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Hexa International Pvt. Ltd.
Dhalku-5, Kathmandu, Nepal
Phone: +977-01-4423136/9841487840

Government of Nepal
Ministry of Land Management, Cooperatives and Poverty Alleviation
Topographical Survey and Land Use Management Division
Minbhawan, Kathmandu, Nepal

FINAL REPORT

Preparation of Rural Municipality/Municipality Level Land Resource Maps (Present Land Use Map, Soil Map, Land Capability Map, Risk Layer, Land Use Zoning Map, and Superimpose of Cadastral Layer), Rural Municipality/Municipality Profile, Database and Reports of All Rural Municipality/Municipality of Dhading District for Fiscal Year 2077/078

Package No: TSLUMD/CS/QCBS/01/07/2077/078

Jwalamukh Rural Municipality, Dhading District

- Present Land Use Report
- Soil Report
- Land Capability Report
- Risk Layer Report
- Land Use Zoning Report
- Cadastral Layer to Superimpose Report
- Rural Municipality Profile

Submitted By:

Hexa International Pvt. Ltd.
Dhalku-5, Kathmandu, Nepal
Phone: +977-01-4423136/9841487840

Experts Involvement in the Assignment

for

Package No: TSLUMD/CS/QCBS/01/07/2077/078

(All Rural Municipality\Municipality of Dhading District)

Proposed Position	Name of Experts	Signature
Team Leader	Dr. Ananta P. Gajurel	
Soil Scientist	Ram Kumar Shrestha	
	Biplov Oli	
Agriculture Expert	Rajesh Poudel	
	Roshan Subedi	
Senior Surveyor	Biplov Parajuli	
	Yogendra Pandey	
NRM	Anju Pokharel	
	Prakash Chandra Aryal	
Forester	Shiva Kumar Sharma	
	Yam Bahadur K.C.	
GIS Expert	Kamal Acharya	
	Youvaraj Khatiwada	
RS Expert	Bhanu Bhakta Parajuli	
	Krishna Pd. Joshi	
Land Use Planner	Rabin Shrestha	
	Rojeena Dangol	

Proposed Position	Name of Experts	Signature
Geologist	Champak Babu Silwal	
	Gopal Man Shrestha	
Hydrologist	Bir Bal Rai	
	Dr. Tirtha Raj Adhikari	
Socio Economist	Dev Raj Ojha	
	Dhurba Raj Shiwakoti	
Digitization Operator	Anu Subedi	
	Puskar Nepal	
GPS Operator	Abin Prajapati	
	Yadhav Raj Ghimire	
Field Enumenetor	Bhuban Pokhrel	
	Narayan Devi Shrestha	
Soil Sample Collector	Prabhat Jha	
	Prakash Sejwal	

सारांश

ज्वालामुखी गाउँपालिका

स्थलरुप नापी तथा भू-उपयोग व्यवस्थान महाशाखा, भूमि व्यवस्था, सहकारी तथा गरिबी निवारण मन्त्रालय द्वारा "नगरपालिका/गाँउपालिका स्तरीय भू-उपयोग नक्सा (बर्तमान भू-उपयोग नक्सा, माटोको नक्सा, भूमि क्षमता नक्सा, जोखिम नक्सा, कित्ता नापी नक्सालाइ बर्तमान भू-उपयोग नक्सा माथि राखिएको नक्सा, भू-उपयोग बर्गीकरण नक्सा तथा गाँउपालिका/गाँउपालिका पार्श्वचित्र)" डाटा तथा रिर्पोट तयार गर्ने कार्य अर्न्तगत प्याकेज नं (TSLUMD/CS/QCBS/01/07/2077/078) धादिङ जिल्लाको ज्वालामुखी गाउँपालिकाको कार्य गर्न यस Hexa International Pvt. Ltd., Dhalku, Kathmandu लाई कार्यादेश प्रदान गरिएको थियो।

कार्य सम्पन्न गर्न दिइएको महाशाखाबाट प्राप्त उच्च स्तरीय (High Resolution) स्याटेलाइट इमेज ZY-3) लाई आधार मान्दै Feature Extraction-based Hierarchical Image Classification बिधिको प्रयोग गरी सात तहसम्मको तहगत बर्गीकरणमा लगि मबतबदबकभ तयार पारिएको छ। जसको लागि भु-उपग्रह तस्विर (ZY-3), सरकारी निकायद्वारा उपलब्ध सूचनाहरु र फिल्ड सर्वेक्षणबाट संकलित प्राथमिक सूचनाहरुका आधार लिइएको छ। स्याटेलाइट इमेज (ZY-3) लाई जमिनको अवस्थितिसँग मिलाउन आबश्यक भू-नियन्त्रण विन्दुहरु लिइएको थियो र confusion matrix र kappa statistics को प्रयोग गरि भुमि बर्गिकरण को गुणस्तर जाँच गरिएकोमा दिइएको मापदण्ड भित्र नै पाइएको छ।

यो गाउँपालिकाले ११२.९० वर्ग कि.मि. क्षेत्रफल ओगटेको छ। यो गाँउपालिका ३३३.८४ मिटर देखी १३४३.१४ मिटर सम्मको उचाईमा रहेको छ। यस गाँउपालिकामा उपोष्ण र उस्ण हावापानी पाईन्छ। यहाँका मानिसहरुको मुख्य पेशा पशुपालन र निर्वाहमुखी खेती हो। यहाँका मानिसहरुको मुख्य पेशा कृषि हो। यहाँका प्रमुख बालीहरु धान, गहुँ, कोदो र मकै हुन र विभिन्न तरकारी बालीहरु पनि उत्पादन गरिन्छ यस गाउँपालिकाको कुल जनसंख्या २३९६६ छ र जनघनत्व २३७.२१ जना प्रति वर्ग कि.मि. रहेको छ। यो जनघनत्व देशको औसत जनघनत्व भन्दा कम देखिन्छ।

नक्साको विष्लेषण गर्दा वर्तमान भू-उपयोग यस गाउँपालिकामा ४२.३४ प्रतिशत जमिन वन क्षेत्रले ढाकेको छ भने ४९.९८ प्रतिसत जमिन कृषिले ढाकेको छ। पहाडको समथर गह्राहरु र भिरालो गह्राहरुमा कृषि प्रणाली अपनाईएको छ जहाँ धान-मकै-तरकारी (३३.३९%) र धान-आलु-तरकारी (१६.४६%) बालीचक्र मुख्यरुपमा लागाईन्छ।

यस गाँउपालिकामा माटोको विष्लेशण गर्दा विभिन्न भु-स्वरुप प्रतिनिधत्व हुनेगरी आबश्यक खाल्डा एष्तक हरु खनेर माटोको नमुना परिक्षण गरिएको थियो। माटोको वर्गिकरण USDA को माटो वर्गिकरण र माटोको क्रमानुसार गरिएको थियो र यो गाँउपालिकामा एन्टिसोल्स Entisols ३.५७ प्रतिशत र ईन्सेप्टिसोल्स Inceptisols ८९.६९ प्रतिशत पाईएको छ। माटोमा हुने पौष्टिक तत्वको स्तर हेर्दा यस गाउँपालिकामा pH को स्तर ३७.११०% क्षेत्रमा उच्च, जैविक पदार्थ को स्तर ५२.०३% क्षेत्रमा उच्च, नाइट्रोजन को स्तर ५२.०३% क्षेत्रमा उच्च र फोस्फोरसको स्तर ०.३१% क्षेत्रमा उच्च रहेको छ। पौष्टिक तत्वको आधारमा, यस गाउँपालिकाको धेरै क्षेत्रहरुमा विभिन्न किसिमका बालीनालीहरु उत्पादन गर्न सकिन्छ तरपनि माटो संरक्षणका उपायहरु र थप प्राङ्गरीक पदार्थ व्यबस्थापनमा ध्यान दिनुपर्छ।

भूमि क्षमता र जमिनको उत्पादकत्वलाई वर्गिकरण गर्नका लागि भौगोलिक सूचना प्रणालीमा आधारित बहुशर्तिय मुल्याङ्कन GIS-based Multi-criteria Evaluation प्रयोग गरी कृषि योग्य जमिनको वर्गिकरण गरिएको छ। यस गाउँपालिकामा उपलब्ध भुमि मध्ये ५०.००% भूमि खेतीयोग्य पाईएको छ। भिरालोपना, हावापानी र माटोको बिशेषताका कारणले यस गाउँपालिकाको जमिन मध्यम देखि उच्च जोखिम क्षेत्रमा पर्दछ र आबादीका लागि लगभग अनुपयुक्त भू-भागलाई चरन क्षेत्र, वन र उपयुक्त संरक्षण सहित प्राकृतिक सौन्दर्यस्थलका रुपमा उपयोग गरिनु उचित छ। मध्यम-भिरालो क्षेत्रहरुमा आवादी गर्नका लागि विशेष उपायहरु जस्तै घाँस लगाउने र गह्राहरु (terracing) बनाउनु पर्दछ। यस गाउँपलिकामा भु-क्षय प्रकोपमा छ। अधिकाशं जमिन आबादीको लागि मध्यम देखि उच्च जोखिमका छन्। जमिनको व्याबसायिक प्रयोजनका लागि विशेष माटो संरक्षणका गरी यस गाउँपालिकामा भएको IV किसिमको जमिनलाई हरियाली क्षेत्रका रुपमा उपयोग गरी बाताबरणको संरक्षण गर्दै पर्यटनको विकास गर्नु पर्दछ।

बाढी, आगलागि, पहिरो, औधोगिक, भुकम्पीय, माटोको क्षयीकरण तथा अन्य जोखिमको अध्ययन गरिएको छ। नतीजालाई विष्लेशण गर्दा कुल भूभागको ८.०३ हे. बाढीको उच्च जोखिममा पर्दछ भने ०.५६% कृषि क्षेत्र बाडिको उच्च जोखिममा पर्दछ। गाँउपालिकाको भौगभिक वनावटका कारणले धेरै भू-भाग पहिरो जोखिम क्षेत्र भित्र पर्दछ।

जमिनको उपयूक्ततालाई भू-उपयोग ऐन २०७६ ले निर्दिष्ट गरेको दश भू-उपयोग क्षेत्रमा बर्गीकरण गरि नक्साकन गरिएको छ। जस अन्तर्गत आवासिय क्षेत्र, व्यापारिक, औद्योगिक तथा खुला क्षेत्र भूमि क्षमता कम रहेको उत्पादकत्व कम रहेको जमिनमा गरिएको छ। सहरी क्षेत्र विस्तार तथा वस्ती विकाश क्षेत्रका लागी सुरक्षित क्षेत्र वा जोखिमरहित क्षेत्रबाट डाटा प्रस्तावित गरिएको छ भने सडक क्षेत्र अधिकार डोलीडार को मापदण्ड र गाँउपालिकाको By Laws अनुसार निर्धारण गरिएको छ। भू-उपयोग योजना तथा Zoning मा भविष्यमा वृद्धि हुन सक्ने सार्वजानिक क्षेत्र आवशिय क्षेत्र र पुर्वाधार निर्माण क्षेत्र अहिलेको अनुपातमा वृधि हुने र कृषि क्षेत्र घटेको देखिएको छ। यस गाँउपालिकामा मा कुल २८४६९ वटा कित्ता छन भने जसमध्ये २४६०१ वटा कित्ता कृषि क्षेत्रमा रहेका छन भने १०४ वटा कित्ता बन क्षेत्रमा परेको देखिन्छ।

सिफारिस

भू-उपयोग योजनाका आधारमा गाँउपालिकाको होचो वा नदिको खोंच उपत्यका वा समथर भू-भागमा सिँचाइ सुविधा विस्तार गरी बर्षमा धेरै खेतीवाली गर्ने गाँउपालिकाको प्राथमिकता क्षेत्र बनाउन आवश्यक छ। गाँउपालिका स्याउ, ओखर, नास्पाती, आरु, आदि फलफुल,तरकारिमा राज्मा, बोडी, सिमि, भटमास आदी र खेतिबालीमा मकै, जौ, कोदो, फापर, धान आदी का लागी भौगलिक तथा हावपानीका दृष्टीले अनुकुल भएकाले देखिन्छ। मौरीपालन को पनि सम्भाव्यता छ। प्रधानमन्त्री कृषी आधुनीकीकरण परियोजनाले गाँउपालिकालाई घोषणा गरे अनरुप गाँउपालिकाले सम्बन्धित किसान वा व्यवसायहरुलाइ उत्साहित तथा आवश्यक सहयोगको वातावरण सृजना गरी घोषित कार्यक्रमको लक्ष्य हासिल गर्न आवश्यक सहयोग गर्न जरुरी छ।

बेमौसमी तरकारी खेती अम्लीय जातका फलफुल खेती सौन्दर्य एवं औषधीजन्य जडीवुटी गैह्र काष्ठ पैदावर जन्य वनस्पती संरक्षण खेती गर्ने प्रसोधन गर्ने तथा उचित बजारको व्यवस्था गर्ने कार्यलाई विशेष जोड दिइ गाँउपालिकाबासीको आयआर्जन तथा स्वरोजगारका अवसर सृजना गर्ने व्यवस्था गर्नुपर्दछ।

यस गाँउपालिकाको मुख्य कृषी क्षेत्रलाई मानविय अतिक्रमण तथा प्राकृतिक प्रकोपबाट सुरक्षित राखी खाद्यन्न वाली तथा नगदेवालीका लागी मात्रा प्रयोगमा ल्याउन अत्याधिक पहल गर्न आवश्यक छ। उद्यम व्यवसायलाई प्रोत्साहित गर्ने वातावरण सृजना गरी विशेष गरेर गैर काष्ठ पैदवार तथा जडीबुटीमा आधारित उद्यम व्यवसायको विकास गरी उपलब्ध साधन स्रोतको दिगो प्रयोगबाट जिविको पार्जनमा सुधार ल्याउने विकाश निती तर्जुमा गर्न जरुरी छ।

उच्च भेग भएका खोला तथा गाड भएकाले साना जलविधुत विकास योजनामा र नदिमा ठूला जलविद्युत योजना वनाउन केन्द्रित हुन जरुरी छ। उच्च रमणिय स्थलमा पर्यटन क्षेत्रको रुपमा बिकाश गर्न आवश्यक छ।

नदी तथा आसपासका बाढी जोखिम क्षेत्रहरुमा तटबन्धन तयार नदी नियन्त्रण गरि नदिखोला र गाढको कटान भु-क्षय तथा बाढी पहिरो नियन्त्रन सम्बन्धी काम गर्न जरुरी छ साथै बिकाश निर्माण गर्दा न्युनीकरणका उपायहरु अबलम्बन गर्नुपर्दछ।

पर्याबरणीय दृष्टिकोणले आवश्यक पर्ने हरियालिका लागी बृक्षारोपन बन संरक्षन र बन क्षेत्र बिस्तार तथा प्राकितिक जोखिम न्युनिकरण एवम व्यवस्थापनका कार्यहरु गर्न आवश्यक छ। भौतिक पुर्वधारको बिकास बन कृषि तथा वातावरणीय दृष्टिले संबेदनशिल मानिने क्षेत्रमा नगरी खुल्ला तथा कम उत्पादनशिल मानिने क्षेत्रमा मात्र गर्न जरुरी छ।

भौगोलिक बिकटता प्राकृतिक प्रकोपको सम्भावना र आधुनिक सेवा सुविधा बाट पछि परेका छरिएर बस्तिहरुको वर्तमान अवस्थाका आधारमा गाँउपालिकाले सुरक्षित आधुनिक सेवा सुविधा बिस्तार गर्न सहज अवस्थिति र प्राकृतिक जोखिम रहित तथा पर्याबरणीय अवश्थामा प्रतिकुल असर नपर्ने ठाउमा एकिकृत बस्ती बिकास योजना तर्जुमा गरी कार्यान्वयन गर्न अति आवश्यक छ भने सघिंय तथा प्रदेश सरकारले आवश्यक आर्थिक तथा प्राविधिक सहयोग गर्न पर्ने देखिन्छ।

यस भु-उपयोग योजनाले उल्लेख गरे अनुसार भु-उपयोग मापदन्डलाई कार्यान्वयन गरि बस्ति, सहर, बन, कृषि र भौतिक पुर्वाधार तथा आवशिय क्षेत्रको व्यवस्थापन गर्दा जोखिम न्युनिकरन गर्नु पर्दछ। जलवायु परिबर्तन ग्रहन क्षमता बिकासका लागी नविकरणीय उर्जा प्रयोग तथा वातावरणीय संरक्षण कार्य संचालन गर्न जरुरी छ।

भु-उपयोग योजनाले प्रस्तातिि गरेका भु-उपयोग वर्ग तथा क्षेत्रको उचित कार्यान्वयनका लागी राष्ट्रिय भु-उपयोग ऐन २०७६ ले निर्दिष्ट भु-उपयोग वर्गिकरण तथा व्यवस्थापन एवम अनुगमन सम्बन्धी निर्देशालयको उपयोगी आवश्यक भएकाले गाँउपालिकाले सो सम्बन्धी गाँउपालिका स्तरिय कार्यान्वयन गर्न आवश्यक छ ।

FINAL REPORT

Preparation of Land Capability

Jwalamukh Rural Municipality, Dhading District

Package No.: TSLUMD/CS/QCBS/01/07/2077/078

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EXECUTIVE SUMMARY

Land capability classification of Jwalamukhi Rural Municipality is done on the basis of topography (slope), soil parameters (depth, texture, drainage, pH, OM, N, P, and K), climate, erosion hazard and land management. There are three capability class of land exist in Rural Municipality namely class II, III and IV. Among these class II land is the most suitable for agriculture, forestry and grazing with few limitations of soil and erosion parameters. The total land of Jwalamukhi Rural Municipality is 11289.62 ha and the proportion of non arable land is about 50% of total land area. The Rural Municipality has very limited land 902.71 ha (7.98%) which consists of capability Class II and this land has the potential for the diversified agricultural crops cultivation, vegetables, fruits and forestry usages with no limitations, requiring minimum management inputs. The class III land present in the Rural Municipality is having deficiency of soil rooting depth, drainage deficiency, topography, which is about 52.46% in proportion of the total land area. 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. Class III land is dominated in this Rural Municipality which need careful management and conservation for optimum productivity and uses for agriculture. Terracing is compulsory to control erosion when used for agriculture. The Rural Municipality with class IV land in this Rural Municipality cover with 4464.45 ha and it accounts for 39.55%, which is having topographic restriction for agriculture. 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 (>28^{o} slope) or lie above the altitude limit of agriculture.

1.1 Background and Rationale

The land capability classification is an interpretive groupings made primarily for agricultural purposes (Klingebiel and Montgomery, 1961). This serves as a sound planning tool for guiding landscape level sustainable land management policy. A wise execution of this approach helps to ensure ecological integrity, adequately supply food and fiber and provide cushioning to external shocks and stresses (FRP, 2005).

Land use activities such as clearing forests, practicing subsistence agriculture, intensifying farmland production, or expanding urban centers, have changed the world's landscapes. Although land use practices vary greatly across the world, their ultimate outcome is generally the same: (a) to produce food and fiber, and (b) to acquire natural resources for immediate human needs.

Recent decades Nepal have experienced a trend of rapid urbanizations and the fertile agricultural land being converted into settlements or infrastructure development. The economic and social lifestyles of most of the Nepalese people are intimately related to land resources. Haphazard use of land resources and faulty land use plans have decreased the land productivity due to the depletion of natural resources. Hence, land capability classification has become increasingly important task for sound land use planning leading to sustainable land management in Nepal.

Planning is an essential function of rational use of available natural resources for overall development of the nation. FAO (1983) defines land use planning as a systematic assessment of land and water potentials, alternatives for land use and economic and social conditions in order to select and adopt the best land use options. Except sporadic attempts for the urban areas (NLUP, 2007), Nepal has not practiced land use planning for the country as a whole. However, 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 (Rural Municipality) level. The government of Nepal (GoN) has started to look into this problem through the TSLUMD for collecting detail basic information on land, land resources and the social services at local level under the land use act 2076. Until now, Nepal has only regional level database on land use, land system and land capability produced by earlier Land Resource Mapping Project (LRMP, 1986). On the one hand, these regional level data are already over three decades old and on the other hand, they might not be very useful for local level planning.

In the modern era, space science 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 from the field survey even at Rural Municipality level and information derived could be used for developing decision making support systems (DSS).

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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 the keys to more productive and sustainable use of land resources. Stijns (2006) defined ‘land capability classification’ as a technique of determining the most suitable use of any area of land. The purpose of land capability classification systems is to study and record all data relevant to combination of agricultural and conservation measures which would permit the most intensive, sustainable and appropriate use of land without significant degradation of the soil resource.

A systematic grouping of the land requires information on existing soil quality, landforms, climate, land use patterns, irrigation, topography and other aspects of land as well as socio-economic condition of the area. Due to variation in terrain, climate features and human activities, diversities are observed in faunal and floral population and activities. Land capabilities are also affected by the topographic and climatic factors. Greater variation in landforms and soil exists across Nepal. The variability not only poses the problem but also offers enormous opportunities for the development. Increase in population, and industrialization activities as well as increasing disasters in the wake of climatic change always pose threat to the land resources and its management. Therefore, extensive information is needed on land types, land cover and land use for the formulation of proper land management policies and strategies for the sustainable development of a country. A systematic approach to sustainable land resource management through land utilization planning, land use zoning and assessment of land could be an appropriate measure for this purpose.

A great spatial and temporal variability in land capability can, thus, be studied only by the use of technologies that encompass the spatial and temporal properties. Remote Sensing (RS) and Geographic Information System (GIS) are the tools available for analyzing the variation in space and time and help in decision making. In addition an efficient approach to management of resources can be formulated and implemented over short time period.

Realizing this fact, the Ministry of Land Reform and Management of GoN established the NLUP in 2057/058 to generate the necessary database 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 Nepal. It also prepared maps and database for Kirtipur, Madhyapur Thimi and Bhaktapur municipalities at larger scales. Finally, TSLUMD got a mandate to prepare land resource maps of Rural Municipality of Nepal for local level planning through outsourcing modality.

In the context of the above strategies, Hexa International Pvt. Ltd. has been assigned to carry out the Package No.: TSLUMD/CS/QCBS/01/07/2077/078 project entitled Preparation of Rural Municipality level land resource maps, database and reports by the Government of Nepal/Ministry of Land Reform and Management, National Land Use Project in the Fiscal Year 2077/078. The Rural Municipality covered in this Package is of Dhading District of Nepal.

The rationale for the preparation of Rural Municipality level land capability maps by TSLUMD are:

a. Preparation of land capability maps of the Jwalamukhi Rural Municipality for formulating land use planning according to the quality of land in order to identify areas of Agricultural area, Residential area, Commercial area, Industrial area, Forest area, Public service area and other uses.
b. Identification of the residential and other non-agricultural areas according to the capability of land.
c. Promotion of agricultural productivity as per land capability in comparatively advantageous sub-areas.
d. Conservation of natural resources including forest, shrub, rivers and rivulets and wetland in agricultural/non-agricultural areas.

1.2 Objectives of the study

The general objective of this study is to **prepare Rural Municipality level land resource maps** (Present Land Use Map, Soil Map, Land Capability Map, Land Use Zoning Map, and Rural Municipality Profile for Land Use zoning and Superimpose of Cadastral Layers), **database and reports** of the concerned Rural Municipality. The specific objective is to prepare Land Capability Maps, GIS database and Reports for the Jwalamukhi Rural Municipality at 1:10,000 scales.

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 Jwalamukhi Rural Municipality at 1:10,000 scales by analyzing relevant data, maps, field samples and information of soil laboratory test analysis.
c. Design appropriate GIS database logically.
d. Discuss the accuracy, reliability and consistencies of data.
e. Prepare reports describing methodology, existing land capability types and model of GIS database.

1.3 Study Area

Jwalamukhi rural municipality is in mid-western part of the Dhading District in Bagmati Province of Nepal. The rural municipality was formed on 10th March 2017 (2073/11/27) by merging four VDC units i.e. Khari, Dhola, Nepal, Maidi and Chainpur. Administratively, it is divided into seven wards. Politically, the rural municipality is placed under constituency no 2 for federal parliament and 2 (ka) for provincial parliament.

Jwalamukhi municipality shares border with three municipalities each in Dhading and Gorkha District. In the Dhading district, the municipality shares its border with Tripurasundari, Neelkantha and Siddhalek. Additionally, Shahid lakhan, Bhimsen and

Gandaki municipality of Gorkha district are connected to the municipality. Geographically it extends from 84º 44' 3.07" E to 84º 51' 22.92" E and 27º 51' 25.51" N to 27º 58' 52.45" N. The total area of the municipality is 112.90 sq.km with the altitudinal elevation ranging from 333.84 m to 1343.14 m (Figure 1-1). As of census 2011, the population of the municipality is 32922. The total population of this Rural Municipality is 23966 of which male population is 10573 (44.1%) and female population is 13393 (55.9%). The total households are 5730 and the average family size of the Rural Municipality is 4.2.

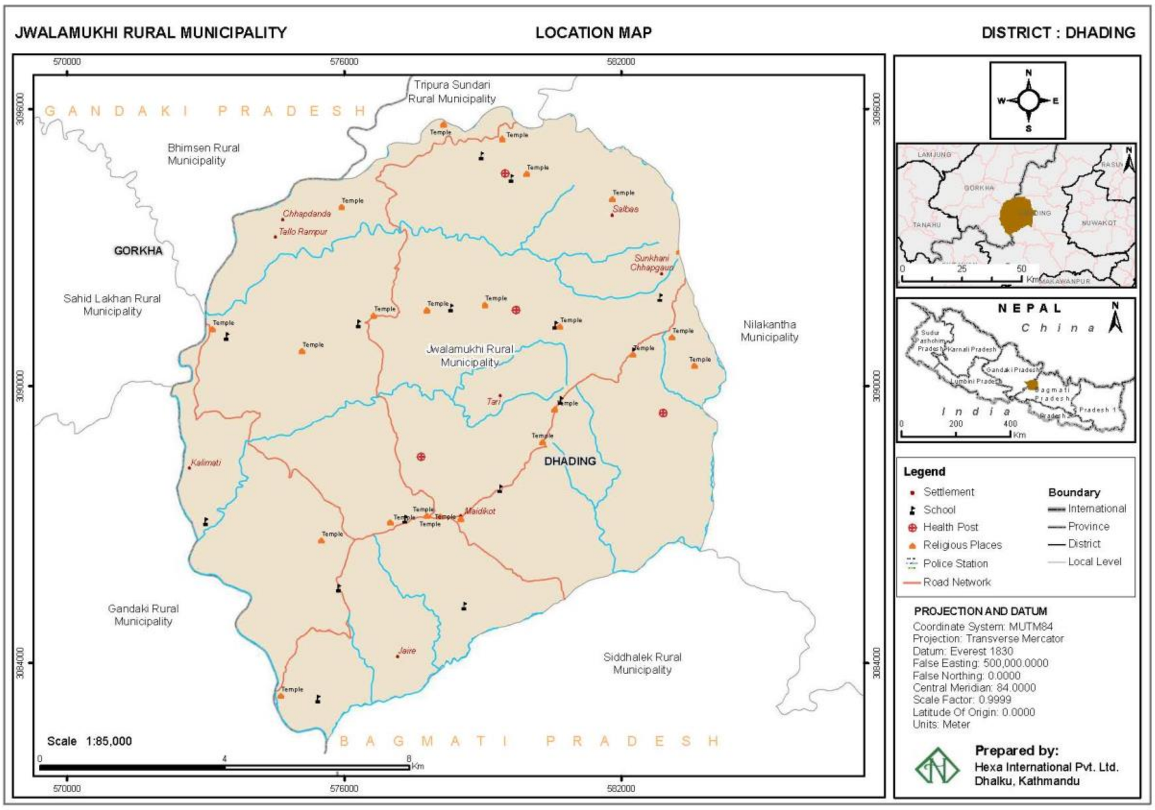

Figure 1-1: Location Map of the Study Area

CHAPTER 2 : CONCEPTUAL BASIS OF LAND CAPABILITY CLASSIFICATION

Land capability assessment provides the ranking of the land on the basis of its ability to sustain a range of agricultural land uses without degradation of land resources on sustainable basis. It was originally developed by United States, Department of Agriculture and has been used in identifying appropriate land usages and required management practices that can sustain its productivity for long run. 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 local level requires assessment of land for agricultural usages considering land suitability, limiting factors for the use of that land and required management and conservation options to conserve land resources for best productivity. This chapter gives a framework for land capability classification at Rural Municipality level. It includes, review of land capability of LRMP, land capability classes, irrigation suitability classes, irrigation suitability sub-class, land capability sub-class, land capability sub-divisions, framework for RURAL MUNICIPALITY level land capability classifications and land capability classification hierarchy.

2.1 Review of Land Capability of 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. Over the span of human history, man has drawn most of his sustenance and much of his fuel, clothing and shelter from the land. Land has been men's habitat and living space. Vink (1975) indicated that, as circumscribed by the earth, the area of what is considered to be land is finite and fixed in place. Land uses are subject to control by people, whose numbers are not fixed, who have many needs, and who move easily. According to Davis (1976), some areas of land have certain characteristic that makes it more useful than others. These include location and suitability of a particular piece of land for specific use

Vink (1975) has defined land use as the ability of human being to manage their ecosystem in order to produce some of his needs. This indicates the ability of man to preserve or destroy land; i.e. man has a full control over land. As Spellerberg (1992) noted, large forest areas have been cleared for agriculture and most remaining forests have sadly been damaged in some way. The consequence is increasing erosion and land degradation. In addition, in western countries, because of industrialization, the invasion of prime agricultural productive land is prominent. These problems bring about the need for classification. Dent (1986) citing Jacks (1946) defines land classification as "the way of grouping of land according to its suitability for producing plants of economic importance".

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 American system of land assessment goes back to 1930s, but it came into effect only after 1961 when a comprehensive book was published (Klingebiel and Montgomery, 1961). The Soil Conservation Service of the US Department of Agriculture evolved 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 is based on a broader range of characteristics than soil properties. Information on slope angle, climate, flood and erosion risk as well as on soil properties is 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 types of land for agriculture usages in identifying land uses and management practices that can minimize soil erosion, especially induced by rainfall (Brady and 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, does take 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 land (Grose, 1999). Land capability classification gives a grading of land for broad scale agricultural uses drainage, sewage disposal including landfill. The factors acting on land classification and its limitation is presented in Figure 2-1.

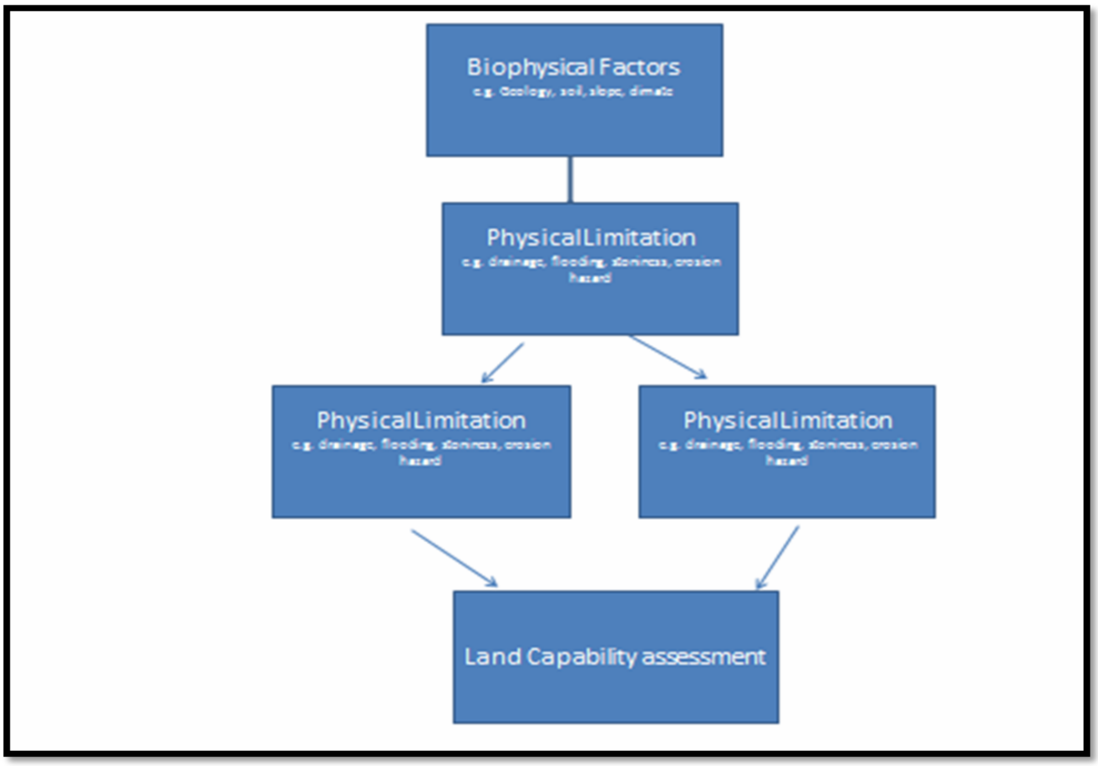

Figure 2-1: Factors Affecting Land Capability Assessment/improve this

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 local 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 Rural Municipality level.

During 1980-1985, 266 Land Capability Maps were made by the LRMP covering 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). LRMP’s 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. Lands are grouped into seven classes and five sub-divisions according to their opportunities, limitations and hazards for different sustainable usages in LRMP land capability classification system. Land suitability for arable agriculture and forestry uses are emphasized; thus the class arrangements shows the decreasing suitability / opportunities for use as well as decreasing intensity of use. There are seven classes assigned as “Class I” to “Class VII”, according to the order of opportunity each class offers. For example, Class I land has the very less limitations for arable agriculture or forestry development usages. The categorization of classes is influenced by the land system and soil units.

The subclasses of land capability are based on distinct temperature regimes according to elevation breaks. The subclasses are categorized into five climatic regime groups’ viz. sub-tropical, warm temperature, cool temperature, alpine, and arctic. These subclasses are further differentiated to represent major climatic moisture regime zones, which are arid, semiarid, sub-humid, humid, and per-humid.

Each land capability unit for Class I and Class II is further designated with irrigation suitability. By applying the United States Bureau of Reclamation, land classification framework, modified for local conditions, the irrigation suitability classification is done. Irrigation suitability classes are further sub-classified on the basis of deficiency in soil, topography or drainage conditions, which attributes to the arability of land.

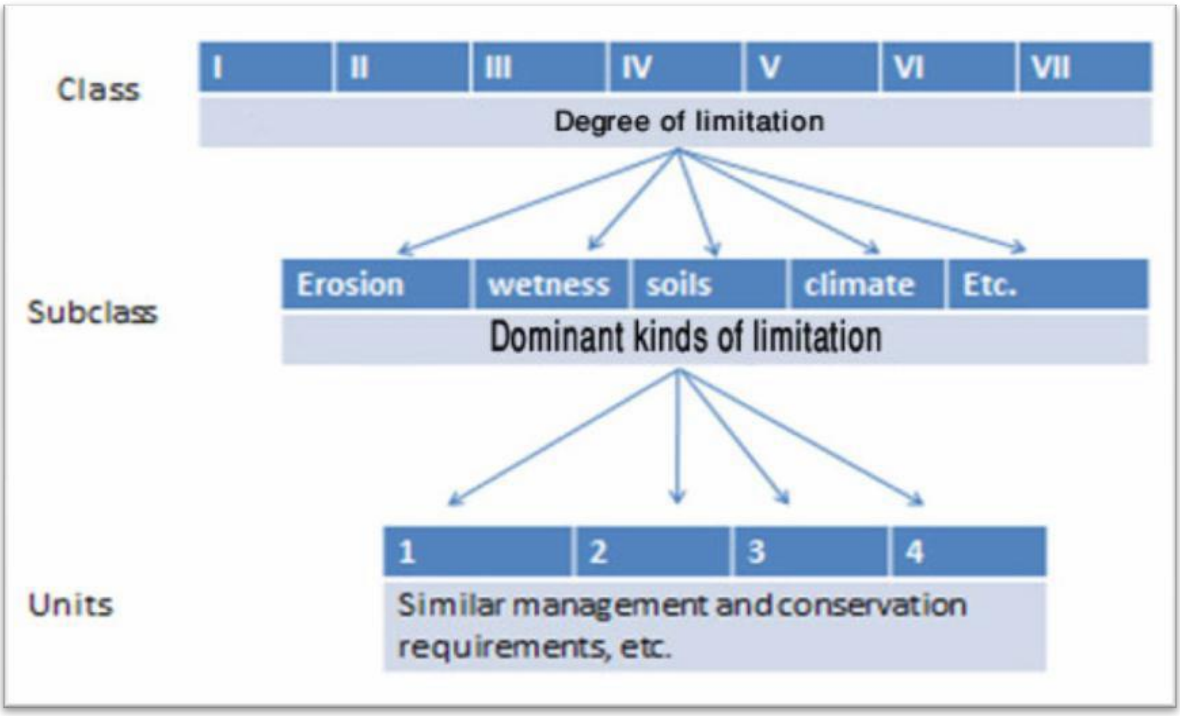

Figure 2-2: Levels of Land Capability Classification System (Grose, 1999)

Table 2-1: LRMP Land Capability classification scheme.

Capability Classes						
Class I	Class II	Class III	Class IV	Class V	Class VI	Class VII

Temperature Regimes	Elevation (m)	Mean Annual Air Temperature (^{o}C)	Dominant Soil Temp. Regimes
Sub tropical	<1000	20 – 24	Hyperthermic
Warm Temperature	1000-2000	15 – 20	Thermic
Cool Temperature	2000-3000	10 – 15	Mesic
Alpine	3000-4000	3 – 10	Cryic-frigid
Arctic	>4500	< 3	Pergelic

Sub-Division (Moisture regime)
Arid
Semiarid
Sub-humid
Humid
Per-humid

Deficiency Subclass
Soil
Topography
Drainage

Irrigation Suitability Class
Class 1
Class 2
Class 1 R
Class 2 R
Class 5
Class 6

A brief description of land capability classes are presented in subsequent subsections.

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). Descriptions of each of seven classes are given below.

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, the erosion mitigation and river embanking 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 percent 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 stratum is deep and well to moderately well drain. No limitations exist in this class for arable agriculture, terracing and contouring many require to control soil erosion and suitable provisions are required for controlling surface runoff and drainage waters. Major 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 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

Land in this class is characterized as moderately to steeply sloping (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 flow and river bank failures.

There are few limitations in this class of land for the forest development, fodder, fuel wood, or timber production. Grazing is restricted due to heavy physical damage to soil by livestock overgrazing.

When land is used for arable agriculture, terracing is compulsory to control erosion. Class III land can be cultivated making terraces, which is 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 manuring. 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 (>30o slopes) to be profitably 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.

The major area 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 meters, 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

Class VI lands are characterized by steep slope (40–50 degrees), severe gully erosion with less than 20 cm 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

Class VII 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, the 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 I Diversified Crops-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 these lands are 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 other 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 high paddy yields at reasonable cost hence highly suitable for paddy production under irrigated condition.

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:

Soil deficiency (s)
Topography deficiency (t)
Drainage deficiency (d)

The combinations of any of the above two indicate deficiencies of irrigation of land capability class.

2.1.4 Land Capability Sub-Classes

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 taken as 5000m as the height increases the climate decrease when altitude increases (Seinfeld and Pandis, 2012). When altitude reaches to 5000m, the mean air and soil temperature reaches to 0oC. Likewise, natural vegetation changes at every 1000 m altitude. At lower altitude the natural vegetation is dominated by Sal forest, Pinus forest is available between

1000 to 2000 m, Quircus forest between 2000 to 3000 m, Betula forest between 3000 to 4000 m and above it there is no forest vegetation. Between 4000 and 4500 m open vegetation is found and above it up to 5000 m Tundra vegetation is available. For agriculture, 1000 m is the limit for the double crops of rice. Rice 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 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 is raised successfully.

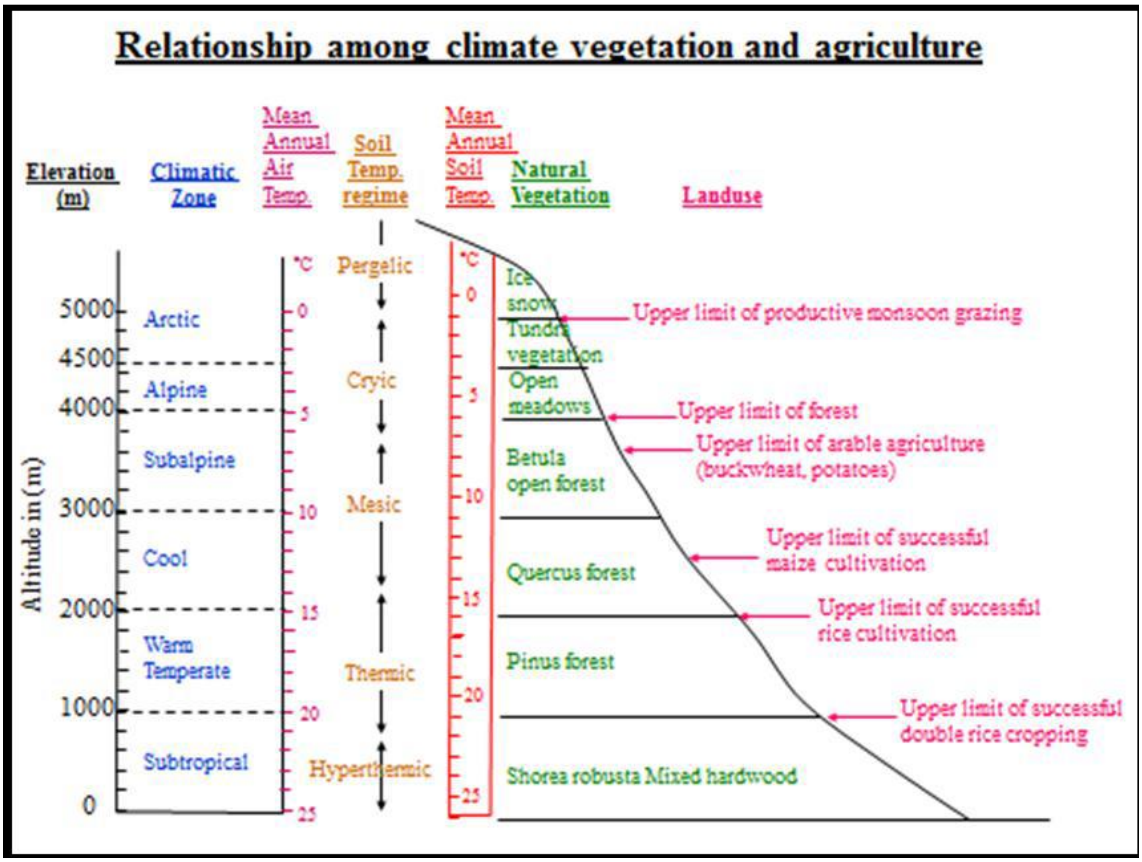

Figure 2-3: The Relation of Climate, Vegetation and Agriculture (LRMP, 1986)

It summarizes associated farming up to 4500 m and above it no vegetation and also limited sheep and yaks could be raised.

Table 2-2: Land Capability Sub-class Climatic Zones

Climatic Zone	Associated Farming Systems
Sub-tropical (altitude <1000 meters)	Intensive farming (multi-crops and livestock)
Warm temperate (altitude 1000-2000	Farming crops and livestock
Cool temperate (altitude 2000-3000	Livestock, fruits, limited crops farming
Alpine (altitude 3000-4000 meters)	Monsoon Grazing, fruit farming and Yak
Arctic (altitude>4500 meters)	None

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.

2.2 Framework for Rural Municipality Level Land Capability Classification

Land capability classification at Rural Municipality 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 was widely used by State Planning Commission of USDA in 1989 (Grose, 1999) and also adapted in Nepal to suite the context of agricultural soil management.

The salient features of this classifications system are as follows:

f. It follows LRMP Land Capability Classifications System
g. Classifications rating is done for geomorphological land unit i.e. land system land type unit considering several natural and bio-physical parameters.
h. The classification system contains three tiers viz. class, subclass, and unit.
i. 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.
j. 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 RURAL MUNICIPALITY, which is the scope of this 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 2.3.

Table 2-3: 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.

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. A brief description of each capability class is presented 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 as described above in Section 2.2.2.

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 (1–5^{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 (5-30^{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^{0} 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 30o 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 lesser 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:

Table 2-4: Unit Code for Sub-class Soil Deficiency

Soil Deficiency	
Soil Depth Deficiency	s
Topography Deficiency	t
Drainage Deficiency	d
Erosion Deficiency	e
Fertility Deficiency	f

CHAPTER 3 : METHODOLOGY

3.1 Methodology Framework

Based on the polygons developed by overlapping land system, geology, present lad use maps were overplayed and the polygons were developed. At the center of each polygons soil sampling points are marked and soil profiled opened. The profile is described as per the format provided by TSLUMD which is based USDA and FAO profile description sheets. All information such as landforms, slope, irrigation availability, land drainage, land use, climate, geology, ground water table, cropping sequence etc. are noted on the forms with the GPS location of the pit. Collected soil samples are sent to accredited laboratory for analysis. N, P, K, texture, pH and organic matter were analyzed and interpreted.

3.2 Land Capability Evaluation Criteria

The following criteria were used to classify the capability classification:

3.2.1 Soil Fertility Criteria:

Soil fertility mainly, Soil Depth, Organic matter, soil pH, drainage class, permeability (based on soil texture as explained by USDA 2016) and Nitrogen, Phosphorous, Potassium, are given certain numerical points. They are pooled and the soil data is multiplied by the obtained value and weighted average is taken to evaluate the fertility.

Multi-Criteria Evaluation (MCE): MCE is a decision support tool aiding a choice to be made between alternatives. The basis for a decision is known as a criterion. In a Multi-Criteria Evaluation, an attempt is made to combine a set of criteria to achieve a single composite index for a decision according to a specific objective. Decision need to be made about what areas are the most capable for specific land use type development. In this analysis, criteria or factors affecting capability of crops 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) and available Potassium (K). Land capability maps were generated from the MCE process in which parameter weight was derived from the expert knowledge given below table 3.1. Since the land that we evaluate falls on flat plain of Terai and no erosional class is mentioned.

Table 3-1: Parameters and given weightage for MCE

SN	Parameters	Weightage	Weight Percentage
1	Soil Depth	4	20
2	pH	3	15
3	OM	3	15
4	Drainage (Texture)	3	15
5	K2O	2	10
6	P2O5	2	10
7	Nitrogen	2	10
8	Permeability	1	5
	Total	**20**	**100**

Soil Deficiency Criteria:

Soil had a general connotation to the depth of the soil. Therefore, this part was considered in depth rating of soil horizon.

Table 3-2: Topsoil Root Depth Rating

Soil Depth (cm)	Category	Suitability	Deficiency	Mapping Symbols
>54	Deep	High Suitability	Low Soil Deficiency	sL
36-54	Moderately Deep	Medium Suitability	Medium Soil Deficiency	sM
18-36	Shallow	Very Low Suitability	High Soil Deficiency	sH
<18	Very Shallow	Very Low Suitability	Very High Soil Deficiency	sVH

3.2.2 Topography Criteria:

Topography had a general connotation similar to relief, but has to be used for the featured disclosed on a contour map-even by some people for all the natural and cultural feature considered collectively that are ordinarily shown on a topographic map. In soil description the more specific terms-relief physiography and land forms or soil slope should be used rather than topography. Therefore, this part was considered in slope rating (Table 3.3).

Table 3-3: Criteria for Slope Evaluation

Description	Dominant Slope (^{0})	Deficiency	Suitability	Mapping Symbol
Flat to gently sloping	1-3	Low Deficiency	High Suitability	tL
Sloping to moderately steep	3-14	Medium Deficiency	Medium Suitability	tM
Steep	14-28	High Deficiency	Low Suitability	tH
Very steep	>28	Very High Deficiency	Very Low Suitability	tVL

3.2.3 Erosion Susceptibility Criteria

Erodibility of soil would have been estimated using USLE formula as erodibility, too, is an inherent quality of a soil and not itself a criterion for erosion phases but in this regards only erosion phases is evaluated. Phases of eroded soil are identified on the basis of the properties of the soil that remains, although the amount of soil lost is estimated and noted. In some places, erosion has changed the taxonomic classification of a soil. Properties related to natural erosion are a part of the definition of a taxon, not bases for erosion phases. Eroded phases are defined so the boundaries on the soil maps separate soil areas of unlike suitability and soil areas of unlike management needs and responses. Guidelines for naming phases of soil that are eroded by water are as follows.

Slightly eroded: Erosion has changed the soil enough to require only slight modification of management from that of the non-eroded soil; potential use and management remain generally the same. Most slightly eroded soils have class 1 erosion. Slightly eroded areas are not distinguished from non-eroded areas in most surveys.

Moderately eroded: Generally, the plow layer consists of a mixture of the original A horizon and the underlying horizons. Most mapped areas of moderately eroded soils have patches in which the plow layer consists wholly of the original A horizon and others in which it consists wholly of underlying horizons. Shallow gullies may be present in some places. Erosion has changed the soil to such an extent that required management or the response to management differs in major respects from that of the uneroded soil. In most moderately eroded soils, ordinary tillage implements reach through the remaining A horizon or well below the depth of the original plowed layer. Most moderately eroded soils have class 2 erosion.

Severely eroded: Severely eroded phases commonly have been eroded to the extent that the plow layer consists the essentially of material from underlying horizons. Patches in which the plow layer is a mixture of the original A horizon and underlying horizons may be present within some delineations. Shallow gullies, or a few deep ones, are common in some places. Erosion has changed the soil so much that:

The eroded soil is suited only to uses significantly less intensive than the uneroded soil, such as use for pasture instead of crops;

The eroded soil needs intensive management immediately or over a long period to be suitable for the same uses as the uneroded soil;

Productivity is reduced significantly; or

Limitations for some major engineering interpretations are greater than on the uneroded soil. Most severely eroded soils have class 3 erosion (Table 3.4).

Table 3-4: Erosion Classes and Deficiency Rating

Erosion	Suitability	Mapping Symbol
Very slight / Slight (splash and sheet)	High Suitability	eL
Moderate (rill erosion)	Medium Suitability	eM
Rill/Gully erosion	Low Suitability	eH
Soil slump/Mass movement	Very Low Suitability	eVH

3.2.4 Surface Drainage Criteria

Natural Drainage Classes: Natural drainage class refers to the frequency and duration of wet periods under conditions similar to those under which the soil developed. Alteration of the water regime by man, either through drainage or irrigation, is not a consideration unless the alterations have significantly changed the morphology of the soil. The classes follow:

Excessively drained- Water is removed very rapidly. The occurrence of internal free water commonly is very rare or very deep. The soils are commonly coarse-textured and have very high hydraulic conductivity or are very shallow.

