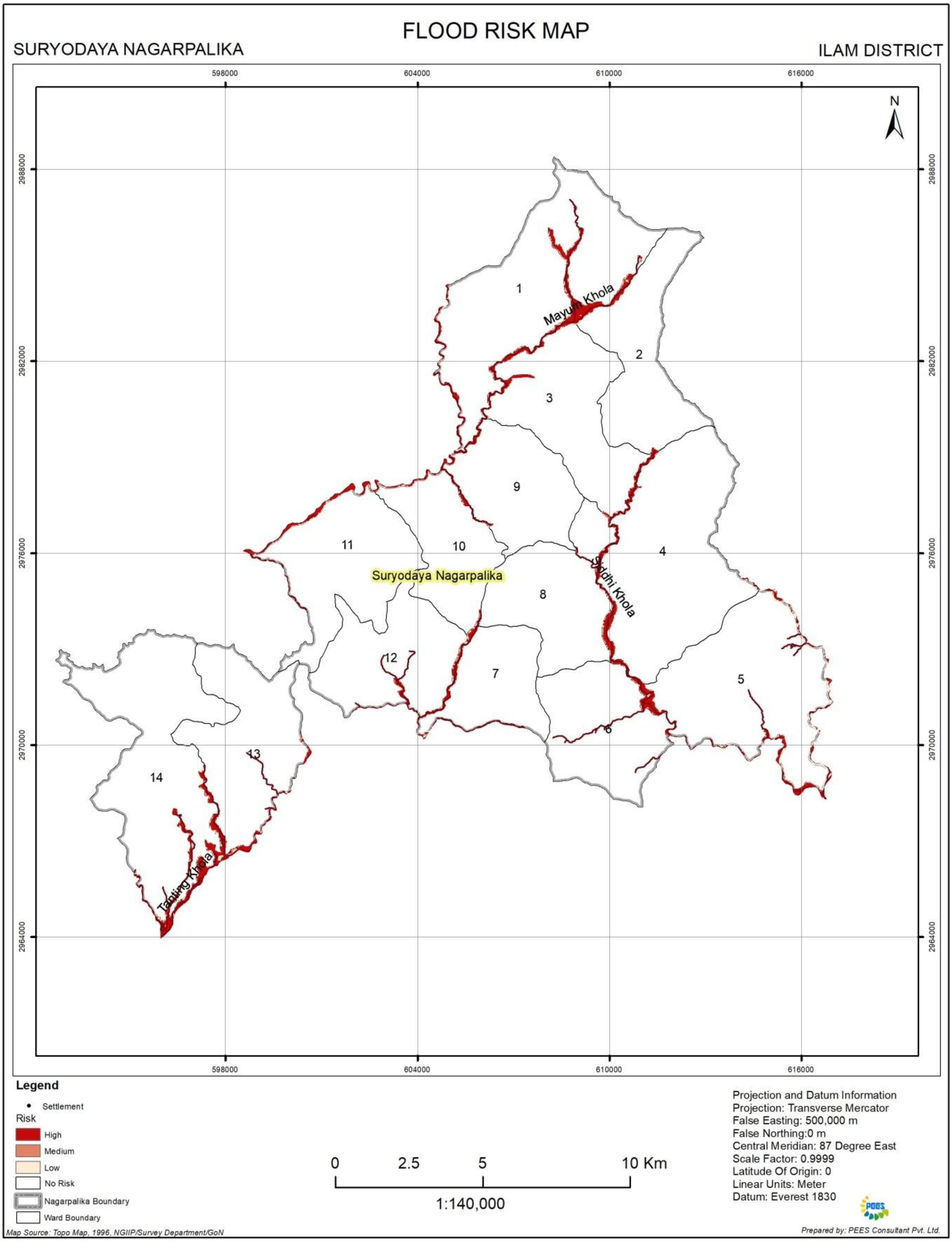

Figure 7.1: Flood Risk of Suryodaya Nagarpalika

7.2 Fire Risk

In the study area, the presence of a number of houses with thatch or straw roof; burning of agricultural wastes; unmonitored children's activities, careless smoking, and negligence in cooking could contribute to the risk of fire. The tile/slate buildings are also at risk to fire because of the faulty electrical wiring and equipment, and LPG gas, however, the risk is low compared to houses made of wood and a thatched roof. With the presence of the tea industries and petrochemical stations in the Suryodaya Nagarpalika, the Nagarpalika has fire risk inherent in such businesses.

Apart from the built-up areas, the risk of forest fire is very high during the hot-dry season in hilly areas. Suryodaya Nagarpalika has community-managed forest areas nearby and the risk of a forest fire as well. Figure 7.2 shows the potential forest fire in the Suryodaya Nagarpalika.

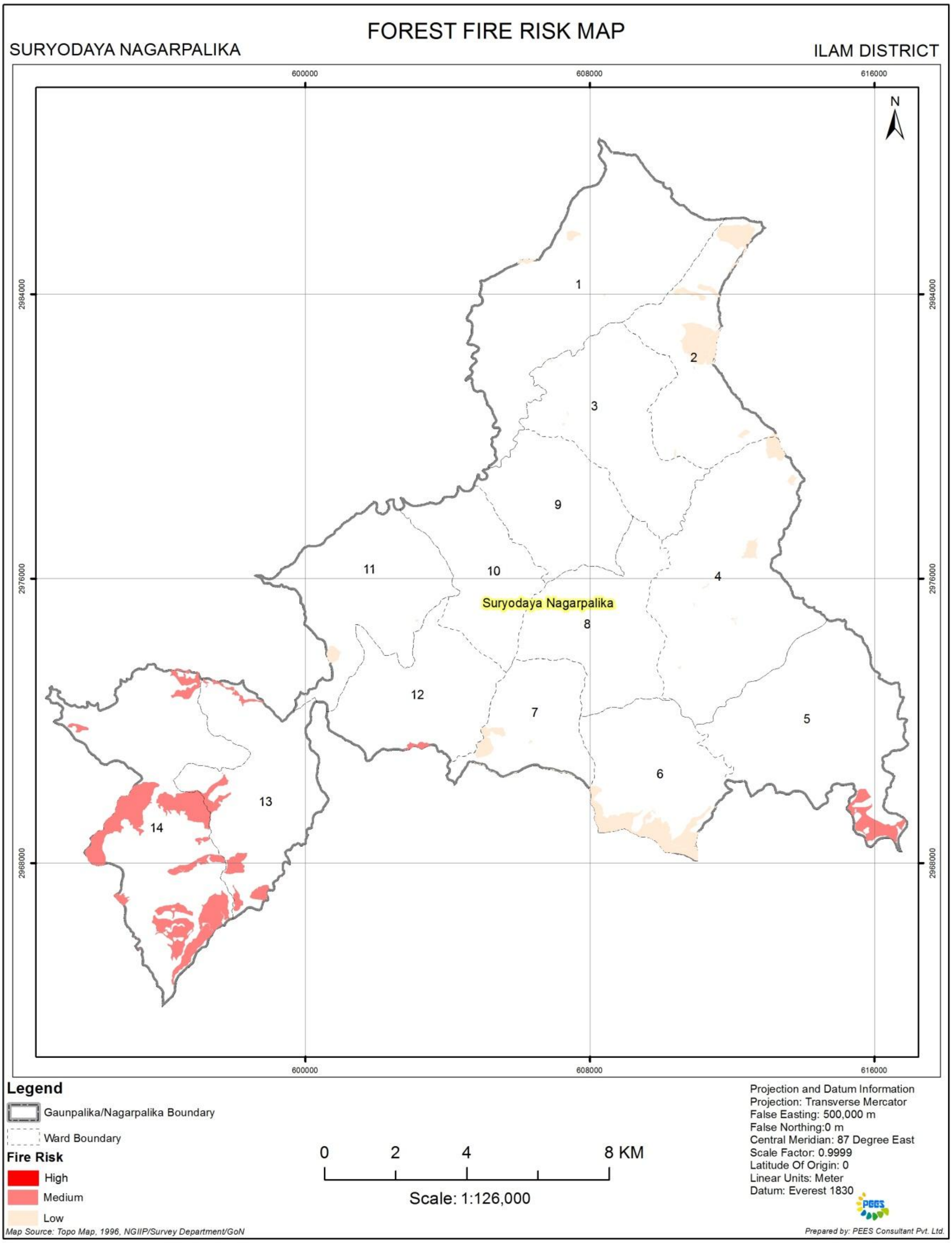

Figure 7.2: Forest Fire Map of Suryodaya Nagarpalika

In rural parts of Suryodaya Nagarpalika, there have been practices of using fire by farmers for burning crop residue, and for converting forest to agricultural land. Because fire removes the organic matter and provides an ash bed, which facilitates the growth of grasses, local people set fire to gather ash, which is locally used as manure, the activity which is sometimes blamed for fire in settlements.

The Nagarpalika is at a reasonable risk of fire in the settlement area too due to the practice of constructing houses using thatch/straw for roofing (ward number 1 has 92/1848 households; ward numbers 2 and 3 have 25/1980 households; ward number 4 & 5 have 87/2185 households; ward numbers 6-12 have 221/6317 households; ward numbers 13 and 14 have 310/2035 households;) clustered settlement in market areas, unmonitored children's activities, careless smoking, and negligence in cooking. The risk of fire is mainly likely to outbreak during the windy and the dry season e.g. Chaitra & Baisakh. During the field observation, people reported that occasional fire breakouts had affected the municipality in the past. It has been found that the Suryodaya Nagarpalika has had three major fire incidents with an estimated loss of property valuing NRs 12500000 in the past.

The lack of equipment and skilled manpower such as trained firefighters poses serious challenges in Suryodaya Nagarpalika. Furthermore, the difficult topography of the hill settlements makes it difficult for the authorities to bring a raging fire under control quickly. The clustered settlements in the market areas and building materials further worsen the risks. Because significant number of houses in the market areas in Suryodaya Nagarpalika are built in clusters with thatch and timber with no fire protection. Negligent handling also could lead to an outbreak of a major fire. Similarly, haphazard construction of houses without complying construction code and fire safety measure invariably puts such property at great risk.

The marginalized and poor community has inhabited the area. The lack of education, slash and burn cultivation, burning of agricultural residues, the clustered settlement made up of thatch and straw houses, and negligent fire handling practices among the people in these wards of the Nagarpalika potentially contributes to the fire risk in the area.

7.3 Landslide Risk

Landslides are a form of erosion and are an important process in the shaping and reshaping landscapes and landforms. Landslide hazard is frequent phenomenon is Nepal due to several reasons including tectonic activities, uncontrolled and unsafe development, heavy precipitation and environmental degradation. However it is observed that rainfall induced landslides is most prevalent in the hills and mountainous districts. In Nepal, high susceptibility zone of landslide are identified in the areas of high intensity rainfall and earthquake hazard. Earthquake induced hazard are distributed in centre (hill) zone of Nepal, which is largely dependent on Pick Ground Acceleration (PGA) values.

The landslide mapping of package 04, Ilam district is carried out using susceptibility methodology outlined under methodology by using overlay analysis in GIS environment. As more than 56 percent of the project area have slope greater than 20 degree and lies in higher rainfall zone, landslide susceptibility is found in more than 33 percent area. Among total landslide susceptible area, 5 percent area is under high susceptibility zone covering more than 400 hectare while 58 percent area has medium susceptibility of landslide occurrence (Table 7.3.). The south western and northern part of the project area is highly vulnerable to landslide susceptibility whereas middle part has relatively lower susceptibility. Forest area is relatively lower with only 12 percent coverage while more than 56 percent of the area is above 20 degree slope indicating vulnerability to landslides. Settlement and road infrastructure distribution is dispersed to all over the project area and hence landslide vulnerability of settlement and infrastructure is also variable.

Table 7.2: Landslide Susceptible Area in Suryodaya Nagarpalika (in %)

SN	Susceptibility	Area Ha	Percentage
1	High	404.65	5.32
2	Medium	4426.76	58.14
3	Low	2781.92	36.54
	Total	**7613.331**	**100.00**

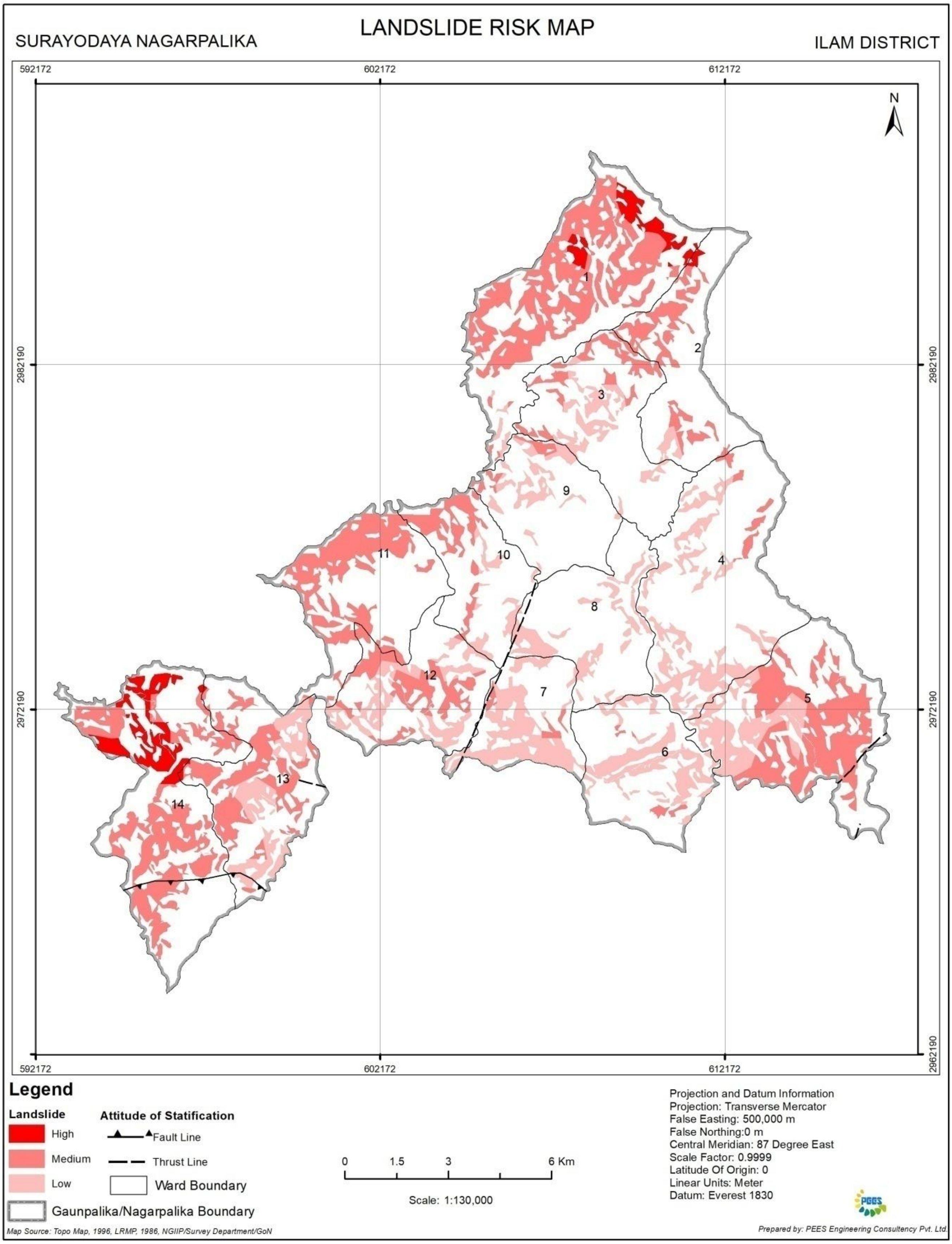

Figure 7.3: Landslide Susceptible area distribution

Landslide susceptible area of varying degree, potential landslides may be of varying likelihood of occurrence based on management practices and protection measures in the area. South-western and northern part of the project area are most vulnerable to landslides because of weak geology, hence proper management strategies and protection measures should be implemented for agriculture practices, settlement and infrastructure development.

The assessment of landslide susceptibility based on Multi criteria analysis in GIS environment indicate that there is a close relationship between slope, land cover land use and geology and landslide susceptibility. Beside, infrastructure construction mostly road construction in higher slope area with weak geology is another major factor along roadside landslide occurrence. A study by DWIDP in 2003 also reported that transport infrastructure in Nepal is heavily affected by landslide incidences every year. A field survey conducted in 2003 in arterial routes of Nepal, it was found that small- to medium-scale roadside landslides very often occur as partial landslips within existing large-scale landslides in the area. Therefore, considering greater and effective serviceability of existing transport infrastructure, better planning of newer transportation routes, and safe land-use planning, it is very important to understand the distribution pattern of large-scale landslides so as to mitigate the risk of future infrastructure damage and economic losses.

Landslide record reveals that road and human settlement slopes are more vulnerable to landslides than ordinary natural slopes. This suggests that there is significant influence of human intervention, particularly in terms of road slope cutting, land development, agricultural practices, etc., on the occurrence of landslides and related failures in Nepal (Bhandary et. al., 2012).

7.4 Seismic Risk

Nepal lies within the seismic hazards zones of the world. The Himalaya seismicity, in general, owes its origin to the continued northward movement of Indian plate after the continental collision between Indian plate and Eurasian Plate. The magnitude, recurrence and the mechanism of continental collision depend upon the geometry and plate velocity of Indian plate in relation to southern Tibet (Eurasian Plate). Recent result suggests that the convergence rate is about 20 mm/ year and the Indian plate is sub-horizontal below the sun-Himalaya and the Lesser Himalaya.

The Suryodaya Nagarpalika lies in the eastern part of Nepal which is comparatively less vulnerable in terms of seismic activities in comparison to other parts of Nepal. However, the project area is bounded by the MCT forming the tectonic window certainly have threats of seismic activities in future. This shows that a due consideration is required before planning the large scale projects like hydropower development, tunnel construction, reservoir development, highway construction, large irrigation projects and landslide mitigation techniques. That’s why geotechnical considerations are the must before starting any kind of development activities in the area. Following figures are presented here for understanding seismic status in Suryodaya Nagarpalika.

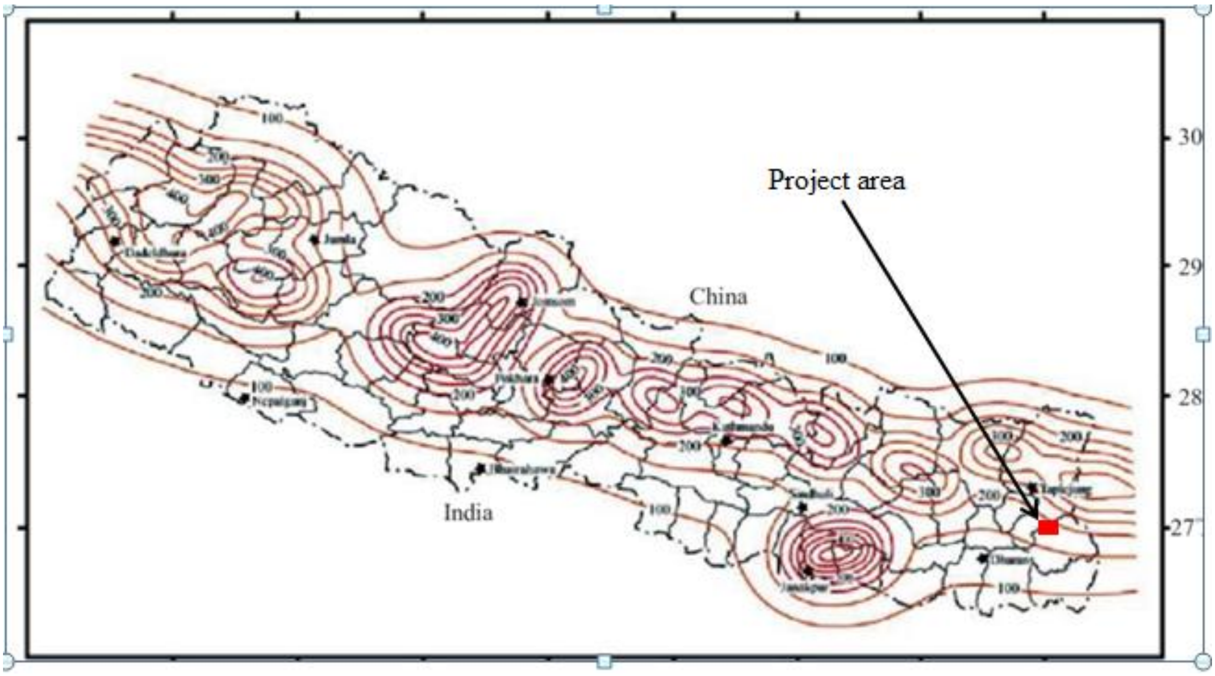

Figure 7.4: Seismic-hazard map of Nepal, (Pandey et al.2002)

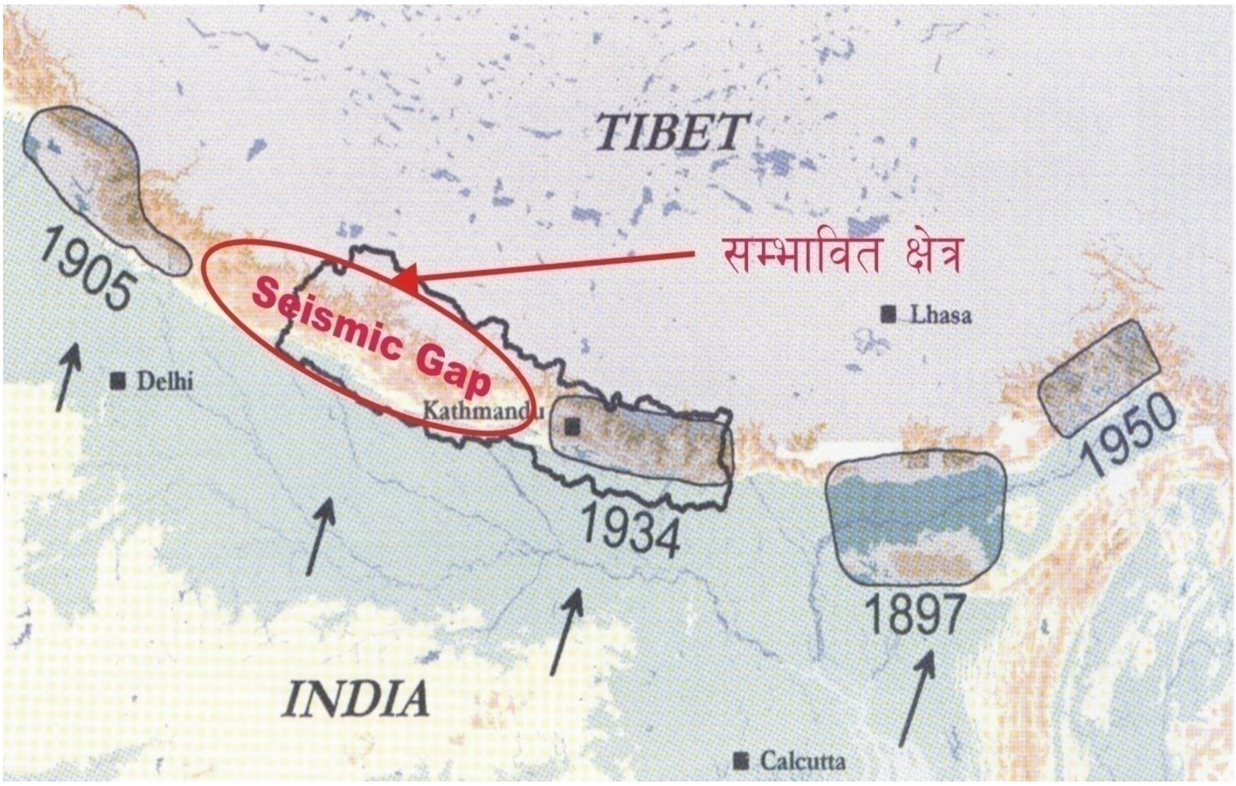

Figure 7.5: Map shows that the present area lies in the seismic gap of the region.