Somewhat excessively drained: Water is removed from the soil rapidly. Internal free water occurrence commonly is very rare or very deep. The soils are commonly coarse textured and have high saturated hydraulic conductivity or are very shallow.

Well drained: Water is removed from the soil readily but not rapidly. Internal free water occurrence commonly is deep or very deep; annual duration is not specified. Water is available to plants throughout most of the growing season in humid regions. Wetness does not inhibit growth of roots for significant periods during most growing seasons. The soils are mainly free of the deep to redoximorphic features that are related to wetness.

Moderately well drained: Water is removed from the soil somewhat slowly during some periods of the year. Internal free water occurrence commonly is moderately deep and transitory through permanent. The soils are wet for only a short time within the rooting depth during the growing season, but long enough that most mesophytic crops are affected. They commonly have a moderately low or lower saturated hydraulic conductivity in a layer within the upper 1 m, periodically receive high rainfall, or both.

Somewhat poorly drained: Water is removed slowly so that the soil is wet at a shallow depth for significant periods during the growing season. The occurrence of internal free water commonly is shallow to moderately deep and transitory to permanent. Wetness markedly restricts the growth of mesophytic crops, unless artificial drainage is provided. The soils commonly have one or more of the following characteristics: low or very low saturated hydraulic conductivity, a high water table, additional water from seepage, or nearly continuous rainfall.

Poorly drained: Water is removed so slowly that the soil is wet at shallow depths periodically during the growing season or remains wet for long periods. The occurrence of internal free water is shallow or very shallow and common or persistent. Free water is commonly at or near the surface long enough during the growing season so that most mesophytic crops cannot be grown, unless the soil is artificially drained. The soil, however, is not continuously wet directly below plow-depth. Free water at shallow depth is usually present. This water table is commonly the result of low or very low saturated hydraulic conductivity of nearly continuous rainfall, or of a combination of these.

Very poorly drained: Water is removed from the soil so slowly that free water remains at or very near the ground surface during much of the growing season. The occurrence of internal free water is very shallow and persistent or permanent. Unless the soil is artificially drained, most mesophytic crops cannot be grown. The soils are commonly level or depressed and frequently ponded. If rainfall is high or nearly continuous, slope gradients may be greater.

Table 3-5: Land Drainage Rating

Drainage	Deficiency	Suitability	Mapping Symbol
Well drained	Very Low Deficiency	Very High Suitability	dVL
Moderately Well Drained	Low Deficiency	High Suitability	dL
Imperfect Poorly Drained	Medium Deficiency	Medium Suitability	dM
Poorly Drained	High Deficiency	Low Suitability	dH

3.3 Land Capability Evaluation Method

Weighted Composite Score (WCS): Weighted Composite Score (WCS) is a systematic procedure for developing factor weights required for preparing capability map. 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 as described by Malczewski (2000).

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 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*2 + Permeability weightage Value*3

Total fertility level is 64 and minimum is 20

Table 3-6: Land Drainage Rating Drainage Deficiency

Fertility Range	Suitability	Mapping Symbol
>20	Very Low Suitability	fVL
20-36	Low Suitability	fL
36-46	Medium Suitability	fM
46-64	High Suitability	fH

A minor improvement is temporary in nature and lies within the technical capacity of an individual farmer (e.g. fertilizer application). On the other hand, a major improvement is a large, non-recurrent input which causes a permanent change in the land qualities and which lie usually outside the technical capacity of an individual farmer (e.g. a regional drainage scheme) (FAO, 1983).

As presented in earlier sections of methodology, land capability classification is carried out on the basis of established criteria of soil quality, deficiencies, arability, climatic and soil moisture conditions. This chapter presents the results of land capability classification framework applied to Jwalamukhi Rural Municipality of Dhading District.

4.1 Capability Class

The capability classification is done mostly on the basis of land slope, soil rooting depth, soil attributes and other major limitations for crop cultivation. The majority land area of this Rural Municipality has moderate sloppy terrain. Based on these standard criteria of land capability classification, nearly whole land area of this Rural Municipality is classified broadly in 3 classes i.e. class II, Class III and Class IV. The total land area is 11289.62 ha and majority of area (52.46%) falls in Class III with 5-30º slope and are moderately severe limitations that limit the choice of crops and/or require very careful management practices. All lands falling in capability class III need careful management and conservation for optimum productivity and uses for agriculture. Class IV consists of lands with moderate limitations that restrict its use to agriculture due to difficulty in terracing. These lands include areas with greater than 30o slope with soils less than 20 cm deep. These lands are considered as fragile because of extreme erosion hazard and/or poor regeneration potential. (Table 4.1- 4.8, Figure 4.1 and 4.2).

Table 4-1: Land Capability Classes of Jwalamukhi Rural Municipality of Dhading District.

S.N.	Land Capability Sub Class	Area (Ha)	Percent
1	IIAu/2st	574.89	5.092
2	IIAu/5	128.02	1.134
3	IIAu/6	199.80	1.770
4	IIIAu	2035.89	18.033
5	IIIAu/5	1733.68	15.356
6	IIIAu/6	0.05	0.000
7	IIIBh	1612.77	14.285
8	IIIBh/5	540.03	4.783
9	IIIBh/6	0.04	0.000
10	IVAu	1408.95	12.480
11	IVAu/5	3055.39	27.064
12	IVAu/6	0.12	0.001
	Total	**11289.62**	100.00

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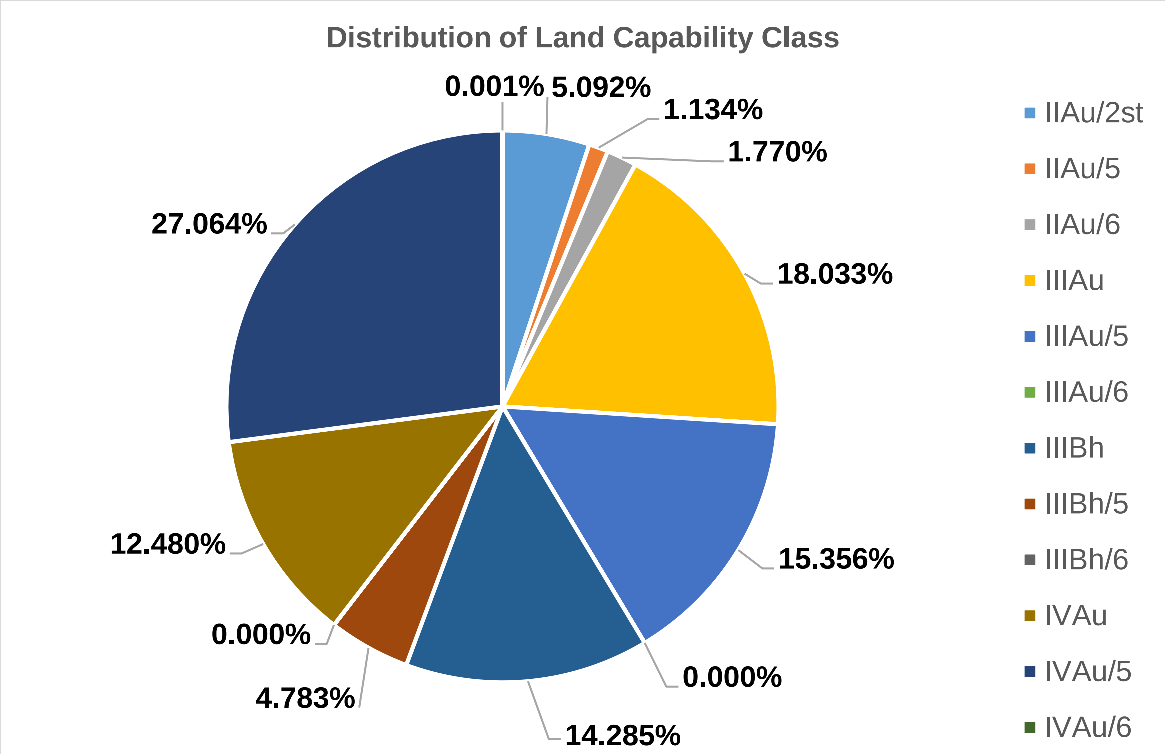

Figure 4-1: Distribution of Land Capability Classes of Jwalamukhi RM of Dhading District.

Table 4-2: Land Capability Classes of Jwalamukhi RM ward number 1 of Dhading District.

Land Capability Class	Area in Sq.m	Area in Hectare	Percentage
IIAu/2st	300352.5	30.03525	2.294445
IIAu/5	27331.86	2.733186	0.208793
IIAu/6	543048.9	54.30489	4.148445
IIIAu	311393.8	31.13938	2.378791
IIIAu/5	122644.6	12.26446	0.936903
IIIBh	496466	49.6466	3.79259
IIIBh/5	212854.7	21.28547	1.626034
IVAu	3757338	375.7338	28.70296
IVAu/5	7318879	731.8879	55.91019
IVAu/6	111.5485	0.011155	0.000852
Grand Total	**13090420**	**1309.042**	**100**

Table 4-3: Land Capability Classes of Jwalamukhi Rural Municipality ward number 2 of Dhading District

Land Capability Class	Area in Sq.m	Area in Hectare	Percentage
IIAu/6	58110.56	5.811056	0.405567
IIIAu	3670785	367.0785	25.61926
IIIAu/5	1344007	134.4007	9.380136
IIIAu/6	2.86848	0.000287	2E-05
IIIBh	2099433	209.9433	14.65243
IIIBh/5	713290.5	71.32905	4.978219
IVAu	2023964	202.3964	14.12571
IVAu/5	4418464	441.8464	30.83748
IVAu/6	169.2678	0.016927	0.001181
Grand Total	**14328227**	**1432.823**	**100**

Table 4-4: Land Capability Classes of Jwalamukhi RM ward number 3 of Dhading District

Land Capability Class	Area in Sq.m	Area in Hectare	Percentage
IIAu/2st	224976.2	22.49762	1.751681
IIAu/5	18981.94	1.898194	0.147795
IIAu/6	46220.36	4.622036	0.359875
IIIAu	2766342	276.6342	21.53894
IIIAu/5	1592564	159.2564	12.39982
IIIAu/6	24.19409	0.002419	0.000188
IIIBh	4854066	485.4066	37.79411
IIIBh/5	2053222	205.3222	15.98653
IIIBh/6	13.59732	0.00136	0.000106
IVAu	505253.2	50.52532	3.933938
IVAu/5	781765.2	78.17652	6.086881
IVAu/6	17.27406	0.001727	0.000134
Grand Total	**12843445**	**1284.345**	**100**

Table 4-5: Land Capability Classes of Jwalamukhi RM ward number 4 of Dhading District

Land Capability Class	Area in Sq.m	Area in Hectare	Percentage
IIAu/2st	2386601	238.6601	12.97906
IIAu/5	360282.2	36.02822	1.959324
IIAu/6	164693.5	16.46935	0.895653
IIIAu	3269615	326.9615	17.78116
IIIAu/5	2344030	234.403	12.74755
IIIAu/6	36.83041	0.003683	0.0002
IIIBh	4465869	446.5869	24.28675
IIIBh/5	1388269	138.8269	7.549828
IIIBh/6	285.7262	0.028573	0.001554
IVAu	1414849	141.4849	7.694379
IVAu/5	2593523	259.3523	14.10436
IVAu/6	31.20767	0.003121	0.00017
Grand Total	**18388085**	**1838.809**	**100**

Table 4-6: Land Capability Classes of Jwalamukhi Rural Municipality ward number 5 of Dhading District

Land Capability Class	Area in Sq.m	Area in Hectare	Percentage
IIAu/2st	1062299	106.2299	3.514836
IIAu/5	534376.6	53.43766	1.768097
IIAu/6	462905.7	46.29057	1.53162
IIIAu	6121931	612.1931	20.25569
IIIAu/5	4173192	417.3192	13.80788
IIIAu/6	115.0133	0.011501	0.000381
IIIBh	394150.5	39.41505	1.304129
IIIBh/5	120156.3	12.01563	0.397562
IIIBh/6	3.642006	0.000364	1.21E-05
IVAu	4525335	452.5335	14.97302
IVAu/5	12828225	1282.823	42.44486
IVAu/6	581.2734	0.058127	0.001923
Grand Total	**30223271**	**3022.327**	**100**

Table 4-7: Land Capability Classes of Galchi RM ward number 6 of Dhading District

Land Capability Class	Area in Sq.m	Area in Hectare	Percentage
IIAu/2st	378809	37.8809	4.671945
IIAu/5	69465.07	6.946507	0.85673
IIAu/6	37178.18	3.717818	0.458528
IIIAu	1974.414	0.197441	0.024351
IIIAu/5	220637.8	22.06378	2.721181
IIIBh	3810114	381.0114	46.99108
IIIBh/5	903180.8	90.31808	11.13915
IIIBh/6	88.56723	0.008857	0.001092
IVAu	961682.5	96.16825	11.86067
IVAu/5	1724929	172.4929	21.27398
IVAu/6	105.0611	0.010506	0.001296
Grand Total	**8108164**	**810.8164**	**100**

Table 4-8: Land Capability Classes of Galchi RM ward number 7 of Dhading District

Land Capability Class	Area in Sq.m	Area in Hectare	Percentage
IIAu/2st	1395878	139.5878	8.7748
IIAu/5	269779	26.9779	1.695891
IIAu/6	685821.9	68.58219	4.31123
IIIAu	4216880	421.688	26.50825
IIIAu/5	7539708	753.9708	47.39629
IIIAu/6	282.2252	0.028223	0.001774
IIIBh	7573.416	0.757342	0.047608
IIIBh/5	9362.104	0.93621	0.058852
IVAu	901060.7	90.10607	5.664268
IVAu/5	881294	88.1294	5.540011

IVAu/6	163.6415	0.016364	0.001029
Grand Total	**15907804**	**1590.78**	**100**

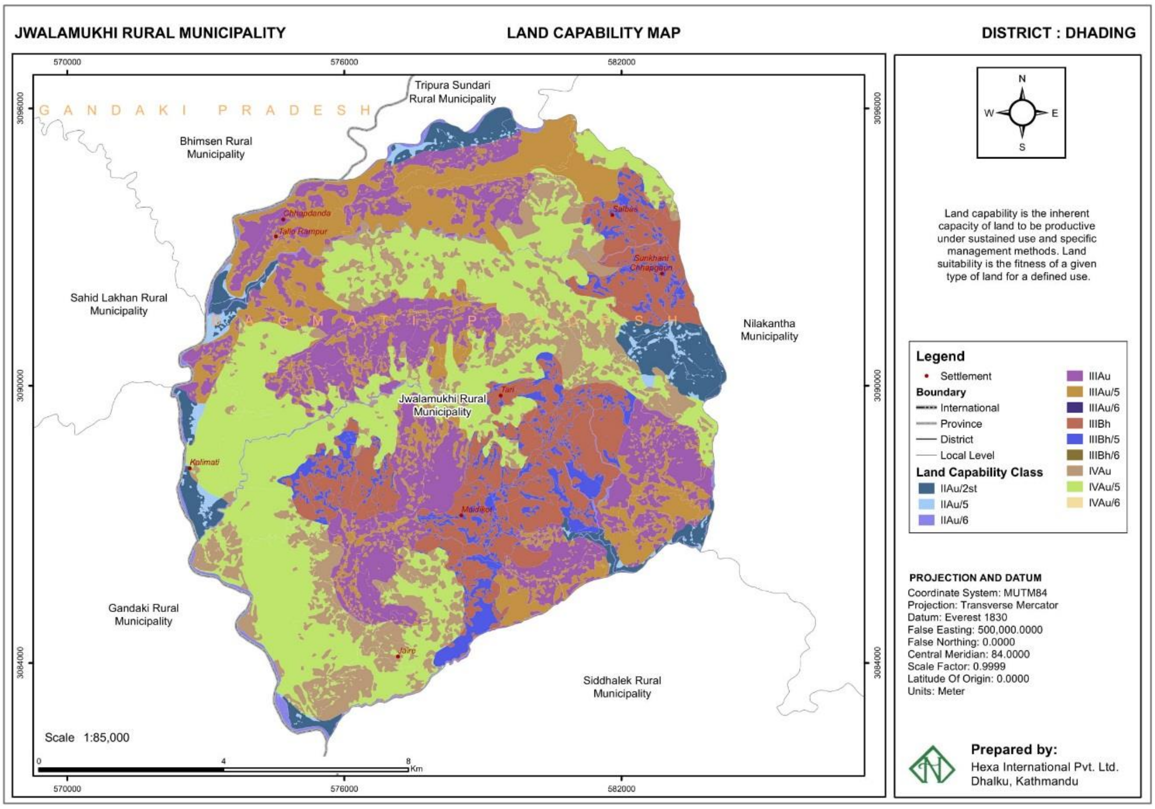

Figure 4-2: Land Capability Map of Jwalamukhi Rural Municipality

IIAu/2st: Subtropical areas, Subhumid moisture regime, Diversified Crops can be grown. It is moderately suitable for arable agriculture intensive farming (multi-crops and livestock) under the irrigation and soil management with suitable soil conservation practices. It cooupies 5.01% of the total land area.

IIAu/5: Subtropical areas, Subhumid moisture regime, Diversified Crops can be grown. It is non-arable and generally subjected to seasonal inundation. It occupies 1.13% of the total area of land of Rural Municipality.

IIAu/6: Subtropical areas, Subhumid moisture regime, Diversified Crops can be grown. It is non-arable due to shallow or impervious to root or water. It covers 1.77% of total land area.

IIIAu: Subtropical areas, Subhumid moisture regime. It is moderately suitable for arable agriculture under soil conservation practices. It is suitable for arable agriculture intensive farming (multi-crops and livestock) under the irrigation management. It occupies 18.03% of total area of Rural Municipality.

IIIAu/5: Subtropical areas, Subhumid moisture regime. It is moderately suitable for arable agriculture under soil conservation practices. It is non arable and generally subjected to seasonal inundation. It covers 15.356 % of total land.

IIIAu/6: Subtropical areas, Subhumid moisture regime. It is moderately suitable for arable agriculture under soil conservation practices. It is non arable due to complex topography, shallow or impervious to root or water. It covers negligible portion of land.

IIIBh: Warm temperate, Humid, Moderately to Steeply sloppy, Best for terrace cultivation, suitable for irrigated farming and are capable of producing sustained and relatively high yields of climatically suited upland crops, but sometimes not arable due to severe limitation of topography. It covers about 14.29% land of total Rural Municipality.

IIIBh/5: Warm temperate, Humid, Moderately to Steeply sloppy. These lands are generally considered as non-arable and subjected to seasonal inundation hence suitability rating is very low for successful crop production. The land in this class can be used for rough seasonal grazing under special management practices. It covers 4.79% portion of land.

IIIBh/6: Warm temperate, Humid, Moderately to Steeply sloppy. These lands are generally considered as non-arable hence suitability rating is very low for successful crop production, it may be could be due to complex topography. It covers negligible portion of land.

IVAu: Warm temperate, sub humid. Too steep mostly suitable for forestry but topographic and climatic severity. It covers 12.48% of land.

IVAu/5: Warm temperate, sub humid. Too steep mostly suitable for forestry but topographic and climatic severity. It is non arable. It covers maximum portion of area of the Rural Municipality i.e. 27.06%.

IVAu/6: Warm temperate, sub humid. Too steep mostly suitable for forestry but topographic and climatic severity. It is non-arable due to steep slope. It covers negligible portion of land.

4.2 Land Capability GIS Database

The land capability GIS data is stored in vector geo-database and “shape” file formats as a single land unit class which contains a hierarchy of sub-classes that are defined in various attribute fields of vector GIS database. Table 4.2 represents the data model of GIS database.

IIAu/2st: Subtropical areas, Subhumid moisture regime, Diversified Crops can be grown. It is moderately suitable for arable agriculture intensive farming (multi-crops and livestock) under the irrigation and soil management with suitable soil conservation practices. It cooupies 5.01% of the total land area.

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Table 4-9 : Land Capability GIS Attribute Data

S.N.	Attribute	Data Type	Description	Remarks
1	FID	Feature Id	Feature	
2	SHAPE	Geometry	Geometric Object type	
3	OBJECTID	Long	Unique Object ID	
4	CAPABILITY	String	Land Capability Class	
5	ARABILITY	String	Arability Class	
6	AREA	Double	Area in m^2	
7	AREA_HA	Double	Area covered by land capability land unit in ha	
8	SYMB_NUME	Integer	Land Capability mapping symbol	
9	SYMB_DINO	String	Land Capability deficiency mapping symbol	
10	DEFICIENCY	String	Deficiency in land unit (soil, topography,)	
11	CLIMATE	String	Climate Regime	
12	MOISTURE	String	Moisture Regime	
13	ASSO_LS	String	Associated land system	
14	SLOPE_CLS	String	Associated slope class of terrain	
15	SLOPE_DEG	String	Slope description	
16	SOIL_TXT	String	Associated soil texture class	
17	DRAINAGE	String	Associated soil drainage pattern	
18	PH	Integer	Associated soil pH value	
19	PH_RATE	String	Associated soil pH rating	
20	OM_PER	String	Associated soil organic matter percentage	
21	OM_RATE	String	Associated soil organic matter rating	
22	TN_PER	String	Associated soil total nitrogen percentage	
23	TN_RATE	String	Associated soil total nitrogen rating	
24	P_2O_5_ KGHA	String	Associated soil available P_2O_5 in kg/ha	
25	P_2O_5_ RATE	String	Associated soil available P_2O_5 rating	
26	K_2O_ KGHA	String	Associated soil available K_2O in kg/ha	
27	K_2O_ RATE	String	Associated soil available K_2O rating	
28	FERTILITY	String	Associated soil fertility value (based on different soil parameters)	
29	FER_RATING	String	Associated soil fertility rating	
30	EROSION	String	Erosion susceptibility rating	
31	SOLUM_DPTH	String	Top soil depth in cm	
32	TOPO_DEF	String	Terrain slope type	

S.N.	Attribute	Data Type	Description	Remarks
33	DRAIN_DEF	String	Surface drainage problem	
34	PERMIABILI	String	Associated soil permeability	
35	SOIL_DEF	String	Associated soil deficiency symbol	
36	ERO_DEF	String	Associated erosion deficiency symbol	
37	TERRA_DEF	String	Associated terrain deficiency symbol	
38	DRAINAGE_D	String	Associated surface drainage deficiency symbol	
39	Class	Short	Subtype for Top Level of Land Capability	
40	Land Cap_Subclass	String	Land Capability Sub Class	
41	Land Cap_Subdiv	String	Land Capability Sub division	
42	Land capability Class	String	Land Capability of each mapping unit	

CHAPTER 5 : CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This report presents a land capability classification of Jwalamukhi Rural Municipality, Dhading district, Nepal. The study was based on USDA Land Capability Classification and also incorporated the modifications received from TSLUMD to suit the local conditions. Bio-physical and topographic parameters combined with detailed soils data were used to derive soil mapping units. Part of the major process involved the use of GIS and RS tools for an efficient and reliable data collection, spatial analysis and map outputs generation. Fertility status representing mapping units were derived using laboratory analysis of soil samples. These included edaphic properties of soils such as soil texture, soil depth, drainage and fertility properties such as organic matter content, soil acidity, total N, available P2O5, and K2O. Crop lands were put to varied capability classes but Class I remained nonexistent. Of the total area (11289.62 ha), Class II comprise 7.98 % and III comprise 52.46 percent, suited to mostly upland crops with limited choices for diversification. Topographic deficiency and altitudinal limits are major constraints.

There was no class I land Class. The total land of the Jwalamukhi Nagarpalika is 11289.62 ha out of which about 50% land is non arable and generally subjected to seasonal inundation. The area covered by arable land is about 50 % of the total area. There is about 902.71 hectare land under class II which is suitable for agriculture crop production but has some degree of limitation. Class IIAu/2st occupied about 5.092% of total area which is suitable for agriculture but requires soil conservation practices like terracing, strip cropping, etc. Class IIAu/5 and IIAu/6 covers about 2.90 % area which can be used for farming with moderate conservation but irrigation is major problems in this class. The land category with IIIAu/5 and IIIAu/6 covered 15.36 % area suitable for different crop and livestock production but due to slope, erosion is frequent and it requires moderate conservation practices. About 18.03% area is under the class IIIAu where farming and livestock production is suitable erosion is frequent due to slope and requires soil conservation practices. Class IVAu, IVAu/5 and IVAu/6 (39.55 %) have very severe limitations that reduce the choice of plants or that require very careful management. So, special soil conservation measures should be adopted. These lands are suitable for forestry uses and require forest cover in the slopes to minimize erosion. Classifying land according to its capability or suitability helps to land users and planners to direct their resources to particular type of production in the most suitable area and protect the highly suitable land for crop production from encroachment by non-agricultural practices. Depending on the socio-economic and environmental consequences that can result from the introduction of new practices, suitability classes can provide policy makers with information to make best choice among alternatives.

5.2 Recommendation

The land capability classification of the Jwalamukhi Gaunpalika is necessary to implement for sustainable land management. It helps to develop the local strategy of land evaluation which is helpful to formulate national land policy. It is helpful in resource mapping of the study area in farm level. So, this type study should be done in every local units of the country. In this Gaunpalika there is no land with less intensity of erosion. Major portion of the land have moderate limitation for cultivation. So, commercial cultivation should be done carefully with adoption of special soil conservation practices. In class III type land forest and vegetation should be promoted or agro-forestry system is necessary to promoted. Class IV land should be used to develop greenery.

Table 5-1: Potential Crops in Jwalamukhi Rural Municipality

Ward No 1

Land Capability Class	Existing Dominant Cropping Pattern	Proposed cropping system/crops	Proposed Fruit Orchard	Area in Hectare
IIAu/2st	Rice-Wheat-Maize Rice- Maize, Mustard/Potato	Rice-Mustard-Potato/Maize / Winter vegetables	Orange, Lemon, Peach, Papaya	30.03525
IIAu/5				2.733186
IIAu/6				54.30489
IIIAu	Maize – Finger millet, Maize-Finger millet-Barley	Millets-Legume-Maize Rice-Potato/Winter vegetables-Maize	Avocado. Orange, Lemon, Peach	31.13938
IIIAu/5				12.26446
IIIBh	Finger Millet-Maize Rice-wheat-Mustard Maize-Potato-Millet	Rice-Mustard-Potato/Maize	Orange, Lemon, Peach	49.6466
IIIBh/5				21.28547
IVAu	Maize - Potato	Citrus based	Lemon, Nibuwa, Guava, Peach	375.7338
IVAu/5				731.8879
IVAu/6				0.011155
			Grand Total	**1309.042**

Ward No 2

Land Capability Class	Existing Dominant Cropping Pattern	Proposed cropping system/crops	Proposed Fruit Orchard	Area in Hectare
IIAu/6				5.811056
IIIAu	Maize – Finger millet, Maize-Finger millet-Barley	Millets-Legume-Maize Rice-Potato/Winter vegetables-Maize	Avocado. Orange, Lemon, Peach	367.0785
IIIAu/5				134.4007
IIIAu/6				0.000287
IIIBh	Finger Millet-Maize Rice-wheat-Mustard Maize-Potato-Millet	Rice-Mustard-Potato/Maize	Orange, Lemon, Peach	209.9433
IIIBh/5				71.32905
IVAu	Maize - Potato	Citrus based	Lemon, Nibuwa, Guava, Peach	202.3964
IVAu/5				441.8464
IVAu/6				0.016927
			Grand Total	**1432.823**

Ward no 3

Land Capability Class	Existing Dominant Cropping Pattern	Proposed cropping system/crops	Proposed Fruit Orchard	Area in Hectare
IIAu/2st	Rice-Wheat-Maize Rice- Maize, Mustard/Potato	Rice-Mustard-Potato/Maize / Winter vegetables	Orange, Lemon, Peach, Papaya	22.49762
IIAu/5				1.898194
IIAu/6				4.622036
IIIAu	Maize – Finger millet, Maize-Finger millet-Barley	Millets-Legume-Maize Rice-Potato/Winter vegetables-Maize	Avocado. Orange, Lemon, Peach	276.6342
IIIAu/5				159.2564
IIIAu/6				0.002419
IIIBh	Finger Millet-Maize Rice-wheat-Mustard Maize-Potato-Millet	Rice-Mustard-Potato/Maize	Orange, Lemon, Peach	485.4066
IIIBh/5				205.3222
IIIBh/6				0.00136
IVAu	Maize - Potato	Citrus based	Lemon, Nibuwa, Guava, Peach	50.52532
IVAu/5				78.17652
IVAu/6				0.001727
			Grand Total	**1284.345**

Ward No.4

Land Capability Class	Existing Dominant Cropping Pattern	Proposed cropping system/crops	Proposed Fruit Orchard	Area in Hectare
IIAu/2st	Rice-Wheat-Maize Rice- Maize, Mustard/Potato	Rice-Mustard-Potato/Maize / Winter vegetables	Orange, Lemon, Peach, Papaya	238.6601
IIAu/5				36.02822
IIAu/6				16.46935
IIIAu	Maize – Finger millet, Maize-Finger millet-Barley	Millets-Legume-Maize Rice-Potato/Winter vegetables-Maize	Avocado. Orange, Lemon, Peach	326.9615
IIIAu/5				234.403
IIIAu/6				0.003683
IIIBh	Finger Millet-Maize Rice-wheat-Mustard Maize-Potato-Millet	Rice-Mustard-Potato/Maize	Orange, Lemon, Peach	446.5869
IIIBh/5				138.8269
IIIBh/6				0.028573
IVAu	Maize - Potato	Citrus based	Lemon, Nibuwa, Guava, Peach	141.4849
IVAu/5				259.3523
IVAu/6				0.003121
			Grand Total	**1838.809**

Ward No. 5

Land Capability Class	Existing Dominant Cropping Pattern	Proposed cropping system/crops	Proposed Fruit Orchard	Area in Hectare
IIAu/2st	Rice-Wheat-Maize Rice- Maize, Mustard/Potato	Rice-Mustard-Potato/Maize / Winter vegetables	Orange, Lemon, Peach, Papaya	106.2299
IIAu/5				53.43766
IIAu/6				46.29057
IIIAu	Maize – Finger millet, Maize-Finger millet-Barley	Millets-Legume-Maize Rice-Potato/Winter vegetables-Maize	Avocado. Orange, Lemon, Peach	612.1931
IIIAu/5				417.3192
IIIAu/6				0.011501
IIIBh	Finger Millet-Maize Rice-wheat-Mustard Maize-Potato-Millet	Rice-Mustard-Potato/Maize	Orange, Lemon, Peach	39.41505
IIIBh/5				12.01563
IIIBh/6				0.000364
IVAu	Maize - Potato	Citrus based	Lemon, Nibuwa, Guava, Peach	452.5335
IVAu/5				1282.823
IVAu/6				0.058127
			Grand Total	**3022.327**

Ward No.6

Land Capability Class	Existing Dominant Cropping Pattern	Proposed cropping system/crops	Proposed Fruit Orchard	Area in Hectare
IIAu/2st	Rice-Wheat-Maize Rice- Maize, Mustard/Potato	Rice-Mustard-Potato/Maize / Winter vegetables	Orange, Lemon, Peach, Papaya	37.8809
IIAu/5				6.946507
IIAu/6				3.717818
IIIAu	Maize – Finger millet, Maize-Finger millet-Barley	Millets-Legume-Maize Rice-Potato/Winter vegetables-Maize	Avocado. Orange, Lemon, Peach	0.197441
IIIAu/5				22.06378
IIIBh	Finger Millet-Maize Rice-wheat-Mustard Maize-Potato-Millet	Rice-Mustard-Potato/Maize	Orange, Lemon, Peach	381.0114
IIIBh/5				90.31808
IIIBh/6				0.008857
IVAu	Maize - Potato	Citrus based	Lemon, Nibuwa, Guava, Peach	96.16825
IVAu/5				172.4929
IVAu/6				0.010506
			Grand Total	**810.8164**

Ward No.7

Land Capability Class	Existing Dominant Cropping Pattern	Proposed cropping system/crops	Proposed Fruit Orchard	Area in Hectare
IIAu/2st	Rice-Wheat-Maize Rice- Maize, Mustard/Potato	Rice-Mustard-Potato/Maize / Winter vegetables	Orange, Lemon, Peach, Papaya	139.5878
IIAu/5				26.9779
IIAu/6				68.58219
IIIAu	Maize – Finger millet, Maize-Finger millet-Barley	Millets-Legume-Maize Rice-Potato/Winter vegetables-Maize	Avocado. Orange, Lemon, Peach	421.688
IIIAu/5				753.9708
IIIAu/6				0.028223
IIIBh	Finger Millet-Maize Rice-wheat-Mustard Maize-Potato-Millet	Rice-Mustard-Potato/Maize	Orange, Lemon, Peach	0.757342
IIIBh/5				0.93621
IVAu	Maize - Potato	Citrus based	Lemon, Nibuwa, Guava, Peach	90.10607
IVAu/5				88.1294
IVAu/6				0.016364
			Grand Total	**1590.78**

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FINAL REPORT

Risk Layer

Jwalamukhi Rural Municipality, Dhading District

Package No.: TSLUMD/CS/QCBS/01/07/2077/078

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1.1 Background and Rationale

Background Social, environmental and economic costs associated with the use and development of lands are greatly impacted by the natural hazards. Hazard and risk is always important component in land use planning because it plays key role to demarcate the safe and un-safe areas for settlements and any development programs. The land units are suitable for cultivation which may not be suitable from hazard and risk point of view.

Risk assessments helps to identify risk zone, prioritize hazards and control measures, create awareness of hazards and risk, and finally establish proper land use zoning regarding risk and hazard. It is the phenomenon of determination of quantitative or qualitative estimation of risk related to a well-define situation and a recognized threat. It consists of an objective evaluation of risk in which assumptions and uncertainties clearly considered and presented. It is believed to be increased very rapidly mainly due to the growth in population, especially in urban and urbanizing areas. Another major factor for the increasing risk is the lack of a favourable policy and legal environment commensurate with the present-day situation, needs, opportunities and resource availability.

As the availability of the land resources is limited and their utility for human beings needs some proper management to use it wisely. Land use planning is newly emerged disaster reduction methods that guides to select the best land meeting the peoples need and improve the quality of life in urban areas. The land use planning has numerous benefits and their exercises help to improve the quality of life in both urban and rural areas, protect the agricultural land, establish appropriate buffer zone for risk assessment, flood plain management, improve the overall management of different facilities and seek to mitigate the risks and vulnerability from various geological factors and other hazards. There are number of resources that need to be considered during risk assessment and they are rivers, glaciers, human settlement, ponds, lakes, industries, petrol pumps, high tension line, forests, topography, geological factors etc. The risk assessment task is one of most challenging issues that need renegotiation before coming to certain goals. Before the land use planning, assessment of risk and hazard are the inevitable task. The assessment of risk and hazard help government policies for proper management of land keeping in regard of any serious damage to the natural resources and environment. Hazard and risk are described as:

Hazard: Hazard is the potentially damaging phenomena in particular space and time. The phenomena hazard produces the undesirable consequences and it is the source of risk.

Risk: A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability of a phenomenon of a given magnitude times the consequences.

Knowledge of the relationships of development, land use and disaster risks provide planners a deeper understanding of what drives people to locate themselves in high risk areas (RCC 2011). Generalized procedure of risk assessment is shown in Figure 1-1 and through the use of hazard and risk information, land use planners would be able to:

- To identify areas that are of high risk from impacts of hazard
- that need lessening of effects of hazardous events
- To identify areas for restricting location of human settlements and choosing suitable economic activities.
- To understand the area of land actually available for development (considering development is not allowed in areas prone to natural hazards)
- To provide guidance in formulating suitable risk reduction policies and zoning regulations.

Figure 1-1: Generalized Procedure of Risk Assessment.

1.2 Objectives of the Study

The objectives of hazard and risk study in Municipality/Rural Municipality level were:

- To assess the source of risk and their situations
- To prepare the possible hazard and risk layers

1.3 Study Area

Jwalamukhi Rural Municipality is in mid-western part of the Dhading District in Bagmati Province of Nepal (Figure 1-2). The rural municipality was formed on 10th March 2017 (2073/11/27) by merging four VDC units i.e. Khari, Dhola, Nepal, Maidi and Chainpur. Administratively, it is divided into seven wards. Politically, the rural municipality is placed under constituency No. 2 for federal parliament and 2 (ka) for provincial parliament.

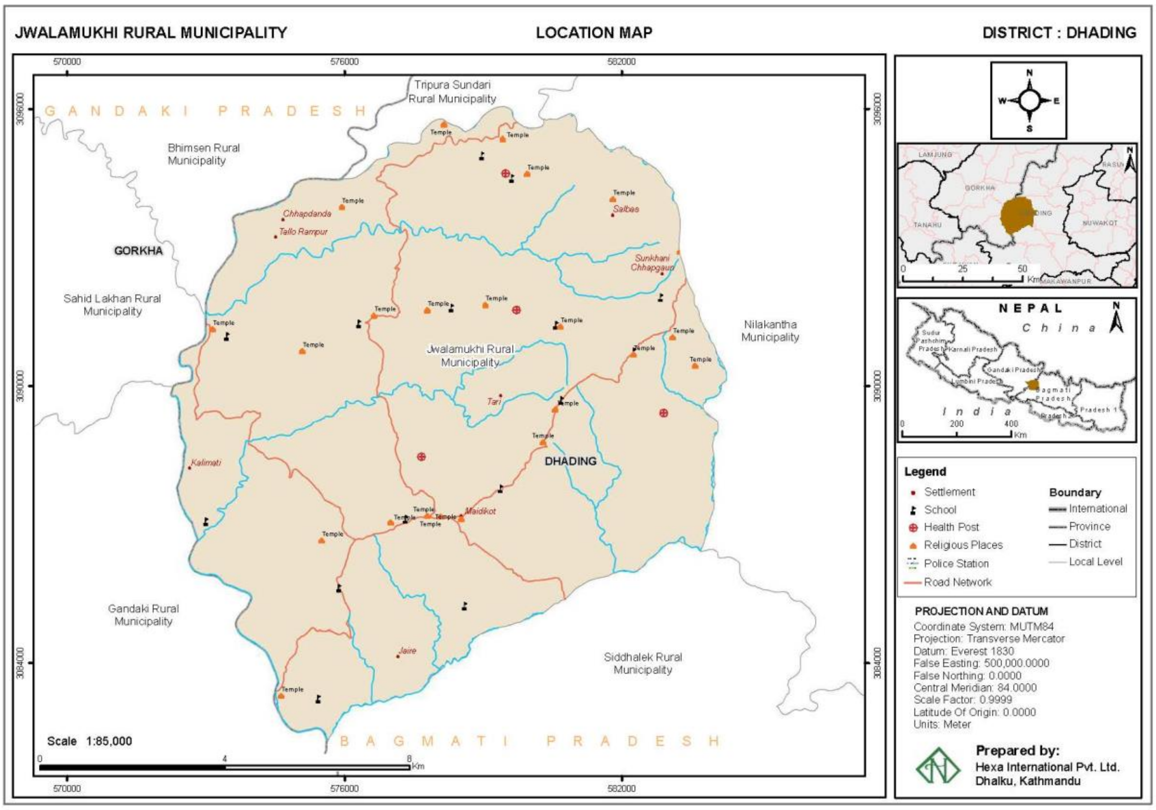


Figure 1-3: Location Map of of the Study Area.

This Rural Municipality shares border with three municipalities each in Dhading and Gorkha District. In the Dhading district, the rural municipality shares its border with Tripurasundari, Neelkantha and Siddhalek. Additionally, Shahid lakhan, Bhimsen and Gandaki municipality of Gorkha district are connected to the rural municipality. Geographically it extends from 84º44'3" to 84º51'22" E longitudes and 27º51'25" to 27º58'52" N latitudes. The total area of the rural municipality is 112.90 sq.km with the altitudinal elevation ranging from 333 to 1343 m.

As of census 2011, the population of the rural municipality is 32922. The total population of this Rural Municipality is 23966 of which male population is 10573 (44.1%) and female population is 13393 (55.9%). The total households are 5730 and the average family size of the Rural Municipality is 4.2.

CHAPTER 2 : CONCEPTUAL BASIS OF RISK MAPPING

2.1 Risk and its relation to Land Use Zoning

Hazard and risk mapping can increase community resilience against the impacts of natural hazards and allows decision maker to strategically consider the hazard when planning settlements, and set policy on acceptable risk and controls that increase the ability of individuals and the community to resist and recover from a hazardous events. Moreover, it is a process for land-use recovery that requires consideration of a range of options such as repairing, reconstructing or relocating existing at-risk land-uses before a natural hazard event occurs.

A planned outline of land use and its strict implementation will ensure the appropriate management of hazard and reduction in risk and concomitant losses. At present, the risk mapping and land use zoning are closely related as they both involves a number of components which includes potential hazard and related information, land use planning practice and a prescription of disaster risk reduction strategies, emergency management considerations and developing a rational risk-sensitive land use plan to guide the development in future. The existing practice of occupying the areas close to river channels and wetlands for residential, commercial and industrial purpose exemplify preponderant economic considerations over risk potentials and perceptions. The precautions practiced by local communities though limited in land use management and land use zoning in the past were discarded for pecuniary gains. Risk mapping and land use zoning plans at present are of paramount importance as everyone has realized that the country cannot afford to wait for imposition of regulatory measures that focus on land use planning and reduction on risk and damages. Some general principles on land use zoning apposite to risk reduction measures are given below:

- Risk mapping for land use zoning provides basis for both sustainable development and measures of reduction in risk borne losses.
- Land use zoning functions at different scales, which demands different, ranges of management tools and operational mechanisms.
- It spans over legal, technical and socio-economic dimensions.
- It includes integral services as well as individual and sectorial interests.
- Successful land use zoning management plans will confront challenges, tensions between government and private interests, national and local interests and vested interests.

Zoning allows municipalities to shape their residential environments and their property-tax base. The efficiency of zoning thus depends on the transaction costs of making mutually advantageous trades between existing voters and development-minded landowners. It divides a jurisdiction into geographically contiguous ‘zones’. The local zoning ordinance prescribes what may be done in each zone and what may not be done. The land-use zoning will give an indication of the acceptability or otherwise of particular uses in particular areas, proposed development will also be assessed in terms of compatibility with the development control guidelines and standards outlined in this plan. Land-use planning can help to mitigate disasters and reduce risks by discouraging high-density settlements and construction of key installations in hazard-prone areas, control of population density and expansion, and in the siting of service routes for transport, power, water, sewage and other critical facilities. Decision to make proper land use is very crucial tasks. It is even more daunting if there are competing views about the role that land should play in reducing collective exposure to risk. Considerations invariably revolve around whose land it is, whose risk is involved and who is to benefit. Too often, the desire for short-term gains override anticipated benefits that stretch further into the future. For these reasons, land-use management and related regional and territorial planning, have to be considered as natural extensions of conducting hazard assessments and risk mapping. They must take account of the spatial parameters of physical vulnerability considered in accordance with the broader social, economic and environmental requirements of a society (UN/ISDR 2004).

2.2 Relation of vulnerability and hazard with Risk

Vulnerability describes the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. Risk is that can affect particular element which is in vulnerable conditions. Vulnerability can be treated and risk can be mitigated. Hazard, vulnerability and risk are closely interlinked and their relationship can be expressed as;

Risk = Hazard x Elements at risk x Vulnerability

Hazard	:	potential threat to humans and their welfare
+		
vulnerability	:	exposure and susceptibility to losses
=		
risk	:	probability of hazard occurrence
disaster	:	realization of a risk

In brief, hazards are the source of risks which create risks by exposing pre-existing vulnerabilities. The risk that a community faces is mitigated by its level of preparedness, response and recovery or readiness.

2.3 Risk types and their Descriptions

There are four different types of risk and they are described as:

Individual risk: the risk of fatality or injury to any identifiable (named) individual who live within the zone impacted by the natural hazard; or follows a particular pattern of life that might subject him or her to the consequences of the hazard.

Societal risk: the risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injury, financial, environmental, and other losses.

Specific risk (Rs): the expected degree of loss due to a particular natural phenomenon.

Total risk (Rt): the expected number of lives lost, persons injured, damage to property, or disruption of economic activity due to all natural phenomena. It is therefore the sum of the specific risks for all return periods and all types of events.

Nepal is one of the highest risk countries in the world due to various types of disasters. Two types of risk exist for land use zoning namely natural and manmade. The natural risk that usually exists in the flat plain areas are flood, inundations and bank cutting, where as in the sloping areas, debris fans deposits, landslides and soil erosion. Similarly, the fuelling stations, and nearby storage of LP gas area are potential hazards for the fires. Therefore, zoning plays an important role in protecting infrastructures and property from frequent disasters such as: landslides, floods, and fires. Nepal has steep and rugged topography with complex geology resulting different calamities such as flood, fire, landslides and debris flow. Different types of natural risk that are present in the country are described as:

Fire: Usually, fire takes place in the dry and windy season that may be both accidental and deliberate form. They occur in the rural areas of the Terai and Middle hilly region. The monsoon climate that prevails in Nepal is characterized by long period of drought or dry season. Fire is prevalent in the windy summer days in both Terai and mountains of Nepal. Forest fires are both accidental and deliberate. However, the incidences of fires in the rural areas are accidental. Most of the houses in the rural areas are of small, thatched and made up of straw, timber and stalks and they easily catches the fire causing fire hazard. Forest fire incidents occur throughout Nepal and result deforestation of around 1.7 % of the total forest area annually. Most of the fire incidents are caused by negligence of the people such as hunting practices, negligence by cigarette smoker, intentional fire to accelerate growth of grasses to feed livestock, intentional fire setting by herb and charcoal collectors and children playing with fires.

Flood, landslide and debris flow: The topographical feature of Nepal is mainly responsible for flood. Flood is caused by heavy precipitation that may occur at any place except high Himalayan region during the monsoon season. The floods of august 2008 in Koshi River, September 2008 in western Nepal and July and august 1993 in the Bagmati and other rivers were the most devastating floods in Nepal (MOHA 2008). Nepal ranked in 30th in terms of flood hazards (Nepal et al. 2018). As a result, the hazards like landslides and debris fall on the mountain slopes and floods in the river valleys and Terai plain become quite frequent causing damage to soil, cultivated land, crops, residential buildings, infrastructures, human lives and animals. Landslide usually occurs as secondary effects of heavy rainfall and earthquakes. A debris flow is slurry of soils, rocks and organic matter combined with air and water. Complex geology, steep slope and rugged topography lead to different calamities such as flooding, landslide and debris fall. Soil erosion near the river flow at the mountainous and plain land increases during monsoon season.

Earthquake: Nepal is among the countries where seismic activities are high. According to e Report on Disaster Risk, Nepal ranks the 11th position in terms of earthquake risk as earthquakes have often occurred in Nepal. It is mainly due to its young and fragile geology, haphazard and unplanned settlements and poor construction practice. Geologists have forecast that devastating earthquake can occur anytime and anywhere in Nepal. It is likely to cause landslides, GLOFs, liquefaction and change in topography. Earthquakes threaten the entire country all the time and it is poised for a mega disaster for which scientist are forecasting with a high probability of its occurrence anytime anywhere in the region.

Glacial Lake Outburst Flood: Himalayan region is dotted with several big and dangerous glacial lakes that pose a serious threat to the people living downstream. About 15 glacial lakes are found substantially dangerous in Nepal (MoHA website). Major events shown in past were Tamor Koshi (1980), Sun Kosi River (1935, 1981), Dudh Kosi River (1977, 1985), Arun River (1968, 1969, 1970) etc. A glacial lake outburst flood (GLOF) is a type of outburst flood that occurs when the dam containing a glacial lake fails. The dam can consist of glacier ice or a terminal moraine.

CHAPTER 3 : METHODOLOGY

Different types of risk exist in this study area. The prominent risks are due to flood, fire, landslide, seismic and industrial. Risk layers are prepared based on visual interpretation of images and field verified evidences which rely on subjective analysis or expert judgment of geo-scientific principles. Moreover, adaptability and mitigation or reduction measures for probable losses due to hazard and risk are also the pragmatic concern. A standard geological map published by Department of Mines and Geology was used to assess the risks as well as different published literatures are referenced in order to justify commonly practiced methodologies. The practiced methods are always controlled by available data, resources and duration of project time frame which are taken into consideration while analyzing the risks.

3.1 Flood Risk

Flood is one of the disastrous and vulnerable water induced natural disasters which occurs frequently in plain land, river valley and Terai region. Since the study area lies in mountain and valley this region usually bank cutting and landslide problem. River banks and low-level terraces face flood and inundation during high-flood events. The nearby settlement areas of one major Aakhu Khola may face greater risk bank cutting and few areas are flooding and inundation. Time series analysis of river morphology shows that the Aakhu Khola is shifting some time right and left from river bank as low-level terrace areas. Mostly in Aakhu Khola right and left bank areas having the deep gorges with river valley which threats for flooding and bank cutting problem.

3.1.1 Data

Rainfall data was collected from the Department of Hydrology and Meteorology (DHM) and topographical data were collected from the Department of Survey, Government of Nepal for the flood analysis of Jwalamukhi Rural Municipality. Inside the Jwalamukhi Rural Municipality, there is hydrological station available which is installed by DHM at Aakhu Khola. The discharge data was collected from DHM for the flood risk in this Rural Municipality. For the basin wise hydrological analysis DEM data is necessary and DEM data is provided from the Department of Survey but this is not sufficient for the catchment wise analysis. So, SRTM 30X30 m resolution DEM were used in Hec-GeoRAS (HEC, 2002) model for the watershed delineation and geometric data digitization.

Rainfall: In the Dhading district four precipitation stations were found which was established by Department of Hydrology and Meteorology (DHM), Government of Nepal as shown in Table 3-1. Rainfall data of twenty-four years (1991 - 2014) was collected for spatial analysis of receiving maximum and annual rainfall amount over the Dhading district which is depicted in figures 3-3 and 4-4. The nearest rainfall station 18 number from 7 district of Gorkha, Tanahun, Makwanpur, Rasuwa, Nuwakot, Kathmanduand Dhading, were collected for regional maximum analysis. Among these eighteen stations, Markhu Gaun station shows the monthly maximum rainfall 385.6 mm the, whereas the highest of

Dhading district maximum rainfall of 180.4 mm and annual average rainfall 1867 mm Figure 3-1.

Table 3-1: Rainfall station of Dhading district inside the project area

Longitude	Latatitude	Name of Station	Station Index	Elevation (m)	Max Rainfall (mm)
84.90	28.37	Jagat (Setibas)	801	1334	135.6
84.62	28.00	Gorkha	809	1097	164
84.75	28.20	BARPAK	850	1889	339.5
84.55	27.87	SAKHER	863	286	173.2
85.08	27.60	Daman	905	2314	373.2
85.15	27.62	Markhu Gaun	915	1530	**385.6**
85.38	28.28	Timure	1001	1900	86
84.82	28.05	Aru Ghat D.Bazar	1002	518	182.6
85.17	27.92	Nuwakot	1004	1003	147
84.93	27.87	Dhading	1005	1420	180.4
85.25	27.80	Kakani	1007	2064	154.2
85.20	27.68	Thankot	1015	1630	300.1
85.16	27.72	Dhunibesi	1038	988	313
85.32	28.17	Thamachit	1054	1847	333
85.30	28.10	Dhunche	1055	1982	108.5
85.12	28.02	Pansayakhola	1057	1240	212
85.25	27.75	Nagarjun	1079	1690	147.5
85.28	27.78	Jetpurphedhi	1081	1320	128.2

Discharge: Hydrological extreme discharge data were collected from (1991 - 2007) at the station (259.2) and daily discharge data collect (1986- 2014) from Department of Hydrology and Meteorology. The extreme flood discharge was using in the Gumbel's flood frequency analysis was carried out in different return period the result of frequency analysis given in Table 3-2, Figure 3-5 respectively. The prediction of the future 100-year return period floods magnitude was made on the basis of output form measured extreme discharge data using theoretical probability distribution (Gumbel's) method of flood mapping for HEC-RAS (HEC 2019) model. The flood frequency analysis was conducted with the measured extreme discharge section at the station.

3.1.2 General Approach and Methodology Framework

After the collection of the Meteorological and Hydrological data, flow data for different return period were obtained by using observed Instantaneous discharge data from DHM hydrological station (447) at Trishuli river, but the Aakhu Khola is ungauged catchment therefore for extreme flood estimation ungauged basin flood method was used (DHM, 2004).

$Q_2=2.29(A<3k)^{0.86}$ Eq. 1

$Q_{100}=20.7(A<3k)^{0.72}$ Eq. 2

Using all the hydro-meteorological data and cross section data, the required geometry data of the Aakhu Khola such as river, banks, flow paths and cross-sections were developed in HEC-GeoRAS (HEC, 2002) in GIS environment. Then these geometry data were imported to the hydrodynamic HEC-RAS (HEC, 2019) model. The HEC-RAS (HEC, 2019) model is setup for the steady flow analysis for flood modeling and the results were analyzed for the assessment of high, medium and low risk level of Jwalamukhi Rural Municipality.

3.1.3 Methods

Rainfall: Collected rainfall data from DHM of different four stations for Dhading district rainfall analysis by helping the Surfer software using kriging method for the spatial analysis of rainfall data (Table 3-1) shown in Figure 3-1 and 3-2.

Discharge: The basis of available past measured extreme floods data of DHM using theoretical probability distribution method (Gumbel's method). The flood frequency analysis was conducted with the measured extreme discharge at the station and statistical analysis was conducted to determine the required parameters. After having the required statistical parameters, the flood magnitude for any specific return period 2, 5, 10, 20, 25, 30, 40, 50, 60, 70, 80, 90, and 100 was calculated Table 3-2. But, due to the landscape and river cross section profile only 100-year return period data was used for inundation analysis in this study area.

Hydrodynamic Analysis and Inundation Mapping: The HEC-RAS (HEC, 2019) model is setup for the steady flow analysis and the results were analyzed for the assessment of high, medium and low risk level. HEC-GeoRAS (HEC, 2002) and HEC-RAS (HEC, 2019) model were used for the flood modeling. The HEC-GeoRAS (HEC, 2002) as a GIS extension tool is used for preparation of all geometry data and cross sections along the river. These geometry data are then imported to the HEC-RAS (HEC, 2019) model. The HEC-RAS (HEC, 2019) model is set for the steady flow analysis by giving the different return period flow data and manning's value n for the channel. For this analysis the Manning n value was taken from the Herry H. Barnes, Jr. (1987). The Manning's roughness coefficient, n value can be calculated by using the Manning's equation for the discharge calculation. The model is then run for the steady flow simulations and the results were again transported to the HEC- GeoRAS (HEC, 2002). The final inundation maps were prepared with the help of imported water surface profiles and raster maps of depths.

3.1.4 Result

Rainfall: Rainfall data from Table 3-1 were analyzed in monthly and annual rainfall basis over the project area by surfer software and plot by kriging methods the spatial rainfall distribution present in the isohyet's method over the Dhading district as shown in Figure 3-1. The spatial analysis result of 18 number stations in 7 nearest district annual rainfall (125 to 350 mm) received in the entire area of Dhading district. However, the observed temporal (1991-2014) annual average rainfall 1790 mm received in Dhading district, there is significantly decreasing order in Dhading station no.1005, which is closed with the Jwalamukhi Rural Municipality Figure 3-2. Similarly, the temporal average maximum monthly rainfall 452 mm received in the month of July and the minimum monthly rainfall (6 mm) received in the month of November in Figure 3-3.

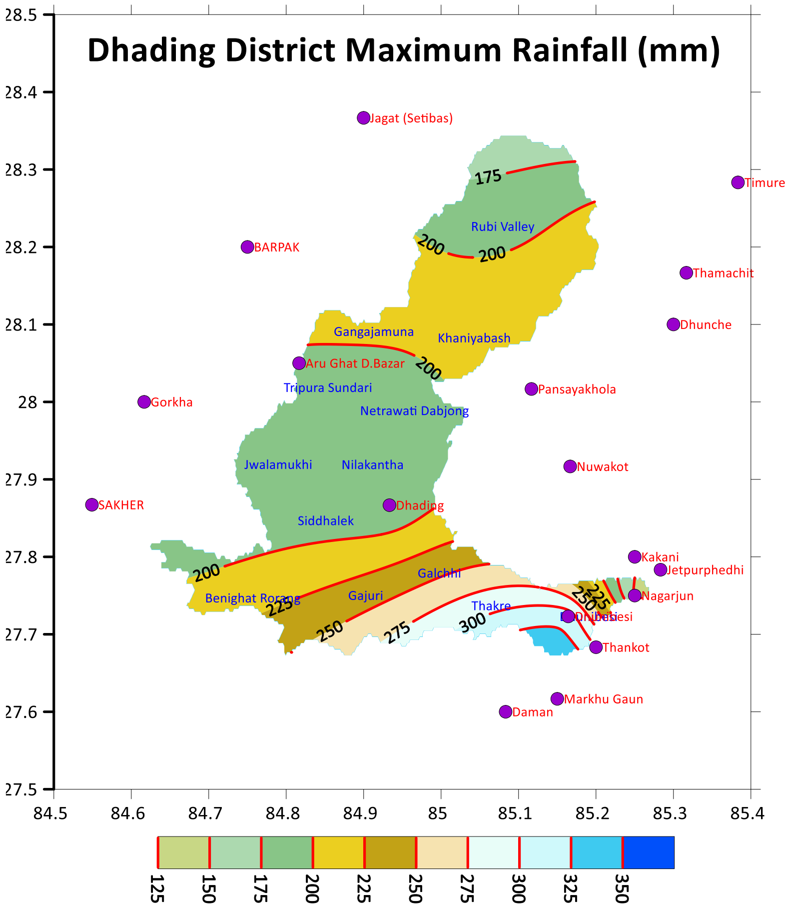


Figure 3-1 Spatial monthly maximum rainfall of Dhading district

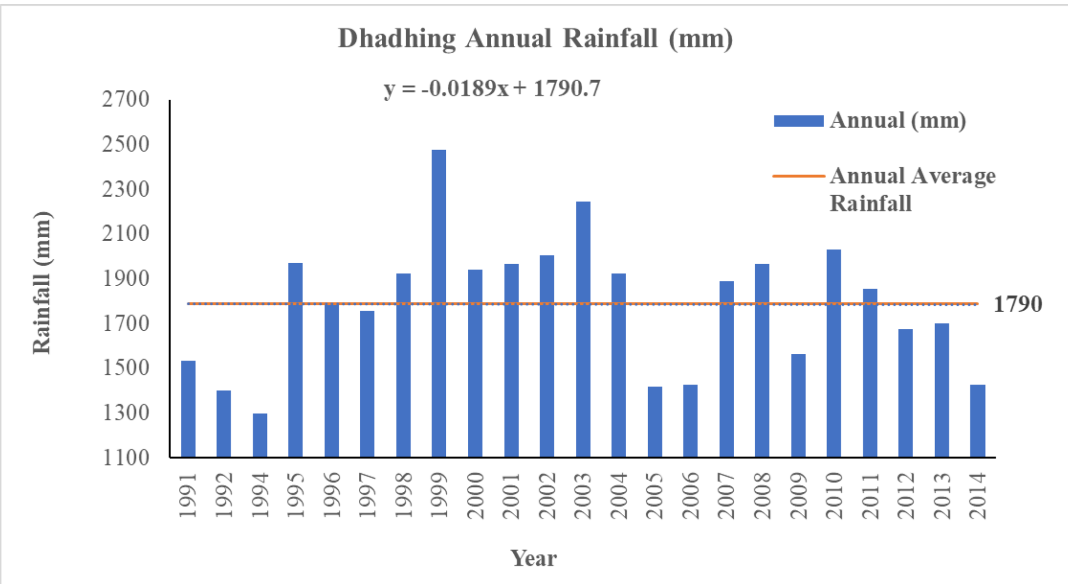
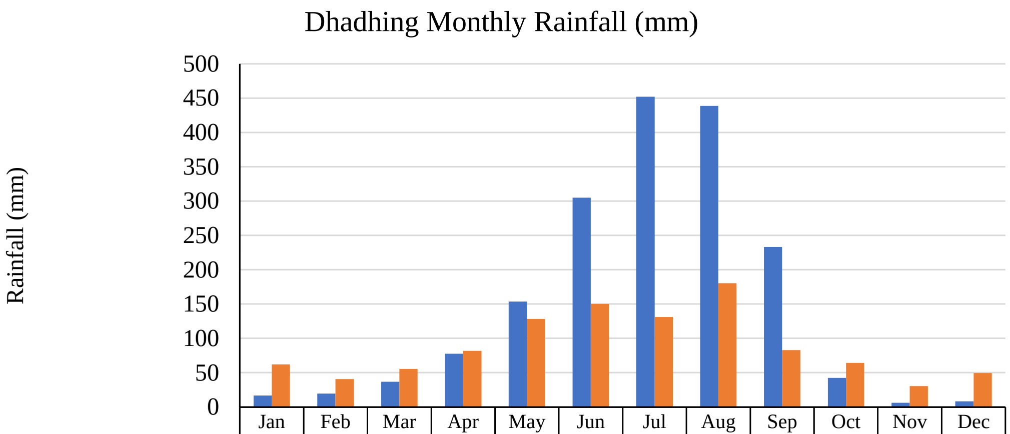


Figure 3-2 Annual average rainfall of Dhading District



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Rainfall (mm)	17	19	37	78	154	305	452	439	233	42	6	8
Maximum Rainfall (mm)	62	41	56	82	128	150	131	180	83	64	31	49

Figure 3-3: Temporal average monthly and maximum rainfall Dhading district

Discharge: Aakhu Khola is ungauged catchments it covers the Jwalamukhi Rural Municipality of ward no. 7. The discharge data are not available in this catchment for flood analysis. In the Aakhu Khola catchment the discharge estimation DHM, 2004, method was applying for monthly average flow estimation and extreme flood frequency analysis using equation- 1 and equation- 2. The monthly maximum discharge found august and minimum in March as shown in Figure 3-4.

The estimated extreme flood from the Aakhu Khola ungauged catchment were used to frequency analysis in Gumbel's frequency analysis different return period is depicted in Table 3-2 and the plot is present in the Figure 3-4. The maximum discharge from 2-year return period to 1000-year return period found from 89 m^3/s to 1160. m^3/s, in the Aakhu Khola catchment.

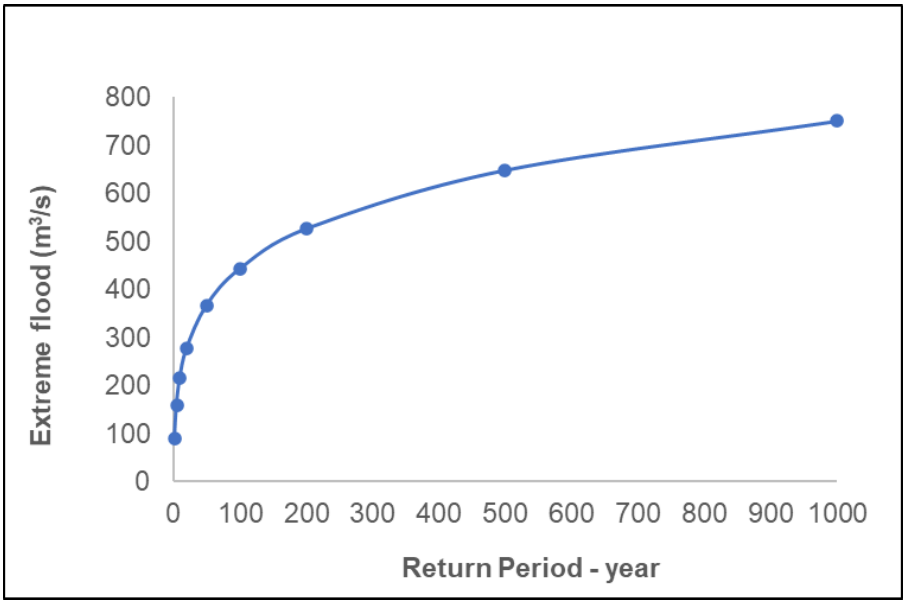


Figure 3-1 Aakhu Khola Dhading monthly maximum discharge (m^3/s)

Table 3-2 Frequency analysis

Return Period	Flood (m^3/s)
2	89
5	159
10	216
20	277
50	367
100	443
200	527
500	649
1000	751
5000	1025
10000	1160

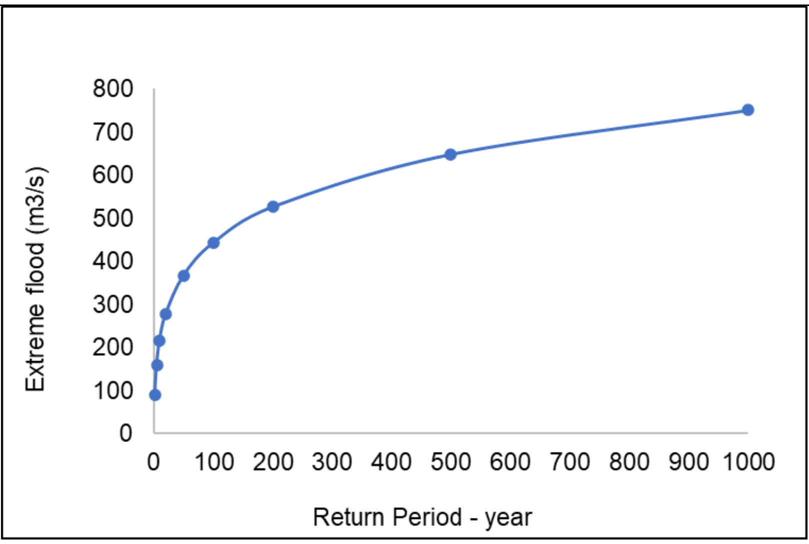


Figure 3-5 Frequency analysis of different return period at Aakhu Khola

3.1.5 Flood Modeling

Pre-processing to develop RAS GIS import files: The Aakhu Khola geometry data were prepared in HEC-GeoRAS (HEC, 2002) extension tool in GIS. With the help of Digital Terrain Model (DTM), which represents the channel bottom and adjacent floodplain areas, Triangulated Irregular Network (TIN) and image file of the study area, stream centerline, flow path lines, bank lines and cross sections cut lines layers were digitized (Figure 3-5).

Result of Pre-processing to develop RAS GIS import files: The Aakhu Khola geometry data were prepared in HEC-GeoRAS (HEC, 2002) extension tool in GIS. With the help of Digital Terrain Model (DTM), which represents the channel bottom and adjacent floodplain areas, Triangulated Irregular Network (TIN) and image file of the study area, stream centerline, flow path lines, bank lines and cross sections cut lines layers were digitized (Figure 3-5a and Figure 3-5b).

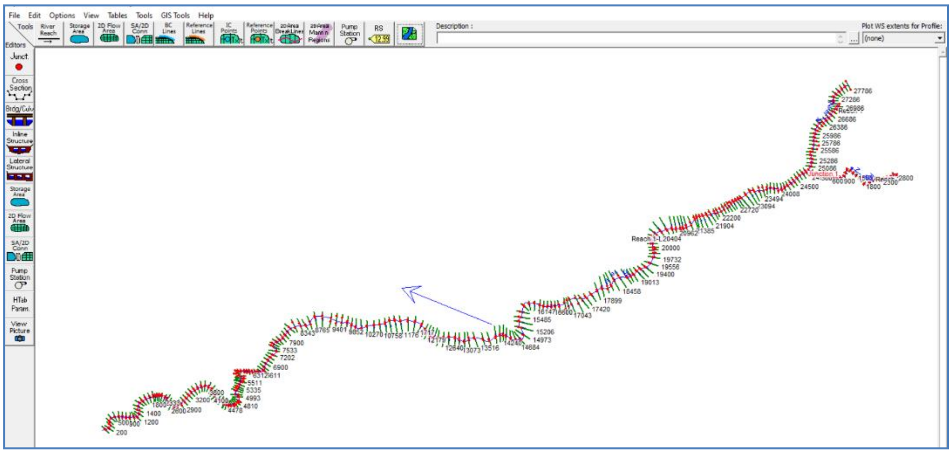


Figure 3-2a: Geometry data of Aakhu Khola Dhading prepared in HEC- GeoRAS

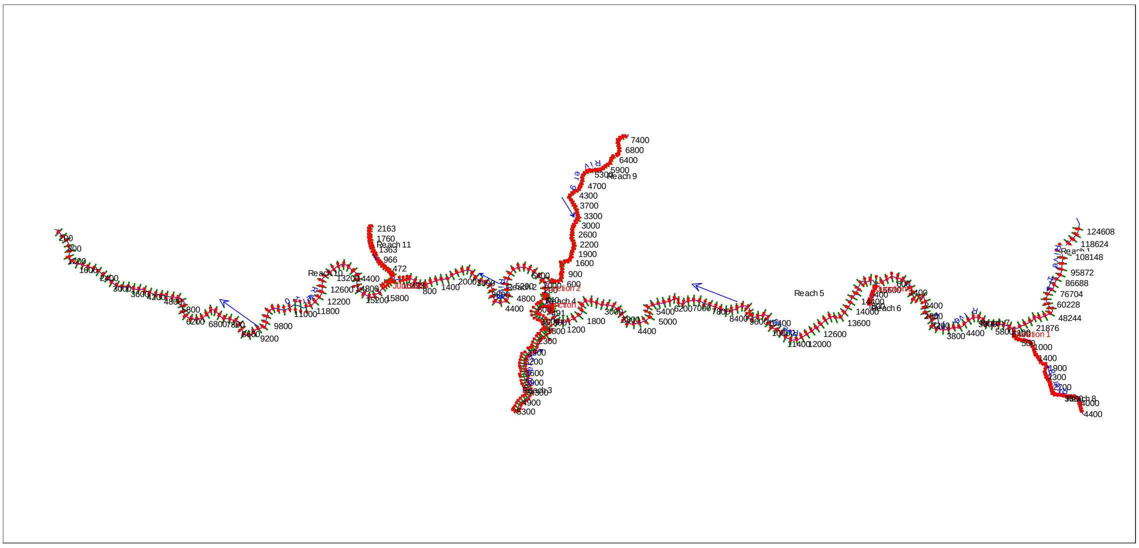


Figure 3-3b: Geometry data of Aakhu Khola Dhading and hole district prepared in HEC-GeoRAS.

The river and reach network are represented by the stream centerline layer. Then the topology, elevation and lengths of the river were calculated. Similarly, for the cross-section lines, different attributes such as river/reach names, stationing, and elevations etc. were computed in HEC-GeoRAS (HEC, 2002). The RAS GIS import file is then created to upload in HEC RAS (HEC, 2019) model.

Flow calculations in HEC-RAS: HEC-RAS (HEC, 2019) model perform 1D water surface profile calculation for steady flow. The model computes the water surface profile by using energy equation. The water surface profile is generated from one cross section to another considering the parameters of energy equations such as elevation of main channel, depth of water at cross sections, average velocity, energy head loss and gravitational acceleration. The 1D steady flow simulation was performed based on the flow of the river when the flow is steady, it is gradually varied, flow is one dimensional etc. Figure 3-6 and 3-7 shows the output at the one of the cross sections of the river profile.

Post processing to generate GIS data from HEC-RAS results: The HEC-RAS (HEC, 2019) model result files were analyzed with the RAS mapping tool in HEC-Geo RAS (HEC, 2002). The RAS MAP tool requires the DTM in grid format. The inundation mapping was done with the help of water surface elevation, cross section cut lines and bounding polygon. The inundation depth grid is created comparing the water surface elevation. The floodplain is generated where the water surface elevation is higher than terrain grid. The RAS mapping tool creates the floodplain boundary based on the depth grid and it is the outline of the depth grid along the Aakhu Khola system Figure 3-6 and 3-7.

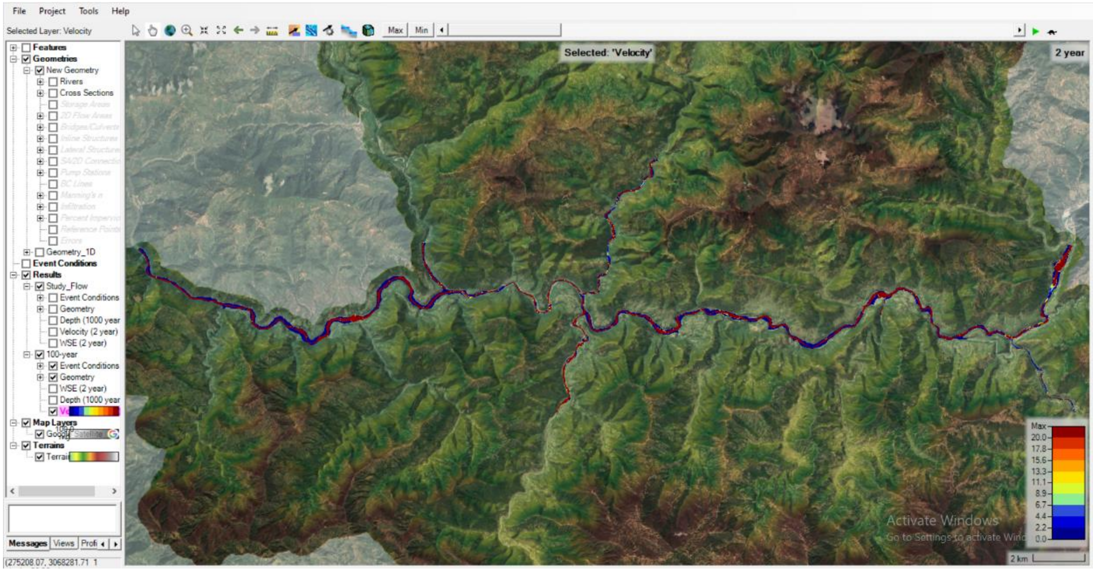


Figure 3-4: Cross section profile Aakhu Khola and existing river of Dhading district

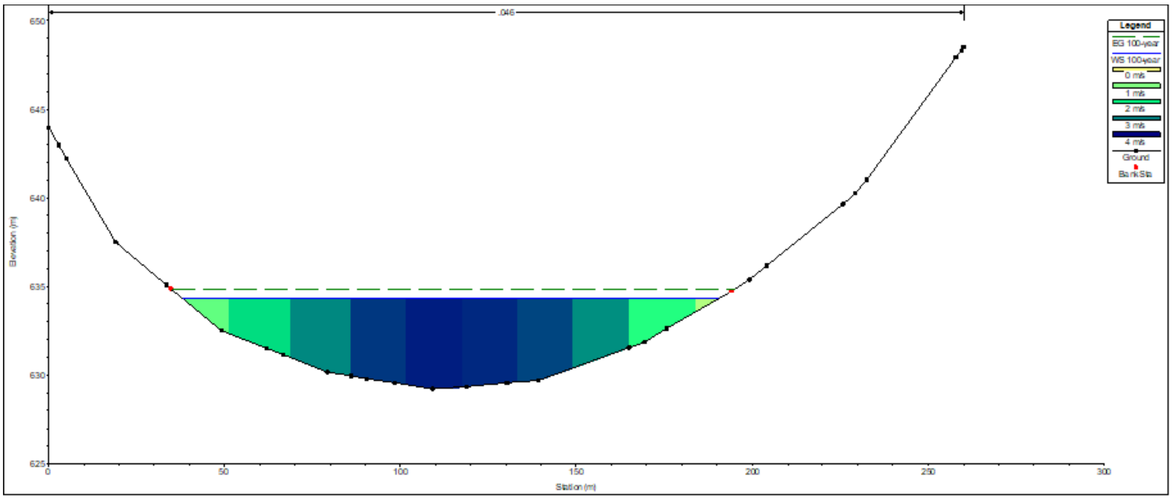


Figure 3-5: River cross section profile of Aakhu Khola outlet

Validation of result: Validation of the water level results for the HEC-RAS (HEC, 2019) model Table 3-3 and the field observed output result. From the field observed data, the lowest depth less than 2.0 m and the maximum depth is 5.09 m found. However, from the HEC-RAS (HEC, 2019) model the maximum depth 5.09 m found in Aakhu Khola outlet at the downstream of Jwalamukhi Rural Municipality Ward No. 7.

Table 3-2: Aakhu Khola Cross section output of the downstream outlet

Cross Section Output

File Type Options Help

River: River 1 Profile: 100-year

Reach Reach 1 RS: 27086 Plan: First_Run

Plan: First_Run River 1 Reach 1 RS: 27086 Profile: 100-year

E.G. Elev (m)	634.86	Element	Left OB	Channel	Right OB
Vel Head (m)	0.55	Wt. n-Val.	0.046	0.046	0.046
W.S. Elev (m)	634.31	Reach Len. (m)	92.90	100.00	98.70
Crit W.S. (m)		Flow Area (m2)	127.78	350.77	36.98
E.G. Slope (m/m)	0.003583	Area (m2)	127.78	350.77	36.98
Q Total (m3/s)	1613.15	Flow (m3/s)	319.57	1232.22	61.37
Top Width (m)	152.24	Top Width (m)	47.72	79.00	25.52
Vel Total (m/s)	3.13	Avg. Vel. (m/s)	2.50	3.51	1.66
Max Chl Dpth (m)	5.09	Hydr. Depth (m)	2.68	4.44	1.45
Conv. Total (m3/s)	26950.2	Conv. (m3/s)	5338.9	20586.1	1025.2
Length Wtd. (m)	98.68	Wetted Per. (m)	47.96	79.08	25.68
Min Ch El (m)	629.22	Shear (N/m2)	93.61	155.85	50.60
Alpha	1.10	Stream Power (N/m s)	234.11	547.46	83.97
Frctn Loss (m)	0.39	Cum Volume (1000 m3)	358.43	663.41	503.24
C & E Loss (m)	0.01	Cum SA (1000 m2)	58.06	124.32	107.06

Flood Inundation Mapping: Based on the flood depth simulated by the HEC–RAS (HEC, 2019) model, the low, medium and high-risk areas were determined. According to the field verification the maximum flood depth 7.41 m occurred during the monsoon season which was extremely erosive soil, river bank cutting, turbulent flow in upstream areas, inundation in downstream, highly flood risk problem found by Aakhu Khola in the Jwalamukhi Rural Municipality. According to Inundation mapping of Jwalamukhi Rural Municipality territory flood depth has been classified low risk having depth of 0.0 m – 2.0 m, medium risk having depth of 2.0 - 6.0 m and high risk having above depth of greater than 6.0 m as shown in Figure 3-8a, enlarge of resident without flood in google map Figure 3-8b, and with enlarge view of inundation area of flood depth in Figure 3-9c.

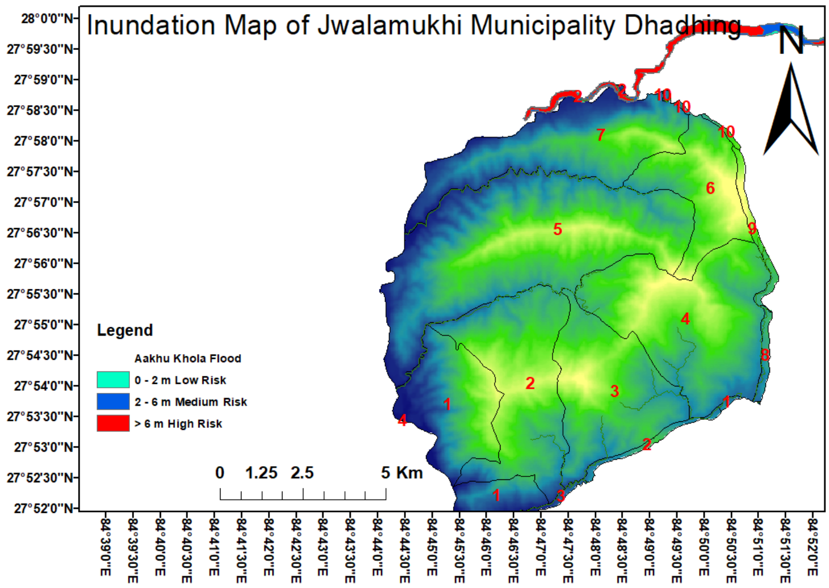


Figure 3-6a: Inundation map of Dhading 100 Years return period flood

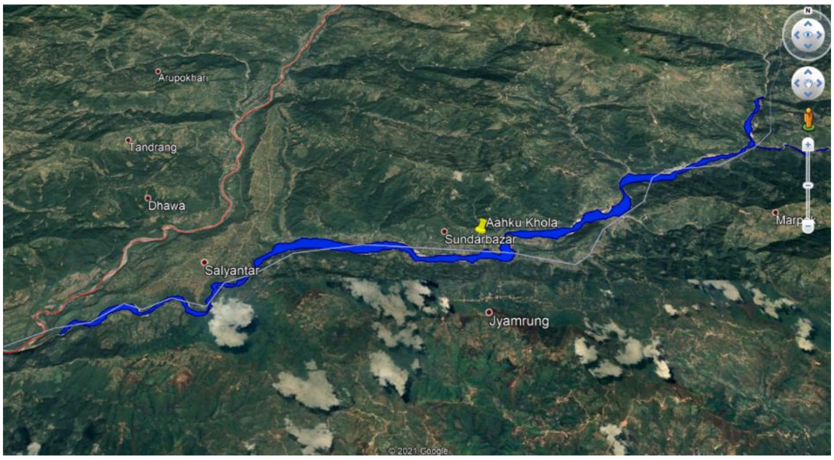


Figure 3-7b: Inundation map of Dhading 100 Years return period flood

Figure 3-8c: Inundation map of Dhading 100 Years return period flood

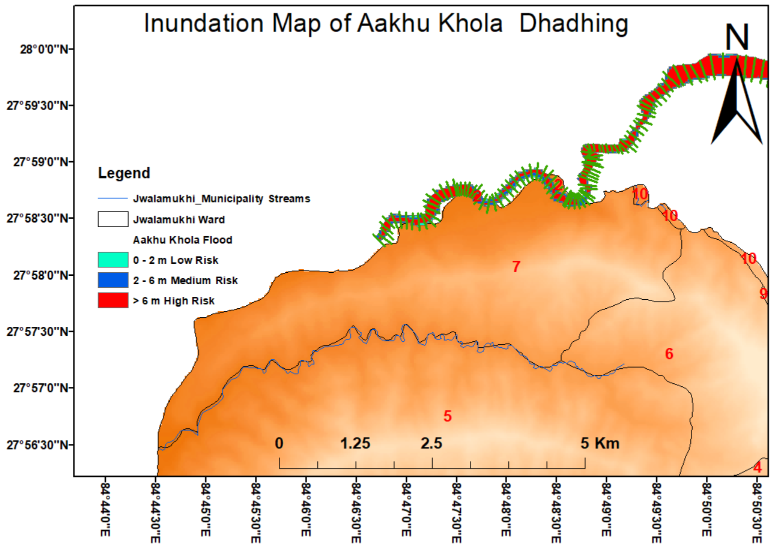


Figure 3-9: Aakhu Khola inundation flood depth map of 100 years return period

Flood Risk status of Jwalamukhi Rural Municipality: Aakhu Khola, cover the high risk 8.03 -hectare land, Medium risk cover 18.89-hectare land and Low risk cover about 2.74-hectare areas shown in Table 3-3.

Table 3-3: Risk status of Jwalamukhi Rural Municipality

S.N.	Class Type	Area (Ha)				
		High	Medium	Low	No Risk	Total
1	Agriculture	0.56	3.33	0.85	5637.81	5642.54
2	Forest	0.67	0.52	0.13	4778.71	4780.03
3	Residential	0.01	0.00	0.00	542.97	542.97
4	Commercial	0.01	0.00	0.00	3.24	3.24
5	Industrial	0.01	0.00	0.00	0.00	0.00
6	Public Service	0.02	0.00	0.00	135.09	135.11
7	Mine and Minerals	0.00	0.00	0.00	0.00	0.00
8	Cultural and Archeological	0.00	0.00	0.00	1.31	1.31
9	Riverine, stream, Lake and Marsh Area	6.77	15.04	1.77	160.84	184.42
10	Other					
	Total	8.03	18.89	2.74	11251.0	11289.6

Result of flood risk map: Flood events are common in monsoon season in Jun to September in Nepal and Dhading district too, that attributed to its geographical conditions with elevated terrain and river valleys. Many seasonal streams flow along the river valley that are damaging arable lands and sometimes cause human casualties. Aakhu Khola is major small tributary in the area which flows in long stretch and creates flooding problems in different ward no 7. Field investigation and HEC-RAS modelling showed that the area is in risk of flood hazard by Aakhu Khola. The Aakhu Khola is flowing almost west to south it is usually narrow river channel system causing the banks cutting and few areas are inundation problem Table 3-3 shows the statistics of flood risk status of Jwalamukhi Rural Municipality at Dhading district shown in Figure 3-10.

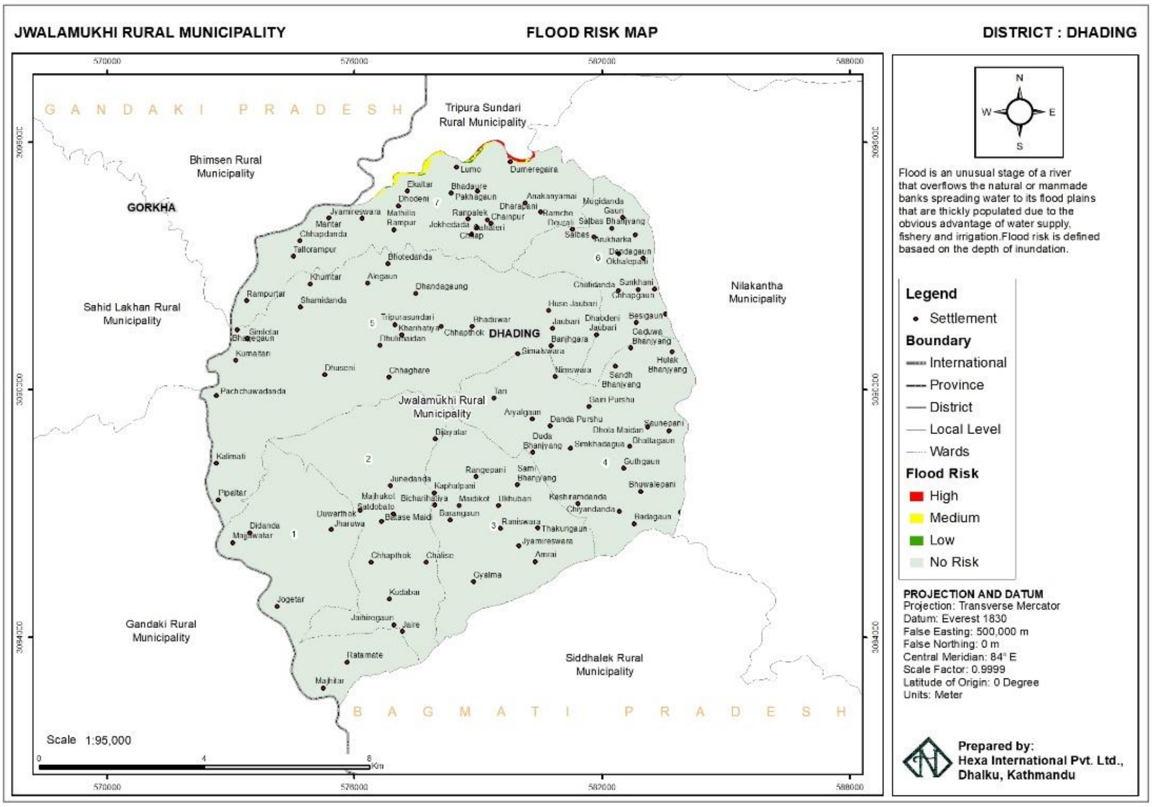


Figure 3-10: Flood risk map of the study area.

3.1.6 Discussion

The distribution of rainfall over the project boundary of Aakhu Khola catchment four Table 3-4 rainfall stations different contributes rainfall during the monsoon season but the annual average rainfall 1790 mm received in Jwalamukhi Rural Municipality. Frequency analysis result of 100-year return period flood of Table 3-4 using the HEC-RAS (HEC, 2020) model in the Aakhu Khola for inundation mapping shown in Figure 3-10. The result of inundation map displays the Ward No 7 in the flood risk areas of Jwalamukhi Rural Municipality.

3.2 Fire Risk

Fire risk can be viewed as the possibility of an unwanted fire hazard in an uncertain situation, where loss or harm may be induced to the valued, typically life, property, business continuity, heritage, and/or environment (Meacham 2001 2002). The fire risk is critical concern in Nepal during hot and dry period as well as sometimes it is associated with any time accidental cases of inflammable objects or sparking phenomena.

3.2.1 Data

Fire risk data in the area has been assessed from existence of thatch-roofed houses, inflammable elements (e.g. petrol pump) and forested areas. These fire risk elements are mapped as present land use for database in fire risk zoning.

3.2.2 General Approach and Methodology Framework

Decision on fire risk remains a frustratingly large degree of disagreement and confusion over basic purposes and terminology. In most other areas of fire science, disagreements, however strong, tend to be over the validity of alternative means to achieve particular assessment objectives. In fire risk analysis, disagreements often are more fundamental and involve the basic objectives of methodology. A "scenario" is sometimes used to describe a single element (that is, a single fire situation). Alternatively, a "scenario" may refer to groups of elements that share those characteristics that define the initiation, growth, and termination of the fire but which may differ with respect to other characteristics. These other characteristics might include the type of building, vehicle, or other property involved; the number and characteristics of occupants; or physical properties of the building, vehicle, or other property that do not affect the fire development but do affect the harm caused to people or property (Hall and Sekizawa 1991).

Moreover, the "exposure" in a fire situation refers to those characteristics of an element of that specify the number of persons and the quantity of property that may be affected by the fire and their characteristics. "Property" may be used broadly to mean not just the asset value of fixed objects but also the functional capacity of property (such as its ability to sustain productive operations or its ability to support human habitation).

3.2.3 Methods

Methods of fire risk analysis can be classified into four categories, narratives, checklists, indexing, and probabilistic methods (Watts 1995, Watts and Hall 2002). Narratives do not attempt to evaluate the fire risk quantitatively; instead, a risk is judged acceptable if it complies with published recommendations. A common accessory of fire protection is a listing of hazards and recommended practices. These checklists comprise valuable tools for identifying fire risk factors but they do not distinguish among the importance of these factors. Fire risk indexing methods assign values to selected variables based on professional judgment and past experience. Probabilistic methods are the most informative approaches to fire risk assessment in that they produce quantitative values, typically produced by methods that can be traced back through explicit assumptions, data, and mathematical relationships to the underlying risk distribution (Watts and Hall 2002).

Despite availability of comprehensive methods of fire risk assessment, general approach of fire risk approximation is followed which based on the field assessment and historical information. For fire risk zonation, land cover with high accumulation of inflammable object like petrol pumps and adjoining forested areas are the main focus. Zonation of risk levels (low, medium and high) are carried out by proximity analysis of fire risk elements with using the arbitrary values. Proximity for forest fire risk are <30 m is high, 30–60 m is medium, >60 m is low; for rick mill – within 10 m is high; for petrol pump – within 20 m is high and for brick factory – within 20 m is high. Beyond high and medium risk zones of fire susceptible elements are considered as low risk that is relatively safe area.

3.2.4 Result

The area is in some risk of fire due to presence of forested area. Result showed that the region with area of 12.51% is high, 51.55% is medium and 35.94% low risk levels of fire. The risky areas are seen in considerable portions of the area (Figure 3-11) and the rest of area lies in medium and low risk zones. Water bodies cover 184.42 ha and Table 3-4 shows the statistics of fire risk in terms of land use.

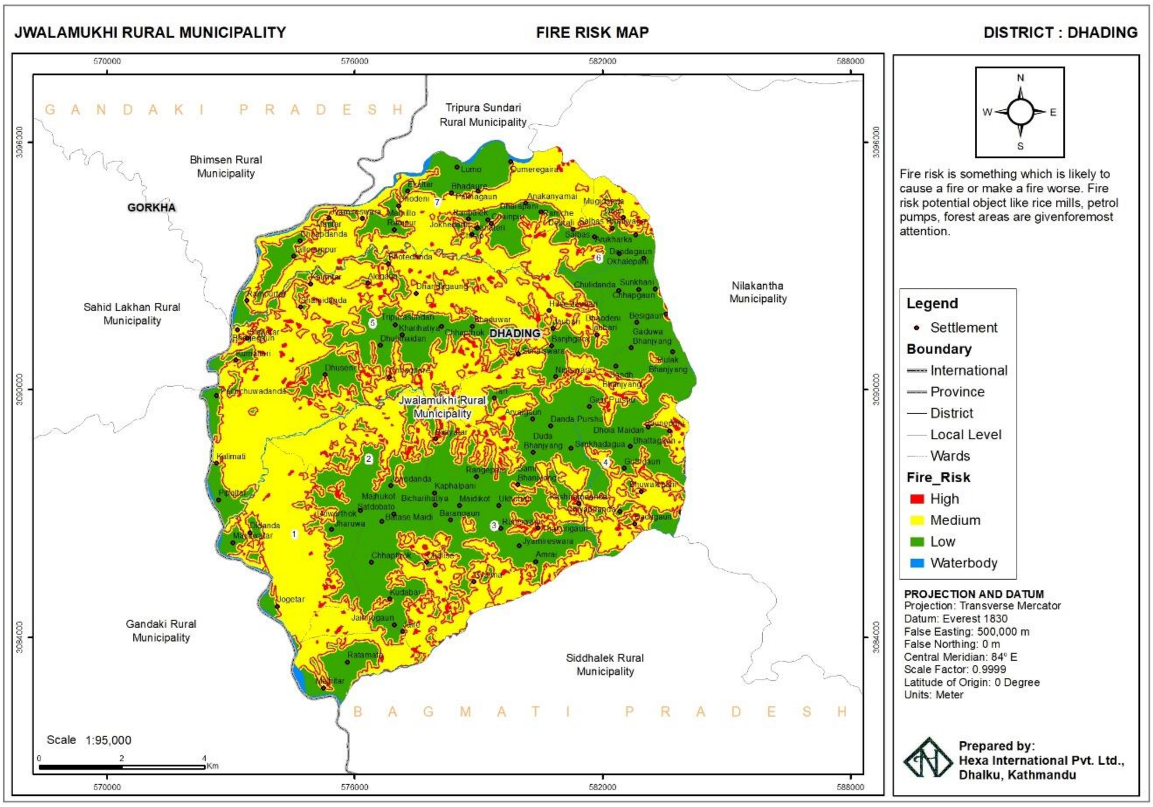


Figure 3-11: Fire Risk Map of the Study Area.

Table 3-4: Statistics of fire risk in terms of land use.

S.N.	Land Use	Area (ha)			
		High	Medium	Low	Total
1.	Agriculture	1231.72	914.79	3496.04	5642.54
2.	Forest	58.51	4715.74	5.78	4780.03
3.	Residential	66.36	58.95	417.67	542.97
4.	Commercial	0.53	0.50	2.21	3.24
5.	Industrial	0.00	0.00	0.00	0.00
6.	Public Service	32.34	34.41	68.35	135.11
7.	Mine and Minerals	0.00	0.00	0.00	0.00
8.	Cultural and Archeological	0.27	0.32	0.72	1.31
9.	Riverine, Stream, Lake and Marsh	0.00	0.00	0.00	184.42
10.	Other	0.00	0.00	0.00	0.00
	Grand Total	1389.72	5724.71	3990.77	11289.62

3.2.5 Discussion

Fire risk is prominent in the study area as the forested areas distributed in this area have possibility of fire risk during hot season (April-June) every year. In some locations, the thatch-roofed houses are also surrounded by reinforced concrete houses and have less probability of spreading fire. The spreading fire hazard depends on direction and speed of prevailing wind at particular time. Those parts of region which are close to forest may have potential chances of getting fire if by accidentally or mistakenly happen. Mitigation measures for fire risk must involve the increasing social adaptability for using fire elements in proper way of safety precautions.

3.3 Landslide Risk

Landslide risk evaluation aims to determine the expected degree of loss due to a landslide and the expected number of live lost, people injured, damage to property and disruption of economic activity (Varnes 1984). Landslide is one of the most serious slope movements risk in the mountainous terrain of Nepal due to fragile geology, frequent extreme weather events and rugged topography.

3.3.1 Data

Spatial data that requires analyzing landslide risk consists of landslide inventory map and their causative parameter maps as well as elements at risk. Landslide inventory can be acquired through aerial photo interpretation, image analysis and detailed fieldworks. Similarly causative parameters and risk elements can be obtained. The data set of landslide inventory is an indispensable data source representative of samples of landslide presence that may represent single or multiple events (Chacón et al. 2006). Thus, acquired data are used to construct database that are necessary for risk analysis.

3.3.2 General Approach and Methodology Framework

General approach of landslide risk evaluation is to determine the "expected degree of loss due to a landslide (specific risk) and the expected number of live lost, people injured, damage to property and disruption of economic activity" (Varnes 1984). The methodological framework begins with the identification and the description of the threat, to succeed towards an evaluation of the claimed exposure and a characterization of the risk. The hazard analysis is based on four fundamental assumptions: (a) landslides will always occur in the same geological, geomorphological, hydrogeological and climatic conditions as in the past; (b) the main conditions that cause landsliding are controlled by identifiable physical factors; (c) the degree of hazard can be evaluated; (d) all types of slope failures can be identified and classified (Hutchinson 1995).

3.3.3 Methods

Landslide risk analysis can be done either in qualitative, semi-quantitative or quantitative approaches. Dai et al. (2002) pointed out “whether qualitative or quantitative assessments are more suitable depends on both the desired accuracy of the outcome and the nature of the problem, and should be compatible with the quality and quantity of available data". The application of methods also depends on the experience of the specialist, and the scope and purpose of the hazard and risk assessment (Fell et al. 2005). Fell and Hartford (1997) emphasized that using descriptive terms may be the most appropriate approach and is quite acceptable. In general, landslide hazard and risk is analyzed by the likelihood occurrence of a landslide based on role of individual factors controlling the landslide location, geographical pattern, and spatial density to predict where landslides will likely occur in the future (Varnes 1984). In this assessment, landslide hazard and risk was evaluated based on subjective rating of important factors (Deoja et al. 1991). Application and description of subjective rating methods are frequent in literature (Kienholz 1978, Ives and Messerli 1981, Rupke et al. 1988, Aleotti and Chowdhury 1999 etc.). The analysis parameters include as slope angle, slope aspect, Land Use, drainage proximity, geology and thrust or fault proximity and assigning of rating value in each parameter class (Table 3-5) depends on the priori knowledge of their contribution for the landslide initiation (i.e. experience-based weighting factors). The following operations were carried out to prepare landslide hazard and risk map (see Figure 3-12 also):

- Subdivision of each parameter into a number of relevant classes
- Assigning weight values to each class
- Overlaying and combining weight maps
- Reclassification of combined weight map and
- Vectorization of reclassified map

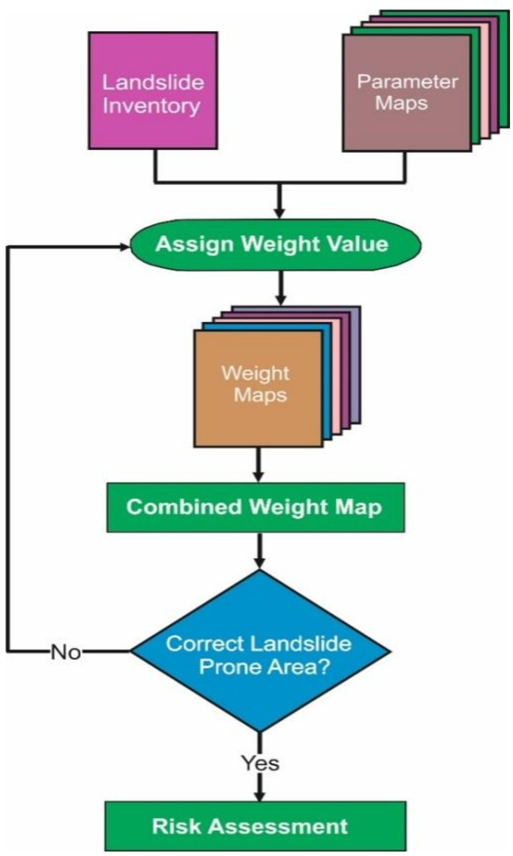


Figure 3-12: Flowchart of Landslide Hazard and Risk Assessment.

Table 3-5: Hazard and risk parameter rating values (modified after Deoja et al. 1993).

Parameters	Rating values	Parameters	Rating values
Landslide		Slope angle	
Present	0.80	0-15°	0.01
Absent	0.20	15-25°	0.08
Slope Aspect		25-35°	0.38
Flat	0.01	35-45°	0.36
N	0.09	45-90°	0.17
NE	0.09	Distance to thrust	
E	0.12	0-25 m	0.42
SE	0.15	25-50 m	0.34
S	0.17	>50 m	0.24
SW	0.18	Distance to drainage	
W	0.12	0-20 m	0.40
NW	0.07	20-40 m	0.33
Land cover		>40 m	0.27
Forest	0.17	Geology	
Shrubland	0.17	Rm	1.00
Grassland	0.15		
Cultivated land	0.22		
Barren land	0.23		
Debris deposit	0.05		
Water body	0.01		

3.3.4 Result

Study area is susceptible to landslide occurrence due to topographic variation in elevated region. The result showed that the region with area of 1.31% is high, 42.12% is medium and 56.58% low risk levels of landslide (Figure 3-13). As the area is located in mountainous terrain, both high and medium risk level zones are susceptible to landslides. Table 3-6 shows the statistics of landslide risk in terms of land use.