Preliminary seismic hazard assessment of the country using Gamble's third asymptotic extremes with the instrumental seismicity database of ISC is carried out by Bajracharya (1994) for different return periods 50, 100, 200, and 300 years, Attenuation model with mean value of McGuire and Oliveira is used for Horizontal acceleration.

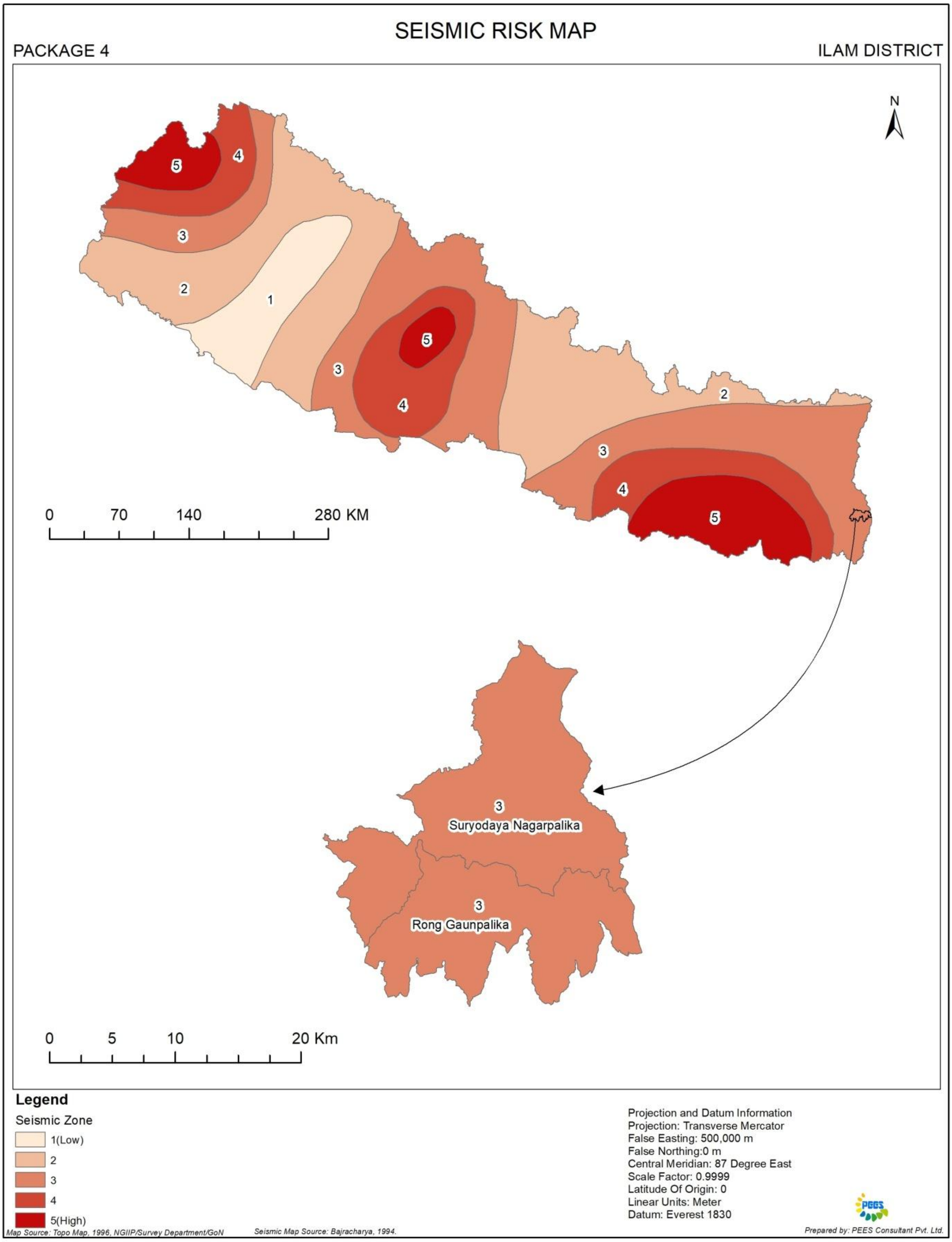

Figure 7.6: Seismic Risk map of Nepal showing the project area (Bajracharya 1994)

Several seismicity studies have been carried out for the various projects in the country during the engineering design phase and seismic design coefficient have been derived for the project. There are several methods to convert the maximum acceleration of the earthquake motion into the design seismic coefficient. Generally three methods are commonly used to establish the seismic coefficient. These are:

i. Simplest method
ii. Empirical Method
iii. Dynamic analysis method using dynamic model

The effective design seismic coefficient is determined by using the simplest method. The result obtained from this method is found to be similar in the recent studies carried out by using the dynamic analysis and the static analysis. Therefore, this method is considered to be the most common method to establish the design seismic coefficient at present. The result obtained from this method is found to be similar in the recent studies carried out by using the dynamic analysis and the static analysis. Therefore, this method is considered to be the most common method to establish the design seismic coefficient at present. The calculated effective design coefficient of Suryodaya Nagarpalika area is considered as 0.117.

7.5 Industrial Risk

There are few industries in Suryodaya Nagarpalika mostly related to tea processing. According to the latest available industrial statistics report (2072/2073) published by Ministry of Industry, there is one major tea processing industry named Phikkal Tea and Coffee Private Limited in Suryodaya Nagarpalika with a production capacity of 75 metric tons of CCT Tea, 275 metric tons of Orthodox Tea, and 20 metric tons of Coffee employing 60 workers. Except for this large-scale industry in the Nagarpalika, other industries have medium production capacity and use coal and wood as fuels to operate. They operate about 8 hours a day, generating a smoke thereby affecting the surrounding environment and settlements. The Nagarpalika has a solid waste problem, as the current solid waste disposal practice is to dump the waste into random lands. With growing number of population and the Nagarpalika's inability to tackle the garbage management issue, there has been an increase in the production of garbage and other solid waste.

Although the pollution caused by the industries in the Nagarpalika creates a nuisance to the residents who feel uncomfortable, risks from the industries are moderately negative in nature, for the long-term duration and low in magnitude as the majority of industries are agro-based. The agro-based industries generate effluents and solid wastes that need to be disposed of in an environmentally acceptable manner. In concurrence with the regulatory requirements, the industries need to adopt a sustainable approach to the waste management. The effluents generated by agro-based industries are biodegradable and non-toxic and treated by physical, chemical and biological processes. With the application of appropriate technologies, it is possible to minimize the pollution and also to recover the water and other useful materials from the waste streams.

The best way to reduce the industrial risk would be a land use planning and zoning. Industries need to abide by the environmental rules and regulations and other statutory provisions of the Government of Nepal. The discharges from the industries need to meet the requirements of quality standards as set up by the Government of Nepal. To assure the public and concerned stakeholders about the minimization of industrial risk, the Government of Nepal needs to initiate an effective monitoring system and its thorough implementation.

7.6 Other Risk

Besides above, there is other natural and anthropogenic factor that produces risk and/or hazard. Hailstone, rills and gully formation, wind and storms/thunderstorm, insecticide and pesticide are other risks in the study area but their extent and intensity is relatively low.

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PHOTOGRAPHS

Office of Suryodaya Nagarpalika

Shree Krishna Ashram Ma Vi in Suryodaya Nagarpalika

Shree Antu Tea industry

Shree Pancha kanya Temple in Suryodaya Nagarpalika

NAGARPALIKA LETTER

सूर्योदय नगरपालिका
नगर कार्यपालिकाको कार्यालय

फिक्कल, इलाम
१ नं. प्रदेश, नेपाल।

प.सं. ०७४/७५
च.नं. ३९८

मिति : २०७४/९/२१

विषय : जानकारी गराइएको सम्बन्धमा।

श्री राष्ट्रिय भू-उपयोग आयोजना
मध्यबानेश्वर, काठमाण्डौ।

प्रस्तुत सम्बन्धमा तहाँ कार्यालयबाट प.सं. ०७४/७५ च.नं. ३९८ मिति २०७४/९/१४ मा प्राप्त पत्रानुसार यस नगरपालिकाको नगरस्तरीय भू-उपयोग नक्सा तथा तथ्यांक तयार गर्ने कार्यका लागि Project Engineering and Environmental Studies (PEES) Consultant Pvt. Ltd. कोटेश्वर, काठमाण्डौबाट फिल्ड कार्यका लागि खटिएका प्रतिनिधिलाई यस नगरपालिकामा रहेका सम्बन्धित तथ्यांकहरु उपलब्ध गराइएको व्यहोरा अनुरोध छ।

सचीन्द्र भट्टराई
प्रमुख प्रशासकीय अधिकृत

Risk Report

Preparation of Risk Layer Report

Suryodaya Nagarpalika, Ilam District

This document is the output of the project entitled **Preparation of Nagarpalika/Gaunpalika level Land Resource Maps (***Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps, Cadastral Layer Superimpose and Nagarpalika/Gaunpalika Profile***), Database and Reports (Package-04)** awarded to *PEES Consultant (P) Ltd.* by Government of Nepal/Ministry of Agriculture, Land Management and Cooperatives, National Land Use Project (NLUP) in Fiscal Year 2074-075.The area covered under the Package 04 of Ilam District are: Suryodaya Nagarpalika and Rong Gaunpalika.

The Nagarpalika/Gaunpalika areas analysed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the Nagarpalika/Gaunpalika may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

The consultant is obliged to state that the Imageries, GIS database and other out puts produced for the project is owned by National Land Use Project (NLUP), Mid Baneshwor, Kathmandu. Therefore, the authorization from the NLUP is required for the usage and/or publication of the data in part or whole.

ACKNOWLEDGEMENT

The PEES Consultant (P) Ltd. is highly obliged to National Land Use Project (NLUP), for awarding the project **Preparation of Nagarpalika/Gaunpalika level land resource maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and Nagarpalika/Gaunpalika Profile)**, database and reports, Package 4 of Ilam district**. The consultant and the team members would like to extend special thanks to **Mr. Prakash Joshi**, the Project Chief of NLUP, for the positive supports during the project period. Similarly, the consultant and the team members would also like to highly acknowledge the overall supports of **Mr. Sumeer Koirala,** Survey Officer. Likewise, the consultants would like to extend thanks to Mr. Rajan Kumar Phuyal, Account Officer, Survey Officer, Mr. Prakash Dulal, Mr. Karan Singh Rawal, Mr. Dipendra Khadka, Mr. Dharma Raj Dangi, Ms. Bandana Dev, Ms. Radhika Timalsina, Ms. Sarita Gautam and Madhu Maya Bhatta and Ms. Nutan Kumari Yadav for their supports during the project period.

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CHAPTER 1: INTRODUCTION

1.1 Background and Rationale

Hazard is simply means as a condition of a potential harm. It poses a level of threat to life and properties and/or local environment. It is commonly defined as 'the potential to cause harm'; whereas the term 'risk' is generally used to described 'chance of disaster. However, it is commonly defined as 'the combination of the probability or frequency of occurrence of a defined hazard and the magnitude of the consequences of occurrence' (Royal Society 1992, cited in EEA 2011). Generally, in many environmental literature, the term 'hazard' and 'risk' used simultaneously to describe those activities which are threats to human lives properties and the surrounding environment. The analysis of risk-hazard will increase the level of awareness and knowledge for decision makers. It also provides a picture of the risk and vulnerability that may exist in our society, which supports to make threat mitigation plan or safety preparedness plan.

Land use planning is a tool to reduce potential risk from natural or manmade hazards. Man-Made Hazards are the events caused by humans and occur in or close to human settlements whereas natural hazard refers to all atmospheric, hydrologic and geologic phenomena that have potential to affect human beings, their structures, and/or activities adversely (Burton, Kates and White, 1978). Land use planning without due consideration these hazards/risks are not effective. Mainstreaming disaster risk reduction in land use planning can systematically reduce impact of specific hazard. There exist diversities in risk type such as fire, flood, landslide, seismic, industrial etc. The government of Nepal has enacted the Land Use Policy 2072. The policy has encouraged to make different land use zones (see Land Use Policy- 8-1) through the analysis of geology, capacity and suitability of land; present land use and/or as per necessary. Land use policy 2072 (policy 13) has also focused on the development of land use planning information system through the preparation of land use/land resources maps, land capability maps, hazards maps and generated database. The policy assumed that the preparation of land use zoning through the analysis of hazard risk will be more suitable to secure people's lives and properties and conducted related activities. Therefore, the main objective of this study is to investigate the risk factor associated with the land use planning.

1.2 Objectives of the Study

Disaster risk layer is considered as key components for the preparation of land use zoning maps and database. For this purpose fire, flood, landslide, soil erosion, industrial and seismic hazards are taken into consideration. Depending on the nature of disaster their inputs, objective, scope, method and output varies. Therefore, the general objective of this study is to identify the risk events potentially caused by flood, landslide, soil erosion, earthquake, fire and industry within the study areas; and prepare a risk map at 1:10,000 scale and GIS database which is required for preparation land use zoning of **Suryodaya Nagarpalika** of Ilam District (Package-04) (fiscal year 2074/75).

1.3 Study Area

Suryodaya Nagarpalika, name being the Nepali translation of "Rising Sun" declared Nagarpalika status in 2013 (2070 BS), with the merged of three Village Development Committees (VDCs) namely: Phikkal, Panchakanya and Kanyam. After, the restructuring of local body in 2073 BS, Gorkhey, Pashupatinagar, Sriantu, Samalbung, Laxmipur and Jogmai ward no. 8 and 9 were also merged into the Nagarpalika. It is located in Ilam district, province no. 1, approximately 40 km south-east of the district headquarter Ilam. Geographically, it lies in the hill region which is mostly known as Mahabharat range with natural scenery and pleasant weather. Its geographical coordinates are 87°55'59" to 88°10'37" east longitude and 27°0'28" to 26°47'17" north latitude. The Nagarpalika is bordered with India on the east, Ilam Nagarpalika and Maijogmai Gaunpalika on the west, Mai-Jogmai Gaunpalika on the north and Rong Gaunpalika on the south (Figure 1.1). Phikkal is the center of the Nagarpalika. The total area of the Nagarpalika is 22438.57 ha. which is extended north-south 25.29 km and east-west with 24.71 km.

The inhabitants are believed to have been living in this Nagarpalika since ancient time. According to the Population Census of 2011, the total population of this Nagarpalika was 56,707 and the numbers of households were 13,211. This gives an average household size of 4.3 which was lower than the national average (4.88). Administratively, the Nagarpalika has been divided into 14 wards. Ward 1 is the largest in terms of population size whereas ward 7 is the smallest one.

The Nagarpalika has diversity both in its physical and cultural aspects. It is a business hub of Ilam with beautiful landscapes. Tea, ginger, Amriso, cardamom, round chilies (Akabare Khursani), milk and potatoes are the major trade items of this Nagarpalika. The Nagarpalika has grate possibility for the tourism. Kanyam, Pashupatinagar, Phikkal, and Sri Antu are famous for tourist destination sites. Rai, Brahmin, Chhetri and Tamang are major ethnic group inhabited in the Nagarpalika.

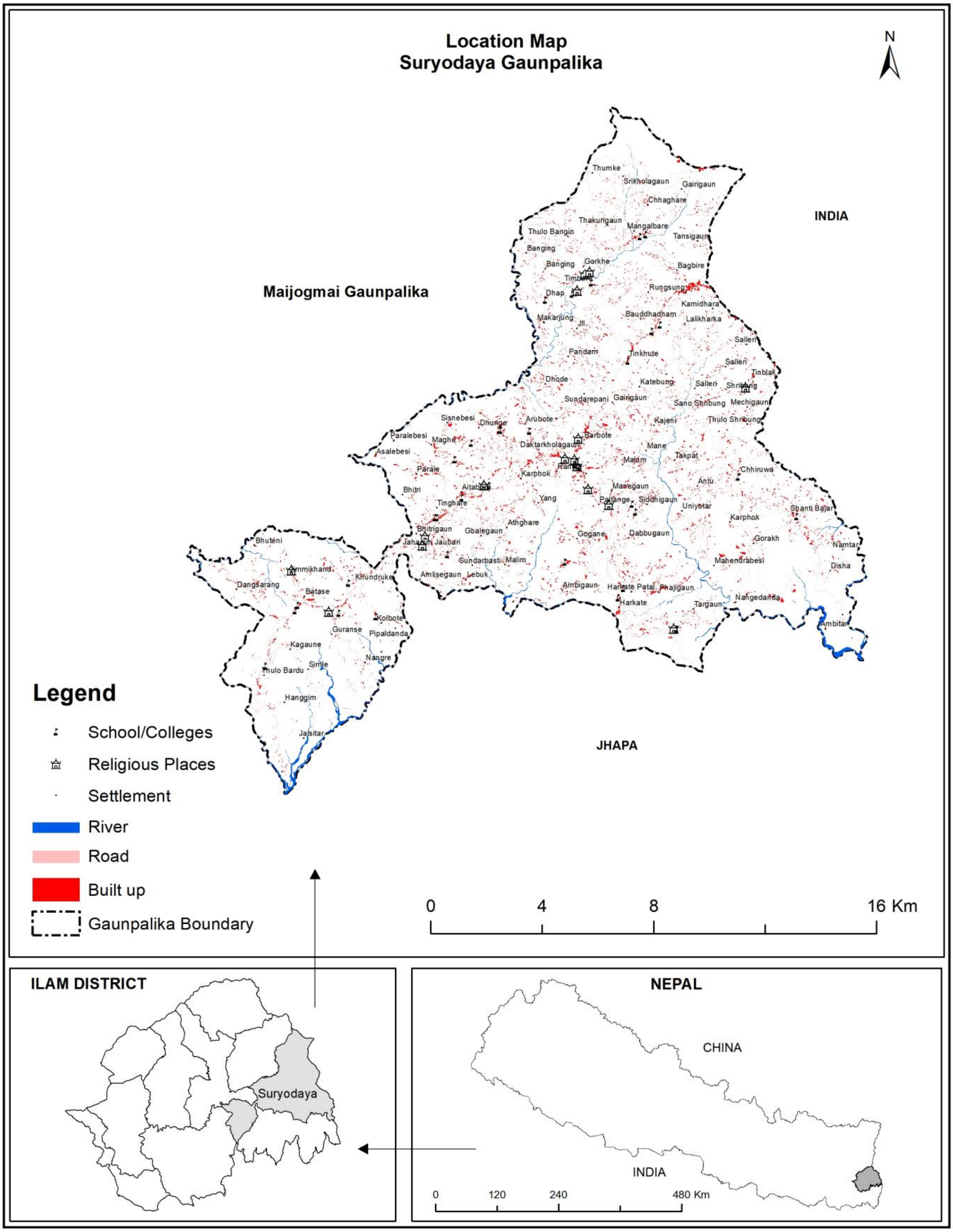


Figure 1.1: Location of Suryodaya Nagarpalika, Ilam District

CHAPTER 2: CONCEPTUAL BASIS OF RISK MAPPING

2.1 Risk and its relation to Land Use Zoning

Planning has the greatest chance to reduce risk, and land use planning process should aim to reduce the risks associated with populations exposed to disaster. Land-use planning is considered one of the best practices for the disaster risk management, by which a community can consider disaster risks and their spatial distribution, steer more sustainable land development and use, and reduce the vulnerability of poor people who are often settled on degraded sites with significant risks and constraints (Roy and Ferland, 2015). Recently in many countries, integration of disaster risk into spatial planning has been largely emphasized. Spatial planning requires hazard information, and hazard information is needed by planners to decide which areas should be prohibited for future development due to excessive risks or to allocate land for potential uses on the basis of hazard intensity or recurrence interval. In this context, land use planning is recognized not only as a key for achieving sustainable development but also as a tool to mitigate risks, generated due to natural and manmade disaster. Greiving and Fleischhauer (2006) discussed various aspects of the integration between risk and spatial planning; and Fleischhauer et al. (2006) have identified four possible roles of spatial planning in risk management namely;

- Keeping areas free of future development that are; a) hazard pone, particularly with history of occurrence of disaster events, b) needed to lower the effects of hazardous event (e.g. flood retention basins), and c) needed to enhance effectiveness of disaster response (e.g. evacuation routes etc).
- Differentiated decisions on land use – allocating land for different uses based on hazard intensity, frequency or other hazard criteria. For instance flood prone areas may be used for agriculture purposes and may be forbidden for residential or siting of critical buildings, avoiding construction on steep slopes but encouraging forestation on those areas etc.
- Regulating land use by legally binding status – for instance regulating building density in earthquake prone areas, recommended roof types for buildings in the hurricane belt, or prohibition of basements in flood prone areas.
- Hazard modification - spatial planning can contribute in reduction of hazard potential of some of the natural hazards such as floods. This can be achieved by influencing intensity and frequency of a hazard.

(Source: Spatial planning and Hazard Data Requirements, ACE-EU Natural Disaster Risk Reduction Programme. Retrieved from www.charim.net/methodology/71 .)

Population, buildings and infrastructure, economic activities, public services utilities, other infrastructures and environmental values in the area potentially affected by the hazard are deemed as elements at risk. The assets at risk from disaster can be enormous and include private housing, transport and public service infrastructure, commercial and industrial enterprises, and agricultural land. FAO’s Guidelines for Land Use Planning (1989, 1993) make it clear that in the long run, land use must be economically viable and socially acceptable, and that one major goal of development planning is to make an efficient and productive use of the land. In this context, hazard and risk factor must be analyzed while preparing land use planning/zoning. Land use zoning refers to the division of land into homogeneous areas and their ranking according to degrees of actual or potential hazard or risk or applicability of certain hazard-related regulations; and modern land use planning has also emphasized to environmental component, and in this respect it is often restrictive in the kind of land uses permitted (Verheye, 2009).

2.2 Relation of vulnerability and hazard with Risk

Hazard: Hazard is a prime component of risk. It is a condition for causing an undesirable consequence, which expressed as the probability of a potentially damaging event of a certain magnitude occurring within a certain period of time. Hazards depend on site-specific and seasonal climatic conditions. For example, the description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the probability of their occurrence within a given period of time.

The initiating causes of a hazard may be either an external (e.g. earthquake, flood or human agency) or an internal (defective element of the system e.g. an embankment breach) with the potential to initiate a failure mode. Hazards are also classified as either of natural origin (e.g. excessive rainfalls, floods) or of man-made and technological nature (e.g. sabotage, deforestation, industrial site of chemical waste). Regarding hazard identification and estimation, two approaches can be identified based on the ANCOLD Guidelines (2003) and the ISDR principles (2004):

a. Traditional deterministic approach: a first level estimation of the potential adverse consequences, if the hazard occurs, in order to classify the system under threat, identify the necessity or not of further investigation. This approach is also the most comprehensive way of estimating man-induced and /or technological hazards, e.g. a forest fire hazard that cannot be captured by a probability distribution.

b. Probabilistic approach: it is based on the theory of probability and regards hazard estimation as the estimation of the probability of occurrence of a particular natural event with an estimated frequency within a given period of time. It can be applied on hazards of natural origin and it represents a very common method used in most flood plain delineation studies when the potential for loss of life is considered negligible in terms of historical floods. The probabilistic approach tends to assume that events in the future are predictable based on the experience of the past.

Vulnerability: One of the best-known definitions of vulnerability was formulated by the International Strategy for Disaster Reduction (ISDR, 2004), which regards it as "a set of conditions and processes resulting from physical, social, environmental and economical factors, which increase the susceptibility of a community to the impact of hazards". A basic consensus has emerged, that the concept of vulnerability addresses a double structure consisting of an external side (exposure) (Bohle, 2001), and also that vulnerability is:

- Multi-dimensional and differential (varies across physical space and among and within social groups).

- Scale-dependent (with respect to time, space and units of analysis, such as individual, household, region, system).
- Dynamic (characteristics and driving forces of vulnerability change over time, certainly exceeding that time of the extreme event itself).

The vulnerability function could be treated as a function between 0 and 1. However, the most appropriate approaches for the case of vulnerability of the society and the cultural heritage are thought to be qualitative. A vulnerability analysis in the event of a hazard like flood considers the population and structures at risk within the affected area. In the start of the analysis, a reference level of the system's vulnerability should be determined that usually refers to existing flood protection systems of the affected area. The vulnerability analysis evaluates the potential costs of disaster event in terms of damages to buildings, crops, roads, bridges and critical infrastructure etc.

Risk is defined as the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions (UN-ISDR, 2009, EC, 2011 cited in Westen, n.d). Risk can presented conceptually with the following basic equation.

Risk = Hazard * Vulnerability * Amount of elements-at-risk

The equation given above is not only a conceptual one, but can also be actually calculated with spatial data in a GIS to quantify risk from geomorphological hazards. The way in which the amount of elements-at-risk are characterized (e.g. as number of buildings, number of people, economic value) also defines the way in which the risk is presented.

The relationship between risk, hazard and vulnerability has been presented in figure 2.1

Figure 2.1: Factors of Disaster

2.3 Risk types and their Descriptions

Depending upon the types of factor causing an area to expose into vulnerability and hazard associated with it, risk can be classified into various categories. However, for the land use mapping process, risk factors have been specified related to the following event: Flood, Landslide, Soil erosion, Fire, Earthquake (Seismic event) and Industrial hazard.

Flood

A **flood** is an overflow of water. It usually occurs in rivers when the flow rate exceeds the capacity of the river channel. Moving water has awesome destructive power when a river overflows its banks. Country like Nepal, there is high potentiality of flash flood (rapid flooding event), erosion and inundation particularly during the monsoon season. Nepal has more than 6000 rivers and rivulets (Manandhar, 2010). These rivers and rivulets support irrigated agriculture and other livelihoods, but also wreak havoc in valleys and in the terai when they overflow (Dixit, 2010). This phenomenon occurs mainly in Monsoon. Intense monsoon rainfall causes flooding in many rivers of Nepal. The frequency of flood and scale of damage have increased in the terai and inner terai regions of Nepal. Thousands of people are affected by flood every year in Nepal during the monsoon season. Altogether, water induced disasters cause an average annual loss of 309 lives and affect 27654 families (Asia et al., 2009). MOHA (2013) reported loss of 4079 lives and affected 181961 households in 2012 due to floods in Nepal.

According to EU Directive (COM, 2006) for flood management, "flood risk" is the likelihood of a flood event together with the actual damage to human health and life, the environment and economic activity associated with that flood event. In this context flood risk can be considered as the actual threat, in other words the real source of flood hazard to the affected areas. The quantification of flood risk results either in monetary units or in loss of life units, if the losses are measurable, or in qualitative terms (e.g. allocation in classes) in the case of intangible damages (social, environment, cultural) to the affected areas. In general, risk as a concept incorporates the concepts of hazard {H} (initiating event of failure modes) and vulnerability {V} (specific space/time conditions). Mathematically, it is expressed risk (R) as a functional relationship of hazard (H) and vulnerability (V); $R = \{H\} \times \{V\}$.

Flood in Nepal: Flood occurs repeatedly in low plains of Nepal causing loss of lives and properties. Nepal has more than 6000 rivers and rivulets (Manandhar, 2010). Major sources of water are Glaciers Rivers, lakes, rainfall, ponds, groundwater etc. Intensity of rainfall with average 1700 mm annually contributes to surface water flow in average annually of approximately 224.7 billion m^3or in terms of flow rate; it is 7,125 m^3/sec (Bajracharya and Mool *et al*., 2009). It further adds that Nepal suffers from frequent water induced disaster like flood, landslide, erosion, debris flows, glacial lake outburst, drought and epidemic. This phenomenon occurs mainly in Monsoon. Intense monsoon rainfall causes flooding in many rivers of Nepal Altogether, water induced disasters causes average annual loss of 309 lives and affects 27654 families (Baracharya and Mool *et al*., 2009).

Landslide

Landslides are a form of erosion and are an important process in the shaping and reshaping landscapes and landforms. Landslide hazard is frequent phenomenon is Nepal due to several reasons including tectonic activities, uncontrolled and unsafe development, heavy precipitation and environmental degradation. However it is observed that rainfall induced landslides is most prevalent in the hills and mountainous districts. In Nepal, high susceptibility zone of landslide are identified in the areas of high intensity rainfall and earthquake hazard.

Landslide susceptible area of varying degree, potential landslides may be of varying likelihood of occurrence based on management practices and protection measures in the area

Fire

Fire is common event every year in Nepal, particularly in the settlements of Terai and forests in hills region of Nepal. Government of Nepal has given less priority in managing settlement and/or forest fire due to limited resources. It is common in Terai during the dry, stormy season between April and June when temperatures exceed 35°C, houses in the region are wooden and have thatched roofs, they are extremely vulnerable to incendiary lighting strikes, suffers from numerous fire outbreaks mainly during the process of cooking. In the winter, the major cause of fires is the short circuiting of electrical appliances, particularly heaters. In urban and other areas, houses are built in close proximity; these too are vulnerable, as fires easily leap from one house to the next. This fires cause great loss of life and property and can have a devastating impact on local economies.

Very few fires are naturally caused in Nepal (NBS, 2002). Karkee (1991) observed that 40% of forest fires in the mid-hills are caused by accidents while 60% are started deliberately e.g. Shifting cultivation, forest encroachment. In settlement areas, due to negligence while cooking, firing is common house and shelter. Faulty wiring and electrical equipment, candles, home heating and cooking, children activities, flammable liquids (fuels, solvents, adhesives, paints, and other raw materials – can ignite or explode if stored improperly) and careless smoking were the main sources of firing in houses and settlements areas.

In an industrial area the fires occur when hazardous materials such as petrochemicals spill or leak and subsequently explode, technology fails, vehicles collide, and factories catch on fire. Within minutes, an entire industrial area can be aflame and billions of rupees of property swallowed up. They also take lives and destroy the environment.

Earthquake (Seismic event)

Earthquake or seismic event is the sudden shaking of the earth surface. Its magnitude is measured by Richter scale ranges between 0-9. An earthquake of magnitude above 7 is considered as a big earthquake. The Himalaya seismicity owes its origin to the continued northward movement of Indian plate after the continental collision between Indian plate and Eurasian plate. The magnitude, recurrence and the mechanism of continental collision depend upon the geometry and plate velocity of Indian plate in relation to southern Tibet (Eurasian Plate). Recent studies also suggest that the convergence rate is about 20 mm /

year and the Indian plate is sub-horizontal below the Sub- Himalaya and the Lesser Himalaya. The result of micro seismic investigation, geodetic monitoring and morphotectonic study of the Central Nepal has depicted that the more frequent medium sized earthquakes of 6 to 7 magnitude are confined either to flat decollment beneath the Lesser Himalaya or the upper part of the middle crustal ramp. The ramp is occurring at about 15 km depth below the foothills of the Higher Himalaya in the south of MCT surface exposures. Big events of magnitude greater than eight are nucleated near the ramp flat transition and rupture the whole ramp-flat system up to the blind thrust (MBT) of the Sub-Himalaya (Pandey et. al., 1995). According to Bajracharya (1994), Nepal has been divided into five seismic zones (Zone1, Zone 2, Zone 3, Zone 4, Zone 5) with relation to the seismic hazard (Low, Moderate and High). The study area falls in the seismic medium hazard area (Seismic zone 3) of the Nepal Himalaya.

The Richter scale shows the how big earthquake is, and their hazardous impacts are decided on the basis of quantum of damage or loss of lives and properties. An earthquake becomes a hazard when it strikes in the urban area or the highly populated areas. Loss lives and properties, damage infrastructure and other man made structure, slope failure, decreasing underground water table, drought etc. are direct impacts of the seismic event.

Industrial Hazards

The adverse impacts caused by industrial pollution and expansion within the zone needs to be identified and assessed to conserve the environment, living organism, as well as the biodiversity of the region for promoting the sustainable development of the surrounding communities in a deliberate and tactful way. The major risk area has to be identified so that the proper planning for settlement and other development activities can be done in planned and sustainable way followed by land use planning. The areas nearer to the industries are in high risk in all aspect such as health, environmental, water ecology, agricultural productivity etc.

The risks from the industries in Suryodaya Nagarpalika are minimally negative in nature, for long-term duration and low in magnitude as none of the industries are of large scale. As stated above, the majority of the small scale industries are agro based. The agro based industries generate effluents and solid wastes that need to be disposed in an environmentally acceptable manner. However, there is a marginal risk of air pollution and water contamination from wastewater generated by those industries as the industrial discharges end up in surface water, causing a risk on flora and fauna, as well as on human beings, who use the surface water.

CHAPTER 3: METHODOLOGY

3.1 Flood Risk

In natural stream, when quantity of water increased sufficiently, it is said to be flood. Flood is a natural event of rising water level in a stream, lake, reservoir or coastal region (Friesecke, 2004). Flood is too much water in the '*wrong*' place (Singh et al., 2014). A flood is caused by heavy rainfall during short period of time that causes river/oceans to over flow. Flood can happen very quickly when heavy rain falls over a short period of time. Such type of flood is called flash flood, which can occur with little or no warning. This can cause huge damage of human life. The flooding can be worst if storms, 'spring tides' and low atmospheric pressure occur at a time. Floods can distribute large amounts of water and suspended sediment over vast areas, restocking valuable soil nutrients ruining crops, destroying agricultural land and buildings and drowning farm animals (Singh et al., 2014).

Natural hazard due to flood events is a part of nature that is always existed. Floods are climatological phenomena, which are influenced by geology, geomorphology, relief, soil, and vegetation conditions. Meteorological and hydrological processes can produce flash floods or more predictable, slow developing floods causing riverside floods. In some cases, floods are invited by the failure of dam and landslides. Mitigation and non-structural measures are found to be more effective and long-term solution for the river water related problems. The local flood protection measures create negative effect in both upstream and downstream. Therefore, whole river basin should be taken into account. Flood plain should be identified before assigning any land use in such area (UN/ECE, 2003). The identification of flood plain can be performed by delineating flood hazard areas on the map. This can be helpful to keep away the building development in immediate flood risk areas.

Mathematical Method of Flood Risk

According to the EU directive for flood management (COM, 2006), "flood risk" is the likelihood of a flood event together with the actual damage to human health and life, the environment and economic activity associated with that flood event. In this context flood risk can be considered as the actual threat. The flood risk effects can be measured either in monetary terms or in loss of life terms, or in qualitative terms (*e.g.* allocation in classes) in the case of intangible damages (social, environment, cultural) to the affected areas. In general, risk as a concept incorporates the concepts of hazard {H} (initiating event of failure modes) and vulnerability {V} (specific space/time conditions). It is customary to express risk (R) as a functional relationship of hazard (H) and vulnerability (V).

$$\{R\} = \{H\} ☼ \{V\}$$

Where, the symbol ☼ represents a complex function incorporating the interaction of hazard (H) and vulnerability (V). Consequently, in mathematical terms it can be expressed as:

$$R = \{H\} \times \{V\}$$

Since vulnerability is a dimensionless quantity (Villagran, 2006) and therefore, risk can be measured in the same units as hazard. In quantitative terms, annualized risk can be estimated as the product of probability of occurrence of the hazardous phenomenon and the actual consequence, combined over all scenarios. According to the method of estimating average (annualized) hazard, the expected value of flood risk can be calculated as follows:

$$E(X) = \int^{\infty} x \, . V(x). \, f(x)dx$$

Where X is the actual flood damage caused by the flood hazardous phenomenon, $f(x)$ is the probability density function (*pdf*) that describes the phenomenon and $V(x)$ is the vulnerability of the system towards the corresponding magnitude of the phenomenon. While estimating the flood risk, it involves major restrictions such as:

- It can be applied only on hazards of natural origin due to probabilistic analysis
- As it abides to a general methodological framework , it is highly case specific
- It is highly dependable on expert's judgment

3.1.1 Data

Data for the flood risk assessment can be classified into various groups as follows:

- Land use and land cover
- Elevation data (such as spot height, contour, digital elevation model, etc.)
- Hydrologic parameters (such as catchment area, cross-sectional at defined interval, river bank lines, flow path geometry, stream centre line, etc.)
- Discharge at strategic points
- Soil type and flood plain property (such as manning's constant, river boundary delineation, etc)

The data on those aspects stated above were collected during the field visit done.

3.1.2 General Approach and Methodology Framework

In Nepal, there are various methodological frameworks in practice for flood modeling. It is generally accepted that *the flood risk management framework* should be mainly oriented towards non-structural measures (e.g. land use planning, flood warning systems, evacuation plans, insurance policy). They are mainly driven by the need of cultural heritage protection and also by the socioeconomic conditions of the area concerned. In this context, the methodological framework adopted for the flood risk assessment in this study is shown in Figure 3.1.

In the context of flood risk, the concepts of hazard, vulnerability and risk have been extensively used in various disciplines with a different meaning, impeding cross-disciplinary cooperation for facing hazardous events. Flood, a common natural hazard, has also hard to find the unique definitions and assessment procedures. In this study, it is used a comprehensive way for defining and assessing flood risk and vulnerability in the flood-prone areas. The suggested methodology follows a three-step assessment approach:

i. Annualized hazard incorporating both probabilities of occurrence and the anticipated potential damages
ii. Vulnerability (exposure and coping capacity) in the flood- prone areas, and

iii. Annualized flood risk (estimated on annual basis).

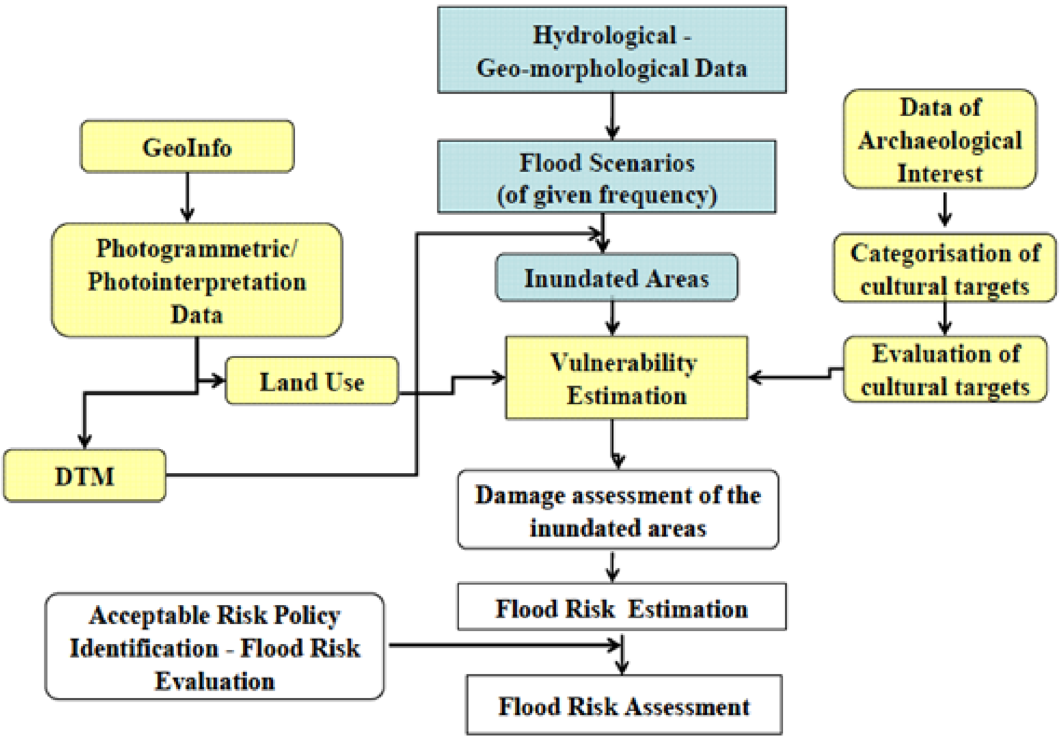


Figure 3.1: Methodological framework for flood risk assessment

The methodology aims to assist water managers and stakeholders in devising rational flood protecting strategies. To apply the methodology, terms such as flood plain, flood hazard map, flood modeling etc are defined with data sources in the following sub-sub sections.

i. Flood plain

The land that lies next to the river or along the river side during normal river flow and submerged during the flood is called as 'flood plain' (Shahiriparsa & Vuatalevu, 2013).

ii. Flood hazard mapping

Flood hazard mapping (FHM) refers to the map that provides information on inundation like predicted inundation, inundation depth etc. This also includes the evacuation routes graphically in understandable format. Flood hazard mapping is an example of non-structural measures for minimizing risk (Konecny *et al*., 2003). FHM includes the information on historical as well as potential future flood events. This can be the basis for determining land use control, flood proofing of constructions and flood awareness and preparedness. FHM provides information on type of flood, the flood extent, water depths or water level, flow velocity or the relevant water flow direction (Prinos, 2009). Flood hazard mapping should be considered before any investments or implementation of development projects.

iii. Flood modeling

It is an engineering tool that provides accurate information regarding flood profile. The governing factor for causing flood are rainfall, run off, catchment characteristics and return period (Singh et. al, 2014). The main input data for calculating flood hazard maps is the occurrence probability and the amount of high water discharge in rivers (Prinos, 2008). Flood discharge calculation is a prominent task for designers of hydraulic structures and river training works. This task is difficult to be adopted as Nepal lacks sufficient hydrological information (Rijal, 2014). To carry out the calculation of flood flow, different approaches can be adopted based on site condition and available data. There are various methods adopted for calculating flood discharges. They are such as rational method, empirical formula (modified Dicken's formula), water and energy commission secretariat (WECS) approach, flood - frequency method, etc. Brief introductions of these methods are given in following sub-sections.