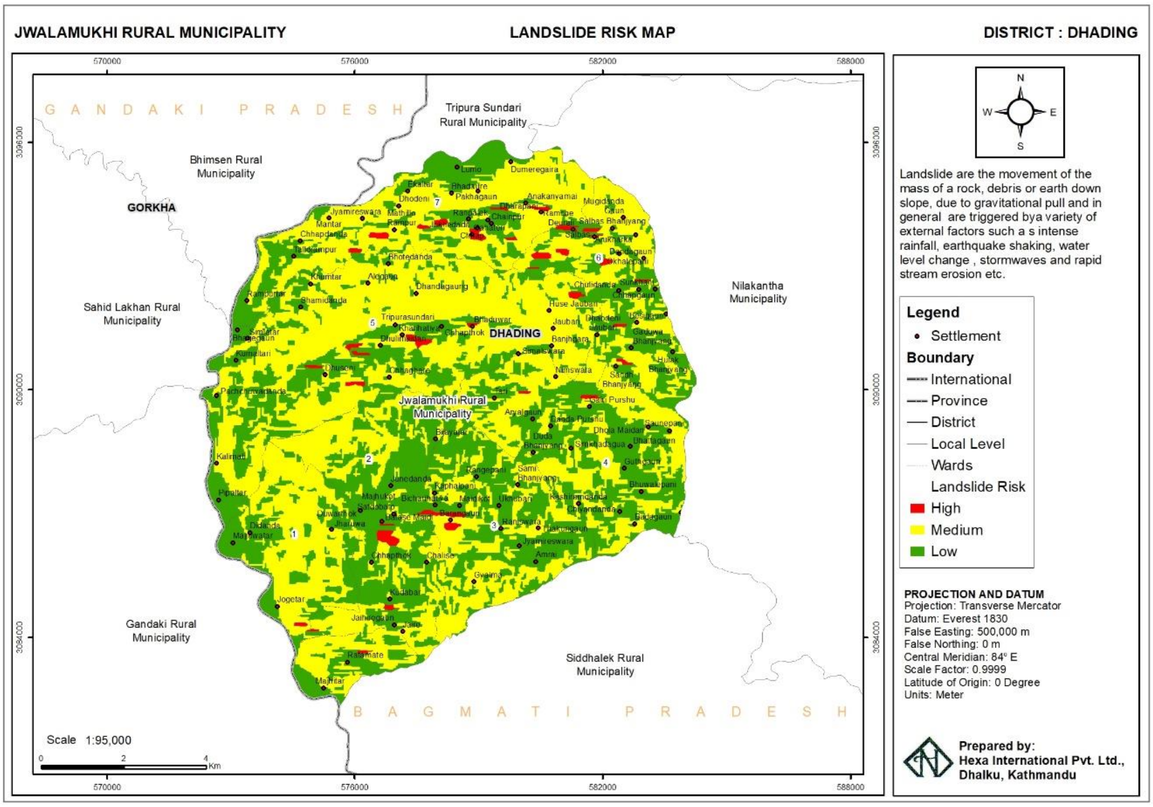


Figure 3-13: Landslide Risk Map of the Study Area.

Table 3-6: Statistics of landslide risk in terms of land use.

S.N.	Land Use	Area (ha)			
		High	Low	Medium	Total
1.	Agriculture	96.73	3023.30	2522.52	5642.54
2.	Forest	34.72	1136.58	3608.73	4780.03
3.	Residential	13.53	367.86	161.58	542.97
4.	Commercial	0.15	1.72	1.37	3.24
5.	Industrial	0.00	0.00	0.00	0.00
6.	Public Service	2.20	76.25	56.65	135.11
7.	Mine and Minerals	0.00	0.00	0.00	0.00
8.	Cultural and Archeological	0.00	1.16	0.15	1.31
9.	Riverine, Stream, Lake and Marsh	0.00	148.15	36.26	184.42
10.	Other	0.00	0.00	0.00	0.00
	Grand Total	147.34	4755.02	6387.27	11289.62

3.3.5 Discussion

Study area has risk of landslides in upper elevated region of hill-slope areas as landslides in the mountainous terrain generally occur in slopes exceeding 10 degrees. A case study in Lesser Himalayan zone of central Nepal also showed that predominant occurrences of landslides are found in slope angles range from 25 to 35 degrees (Thapa 2011). The landslides distribution are frequent even if high hazardous are predicted but gully erosion and minor slope failures are commonly found. Landslides can be mitigated by structural and non-structural means.

3.4 Seismic Risk

Seismic hazard and risk describes natural phenomena caused by an earthquake that have the potential to cause harm, such as surface rupture, ground motion, ground-motion amplification, liquefaction, or induced landslide (Wang 2008). The seismic hazard and risk are two very important concepts in engineering design and other policy considerations. Although seismic hazard and risk have often been used inter-changeably, they are fundamentally different. Furthermore, seismic risk is more important in engineering design and other policy considerations. Seismic hazard assessment is an effort by earth scientists to quantify seismic hazard and its associated uncertainty in time and space and to provide seismic hazard estimates for seismic risk assessment and other applications (Wang 2010).

3.4.1 Data

A large number of interrelated parameters are required to evaluate seismic hazard and risk which are costly elements of investigation (e.g. sufficient drilling data, geo-technical testing of subsurface samples, ground water conditions etc.). Up to now, National Seismological Centre, Department of Mines and Geology (DMG) has published PGA map of Nepal which shows peak ground horizontal acceleration contours (gals) in bedrock for five hundred years return period and approximately corresponds to 10 percent chance of exceeding in fifty year. Only this map can be taken into consideration for input data in GIS to explain the seismic risk in the study area.

3.4.2 General Approach and Methodology Framework

Approach and methodology implemented to prepare seismic hazard and risk map of the study area by utilizing the published Peak Ground Acceleration (PGA) map of DMG which is short period ground motion parameter that is proportional to seismic forces. The PGA map is used to extract as a region of interest (ROI) in Rural Municipality/Municipality level.

3.4.3 Methods

Empirical relationship is used to evaluate seismic risk by correlating between PGA values and corresponding resultant damages. PGA can be expressed in g (the acceleration due to Earth's gravity, equivalent to g-force) as either a decimal or percentage; in m/s^2 (1 g = 9.81 m/s^2) (USGS 2011); or in Gal, where 1 Gal is equal to 0.01 m/s^2 (1 g = 981 Gal). Unlike the Richter and moment magnitude scales, PGA value is not a measure of the total energy (magnitude, or size) of an earthquake, but rather of how hard the earth shakes at a given geographic point. The PGA provides a measurement of instrumental intensity, that is, ground shaking recorded by seismic instruments. There is correlation between these scales, but not always absolute agreement since experiences and damage can be affected by many other factors, including the quality of earthquake engineering.

Generally speaking,

g (0.01 m/s²) – perceptible by people

g (0.2 m/s²) – people lose their balance

0.50 g – very high; well-designed buildings can survive if the duration is short.

3.4.4 Result

PGA value of the area comprises the values ranging between 250 and 350 gals comprising three zones of DMG seismic map and interpreting such value has showed the area is situated in seismic risk of low value (Figure 3-14). However, lower PGA value does not mean that it lies in low to moderate seismic risk zone because Nepal is located in seismically very active zone and always possesses risk of frequent earthquakes and their aftershocks. Table 3-7 shows statistics of seismic risk in terms of land use.

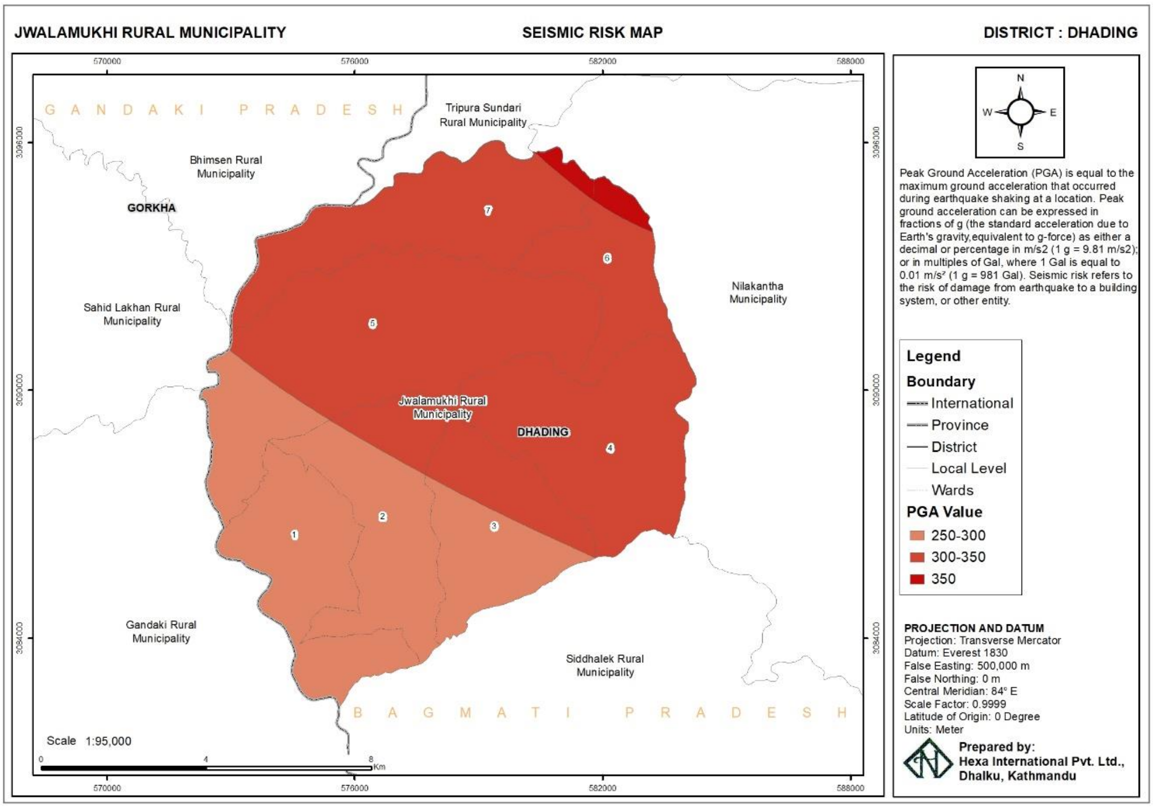


Figure 3-14: Seismic Risk Map of the Study Area.

Table 3-7: Statistics of seismic risk in terms of land use.

S.N.	Land Use	Area (ha)			
		PGA (Gal)			Total
		250-300	300-350	350.00	
1.	Agriculture	1738.65	3873.27	30.62	5642.54
2.	Forest	1736.56	2929.80	113.67	4780.03

3.	Residential	187.70	355.01	0.26	542.97
4.	Commercial	1.42	1.82	0.00	3.24
5.	Industrial	0.00	0.00	0.00	0.00
6.	Public Service	42.10	92.75	0.25	135.11
7.	Mine and Minerals	0.00	0.00	0.00	0.00
8.	Cultural and Archeological	0.13	1.18	0.00	1.31
9.	Riverine, Stream, Lake and Marsh	85.24	99.18	0.00	184.42
10.	Other	0.00	0.00	0.00	0.00
Grand Total		3791.82	7353.01	144.79	11289.62

3.4.5 Discussion

The area equally possesses earthquake risk because Nepal is located in seismically active zone. In comparison to other hazardous events, return period of catastrophic earthquake can be longer (ranges from 80 to 100 years per cycle) which is inferred from past historic earthquake events of 1933, 1934, and 2015 but the 2015 Gorkha Earthquake did not release all stored energy because it happened without forming the rupture surface indicating that geological hell of Nepal earthquake may not be over. Therefore, not only in this area, all municipalities/rural municipalities in the Nepal must always get ready to face with anytime earthquake risk that may happen in future. The seismic risk is unavoidable in the Himalayan region that cannot be mitigated but losses can be reduced by high level geo-scientific research to know the mechanism of risk propagation through different geological situations, implementing building codes and increasing awareness. Adaptation of community awareness and sound engineering designs are important for reducing seismic risk. In fact, whole country lies is high seismic risk zone that indicating all lands are susceptible to earthquake but in precise sense, liquefaction or bedrock amplification can be distinct noticeable factors to incorporate in Land Use zoning when provided resources are sufficient to evaluate.

3.5 Industrial Risk

The presence of factories for their production activities in the territory exposes the population and surrounding environment to industrial risk. An industrial accident can in fact cause harm to population and territory. The problem related to industrial hazard is that diversification of risk type has increased in recent times. People staying nearby industrial estates in developing countries are more vulnerable, particularly in the absence of governmental facilities to cope with disasters.

3.5.1 Data

Data for industrial risk can be obtained as present land use to enter in database for analysis. Industries are not existing in this area.

3.5.2 General Approach and Methodology Framework

Geoscientists, hazardous waste managers and other professionals should recognize the importance of incorporating elements of risk assessment with life-cycle assessment of industries. But until now this development has been found to be ignored by industry owners that ultimately cause industrial risk in proximity areas. The industrial risk levels varies considerably according to types of industry for example risk from nuclear power plant is extremely severe than risk from brick factory. Thus, a methodological framework to estimate industrial risks varies from a general approach to sophisticated computer modelling for the explanations of methods and descriptions of analysis in industrial processes and resultant risk consequences. Furthermore, industrial life-cycle assessment experts and risk assessment scientists need to be well communicated to identify and evaluate the major hazards - adoption and implementation of procedures for normal and abnormal operation and the assessment of their likelihood and severity.

3.5.3 Methods

The locations of industries are taken into consideration for industrial risk assessment. Selections of method depend on the available data. Among the different methods of assessment, general approach of proximity analysis is to demarcate low, medium and high levels of risk with assigning proximity values for petrol pump are <100 m is high, 100–300 m is medium, >300 m is low; for brick factory are <50 m is high, 50–200 m is medium, >200 m is low.

3.5.4 Result

Industries are not present as the area is just in growing phase of development.

3.5.5 Discussion

Accidental hazards that can arise from the industry must be identified and necessary measures must be implemented to prevent such accidents and to limit their consequences for man and the environment. Thus, it is important to maintain appropriate distances between the location of industry and land use development for avoiding the dangerous phenomenon like dispersion, fire or explosion or noise. There are no industries in this area at present and therefore, the area lies in low industrial risk.

The industrial risk can be mitigated by making fence to avoid noise and dust pollution in the surrounding area. Appropriate drainage can reduce soil and water pollution. Reducing high emission of smoke is helpful to control air pollution.

3.6 Soil Erosion Risk

The displacement of the upper layer of soil refers as Soil Erosion. Soil Erosion can also be defined as one of the form of soil degradation and it is considered a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing a serious loss of topsoil.

3.6.1 Data

Present Land Use, Soil Texture, Geology, Slope and Rainfall data were the main source of data for the study. They are as:

Table 3-8: Parameter and source of data.

S.N.	Parameter	Source
1.	Present Land Use Data	Land use Database 2077/078
2.	Soil Texture Data	Land Use Database 2077/078
3.	Geology Data	Land Use Database 2077/078
4.	Slope Data	Derived from DEM prepared from Survey Department provided data
5.	Rainfall Data	Department of Hydrology and meteorology (DHM)

3.6.2 General Approach and Methodology Framework

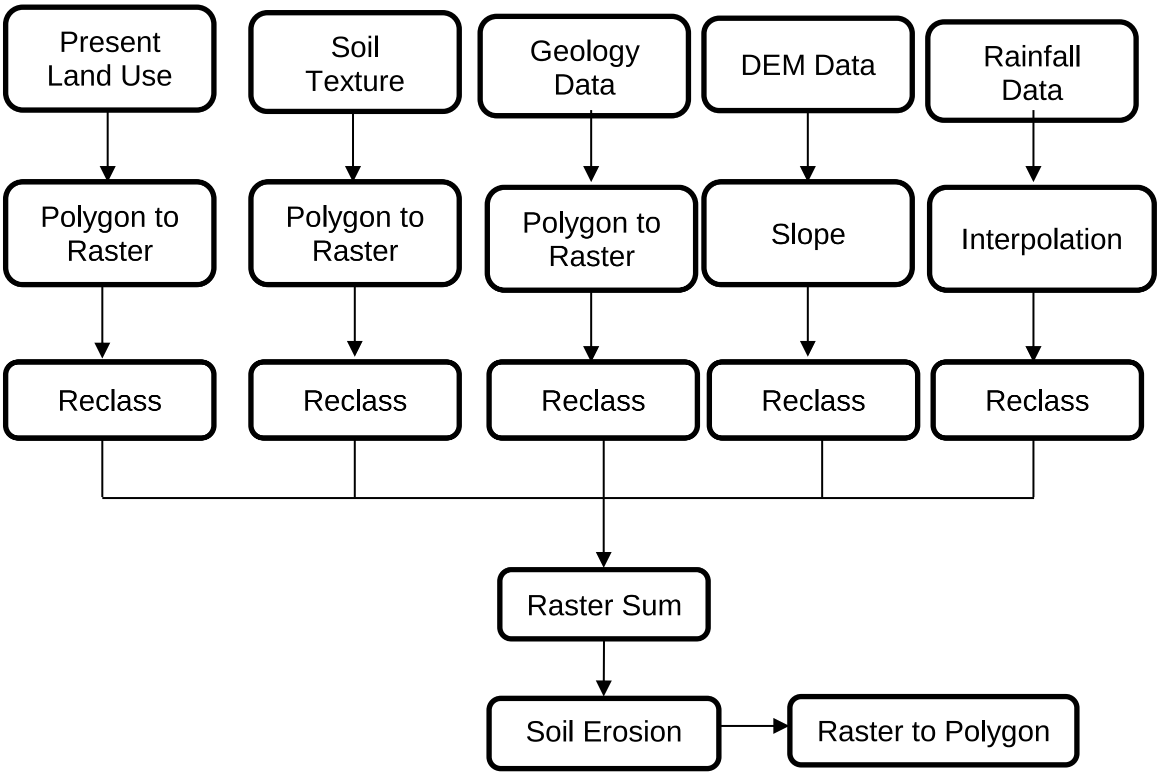


Figure 3-15: Methodology Framework for Soil Erosion Methods.

With the available data soil erosion mapping was done. Initially the vector data (Present Land use Data, Soil Texture Data and Geology Data) were converted into the raster file. On the very time, slope was prepared from the available DEM and the secondary rainfall data was clipped for the project area.

Once the raster file for all the above-mentioned data has been prepared, reclassification based on the weightage has been done for the entire raster file. Raster sum has of all the re-class file has been performed obtain the final soil erosion map. Finally, the soil erosion map was converted from raster to polygon to get the vector data of the soil erosion.

Table 3-9: Parameters and rating values.

S.N.	Parameters	Categories	Weightage Value
1.	Present Land Use Data	Agriculture	12
		Built Up Area	4
		Water Body	4
		Forest	16
		Others	16
2.	Soil Texture Data	Clay Loam	5
		Loam	10
		Loamy Sand	20
		Sand	20
		Sandy Clay	20
		Sandy Clay Loam	15
		Sandy Loam	15
		Silty Clay	5
		Silty Clay Loam	5
		Silty Loam	10
		Clay	5
		Silt	10
3.	Geology Data	BH	8
		BU	12
		DA	8
		GH	12
		GL	8
		GN	4
		GP	8
		GR	12
		HM	4
		HX	6
		KH	8
		KK	8
		KN	8
		KS	8
		LK	12
		LS	8
		ME	6
		MP	8
		MS	12
		NA	12
		ND	8
		OGR	8
		PH	8
		PZ	6
		RM	8
		SB	12
		SG	4
		SI	12
		SL	8
		SN	12

S.N.	Parameters	Categories	Weightage Value
		SR	8
		ST	8
		SW	16
		SY	8
		TN1	8
		TN2	8
		TN3	12
		US	8
4.	Slope	<15	6
		15-30	12
		30-45	18
		>45	24
5.	Rainfall	<500	6
		500-650	12
		650-800	18
		>800	24

3.6.3 Result

The area is in considerable risk of soil erosion due to sloping lands during rainy season. The result showed that the area with 9.09% is high, 49.97% is medium, and 40.94% low risk levels (Figure 3-16). Table 3-10 shows the statistics of soil erosion risk in terms of land use.

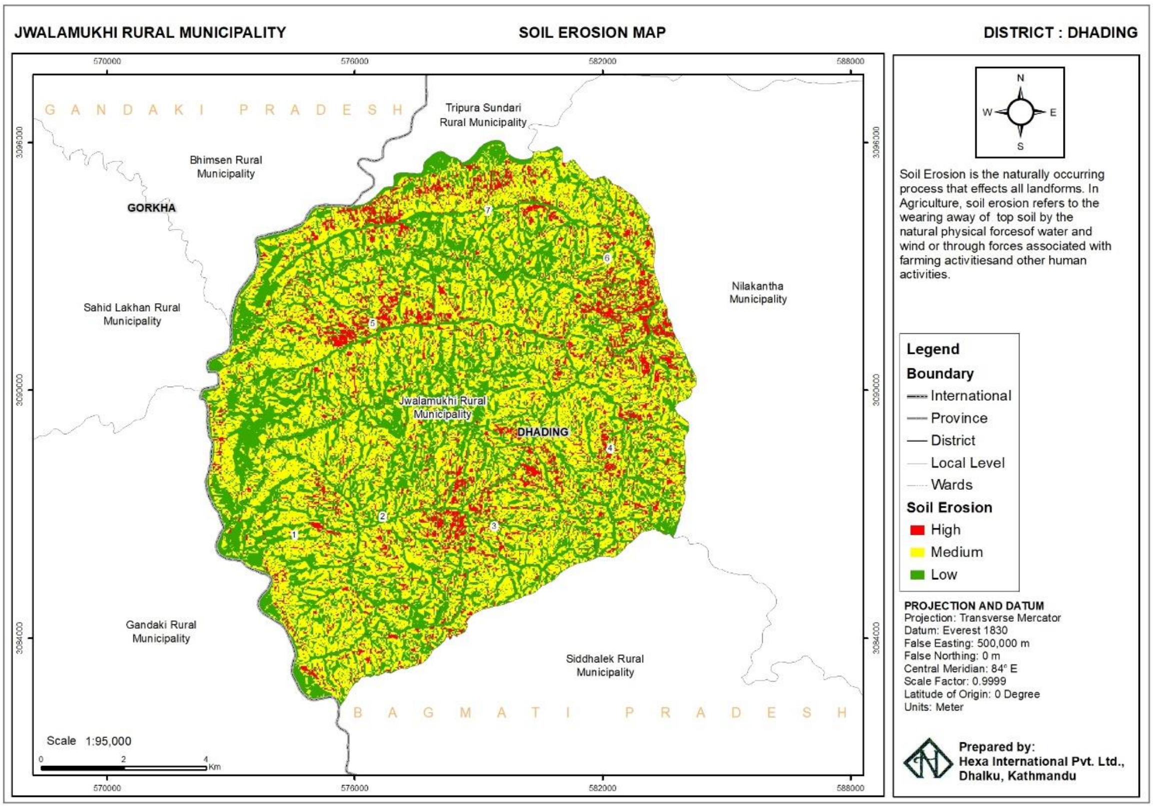


Figure 3-16: Soil Erosion Risk Map of Study Area.

Table 3-10: Statistics of soil erosion risk in terms of land use.

S.N.	Land Use	Area (ha)			
		High	Medium	Low	Total
1.	Agriculture	689.81	2823.38	2129.35	5642.54
2.	Residential	144.28	159.56	239.14	542.97
3.	Commercial	1.42	0.73	1.09	3.24
4.	Industrial	0.00	0.00	0.00	0.00
5.	Mines and Minerals	0.00	0.00	0.00	0.00
6.	Forest	165.39	2568.80	2045.83	4780.03
7.	Riverine, stream, lake and marsh	2.78	38.66	142.98	184.42
8.	Public Service	22.61	49.43	63.07	135.11
9.	Cultural and Archeological	0.30	0.37	0.64	1.31
10.	Others	0.00	0.00	0.00	0.00
	Grand Total	1026.59	5640.93	4622.10	11289.62

3.6.4 Discussion

From the final output, it shows that the project area has suffered from huge soil loss. Several factors leads to the soil erosion, which can be bad agricultural practices, human encroachment into vegetated areas, increasing population pressure and lack of awareness.

3.7 Other Risk in the study area

Other risk in the area can be due to high tension line (HTL) and Glacial Lake Outburst Flood (GLOF). The HTL passes through the region may produce electromagnetic field with causing health hazard and abnormal functionality of equipment. The effect of high tension line should be minimized by avoiding of settlement or utilities within the influence zone on either side from the central line. Prehistoric record of GLOF event affected zones along the river course is potential for future risk.

Health Institutional Waste: The risk of health care waste is always from the infectious component, which can be transmitted as result of improper management of health care waste. Among the various types waste management, local or conventional type of options are in practice. During field survey, it is found that this rural municipality partly sorts out various wastes depending on material properties whether they are risky to human health or surrounding environment. According to the WHO estimation, among the total amount of health care waste (HCW) generated, 80% is general HCW, 15% is pathological waste and infectious waste,1% is sharp waste,3% is chemical or pharmaceutical waste and less than1% special waste such as radioactive or cytotoxic waste, pressurized container or broken thermometer and used batteries. Currently available waste treatment options have various capabilities and limitations. As technology changes, HCFs should evaluate treatment alternatives for their safety, effectiveness, environmental impacts, costs and compliance with country requirements. HCW can be treated and disposed through the various techniques: biological procedure, Autoclave, Chemical disinfection, Encapsulation, Sanitary landfill, Burial, Septic/concrete vault, Incineration etc.

CHAPTER 4 : RISK IN THE STUDY AREA

4.1 Existing risk in the study area

There are existing risks in the area which are due to landslide, flood, soil erosion and fire. Flood risk is mainly in rainy season and fire risk is during hot and dry season. The higher elevated hill-slope of this region is susceptible to landslide risk.

4.2 Potential risk in the study area

Potential risk in the study area can be due to either flood or earthquake or fire or landslide or soil erosion etc. A composite map which combining all potential risk in the area is shown in Figure 4-1. Fire risk can be from forest whereas landslide risk is from sloping land with weak geology. Occurrence of landslides and return period of flood is shorter in comparison to catastrophic earthquake (ranges from 80 to 100 years per cycle) which is inferred from past historic earthquake events of 1933, 1934, and 2015 but the 2015 Gorkha Earthquake did not release all stored energy because it happened without forming the rupture surface indicating that geological hell of Nepal earthquake may not be over. Therefore, not only in this study area, all municipalities/rural municipalities in the Nepal must always get ready to face with anytime earthquake risk that may strike in future.

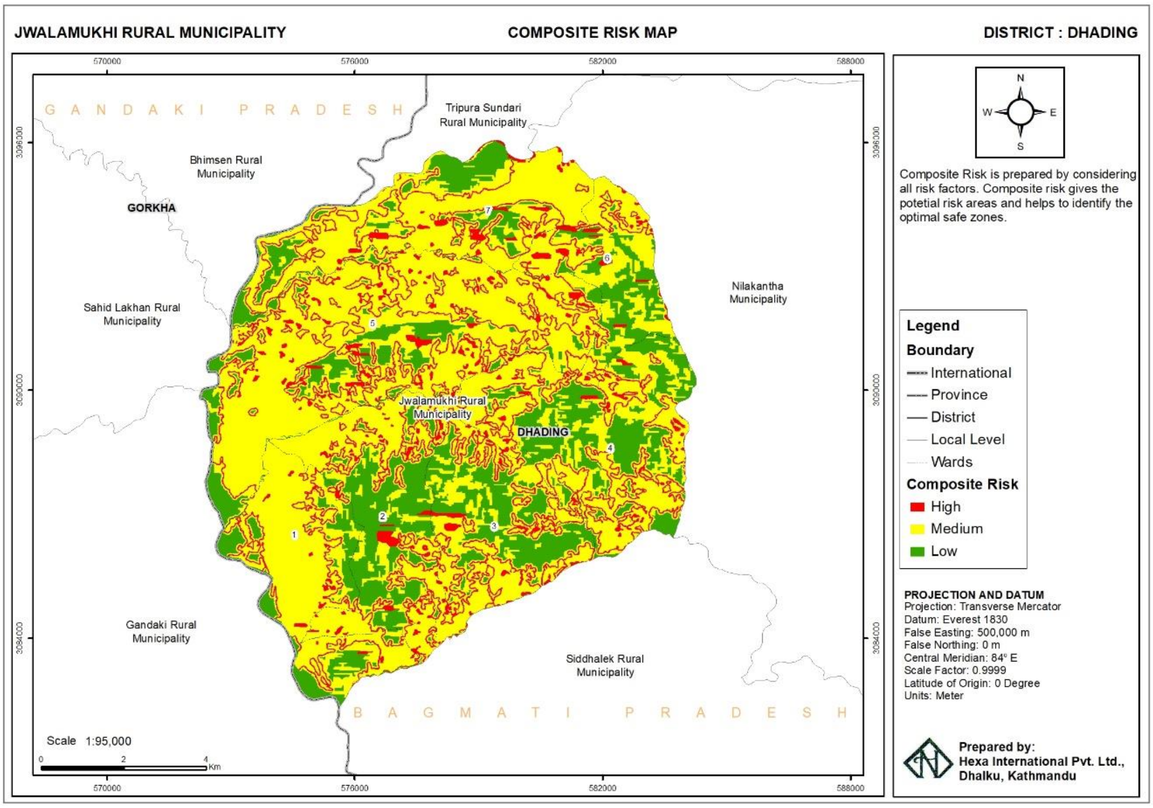


Figure 4-1: Composite Risk Map of the Study Area.

4.3 Risk Data Model

There exist diversities in risk type. Land use mapping focuses different types of risk such as fire, flood, landslide, seismic, industrial etc. Similarly, from the view of proximity of occurrences, risk can be hieratically classified as different level: such as High, Medium and Low. Different levels have been given to the risk type and its level (Table 4-1).

Table 4-1: Description of risk data model.

Description	Level1	Level2
Risk theme types	Risk type	Risk Level
Flood Risk	Flood Risk	High, medium, low
Fire	Fire	High, medium, low
Seismic	Seismic	High, medium, low
Landslide	Landslide	High, medium, low
Industrial Risk	Industrial Risk	High, medium, low
Soil Erosion	Soil Erosion	High, medium, low
Other	Other	High, medium, low

4.4 Risk GIS Database

Database is prepared for different types of risk which are found in this study area. The database consists of different layers of input data and series of computed layers with defining their spatial entities and attributes as shown in the Table 4-2.

Table 4-2: Description of risk GIS Database.

S.N.	Attribute	Data	Description	Remarks
1	SHAPE	Geometry	Geometric Object type	
2	OBJECTID	Long	Unique Object ID	
3	RiskID	Long	Unique ID of different type of risk	
4	RiskType	String	Different type of risks	
5	RiskLvl	String	Different level of risks	

CHAPTER 5 : CONCLUSIONS

5.1 Conclusions

Risk evaluation for land use planning is very useful because it has verified the area for existing and potential risks that may happen in future. The area is suitable for cultivation that may not be suitable from the hazardous conditions, for example flood prone areas might be allowed for agricultural use but not for human settlements. Landslide, flood, soil erosion and fire risks are often major risk in the area and earthquake can be any time risk in the future.

Risk zoning map provides guidance in formulating suitable risk reduction policies and adopting suitable risk reduction measures because the disaster risk assessment results form the basis for understanding implications of current and future land use management and development. Moreover, it can provide a wide array of options for land use planning by locating development activities in low risk zone.

5.2 Recommendations

Disaster risk reduction and land use planning is both multi-disciplinary arena; they require a multi-stakeholder participation. Within government, both are collaborative endeavors that need to be undertaken together by various concerned authorities but combined efforts of suitability assessment for land use planning from agricultural and hazardous point of view are not well matched in Nepal. It is therefore important for a government to design a multi-stakeholder committee to ensure the incorporating of disaster risk information in land use planning. Furthermore, hazard and risk assessment should be done by conducting rigorous fieldworks to obtain various required parameter from particular area for analysis. Adaptability and mitigation measures pointed out in different section of individual risk must be considered.

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FINAL REPORT

Soil Report

Jwalamukhi Rural Municipality of Dhading District

Package No.: TSLUMD/CS/QCBS/01/07/2077/078

Executive Summary

Systematic land use planning is an effective to formulize national level land policy for effective utilization of land according to its productive capacity and usefulness. Soil survey aimed to identify such land based on several observed and measured parameters. Soil classification is one of the important parameters helpful to classify land that reflects a soil quality indicator. 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. A total of 32 soil pits were taken in the field representing varied micro topography. Soil Sample pits covering all the units were dug based on the interpreted soil map, topographical map, ZY3 Satellite imagery for determination of soil profile. Soil classification of the area was done based on the USDA soil taxonomy and soil orders found in the region are Entisols (3.57 %), Ultisols (4.97%) and Inceptisols (89.69%). In the context of soil nutrient status, the study area has pH with very strongly acidic to very high alkaline. Majority of the soil are silty clay (37.80%), silty loam (26.61%) and clay loam (17.55%). There is low to high level of organic matter present in the study area with more proportion of land (73.20%) under medium to high range of organic matter. Nitrogen content in the study area ranges from low to high level with medium to high level of Nitrogen (79.86%) was major proportion of the area. Low to high level of phosphorous content was found in the study area with the dominance of low (69.06%) phosphorous level. Potassium level in the study area is very low to very high. Around 76.65% land have very low to low level of potassium. Based on the nutrient status of the Jwalamukhi rural municipality wide range of crop can be grown in majority of the area but special attention should be given in addition of organic manures, chemical fertilizer and other different biofertilizers. Moreover, soil conservation measures and integrated nutrient management strategies should be followed for the conservation and management of soil.

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CHAPTER 1 : INTRODUCTION

1.1 Background and Rationale

Sustainable improvement in food production is a key challenge for feeding rapidly increasing population in future (FAO, 2017). For the states, it is important to device policies together with incentives to the community people to achieve increase in food production in the framework of sustainability i.e. in the process of food production, ecological balances are kept in due priority (Tilman et al., 2002) and we have no viable alternative other than to intensify food production in an environmentally-friendly manner. This is only possible through the appropriate land-use planning.

Land is one of the important and precious, natural resources of the earth. 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). Land use decision requires all the land and associated information including the local people and the all forms of services at spatial scale. Land use planning begins with getting site-specific information on particular area of land that includes present land use practices and assessing best possible options. Since land and climate related properties are constantly changing, Periodical assessment of the land suitability is key for their future use. Land use planning begins with the systematic gathering of soils data, and developing information to provide a basis for policy direction required for sustainable land-use in the future. This is carried out through soil survey in which a comprehensive collection, interpretation and implementation of soils data is undertaken. Soil survey provides a strong scientific tool to describe soils in a given area, classify them, locate boundaries on the map, and help make predictions about the responses of individual soils to specific management practices.

Land degradation is one of the greatest challenges in Nepal (Karkee, 2004), and is accelerated by a host both natural and anthropogenic factors including steep topography, intense rainfall during monsoon, high seismicity, mismanagement of land, overgrazing, deforestation etc. Soil erosion, soil, water and air pollution, landslides and flooding have been common phenomenon across the different parts of the country. Poverty in terms of income and employment, education and information, health and other socio-economic problems have been making the land degradation problems more complex (Singh, 2007) that is unique in Nepal. Food safety is threatened therefore; an improvement is urgently needed in management practices so that soils quality is maintained for sustaining diverse cropping systems and productivities. This is where lies the value of soil survey in documenting detailed soil information based on ground realities and thus helps identifying its limitations and suitability for various productive purposes. To address such land degradation problems, land–use planning is utmost for making the best use of the limited land resources. The country have attempted for balanced use of country's existing natural resources in the past through different policies and national planning efforts. 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. Proper land-use planning is a pre-condition to address all the problems associated with the food problems that the human-kind is currently facing at global level. Land-use planning can be applied at three broad levels: national, Province 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 database on land use, land system and land capability which were produced by Land Resource Mapping Project (LRMP, 1983/84). 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 databases on the land resources of the country. In the first phase, the National Land Use Project of Nepal (NLUP) 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 Bhaktpur municipalities at larger scales. Finally, NLUP was mandated to prepare land resource maps of Village Development Committees (VDCs) of Nepal for local level planning through outsourcing modality. Up to fiscal year 2074/0754, NLUP had completed preparation of land resource maps and database for 1404 VDC/ Rural Municipality (369 municipalities/Rural municipalities) of 20 districts of terai region and some VDCs/ Municipalities of Kathmandu, Kavreplanchok Lalitpur, Gulmi, Tanahu, Palpa, Syangja and Illam District. These digital database includes VDC/Municipalities level present land use, soil, land capability, land use zoning, cadastral layers and VDCs/ Municipalities profile with bio-physical and socio-economic information. The Government of Nepal has approved the National Land Use Policy, 2069 on the 4th Baishakh of 2069, it has intended to manage land use according to land use policy of the government of Nepal and had outlined six zones such as Agricultural area, Residential area, Commercial area, Industrial area, Forest area and Public use area. However, based on the scenario developed after the major earthquake of 12th of Baishakh 2072, Government of Nepal issued the Land use policy 2072 had out lined the eleven-land use classification: (a) Agricultural Zone (b) Residential Zone (c) Commercial Zone (d) Industrial Zone (e) Mines and Minerals Zone (f) Cultural and Archaeological Zone (g) River and Lake-Reservoir Zones (h) Forest Zones (i) Public Use and Open Space Zone (j) Building Materials (Stone, Sands, Concrete) Excavation Zone (k) Other Zones as specified as per necessity

Topographical Survey and Land Use Management Division (TSLUMD) at present endeavours on the same to maintain National Land Use Policy 2072 and as mandated by the Land use act 2076 at the same time with the strategy of completion of land use mapping within 1 year as directed by the Land use act 2076. Land Use classification should be carried on the basis of Land Use Act, 2076. In the context stated above, the TSLUMD, Survey Department of Government of Nepal commissioned the Hexa International Pvt. Ltd. Dhalku, Kathmandu to pursue the project entitled Preparation of Rural Municipality/Municipality level land resource maps, databases and reports) of Dhading district including Jwalamukhi Rural Municipality (Rural Rural Municipality) under package no. TSLUMD/CS/QCBS/01/07/077/2078 .

The TSLUMD envisaged the following points as the basis for the preparation of soil maps of the concerned Rural Municipality:

- Preparation of soil maps of the Rural Municipality/Municipality for formulating land use plan according to the quality of soil in order to designate of Agricultural, Residential, Commercial, Industrial, Forest, Public Use, Riverine Stream Lake and Marsh, Cultural and Archaeological Mines and Minerals, and other area as per Land Use Act 2076.
- Identification of the residential and other non-agricultural areas within the inferior soil quality areas.
- Promotion of agricultural productivity as per soil quality in comparatively advantageous sub-areas.
- Conservation of non-agricultural areas including forest, shrub, rivers and rivulets and wetlands for sustainable development.

1.2 Objectives of the Study

The main objective of the study was to prepare Soil Maps, GIS database and Reports for the selected Rural Municipality/Municipality at 1:10,000 scales. The specific objectives, however, were:

- Prepare Geological Maps of the selected Rural Municipality/Municipality at 1:10000 scale. Identify different geological formation based on the field visit and taking the reference of existing geological maps.
- Prepare Land System Maps for the selected Rural Municipality/Municipality at 1:10000 scales. Sub divide the land system maps into different land units as per the specification supplied.
- Prepare maps of sample pits location covering land unit/land type of the RURAL MUNICIPALITY/MUNICIPALITY with coordinate points to be identified in the field.
- Carry out extensive field survey for field verification of land system maps and to collect soil samples from the pits as approved by TSLUMD and fill up of the soil profile description form.
- Analyze the physio-chemical characteristics of soils including nutrients based on the field survey as well as detailed Laboratory test of the soil samples
- Prepare Soil Maps from order to family level following United States Department of Agriculture & Soil Conservation (USDA) system for the selected Rural Municipality/Municipality at 1:10000 scales.
- Populate the given database with the analyzed, collected and lab supplied soil nutritional and other parameters.
- Discuss the accuracy, reliability and consistencies of data.

- Prepare reports describing methodology, distribution of different soil types and discuss the soil distribution of the area under study.
- Prepare A4 size Maps of N, P, K, OM, Texture, and pH to attach in the soil reports of the Rural Municipality/Municipality.

1.3 Study Area

Jwalamukhi rural municipality is in mid-western part of the Dhading District in Bagmati Province of Nepal. The rural municipality was formed on 10th March 2017 (2073/11/27) by merging four VDC units i.e. Khari, Dhola, Nepal, Maidi and Chainpur. Administratively, it is divided into seven wards. Politically, the rural municipality is placed under constituency no 2 for federal parliament and 2 (ka) for provincial parliament.

Jwalamukhi rural municipality shares border with two municipalities each in Dhading and Gorkha District. In the Dhading district, the rural municipality shares its border with Tripurasundari, Neelkantha and Siddhalek. Additionally, Shahid lakhan, Bhimsen and Gandaki municipality of Gorkha district are connected to the municipality. Geographically it extends from 84º 44' 3.07'' E to 84º 51' 22.92'' E and 27º 51' 25.51'' N to 27º 58' 52.45'' N. The total area of the rural municipality is 112.90 sq.km with the altitudinal elevation ranging from 333.84 m to 1343.14 m (Figure 1-1).

As of census 2011, the population of the rural municipality is 32922. The total population of this Rural Municipality is 23966 of which male population is 10573 (44.1%) and female population is 13393 (55.9%). The total households are 5730 and the average family size of the Rural Municipality is 4.2 The Ward wise population distribution of the Rural Municipality has presented in table 1-1.

Table 1-2: Population distribution by ward and gender

Ward No.	Household	Population						
		Total	Male	Female	Male %	Female %	Household Size	Ward
1	729	3,285	1,472	1,813	44.8%	55.2%	4.5	13.7%
2	693	2,796	1,275	1,521	45.6%	54.4%	4.0	11.7%
3	745	3,122	1,363	1,759	43.7%	56.3%	4.2	13.0%
4	998	4,033	1,772	2,261	43.9%	56.1%	4.0	16.8%
5	1,051	4,381	1,944	2,437	44.4%	55.6%	4.2	18.3%
6	802	3,439	1,477	1,962	42.9%	57.1%	4.3	14.3%
7	712	2,910	1,270	1,640	43.6%	56.4%	4.1	12.1%
Total	5,730	23,966	10,573	13,393	44.1%	55.9%	4.2	100.0%

Source: CBS 2011 / Updated 2018

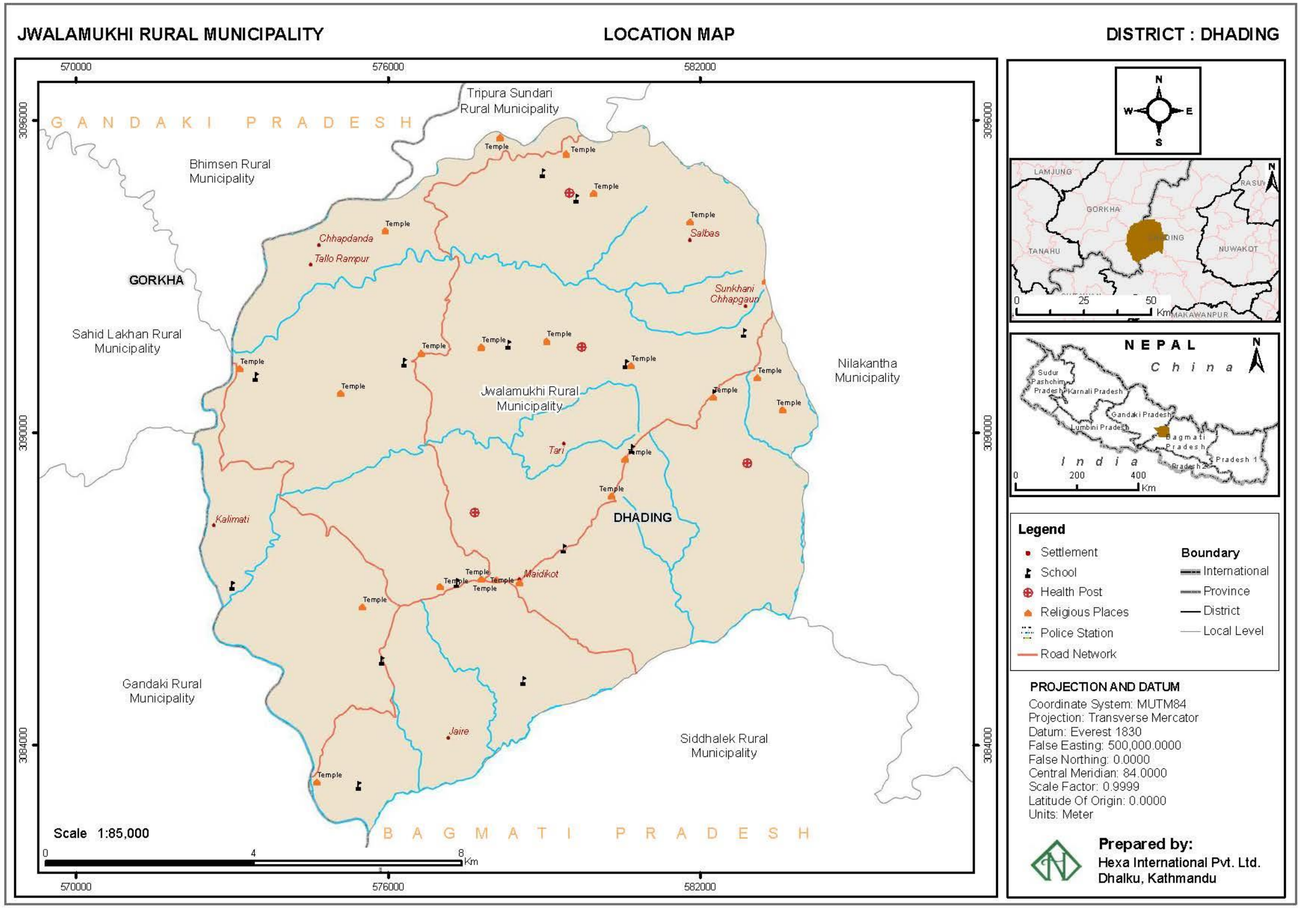

Figure 1-1: Location map of the study area

Table 1-3 shows that the ward wise population distribution pattern varies across the rural municipality. The highest population is in ward 5 (18.3%) % whereas the ward no 2 have lowest percentage i.e. of population 11.7 %. Similarly, Ward 1 have highest household size i.e. 4.5 and the ward no 2 and 4 have the lowest household size i.e. 4.0.

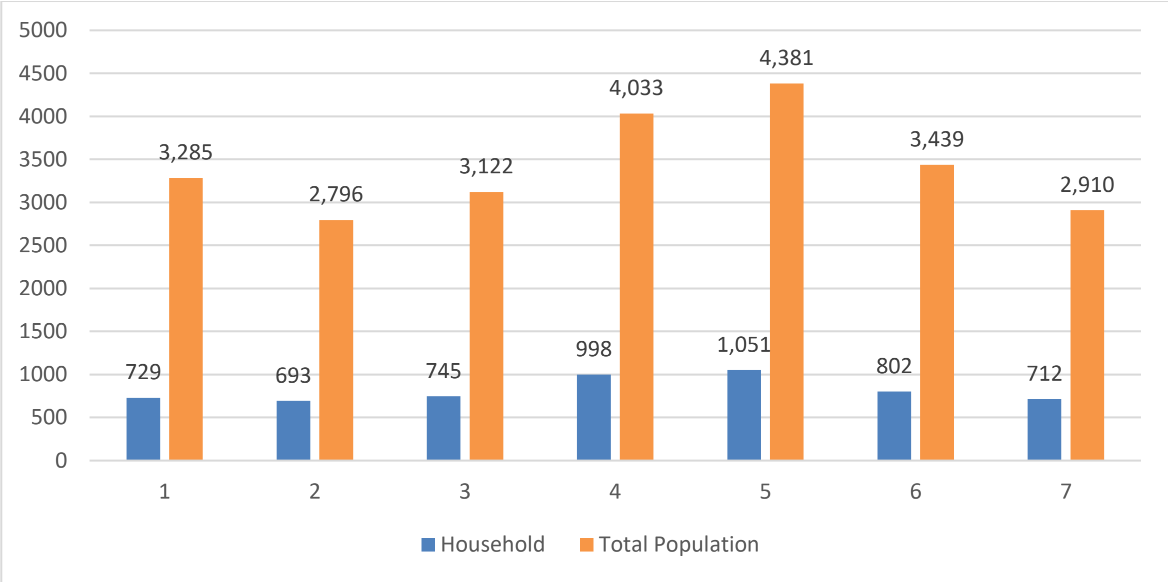

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Figure 1-2: Population distribution by ward in Jwalamukhi Rural Municipality

CHAPTER 2 : - BIO-PHYSICAL CONDITIONS OF THE STUDY AREA

2.1 Physiography

The physical condition, geological structure, topographic features, and visible terrain indicate the Jwalamukhi rural Municipality falls under midlands. The foundation of the muncipality is made up of single formation i.e., Ranimatta. The Ranimatta covers 100% of the land. 15 % of the land i.e., 17677 ha, is south facing and 76 % of land has slope greater than 15 degrees.

This has the elevation range from 333 to 1343 m. Topography of the varies from river basin and tar and low land with gentle slope to hills, ridge, middle hills, and hilltop and high hills with steep slope. The relief features of the appear in complex form from lowland with gentle slope to hills and hillocks with steep slope. Due to the relief feature variations number of micro topographic features are also apparent in the terms of shaded relief, slope gradient, and digital elevation.

2.2 Elevation

Jwalamukhi rural municipality is located midlands and its elevation ranges from 333 to 1343 m. The region is geologically fragile and geomorphologically unstable and overly sensitive in terms of natural hazards like landslides, soil erosion and watershed degradation. Major land-cover in the constitutes the rocky topography, hillocks, hilltops, hills, F ridges and river valley. Thins soils distributed in this region are highly susceptible to erosion along the active streams and gullies.