Rational method

The rational method is applied for the peak flow calculation of smaller basin that responds to storms, as it is simple and requires limited data. In this method it is assumed that intensities of rainfall and infiltration are uniformly distributed in time and space. To apply the rational method, the scientific community suggested that the smallest basin area should be 25 km^2 (Hua, Liang, & Yu, 2003).

Empirical formula

The empirical formula (Modified dickens formula) has been derived for the first time for Northern India. The formula uses the catchment area as a single parameter affecting the flood peak and other factors are constant based on the specific region. This formula is applicable in the region from which the formula has been developed and then is applied to other areas that at best can give rough estimates (Subramanya, 2006). Even though, northern India and southern part of Nepal have similar catchment, it is not opted to apply the empirical formula for current study because of the data limitation.

Flood frequency analysis

The flood frequency method is the statistical method of flood frequency analysis. The method needs a large-scale data (a minimum of 30 years) to get the accurate result. In case of the data records with less than ten years, flood frequency analysis should not be adopted (Subramanya, 2006).

WECS method

The WECS method (DHM, 1990) is the unique method for Nepal and found to be accurate comparing others. In this method, the whole country is considered as single hydrological region. As per flood records, low flows, long-term flows and high flood flows sub regions are divided. The method is first developed jointly by the Water and Energy Commission Secretariat (WECS) and Department of Hydrology and Meteorology of Nepal in 1982. Later it is modified and came up in improved form in 1990. The World Meteorological Organization (WMO), Water and Energy Resource Development Project (WERDP) and WECS/NEA Institutional Support Programme (WISP) are major partners to develop this method. The following equations are used for flood flow of any river having catchment area ‘A’ below 3000.

$$Q_2 = 1.8767\ (A+1)^{0.8783}$$

$$Q_{100} = 14.63\ (A+1)^{0.7342}$$

Where, the subscript 2 and 100 stand for the return periods in number of years.

The flows for any other return period 'R' is then given by:

$$Q_R = exp\ (\ln Q_2 + 3\ \sigma)$$

Therefore, comparing the merits and de-merits of all the methods and their suitability, WECS/DHM method is found to be appropriate for this study. By using this method, the flood discharge for the return period of 2 years and 100 years have been calculated and analysed.

iv. Manning's roughness coefficient (n)

The Manning's roughness coefficient, *n*, is commonly used to represent flow resistance (Phillips & Tadayon, 2006). The friction parameters have been selected from the guidance of the standard hydrological textbook by visual judgment.

v. Computer Applications used for flood modeling

Computer application software such as GIS, HEC GEO-RAS, and HEC RAS has been used to develop the flood plain map in this study.

vi. Geographic Information System (GIS)

GIS is computer based system for mapping and analyzing spatial data. GIS is considered revolutionary new technology, which increases ability to make decision and solve problems. GIS differs from other information system as it integrates common data base operations like query and statistical analysis, unique visualization and geographic analysis benefits offered by maps. This is helpful for explaining events, predicting outcomes and planning strategies. The careful analysis of spatial data using GIS can provide detail information on problem like pollution, deforestation, natural disasters and suggest the way to address them. GIS comprises five components i.e. hardware, software, data, people, and methods (Joerin & Musy, 2000).

vii. HEC-GeoRas

HEC-GeoRas is an extension for ArcGIS. This extension allows users with limited GIS experience to create an HEC-RAS import file containing geometric attribute data from an existing digital terrain model (DTM) and complementary data sets. Water surface profile results may also be processed to visualize inundation depths and boundaries (Ackerman, 2011). HEC-GeoRAS is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS using a graphical user interface (GUI).

viii. HEC-RAS

HEC-RAS is numerical analysis software. It is a computer program that models the hydraulics of water flow through natural rivers and other channels (Prinos, 2008). "It is an integrated package of hydraulic analysis programs, in which the user interacts with the system through the use of a Graphical User Interface (GUI)" (Brunner, 2010). This provides the details of flood profiles. This software is easily available and has precise calibration accuracy (Kute *et al.*, 2014). This is the major part of the modeling where flood simulation is done. This program is one-dimensional, which means the flow is considered to be uniform from point to point upstream to downstream. It includes numerous data entry capabilities, hydraulic analysis components, data storage and management capabilities, and graphing and reporting capabilities (Prinos, 2008). HEC-RAS system is the composition of four one-dimensional river analysis components viz. steady flow water surface profile computations, unsteady flow simulation, movable boundary sediment transport computations, water quality analysis (Brunner, 2010). In HEC-RAS, we can see the two major water surface profile facilities: *a*) Steady flow water surface profile, and *b*) Unsteady flow water surface profile.

ix. Steady Flow water surface profile

This component of modeling system is intended to calculate water surface profiles. The system can handle a single river reach, a dendrite system, or a full network of channels. The component is capable of modeling subcritical, supercritical, and a mixed flow regime water surface profiles. The basic computational procedure is based on the solution of the one-dimensional energy equation. Friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head) are used for the evaluation of Energy loss while momentum equation is applied in situations where the water surface profile is rapidly varied. These situations include mixed flow regime calculations i.e., hydraulic jumps, hydraulics of bridges, and evaluating profiles at river confluences (stream junctions). The steady flow system is designed for application in flood plain management and flood insurance studies to evaluate floodway encroachments (Brunner, 2010).

x. Unsteady Flow water surface profile

This component is capable of simulating one-dimensional unsteady flow through full network of open channels. This component gives the design value for subcritical flow regime. However, new releases of the model give the mixed flow regime (subcritical, supercritical, hydraulic jumps, and drawdown). Special features of this component include: Dam break analysis; levee breaching and overtopping; Pumping stations; navigation dam operations; pressurized pipe systems, and sediment analysis (Brunner, 2010).

Upon discussion with NLUP authorities, it was found that that the study should also aim to evaluate land use plan from disaster (flood) management perspective for which requires the evaluation of flood way encroachment. From the experience knowledge, it is concluded that, steady flow analysis is designed to evaluate flood way encroachment. Therefore, in this study, steady flow analysis has been used for the flood simulation as required for the project. It has to keep noticed that; due to the lack of unsteady flow data, this study is limited to choose steady flow analysis.

3.1.3 Methods

In order to obtain the objectives defined in TOR regarding flood risk, spatial and non-spatial data were collected. Both qualitative and quantitative approaches were adopted for data generation. The primary sets of data were acquired using the method of interview with the people of residing in the flood prone areas and government officials. The secondary data were collected from the National Land Use Project. The census of 2011 was obtained from website of CBS of Nepal (www.cbs.gov.np). A short description of data collection and processing is given in the following sub-sections.

i. Data Collection

Data collection is the systematic gathering of information necessary is this study. The information can be of people, objects or phenomena. Haphazard collection of data may create difficulty in answering the set question in a conclusive way (Chaleunvong, 2013). So, the method applied for collecting data is both qualitative and quantitative, which are such as available information, observation, interviewing face to face, written questionnaire, etc. The primary data was obtained using the method of interview with the people residing in flood prone area to get responses to the frequency of occurrence of flood and the methods they adopted to cope with. In addition, more information was collected through the questionnaire being administered to the local people. Non-probability, purposive sampling was used with the sample size of twelve questions.

ii. Data Analysis

- ***Conversation with local people***

From the information obtained through interview with local people, it is known that flood was not frequent in most of the study area, Package-04 (Suryodaya Nagarpalika and Rong Gaunpalika). However, there were some floods: on 2044, 2042, 2061 and 2072 BS in Jil khola (minor flood problems in ward no. 9 of Suryodaya Nagarpalika); Chhiruwa Khola (minor flood problems in ward no. 6 of Suryodaya Nagarpalika); Mechi river (some flood effects in ward no. 5 of Suryodaya Nagarpalika and eastern part of ward no. 6 of Rong gaunpalika); Goyang Khola and Biring Khola (minor problems of ward no. 1, 2 4, 13 &14 of Rong Gaunpalika). The main problems due to flooding are: River bank cutting and landslides which was verified during the time of field visits. The drainage network map under Package 04 (Rong Gaunpalika and Suryodaya Nagarpalika) is shown in figure 3.2.

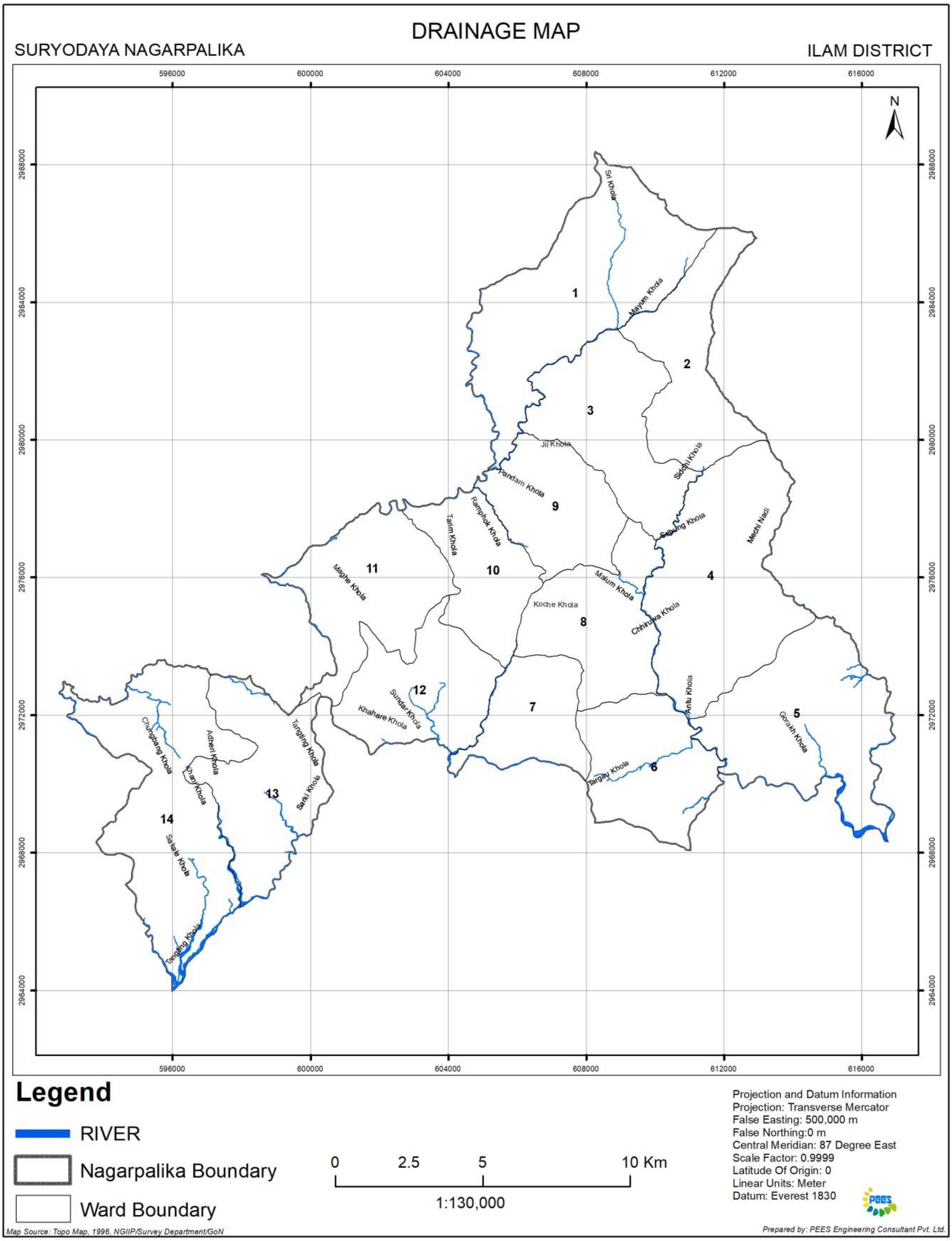


Figure 3.2: Drainage network Map of Package -04, Ilam District

- ***Analysis of Watershed area***

While analyzing flood hazard and risk areas for Package 04 project (Suryodaya Nagarpalika and Rong Gaunpalika), following rivers were digitized from the WorldView-2 image. The names are: Mechi khola, Sakale khola, Jogmati khola, Mayum Khola, Biring Khola, Siddhi khola, Thule khola, Tanting Khola, Tri 1 and Tri 4. Digital elevation model was prepared by using contour and station point from the topographic maps published by the Survey Department of Nepal. Water discharge for return period 100 years was calculated with the determination of watershed area for flow direction and flow accumulation. The process adopted in this study is shown in the Figure 3.3.

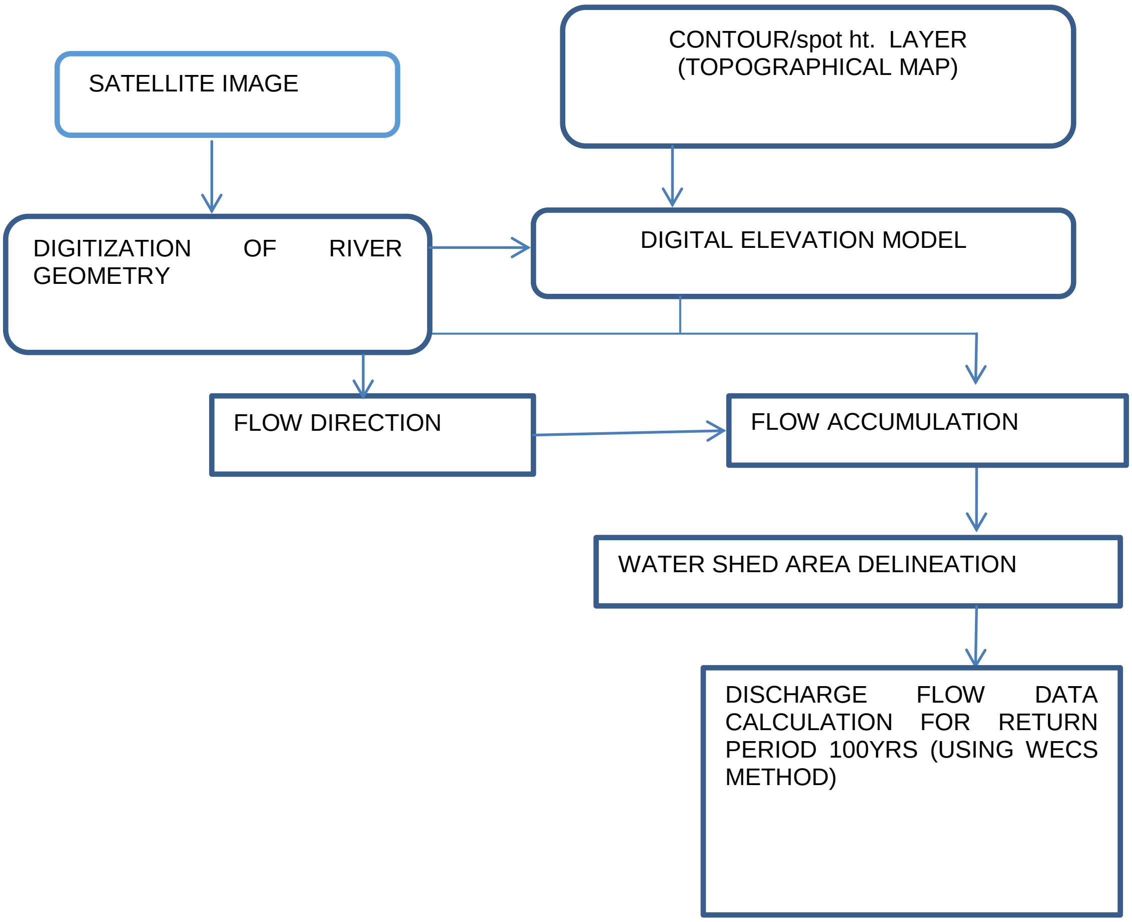


Figure 3.3: DEM processing and Discharge calculation

Calculated flow discharge for the given catchment area of return period 100 years is given in Table 3.1.

Table 3.1: Discharge calculation for given Return Periods 100 years

River Name	Chainage (Km+m)	Catchment Area (Km^2)	Discharge (m^3/sec)
Mechi Khola	15+892	8.19	174.57
Mechi Khola	5+405	39.25	320.54
Mechi Khola	5+203	119.28	592.65
Mechi Khola	3+994	121.03	597.89
Mechi Khola	2+001	126.30	613.52

River Name	Chainage (Km+m)	Catchment Area (Km²)	Discharge (m³/sec)
Mechi Khola	0+211	133.21	633.90
Sakale	1+996	4.51	80.00
Sakale	0+147	1.27	104.00
Tri 1	3+426	5.64	58.75
Tri 1	0+126	6.63	90.00
Jogmai	18+090	34.86	250.00
Jogmai	10+343	97.29	450.00
Jogmai	0+11	139.88	570.00
Mayum	11+885	0.50	50.00
Mayum	7+984	21.82	175.00
Mayum	0+32	41.94	250.00
Biring Khola	15+419	9.25	80.78
Biring Khola	0+55	68.21	350.00
Siddhi Khola	22+245	16.82	215.00
Siddhi Khola	0+113	85.749	430.00
Thule Khola	6+754	4.52	58.00
Thule Khola	4+189	7.90	90.00
Thule Khola	0+25.	12.33	130.00
Tri 4	7+068	3.52	44.29
Tri 4	0+33	7.56	82.00
Tanting	10+342	1.80	50.00
Tanting	6+987	10.39	103.00
Tanting	3+478	19.40	201.00
Tanting	0+975	27.61	291.00
Tanting	0+20	32.36	345.00

iii. Pre-Processing in GIS environment

RAS layers (Stream centerline, river banks, flow path centerlines and cross sections) were created which was later followed by layer setup and finally RAS-GIS import file was created. The file then processed by the HEC-GeoRAS layer.

iv. HEC-RAS Processing

The file created in HEC-Geo RAS was imported in Geometric Data Editor interface in HEC-RAS. The study flow analysis was preceded by using the flood discharge for return periodic 100 years, which was obtained from WECS/DHM method. Reach boundary conditions were defined as critical depth for both upstream and downstream. Manning's constant for left and right bank was set as 0.04 while 0.035 for centre of channel. It was judged by field observation. Mixed flow analysis is done. Then the generated data is exported in GIS format. The process in block diagram form is shown in Figures 3.4.

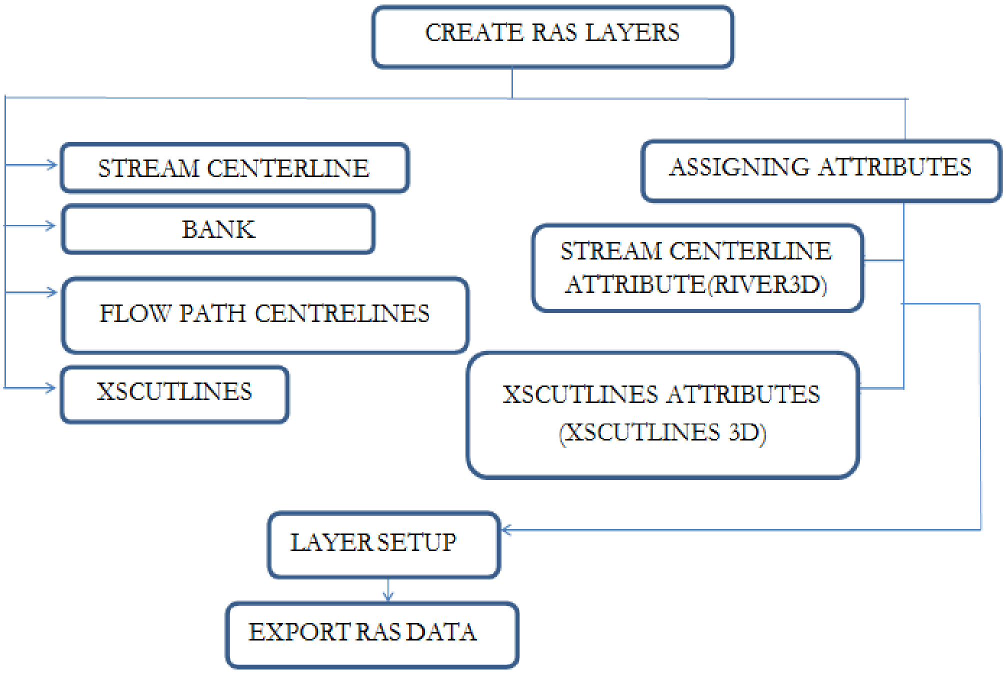


Figure 3.4: HEC-GeoRAS processing

Each of the rivers has its own water surface profiles and they are different in nature. For example, Thule Khola water surface profile is shown in Figure 3.5.

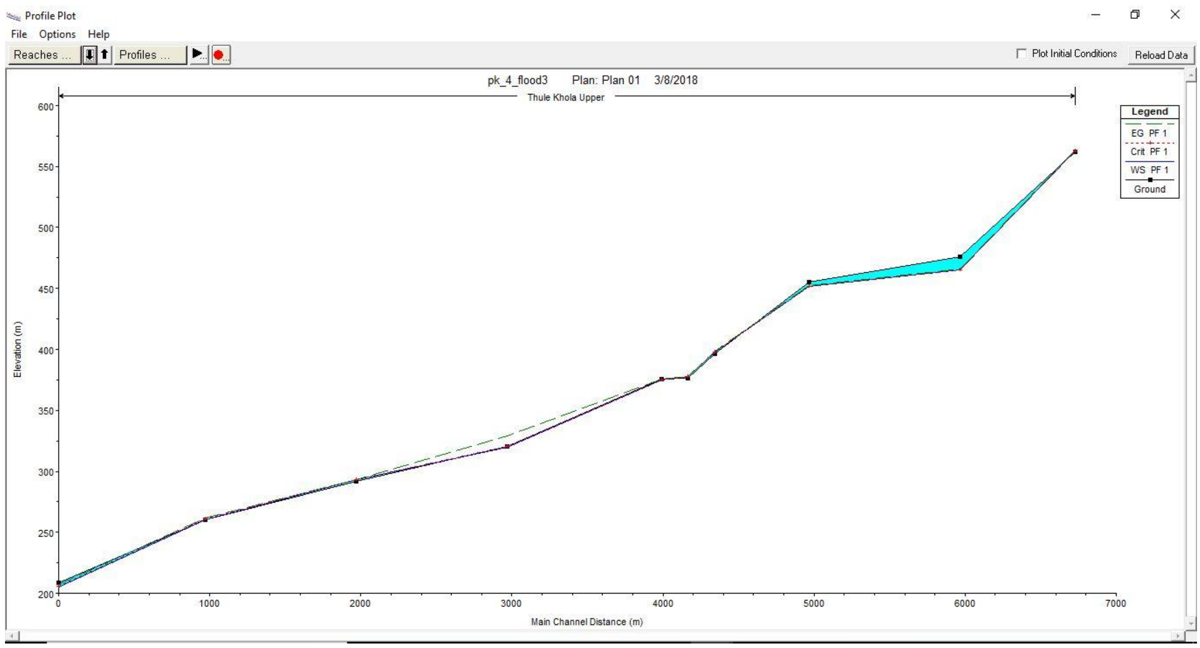


Figure 3.5: Water Surface Profile of Thule Khola for 100 years floods

iv. HEC GEO RAS Post Processing

In this phase inundation mapping was performed with the generation of water surface which was later followed by flood plain delineation. The process involved is given in Figure 3.6.

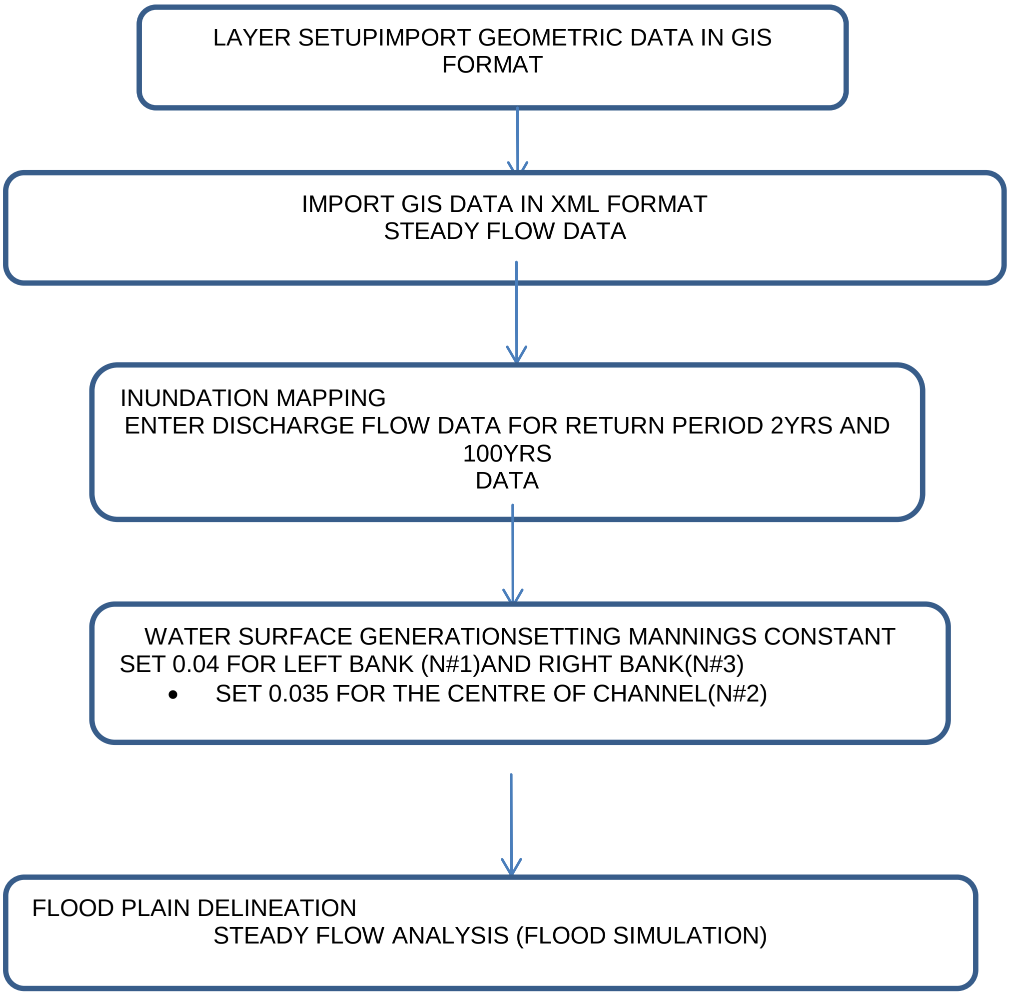


Figure 3.6: HEC-GEO RAS post processing

3.1.4 Result

Flood hazard map was prepared by overlaying land use map with flood area polygon for return period of 100 years. This has given clear picture of possible flood that can affect land use of the area. The assessment has been done for period which is represented in given map shown at the end of this section.

Preparing flood Hazard Map

There are major rivers are: Mechi khola, Sakale khola, Jogmati khola, Mayum Khola, Biring Khola, Siddhi khola, Thule khola, Tanting Khola, Tri 1 and Tri 4. The major problems due to floods are bank cutting and landslides in nearby banks.

Flood hazard map was prepared by overlaying land use map with flood area polygon for return period 100 years. This has given clear picture of possible flood inundation that can affect land use in Suryodaya Nagarpalika, which is presented in Table 3.2, and Figure 3.7.

Table 3.2: 100 year Return Period Flood Prone Area in Suryodaya Nagarpalika

Suryodaya Nagarpalika					
Land use Type	**High**	**Medium**	**Low**	**No Risk**	**Grand Total**
Agriculture	333.68	25.79	111.71	15725.63	16196.82
Commercial	0.10	0.00	0.08	4.01	4.18
Cultural and Archeological	0.12	0	0.002	0.69	0.81
Forest	186.20	9.82	49.70	4749.47	4995.19
Riverine and Lake Area	140.14	7.18	44.59	42.47	234.37
Industrial	0.00	0.00	0.00	3.92	3.92
Other	0.29	0.01	0.62	23.11	24.03
Public	4.62	0.35	1.47	398.78	405.23
Residential	3.55	0.36	1.10	569.00	574.01
Grand Total	**668.70**	**43.51**	**209.27**	**21517.08**	**22438.57**

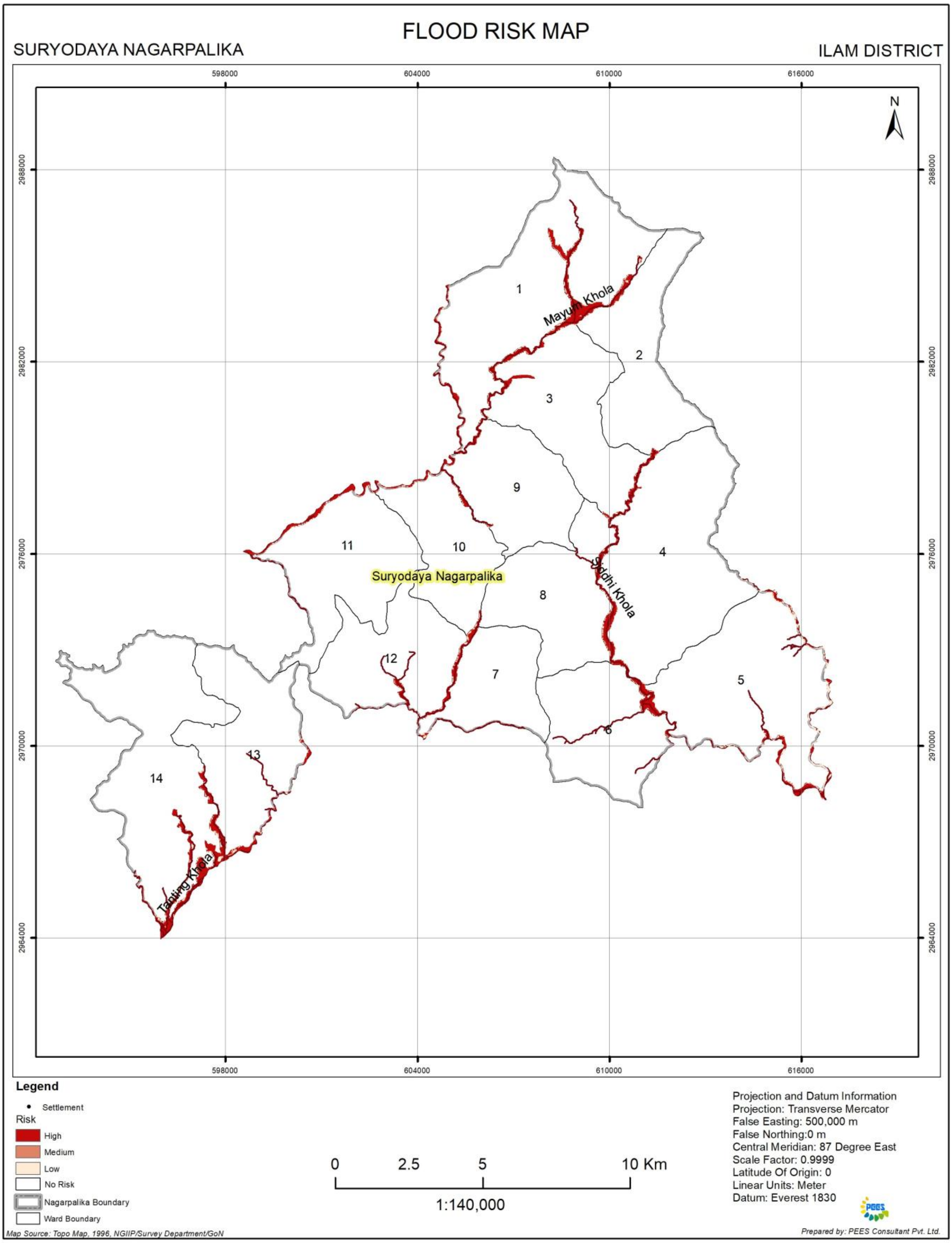
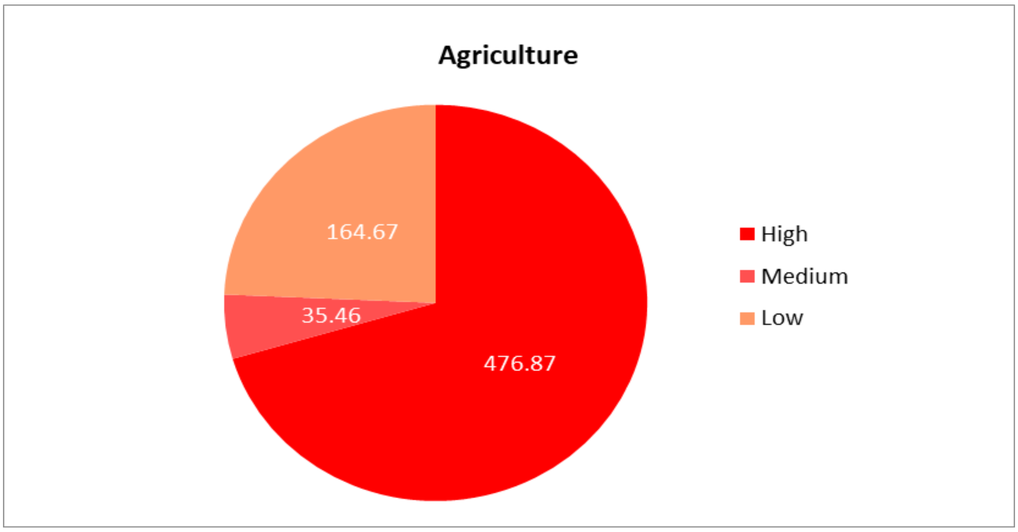


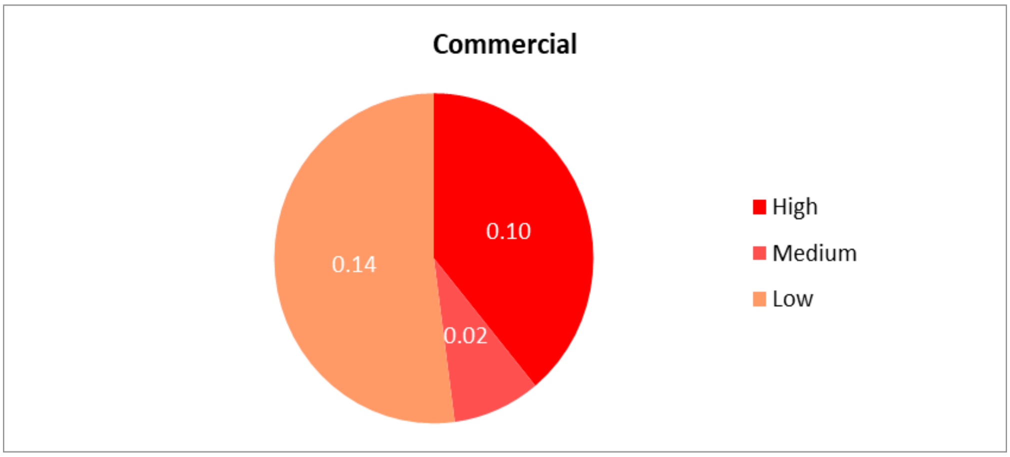
Figure 3.7: Flood Risk Map of Suryodaya Nagarpalika, Ilam

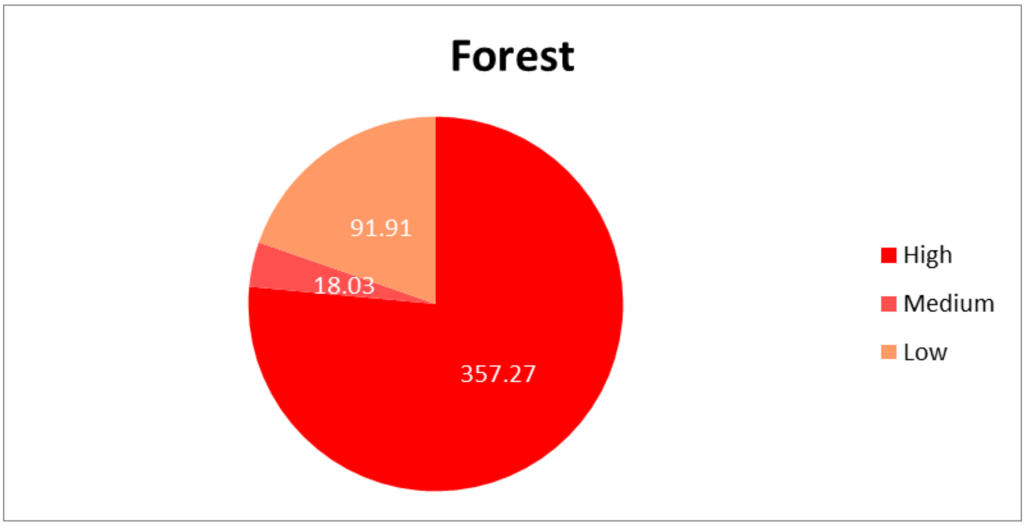
Flood depth for 100 year return period

From experience, it shows that there is possibility of occurrence of flood, affecting the nearby areas of the river and streams, because of bank cutting and landsides takes place. This may destroy the agricultural land. It is necessary to make conservation of agricultural land from entering the floods. In addition at present the people of the nearby areas of the rivers are found suffering from water logging problem during the summer rainfall season. From observations it seems that Mechi khola, Sakale khola, Jogmati khola, Mayum Khola, Biring Khola, Siddhi khola, Thule khola, Tanling Khola, Tri 1 and Tri 4 Rivers are the most flood prone river.

According to flood assessment for return period 100 years, It is found that the flood depth is greater than 1.5 m cover, .56 % of residential area, 1.02% of public use area, 1.86% of agriculture area, 1.89% of commercial area, 7.78% of cultural and archeological area, 3.35% of forest area, around 40% of riverine and lake area, around 2% f other area. It shows that major areas are riverine parts where, as per Hindu rituals, many temples are situated. The graphical representation of major lands for the return period 100 years are shown in Figure 3.8.







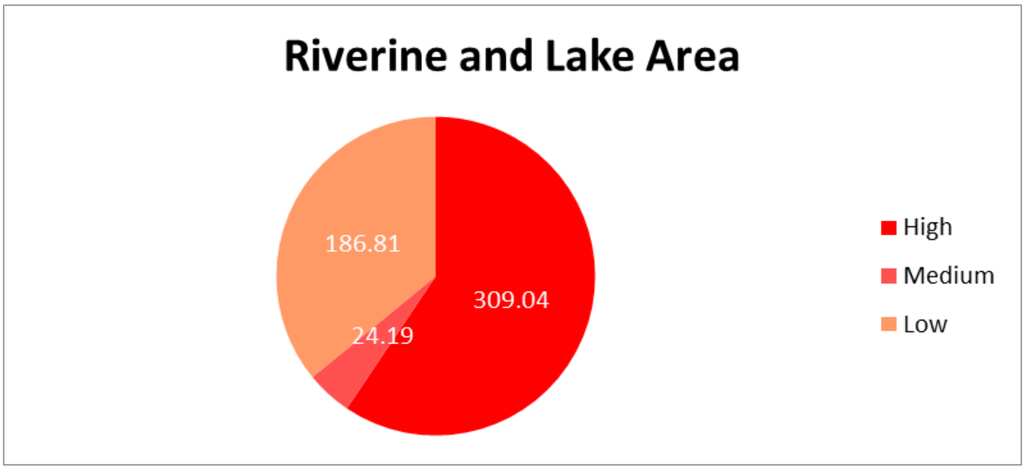


Figure 3.8: Flood Depth for return period 100 years package 04 (Hectares)

3.1.5 Discussion

It is found that the settlements near by the high flood risk areas as shown in Figure 3.7 are more prone to flood. The people in such area are at risk of flood hazard so these people need to be shifted from such flood risk area to the area free of flood. It is also suggested to take immediate action against mitigating flood hazard by undertaking river training or embankment or levee construction along the rivers having flood potential.

Major flood had occurred on 2044, 2042, 2061 and 2072 BS in Jil khola (minor flood problems in ward no. 9 of Suryodaya Nagarpalika); Chhiruwa Khola (minor flood problems in ward no. 6 of Suryodaya Nagarpalika); Mechi river (some flood effects in ward no. 5 of Suryodaya Nagarpalika and eastern part of ward no. 6 of Rong gaunpalika); Goyang Khola and Biring Khola (minor problems of ward no. 1, 2 4, 13 &14 of Rong Gaunpalika). The main problems due to flooding are: River bank cutting and landslides which was verified during the time of field visits. The probability of entering floods of these rivers usually is in the months of June, July, August and September. From interview with the local peoples, it is noticed that many agricultural lands have been converted to river bank due to bank cutting and landslide problems. According to the local people, flooding can be minimized with the construction of Gabion works along the rivers.

3.2 Fire Risk

Land Use and Fire Hazard

The overall impact of land use change on drivers of fire risk is often specific to the location, ecosystem, land use system, and underlying climate of a particular place, and thus it can be difficult to generalize across multiple systems, although some general trends have emerged. Fire risk can drive land use change by creating the need for alternative vegetation management activities, such as type converting flammable fuels and landscape planning. Land use change can in turn impact fire risk by impacting fuel loads and ignitions. Combined, these impacts interact on the landscape and thus inform both future land use change decisions and future fire risk (Figure3.9). Low density housing can lead to increased fuel loads if houses are not designed with flame resistant materials. But if plant vegetation or natural ecosystem nears their homes, there is low chance of firing. Alternatively, small scale fuel treatments associated with increased housing density can decrease fuel loads, although different ownership types may be more or less likely to manage fuels. Increased land use intensity can result in decreased fuel loads, as is the case in dense cities where most buildings are built from non-flammable concrete and steel (Van Butsic, Maggi Kelly and Max A. Moritz; 2015).