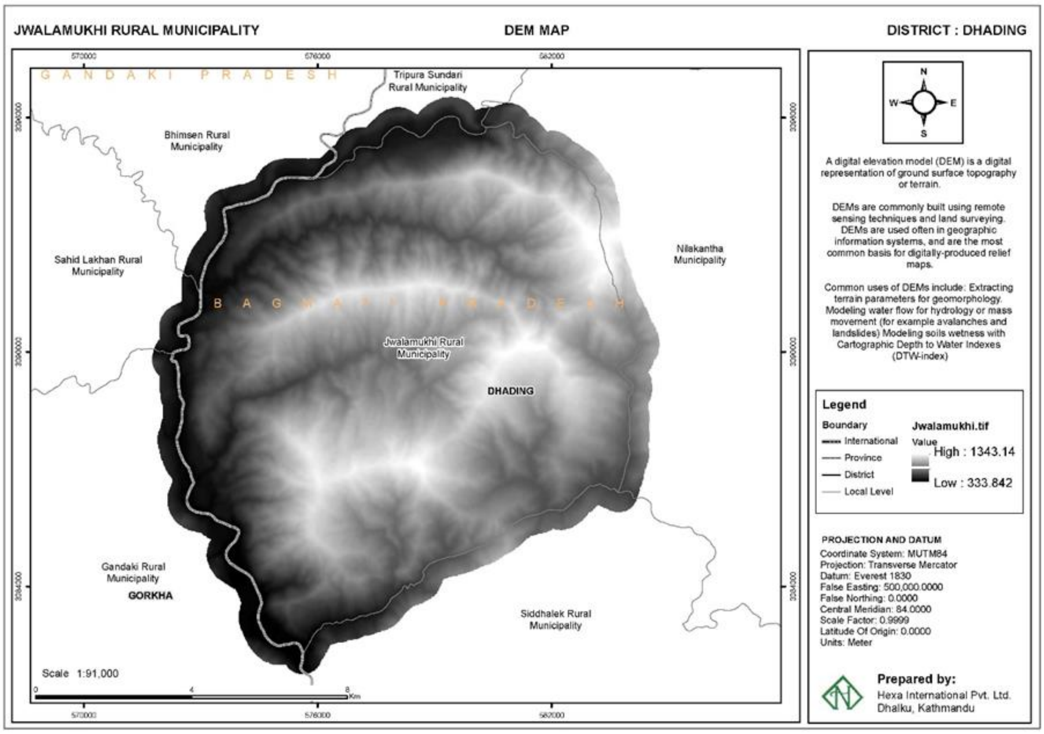

Figure 2-1: DEM Map of Study Area

2.3 Slope

The study consists of mountains and tars and mostly they have <7 to >30-degree slope. About 82.87% lands are moderately to steeply sloping (5 to 30 degree), nearly 14% are steeply to very steeply sloping (>30 degree), and small fraction (3.08%) of the lands are relatively flat to gently sloping (1 to 5 degree). The steeper slopes of the lands in the Jwalamukhi Rural has been presented in Figure 2-2 are less stable, all other factors being constant. The steeper the slope, the shallower the unconsolidated material on the slope, which is likely to be removed by erosion processes. Conversely, landscape on the gentle slopes is stable and hence the soil forming processes is relatively less hindered.

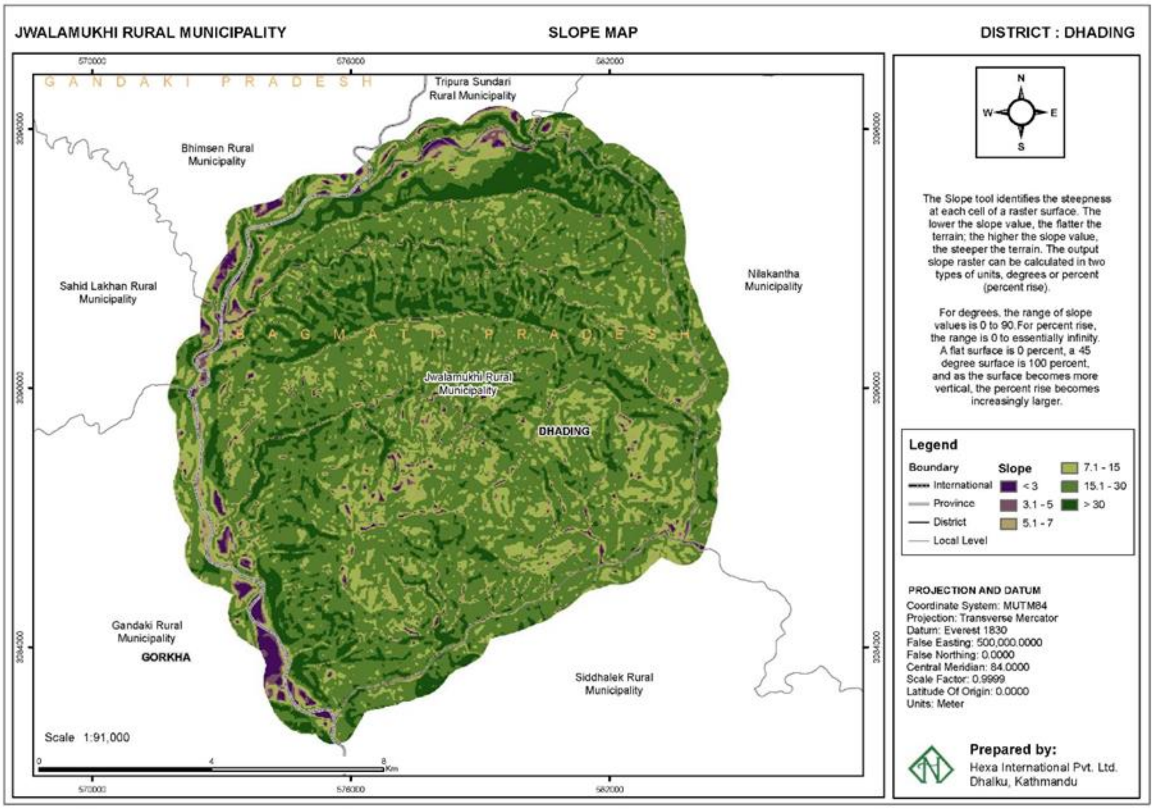

Figure 2-2: Slope Map of Study Area

2.4 Geology

Geology and landforms in Jwalamukhi Rural Municipality characterizes the rocks of Dailekh Subgroup which consists of Ranimatta Formation. Rocks are dipping towards south to southwest. A geological map is given in Figure 2-3 and geology of the area can be represented from Table 1-1. Lithology in the formation is given as:

Ranimatta Formation: Greenish grey gritty phyllites grit-stones with conglomerates and white massive quartzites in the upper parts

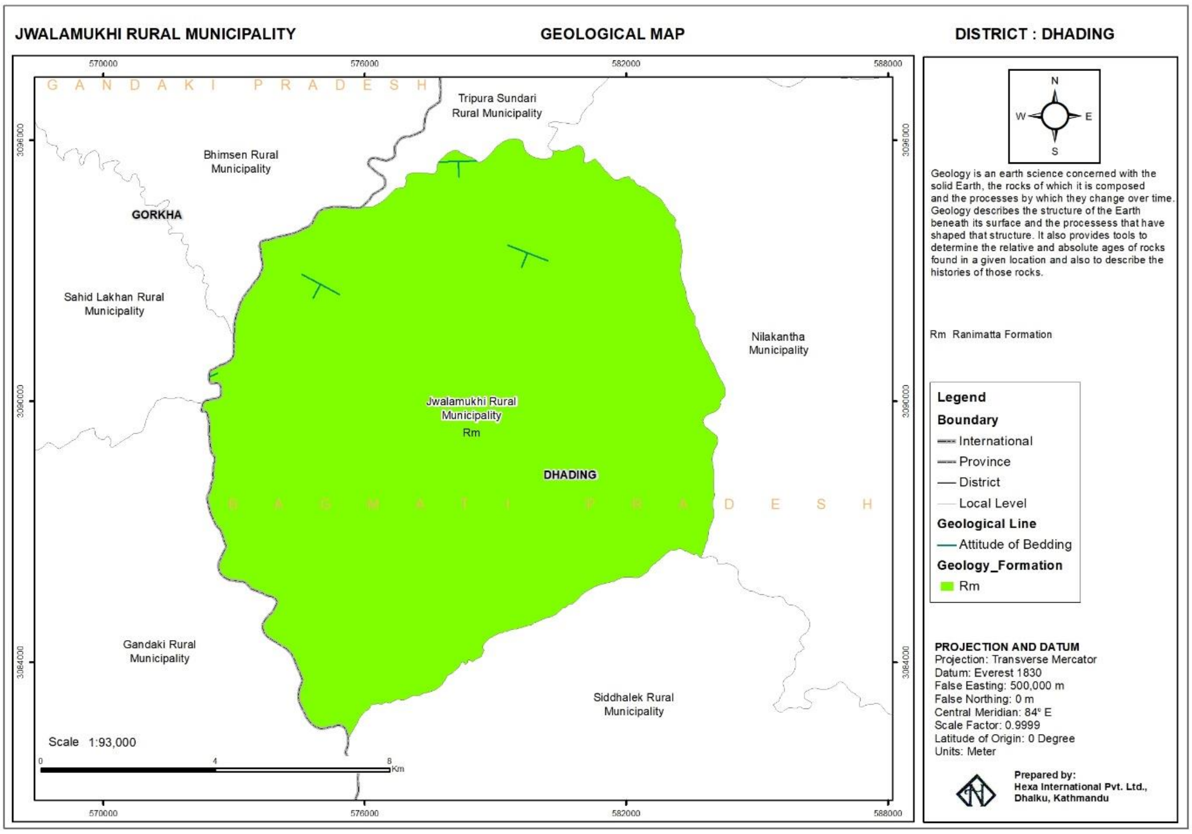

Figure 2-3: Geological Map of Study Area

Table 2-1: Geology (lithostratigraphy) of Dhading District. (Source: Department of Mines and Geology)

Zone	Group	Subgroup	Formation	Code	Rock types
QUATERNARY			Quaternary deposit	Q	Alluvium, boulders, gravel, sands, clays
LESSER HIMALAYA	Gneiss			Gn	Augen gneisses, banded gneisses
	Dadeldhura Group		Intrusive Granite	Gr	Biotite-tourmaline granites
	Basic rocks			Br	Metamorphosed gabbroic rocks
	Mid-land Group	Lakharpata Subgroup	Lakharpata Formation	Lk *(Rb)*	Fine-grained, light blue, grey limestones, dolomites with thin interactions of grey shales, white, pink dolomite limestones, purple quartizes, green shales at the top. Algal structure & stromatolites are present
			Syangja Formation	Sy	White pale orange pinkish or purplish or calcareous quartzites, quartzitic limestones intercalated with dark grey purple & green shales, strongly ripple marked quartzites at the base
			Sangram Formation	Sg	Black, dark grey to greenish grey shales with interaction of limestones & quartzites

Zone	Group	Subgroup	Formation	Code	Rock types
			Galyang Formation	Gl	Dark grey slates intercalated with thin grey calcareous slates & lamellae of carbonates. Thick beds of grey siliceous dolomites are found at place (Baitadi beds)
			Ghan Pokhara Formation	Gp *(Cr)*	Black to grey carbonaceous slates & green shales. Carbonates, white to grey compact dolomite & dolomitic limestones interbedded with shales beds
			Naudanda Formation	Nd	White massive fine to medium grained quartzites with ripple marks interbedded with green phyllites. Basic intrusions are noted
		Dailekh Subgroup	Ulleri Formation	Ul	Augen gneisses muscovite biotite gneisses feldspathic schists
			Ranimatta Formation	Rm	Grey greenish grey gritty phyllites grit-stones with conglomerates & white massive quartzites in the upper parts. Basic intrusions are abundant
	Kathmandu Group	Phulchoki Subgroup	Chitlang Formation	Ch	Dark slates with white quartzites at the base. Impure limestones & ferruginous beds with trilobites
			Chandragiri Formation	Ca	Light fine grained crystalline limestones partly siliceous thick to massively bedded white quartzites in upper parts. Wavy limestones contain Ordovician schinoderms
			Sopyang Formation	So	Augen gneisses muscovite biotite gneisses feldspathic schists
			Tistung Formation	Ti	Dark grey slates intercalated with thin grey calcareous slates & lamellae of carbonates. Thick beds of grey siliceous dolomites are found at place (Baitadi beds)
		Bhimphedi Subgroup	Markhu Formation	Mr	Massive coarse to medium grained, crystalline marble changing northward to dark fine biotites schists interbedded with impure marbles & quartzites, stromatolites are found
			Tawa Khola Formation	Ta	Coarse-grained dark grey garnetiferous muscovite biotite quartz schists interbedded with grayish impure quartzites pandrang quartzite member light green quartzites
			Udayapur Formation	Ud	Coarse-grained crystalline marbles with intercalated schists
			Sarung Khola Formation	Sk	Fine grained dark green grey biotite and quartzitic mica schists occasionally garnetiferous interbedded with impure strongly micaceous quartzites
			Maksang Formation	Mk	White fine grained quartzites cross bedded

Zone	Group	Subgroup	Formation	Code	Rock types
			Shiprin Khola Formation	Sp	Coarsely crystalline garnetiferous muscovite-biotite-quartz schists, quartzites, green chlorite schists at the base
			Undifferentiated Schist	Sh	Undifferentiated schists, quartzites gneisses and calcareous silicate rocks with various stages of migmatization

2.5 Streams and Canals

The drainage/hydrology of Jwalamukhi rural Municipality determined by its relief features and drainage pattern that consists of streams, Gads, and source points of water in the different watersheds of Municipality. Drainage system greatly varies from valley to steep mountain slopes and the drainage pattern is dendritic. Budhi Gandaki River is on western side of the Municipality. Besides many tributaries, there are other prominent streams such as Anderi Khola, Angtar Khola, Ankhu Khola, Bhalu Khola, Chhargandi Khola, Chisopani Khola, Chyandu Khola, Dhawa Khola, Gamnsur Khola, Gyalma Khola, Jyadul Khola, Kalopani Khola, Maste Khola, Pipaltar Khola, Sand Khola, Sang Khola etc. Gads have high volume of water with high velocity then streams so that all of the stream flow in the area of the which has great importance for irrigation, water supply. Several tributaries flow into chhargandi khola in center and ultimately to Budhi Gandaki. Due to the weak geological structure of the area and high speed with water velocity the drainage pattern caused to high landslide and riverbank cutting hazard prone area. Thus, the drainage pattern and hydrological condition of the rural municipality seems from north-east to south-west which governed by the existing watersheds of the municipality. Number of small streams meet together and confluence into their higher order streams and then into gads and flow to west south part of the district. The drainage pattern/hydrology of the has shown in Figure 2-4.

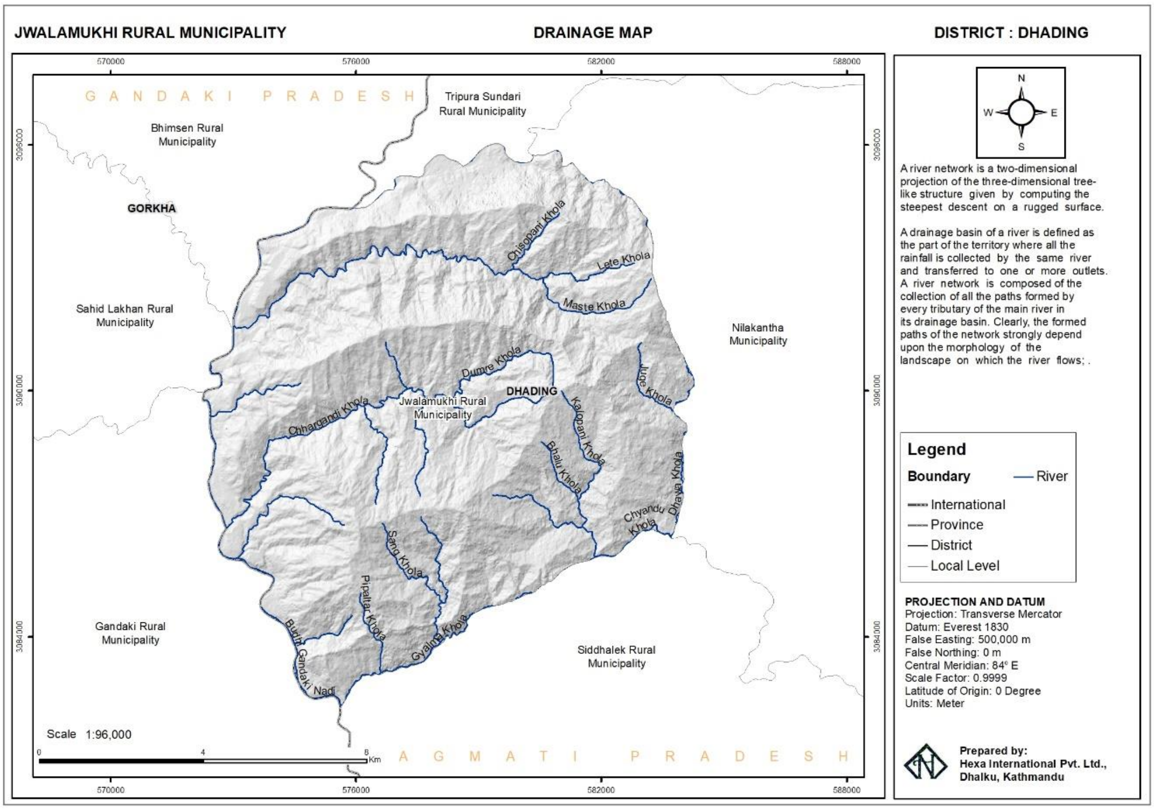

Figure 2-4: Drainage map of the study area

The drainage pattern and geological features of the indicate favourable conditions for the recharge capacity of the groundwater in the southern low-lying area. So, the hydro geological condition appears suit for irrigation and power production.

2.6 Climatic Condition

Rainfall data were analyzed in monthly and annual rainfall basis over the project area by surfer software and plot by kriging methods the spatial rainfall distribution present in the isohyet's method over the Dhading district. The spatial analysis result of 18 number stations in 7 nearest district annual rainfall (125 to 350 mm) received in the entire area of Dhading district. However, the observed temporal (1991-2014) annual average rainfall 1790 mm received in Dhading district, there is significantly decreasing order in Dhading station no.1005, which is closed with the Jwalamukhi Rural Municipality. Similarly, the temporal average maximum monthly rainfall 452 mm received in the month of July and the minimum monthly rainfall (6 mm) received in the month of November.

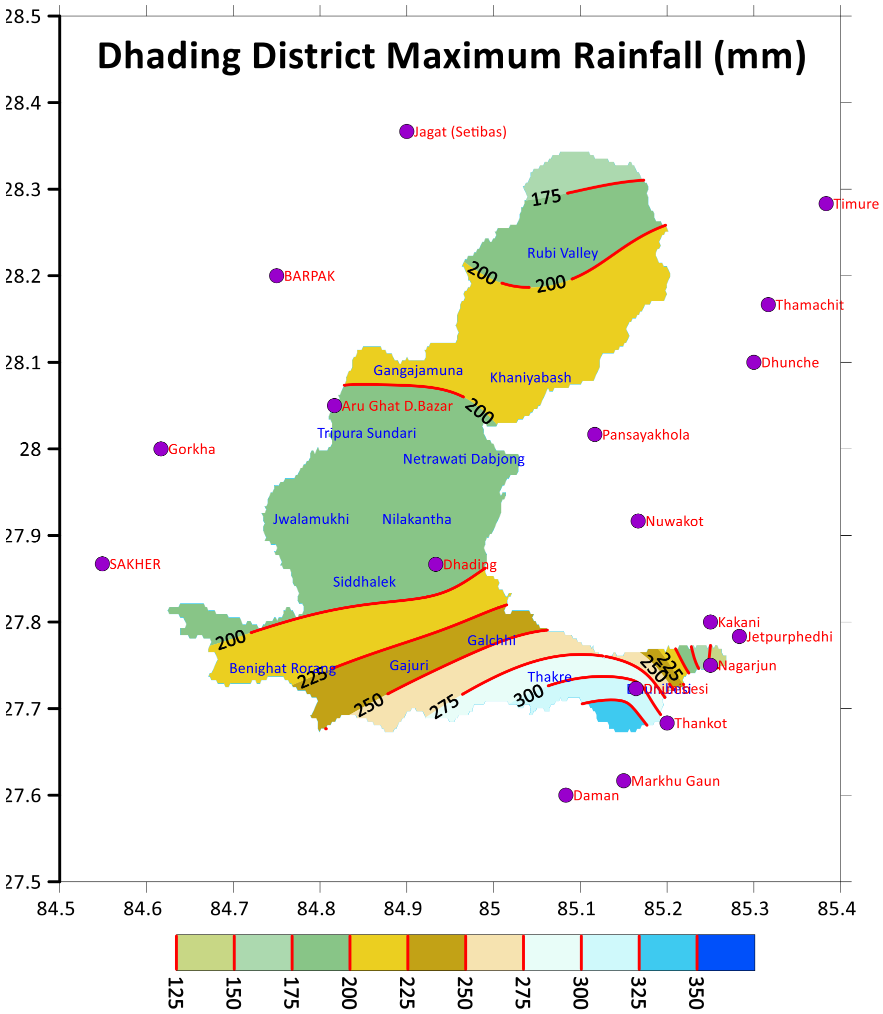

Figure 2-5: Spatial monthly maximum rainfall of Dhading district

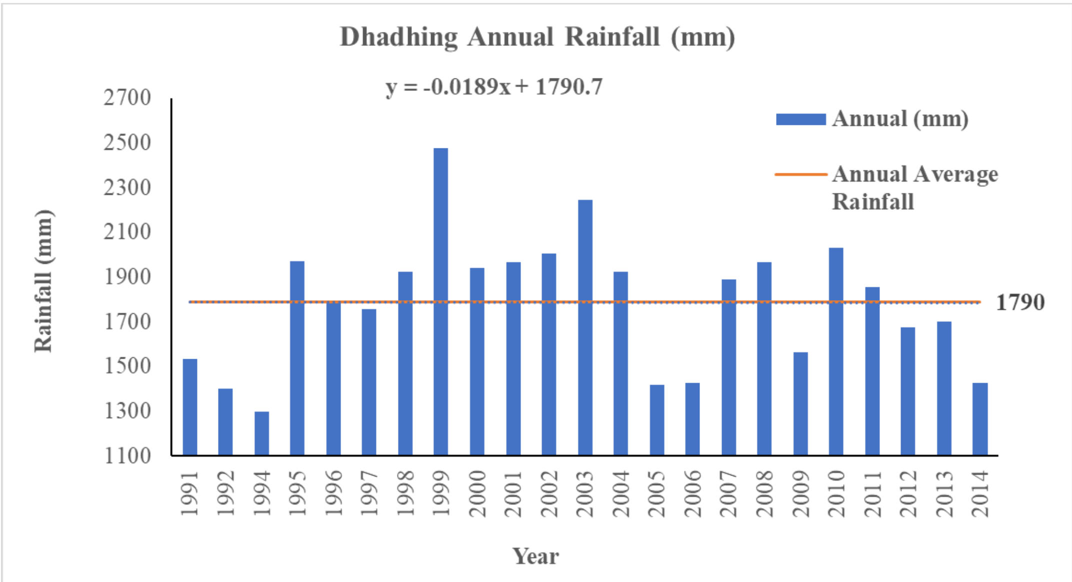

Figure 2-6: Annual average rainfall of Dhading District

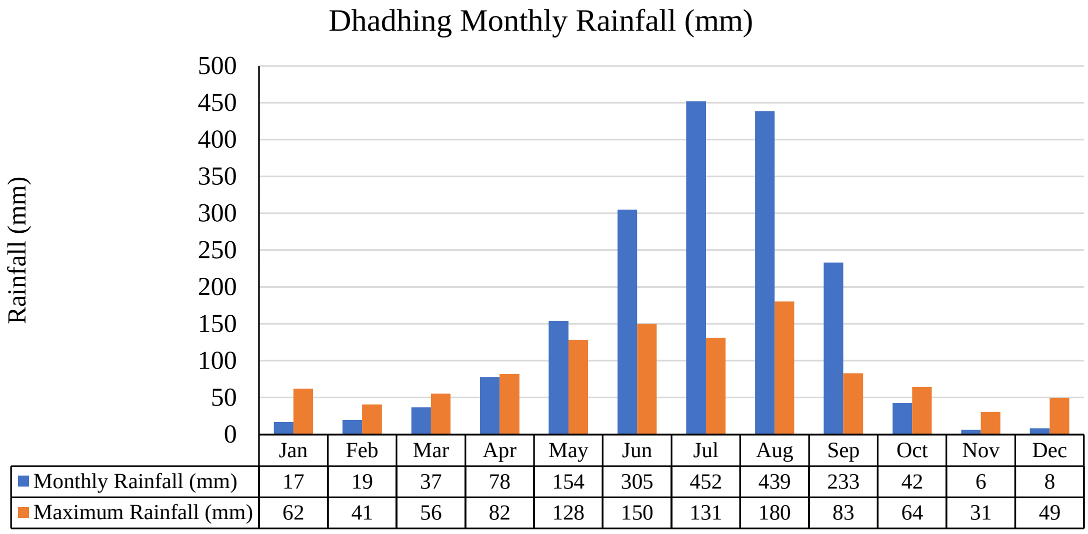

Figure 2-7: Temporal average monthly and maximum rainfall Dhading district

2.7 Vegetation/Land use-Land cover

Forest area that accounts for 42.34 percent of the total land use area of Jwalamukhi Rural Municipality is a gifted natural resource for the people of this area. Almost all of the forest available in this Rural Municipality is tropical in nature leaving only 0.01 percent of area for subtropical forest (Table 2-2).

Table 2-2: Forest Land Use at Classification Level 2

S.N.	Description	Area(ha)	Percentage
1	Sub-tropical	0.52	0.01
2	Tropical	4779.51	99.99
	Grand Total	**4780.03**	**100.00**

Field survey confirms that the alnus woods, pines trees, sals, and various hardwood trees are the dominant vegetation in the tropical region in this Rural Municipality. Also during field survey, it is noticed that some dwarf bamboo are available on the exposed ridge along with some twisted juniper on the dry slopes. At classification level 3, hardwood forest and mixed forest are the large area covering forest found in this rural municipality. As the Rural Municipality falls in the low hilly region, tropical forest contains primarily hardwood and mixed type of forest (Table 2-3).

Table 2-3: Categories of Forest land use at classification at Level 3

S.N.	Description	Area(ha)	Percentage
1	Bushes	310.68	6.50
2	Coniferous	22.03	0.46
3	Hardwood	3613.87	75.60
4	Mixed	833.45	17.44
	Grand Total	**4780.03**	**100.00**

Bushes which occupies only 6.50 percent are a plant community characterized by vegetation dominated by shrubs, often also including grasses, herbs and geophytes. Bushes and shrubs may either occur naturally or be the result of human activity. It may be a mature vegetation type in a particular region and remain stable over time, or a transitional community that occurs temporarily as the result of a disturbance, such as fire. Various species of bushes belonging to the family of Hippophae and Vaccinium scrub are the dominant scrub in this region. Deodar, chiuri and khayer, jaamum and sal are the hardwood available among others in this area that covers only 75.60 percent of the land (Figure 2-8).

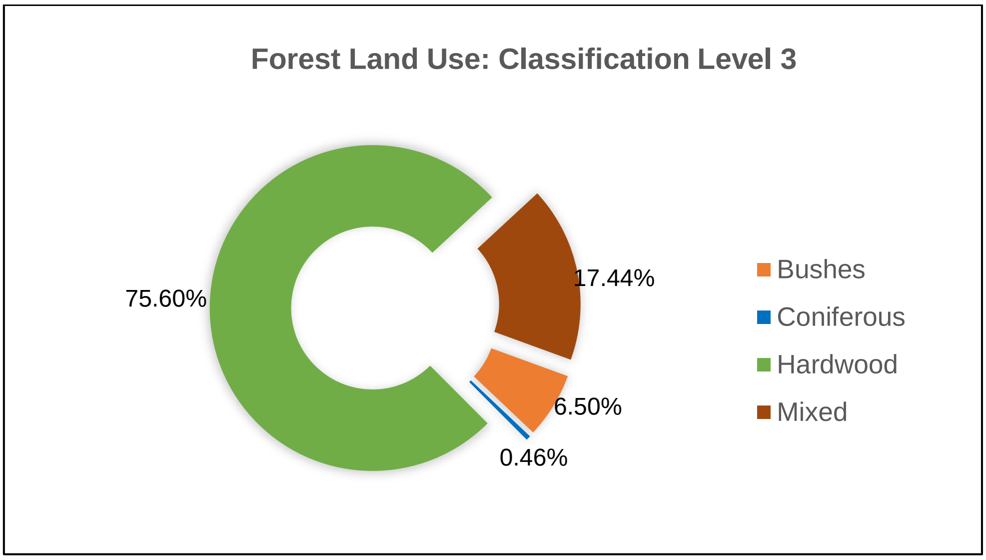

Figure 2-8: Forest Land Use: Classification Level 3

Alnus Woods and Pinusroxburghii Forest cover 25.66 percent and 53.92 percent whereas subtropical evergreen forest covers only 0.31 percent of the total forest area. Because of the highest concentration of hardwood and Pinusroxburghii forest in this Rural Municipality, rainfall is sufficient for the agricultural cropping and animal husbandry as it brings lot of growth of grass and bushes in the season. Table 2-4 shows the classification level 4 of forest land use at the Jwalamukhi Rural Municipality.

Table 2-4: Categories of Forest land use at classification level 4

S.N.	Description	Area(ha)	Percentage
1	Abiesspectabilis Forest	84.92	1.78
2	Alnus Woods	1226.50	25.66
3	Pinusroxburghii Forest	2577.48	53.92
4	Quercus lamellose Forest	39.99	0.84
5	Quercusdilata Forest	310.68	6.50
6	Quercussemecarpifolia Forest	3.41	0.07
7	Rhododendron Forest	132.24	2.77
8	Schima-Castonopsis Forest	390.07	8.16
9	Sub-tropical Evergreen Forest	14.74	0.31
	Grand Total	4780.03	100.00

Though the forest is standing tall in this region with 88.86 percent of the forest in the state of good crown density but are found in a state of high maturity (93.50%). Harvesting this matured forest could bring lot of revenue to the local government with proper management. Few area of forest in this Rural Municipality are found to be in a sparse state which is not good for the land as it does not bring sufficient rain in a season for timely cultivation. Forest covering 532.64 hectare of land is found to be in a sparse state.

Table 2-5: Categories of Forest land use at classification level 5

S.N.	**Description**	**Area(ha)**	**Percentage**
1	Dense	4247.39	88.86
2	Sparse	532.64	11.14
	Grand Total	4780.03	100.00

Some reviving measure can be taken to increase the crown density of a forest in this Rural Municipality. Management of soil quality, insect and disease damage, or other environmental factors such as drought, wind, competition, or soil compaction can be some effective measures that can speed the crown density rate.

For the sake of this report, maturity of a tree is defined as a state of a tree those have reached at least the estimated rotation age or saw timber size as specified. Any trees below this age or size is immature tees and trees that are in state of new generation to the pole size is Generation tree. 93.50 percent of the total forest in the Jwalamukhi Rural Municipality are in a mature state that could be harvested replacing with new plantation. Huge revenue could be generated with these tree logs for the Rural Municipality. Immature trees cover 14.45 percent of the forest area. Table 2-5 shows the maturity state of a forest as a classification level 6 in Jwalamukhi Rural Municipality in the term of their age and size.

Table 2-6: Categories of Forest land use at classification level 6

S.N.	Description	Area(ha)	Percentage
1	Mature	4469.35	93.50
2	Not Applicable	310.68	6.50
Grand Total		4780.03	100.00

Based on the forest ownership and use right at classification level 7, community owned forest and government owned forest covers 32.05 percent and 67.72 percent of the total forest land (Table 2-7). It means cooing fuel, fodder and bread and butter comes from community owned forest for the residents of this Rural Municipality.

Table 2-7: Categories of Forest land use at classification level 7

S.N.	**Description**	**Area(ha)**	**Percentage**
1	Community	1531.80	32.05
2	Government	3237.22	67.72
3	Private	11.01	0.23
Grand Total		**4780.03**	**100.00**

These community-owned forests need specifically precise control mechanism to protect on the basis of use right and management. Private owned forest covers only 0.23 percent of the total forest. Figure 2-9 shows the forest ownership at classification level 7 in the Jwalamukhi Rural Municipality.

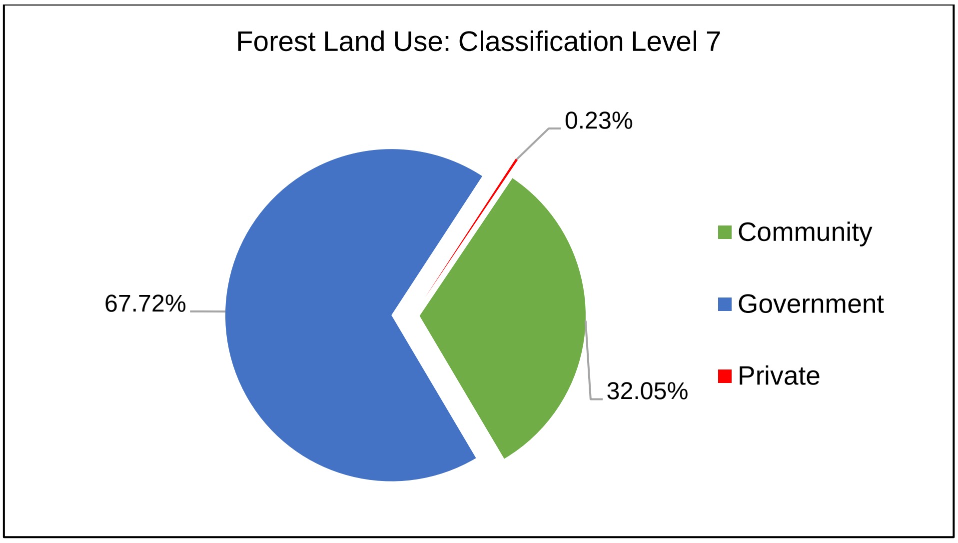

Figure 2-9: Forest Ownership: Classification Level 7

CHAPTER 3 : - METHODOLOGY OF SOIL SURVEY AND MAPPING

Both the desk study and field survey as well as sampling and laboratory analyses were carried out for the soil survey and mapping.

3.1 Review of Soil Survey Methods

Soil survey explores the information needed for land use management and planning. The selection of good land for farming is as old as agriculture. The fact that during early Holocene, some 8000 years ago the first farmers in Europe were cultivating the relatively rich loss soils and alluvial plains shows that these people were aware of major differences in fertility between major land units, and that they were able to identify the more productive soils than others. Gong (1994) stated that the oldest historical record of soil survey and land classification is most likely the Chinese book “Yugong” in which soils of China were classified into three categories and nine classes, based on soil color, texture and hydrological features. Still now, crop selection and the cultivation practices are carried out on the basis of visual observation. Farmers have a vast range of indigenous knowledge on soil and land resources which ought to be taken into account during soil surveys. One of the limitations associated with the conventional system, however, is that this information is rather location-specific and not transferable. Unless brought together under a common denominator, indigenous knowledge will seldom lead to a synthesis of land resources for land planning and management.

Soil survey involves the study and mapping of soils in their natural setting. It is the systematic examination, description, classification and mapping of soils of an area. Soil survey consists of group of activities which are;

- ✓ Field work to study the important characteristics of soils and the associated external land features such as landforms, natural vegetation, slope etc.
- ✓ Laboratory analysis to support and supplement the field observations.
- ✓ Correlation and classification of soils into defined taxonomic units.
- ✓ Mapping of soils that is establishing and drawing soil boundaries of various kinds of soils, on standard topographical base map.
- ✓ Soil survey interpretation, that is making prediction about the potential of soils for alternative uses, like agricultural crops, grasses, fruit, forestry or plantation crops and ascertaining their management requirements for sustained production.

Soil surveys are meant to investigate the geographical distribution of soils that occur in a given area; to determine the most important characteristics of the soils; to delineate map units and describe them in a logical legend in terms of dominant, associated and inclusion soil units, including classification of soils.

The study methodology of soil map preparation can be divided into two parts, i.e. 1) desk study as secondary information collection, analysis and report preparation and 2) field study as primary information collection with verification of secondary information with observation by the team of expert. In case of desk study, the secondary information was collected from various sources such as published and unpublished reports, various maps and other sources. The primary information of soil was collected using field sampling with strong support from GIS and RS analysis and other remote sensing techniques. However, the soil survey was comprised of identification, examination, classification and mapping of the soil and land units with characterization of both the physical and chemical properties of the soil units.

There are basically two approaches commonly used in other parts of the world for soil mapping using satellite remote sensing data which is available in both format as digital (softcopy) and imageries (hard copy).

Methods of survey have been changing with the advancement of science and technology. Soil survey methods have undergone large changes during the recent past with the availability of satellite imagery, apart from topographical maps and aerial photographs. In earlier days aerial photographs were used as base map for demarcating physiographic-photomorphic units using photo-interpretation technique. More recently, medium to high resolution satellite data are common in mapping of soil resources. The current project has used high resolution satellite imagery for the soil survey and mapping purpose. Usually, there are two approaches in soil mapping using satellite data.

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.

The current project has used visual image interpretation for soil survey and it is discussed below:

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 digging 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.

Studying and mapping of soils in the field are the two most important activities of the soil survey. The advancement of technology and technical knowledge has made change in the trend soil survey as if the basic means and methods remained same. The surveyor analyses the landform, geology, climate and vegetation and their relationship with morphological properties of soil by using aerial photo and satellite imagery before going to the field. After that, surveyor goes to the field to identify the points to be studied based on the intensity of mapping. Then, he observes the morphological characteristics such as horizons, color, mottling, soil depth, moisture status, abundance of roots, texture and structure etc. of the soil at that point through field method and put these observed data on the map.

3.1.2 Grid Survey

Grid survey is the field observations at fixed intervals in both directions. The setting of legend before, during and after the field observation is performed in this survey. In very steep terrain, water body, limited budget and large number of soil pit, the grid survey is difficult to perform. If it is necessary to reduce the number of sample site, we can do this by modifying the grid system considering the pedogenesis, water body, slope, land use, degree of difficulties, research objectives and research budget producing accurate and sufficient data.

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.

The free survey is suitable for small scale survey where large areas of inaccessible terrain must be covered in a short time within a limited budget. The soil sampling points are maintained on the basis of changes in physiography interpreted through satellite imagery and other surface features such as soil color, vegetation and land use. Number of sampling points depends on the uniformity of soil and mapper concentrates of inferred boundaries within the boundary. On small scales, the inferred boundaries are often accepted as oil boundries and very limited efforts are made to find soils within the physiographic boundaries. On large scales, however, within the physiographic boundaries are recognized depending on the scale of mapping. Based on the differences in physiography, parent material, drainage class and profile development the grouping of soils of an area into defined soil map units.

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.

For the present study we adopted Free survey and the entire methodology comprises three - tier approach furnished below in detail.

3.2 Desk Study

Before starting field survey, we thoroughly reviewed the available maps and previous reports relevant to soils of the study area before making filed strategy. Multiband satellite imagery The spectral image of the study area comes with 4 bands with wave length of the bands ranging from 450nm to 890nm. Red, Green and Blue bands are of visible range whereas NIR is of nonvisible range. One panchromatic image was also used with spatial resolution of 2.1m. was obtained from the TSLUMD and ortho-rectification of the imagery was performed. We also obtained Topographical Maps and map of land resources; Land System, Land Capability, Land Utilization and their related reports prepared by Land Resource Mapping Project (LRMP) published in 1984/86 were from the TSLUMD and reviewed to identify the landforms and land units of survey area. All these layers and satellite images were made compatible for overlay analysis by geo-rectifying and geo-referencing them in same projection system prescribed by TSLUMD. Standard False Color Composite (RGB: 4,3,2) of the project area at the scale of 1:10000 were produced. These imagery sheets were visually interpreted for lithological (parent material) units which were initially delineated based on available geological maps.

Then after, broad physiographic units were delineated based on relief information available in topographical maps. Topographic information, such as relief and slope, were also produced 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 type units that was used for detailed soil survey. The soil mapping units were interpreted and delineated on the imagery with the aid of bio-physical-soil relationship such as topography, geology, drainage and land use. The physiographic units were further sub-divided based on land use/land cover as revealed in the image. After demarcating the land forms/units through available thematic maps and satellite images, pit location for soil sampling were fixed. Pit locations were determined in the geo-referenced images covering at least each land forms/ units as identified in the images with the help of Land resources Maps of LRMP. The major considerations while selecting the pits were 1) representation of similar characteristics of land form and soils, 2) priority for the cultivated and plain area, 3) discarded or less priority for the rock-out and very steep slope areas etc. Then, maps with pits were prepared at the scale of 1:10000 for field work. The spatial distribution of pit locations of this RM.

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 landform association and soil variation. It helped in identifying soil mapping units and designing the soil sample pit collection work. Field work was carried out to study the physiography, landform and their associated soils based on the soil pit. Soil sample pits covering all the units were dug based on the interpreted soil map, topographical map, and satellite imagery for determination of soil profile.

Each of the sample points identified in the base map were visited, pits dug, described and samples collected following standard soil profile description sheets provided by the TSLUMD.

Various field test, analysis and interpretation for each of soil pits were done to study the physical and morphological characteristics of the sols at different horizons.

The soil profile description sheet provided by the TSLUMD includes the following information:

a. On-site record of:

- Sampled pit number, date of observation/sampling, author of sampling, GPS coordinates of sample site location, elevation, landform, vegetation, and tentative soil classification

b. General information of soil

- Parent material, Slope and slope direction, drainage, moisture condition, ground water table, surface stones of rock outcrops

c. Detail description of individual soil horizon

- Soil horizon, solum depth, colour, mottling, texture, structure, consistency, cutans (clay skins), cementation, pores, pans, biological contents, roots, pH, soil boundary

Soil samples collected from profiles with auger bores were transferred to soil laboratory for analysis. Based on morphological and lab test results, soils were classified according to USDA Soil Taxonomy (2014).

Post Field Soil Data Interpretation

After fieldwork, soil pits information was compiled and modifications in the soil mapping units associated with physiographic units were made as necessary. Soil mapping units with the land type were subsequently translated into soil scape units by incorporating soil information. Soil scape units were 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 contour, spot height, drainage and Rural 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.

Attribute data analysis:

The attribute data analysis included 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 the soil pit were transferred into the base map of same scale geo-referenced base map projected on MUTM parameters.

Table 3-1: Location of Soil Sampling Pits in Jwalamukhi Municipality of Dhading District

SN	Location	Ward No	Soil Profile Name	Pit No.	EAST	NORTH	ELEVATION
1	Majhigaun	1	JW-268	268	279595	3083949	373
2	Galma Khola	3	JW-276	276	282472	3085641	644
3	Dhada Gaun	1	JW-280	280	280064	3086316	1020
4	Sadimudha	3	JW-286	286	283437	3087042	840
5	Amrai	3	JW-288	288	285686	3087246	777
6	Jamuana	2	JW-289	289	280753	3087402	1071
7	Dhola,Dobantaar	4	JW-291	291	288152	3087530	582
8	Pipaltar	5	JW-296	296	277345	3088645	414
9	Kharka Tole	3	JW-299	299	284236	3088930	1030
10		2	JW-300	300	280417	3089059	910
11	Kaphlapani	3	JW-301	301	282297	3089102	1013
12	Dhola	4	JW-303	303	287153	3089226	990
13	Dhadeytole	4	JW-309	309	285650	3090319	1058
14	Pachmura	5	JW-311	311	277258	3090506	444
15	Dhusen	5	JW-314	314	279368	3091207	864
16	Bandipur(Khari)	5	JW-317	317	281230	3091712	885
17	Milantol,Chainpur	6	JW-319	319	287467	3092011	1010
18	Kumaltari	5	JW-320	320	278134	3092095	540
19	Bajoghar	5	JW-321	321	279432	3092582	693
20	Chhapthok	5	JW-322	322	282607	3092654	1032
21	Hussey Tole	5	JW-325	325	284834	3092935	912
22	Jalkinifaat	7	JW-326	326	277983	3093093	413
23	Khatrigau,Jamunaphat	6	JW-327	327	287195	3093097	804
24	Khari,Bhalukhola	5	JW-331	331	281807	3093483	855
25	Tallo Rampur,Bungkot	7	JW-334	334	278457	3093899	506
26	Okhlepaimagar,Besigau	6	JW-336	336	286737	3094144	1005
27		7	JW-338	338	279825	3094428	610
28	Upper Rampur	7	JW-342	342	281610	3095070	752
29	Chisapani,Chainpur	7	JW-343	343	285376	3095181	978
30	Chainpur,Jokheydada	7	JW-344	344	283389	3095304	847
31	Lumha,Chainpur Besi	7	JW-348	348	283280	3095993	546
32	Besi Baltar	7	JW-355	355	284135	3096770	446

Then after, samples from A Horizon was collected, packed and labeled in canvas bags and were sent to the Soil and Fertilizer Testing Laboratory, Sundarpur, Kanchanpur for the analysis of soil parameters that include particle size distribution, soil pH, total nitrogen, organic matter, available phosphorus and soil available potassium. These characters were also used in classifying soils.

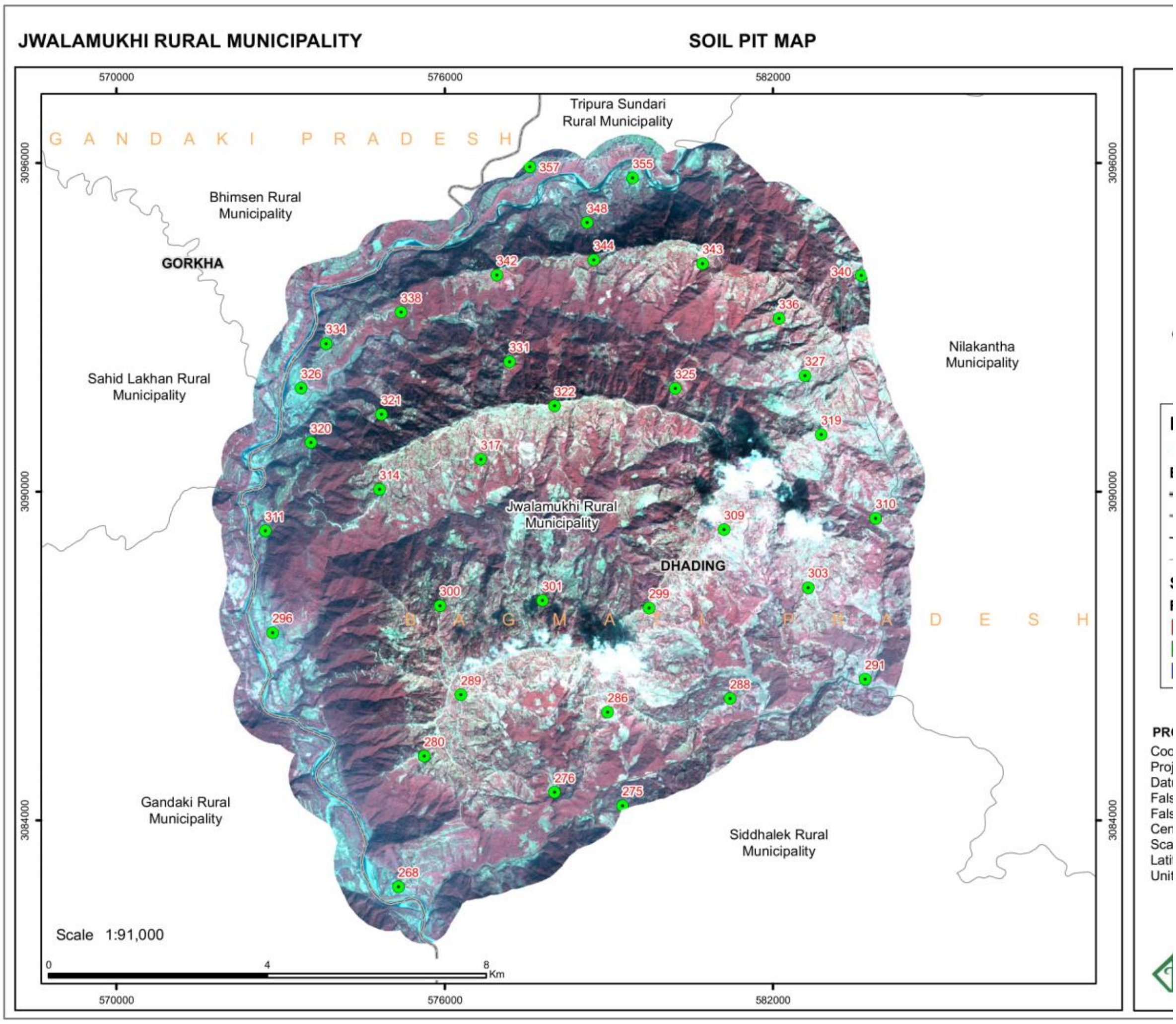

Figure 3-1: Location of soil sampling pits

Figure 3-2: Soil profile observation in the study area

3.4 Laboratory Soil Analysis

Soil samples taken out from each pit were air dried in shade and crushed and sieved for physico-chemical laboratory analysis. The parameters tested and methods used are given below in the table below: The soil analysis was done at Soil and Fertilizer Testing Laboratory, Sundarpur, Kanchanpur. Pit-wise distribution of the soil physical and chemical properties (first horizon) has been given in Appendix 4.

Table 3-2: Parameters of laboratory test of soil

S.N.	Soil parameters	Method
1	Particle size fraction and texture	Hydrometer and Texture classification USDA Texture triangle method (Gee and Bauder, 1986).
2	Ph	1:1 soil water suspension method/ Glass electrode digital ph meter method (Cottenie *et al.,* 1982)
3	Organic matter content (OM %)	Walkley and Black method (Graham, 1948)
4	Total Nitrogen content (Total N %)	Derived from organic matter level
5	Available Phosphorus (P_2O_5 kg/ha)	Modified Olsen's bicarbonate method
6	Available Potassium (K_2O kg/ha)	Neutral normal ammonium acetate extraction method (Pratt, 1965) by flame photometer

After completing the field study, different thematic layers such as contour, spot height, drainage and RMs and wards, land system and land use were made compatible by transforming into the same projection system (MUTM) adopted by Survey Department. The soil pits location was transferred into base map and image. Vector to raster conversion of line segment were made for preparation of digital surface model required for Digital Terrain Model and Hill shade. Based on shape, size, tonal and color variation and relative height, the landform and land types of the project area were identified on, ZY3 2 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. The Anaglyph Stereo Pair Visualization of MSS ZY3 satellite image was made to get the 3-dimensional perspective of terrain relief, land use practices associated with the soil in entire project area. It helps in identification of boundaries of soil mapping units in 3 dimensional views because soil is 3 dimensional natural bodies. Soil association which is universally accepted for soil mapping and classification was adopted in order to correlate the soil pit and soil mapping units because these two spatial entities are geometrically different. One soil pit is enclosed by one soil mapping unit. Thus, classifications were made based on soil association. Based on morphological characteristics and chemical properties derived from lab analysis is used to classify the soil following Soil Taxonomy (USDA/SCS, 1998).