Each year Nepal experiences fire hazard in different areas of the country. The fire hazards take place in both built-up areas as well as forests. Fire hazards can take place in many places, however, so far as the ecological regions are concerned the Terai belts experienced it more and vulnerable as well. In the hilly regions, particularly during the dry, stormy season between April and June when temperatures are higher, wooden houses in clustered settlements are vulnerable to fire risk. This fires cause great loss of life and property and can have a devastating impact on local economies. Likewise, the forest fire occurs every year in Nepal, particularly in the forests of Terai and Churia hills.

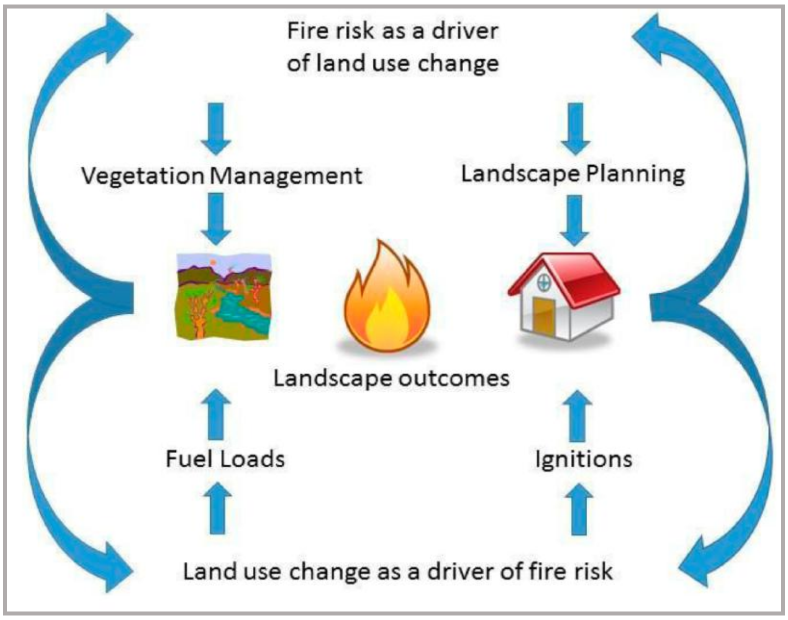


Figure 3.9: Conceptual model of interactions between land use changes and fire risk

(*Source: Van Butsic, Maggi Kelly and Max A. Moritz (2015). Land Use and Wildfire: A Review of Local Interactions and Teleconnections; Department of Environmental Science, Policy and Management. University of California Berkeley, Berkeley, CA 94720, USA).*

3.2.1 Data

The identification of fire risk areas is a difficult process. However, attempts can be made to identify the risk areas based on the past occurrences (hot spots), buffer analysis in ArcGIS, a survey of building materials and observation of building density, and socioeconomic status of the residents, etc. The present analysis has tried to evaluate the fire risk areas by collecting data through buffer analysis in ArcGIS, consultation with local communities as well as field observation.

3.2.2 General Approach and Methodology Framework

General Approach: The general approach for the data collection of fire risk layer is as follows:

i. For Forest:
    - Identification of forest area, forest type and its categorization with current management status
    - Identifying nearby settlement areas, their categorization and adjacency to the forest area,
    - Identification of fire risk with a holistic approach, taking fire risk entities into consideration
    - Identification and delineation of fire risk area.

ii. For settlement areas.
    - Identification and categorization of settlement (clustered, moderately clustered, scattered)
    - Locating nearby industries, petrochemical stations and other factors that relate to fire risk
    - Identification of high-risk settlement areas by identifying entities of fire risk
    - Identification of fire risk with a holistic approach, taking fire risk entities into consideration
    - Identification and delineation of fire risk area.

Methodological Frameworks

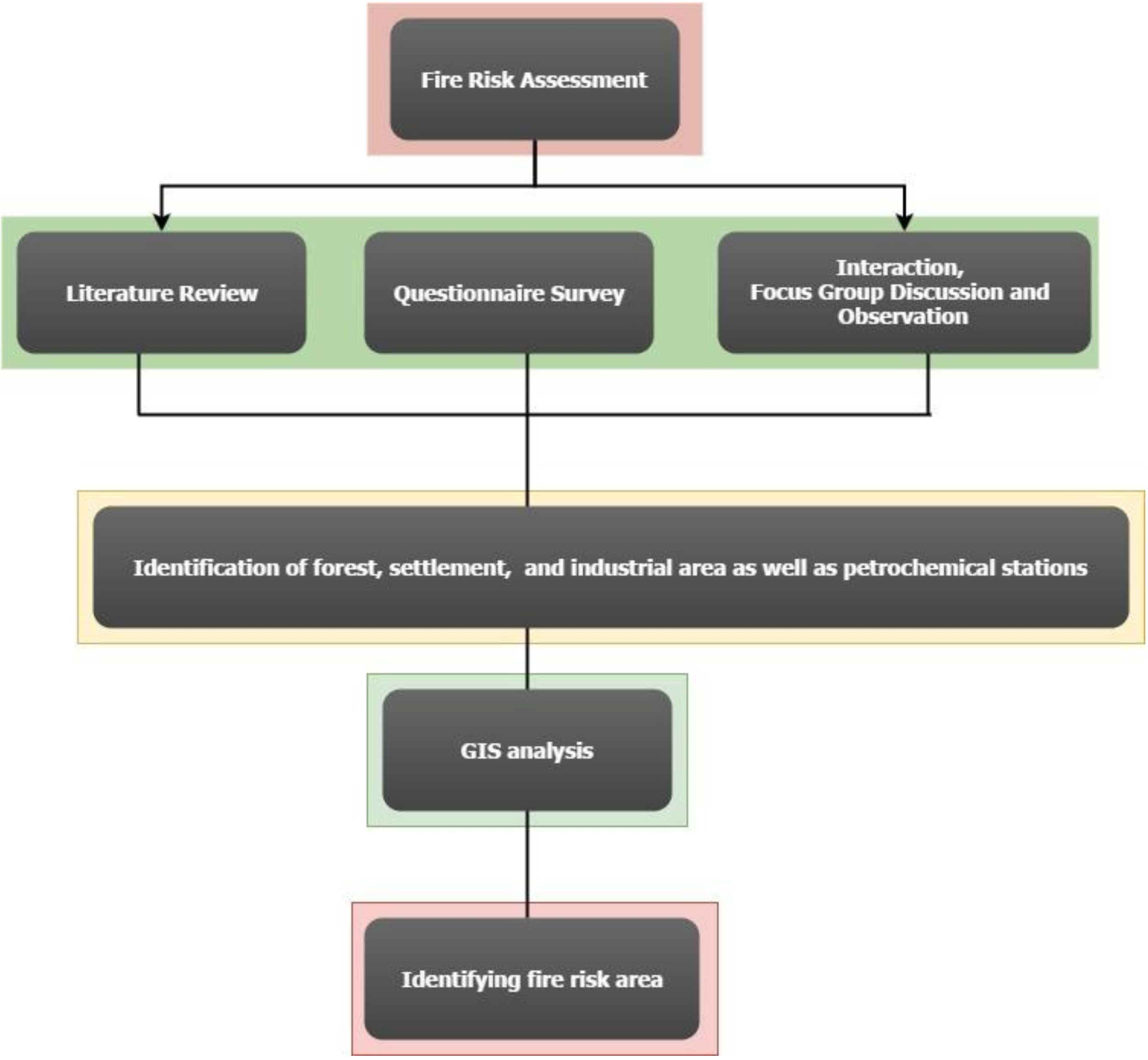


Figure 3.10: Fire Risk Mapping: A Methodological Framework

3.2.3 Methods

The following methods were adopted for the collection

Literature Review

The relevant information was collected from available secondary literature in the form of books, reports, and maps; topographic maps, land use maps, aerial photographs, and cadastral survey maps, etc. information on the coverage of the study areas have been drawn from various web pages.

Field Investigation

A detailed field study was conducted in Nagarpalika by a multidisciplinary team, which comprised of a risk expert, environmentalist, geographer, forestry experts, agricultural scientists, biologist, and sociologists. During the visits, baseline information on forest, settlement, industries and petrochemical stations was taken to incorporate a holistic approach to risk analysis of the Nagarpalika.

Questionnaires Survey and Focus group discussion

The data were gathered through a household survey with questionnaires to obtain information on fire risk of the project area. Extensive consultation with government representatives at various levels, experts and professionals, local communities and industrial stockholders was also undertaken.

Focus group discussions were held at Phikkal, Pashupatinagar, Malim, Laxmipur of the Nagarpalika to interact with local people and stakeholders to collect information on fire risk of the Gaunpalika. Direct observation (walkover survey) was done to collect information on fire risk entities.

GIS analysis

Buffer analysis, a spatial analytical technique for assessing proximity within a certain distance of fire risk areas, was used for the purpose of evaluating fire risk areas of the Nagarpalika. In this method, a buffer is drawn at a pre-defined distance to create the various block groups. These groups are identified that are within or intersect with the area in the buffer, and information about the settlements in these block groups was used to estimate the characteristics of the population inside the buffer and the risks inherent due to the fire hazard.

3.2.4 Result

Apart from the built-up areas, the risk of forest fire is very high during the hot-dry season in hilly areas. Suryodaya Nagarpalika has community-managed forest areas nearby and the risk of a forest fire as well.

In rural parts of Suryodaya Nagarpalika, there have been practices of using fire by farmers for burning crop residue, and for converting forest to agricultural land. Because fire removes the organic matter and provides an ash bed, which facilitates the growth of grasses, local people set fire to gather ash, which is locally used as manure, the activity which is sometimes blamed for fire in settlements.

The Nagarpalika is at a reasonable risk of fire in the settlement area too due to the practice of constructing houses using thatch/straw for roofing (ward number 1 has 92/1848 households; ward numbers 2 and 3 have 25/1980 households; ward number 4 & 5 have 87/2185 households; ward numbers 6-12 have 221/6317 households; ward numbers 13 and 14 have 310/2035 households;) clustered settlement in market areas, unmonitored children's activities, careless smoking, and negligence in cooking. The risk of fire is mainly likely to outbreak during the windy and the dry season e.g. Chaitra & Baisakh. During the field observation, people reported that occasional fire breakouts had affected the Nagarpalika in the past. It has been found that the Suryodaya Nagarpalika has had three major fire incidents with an estimated loss of property valuing NRs 12500000 in the past. Figure 3.11 shows the forest fire risk map of Suryodaya Nagarpalika.

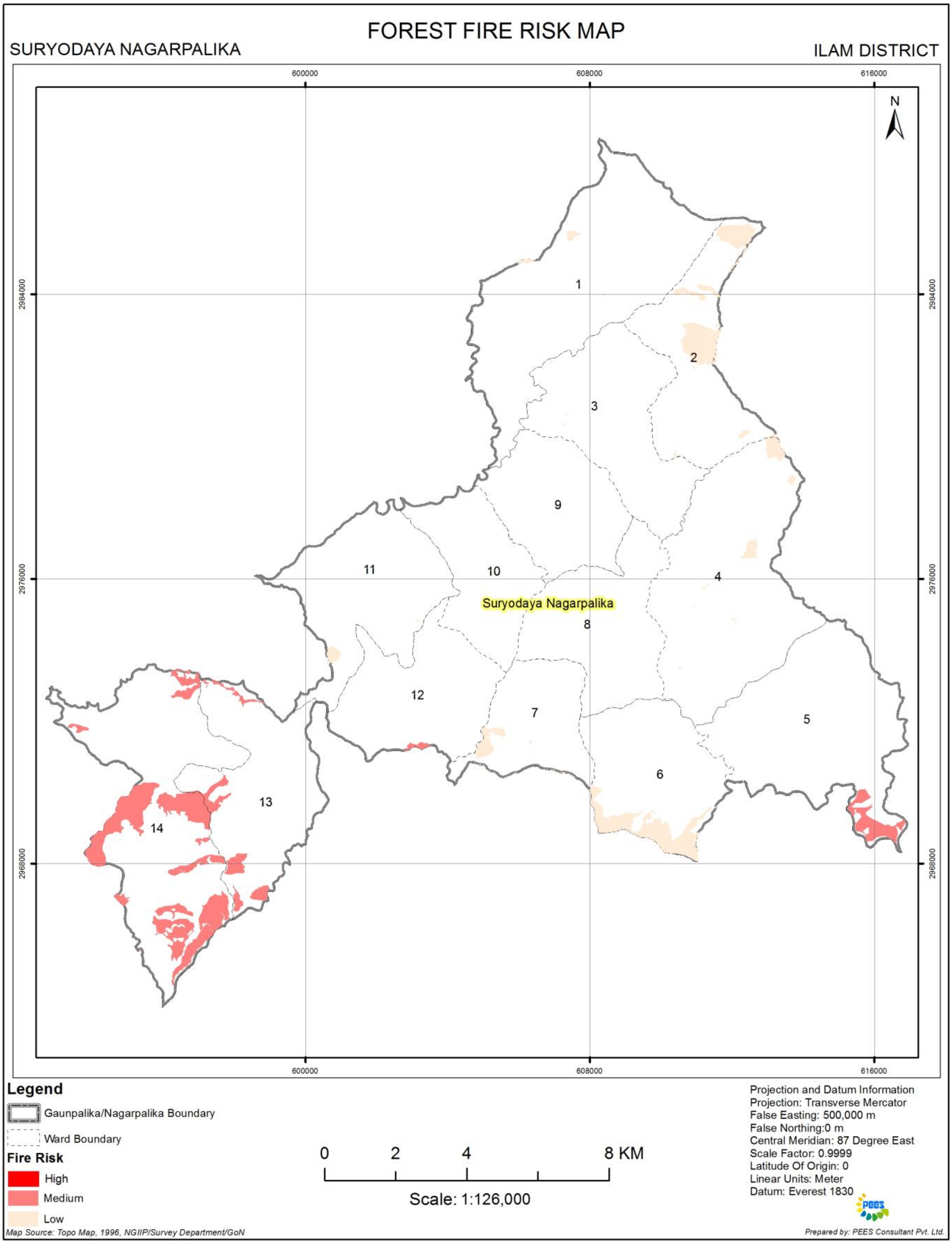


Figure 3.11: Forest Fire Risk Map of Suryodaya Nagarpalika

The lack of equipment and skilled manpower such as trained firefighters poses serious challenges in Suryodaya Nagarpalika. Furthermore, the difficult topography of the hill settlements makes it difficult for the authorities to bring a raging fire under control quickly. The clustered settlements in the market areas and building materials further worsen the risks. Because a significant number of houses in the market areas in Suryodaya Nagarpalika are built in clusters with thatch and timber with no fire protection. Negligent handling also could lead to an outbreak of a major fire. Similarly, haphazard construction of houses without complying construction code and fire safety measure invariably puts such property at great risk.

The marginalized and poor community has inhabited the area. The lack of education, slash and burn cultivation, burning of agricultural residues, the clustered settlement made up of thatch and straw houses, and negligent fire handling practices among the people in these wards of the Nagarpalika potentially contributes to the fire risk in the area.

3.2.5 Discussion

In the study area, the presence of a number of houses with thatch or straw roof; burning of agricultural wastes; unmonitored children’s activities, careless smoking, and negligence in cooking could contribute to the risk of fire. The tile/slate buildings are also at risk to fire because of the faulty electrical wiring and equipment, and LPG gas, however, the risk is low compared to houses made of wood and a thatched roof. With the presence of the tea industries and petrochemical stations in the Nagarpalika, the Nagarpalika has fire risk inherent in such businesses.

Petrochemical sources and stations are always at high risks; therefore should be kept far from the settlement area. Similarly, the areas resided by poor people are always in the high risk of fire. Therefore, fire preparedness activities should be carried out in marginalized communities, which include communication of messages through television, radio, folk songs, drills, posters, pamphlets, and hoarding boards, etc.

To tackle the fire risk, the government should allocate sufficient budget and other necessary assistance to Suryodaya Nagarpalika. Such assistance may include buying modern fire engines and training firefighters. With the rapid urbanization in Suryodaya Nagarpalika, property constructed face high risks of fires, especially during the dry, humid seasons. Awareness about fire safety should also be disseminated to the locals in clustered settlements while enforcing the house construction code strictly.

The study finds a need to discourage the practice of burning agricultural residue and encourage mass awareness to people about careful handling of the fire to reduce the risk of fire in the settlement area.

3.3 Land Slide Risk

Landslides are a form of erosion and are an important process in the shaping and reshaping landscapes and landforms. Landslides re-distribute soil and sediments in a process which can be extremely rapid or very slow. Landslide hazard, defined as the annual probability of occurrence of a potentially destructive landslide event. Landslide hazard is frequent phenomenon is Nepal due to several reasons including tectonic activities, uncontrolled and unsafe development, heavy precipitation and environmental degradation. However it is observed that rainfall induced landslides is most prevalent in the hills and mountainous districts. In view of rapid development in hills and mountains in the country, it has become imperative to review, identify and analyze landslide prone areas and their causative factors. In Nepal, high susceptibility zone of landslide are identified in the areas of high intensity rainfall and earthquake hazard. Earthquake induced hazard are distributed in centre (hill) zone of Nepal, which is largely dependent on Pick Ground Acceleration (PGA) values. For example, in Palpa more than 20% of geographical areas are prone to high landslides triggered by high intensity rainfall and earthquake whereas in Kaski one third of the areas will be in high landslide susceptible zone as per 500 years earthquake return period assessment.

Landslide susceptibility refers to the classification, area spatial distribution of potential landslide occurrence area. Landslide susceptibility zoning refers to the division of land into homogeneous area or domain and their ranking according to degree of potential landslide susceptibility, hazard or risk. Landslide inventory, susceptibility and hazard zoning for local areas for preliminary level risk zoning and the advance stages of planning for larger engineering structures are carried out at 5000 to 2500 scale covering are from 10 to 1000 square km (Fell et. al., 2005).

3.3.1 Data

Landslides are the result of triggering natural factors mainly extreme precipitation, rainfall intensity and seismicity and susceptibility factors dominantly, slope, lithology, soil moisture and land cover and land use. Peak of monsoon usually correlate with high landslide events in Nepal due to high precipitation. Data on the importance of earthquake triggered vs. precipitation triggered in terms of fatalities may not be easily available. However, it is known that in some cases, a significant share of the earthquake fatalities are killed by earthquake triggered landslides. All relevant spatial data at available geographical coverage and format are collected, compiled and processed in GIS platform for the analysis purpose.

Data collected for land use resource mapping and topographical, soil and geology data are used for landslide susceptibility analysis. Data and source of data are detailed below:

- Land cover land use (present land use, Satellite image Worldview-2, 2018)
- Elevation and Slope (from DEM, Satellite image Worldview-2, 2018)
- River network: Drainage density (Present land use, Satellite image Worldview-2, 2018 & Topographical sheets, 1995-97)
- Geology: Fault and lineament, Lithology and Rock type (DoMG, 2009)
- Soil (Land system, SOTER 2009), and
- Rainfall/ precipitation zone (DHM, 2007-2017).

3.3.2 General Approach and Methodology Framework

Landslide susceptibility assessments are based on different methods. Some common landslide susceptibility mapping methods are: Geomorphologic mapping, inventories, Statistical modeling, index based Heuristic analysis and Process based mapping and analysis. The current landslide susceptibility is based on process based mapping. The overall methodology applied is presented in Figure 3.12 and the approach followed for landslide mapping includes:

- Inventory of existing landslides from satellite image
- Verification of landslides in the field
- Mapping areas susceptible to landslide based on integration of scientific methodology and field landslide data characteristics.

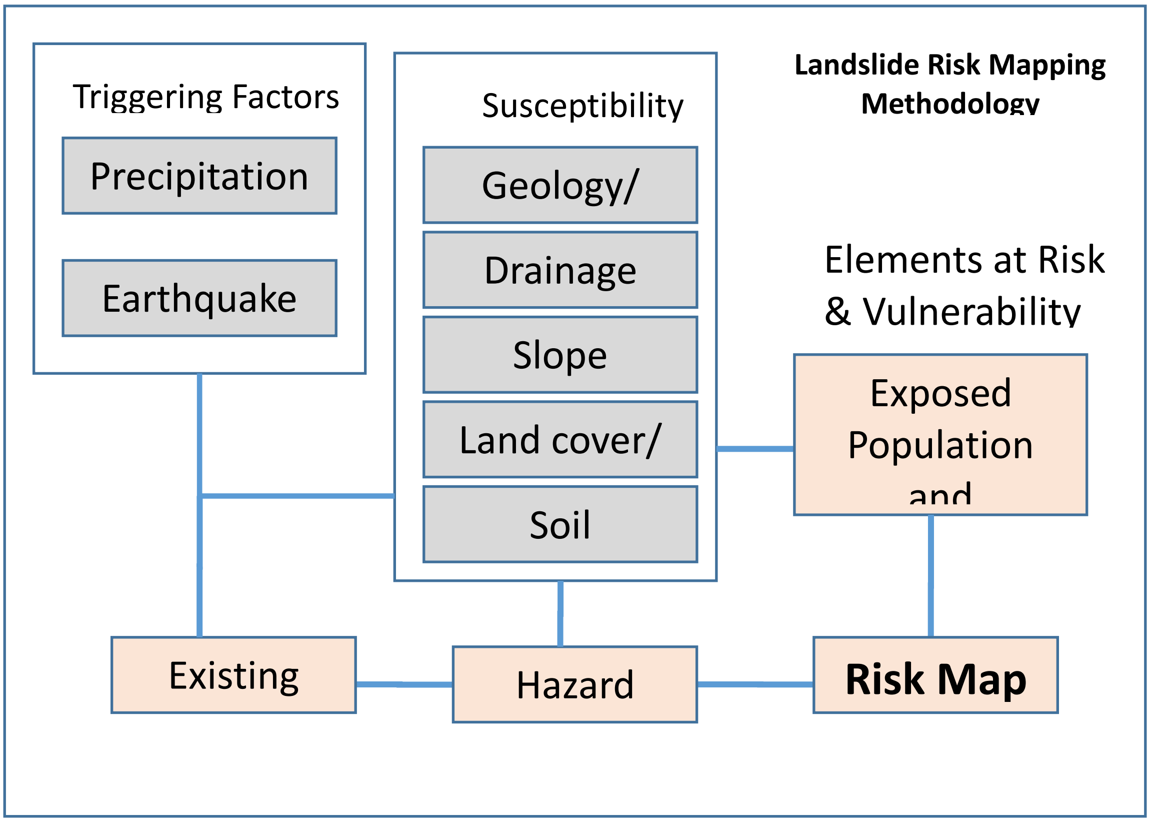


Figure 3.12: Landslide risk mapping methodology

3.3.3 Methods

Landslide susceptibility zoning with existing landslide data integration provides quantitative measure on landslide distribution with the assumption of continuous landslide density in space. Landslide susceptibility zoning usually involves developing an inventory of landslides which have occurred in the past together with an assessment of the areas with a potential to experience land sliding in the future, but with no assessment of the frequency (annual probability) of the occurrence of landslides (AGS, 2007).