CHAPTER 4 : LANDS SYSTEM, LAND FORM AND LAND TYPE

Soils are the integral part of the landscape and their characteristics are largely governed by the landforms in which they are developed. Physiography influences soil formation affecting the climate, vegetation of an area as if it is considered as passive factor of soil formation. Moreover, there is a close relationship between physiography and soil development which ultimately affects the availability of nutrients (Verma et al., 2005). The physiography has influential role in soil formation through slope and exposure. The flat topography has more depth of soil as compared to the steep slopes because the steep slopes are more prone to the erosion (Sehgal, 2002).

Soil properties such as profile development, texture, structure, color, acidity, cation exchange capacity, base saturation etc. are related to land form. There is a close relationship between physiography and soils. The formation of the diverse group of soils can be attributed to the variation in topography causing erosion, leaching, sedimentation and other pedogenic processes modified by water table (Mini et al, 2006). Thus, physiographic influence of soil properties has been recognized which ultimately leads to evolution of the soil-landscape relationship. Topographic maps, aerial photographs stereo-capability and remote sensing data provide useful tool for geomorphic analysis of the region and help in soil survey and mapping.

The present investigation 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. 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 (DTM) is employed for delineation of landform, land units and land types for detailed soil survey at local level planning.

4.1 Land System

LRMP Land Systems have categorized land units of this area into 3 broad land system units namely, Active and Recent alluvial plain; Fans, aprons and ancient river terraces and Depositional basins. For the preparation of land system map at Rural Municipality level, the generic and pragmatic approach that was adopted by LRMP was followed in this chapter. Based on LRMP, 1986 a total of 17 land systems from 1 to 17 were identified.

4.2 Land Form

Landform is further subdivided into land units basically defined by the mapable size of land surface for demarcation in landscape by the user. And it is characterized by landscape features. The land units in the project area are shown as below:

- Intermediate position level.
- Depressions
- Khola, sandbar and flood plain

Among the land units defined by LRMP Land System, land types are demarcated considering the local situation of land units representing micro-relief differences based on the local slope and elevation and its orientation. Landform affects soil formation and its profile development in association with the steepness of land and slope direction. Within the five physiographic regions (Terai, Siwalik, Middle mountain, High mountain and High Himalaya), 17 land system characterized as landform types were identified based on these factors as below.

- pattern and process of landforms
- geological materials
- terrain slope
- limits of arable agriculture land

Formation and distribution of the soils in a given area is affected by Climate, organisms, parent materials, topography and time. There exists a close relationship between topography and soil properties. Topography is basically characterized by land forms and land forms are basically the geo-morphological units with specific ground features like slope. The nature of these geo-morphological units along with other factors determines the nature of soils. Since soil properties vary with these geo-morphological units, certain predictions can be made on the nature of soils occurring in a place based on land forms and land types. Land forms and land types have been classified based on the Land Systems legends (Carson, Shah & Maharjan) of Land Resources Mapping Project (LRMP). The land types have been further elaborated and subdivided into sub types based on slope gradient, positions, drainage patterns etc. that have direct implications on agriculture and other land use purposes.

Landforms in the study area characterize the valley and mountains of the middle mountain region. Valley is depositional zone, which consist of recent to Post-Pleistocene quaternary deposits. The valley is generally flat with minor relief caused by ongoing river actions and tectonism. For the purpose of broad soil mapping unit, the Valley region can be divided into major landform, i.e., active, recent and older alluvial deposits. Active alluvial areas include those lowlands adjacent to major rivers. Soils are usually coarse textured and display little pedogenetic development. Recent alluvial areas lie on slightly higher ground away from the present influence of the rivers. Due to greater geomorphic stability somewhat more mature soil development is evidenced. Water tables are high throughout the year. Older alluvial deposits represent the upper piedmont formed of lateral coalesce of alluvial fans. The soils in the upper piedmont exhibits best developed horizon profiles on the valley. Water table is generally high, i.e., mostly at 50 ft to above 100 ft and drainage conditions is rapid, therefore, topography is flat to steep to very steep sloping and erosional.

The Middle mountain region consist predominant south dipping sedimentary rocks, which comprises predominantly semi-consolidated, interbedded tertiary sandstone, mudstone and conglomerates. In the study area, the landscape is highly rugged and fragile. The soils are generally developed on the in-situ rocks or gravity transported colluviums. Soils development on the alluvium in the hillslopes is very limited. The soils are unable to retain the intensity rainfall that frequently occurs and are therefore subject to severe erosion (rain splash, rills, gullies and stream erosion), which results is flash flood in the downstream onto the valley.

4.3 Description of Individual Land Type Units

The LRMP Land Systems have categorized various land units. These units are used to represent the various land type units of the studied Rural Municipality. Since above land system categorization is at regional level, they have been further categorized into further sub units so that the micro-level relief conditions are well represented (Table 4-1). These sub units are different from each other in the context of the occurrence of soils, present land use and the potential land use purpose as well.

Table 4-1: Land Type Units

Source (Land unit)	Slope, topography and drainage condition	Texture	Soils	Water table depth (Seasonal range)	Land use
Alluvial plains and fans (depositional, River channel (9a)	<1-5^o	Fragmental Sandy, loamy, boulder	Pssaments, Ustochrepts, Ustifluvents, Fluvaqeunts, Haplustalfs	0-15 m	mixed hardwood and oak forest
Alluvial plains and fans (depositional, Alluvial plains (9b)	<1-5^o	Sandy, loamy, bouldry	Pssaments, Ustochrepts, Ustifluvents, Fluvaqeunts, Haplustalfs	0-15 m	mixed hardwood and oak forest
Alluvial plains and fans (depositional, Alluvial fans (9c)	<1-5^o	Sandy, loamy, bouldry	Pssaments, Ustochrepts, Ustifluvents, Fluvaqeunts, Haplustalfs	0-15 m	mixed hardwood and oak forest
Ancient lakes and river terraces (tars) (erosional), Non-dissected (10a)	0-5^o	Loamy	Typic & Rhodic Haplstalfs, Ustochrepts	<2 m	mixed hardwood and oak forest
Ancient lakes and river terraces (tars) (erosional), Disected (10a)	0-5^o	Loamy	Typic & Rhodic Haplstalfs, Ustochrepts	<2 m	mixed hardwood and oak forest

Table 4-1: Land Type Units

Source (Land unit)	Slope, topography and drainage condition	Texture	Soils	Water table depth (Seasonal range)	Land use
Moderately to steeply sloping mountainous terrain (11)	05-30^o	Loamy Skeleton	Typic, Udic, Anthropic Ustochrepts, Dystochrepts and Haplumbrepts	>50 cm to bedrock	Pine forest, mixed hardwood and oak forest
Steeply to very steeply sloping mountainous terrain (12)	>30^o	Loamy Skeleto	Lithic Ustorthents	<50 cm to bedrock	Pine forest, mixed hardwood and oak forest

Analysis of land systems based on standard methodology showed that the majority area is occupied by land unit 11 (52.42%) followed by 12 (39.80%) and 9complex (2.65%) (Table 4-2). Figure 4-1 and figure 4-2 depicts the spatial distribution of land system type of this Rural in graphical form and map. Hence, majority of the terrains are moderately to steeply sloping mountainous. However, some of the areas are alluvial plains and fans and tars (6.13%) which are suitable for the production of agricultural crops.

Table 4-2: Land Units in different wards of Jwalamukhi Municipality, Dhading District

Land Unit	Description	Regions	Area in Sq.m	Area in Hectare
11	Moderately to Steeply Sloping Mountainous Terrain	Middle Mountain	59183873.78	5918.39
12	Steeply to very steeply sloping Mountainous Terrain	Middle Mountain	44935550.85	4493.56
10a	Ancient River Terraces (Tars)	Middle Mountain	1076074.77	107.61
10complex	Ancient River Terraces (Tars)	Middle Mountain	1601978.70	160.20
9c	Alluvial plains and fans	Middle Mountain	1250370.62	125.04
9complex	Alluvial plains and fans	Middle Mountain	2989215.65	298.92
River	River		1860042.42	186.00
Grand Total			**112897106.79**	**11289.71**

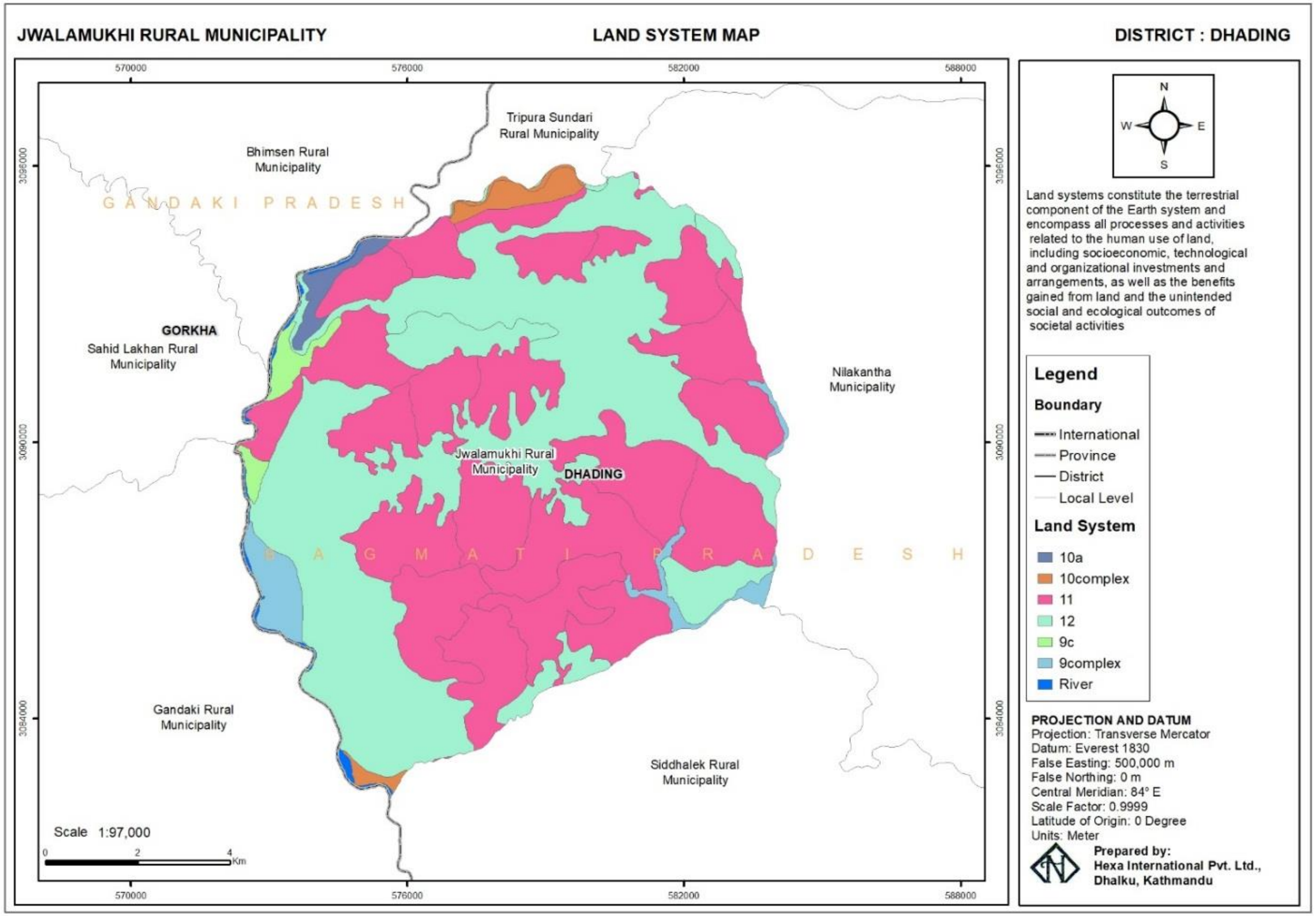

Figure 4-1: Spatial distribution of land units in the Jwalamukhi Municipality

CHAPTER 5 : SOIL CLASSIFICATION SCHEME

Soil classification system is essential to foster global communications about soils among soil scientists, and people concerned with the management of land and the conservation of the soil resources. Such systems offer advantage of gaining broader research experience across locations and help predict the behavior of similarly classified soils at other locations.

Soil classification is grouping of soils into categories based on each soil's morphology (appearance and form). Soil classification is itself a dynamic subject related to the structure of the classification system, to the definition of each classes and finally 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 observable is the filed observable of the soil within various soil horizons and the description of the kind and arrangement of the horizons (Buol et. al., 2011).

There are a number of soil classification systems in use in different parts of the world. Many countries in the world have adopted the following two classification systems:

1. FAO-World Reference Base for Soil Resources-involving a practical classification system used to inventory and describe the world's soil resources.
2. USDA Soil Taxonomy System

The comprehensive soil classification system, called USDA Soil Taxonomy (Soil Survey Staff, 1975), maintains the natural body concept and has two other major features that make it most useful. 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. 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 employed, 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.

The chemical, physical, and biological properties are used as criteria for Soil Taxonomy. A few examples of physical properties include the moisture content, temperature, color, texture, and structure of the soil. Similarly, chemical and mineral properties include organic matter, clay, iron and aluminum oxides, silicate clays, salt, the pH, the % base saturation, and soil depth. Differences between horizons generally reflect the type and intensity of processes that cause differences in soil properties. Ideally, efforts should be made in our profile descriptions to maintain a link between process and morphology. In many soils, these differences are expressed by horizonization reflecting vertical partitioning in the type and intensity of the various processes that influence soil development.

5.1 Soil Diagnostic Horizons

Extent of soil horizon development (horizonization) is described in term of a) master horizons, b) transitional horizons and c) subordinate distinctions within master horizons. They are briefly discussed below:

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 soil horizons is given in Table 5-1.

Table 5-1: 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-mad sod-like horizon created by year of manuring
Melanic	Thick black horizon rich in organic matter usually associated with aluminium-humus complex
Folistic	A more or less freely drained horizon formed in organic materials
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 soil, clay and Fe and Al oxides mostly removed
Calcic	Accumulation of $CaCO3$ or $MgCo3$
Gypsic	Accumulation of gypsum
Salic	Accumulation of salts
Kandic	Accumulation of low activity clays
Petrocalcic	Cemented calcic horizon
Petrogypsic	Cemented gypsichorizon
Placic	Thin pan cemented with iron alone or with manganese or organic matter
Sombric	Organic matter accumulation
Sulphuric	Highly acid with Jarosite mottles

(USDA/NRCS, 2014)

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.

c. Subordinate distinctions within master horizons

Lower case letter 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:

Horizon boundary characteristics, color, texture, rock fragments, structure, consistence, roots, pH, effervescence, and special features such as coatings, nodules, and concretions

Diagnostic Horizons

Diagnostic soil horizons are found in the surface or the subsurface (Table 5.1). Those found in the surface are called epipedons (from the Greek words epi meaning over and peon meaning soil). The epipedons includes the upper part of the soil darkened by organic matter, the upper alluvial horizons, or both. It may include part of B horizon if the latter is significantly darkened by organic matter.

5.2 Local Classification System

At each location, there is a distinct and systematic criterion for soil classification. This local classification system is adopted based on the farmer’s experience on day to day dealing with the soil. Soils, in this system, are differentiated on the basis of color, topsoil texture, depth and consistency. These factors, in combination with slope provide information on infiltration, drainage, soil moisture retention capacity, organic matter content and stability.

Soil color is used by farmer as a key distinguishing criterion for the crop selection and nutrient management. Soil color differences are often related to the age of the soil, the origin or parent material, and the organic matter content etc. The major topsoil colors used by the farmers to differentiate soils are shown in the Table 5-2 alongside the scientific classification. Farmer perceived color is a partial indication of organic matter content in the soil. At higher carbon content the soil colors are usually darker, the moisture content and cation-holding capacity are higher, and the structural stability of soil aggregates is greater.

Table 5-2: Local soil color classification

Local color classification	Munsell Soil Color Chart
Kalo (black)	10 YR 3/1-4/1 –dark greyish brown-very dark greyish
Rato (red)	2.5 YR 4/6-5/6 – red
Haluka rato mato (light red)	5 YR 5/6-6/6-yellowish red-reddish yellow
Khairo mato (brown)	7.5 YR 4/2-5/2- brown-dark brown
Phusro (grey)	10 YR 5/1-5/2- grey –greyish brown
Kharani mato (light grey)	7.5 YR 7/10 YR 7/7- light grey
Jogi mato (yellow)	10 YR 6/6-7/6-8/8 – brownish yellow-yellow

Source: Parihar, 2001

Soil texture refers to the proportion of individual particles in a given soil mass and is another most important physical property of soils considered by farmers. These properties determine nutrient supplying ability of soil solids and also influence the soil structure. The size of particles in mineral soil (texture) is not readily subject to change and remains constant. The textural classes differentiated by farmers in the field are listed in Table 5-3 and their equivalent USDA soil texture classes are also mentioned. The farmer's textural classifications are used primarily for crop selection and soil management. Heavy textured (chimte) soils require higher labor inputs then light textured (domat) soils for ploughing and other cultivation activities. Moisture content in relation to texture is also used as an index of workability of the soil.

Table 5-3: Local terms for texture classification

Local Name	USDA Texture Class
Pango	Silty loam/silt
Balaute	Sand
Domat	Loam
Balaute Domat	Sandy Loam
Balaute Chimte	Sandy clay loam
Domat Chimte	Clay loam
Chim	Clay
Gegran	Gravelly
Masino	Fine
Chimte	Very fine (clay)

Source: Parihar, 2001

Soil depth is one of the most important criteria used by farmers. Deep soils (gahiro) generally have higher moisture-retention capacities than shallow ones. Shallow soils (patalo) restrict the penetration of roots and affect the soil moisture retention. Deep soils (> 1 m) do not restrict the distribution of roots. Farmers prefer soils with a root depth of more than a meter and are aware of factors governing the uptake of nutrients and use of soil moisture by plants.

Soil consistency has important significance for tillage and land management. Major local terms used for classifying consistency are provided in Table 5-4. Terms for classifying soil consistency may be simple but are meaningful and easily understood by farmers.

Table 5-4: Soil consistency classes and scientific equivalent

Local	USDA	Soil texture
Chipplo (chyap-chyape)	Sticky, plastic	Clay (fine)
Khasro	Loose, non-sticky, non-plastic	Sands (coarse)
Lasailo	Slightly sticky, slightly plastic	Loams (medium)

5.3 USDA Soil Taxonomy System

Soil Scientists have developed different systems of soil classification to group soils of similar properties in one class, allowing them to exchange information on soils found in different areas. Soil classification also helps in determining the best possible use and management of soils. Of several soil classification systems, two systems are widely used: The USDA Soil Taxonomy and the FAO/UNESCO legend. In this section the USDA soil classification system is followed.

There are six levels in the hierarchy of categories: Orders (the highest category), suborders, great groups, subgroups, families and series (the lowest category) (USDA, 1978).

Orders: There are ten orders, differentiated on gross morphological features by the presence or absence of diagnostic horizons or features which show the dominant set of soil-forming processes that have taken place. The ten orders and their major characteristics are shown in Table 5-5.

Table 5-5: Soil orders according to USDA, 1978 Soil Taxonomy

Soil Orders	Description
Alfisols	Soils with a clayey B horizon and exchangeable cation (Ca + Mg + K + Na) saturation greater than 50% calculated from NH4OAc-CEC at pH7.
Ultisols	Soils with a clayey B horizon and base saturation less than 50%. They are acidic, leached soils from humid areas of the tropics and subtropics.
Oxisols	Oxisols are strongly weathered soils but have very little variation in texture with depth. Some strongly weathered, red, deep, porous oxisols contain large amounts of clay-sized Fe and Al oxides.
Vertisols	Dark clay soils containing large amounts of swelling clay minerals (smectite). The soils crack widely during the dry season and become very sticky in the wet season.
Mollisols	Prairie soils formed from colluvial materials with dark surface horizon and base saturation greater than 50%, dominating in exchangeable Ca.
Inceptisols	Young soils with limited profile development. They are mostly formed from colluvial and alluvial materials.

Table 5-5: Soil orders according to USDA, 1978 Soil Taxonomy

Soil Orders	Description
Entisols	Soils with little or no horizon development in the profile. They are mostly derived from alluvial materials.
Aridisols	Soils of arid region, such as desert soils. Some are saline.
Spodosols	Soils with a bleached surface layer (A2 horizon) and an alluvial accumulation of sesquioxides and organic matter in the B horizon. These soils are mostly formed under humid conditions and coniferous forest in the temperate region.
Histosols	Soils rich in organic matter such as peat and muck.

Suborders: It is the next level of generalization. The suborder focuses on genetic homogeneity like wetness or other climatic factors. There are 47 suborders within the 10 orders. The names of the suborders consist of two syllables. The first connotes the diagnostics properties; the second is the formative element from the soil order name. For example, an Ustalfs is an alfisols with an ustic moisture regime (associated with sub-humid climates).

Great-groups: The great group permits more specific statements about a given soil as it notes the arrangement of the soil horizons. A total of 230 great groups have been defined for the 47 suborders. The name of a great group consists of the name of the suborder and a prefix suggesting diagnostic properties.

Soil subgroup: is the third level of classification of soils and is formed by subdividing each great group. Subgroups are differentiated on the basis of the kind and arrangement of horizons that reflect 1) similarity to the central concept of the great group, 2) intergrading towards soils of another order, 3) additional features within the control section. A control section is the vertical section of soil upon which classification is based.

5.3.1 Soil Classification at Soil Family Level

USDA Soil Taxonomy developed by United States Department of Agriculture and the National Cooperative Soil Survey provides an elaborate classification of soil types according to several parameters (most commonly their properties) and in several levels: Order, Suborder, Great Group, Subgroup, Family, and Series.

Order (11 taxa): This category is based largely on soil forming processes as indicated by the presence or absence of major diagnostic horizons. A given order includes soils whose properties suggest that they are not dissimilar in their genesis. They are thought to have been formed by the same general genetic processes.

Suborder (60 numbers of taxa): Suborders are subdivisions of orders that emphasize genetic homogeneity. The presence or absence of properties associated with wetness, climatic environment, major parent material, and vegetation.

Great Group (approximate 303): Great groups are subdivisions of suborders according to similar kind, arrangement, and diagnostic horizons. The emphasis is on the presence or absence of specific diagnostic features, base status, soil temperature, and soil moisture regimes.

Subgroup (> 1,200): Subgroups are subdivisions of the great groups. The central concept of a great group makes up one group (Typic). Other subgroups may have characteristics that are intergrades between those of the central concept and those of the orders, suborders, or great groups. Extra gradation is used to identify critical properties common in soils in several orders, suborders, and great groups.

Family: Families are sound in soils with a subgroup having similar physical and chemical properties affecting their response to management and especially to the penetration of plant roots. Differences in texture, mineralogy, temperature, and soil depth are bases for family differentiation.

Series: Its differentiating characteristics are based primarily on the kind an arrangement of horizons, color, texture, structure, consistence, reaction of horizons, chemical, and mineralogical properties of the horizons.

In the soil classification at family level, the intent has been to group the soils within a subgroup having similar physical and chemical properties that affect their responses to management and manipulation for use. In some cases, soil properties are used in this category without regard to their significance as indicators of soil forming processes.

An example of the soil classification based on USDA taxonomy system is presented below:

Order: Entisols

Suborder: Fluvents

Great Group: Torrifluvents20

Subgroup: Typic Torrifluvents

Family: Fine-loamy, mixed, superactive, calcareous, Typic Torrifluvents

Series: Jocity, Youngston

The grouping of soils within families is based on the presence or absence of physical and chemical properties important for plant growth and may not be indicative of any particular process. The properties include particle size distribution and mineralogy beneath the plough layer, temperature regime, and thickness of rooting zone. Typical family names are clayey, kaolinitic, isohyperthermic, etc. There are thousands of families.

5.3.2 Soil Classification at Soil Subgroup Level

There are more than 2400 subgroups. Through the categories of order, suborder, and great group, emphasis has been placed on features or processes that appear to dominate the course or degree of soil development.

Soil subgroup is the third level of classification of soils and is formed by subdividing each great group. Subgroups are differentiated on the basis of the kind and arrangement of horizons that reflect similarity to the central concept of the great group; intergrading towards soils of another order and additional features within the control section. A control section is the vertical section of soil upon which classification is based.

In addition to these dominant features, many soils have properties that, although apparently subordinate, are still markers of important sets of processes. Some of these appear to be features of processes that are dominant in some other great group, suborder, or order. In a particular soil, however, they only modify the traits of other processes. For example, some soils have aquic conditions and have, throughout their depth, gray colors with reddish or brownish redox concentrations. Other soils have aquic conditions only in their lower horizons, and in those horizons the dominant colors may be shades of brown, red, or yellow with some gray redox depletions. The effects of ground water are apparent in both sets of soils, but they have less importance in the latter set. Other properties are features of processes that are not used as criteria of any taxon above the subgroup level. For example, a Mollisols at the foot of a slope, where there has been a slow accumulation of materials washed from the higher parts of the slope, may have a greatly over-thickened mollic epipedon. Thus, there are three kinds of subgroups:

The following differentiae are used to distinguish families of mineral soils and the mineral layers of some organic soils within a subgroup. The class names of these components are used to form the family name. The components are listed and defined in the same sequence in which the components appear in the family names:

- Particle-size classes in horizons of major biologic activity below plow depth;
- Mineralogy classes in the same horizons that are considered in naming particle size classes;
- Cation-exchange activity classes of certain particle-size and mineralogy classes in the same horizons that are considered in naming particle-size classes;
- Calcareous and reaction classes in horizons directly below plow depth;
- Soil temperature classes;
- Thickness of the soil penetrable by roots; and
- Classes of coatings, crack, and rupture resistance used in defining some families to produce the needed homogeneity.

5.4 World Reference Base for Soil Resources (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. The FAO world soils are given in approximate comparisons to the 1975 US system. This comparison provides an acquaintance with taxonomic names and approximate relationship of the systems.

The FAO soil classification system is worldwide, but it is not a system of units grouped into higher categories. The 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 between USDA and FAO Classification Systems

A tabulation of the FAO system is given as the basis for comparing the systems with US system (Table 5-6). These comparisons are only approximate because the systems are very different. The great group of the US 1975 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.

Table 5-6: A comparison between FAO and USDA soil classification systems

FAO Systems and Name Meanings	US Systems (1975)
ACRISOLS Latin acris= very acidic, low base status. Subunits: Orthic, Ferric, Humic, Plinthi	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	Pasmmments Several subgroups
CAMBISOLS Latin cambiare= change Subunits: Eurtic, Dystic, 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 aluminium. Subunits: OrthicXanthic, Rhodic, Hemic, Acric, Plinthic	Fluvents
GELOSOLS, Greek gelid = very cold, permafrost in part	Gellsols
GLEYSOLS Russian gley= mucky soil mass. Subunits: Eutric, Clacaric, Dystric, Mollic, Humic, Plinthi, Gelic	Aquents, Aquepts, Aquolls
GREYZEMS English grey and Russian zemlja= earth. Subunits: orthic, Gleyic	MOLLISOLS Borolls, Aquolla
HISTOSOLS Greek histos= tissue. Subunits: Eutric, Dystic, Gelic	HISTOSOLS
KASTANOZEMS Latin castanea= Chestnut, Russian zemlja= earth.	MOLLISOLS Ustolls, Borolls

FAO Systems and Name Meanings	US Systems (1975)
Subunits: Haplic, Calcic, Luvic	
LITHOSOLS Greek 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 surface 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. Subunits: Orthic, Leptic, Ferric Humic, Placic, Gleyic	SPODOSOLS Orthods, Humod, Aquods
PODZOLUVISOLS From Podzol and Luvisol Subunits: Eutric, Dystric, Gleyic	MOLLISOLS Udalfs, Boralfs, Aqualfs
RANKERS Austrain rank = steep slope, shallow soils. No sub-units	Lithic Haplumbrepts
REGOSOLS Greek rhegos= blnket, 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.	ARIDISOLS

FAO Systems and Name Meanings	US Systems (1975)
Sub-units: Haplic, Calcic. Gypsic, Luvic	CalcidsGypsids-argids
YERMOSOLS Spanish yermo= desert areas Subunits: Haplic, Calcic	ARIDISOLS Cambids Argids
ACROSOLS 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	ANDISOLS Several suborders and great groups
ARENOSOLS Lating arena= sand. Subunits: Cabic, Luvic, Ferralic, Albic: CAMBISOL LatingCambiare= Charge Subunits: Euriric, Dystric, Humic, Gleyic, Golic, Calcic, Chromic, Vertic, Ferralic	Psamments Several subgroups
CHERNOZEMS Russian chern= black, zemlja= earth. Subunits: Haplic, Calcic, Luvic	INCEPTISOLS Many Ochrepts
Glossic FERRALSOLS Latin ferrum= iron and aluminium. 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	GELISOLS
GLEYSOLS Russian gjey= mucky soil mas. Subunits: Eutric, Calcaric, Dystric, Mollic, Humic, Plinthic, Gelic	Aquents, Aquepts, Aquolls MOLLISOLS Borolls, Aquolla
Aquents, Aquepts, Aquolls MOLLISOLS Borolls, Aquolla	HISTOSOLS MOLLISOLUS Ustolls, Borolls Lithic subgroups
HOSTOSOLS Greekhistos= tissue, Subunits: Eurtic, 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, ORTHODS, Humods, Aquods

Source (WRB, 2006, USDA, 2010)

A few terms not shown in Table 5-5 above, are as follows:

Orthic: central concept of that soil

Calcaric: shallow to lime (2-25cm)

Gelic: permafrost within 200cm

Gleyic: hydromorphic (anaerobic)

Luvic: leached, clay moved downward

Solodic: <6% Na in the CEC

Takyric: clayey, massive crust, dry

Thionic: sulphuric horizon/material

Vertic: Vertisol-like properties

5.5 Rating of Soil Fertility Status and Crop Suitability Analysis

Soil fertility evaluation 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 cation exchange capacity (CEC). The ratings of these parameters are presented below in table 5-7 to table 5-11.

Each crop requires specific soil and environmental conditions for proper growth. However, some plants grow in various soil conditions under extreme agro-ecological conditions. The plants growth is controlled by the availability of nutrients and soil moisture which are governed by the soil characteristics. The soil suitability analysis for crop growth was performed by establishing the suitability criteria for growing crops, forest and plantation crops. The land is delineated based on the suitable soil attributes. The land is classified into following categories based on the limitations for crop growth.

Highly suitable (S1): Land has no limitations for the crop growth.

Moderately suitable (S2): Minor physical limitations affecting either productive land use and/or risk of degradation. Limitations overcome by careful planning.

Marginally suitable (S3): Moderate physical limitations significantly affecting productive land use and/or risk of degradation. Careful planning and conservation measures required.

Almost unsuitable (N1): High degree of physical limitation not easily overcome by standard development techniques and/or resulting in high risk of degradation. Extensive conservation measures and careful ongoing management required.

Unsuitable (N2): Severe limitations. Use is usually prohibitive in terms of development costs or the associated risk of degradation.

Table 5-7: Soil depth (cm) rating

Depth	Interpretation	Suitability
>200	Very deep	High
100-200	Deep	
50-100	Moderately deep	
25-50	Shallow	
<25	Very shallow	Low

Source: Soil Testing Manual, FAO

Table 5-8: Soil workability rating based on texture

Loam	**Good**	**High suitability**
Silt loam	Good	
Sandy loam	Good	
Silt loam +loam	Good	
Clay loam	Moderate	
Clay loam over silt loam	Moderate	
Silty clay loam + Silty loam	Moderate	
Silty loam+ Silty clay	Fair	
Silty clay	Fair	
Clay	Fair	Low suitability

Source: Buolet. Al. (2011)

Table 5-9: Soil drainage rating

Well drained	**High suitability**
Moderately well drained	
Somewhat poorly drained	
Poorly drained	
Very poorly drained	
Somewhat excessively drained	
Excessively drained	Low suitability

Source: Buolet. Al. (2011)

Table 5-10: Soil acidity and alkalinity rating

<4.0	**Extremely acidic**	**Low suitability**
4.0-4.5	Strongly acid	
4.5-5.5	Medium acidic	
5.5-6.0	Slightly acidic	High suitability
6.0-6.5	Slight acidic	Most suitable
6.5-7.0	Very slightly acidic	High suitability
7.0-7.5	Very slightly alkaline	
7.5-8.0	Slightly alkaline	
8.0-8.5	Medium alkaline	
8.5-10	Strongly alkaline	Low suitability

(SSD, 2067)

Table 5-11: Soil organic matter and nitrogen, phosphorus and potassium rating (for hills, Nepal)

S.N.	**Test parameter**	**Very low**	**Low**	**Medium**	**High**	**Very high**
1	Organic matter (%)	<1	1-2.5	2.5-5	5-10	>10
2	Soil total nitrogen (5)	<0.05	0.05-0.1	0.1-2.0	0.2-0.4	>0.4
3	Plant available phosphorus (kg/ha)	<10	10-30	30-55	55-110	>110
4	Plant available potassium (kg/ha)	<56	56-112	112-280	280-504	>504

(SSD, 2067)

A comparison of the soil test values and crop requirement of the nutrients content of the soils of the study area has been done. The table below depicts the optimum pH range and major nutrient requirements of major crops including fruits and vegetables.

Table 5-12: Optimum range of test parameters with respect to crop suitability

S.N.	Test Parameter	Optimum Range
1	pH	5.5-7.5 (optimum is 6.5)
2	Organic matter %	1.75-3.0
3	Total nitrogen %	>=0.12
4	Available Phosphorus kg/ha	85-100
5	Available Potassium kg/ha	300-350

The nomenclature of soil texture has been abbreviated and listed in Table 5-13.

Table 5-13: Soil texture abbreviations

S.N.	Texture	Symbol
1	Clay	C
2	Clay loam	Cl
3	Loam	L
4	Sandy loam	Sl
5	Loamy sand	Ls
6	Sand	S
7	Silt loam	Sil
8	Silty clay loam	Sicl
9	Silty clay	Sic
10	Sandy clay loam	Scl
11	Sandy clay	Sc

CHAPTER 6 : SOIL TYPES AND GIS DATABASE

6.1 Soil Types

The soil survey produced a soil classification report based on USDA soil taxonomy. There are mainly three soil orders, i.e. Inceptisols, Ultisols and Entisols. The areal coverage of the various soil units is presented in the table 6-1 and figure 6-1 and figure 6-2. The maximum area is covered by Inceptisols (89.69%) followed by Ultisols (4.97%) and Entisols (3.57%). At great-group level, Dytrustepts predominates-occupies about 68.68% area. Similarly, nearly 21% area consists of Haplustepts. Inceptisols cover the largest area in the and are the most important soils. They occur on more stable slopes and show distinct weathering in the subsoil. The central concept of Inceptisols is that of soils that are of cool to very warm, humid and sub humid regions and that have a cambic horizon and an ochric epipedon. The order of Inceptisols includes a wide variety of soils. In some areas Inceptisols are soils with minimal development, while in other areas they are soils with diagnostic horizons that merely fail the criteria of the other soil orders. Inceptisols have many kinds of diagnostic horizons and epipedons. They can have an anthropic, histic, mollic, ochric, plaggen, or umbric epipedon. Only a very few Inceptisols, however, have a mollic epipedon. The mollic epipedon is restricted to soils with low base saturation below the epipedon. The most common diagnostic horizons are ochric and umbric epipedons, a cambic horizon, and a fragipan. The most common horizon sequence is an ochric epipedon over a cambic horizon, with or without an underlying fragipan. Some Inceptisols have an umbric epipedon overlying a cambic horizon, with or without an underlying duripan or fragipan. A calcic or petrocalcic horizon or a duripan is common in sub humid areas. All soils that have a plaggen epipedon are Inceptisols, and any soil underlying the plaggen epipedon is considered to be buried. The definition of Inceptisols is necessarily complicated. These soils range from very poorly drained to excessively drained. If the epipedon is ochric or anthropic, a diagnostic subsurface horizon or high exchangeable sodium also is required. Inceptisols typically have a cambic horizon, but one is not required if the soil has a mollic, umbric, histic, or plaggen epipedon or if there is a fragipan or duripan or any placic, calcic, petrocalcic, gypsic, petrogypsic, salic, or sulfuric horizon. Inceptisols cannot have an argillic, kandic, or natric horizon unless it is buried. Inceptisols commonly occur on landscapes that are relatively active, such as mountain slopes, where erosional processes are actively exposing unweathered materials, and river valleys, where relatively unweathered sediments are being deposited. Dystrochrepts and Udochrepts are characterized by having low bas saturation percentage and acidic in nature, while Ustochrepts have higher base saturation percentage. Haplustepts do not have either duripan or calcic horizon and base saturation is more than 60%. Dysustepts are the acid Ustepts and developed mostly in Pleistocene or Holocene deposits. Some of the soils that have steep slopes formed in older deposits. The parent materials generally are acid, moderately or weakly consolidated sedimentary or metamorphic rocks or acid sediments. The vegetation was mostly forest

Entisols are the youngest and least developed soils, generally found on hill sides and adjacent to river courses. These soils are formed through deposition of colluvium and alluvium and are present throughout the country. The central concept of Entisols is that of soils that have little or no evidence of the development of pedogenic horizons. Most Entisols have no diagnostic horizons other than an ochric epipedon. Very few have an anthropic epipedon. A few that have a sandy or sandy-skeletal particle-size class have a horizon that would be a cambic horizon were it not for the particle-size class exclusion. Very few Entisols have an albic horizon. In coastal marshes some Entisols that have sulfidic materials within 50 cm of the mineral soil surface have a histic epipedon. On many landscapes the soil material is not in place long enough for pedogenic processes to form distinctive horizons. Some of these soils are on steep, actively eroding slopes, and others are on flood plains or glacial outwash plains that receive new deposits of alluvium at frequent intervals. Some Entisols are old enough to have formed diagnostic horizons, but they consist mostly of quartz or other minerals that are resistant to the weathering needed to form diagnostic horizons. Entisols may have any mineral parent material, vegetation, age, or moisture regime and any temperature regime, but they do not have permafrost. The only features common to all soils of the order are the virtual absence of diagnostic horizons and the mineral nature of the soils. Two sub-groups of this order are recorded. They are Typic Ustorthents and lithic ustorthents. Ustorthents develop through colluvial deposition and are found in landslide scars and on steep slopes. As the soil develops it is constantly removed by erosion. They are shallow, near the bedrock, coarse textured and poorly vegetated. These soils are used for grazing, fodder and firewood collection.

The central concept or Ustorthents is fixed on soils that are deep or moderately deep to hard rock and that do not have ground water within a depth of 150 cm, do not have appreciable cementation by silica, do not have high biologic activity, do not have a clayey texture and a swelling type of clay, and do not have, in the upper 75 cm, a deposit of pyroclastic materials that is as thick as 18 cm. The most common of these soils have a thin or very thin ochric epipedon resting on weakly cemented rock or on sediments. Some Typic Ustorthents formed in mine spoil or fill material. Soils that have a shallow lithic contact are excluded from the Typic subgroup, a convention used throughout this taxonomy. Slopes of Typic Ustorthents range from nearly level to very steep. These soils are used mostly for grazing, forest, or catchments, but some are used for no irrigated grain and a few that have gentle slopes are used as irrigated cropland.

Table 6-1: Areal coverage of different soil types in Jwalamukhi of Dhading District

Soil Types	Area in Sq.m	Area in hectare	Percentage
Dystrochrepts	2007641.52	200.76	1.78
Dytrustepts	77539531.11	7753.95	68.68
Haplohumults	5613649.91	561.36	4.97
Haplustepts	23712658.89	2371.27	21.00
Rhodustults	69.63	0.01	0.00
Ustifluvents	1672036.37	167.20	1.48
Ustochrepts	348880.01	34.89	0.31
Ustorthents	5552.95	0.56	0.00
Waterbody	1997190.63	199.72	1.77
Grand Total	**112897211.01**	**11289.72**	**100.00**

Table 6-2: Areal coverage of different soil types in different wards of Jwalamukhi of Dhading District

Ward No.	1	2	3	4	5	6	7
Great Group	**Area(ha)**	**Area(ha)**	**Area(ha)**	**Area(ha)**	**Area(ha)**	**Area(ha)**	**Area(ha)**
Haplohumults	0.00	0.00	0.01	561.35	0.00	0.00	0.00
Haplustepts	38.31	267.48	152.95	451.23	1219.04	56.76	185.46
Rhodustults	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Ustifluvents	0.00	0.00	0.00	0.00	1.14	0.00	166.06
Ustochrepts	0.00	0.00	0.00	0.02	0.00	34.84	0.03
Ustorthents	0.40	0.00	0.16	0.00	0.00	0.00	0.00
Waterbody	54.34	5.81	4.61	16.45	46.26	3.72	68.57
Grand Total	**1309.04**	**1432.82**	**1284.34**	**1838.81**	**3022.33**	**810.82**	**1591.46**

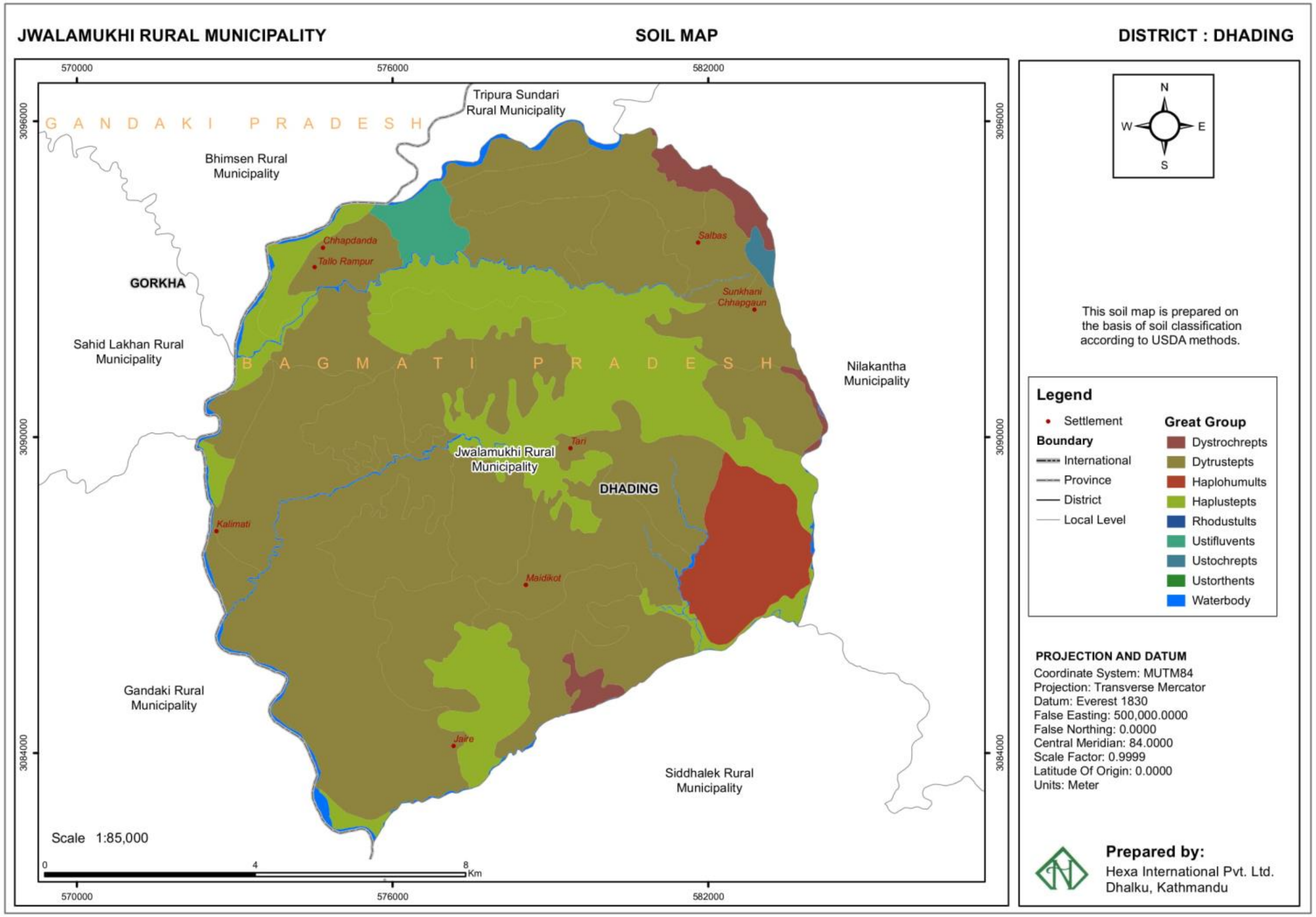

Figure 6-1: Spatial distribution of Soil sub-groups in Jwalamukhi Municipality

Likewise, the physical characteristics of the soil have also been assessed for selected sample pits of the Municipality, which is briefly described below:

Soil color is a variable property, across the landscape and with depth from the surface. Color indicates much about the soil: the amount of organic matter present; the types of minerals and how weathered they are; the current moisture content; how long water is held in the soil (soil drainage class); and oxidation states of iron and manganese.

Red and yellow colors in the subsoil indicate oxidized iron and tell us if the soil is alternately wet and dry, or if it is dry during the growing season. Gray or blue colors may indicate that soils are wet for much of the year, and any iron present is likely to be in chemically reduced form. Dark colors in the soil, especially at the surface, usually indicate higher amounts of organic matter. These soils can be high in nutrients, have favorable structure, and be easily permeable to air, water and plant roots. Light colored soils may be leached (soil constituents such as organic matter, clay, or iron move downward with percolating water faster than they are added from overlying horizons) or contain high amounts of calcium carbonates.

For the objective description of color, the Munsell Color System is used, which has three elements of color: hue, value and chroma. An example of a Munsell description is 10YR 6/2 (the verbal description is "grayish yellow brown"). The 10YR portion is the hue, or the dominant wavelength (the amount of red (R) and yellow (Y) in that color). The formula "10YR" would mean 10 parts of yellow paint to 1-part red paint, giving a grayish color with yellow and brown tones.

In the study area, the color of the soils is dominantly gray to dull yellowish brown (10YR 5/3), grayish yellow brown (10YR 6/2) etc. The color description of Munsell color system is given below in Table 6-3.

Table 6-3: Munsell soil color description

S.N.	Munsell color system	Color description
1	10YR 3/2	Grayish yellow brown
2	10YR 4/2	Grayish yellow brown
3	10YR 4/3	Dull yellowish brown
4	10YR 5/2	Grayish yellow brown
5	10YR 5/3	Dull yellowish brown
6	10YR 6/2	Dull yellowish brown
7	10YR 5/1	Brownish gray
8	10YR 7/1	Ligh gray
9	7.5YR 5/2	Brown
10	10YR 8/1	Light gray

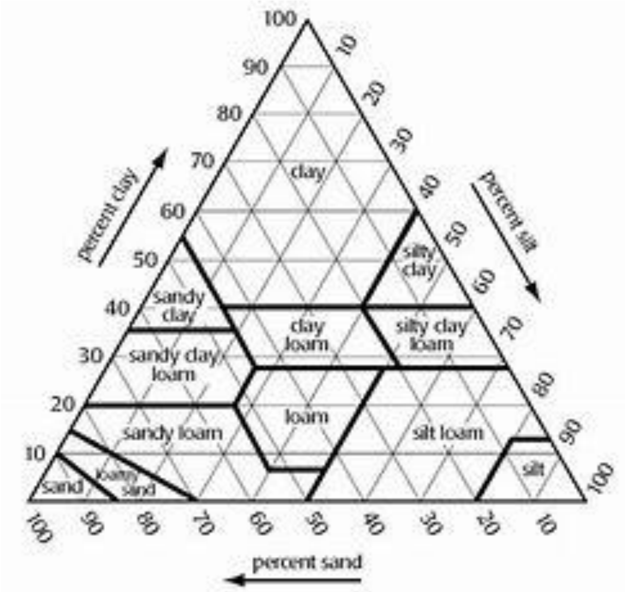

Figure 6-2: Range of surface texture in texture triangle model

Soil texture: Soil texture refers to clay, silt, and sand below 2 mm in diameter. The presence of coarse particles larger than very coarse sand, 2 mm and smaller than 256 mm is recognized by modifiers of textural class names, like gravely sandy loam or cobble loam. The soil texture of the first horizon was determined from the lab test using textural model (Figure 6-3) of the first horizon. The laboratory analysis reveals that the soils (first horizons) of the about 37.8% area silty clay while 26.61% soils were silty loam (Table 6-3, figure 6-2 and figure 6-3). The general characteristics of the textural classification we observed has been described as below.