Landslide susceptibility zoning is carried out in a GIS-based system with multi criteria analysis, MCA using number of spatial data layers so that the zoning can be readily be applied for land use planning and can be up-dated as more information becomes available. Standard processing and conversion methods are adopted in this analysis to minimize data error and methodology is devised accordingly. Landslide susceptibility mapping was carried out based on Nepal hazard assessment methodology(MoHA, 2011) and weights are assigned as specified in landslide hazard zonation mapping in mountainous terrain guideline (Bureau of Indian standards, 1998) combining triggering factors (mainly extreme precipitation and seismicity) and susceptibility factors (slope, lithology, and soil moisture). The following formula was used for weighted spatial analysis using MCA:

Landslide Susceptibility Ranking (LSR),

LSR= Σ (Pc_{rn} +Eq_{rn}) + (Ge_{rn} + Dd_{rn} + Lu_{rn} +Slp_{rn} +$So_{rn)}$…….......**(Equation 1)**

where, rn = Rank, of *Pc*= Precipitation, Eq = Fault and Lineaments, Ge = Geology, Dd = Drainage density, Lu = Land use/Land cover, *Slp*=Slope and So = Soil texture

Based on landslide inventory, geology, topography and geomorphology, soil and land cover/ land use, and using equation 1, weighted value are calculated. Rank 1 to 3 are assigned for each triggering factor and high to low susceptibility rank were summed and final rank grouped as high medium and low through Jenk's natural break method. Higher the rank (i.e. value 1) higher the landslide susceptibility (High) and vice-versa.

3.3.4 Result

The landslide mapping of package 04 is carried out using susceptibility methodology outlined under methodology by using overlay analysis in GIS environment. As more than 56 percent of the project area have slope greater than 20 degree and lies in higher rainfall zone, landslide susceptibility is found in more than 33 percent area. Table 3.3 details the area under different landslide susceptibility zones and Figure 3.13 shows the distribution of landslide susceptible area in the project area. Among total landslide susceptible area, 5 percent area is under high susceptibility zone covering more than 400 hectare while 58 percent area has medium susceptibility of landslide occurrence. The south western and northern part of the project area is highly vulnerable to landslide susceptibility whereas middle part has relatively lower susceptibility. Forest area is relatively lower with only 12 percent coverage while more than 56 percent of the area is above 20 degree slope indicating vulnerability to landslides. Settlement and road infrastructure distribution is dispersed to all over the project area and hence landslide vulnerability of settlement and infrastructure is also variable.

Table 3.3: Landslide Susceptible Area of Suryodaya Nagarpalika

Sn.	Susceptibility	Area Ha	Percent
1	High	404.65	5.32
2	Medium	4426.76	58.14
3	Low	2781.92	36.54
	Total	**7613.331**	**100.00**

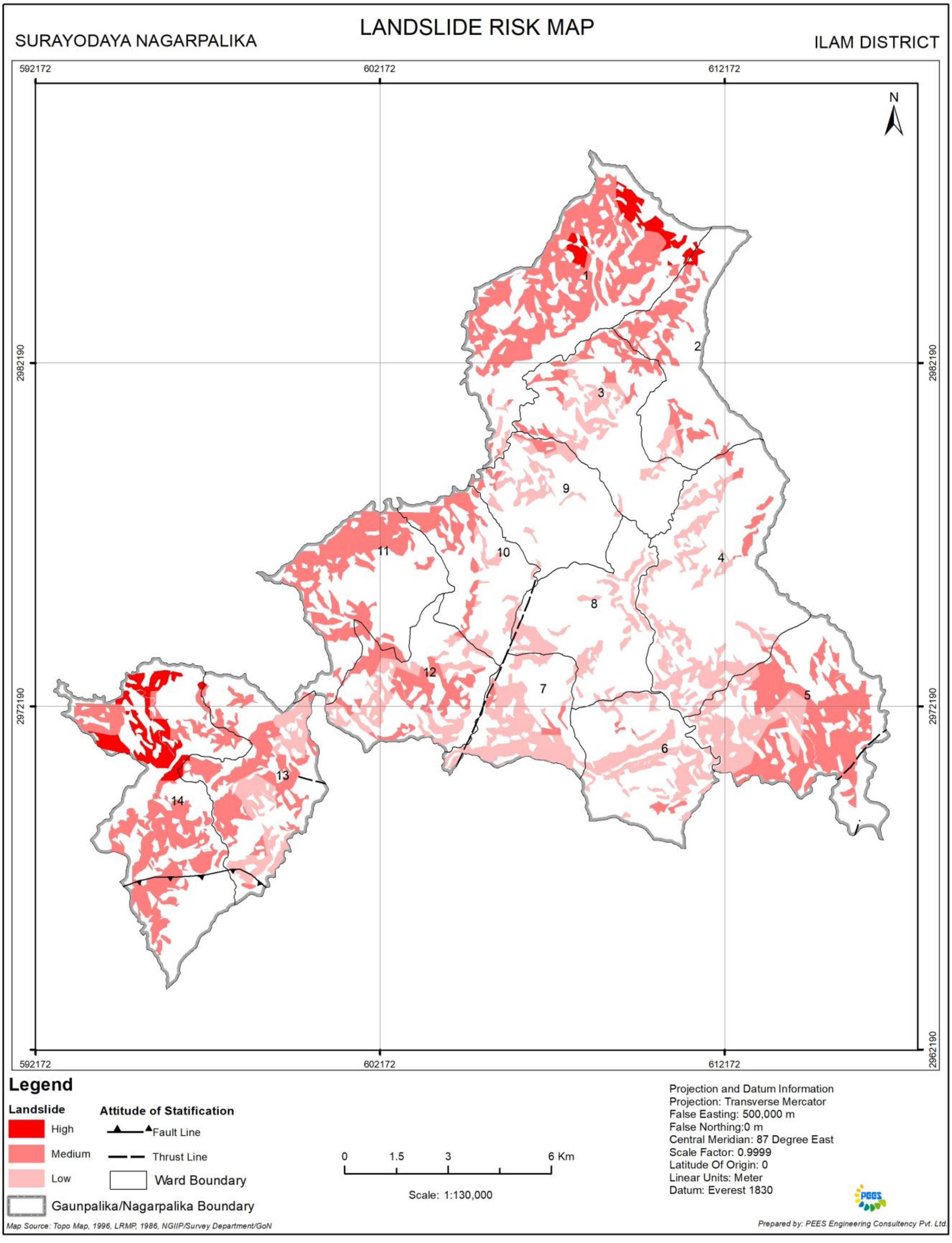


Figure 3.13: Landslide Susceptible Map of Suryodaya Nagarpalika

3.3.5 Discussion

Landslide susceptibility zoning is based on assumption of continuous landslide density in space. Hence while land use planning and zoning, factors which minimizes landslide risks could be excluded such as in plain area and forest cover in relatively lower slopes of 15 to 20 degree. Similarly in identified landslide susceptible area of varying degree, potential landslides may be of varying likelihood of occurrence based on management practices and protection measures in the area. South-western and northern part of the project area are most vulnerable to landslides because of weak geology, hence proper management strategies and protection measures should be implemented for agriculture practices, settlement and infrastructure development.

The assessment of landslide susceptibility based on Multi criteria analysis in GIS environment indicate that there is a close relationship between slope, land cover land use and geology and landslide susceptibility. Beside, infrastructure construction mostly road construction in higher slope area with weak geology is another major factor along roadside landslide occurrence. A study by DWIDP in 2003 also reported that transport infrastructure in Nepal is heavily affected by landslide incidences every year. A field survey conducted in 2003 in arterial routes of Nepal, it was found that small- to medium-scale roadside landslides very often occur as partial landslips within existing large-scale landslides in the area. Therefore, considering greater and effective serviceability of existing transport infrastructure, better planning of newer transportation routes, and safe land-use planning, it is very important to understand the distribution pattern of large-scale landslides so as to mitigate the risk of future infrastructure damage and economic losses.

Landslide record reveals that road and human settlement slopes are more vulnerable to landslides than ordinary natural slopes. This suggests that there is significant influence of human intervention, particularly in terms of road slope cutting, land development, agricultural practices, etc., on the occurrence of landslides and related failures in Nepal (Bhandary et. al., 2012).

Nepal hazard risk assessment report 2011 states Slope, lithology, soil moisture, and precipitation are controlling factors for landslide hazard, while earthquake and rainfall are triggering factors. The report also highlights the paucity of data on the importance of earthquake triggered vs. precipitation triggered in terms of fatalities may not be easily available. High severity zone areas are relatively governed by specific lithology condition and slope degree. Based on analysis, more than 20 % of geographical areas are prone to high landslides triggered by high intensity rainfall. Landslides typically occur in hilly areas and primarily affects the road sector. At the national scale, the damage caused by landslides is negligible in comparison to that caused by earthquakes, floods and droughts. These three disasters (earthquakes, floods and droughts) impact large geographical areas, covering almost all parts of the topography of Nepal.

An approach is required to integrate hazard maps developed by different organizations at suitable scale and used for disaster resilient development. The hazard risk map of particular area should be revised from time to time after major, extreme precipitation, and earthquake and major development infrastructure which may have affected.

3.4 Seismic Risk

Nepal lies within the seismic hazards zones of the world. The Himalaya seismicity, in general, owes its origin to the continued northward movement of Indian plate after the continental collision between Indian plate and Eurasian Plate. The magnitude, recurrence and the mechanism of continental collision depend upon the geometry and plate velocity of Indian plate in relation to southern Tibet (Eurasian Plate). Recent result suggests that the convergence rate is about 20 mm/ year and the Indian plate is sub-horizontal below the sun-Himalaya and the Lesser Himalaya.

3.4.1 Data

The analyzed data has been taken from the secondary sources. The data has been produced by a maps of epicenter of the Earthquake in Nepal Himalaya, Probabilistic seismic hazard assessment map of the Nepal Himalaya (Figure 3.14, Pandey et al. 2002), and seismic zonation of map the Nepal Himalaya (Figure 3.15, National Society for Earthquake Technology-Nepal (NSET) (Figure 3.16).

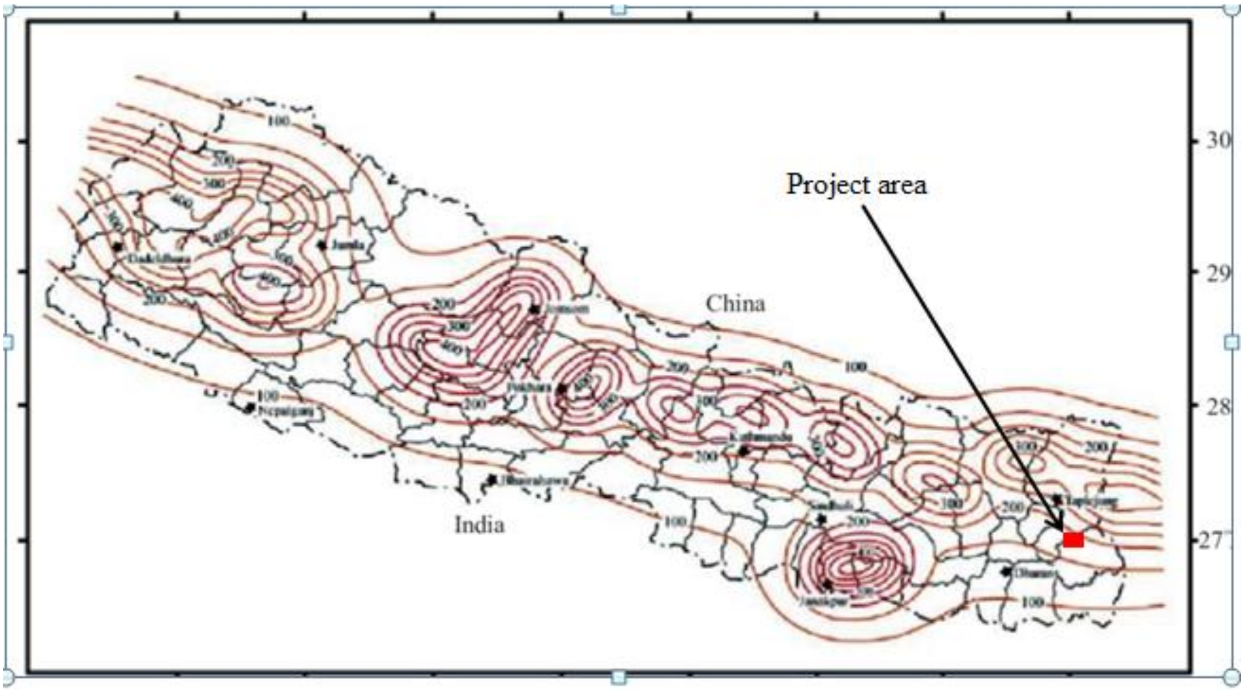


Figure 3.14: Seismic-hazard map of Nepal, (Pandey et al.2002)

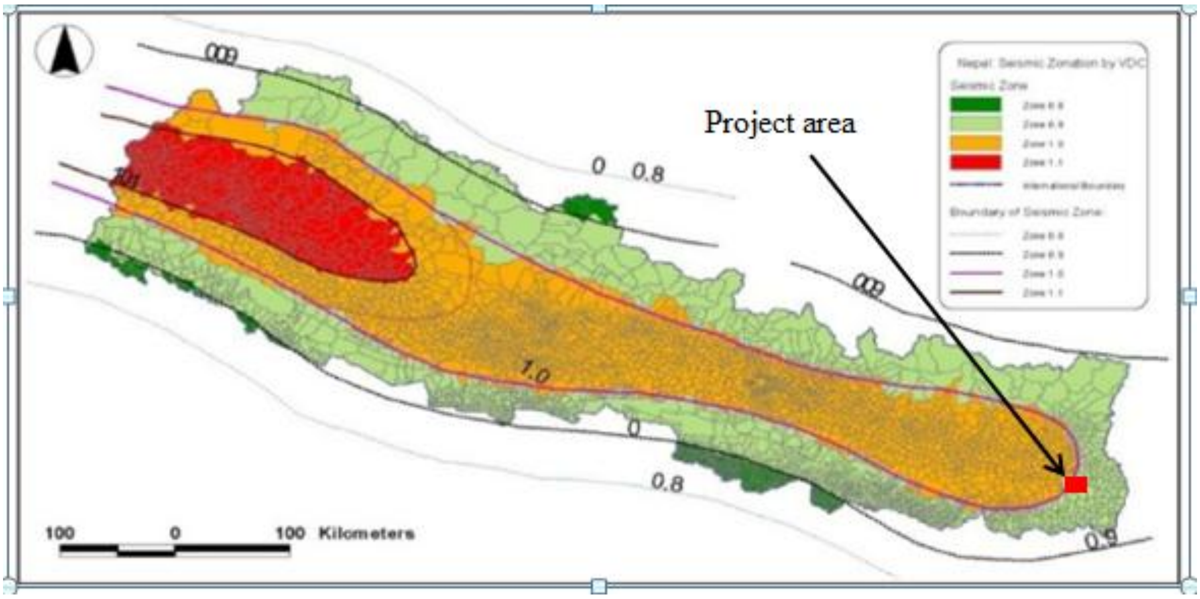


Figure 3.15: Seismic zoning map of Nepal with the lowest governance unit in different seismic zones

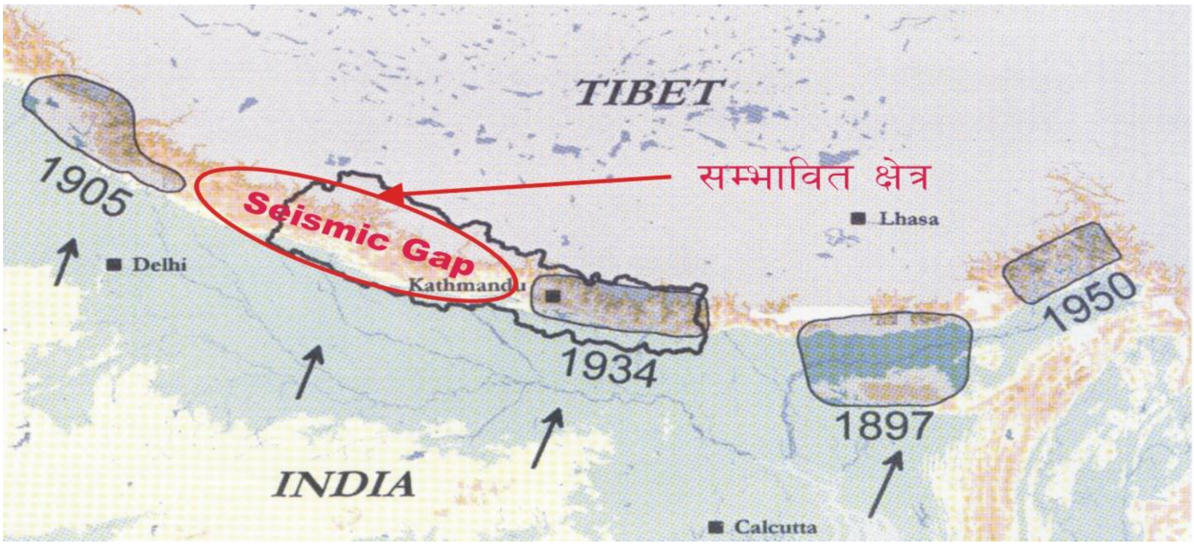


Figure 3.16: Map shows that the present area lies in the seismic gap of the region.

3.4.2 General Approach and Methodology Framework

The seismicity deals with the preliminary investigation of maximum credible earthquake and seismic coefficient of the project area. The result of micro seismic investigation, geodetic monitoring and morpho-tectonic study of the central Nepal has depicted that the more frequent medium sized earthquakes of 6 to 7 magnitudes are confined either to flat decollment beneath the lesser Himalaya or the Upper part of the Middle crustal ramp. The ramp is occurring at about 15 km depth below the foothills of the Higher Himalaya in the South of MCT surface exposures. Beg events of magnitude greater than eight are nucleated near the ramp flat transition and rupture the whole ramp-flat system up to the blind thrust (MBT) of the Sub- Himalaya (Pandey et al. 1995)

Preliminary seismic hazard assessment of the country using Gamble's third asymptotic extremes with the instrumental seismicity database of ISC is carried out by Bajracharya

(1994) for different return periods 50, 100, 200, and 300 years, Attenuation model with mean value of McGuire and Oliveira is used for Horizontal acceleration.

Return period (years)	Peak horizontal acceleration (g)
50	0.10
100	0.15
200	0.20
300	0.25

Several seismicity studies have been carried out for the various projects in the country during the engineering design phase and seismic design coefficient have been derived for the project. There are several methods to convert the maximum acceleration of the earthquake motion into the design seismic coefficient. Generally three methods are commonly used to establish the seismic coefficient. These are:

i. Simplest method
ii. Empirical Method
iii. Dynamic analysis method using dynamic model

The effective design seismic coefficient is determined by using the simplest method, the following equation:

$A_{eff} = R^{*} A_{max}/980$

Where A_{eff} is effective design seismic coefficient

R= Reduction factor (empirical value R=0.50-0.65)

The result obtained from this method is found to be similar in the recent studies carried out by using the dynamic analysis and the static analysis. Therefore, this method is considered to be the most common method to establish the design seismic coefficient at present.

The third method is the dynamic analysis method using the dynamic model. This method is considered to be the most reasonable method at present. However, to apply this method parameters like the design input motion, the soil structure model, the properties of the rock materials have to be known, and therefore, it means that a detailed study is required to use this method. Therefore, the empirical method is considered to be the best to establish the design seismic coefficient for this level of the study.