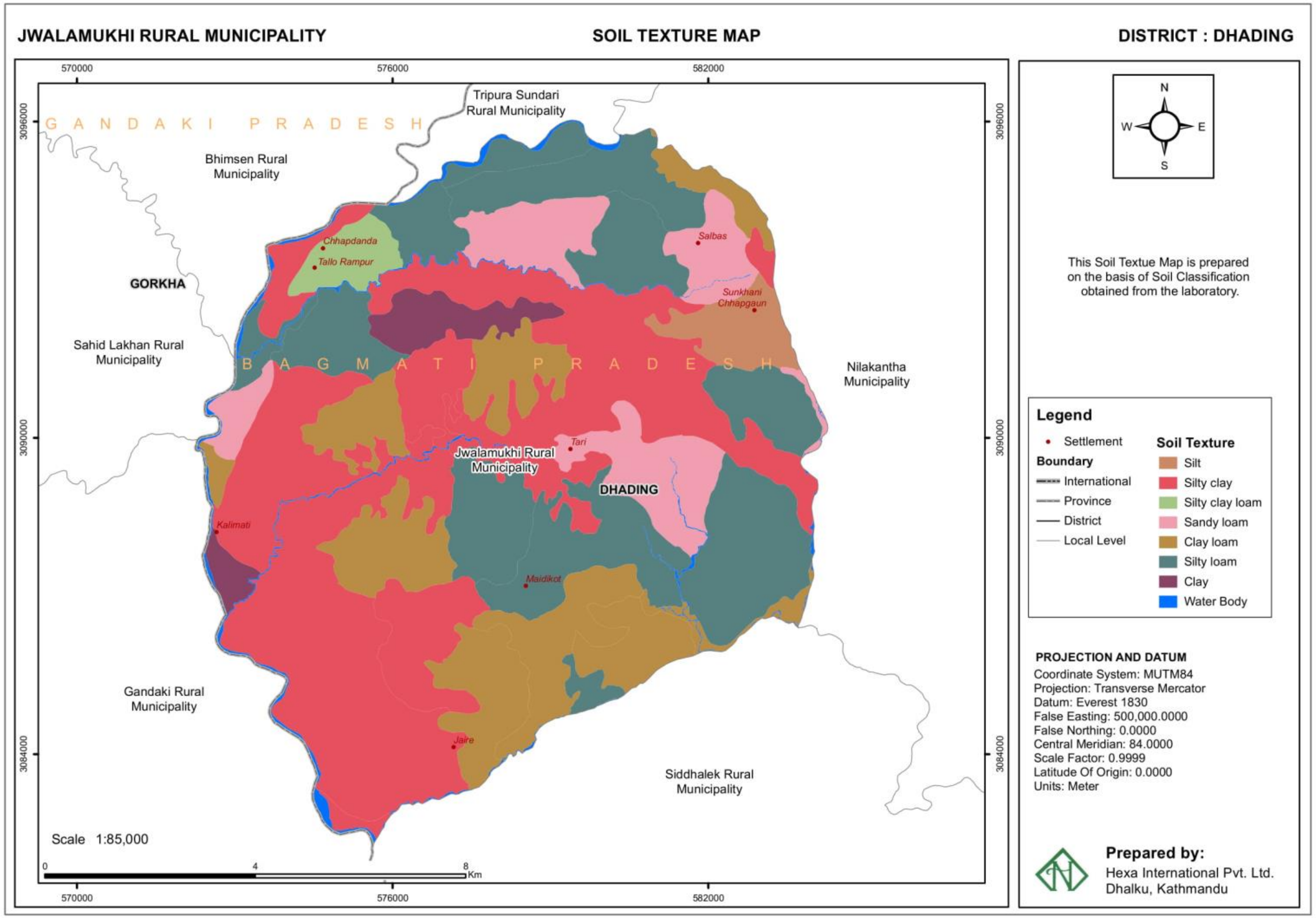

Figure 6-3: Soil texture map in the study area

Table 6-4: Area coverage by different soil textures in Jwalamukhi of Dhading District

Soil Textural Class	Area in Sq.m	Area in Hectare	Percentage
Clay	3191842.36	319.18	2.83
Clay loam	19816293.21	1981.63	17.55
Sandy loam	10560933.26	1056.09	9.35
Silt	2681295.90	268.13	2.37
Silty clay	42671280.81	4267.13	37.80
Silty clay loam	1935725.75	193.57	1.71
Silty loam	30042649.08	3004.26	26.61
Waterbody	1997190.63	199.72	1.77
Grand Total	**112897211.01**	**11289.72**	**100.00**

Loam:

Loam soil consists of three textural components: silt, sand and clay. These elements are mixed with organic matter, water and air to make loam soils. Loam technically consists of 7 to 27 percent clay, 28 to 50 percent silt and 52 percent or less sand. Ranging from clay loam to sandy loam, the classification helps farmers understand how well the soil will support plant life. **Loam soil is recommended for the majority of plants**. Loams with higher levels of sand tend to **resist compaction**. Loam soil holds water better than sandy soil types because of the level of clay particles. **The lack of sufficient organic material in a loam soil may result in soil that dries out too quickly**.

In addition to draining well, **loam soils feature good aeration levels**. Farmers consider loam soils to be in the **middle range when it comes to the ability to maintain nutrient levels**. **It is recommended to add compost for long-term improvement to the nutrient level of loam soil**. The a**mount of sand in loam gives it the ability to drain well**. According to the RAIN network, loam soils are free draining, especially when there is a low organic content.

Silt:

Silt particles are intermediate in size between sand and clay, the other two mineral components of soil. Silt is nothing more than highly weathered rock, broken down to between .002 and .05 millimeters in size. Water is not retained well in larger sand particles, while microscopic clay particles can hold too much water around the roots of plants. Sand also does not bond well with nutrients, while silt tends to be loaded with the soluble nutrients plants need. The organic matter content of soil tends to be highest in soils with a high silt concentration. There is no guarantee that the presence of silt makes good garden soil, but everything else being equal, plants are more likely to prefer it to sandy or clay soils. Silt is most prominent in valley floors, where erosion has deposited large quantities of loose, fertile soil**. Silty soil doesn't warm up as quickly in spring as sandy soil does, so forming it into raised beds with the long face of the bed facing south is also a good idea.**

Silt is granular material of a size between sand and clay, whose mineral origin is quartz and feldspar. Silt is created by a variety of physical processes capable of splitting the generally sand-sized quartz crystals of primary rocks. These involve chemical weathering of rock and a number of physical weathering processes such as frost shattering. The main process is abrasion through water, air or glaciers. The main transport means are fluvial comminution, aeolian attrition and glacial grinding. Silt and clay contribute to turbidity in water. **Silt is easily transported in water or air and is fine enough to be carried long distances by air in the form of dust**. Sedimentary rock composed mainly of silt is known as silt-stone. Thick deposits of silty material resulting from deposition by aeolian processes are often called loess. Silt is chemically distinct from clay, and unlike clay, grains of silt are approximately the same size in all dimensions. Silt may occur as a soil, often mixed with sand and clay or as a sediment mixed in suspension with water in rivers and streams and as deposits in the bottom. **Silt has a moderate specific area with a typically non-sticky, plastic feel**. Silt usually has a **floury feel when dry, and a slippery feel when wet**.

Silt loam:

Plants growing in silty loam need more water than those in clay soil, but much less than those in a sandy soil. The **quantity of organic matter is likely to be adequate, but annual additions of compost only improve the already excellent soil quality**. **It's wise to maintain a cover of mulch on silty soils to prevent the loss of moisture and slowly add organic matter to the soil**.

Silt loam soils are the most balanced and support the greatest diversity of plant life. **When dry, Clods difficult to break; when pulverized, feels smooth, soft, and floury and shows fingerprints**. Moist silt loam has smooth or slick, buttery feel; stains fingers. Silty loam soil is composed of roughly two-thirds silt particles, with the remainder split equally between sand and clay. It consists of Sand: 0–50%, Silt: 50–88%, Clay: 0–27%. **Compared to mucky clay soil or parched desert sand, life is comfortable for plants in silty loam soil**. Plants that grow on high, rocky mountainsides aren't at home here and desert species may not thrive because they are not adapted to the moist, fertile conditions, but all other forms of plant life have it good. It's easier to identify the few types of plants that don't grow well in silty loam, but the species that particularly like loose, fertile soil do especially well -- grasses, bamboo, wetland and aquatic plants, vegetables, fruit trees, berry bushes and ferns, to name a few.

Sandy loam: Sandy loam soils are dominated by sand particles but contain enough clay and sediment to provide some structure and fertility. There are four different types of sandy loam soil that are classified based on the size of the sand particles in the soil. Sandy loam soils have visible particles of sand mixed into the soil. When sandy loams soils are compressed, they hold their shape but break apart easily. Sandy loam soils have a high concentration of sand that gives them a gritty feel. **Sandy loam soils are capable of quickly draining excess water but cannot hold significant amounts of water or nutrients for your plants**. **Plants grown in this type of soil will require more frequent irrigation and fertilization than soils with a higher concentration of clay and sediment**. **Sandy loam soils are often deficient in specific micronutrients and may require additional fertilization to support healthy plant growth**. The best way to improve a sandy loam soil for **cultivation is to mix organic matter into the soi**l. Incorporating a 2- to 4-inch layer of compost or peat moss over the area can significantly improve the ability of your sandy loam soil to hold nutrients and water.

Sandy loams provide a preferred surface for areas that tend to compact because of traffic or other conditions. **Sandy loams that drain freely hold lessened nutrient levels when compared to loams with higher levels of organic materials.**

Sandy soils are not good for most of the crop plants. However, melon and coconut grow in sandy soil. If water is available for irrigation then crops such as maize, millets, barley can be grown in desert soil. Cactus also grows in this soil.

Clayey soils are also not good for many plants. It is only good for crops like paddy, which require a lot of water. Clay is used for making toys, pots, and many other purposes.

Loamy soil is ideal for growing crops such as wheat, sugarcane, cotton, jute, pulses, and oilseeds. Vegetables also grow well in this soil.

Clay loam: Clay loam is a soil mixture that contains more clay than other types of rock or minerals. Loams that contain a great deal of clay tend to be heavy, because they are so dense. While this soil type can be difficult to work with, it can also be improved to be a very good growing medium like adding organic matter. Silty clay is generally brownish gray, with soft and creamy texture, flow shape, rich in organic matter, and with clay content more than 50%.

Soil depth: Depth of a soil refers thickness of unconsolidated, weathered material in centimeters from the mineral soil surface. Depth of soil horizons is an indicator of nature, intensity, and vertical distribution; markedly depend upon the geology, slope, surface process and cover. It provides clues to the stability of the soil material, the characteristics of the bedrock, and the degree of soil weathering. On average, the soil (solum or root influenced depth was found as 60 cm. In some area (sloppy land), it was as low as 25 cm but at the alluvium plains it was appeared to be more than 100 cm.

Soil pH: Soil pH is a measure of the acidity or alkalinity in the soil. It is also called soil reaction. Soil pH influences the solubility of nutrients. It also affects the activity of microorganisms responsible for breaking down organic matter and most chemical transformations in the soil. Soil pH thus affects the availability of several plant nutrients. The acidity or alkalinities in soils have several different sources. In natural systems, the pH is affected by the mineralogy, climate, and weathering. Management of soils often alters the natural pH because of acid-forming nitrogen fertilizers, or removal of bases (potassium, calcium, and magnesium).

Majority of soils of the first horizon collected from the sample pits in the have pH value in the range of 5.02 to 6.48, the average being 5.75. Majority of the soils (52.01%) were slightly acidic in reaction followed by moderately acidic (19.97%). These soils can be safely used for the diversified crop cultivation. About 10.95% area were found to be strongly acidic and should be cautiously used. The spatial distribution of the soil pH in the is presented in table 6-4 and figure 6-6; figure 6-7.

Acidic soils: 4.5-5.5. In acidic soils, soils have high quantities of the iron, manganese and aluminum and could reach to the toxic levels. Micronutrients such as zinc, boron and copper will be deficient as they will be precipitate or will leach out from the soils. Similarly, basic cations such as calcium, magnesium, potassium will be low as they are leached out especially when the soil is coursed nature.

Slightly acidic: 5.5-6.5: In slightly acidic soils sufficient quantities of the iron and aluminum will precipitate, which otherwise could be toxic to the plants. In such soils most of the micronutrients are in sufficient quantities except molybdenum. Such soils are also very suitable for the crops.

Neutral: This is most suitable type of the soil in which soil have enough quantities of calcium to maintain the soils physical and chemical properties. For the nutrient availability, this is most suitable as it can provide plants with all the essential nutrients needed for the growth and development in sufficient quantities and balanced proportion if adequate levels of the water are present there.

Alkaline: >7.5 Alkaline soils contains high reserve of the calcium. But such soils limit the availability of some important nutrients such as phosphorus and zinc through the adsorption and fixation. Similarly, the micronutrients such as iron, copper, manganese will also be deficient in such soils.

Table 6-5: Area covered by major soil reactions in Jwalamukhi of Dhading District.

Soil pH Rating Class	Area in Sq.m	Area in Hectare	Percentage
Strongly Acidic	41895097.38	4189.51	37.11
Moderately acidic	37299433.42	3729.94	33.04
Slightly acidic	27986424.47	2798.64	24.79
Nearly neutral	348511.19	34.85	0.31
very high alkaline	3370553.92	337.06	2.99
Waterbody	1997190.63	199.72	1.77
Grand Total	**112897211.01**	**11289.72**	**100.00**

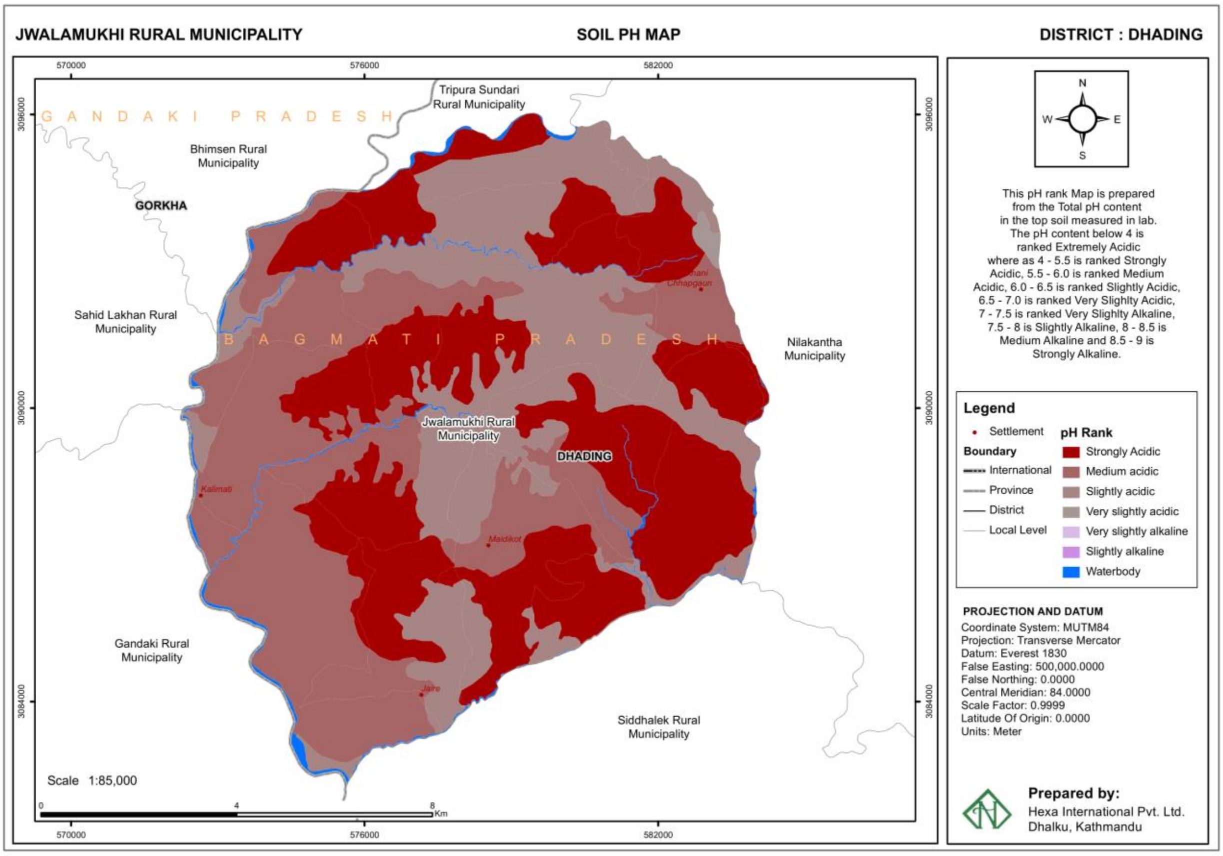

Figure 6-4: Soil reactions map in the study area

Soil organic matter: In broad sense, soil organic matter comprises all living soil organisms and all the remains of previous living organisms in their various degrees of decomposition. Organic matter can be considered a pivotal component of the soil because of its role in physical, chemical and biological processes (table 6-6).

Table 6-6: Functions of organic matter in soil

Physical functions	Chemical functions	Biological functions
Bind soil particles together in stable aggregates	Major source of cation exchange capacity	Food source for microbes and small animals
Influence water holding and aeration	Source of pH buffering	Major reservoir of plant nutrients
Influence soil temperature	Binding site for heavy metals and pesticides	

Therefore, the organic matter (OM) is an important part of soil physical, chemical and biological properties of the soils and considered as the ‘soil’s heart’. This information examines what soil organic matter consists of and how it can contribute to soil fertility. The amount of organic matter in a soil is highly dependent on a range of ecological factors (climate, soil type, vegetative growth, topography) in which it occurs as well as land use and management and tillage of the soil it also discusses how soil management can affect organic matter concentrations in the long term.

In Jwalamukhi Municipality, most of the area (52.03%) were high and 25% land were low in organic matter content but 21.17% area were medium for this soil trait (Figure 6-8 and figure 6-9; table 6-6). While the average value of OM was 3.76%, the value ranged from 1.07 to 6.44%.

The soils with low (<2.5% OM) level of organic matter are not sufficient to maintain the physiological, biological and chemical properties needed for the soils productivity. Even when the nutrients demands are added through the chemical fertilizers, they are inefficiently used. The added nutrients and water get lost through leaching and run off. Soils are highly susceptible to the erosive agents such as water and wind. Biological activities which influences various chemical and physical properties are also low.

Medium (2.5-5% OM) level of organic matter is adequate to maintain the soil productivity. These soils can provide moderate levels of the nutrients through the mineralization and also can hold sufficient quantities of the nutrients and water added to the soils. However, addition of the organic manures at regular interval is needed to maintain its quality. While growing crops at least fifty percent of the recommended dose of organic manures should be added to these soils.

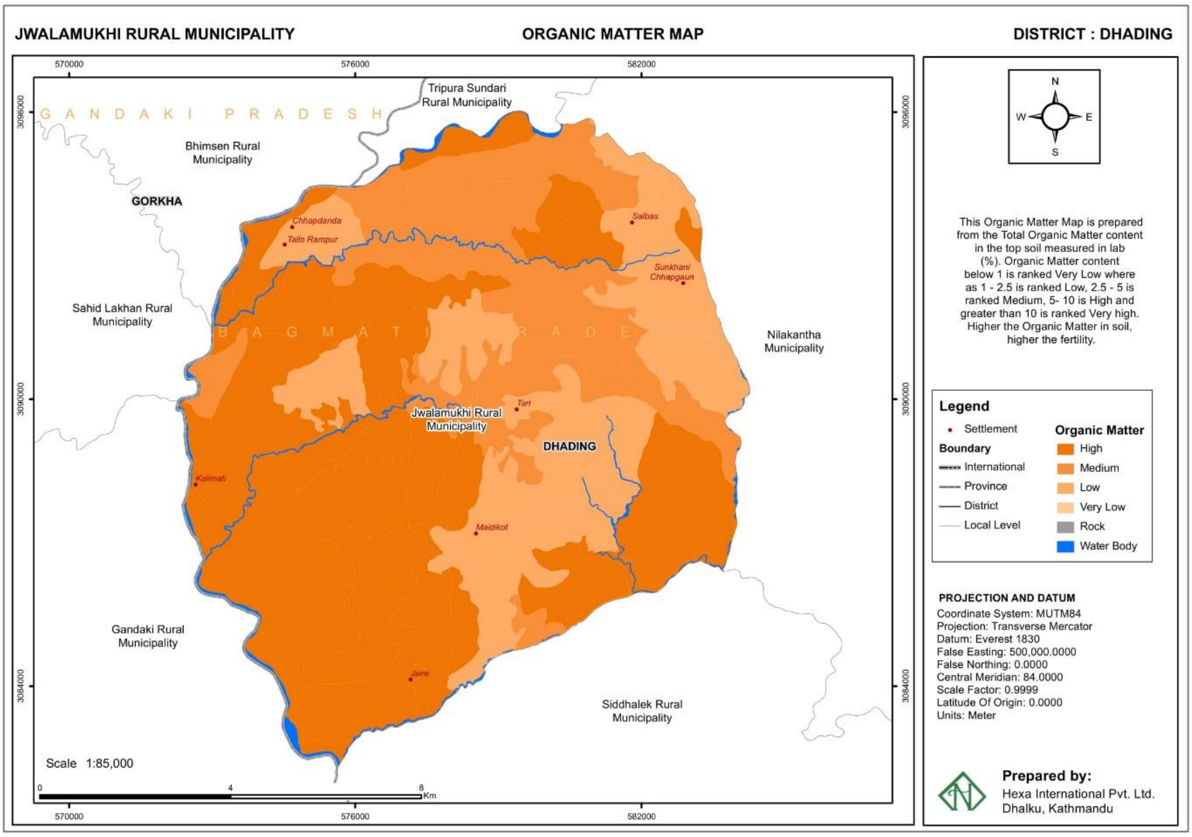

Figure 6-5: Soil organic matter map in the study area

Table 6-7: Area covered by different categories of organic matter in the study area

Soil Organic Matter	Area in Sq.m	Area in Hectare	Percentage
High	58735840.30	5873.58	52.03
Medium	23905890.49	2390.59	21.17
Low	28258289.58	2825.83	25.03
Waterbody	1997190.63	199.72	1.77
Grand Total	**112897211.01**	**11289.72**	**100.00**

Nitrogen, Phosphorous, and Potassium: These soil nutrients play an important role in limited crop production in Nepal. The level and rating of soil nutrients is summarized in Table 6-5.

Nitrogen is needed for the growth and development of the crops as they involve directly in the photosynthesis, amino acids and protein synthesis. Nitrogen in the soils are supplied through organic manures and the chemical fertilizer such as urea. When soil is low in nitrogen, plants are suffered from the nitrogen deficiency and various nutrient deficiency symptoms are appeared. Plant growth is stunted. At initial stage, the lower leaves of the crop show chlorosis at the tip and progress towards base in V-shape pattern. At severe deficiency, the whole plants and field turn yellow. Crops mature unfavorably earlier. It is evident that the soil nitrogen (N) in the varied from 0.05 to 0.32%, and the average value was 0.19%. About 79.86% of the lands were medium to high in in total nitrogen but about 18.37% were low in soil total nitrogen (table 6-7, figure 6-10 and figure 6-11). Hence, soil N can be limiting factor for some areas in this Rural municipality and thus full does of the nutrients should be supplied through the manures and fertilizers to get the optimum crop yield.

Phosphorus mainly involves in the energy storage and transport system in the plants. It is required for the root growth at the seedling stage. Glucose synthesized during the photosynthesis can convert into the carbohydrates such as starch, sucrose etc. only in the presence of phosphorus. Legumes plants demand more phosphorus than non-legume crops as it is very essential for the biological nitrogen fixation at roots. Phosphorus deficient crops shows purple coloration at the older leaves, plants are stunted and root growth is inhibited. The soils were variable in soil available phosphorus (P) (Figure 6-12 and figure 6-13 and table 6-8). The value ranged from 12.49 to 49.51 kg/ha with the mean value of about 31 kg/ha. About 29.17% of the soils were medium to high in plant available phosphorus, and about 69.06% were low in plant available P. This indicates that P management is very important for most of the areas for cultivation in the study area. For the low-level P (30 kg/ha), P should be added through manures and fertilizers at the full recommended doses. The dose can be reduced by half for the medium P (30-55 kg P/ha) soils and to one fourth for high and very high levels of P (>55 kg P/ha).

Potassium directly involves in photosynthesis through regulating the closing and opening of stomata. It helps to maintain osmotic balance in the plants, thus confers resistance to the drought. It makes the stalk/stem very strong and prevents lodging. It provides tolerance to the stresses such as attack of insect pests and diseases. Potassium deficient plants also shows yellowing at the margin of the older leaves and turns to necrosis. Crops are slender and thus easily lodge. They easily lose their turgidity and wilts if the soil moisture decreases. Proportion of unfilled grains increases. The Potassium content in the soil of the varies from nearly 30 to 507.6 kg/ha, average value being 268.8 kg/ha. Majority of the area (76.65%) showed low to very low in plant available potassium, and thus this area should receive special care for the potassium management. However, about 21.58% areas were under medium to very high in plant available K concentrations (Table 6-9, Figure 6-14; figure 6-15).

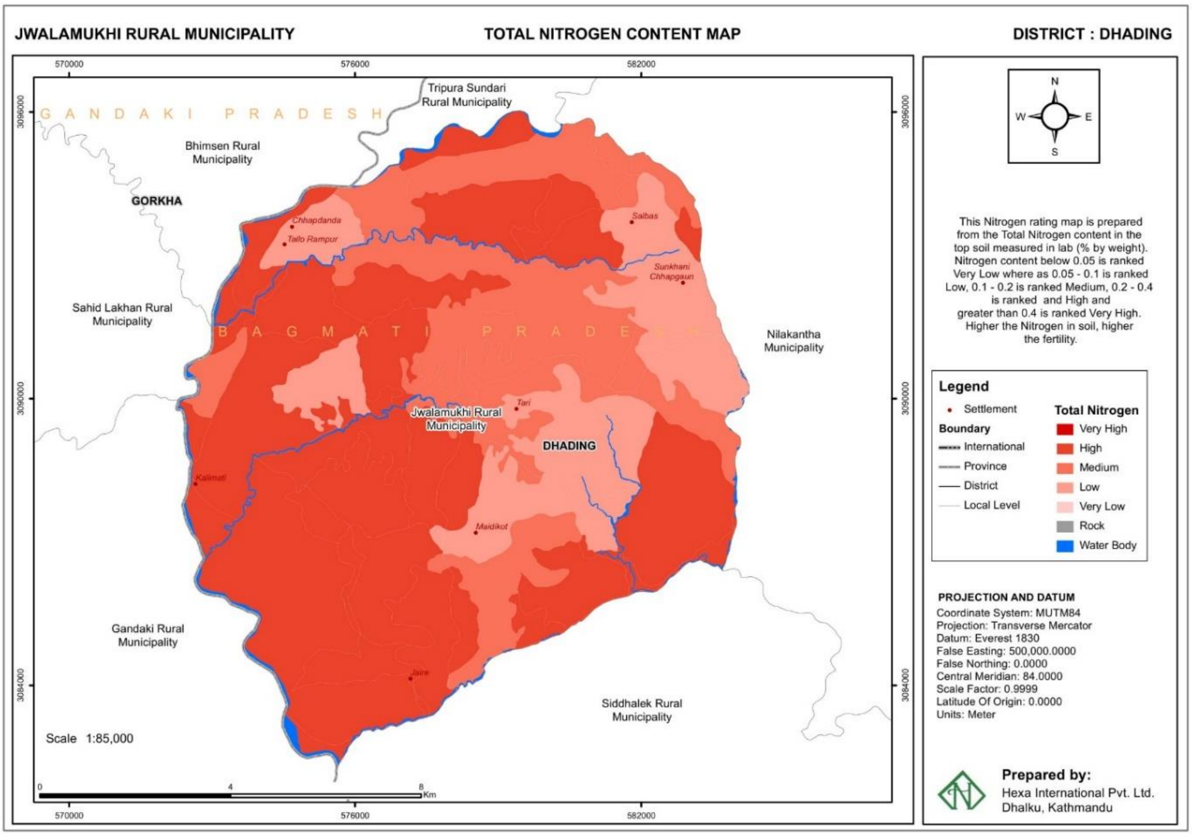

Figure 6-6: Soil Nitrogen map in Jwalamukhi of Dhading istrict

Table 6-8: Area covered by categories of soil total nitrogen in Jwalamukhi of Dhading District

Total Nitrogen	Area in Sq.m	Area in Hectare	Percentage
High	58735840.30	5873.58	52.03
Medium	31421313.61	3142.13	27.83
Low	20742866.46	2074.29	18.37
Waterbody	1997190.63	199.72	1.77
Grand Total	**112897211.01**	**11289.72**	**100.00**

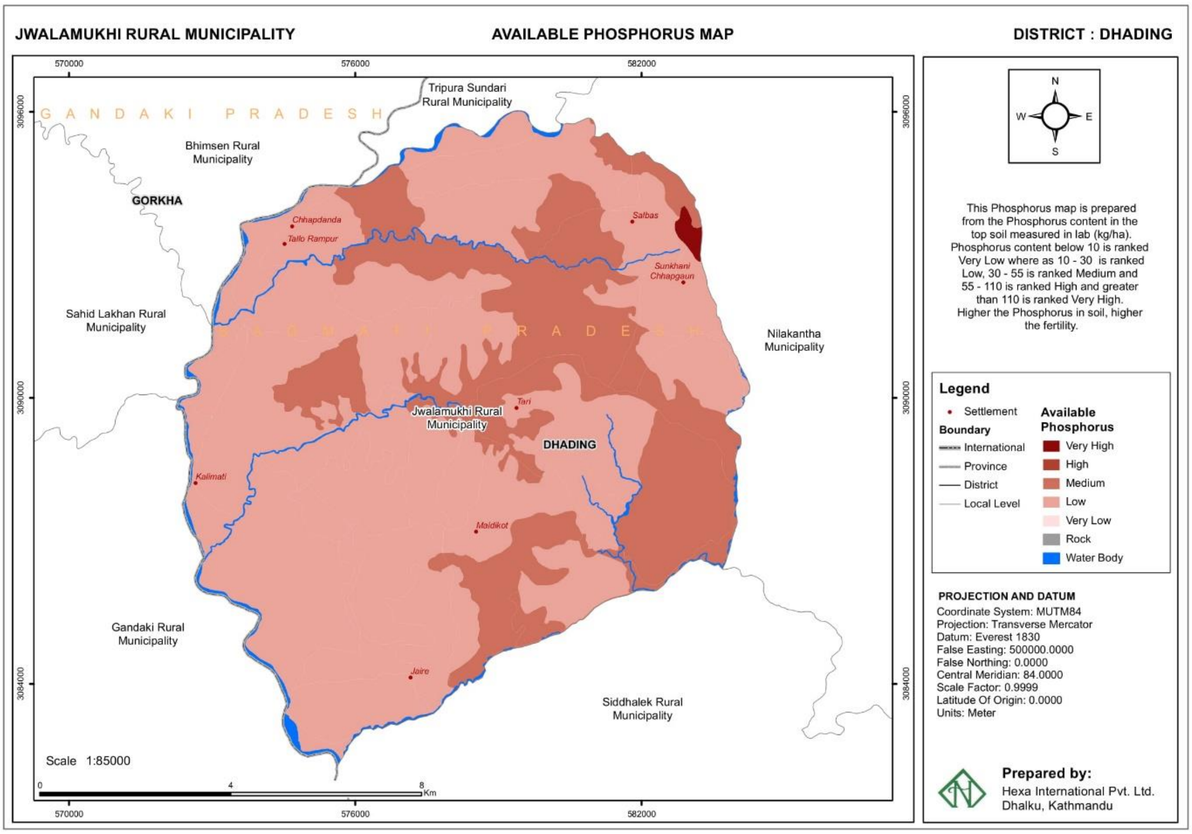

Figure 6-7: Soil available phosphorus in the study area

Table 6-9: Area covered by categories of soil phosphorus levels in Jwalamukhi of Dhading District

Available Phosphorous	Area in Sq.m	Area in Hectare	Percentage
High	354167.10	35.42	0.31
Medium	32573680.66	3257.37	28.85
Low	77972172.61	7797.22	69.06
Waterbody	1997190.63	199.72	1.77
Grand Total	**112897211.01**	**11289.72**	100.00

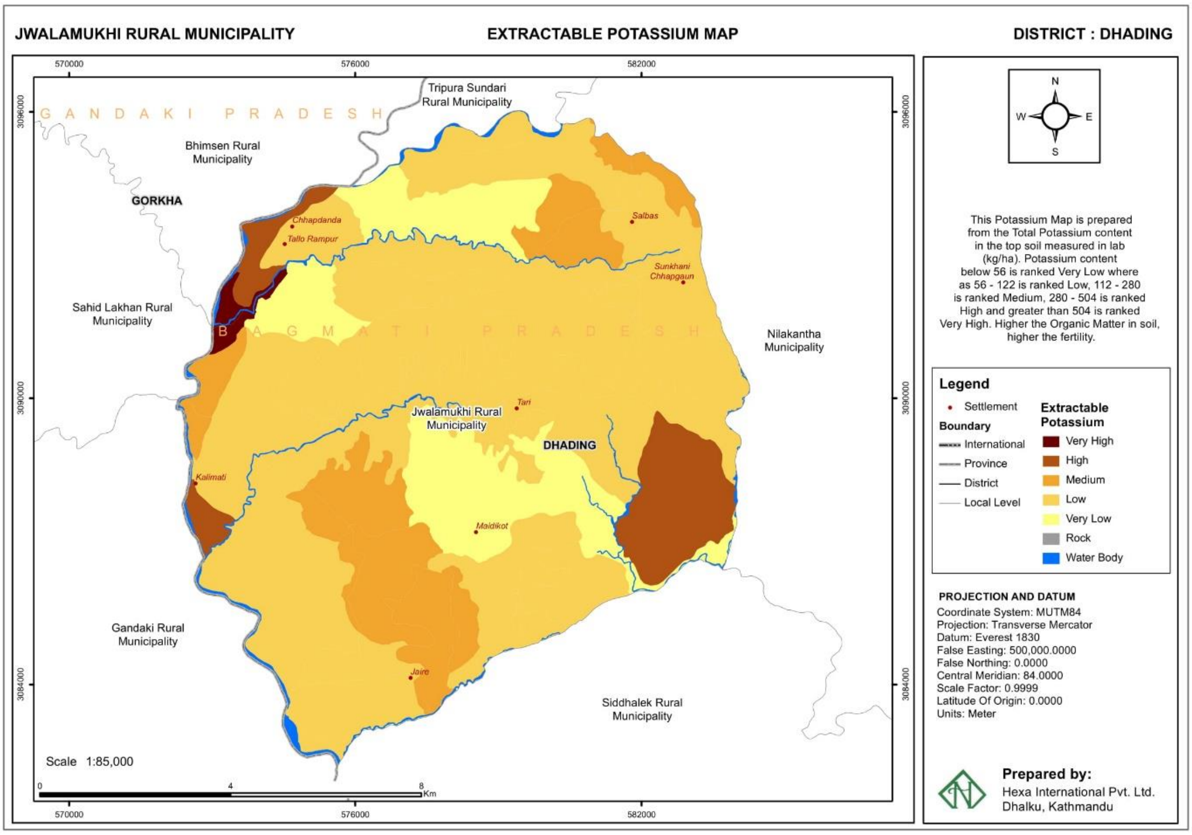

Figure 6-8: Soil available Potassium Map in the study area

Table 6-10: Area covered by categories of available potassium levels in Jwalamukhi of Dhading District

Available Potassium	Area inSq.m	Area in Hectare	Percentage
Very High	870668.20	87.07	0.77
High	7779665.63	777.97	6.89
Medium	15711175.71	1571.12	13.92
Low	84866474.48	8486.65	75.17
Very Low	1672036.37	167.20	1.48
Waterbody	1997190.63	199.72	1.77
Grand Total	**112897211.01**	**11289.72**	**100.00**

For the low available K (<110 kg/ha), K should be added through manures and fertilizers at the full recommended doses. The dose can be reduced by half for the medium K (110-280 kg P/ha) soils and to one fourth for high and very high levels of K (>280 kg P/ha).

6.2 Soil GIS Database

Soil database has been prepared in two different tables as given in the NLUP specification. The first table basically stores the data collected from soil pit right in the field where the second table stores data from laboratory analysis of soil properties.

The soil pit database contains following information in GIS as per the specification provided by TSLUMD:

Table 6-11: Database format for standard soil profile description (soil pit level)

S.N.	Data Field	Data Type	Description	Remarks
1	FID	Feature Id	Feature	
2	SHAPE	Geometry	Geometric Object type	
3	ID	Long	Unique Object ID	
4	PIT_NO	Integer	Soil pit number	
5	CDSTRL_NO	Integer	Cadastral parcel number of the pit	
6	VDC	String		
7	WARD_NO	Integer		
8	EAST	Double	Easting Co-ordinate Value of Pit	
9	NORTH	Double	Northing Co-ordinate Value of Pit	
10	ELEVATION	Double	Elevation of Land (m)	
11	PHY_UNIT	String	Physiographic unit	
12	IMAGE	String	Satellite image used	
13	DATE_	String	Date of digging soil pit or examination	
14	PHY_REL	String	Physiographic (local relief)	
15	LU_VEG	String	Land use and vegetation	
16	SLP_DIR	String	Slope direction	
17	CROP_PTN	String	Cropping pattern	
18	SLOPE_DEG	String	Slope degree	
19	CLIMATE	String	Climate	
20	CLASS	String	High order of Soil classification	
21	PARNT_MET	String	Parent material	
22	DRN_CLS	String	Drainage class	
23	MOIST_CON	String	Moisture condition	
24	DEPTH_GW	Integer	DEPTH of ground water	
25	HUMAN_INF	String	Human Influence	
26	TOTAL_HOR	Integer	Total number of horizon	
27	FIRST_HOR	String	First horizon or Top layer or epipedon	
28	SECND_HOR	String	Second horizon or Sub surface first or indopedon	
29	THIRD_HOR	String	Third horizon or sub surface second	
30	FORTH_HOR	String	Fourth horizon or sub surface third	
31	DEPTH_FH	Integer	Depth of first horizon	
32	DEPTH_SH	Integer	Depth of second horizon	
33	DEPTH_TH	Integer	Depth of third horizon	
34	DEPTH_4H	Integer	Depth of fourth horizon	
35	BOUND_FH	String	Boundaries of first horizon	
36	BOUND_SH	String	Boundaries of second horizon	
37	BOUND_TH	String	Boundaries of third horizon	
38	BOUND_4H	String	Boundaries of fourth horizon	
39	DIO_HR_FH	String	Diagnostic horizon of first horizon	
40	DIO_HR_SH	String	Diagnostic horizon of second horizon	

Table 6-11: Database format for standard soil profile description (soil pit level)

S.N.	Data Field	Data Type	Description	Remarks
41	DIO_HR_TH	String	Diagnostic horizon of third horizon	
42	DIO_HR_4H	String	Diagnostic horizon of fourth horizon	
43	MXT_COL_FH	String	Matrix color of first horizon	
44	MUNSELL_FH	String	Munsell color of first horizon	
45	MOTTL_FH	String	Mottling of first horizon	
46	MOTTL_SH	String	Mottling of second horizon	
47	MOTTL_TH	String	Mottling of third horizon	
48	MOTTL_4H	String	Mottling of fourth horizon	
49	TXTURE_FH	String	Texture of first horizon	
50	TXTURE_SH	String	Texture of second horizon	
51	TXTURE_TH	String	Texture of third horizon	
52	TXTURE_4H	String	Texture of fourth horizon	
53	COFRAG_FH	String	Coarse fragment of first horizon	
54	COFRAG_SH	String	Coarse fragment of second horizon	
55	COFRAG_TH	String	Coarse fragment of third horizon	
56	COFRAG_4H	String	Coarse fragment of fourth horizon	
57	ST_FH	String	Structure of first horizon	
58	ST_SH	String	Structure of second horizon	
59	ST_TH	String	Structure of third horizon	
60	ST_4H	String	Structure of fourth horizon	
61	POR_FH	String	Porosity of first horizon	
62	POR_SH	String	Porosity of second horizon	
63	POR_TH	String	Porosity of third horizon	
64	POR_4H	String	Porosity of fourth horizon	
65	CONSIST_FH	String	Consistence of first horizon	
66	CONSIST_SH	String	Consistence of second horizon	
67	CONSIST_TH	String	Consistence of third horizon	
68	CONSIST_4H	String	Consistence of fourth horizon	
69	ROOT_FH	String	Roots of first horizon	
70	ROOT_SH	String	Roots of second horizon	
71	ROOT_TH	String	Roots of third horizon	
72	ROOT_4H	String	Roots of fourth horizon	
73	ORD_SC	String	Order of soil Classification	
74	SUB_ORD_SC	String	Sub-Order of Soil Classification	
75	G_GROUP_SC	String	Grate group of Soil Classification	
76	GROUP_SC	String	Group of Soil Classification	
77	FAMILY_SC	String	Family of Soil Classification	
78	SERIES_SC	String	Series of soil Classification	

CHAPTER 7 : CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This report presented information combining data from semi-detailed soil survey and laboratory analysis of soil test results – an outcome of the project entitled “Preparation of Rural Municipality level land resource maps, database and reports” (Package No.: TSLUMD/CS/QCBS/01/07/2077/078) assigned to Hexa International Pvt. Ltd. by TSLUMD / GoN. Out of thirteen Municipality/Rural Municipalitys in Dhading district covered under the package, this report contains information of Jwalamukhi Rural Municipality. Soil maps were prepared by integrating GIS, RS and GPS technologies where soil mapping units were identified based on information on landform and distribution of land types. Guided by zoning concept, cadastral maps also formed the major basis for delineating soil boundaries to increase land utilization and for developing sustainable natural resource management in this region.

Soil classification of the area was done based on the USDA soil taxonomy and soil orders found in the region are Entisols (3.57%), Ultisols (4.97%) and Inceptisols (89.69%). A total of 32 soil pits were taken in the field representing varied micro topography. Soil analysis report of all the pits showed that the soil of Jwalamukhi Rural Municipality is suitable for most of sub-tropical crops. As most of the area are under low NPK and OM content, application of organic manures, chemical fertilizers, use of green manures, etc. so as to increase soil OM content and to supply the nutrients like NPK is necessary in this study area. Furthermore, cultivation on the steep slope is common in study area, soil erosion conservation measures like terracing, stripe cropping, etc. should be followed. All individual soil pits are grouped and aggregated into soil mapping units together under different USDA Soil Taxonomy hierarchy as sub-order, great group, sub-group, and family. In the context of soil available nutrients, organic matter content in the soil was found to be within the range of low to high, Nitrogen were found to be within the range of low to high range, available phosphorus was found to be in low to high range and potassium content in the soil were also found to be in very low to very high range. The dominant soil texture of the Jwalamukhi Rural Municipality is silty clay (37.80%) followed by silty loam (26.61%) and clay loam (17.55%). About 37.11% land area have very strongly acidic soil reaction followed by strongly acidic (33.04%), All individual soil pits are grouped and aggregated into soil mapping units together under different USDA Soil Taxonomy hierarchy as sub-order, great group, sub-group, family and series.

7.2 Recommendations

The integration of 3S (RS, GIS & GPS) technology in soil survey is found 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 local units of Nepal for proper land use planning and sustainable development of local units in future. Study of various endopedons and epipedons with their observable physico-chemical properties (pH, texture, color, structure, mottles, roots, and boundary) is effective for soil classification. Laboratory analysis (NPK, pH, texture and OM) of upper 30 cm depth soil further strengthen the soil classification procedure. However, some important parameters like CEC, texture, mineralogy, organic carbon and pH of subsoil is very necessary to characterize the sub-order, great groups and family of each order which is to be done in this process. Most of the soils in the agricultural lands are deep enough to wide range of agricultural crops. Organic matter should be enriched in low level region. Area with moderately acidic to very strongly acidic soil reaction should be reclaimed to increase the soil pH so as to increase the availability of plant nutrients. Moreover, the soils of Jwalamukhi Rural municipality were found to be very much suitable for most of the crops. However, addition of organic manures, soil conservation measures on steep land like terracing, stripe cropping, etc., growing of cover crops in fallow land, and integrated nutrient management is highly recommended for better crop production and sustainable soil management. Furthermore, better soil management practices including developing access to irrigation, periodic soil tests and balanced uses of fertilizers are necessary to maintain soil fertility for sustained food production.

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Annex 1: Annual average rainfall (mm) in the study Rural Municipality from 2004-2019

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
2004	4.2	0.0	0.0	149.8	231.0	640.2	551.2	483.2	390.9	204.4	6.0	0.0	2660.9
2006	0.0	0.0	27.2	15.4	337.8	159.1	397.3	468.5	307.3	18.8			1731.4
2007	0.0	125.4	35.2	67.9	62.5	479.7	385.2	285.1	335.6	42.2	0.0	0.0	1818.8
2008	9.4	6.4	38.3	81.5	84.3	433.2	665.7	569.5	188.9	8.2	0.0	0.0	2085.4
2009	0.0	0.0	27.1	98.5	91.9	156.1	649.3	631.2	136.1	157.6	0.6	0.2	1948.6
2010	0.4	5.6	25.4	87.9	220.1	260.5	732.5	556.2	234.4	45.3	0.0	0.0	2168.3
2011	5.6	15.8	74.4	76.1	152.4	614.2	496.8	414.4	281.6	0.0	39.2	0.0	2170.5
2012	29.6	55.5	4.2	67.3	52.2	478.3	595.4	557.8	429.2	12.4	0.0	0.0	2281.9
2013	14.0	59.3	20.0	44.3	120.0	412.2	509.8	394.0		0.0	0.0	0.0	1573.6
2014	0.0	0.0	0.0	0.0	0.0	22.5	343.2	239.1	84.8	1.2	0.0	0.0	690.8
2015	0.0	1.8	0.0	0.0		188.7	477.8	362.8	234.9	81.2	0.0	0.0	1347.2
2016	3.5	0.0	18.0	10.8	171.4	257.7	536.9	130.2	277.4	0.0	0.0	0.0	1405.9
2017	0.0	11.0	53.8	0.0	18.6	68.3	185.0	204.3	98.8	10.5	0.0	0.4	650.7
2018	0.8	0.0	58.8	150.1	190.6	552.3	461.2	796.6	189.6	2.4	0.0	0.0	2402.4
2019	42.0	80.0	53.4	92.1	80.6	207.4	476.9	429.2	510.8	5.6	0.0	28.4	2006.4
Average	**11.8**	**26.1**	**44.2**	**54.4**	**166.3**	**389.8**	**552.6**	**519.5**	**297.3**	**42.8**	**10.2**	**9.4**	**2106.1**

Station: Arughat, Dhading ***Source: Department of Hydrology and Meteorology***

Annex 2: Annual average temperature (degree Celsius) in study Rural Municipality from 2007-2017

Months	Years																	
	2007		2008		2009		2010		2011		2012		2013		2014		2017	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Jan	-	-	21.6	6.9	24.3	8.1	22.8	6.9	-	-	22.8	9.3	21.5	5.2	-	-	23.1	-
Feb	22.9	-	22.8	6.6	26.3	10.2	24.4	9.2	-	-	25.2	9.3	31.8	15.3	-	-	27.1	8.1
Mar	27.3	-	28.3	12.7	27.2	14.0	32.1	15.6	-	-	30.8	19.3	31.5	15.3	32.0	22.7	28.7	11.4
Apr	32.4	18.0	32.9	16.9	34.4	17.1	33.1	16.9	-	-	31.1	16.3	31.2	15.4	33.1	23.0	31.6	15.1
May	32.6	20.2	33.7	17.5	32.4	18.7	-	-	-	-	31.9	19.4	32.9	23.4	33.4	23.5	31.3	19.5
Jun	32.2	22.8	30.9	18.9	33.1	22.2	33.7	21.7	-	-	33.7	22.9	32.9	23.6	33.3	22.9	-	-
Jul	31.7	23.5	32.4	23.9	33.6	23.1	33.0	22.7	23.7	-	31.7	24.1	34.1	22.4	-	-	-	-
Aug	32.1	24.0	32.2	23.8	32.2	22.2	32.2	23.1	23.6	-	32.3	24.1	29.1	19.1	-	-	-	-
Sept	30.8	19.3	30.5	19.6	33.2	21.7	29.7	17.9	-	-	29.7	17.4	22.0	7.6	-	-	-	-
Oct	26.5	12.2	27.3	13.2	23.6	13.0	26.6	14.4	-	-	26.1	10.6	-	-	21.9	6.6	-	-
Nov	22.3	7.8	25.5	11.5	21.7	10.0	22.8	10.2	-	-	22.8	8.9	-	-	22.3	8.4	-	-
Dec	31.9	22.7	32.0	23.1	32.1	22.1	31.2	22.1	-	-	31.3	23.3	25.8	11.3	-	-	-	-
Average Total	**29.3**	**15.5**	**29.2**	**16.2**	**29.5**	**16.9**	**29.2**	**16.4**	**23.7**	**-**	**29.1**	**17.1**	**29.3**	**15.9**	**29.3**	**17.9**	**28.4**	**10.8**

Station: Dhadingbesi, Dhading ***Source: Department of Hydrology and Meteorology***

Annex 3: Pit-wise distribution of the soil physical and chemical properties in the study area

S.N.	Profile No.	Pit	District	Soil pH	Soil OM%	Total N%	Available P2O5 Kg/ha	Available K2O Kg/ha	Soil Texture	Sand%	Clay%	Silt%
1	JW-268	268	Dhading	6.45	5.95	0.30	21.78	94.8	Silty clay	7.3	42.5	50.2
2	JW-276	276	Dhading	6.05	6.44	0.32	21.12	231.6	Clay loam	40.5	36.6	22.9
3	JW-280	280	Dhading	5.76	5.55	0.28	29.70	94.8	Silty clay	11.3	41.5	47.2
4	JW-286	286	Dhading	5.08	2.35	0.12	30.58	75.6	Clay loam	41.5	35.7	22.8
5	JW-288	288	Dhading	5.36	5.59	0.28	25.52	94.8	Clay loam	41.3	36.8	21.9
6	JW-289	289	Dhading	5.29	5.13	0.26	14.31	140.4	Silty clay	10.6	41.3	48.1
7	JW-291	291	Dhading	6.31	5.29	0.26	43.48	44.4	Clay loam	40.3	37.1	22.6
8	JW-296	296	Dhading	5.75	5.90	0.29	23.32	433.2	Clayey soil	8.6	40.8	50.6
9	JW-299	299	Dhading	5.88	1.41	0.07	22.88	42.0	Silty loam	18.1	16.2	65.7
10	JW-300	300	Dhading	5.1	5.33	0.27	19.14	210.0	Clay loam	37.2	35.8	27
11	JW-301	301	Dhading	6.4	5.52	0.28	19.36	42.0	Silty loam	19.3	18.5	62.2
12	JW-303	303	Dhading	5.27	5.01	0.25	49.51	288.0	Silty loam	17.8	18.3	63.9
13	JW-309	309	Dhading	5.17	1.25	0.06	22.00	94.8	Sandy loam	70.4	17.6	12
14	JW-311	311	Dhading	6.48	5.35	0.27	16.79	174.0	Clay loam	37.9	38.3	23.8
15	JW-314	314	Dhading	5.4	1.28	0.06	37.67	68.4	Clay loam	40.7	35.2	24.1
16	JW-317	317	Dhading	5.31	5.42	0.27	16.79	99.6	Silty clay	10.5	40.6	48.9
17	JW-319	319	Dhading	5.22	1.37	0.07	27.06	68.4	Silty loam	17.4	14.7	67.9
18	JW-320	320	Dhading	5.79	3.69	0.18	18.48	241.2	Sandy loam	66.5	16.3	17.2
19	JW-321	321	Dhading	5.79	5.26	0.26	17.87	54.0	Silty loam	18.6	17.5	63.9
20	JW-322	322	Dhading	5.35	2.18	0.11	19.80	56.4	Clay loam	39.6	37.3	23.1
21	JW-325	325	Dhading	6.28	2.63	0.13	33.58	96.0	Silty clay	11.4	40.7	47.9
22	JW-326	326	Dhading	6.26	5.39	0.27	28.16	507.6	Silty loam	6.3	20.3	73.4
23	JW-327	327	Dhading	5.85	1.07	0.05	12.49	108.0	Silty soil	9.8	8.4	81.8

S.N.	Profile No.	Pit	District	Soil pH	Soil OM%	Total N%	Available P2O5 Kg/ha	Available K2O Kg/ha	Soil Texture	Sand%	Clay%	Silt%
24	JW-331	331	Dhading	5.69	5.69	0.28	12.55	90.0	Clay soil	42.6	55.7	1.7
25	JW-334	334	Dhading	5.92	5.45	0.27	16.95	320.4	Silty clay	6.6	42.2	51.2
26	JW-336	336	Dhading	5.14	1.31	0.07	29.70	82.8	Sandy loam	71.6	15.7	12.7
27	JW-338	338	Dhading	5.26	1.70	0.08	27.72	68.4	Silty clay loam	18.4	31.2	50.4
28	JW-342	342	Dhading	5.18	2.72	0.14	44.34	30.0	Silty loam	18.7	17.1	64.2
29	JW-343	343	Dhading	5.37	5.26	0.26	40.03	147.6	Silty loam	19.7	17.5	62.8
30	JW-344	344	Dhading	6.13	3.92	0.20	29.26	46.8	Sandy loam	71.4	17.8	10.8
31	JW-348	348	Dhading	6.21	3.66	0.18	29.04	99.6	Silty loam	18.3	16.5	65.2
32	JW-355	355	Dhading	5.02	5.10	0.25	17.83	106.8	Silty loam	15.3	13.9	70.8

FINAL REPORT

Land Use Zoning Report

Jwalamukhi Rural Municipality of Dhading District

Package No.: TSLUMD/CS/QCBS/01/07/2077/078

Executive Summary

Dhading district under central area of Nepal, Bagmati Province. Especially this Jwalamukhi Rural Municipality is located middle west part of the district. Land use zoning of Jwalamukhi Rural Municipality is done based on suitability analysis by using various parameter like topographic elements, ZY-3 satellite image, field visit, soil information, land system, land capability, present land use data, risk factors, climatic data (rainfall, temperature and humidity) and socio-economic data. Out of total ten-land use zoning class, there are nine land use zoning classes are defined. Others Zone is not proposed in this Rural Municipality. Result shows that the most of the land in Jwalamukhi Rural Municipality consist under Agriculture zone and Forest zone cover 48.29% and 41.94% of the total land. Similarly, Residential zone consist (5.16%), Public Use Zone (2.80%) and Riverine stream lake and marsh (1.56%). Another land use zoning class like Commercial, Mines and Minerals, Industrial and Cultural and Archeological have occupied less area.