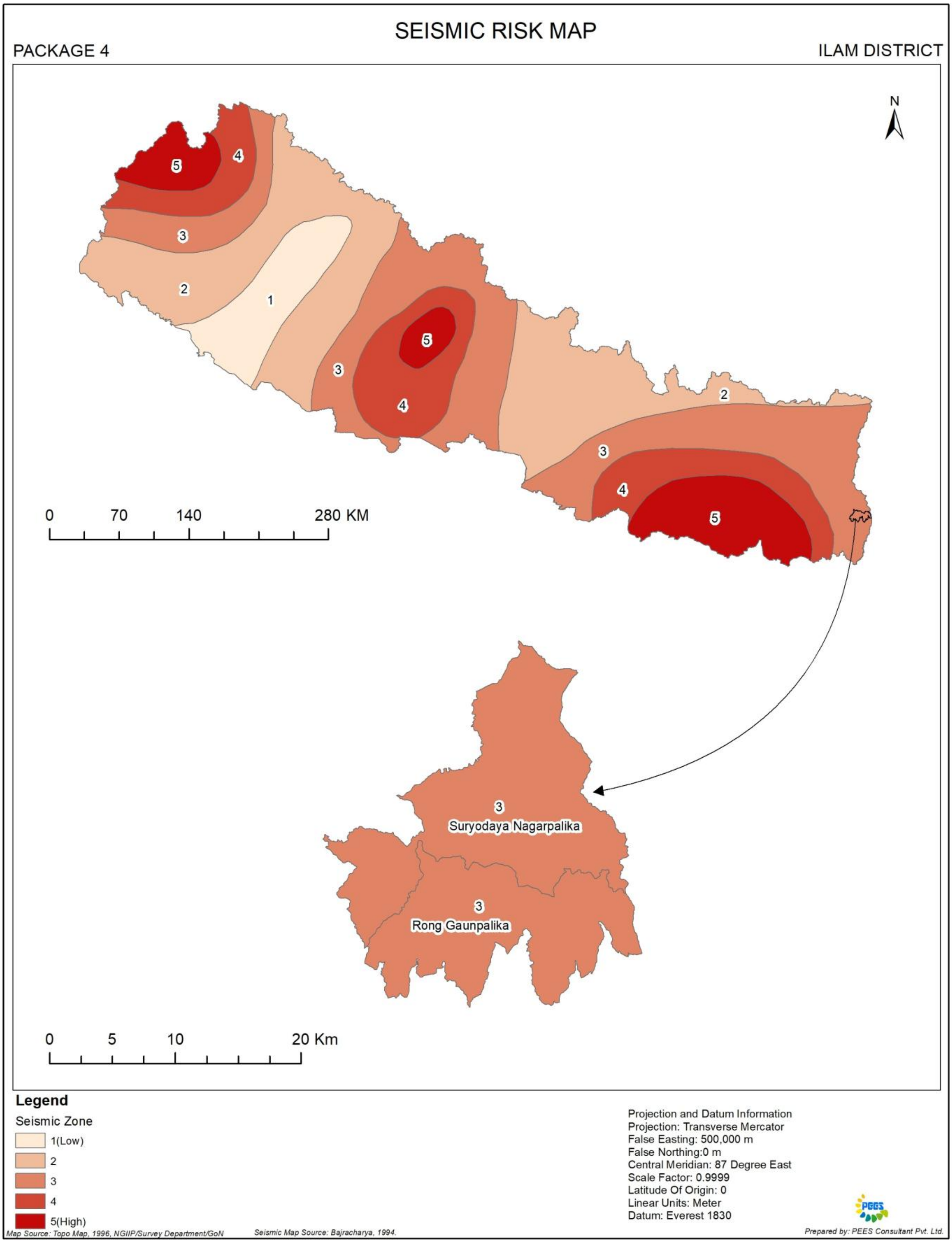


Figure 3.17: Seismic Risk map of Nepal showing the project area (Bajracharya 1994)

3.4.3 Method

The effective design seismic coefficient is determined by using the simplest method, the following equation:

$A_{eff} = R^{*}A_{max}/980$

Where A_{eff} is effective design seismic coefficient

R= Reduction factor (empirical value R=0.50-0.65)

Maximum acceleration A_{max}= 200 gal according to seismic hazard map of Nepal

The result obtained from this method is found to be similar in the recent studies carried out by using the dynamic analysis and the static analysis. Therefore, this method is considered to be the most common method to establish the design seismic coefficient at present.

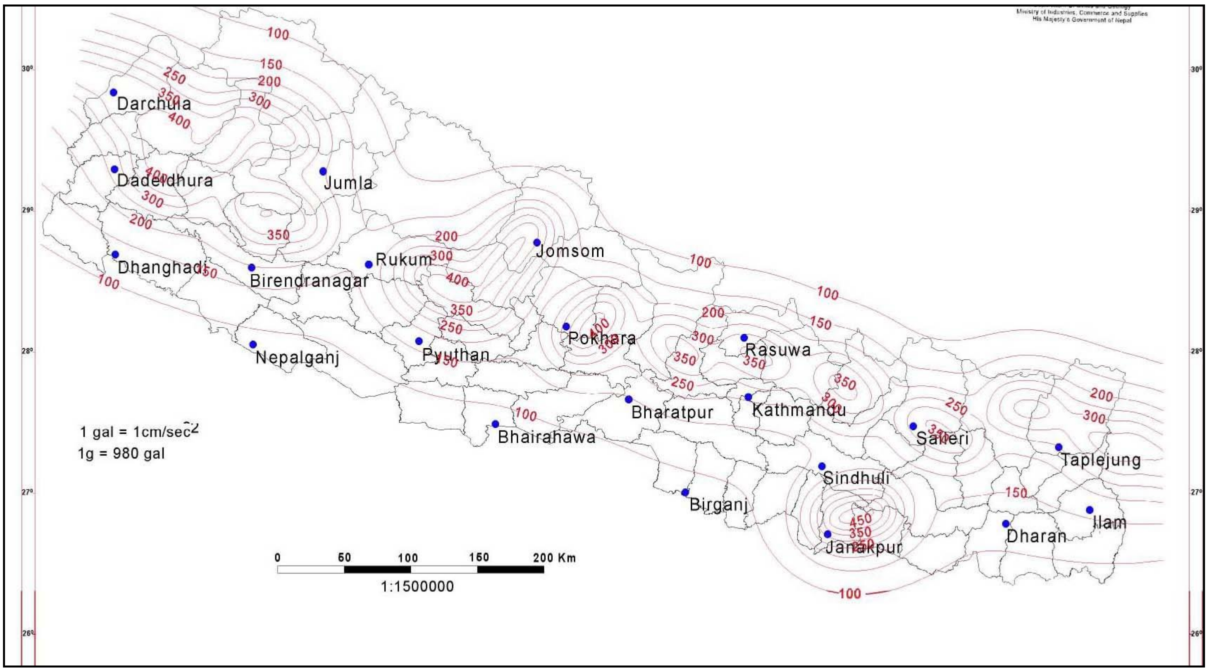


Figure 3.18: Probabilistic Seismic Hazard Assessment Map of the Nepal Himalaya

3.4.4 Results

The result obtained from this method is found to be similar in the recent studies carried out by using the dynamic analysis and the static analysis. Therefore, this method is considered to be the most common method to establish the design seismic coefficient at present. The calculated effective design coefficient of Suryodaya Nagarpalika area is considered as 0.117.

3.4.5 Discussion

The Suryodaya Nagarpalika lies in the eastern part of Nepal which is comparatively less vulnerable in terms of seismic activities in comparison to other parts of Nepal. However, the project area is bounded by the MCT forming the tectonic window certainly have threats of seismic activities in future. This shows that a due consideration is required before planning the large scale projects like hydropower development, tunnel construction, reservoir development, highway construction, large irrigation projects and landslide mitigation techniques. That’s why geotechnical considerations are the must before starting any kind of development activities in the area.

3.5 Industrial Risk

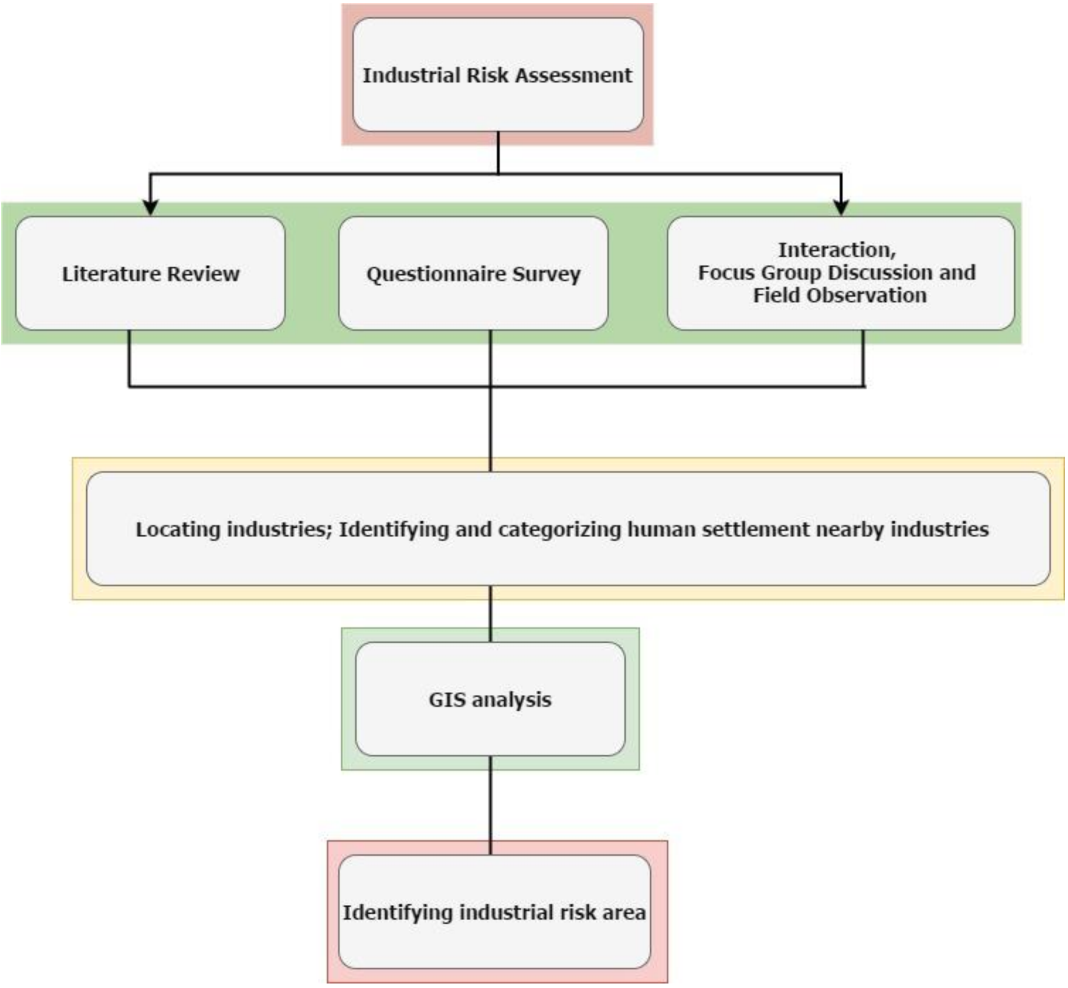
3.5.1 Data

Attempts have been made to identify the risk areas based on the location of industries, human settlements, buffer analysis in ArcGIS, survey of building materials and observation of building density, and socioeconomic status of the residents, etc. The present study has identified the industrial risk areas by collecting data through literature review, GIS analysis, consultation with local communities and field observation.

3.5.2 General Approach and Methodology Framework

General Approach: The general approaches for the industrial risk layer data collection are as follows:

- Location of industries nearby the human settlements and river bodies that may relate to industrial risk
- Identification and categorization of settlement patterns such as clustered, moderately clustered, and scattered
- Identification of high-risk settlement areas by identifying entities of industrial risk
- Identification of industrial risk with a holistic approach, taking various risk entities into consideration
- Identification and delineation of the industrial risk area



3.5.3 Methods

The following methods were adopted for the gathering of data and information related to industrial risk:

Literature Review

The relevant information was collected from available literature in the form of books, reports, and maps of topography, land use, cadastral survey, and aerial photographs. Further information was also acquired from various websites.

Field Investigation

A detailed field study was conducted in the Nagarpalika by a multidisciplinary team, which comprised risk expert, environmentalist, geographer, forestry expert, agriculturalist, biologist, and socio-economist. During the visits, information on the basic components of human settlements, industries, forest, petrochemical stations, etc was collected that has been used to establish baseline data and used for the industrial analysis of the Nagarpalika.

Questionnaires Survey and Informal discussion

The data on the industrial risk of the project Nagarpalika were gathered through household surveys with questionnaires. Extensive consultation with government representatives at various levels, experts and professionals, local communities and industrial stakeholders was also carried out.

Informal discussions were held in the Nagarpalika to interact with its local people and industrial stakeholders to collect information on the industrial risk of the Nagarpalika. Direct observation (walkover survey) was carried out to gather information about industrial risk entities.

GIS analysis

The GIS functions including the buffer analysis and spatial analytical technique for assessing proximity (within a certain distance) of industrial areas from the location of human settlements were used for the purpose of evaluating industrial risk areas of the Nagarpalika. In this method, a buffer zone has been defined at a pre-defined distance to create the various block groups. These buffer zones were used to describe the characteristics of the population inside each zone and the risks inherent due to the industrial location.

3.5.4 Result

There are few industries in Suryodaya Nagarpalika mostly related to tea processing. According to the latest available industrial statistics report (2072/2073) published by Ministry of Industry, there is one major tea processing industry named Phikkal Tea and Coffee Private Limited in Suryodaya Nagarpalika with a production capacity of 75 metric tons of CCT Tea, 275 metric tons of Orthodox Tea, and 20 metric tons of Coffee employing 60 workers. Except for this large-scale industry in the Nagarpalika, other industries have medium production capacity and use coal and wood as fuels to operate. They operate about 8 hours a day, generating a smoke thereby affecting the surrounding environment and settlements. The Nagarpalika has a solid waste problem, as the current solid waste disposal practice is to dump the waste into random lands. With growing number of population and the Nagarpalika inability to tackle the garbage management issue, there has been an increase in the production of garbage and other solid waste.

3.5.5 Discussion

Although the pollution caused by the industries in the Nagarpalika creates a nuisance to the residents who feel uncomfortable, risks from the industries are moderately negative in nature, for the long-term duration and low in magnitude as the majority of industries are agro-based. The agro-based industries generate effluents and solid wastes that need to be disposed of in an environmentally acceptable manner. In concurrence with the regulatory requirements, the industries need to adopt a sustainable approach to the waste management. The effluents generated by agro-based industries are biodegradable and non-toxic and treated by physical, chemical and biological processes. With the application of appropriate technologies, it is possible to minimize the pollution and also to recover the water and other useful materials from the waste streams.

Therefore, there is a medium risk of air pollution and water contamination from wastewater generated by those industries as the industrial discharges end up in surface water causing a risk on flora and fauna, as well as on human beings, who use the river water.

The best way to reduce the industrial risk would be a land use planning and zoning. Industries need to abide by the environmental rules and regulations and other statutory provisions of the Government of Nepal. The discharges from the industries need to meet the requirements of quality standards as set up by the Government of Nepal. To assure the public and concerned stakeholders about the minimization of industrial risk, the Government of Nepal needs to initiate an effective monitoring system and its thorough implementation.

CHAPTER 4: RISK IN THE STUDY AREA

4.1 Existing Risk in the Study Area

Flooding and Landslide are main risk observed in the Suryodaya Nagarpalika (package-04), Ilam district. Area under Suryodaya Nagarpalika falls in the Mid-hills and Siwalik zone that is characterized by of unconsolidated sediments of the Siwalik and the hills. Floods are not frequent in the Nagarpalika; however, there is a chance of entering flood in the area along the Tangting khola, Khani khola, Antu khola, Siddhi khola, Mayum khola (Figure 4.1). The main problems due to flooding are: River bank cutting, degradation of agricultural lands etc. There were some floods: on 2044, 2042, 2061, 2068 and 2072 BS in Jil khola (minor flood problems in ward no. 9 of Suryodaya Nagarpalika); Chhiruwa Khola (minor flood problems in ward no. 6 of Suryodaya Nagarpalika); Mechi river (some flood effects in ward no. 5 of Suryodaya Nagarpalika and eastern part of ward no. 6 of Rong gaunpalika); Goyang Khola and Biring Khola (minor problems of ward no. 1, 2 4, 13 &14 of Rong Gaunpalika). In 2068 floods in Shiddhi Khola, 14 people lost their life due to landslides in Rong Gaunpalika, ward no. 9. The main problems due to flooding are: River bank cutting and landslides which was verified during the time of field visits.

More than 56 percent of the project area have slope greater than 20 degree and lies in higher rainfall zone, landslide susceptibility is found in more than 33 percent area. Among total landslide susceptible area, 5 percent area is under high susceptibility zone covering more than 400 hectare while 58 percent area has medium susceptibility of landslide occurrence. The south western and northern part of the project area is highly vulnerable to landslide susceptibility whereas middle part has relatively lower susceptibility. Forest area is relatively lower with only 12 percent coverage while more than 56 percent of the area is above 20 degree slope indicating vulnerability to landslides. Settlement and road infrastructure distribution is dispersed to all over the project area and hence landslide vulnerability of settlement and infrastructure is also variable.

As per them, many agricultural lands have been converted to river bank due to bank cutting, which was verified during the time of field visits.

Apart from the built-up areas, the risk of **forest fire** is very high during the hot-dry season in hilly areas particularly at the Siwalik region. However, Suryodaya Nagarpalika has mostly community-managed forest; therefore, risk of a forest fire could be low.

The area under package 4 does not have any large-scale industries. Most of the industries in the Nagarpalika are agro-based, tea processing; therefore, their impacts on human seems low.

Besides above, there are other natural and anthropogenic factors that produce risk and/or hazard. Drought, hailstone and wind, agricultural diseases and pest are other risks in the study area but their extent and intensity is relatively low.

4.2 Potential Risk in the Study Area

Flood and landslide are most occurring and potential risks in the study area. South-west, south-eastern and north-eastern parts of the Nagarpalika are basically prone to landslide, these areas are also affected by flooding and river bank erosion as well. Both flood and landslide hazard may affect to the river bank area and erodes the banks, therefore, it may affect to the settlements as well as cultivated land and infrastructure particularly during the monsoon period. Many landslide and flood hazard can be seen along the Tangting khola, Khani khola, Siddhi khola, Gorkhe and Mayum khola. In terms of seismic hazards, according to Bajracharya (1994), the Nagarpalika area falls in the seismic medium hazard zone (seismic zone 3) of the Nepal Himalaya. Agriculture diseases and pest, heat wave, hailstone, frost etc. are also potential risk in the study area but their extent and magnitude is relatively low and in the local level.

4.3 Risk Data Model

The risk developed for Risk data is shown in Table 4.1.

Table 4.1: Risk Data Model

Field	Data Type	Description	Remarks
OBJECT ID	Object	Feature	
SHAPE	Polygon Geometry	Geometric Object type	
RISK ID	Short	Unique Object ID	
RISK Type	Text	1. Flood Risk	
		2. Fire Risk	
		3. Landslide Risk	
		4. Seismic Risk	
		5. Industrial Risk	
RISK LEVEL	Text	High	
		Medium	
		Low	
NAGARPALIKA	Text	Nagarpalika Name	
DISTRICT	Text	District Name	
REMARKS	Text	Any remarks regarding the feature	
SHAPE LENGTH	Double	Meter	
SHAPE AREA	Double	Area in m^2	

4.4 Risk GIS Database

The attribute of risk in the feature database is shown in 4.2. With this geo-database, the risk maps were generated.

Table 4.2: Risk GIS Database

S.N.	Description	Level 1	Level 2	Nagarpalika	District	Remarks
1	Fire	Fire	High Medium Low	Name of Nagarpalika	Name of District	
2	Flood	Flood	High Medium Low	Name of Nagarpalika	Name of District	
3	Landslide	Landslide	High Medium Low	Name of Nagarpalika	Name of District	
4	Seismic	Seismic	High Medium Low	Name of Nagarpalika	Name of District	
5	Industrial	Industrial	High Medium Low	Name of Nagarpalika	Name of District	
6	Other	Other	High Medium Low	Name of Nagarpalika	Name of District	

CHAPTER 5: CONCLUSIONS

5.1 Conclusions

Land use zoning is an essential planning tool for successful and systematic disaster risk reduction. It can reduce the vulnerability of people and infrastructure identifying appropriate locations for settlement and construction by applying adequate building standards during implementation of plan. Flood, landslide, fire, industrial and earthquake are major events that expose into vulnerability and hazard associated with risk. Among others, landslide and flood risks are high in the Nagarpalika as compared with other risks/hazards. South-western and northern part of the Nagarpalika area are most vulnerable to flood and landslides because of weak geology, hence proper management strategies and protection measures should be implemented for agriculture practices, settlement and infrastructure development.

5.2 Recommendation

Based on the present experience of the project, the following recommendations are made for future undertaking of similar projects:

- Settlements developed along the bank of Mayum khola, Chhiruwa khola, Srikhola, Tangting khola, Gorkhe khola are more prone to floods and bank cutting. Therefore, immediate action is needed to take against flood and bank cutting such as river training or embankment or levee construction to protect the agriculture land and settlements from the flood. Additional study is needed for the analyses and forecasting of flood risk.
- Integration of hazard maps developed by different organizations at suitable scale is required, and used for disaster resilient development policy. And that hazard risk map (of particular area) should be revised from time to time after major, extreme precipitation, and earthquake and major development infrastructure which may have affected.
- Fire preparedness activities most be carried out, which includes spreading messages through television, radio, street drama, video, folk songs, drills, posters, pamphlets, and hoarding boards to reduce the risk of firing.
- The seismicity factor should be considered in the detail engineering design.
- The risk layer maps and database may be useful for land use planners and environmentalist for the development intervention. Therefore, it could also be useful for preparation of environmental planning, policies and strategies to the Nagarpalika.

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