Within agriculture zone, mainly, cereal crops, cash crops, horticulture are found more appropriate for cultivation, however, the land adjoining to and surrounded by forest are suitable for agro-forestry. Rice, Millet, maize, buckwheat, potato are the dominant crop in this area. Specially, this Rural Municipality is under High Hill area, Cow, Buffalo, Sheep, Goat, Pig, are main livestock in this region. For animal husbandry, sufficient land has allocated. Cash crops such as Potato, fruits, vegetables, lentils, pulses and beans and oil seed etc. Fish farming identified as potential in this area.

During the zoning, we incorporate the different policy, projects and acts of Government of Nepal like Road policy, Forest Policy, Prime Minister Agricultural Modernization Project (PMAMP), department of mines and geology's mines and minerals etc. Land yielding low agriculture production is allocated for new residential and commercial zones. Prime agriculture lands are preserved for better food production. Human settlements should be far from the potential risks like fire, flood, and landslide as much as possible. As a hilly rural municipality this area consist highly sloping area with land capability class II, III and IV. III Class consist the highest area of the total land. Class II and III are suitable for agriculture specially for cereal and cash crops. Due to steeply slope, it is difficult to manage irrigation facility. Farmer mostly can produce one or two crops in a year only. Preventive method cannot fulfill the require of people. So Modern technology may can help to increase agriculture product. PMAMP program has four categories like Pocket, Block, Zone and Super zone. However Prime Minister Agriculture Modernization Project didn't selected this rural municipality as pocket, zone and super zone, high yield agriculture crops should promote.

This rural municipality is rich in cultural diversity. Most of the people are from Brahmin Kshetri Community and others hilly community. All caste and ethnic group have own culture and tradition. Beautiful religious Jwalamukhi, Chitre Kalika, Kailash Temple, Kag Kot, Maju Kot, Maidi Kot, Mandali Temple, Baraha Kalika, Chainpur Kot, Sthanpati, Bangkot Ghat, Khari Kot and Mahadevasthan etc. are religious place which can be promote as tourist destination.

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CHAPTER 1 : INTRODUCTION

1.1 Background and Rationale

Land Use Zoning is the process of designating legalized uses of certain parcels of land by governments. The government will designate various zones for different uses of land, such as agricultural, residential, commercial, industrial, public use etc. It is a practice of using of land based on mapped zones which separate one set of land uses from another. Generally, land use zoning is done on the basis of a detailed study of Present Land Use Pattern, Land System, Land Type, Land Capability, Geology and different types of potential risk and natural hazards available in the study area where we formulate a classification scheme for land use zoning.

Significance of zoning is prominent in those days even more mostly in the developing countries more and more unplanned residential areas are being developed by unauthorized groups. This leads to complication in providing services to the residents. Services like road access, electricity, communications, water supply, disposal sites for newly developed residential sites may cost much higher for government if not properly planned. We have recent experience of major earthquake in 2015, it is now very important to select the appropriate site for planning, i.e., new selected development sites should be far from risk zones like landslides, flood, fire hazard, seismic risk, geological thrust, liquefaction, industrial pollutions and should be safe from major earthquakes. Land should not be over allocated to residential areas, since it will reduce the agricultural or forest production. Natural beauty will remain intact even after a good land use zoning.

Land use zoning is assessed based on the suitability of sustainable use for a specific 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 off-site effects for farming. In contrary, land use zoning is the suitability classification of land for various land use purposes. The suitability classes are rated from the most suitable to the least. Each suitability class is therefore designated a zone with suitability ratings. Based on the suitability of land for various land use classes, land use zones are classified into eleven broad categories with associated ratings. The zoning is done for agriculture, residential, commercial, industrial, forest, public utility zones, mine and minerals, cultural and archeological, riverine stream, lake and marsh and other zones.

The rationales of the program are to identify and classify the land utilization sectors based on soil quality, land capability and available human and natural resources for more beneficial income generation activities like cash crops, horticulture or herbs production maintain the soil quality. Similarly, it is to identify land for residential, public use, industries and commercial areas among the existing settlements. All these activities will be done in such a way which will balance the environment and national policy of land utilization.

1.2 Objectives of the Study

The main objective of the study is to prepare a scientific and comprehensive land resource inventory at Rural Municipality/Municipality level and assess and delineate land use based on land types, associated soils and land capability classes with the main to formulate a sound and sustainable land use planning. The present study aims to fulfill the following major objectives:

- Classify agricultural lands for the purpose of identifying most suitable and lucrative crop production and classify land for non-agricultural purpose based on land types and associated land characteristics
- Prepare land use zoning maps of Jwalamukhi Rural Municipality at 1:10,000 scale portraying different zones and sub- zones as per the Governmental, Land Use Act 2076.
- prepare appropriate GIS database on present land use zoning of the Rural Municipality; and
- Prepare reports on conceptual basis and methodology of land use zoning and models of GIS database

1.3 Study Area

Jwalamukhi is one of the 11 rural municipalities of the Dhading district. The rural municipality is named after the sacred Jwalamukhi Temple, located in one of the wards. The rural municipality was established on 10th March 2017, merging four VDC units i.e. Khari, Dhola, Nepal, Maidi and Chainpur from the previous administrative structure. Sadhbhyanjang is the administrative center of the rural municipality.

Jwalamukhi rural municipality shares border with three municipalities each in Dhading and Gorkha District. In the Dhading district, the rural municipality shares its border with Tripurasundari, Neelkantha and Siddhalek. Additionally, Shahid lakhan, Bhimsen and Gandaki municipality of Gorkha district are connected to the rural municipality. Geographically it extends from 84º 44' 3.07'' E to 84º 51' 22.92'' E and 27º 51' 25.51'' N to 27º 58' 52.45'' N. The total area of the rural municipality is 112.90 sq.km with the altitudinal elevation ranging from 333.84 m to 1343.14 m (Figure 1-1). The Jwalamukhi Rural Municipality is divided into 7 wards. As of census 2011, the population of the rural municipality is 32922. The geological makeup of the rural municipality is dominated by Ranimatta Formation. Almost 62 % of landscape has slope between 15 and 30 degrees. Major area of the rural municipality is suitable for agriculture. The major produces are cereal, cash-crop, fruits and vegetable. The major cereals are paddy, maize, millet and wheat. Additional, the area is equally known for producing ginger and honey.

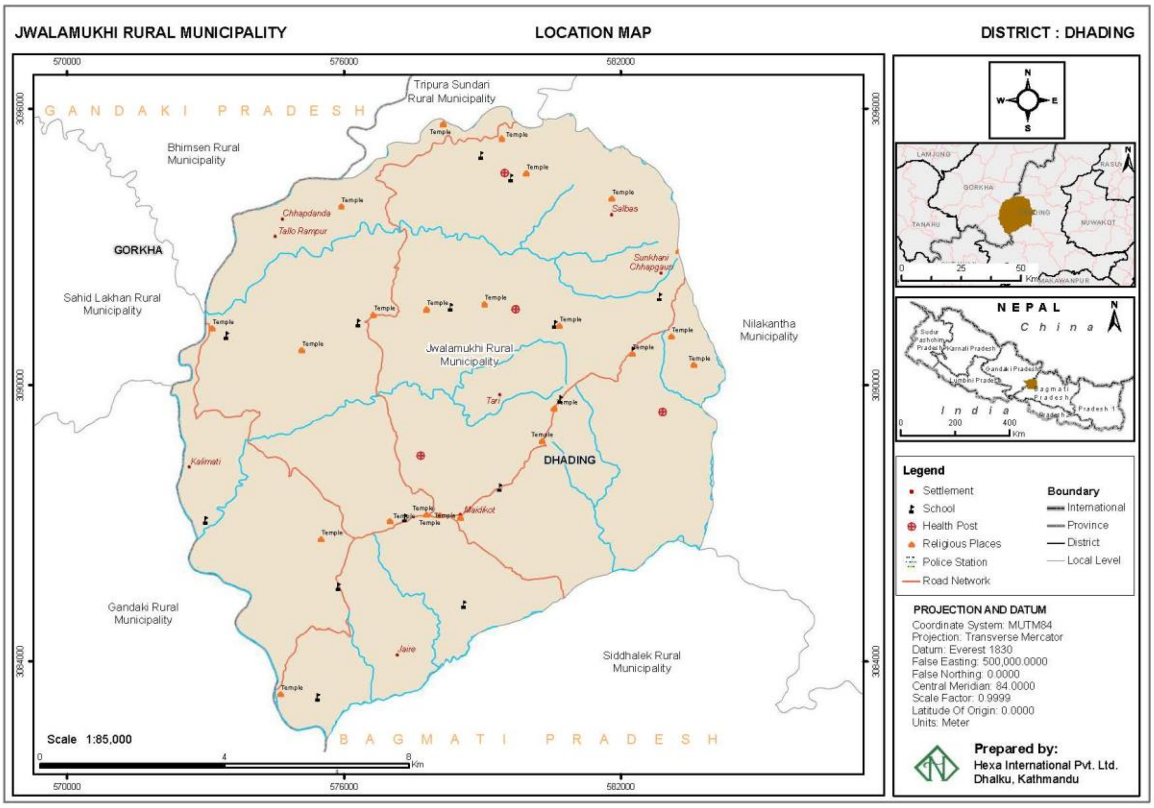

Figure 1-1: Location Map of Jwalamukhi Rural Municipality

The total population of this Rural Municipality is 23966 of which male population is 10573 (44.1%) and female population is 13393 (55.9%). The total households are 5730 and the average family size of the Rural Municipality is 4.2.

CHAPTER 2 : CONCEPTUAL BASIS OF LAND USE ZONING

2.1 Land Use Zoning, Principles and Criteria

The primary purpose of zoning is to separate land uses that are thought to be incompatible to each other. Land use zoning is assessed based on the suitability of sustainable use for a specific 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. Considering the importance of land use zoning, Topography Survey Land Use Management Division (TSLUMD), Ministry of Land Management, Cooperatives and Poverty Alleviation has underlain the following concepts for the land use zoning:

- Classification of land into agricultural area, residential area, commercial area, industrial area, forest, public service area and other uses, Mines and Minerals, Cultural and Archeological, and Riverine stream lake and Marsh area.,
- Identifying areas of potential residential, commercial, industrial and public utility keeping balanced environment.
- Classifying agricultural land into comparatively advantageous sub-areas on the basis quality of land, land capability, irrigation facilities to increase productivity.
- Proper conservation of natural resources including forest, shrub, rivers, rivulets and swampy land etc.

Some basic criteria were taken in consideration for carrying out the land use zoning of the Gaunpalika which are as follows:

- It should not contradict with the essence of the National Land Use Act 2076.
- Existing forest areas should be kept intact or should be managed in such a way that the growing stock of the forest is always optimum
- Agricultural area should be referred to other categories only if it can’t give a good production of crop
- Residential areas should be avoided from the high-risk areas of flood, landslides, industrial pollution etc.
- Open spaces should be allocated among residential areas for recreation, sports and space in case of disasters like earthquakes.
- Commercial areas should be allocated in prime location for surrounding settlements, so that they should not travel long distance to take those services.

2.2 Land Use Zoning and their Descriptions

According to the National Land Use Act 2076, the following hierarchical land use zones and sub-zones were followed while zoning the land use of the study area:

Table 2-1 Hierarchies of Land Use Zones and Sub-zones

Zone No.	Zone Type	Sub type	Data Type	Description
Zone 1	Agricultural Zone	Zone 1A	String	Cereal crop production area
		Zone 1B	String	Cash crop area
		Zone 1C	String	Horticultural area
		Zone 1D	String	Animal husbandry area
		Zone 1E	String	Fish farming area
		Zone 1F	String	Agro forestry area
		Zone 1G	String	Other Agriculture Area
Zone 2	Residential Zone	Zone 2A	String	Existing residential zone
		Zone 2B	String	Potential area for residential zone
Zone 3	Commercial Zone	Zone 3A	String	Service areas
		Zone 3B	String	Business area
Zone 4	Industrial Zone	Zone 4A	String	Areas under industrial use
		Zone 4B	String	Potential areas for industrial use
Zone 5	Forest Zone	Zone 5A	String	Existing forest
		Zone 5B	String	Potential area for forest including barren lands, wet lands etc.
Zone 6	Public Use Zone	Zone 6A	String	Areas under roads, railways, bus parks, airport and land fill site etc.
		Zone 6B	String	Areas under hydrography
		Zone 6C	String	Open spaces, picnic spots, recreational etc.
		Zone 6D	String	Cultural, Archeological and religious areas
		Zone 6E	String	Public health/education/library, police station, fire station, telephone /electricity areas etc.
		Zone 6F	String	Grazing land
		Zone 6G	String	Government Institutional Area
Zone 7	Others Zone	Zone 7	String	Other Area (As per requirement)
Zone 8	Mine and Minerals Zone	Zone 8A	String	Existing Mine and Minerals excavation Area
		Zone 8B	String	Potential Mine and Minerals excavation Area
Zone 9	Cultural and Archeological Zone	Zone 9A	String	Existing Cultural and Archeological Areal
		Zone 9B	String	Potential Cultural and Archeological Areal
Zone 10	Riverine, Stream Lake and Marsh Zone	Zone 10A	String	Existing Riverine, Stream Lake and Marsh Area
		Zone 10 B	String	Potential Riverine, Stream Lake and Marsh Area

The detailed description of the land use zones is as follows:

1. **Agricultural Zone**

The agricultural zone means 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. This word also indicates a region prescribed by the government as an agricultural zone.

2. **Residential Zone**

Residential zone means the land used by people for shelter or housing and the word 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. This word 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.

3. **Commercial Zone**

Commercial zone means 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. This word shall also include a commercial building built in a trade zone by a business company or institution and the land occupied by the same. Moreover, this word shall also indicate an area declared by the government to develop a city for market expansion and commercial use in a definite geographical region.

4. **Industrial Zone**

Industrial zone means the land occupied by or allocated for any workshop, goods manufacturing industry, the associated buildings and sheds. This word 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.

5. **Forest Zone**

Forest zone means an area being covered with public, community, leasehold forests in part or entirety, national parks, wildlife reserves, conservation areas, bushes, shrubs, plains, 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.

Public Use and Open Zone

Public use and open zone mean 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. This term also includes the hills, meadows, cliffs, mountains, snow covered areas, pastures. The word 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.

6. **Other Zones (prescribed as required)**

Other Zones (prescribed as required) mean 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. Mixed zone means the areas 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.

7. **Mining and Mineral Zone**

Mining and mineral zone means 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. This word 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. Land react 2076 include Excavation Area with the Mines and Mineral Zone. Excavation (Construction material) zone means 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.

8. **Cultural and Archaeological Zone**

Cultural and archaeological zone means 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. This word also implies an area declared by the government as a historical, cultural, religious and archaeological place in a definite geographical region.

9. **Riverine, Stream Lake and Marsh Zone**

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

CHAPTER 3 : METHODOLOGY

3.1 Data

Mainly, data used for this study purpose are as following:

- Pan sharpened and Ortho rectified very high resolution (2.1m) satellite image ZiYuan-3 surveying satellite (ZY-3) of the study area.
- DGPS survey data from field and control points from Survey Department
- Soil data collected from sample pits selected in the study area and reports on physical/chemical properties of the soil from lab test
- Present land use data (vector shape file) acquired from high resolution images and field verification.
- Soil map and land capability map and database prepared from satellite image, present land use data, land system and soil data
- Existing Land Resource Mapping Project data, topographic maps, contours and DEMs, and database prepared by the survey Department
- Administrative boundary data, especially Rural Municipality boundary data prepared by NGIIP, Survey Department
- Geological maps/data from department of mine and geology
- Data on other potential hazards and risk in the study area collected from Jwalamukhi Rural Municipality, Dhading DCC and other sources
- Rural Municipality profiles and reports on socio-economic surveys from the Rural Municipality and DCC
- Facts and data collected from questionnaire survey in the field
- Interaction with local people and stakeholders as well as opinion of thematic experts

3.2 General Approach and Methodology Framework

The general approach and methodology adopted for land use zoning is as following:

a. Literature study: Various national / international literature regarding land use zoning are collected and reviewed. Previous projects carried out by different professional, institutions were studied. The specifications, data models and National Land Use Act 2076 were also studied and reviewed before carrying out this study.

b. Data preparation: The used for zoning purpose were already prepared by other study team. Mainly, present land use, land capability, land system, various risk and hazard related information, socio-economic data, etc. as mentioned above were collected and prepared for further use.

c. Criteria formulation: Zoning criteria are formulated within the scope of major guidelines provided by the client and National Land Use Policy. These criteria were developed considering the above-mentioned data. Guidelines are discussed in the following chapter.

d. GIS analysis and mapping: Developed zoning criteria were used, multi-criteria analysis was performed in GIS system and suitability analysis was done to identify most potential land use zones such as residential, commercial, agricultural, industrial and so on. Preliminary draft database and map were prepared for discussion.

e. Discussions with experts: The preliminary result obtained from multi-criteria analysis and zoning was discussed with the various thematic experts such as urban / settlement planner, agriculture experts, natural resource manager, geologist, hydrologist etc. Feedback and suggestions from expert were collected.

f. Subjective analysis: Subjective analysis for land use zoning was carried out and land use zones were classified. In this step, the results obtained from GIS analysis is logically adjusted and expert's opinion are accommodated. Similarly, the opinions from local people and stakeholders which were already collected during field verification visits were also accommodated to prepare final zoning.

g. Database and map finalization: After completion of subjective analysis, final database is prepared and maps were compiled.

h. Draft preparation, presentation and feedback collection: Draft reports is prepared, draft maps and database has demonstrated and present to local administrative (Municipality/Rural Municipality) personnel and in front of the concerned client, officials, technical committees and other relevant experts. Feedback from the client, technical committee members and mentioned experts were collected and draft reports, maps, databases were improved accordingly.

i. Final reporting: After Draft data maps and reports presentation, final report, maps, database are prepare with incorporate the feedback and comments of local body's and land use technical committee will be submit to the client according to the clause mentioned in ToR.

3.3 Methods

Within the above-mentioned general approach and methodological framework, this study is carried out using the following guidelines and criteria developed by TSLUMD:

1. Agricultural Zone

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 most 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 done with agriculture experts and their opinion is taken to further sub classification of agricultural land.

2. Residential Zone

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. Geologically stable
   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 less capable for agricultural crop production

3. Commercial Zone

a. The existing commercial area is kept intact as they are already establishing 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. Geologically stable
   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

4. Industrial Zone

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 impact should be less on the human activities. Such kind of industries, if found affecting human life, will be recommended to relocate.

a. 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 (Rural Municipality/Districts) so that there would be opportunity to share benefits of the resources of both administrative units

5. Forest zone

a. Existing forests 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 product etc.

6. Public use and open 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 category is suggested to be planned after discussion with local community using participatory approach.

7. **Other zones (prescribed as required)**
    a. As per the prescription of experts and decision of the government
    b. If any land use cannot be fit in any class mentioned above

8. **Mining and mineral Zone**
    a. Existing Mining and Quarrying areas as defined and described by National Land Use Act 2076.
    b. Identified and prescribed areas as potential Mining and Quarrying area in future
    c. Areas prescribed and allocated by the national/local government for such use
    d. Areas found appropriate from expert's study for such use in future

9. **Cultural and Archaeological Zone**
    a. Existing religious cultural, archeological areas as defined and described by National Land Use Act 2076.
    b. Area defined as cultural heritage and their master plans

10. **Riverine, Stream Lake and Marsh Zone**
    Existing rivers and water bodies as defined and described by Land Use Act 2076.

The specific technical approach adopted for zoning process is shown in the following schematic diagram:

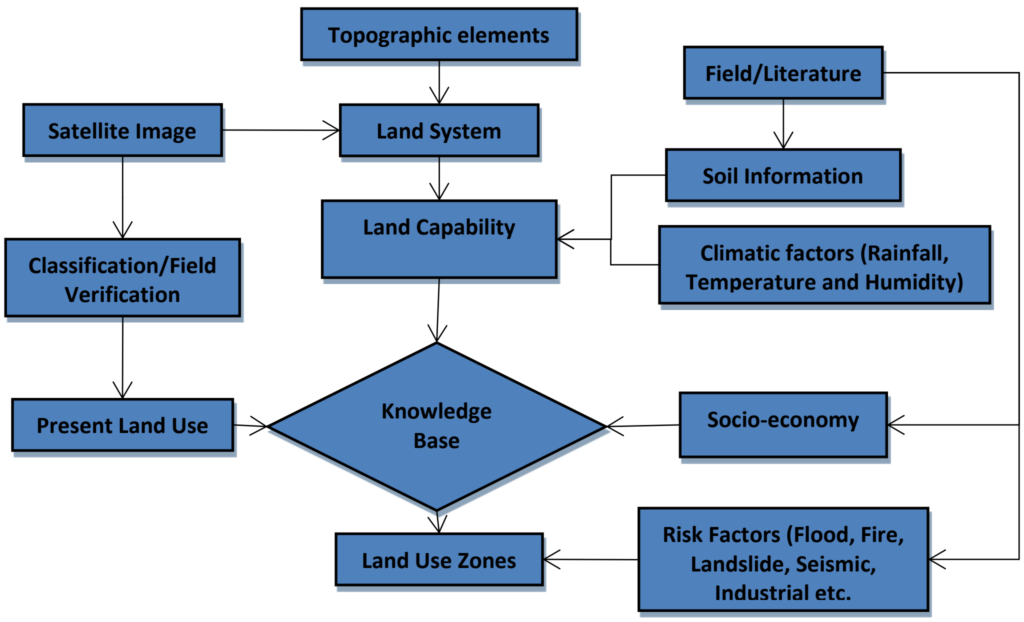

Figure 3-1: Workflow for Land Use Zoning

3.4 Results

The zoning process was carried out adopting the above-mentioned methodology and procedure. Identified land use zones, sub zones in the Jwalamukhi Rural Municipality and their detail description is given in the following table and further discussed in the next section.

Table 3-1: Area under different land use zone in Jawalamukhi Rural Municipality

S.N.	Land use Zone	Area Ha	Percent
1	Agricultural Zone	5451.98	48.29
2	Residential Zone	582.94	5.16
3	Commercial Zone	14.12	0.13
4	Industrial Zone	4.58	0.041
5	Forest Zone	4734.47	41.94
6	Public Use Zone	315.79	2.80
7	Others Zone	0.00	0.00
8	Mine and Minerals Zone	8.10	0.072
9	Cultural and Archeological Zone	1.31	0.012
10	Riverine Stream Lake and Marsh Zone	176.32	1.56
Total		**11289.62**	**100**

The above table shows the most of the land in Jwalamukhi Rural Municipality consist under Agriculture zone and Forest zone cover 48.29% and 41.94% of the total land. Similarly, Residential zone consist (5.16%), Public Use Zone (2.80%) and Riverine stream lake and marsh (1.56%). Another land use zoning class like Commercial, Mines and Minerals, Industrial and Cultural and Archeological have occupied less area having percentage 0.13%, 0.072%, 0.041% and 0.012% respectively. Others zone is not defined area in this rural municipality. Details of the land use has been shown in the below figure.

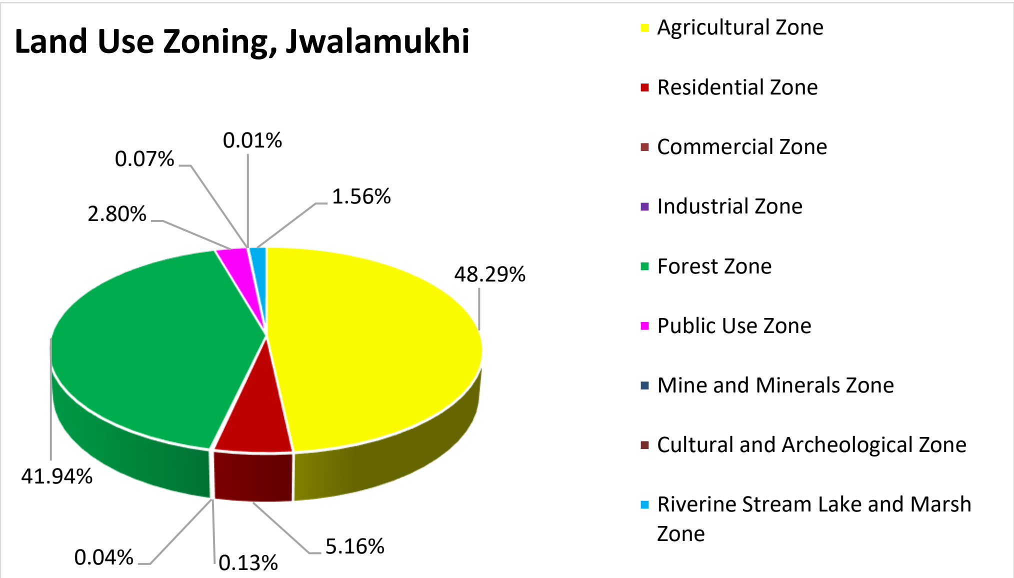

Figure 3-2: Different land use zones in Jwalamukhi Rural Municipality

Table 3-2: Area coverage of different land use zone sub-types in Jwalamukhi Rural Municipality.

Zone	Zone Type	Sub zone	Description	Area of sub zone type (Ha)	% of individual zone	Area of zone type (Ha)	% of total area
Zone 1	Agricultural	Zone 1A	Cereal crop production area	3195.78	58.62	5451.98	48.29
		Zone 1B	Cash crop area	640.29	11.74		
		Zone 1C	Horticulture area	683.73	12.54		
		Zone 1D	Animal husbandry area	505.92	9.28		
		Zone 1E	Fish farming area	0.00	0.00		
		Zone 1F	Agro forestry area	426.26	7.82		
		Zone 1G	Other Agricultural Area	0.00	0.00		
Zone 2	Residential	Zone 2A	Existing residential zone	502.80	86.25	582.94	5.16
		Zone 2B	Potential area for residential zone	80.14	13.75		
Zone 3	Commercial	Zone 3A	Governmental institutions and service areas	0.58	4.13	14.12	0.13
		Zone 3B	Business area	13.54	95.87		
Zone 4	Industrial	Zone 4A	Areas under industrial use	0.00	0.00	4.58	0.04
		Zone 4B	Potential area for Industrial zone	4.58	0.00		
Zone 5	Forest	Zone 5A	Existing forest	4734.47	100.00	4734.47	41.94
		Zone 5B	Potential area for forest including barren lands, wet lands etc.	0.00	0.00		
Zone 6	Public Service	Zone 6A	Areas under roads, railways, bus parks, airport and land fill site etc.	293.47	92.93	315.79	2.80
		Zone 6B	Areas under Hydrography	0.00	0.00		
		Zone 6C	Open space, recreation, picnic spot	9.79	3.10		
		Zone 6D	Cultural, archeological and religious areas etc.	0.00	0.00		
		Zone 6E	Health, education etc institutions	11.86	3.75		
		Zone 6F	Grazing land	0.00	0.00		
		Zone 6G	Public Institution Area	0.67	0.212		
		Zone 6H	Open Space	0.00	0.00		
Zone 7	Other area	Zone 7	as per requirement	0.00	0.00	0.00	0.00
Zone 8	Mine and Minerals area	Zone 8A	Existing Mines and mineral area	0.00	0.00	8.10	0.07
		Zone 8B	Potential areas for Mines and mineral	8.10	0.00		

Zone	Zone Type	Sub zone	Description	Area of sub zone type (Ha)	% of individual zone	Area of zone type (Ha)	% of total area
Zone 9	Cultural and Archeological	Zone 9A	Existing cultural and archeological area	1.31	100.00	1.31	0.01
		Zone 9B	Potential cultural and archeological areas	0.00	0.00		
Zone 10	Riverine Stream, Lake and Marsh	Zone 10A	Existing rivers and riverine area	176.32	100.00	176.32	1.56
		Zone 10B	Potential hydrographic areas	0.00	0.00		
						11289.62	**100**

These statistics are presented in the following pie diagram. Detailed discussion of the result is given in the coming section.

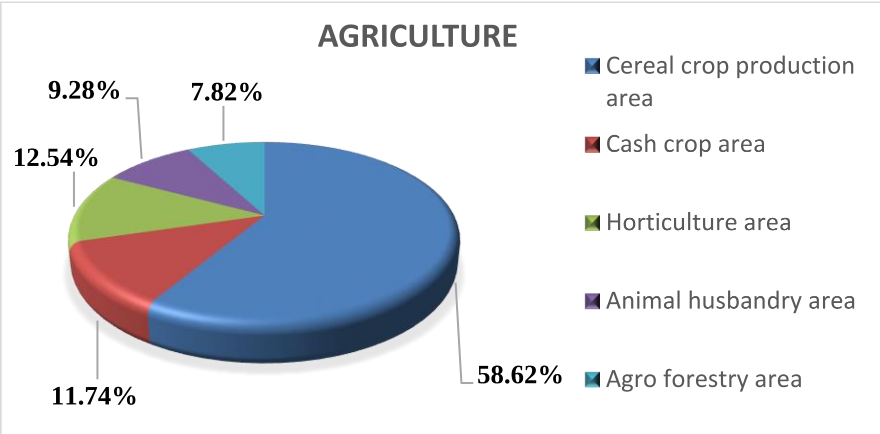

Figure 3-3: Area Coverage under Agriculture Zone

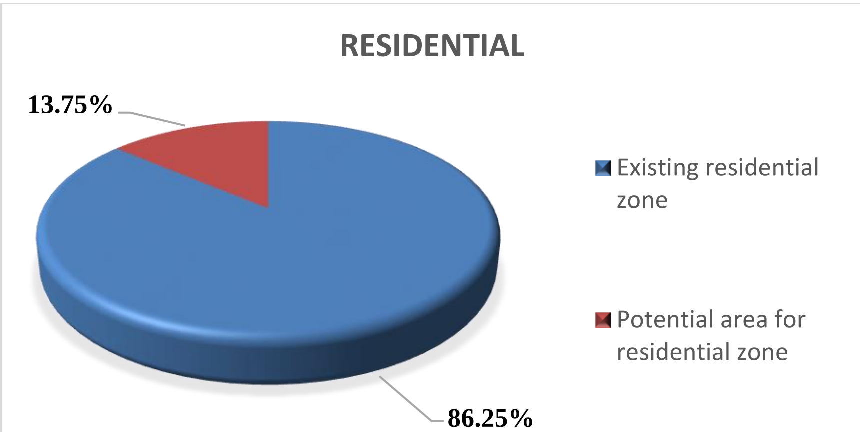

Figure 3-4: Area Coverage under Residential Zone

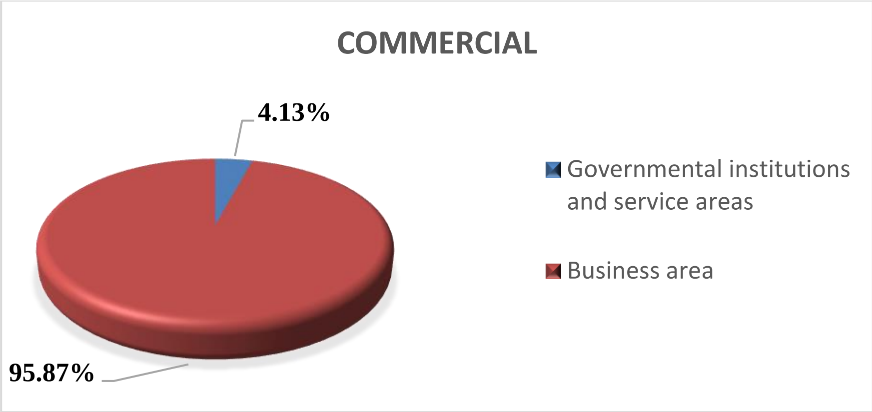

Figure 3-5: Area Coverage under Commercial Zone

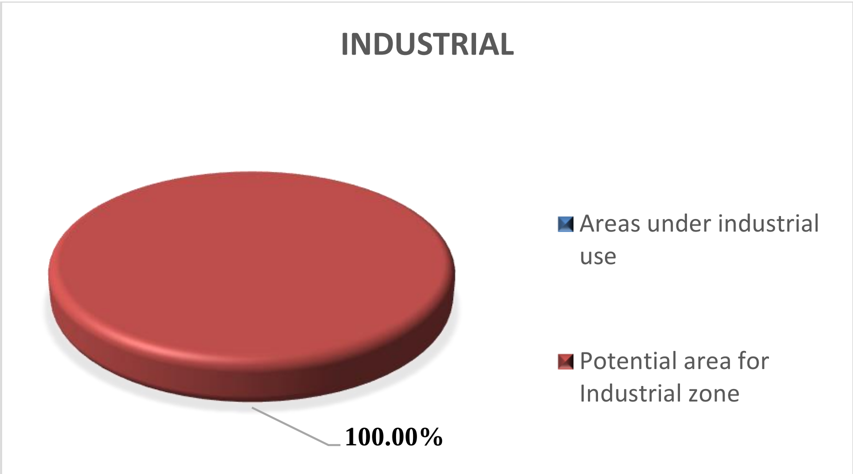

Figure 3-6: Area Coverage under Industrial Zone

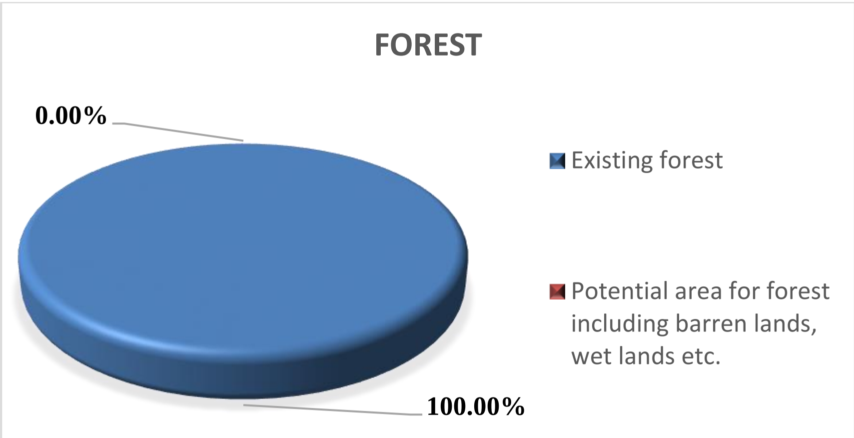

Figure 3-7: Area Coverage under Forest Zone

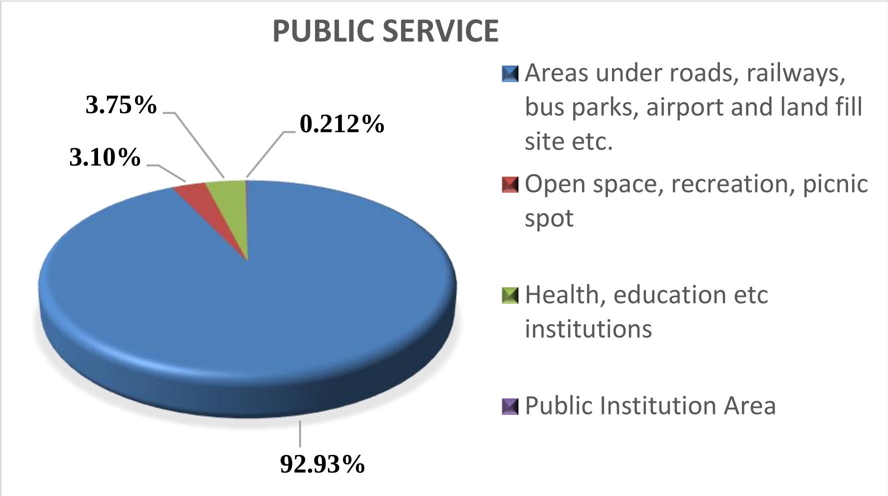

Figure 3-8: Area Coverage under Public Use Zone

Within agriculture zone, most of the land 3195.77 ha allocated for cereal crops production area, and Agroforestry consist less area of 426.26ha of the total agricultural land. 80.14ha residential area has added. Similarly, with in the commercial area 13.53 ha land has allocated for business area. However, noticeable industries does not exist in present, 4.58 ha. land has allocated for new potential industrial area. Forest kept intact. Open space has assigned for the future as well as potential mines and mineral and excavation area has allocated.

3.5 Discussion

Jwalamukhi Rural Municipality is situated in middle-west of the Dhading district with having diverse geomorphic features. Its shares its border with Gorkha District. The physical condition, geological structure, topographic features, and visible terrain indicate the Jwalamukhi rural Municipality falls under midlands. The foundation of the muncipality is made up of single formation i.e., Ranimatta. The Ranimatta covers 100% of the land. 15 % of the land i.e., 17677 ha, is south facing and 76 % of land has slope greater than 15 degrees. This rural municipality has the elevation range from 333 to 1343 m. Topography of the rural municipality varies from river basin and tar and low land with gentle slope to hills, ridge, middle hills, and hilltop and high hills with steep slope. The relief features of the rural municipality appear in complex form from lowland with gentle slope to hills and hillocks with steep slope.

The drainage/hydrology of Jwalamukhi rural Municipality determined by its relief features and drainage pattern that consists of streams, Gads, and source points of water in the different watersheds of rural municipality. Budhi Gandaki River is on western side of the rural municipality. Besides many tributaries, there are other prominent streams such as Anderi Khola, Angtar Khola, Ankhu Khola, Bhalu Khola, Chhargandi Khola etc. During the Land Use Zoning, suitability analysis has done by using various characteristics and properties of land like risk analysis, land fertility, climate, and landforms of the Rural Municipality, Satellite Image, and other parameters. In this section, some major findings from the zoning process are discussed and highlighted.

Agriculture and forest dominant land use found in the Rural Municipality. Forest resources are main source of life and continuing of ecosystem services in the Rural Municipality. Forest resources are main source of life and continuing of ecosystem services of the rural municipality. The total forest area is 4334.47 ha of total land of the rural municipality. The forest of the area is mostly sub-tropical deciduous, semi-deciduous, subtropical Sal Forest mixed with broad leaves, and lower mountain hardwood mixed forest. For densification of forest, following trees and plants proposed in sparse area of the forest. *Uttis, Chilaune, Katus, Mauwa, Mallato, Lapsi, Koirao, Chap, Nigalo and Bamboo are proposed plants based on climate, soil, landform, existing pattern of forest.* Similarly, herbs plantation area has proposed during land use zoning. *Timur, Chiraito, Satuwa, Majitho, Jatamasi, Bojho, Tejpatta, Amla, Harro, Tulsi* are the medical plants (Herbs). If we promote this herbs plantation, the agro based industrial area concept will be success in the future.

Within agriculture zone, mainly, cereal crops, cash crops, horticulture are found more appropriate for cultivation, however, the land adjoining to and surrounded by forest are suitable for agro-forestry. Rice, Millet, maize, buckwheat, potato are the dominant crop in this area. Specially, this Rural Municipality is under High Hill area, Cow, Buffalo, Sheep, Goat, Pig, are main livestock in this region. For animal husbandry, sufficient land has allocated. Cash crops such as Potato, fruits, vegetables, lentils, pulses and beans and oil seed etc. Fish farming identified as potential in this area.

Some agricultural area is allocated for additional residential and commercial areas for future. Land of marginal utility and less suitable for agricultural activities are given priority for this purpose. New residential and commercial area are mostly proposed in low yield area and the neighborhood of existing residential areas because of already available facilities like roads, water supply, electricity, communication, health etc. In some cases, if the agricultural land of lower suitability is not available, land of capability class III is also allocated for residential and commercial purpose. Residential area is allocated to accommodate future housing need along with utility services, public institutions, and infrastructure, open and green areas. At present, it is not practical to propose these infrastructures randomly anywhere in the area. Instead, the local planning authorities may carry out further detailed spatial planning for urban/settlement development and at that time, residential area may be planned with such facilities and infrastructure, which need some additional land as well. Therefore, the quantity of residential area (80.14 Ha) seems slightly more than actual need. Residential area has allocated for the settlements, which will be shift by the extension of road network.

This Rural Municipality consist agro based industries. New industrial area (4.58 ha) is also recommended. Because of the forest dominant rural municipality, agro and forestry based like furniture and minerals excavation based industry can be stablished. Government issued the policy as "one local unit one industrial area". Small agro-based, industry can be stablish in the future. Mine and minerals excavation, sand gravel processing industries seems suitable for the future.

This Rural Municipality has good forest cover and existing forest are kept intact. The open and barren public or government land which are rarely used for public purpose can be classified for potential forest area. Similarly, if some places which are vulnerable to landslide are identified to be proposed for plantation and to be developed as forest in the future. Budhi Gandaki and Aankhu Khola is the major river in this rural municipality.

In the context Public use zone, open spaces, picnic spots, recreational etc. are necessary thing for new development context 9.79 Ha land has allocated under open space. The right of way of various roads is identified and delineated in the map. The RoW of highway is classified as 25m of land on either side from the central line and 6m of setback. For district roads and feeder roads, 15 and 10m of land on either side from central line and 3m of setback is allocated. Blacktop road cannot be seen in the rural municipality. Other public use area, open and green spaces and land for utility services and infrastructure are not allocated as this kind of decision can be taken by the local authority during detailed spatial planning for local development. The quality of road is quite poor. Black top road can be seen only Dhadingbesi to Arughat feeder road.

Risk evaluation for land use planning is very useful because it has verified the area for existing and potential risks that may happen in future. The area is suitable for cultivation that may not be suitable from the hazardous conditions, for example flood prone areas might be allowed for agricultural use but not for human settlements. Landslide, flood and fire risks are often major risk in the area and earthquake can be any time risk in the future. During zoning risk is considered one of the important factors for zoning. Normally, residential areas are allocated on such land which are under no or low risk of flooding, landslide bank cutting, industrial, seismic and fire hazard. Most of the area in this Rural Municipality is under high risk in terms of Landslide, low risk in flooding. Residential area is allocated with mention the risk. Low risk area are proposed for potential land use zoning classes. Risk analysis has described in next chapter.

As a hilly rural municipality this area consist highly sloping area with land capability class II, III and IV. III Class consist the highest area (5922.45Ha) of the total land. Class II and III are suitable for agriculture especially for cereal and cash crops and citrus type fruits. Due to steeply slope, it is difficult to manage irrigation facility. Farmer mostly can produce one or two crops in a year only. Preventive method cannot fulfill the require of people. So Modern technology may can help to increase agriculture product.

Prime Minister Agricultural Modernization Project (PM-AMP) has launched in the year of 2073 BS for incensement of agricultural product, where many peoples can sustain and attract towards agriculture. The policy of the program is use of land in scientific way, use of modern agricultural technology, mechanization in agriculture, development of processing of marketing of agricultural product, agricultural research, quantity and quality agricultural product and environment friendly agricultural system. Seven districts from each Seven Province of the nation are declared as the super zone of different crops and fruits. This program has four categories like Pocket, Block, Zone and Super zone. Dhading District doesn't consist of Super Zone.

Table 3-3: Prime Minister Agricultural Modernization Project (PMAMP) in Dhading District

PMAMP, Zone, FY 2074/075		
Dhading		
	Rural Municipality/Municipality	**Command Area**
Vegetables	Nilakantha Municipality	All Wards
	Jwalamukhi Rural Municipality	All Wards
	Benighat Rorang Rural Municipality	Ward 1-10
	Siddhalek Rural Municipality	3, 4
	Gajuri Rural Municipality	2
Maize	Nilakantha Municipality	All Wards
	Jwalamukhi Rural Municipality	All Wards
PMAMP, Block, FY 2073/074		
Dhading		
	Previous VDCs	**Rural Municipality/Municipality**
Vegetables	Nilakntha	Nilakantha
	Kumpur	Siddhalek 5, 6,7
Potato	Jharlang	Khaniyabas 1,2
	Ree	Gangajamuna 1,2
	Sertung	Ruby Valley 3,4
	Lapa	Ruby Valley 5,6
	Tipling	Ruby Valley 1,2

The above table shows the command area of Block under PMAMP for Dhading District. In this Rural Municipality all wards 1 and 2 has selected for Vegetables and Maize Zone.

This rural municipality is rich in cultural diversity. Most of the people are from Brahmin Kshetri Community and others hilly community. All caste and ethnic group have own culture and tradition. Beautiful religious Jwalamukhi, Chitre Kalika, Kailash Temple, Kag Kot, Maju Kot, Maidi Kot, Mandali Temple, Baraha Kalika, Chainpur Kot, Sthanpati, Bangkot Ghat, Khari Kot and Mahadevasthan etc. are religious place which can be promote as tourist destination.

CHAPTER 4 : LAND USE ZONES OF THE STUDY AREA

4.1 Risk Areas within the study area

Hazard and risk mapping can increase community resilience against the impacts of natural hazards and allows decision maker to strategically consider the hazard when planning settlements, and set policy on acceptable risk and controls that increase the ability of individuals and the community to resist and recover from a hazardous events. Moreover, it is a process for land-use recovery that requires consideration of a range of options such as repairing, reconstructing or relocating existing at-risk land-uses before a natural hazard event occurs. A planned outline of land use and its strict implementation will ensure the appropriate management of hazard and reduction in risk and concomitant losses.

Flood events are common in monsoon season in Jun to September in Nepal and Dhading district too, that attributed to its geographical conditions with elevated terrain and river valleys. Many seasonal streams flow along the river valley that are damaging arable lands and sometimes cause human casualties. Aakhu Khola is major small tributary in the area which flows in long stretch and creates flooding problems in different ward no 7, ward and ward no 10.

The area is in some risk of fire due to presence of forested area. Result showed that the region with area of 12.51% is high, 51.55% is medium and 35.94% low risk levels of fire. The risky areas are seen in considerable portions of the area and the rest of area lies in medium and low risk zones.

Study area is susceptible to landslide occurrence due to topographic variation in elevated region. The result showed that the region with area of 1.31% is high, 42.12% is medium and 56.58% low risk levels of landslide. As the area is located in mountainous terrain, both high and medium risk level zones are susceptible to landslides.

PGA value of the area comprises the values ranging between 250 and 350 gals comprising two zones of DMG seismic map and interpreting such value has showed the area is situated in seismic risk of low value. However, lower PGA value does not mean that it lies in low to moderate seismic risk zone because Nepal is located in seismically very active zone and always possesses risk of frequent earthquakes and their aftershocks.

The area is in considerable risk of soil erosion due to sloping lands during rainy season. The result showed that the area with 9.09% is high, 49.97% is medium, and 40.94% low risk levels.

The risk of health care waste is always from the infectious component, which can be transmitted as result of improper management of health care waste. Among the various types waste management, local or conventional type of options are in practice. During field survey, it is found that this rural municipality partly sorts out various wastes depending on material properties whether they are risky to human health or surrounding environment.

4.2 Analysis of Present Land Use and Potential Land Use Zone

Detailed analysis of the present land use and potential land use zone are shown in table 4-1 below. It clearly shows conversion of agricultural land in various other land use zones, especially in residential, commercial and public use zones. Detailed transform of the land from present land use to land use zoning has given in the following table.

Table 4-1: Present Land Use and Land Use Zone in Jwalamukhi Rural Municipality

Land Use Zoning/PLU Classes	AGR	COM	CUL	FOR	IND	MIN	PUB	RES	HYD	OTH	Total PLU	Change (Ha)
Agriculture	5451.98	3.40			4.58		102.43	80.14			**5642.54**	-190.6
Commercial		2.17					1.07				**3.24**	10.9
Cultural and Archeological			1.31								**1.31**	0.0
Forest				4734.47			45.56				**4780.03**	-45.6
Industrial											**0.00**	4.6
Mine and Minerals											**0.00**	8.1
Public Service							135.11				**135.11**	180.7
Residential		8.55					31.63	502.80			**542.97**	40.0
Riverine Stream Lake and Marsh						8.10			176.32		**184.42**	-8.1
Other											**0.00**	0.0
Total Land Use Zoning	**5451.98**	**14.12**	**1.31**	**4734.47**	**4.58**	**8.10**	**315.79**	**582.94**	**176.32**	**0.00**	**11289.62**	0.0

The data shows 190.6 ha of agricultural land is converted in to other land use zones, mainly in residential and commercial zones and public zone. For residential area 40.0 ha and for commercial area about 10.9 ha is allocated. Existing economic and business activities, commercial activities are in low volume. Like the national scenario, youth from this Rural Municipality are moving towards another region for earning. People are from this Rural Municipality have migrating so in this situation population and settlements, commercial activities are not increasing highly. 45.6 ha forest area is decreasing because of Right of way of road. This RoW of different road will be used for future road extension and construction of various other utility service.

4.3 Analysis of Safe settlement areas and open Areas

After analysis of the land use zone and potential risks, the area is considered as a safe area for settlement, in general. There is no severe risk which may cause any loss of human life, goods or infrastructures. However, there are some risk of landslide risk. To prevent from these risk, residential commercial areas are not proposed along those locations. Similarly, appropriate care is taken to plan new settlements. Detail Geological studies should be carried out and proper building codes should be followed. Appropriate safety measures should be adopted and safe material should be used for infrastructure development and construction. This area has sparse settlement, therefore excess of open spaces is available which may be considered as an asset for safety during any disaster such as earthquake. It was allocated in such a way that several nearby residential areas can be benefited by travelling minimum distance through the existing road networks. After risk analysis, Jwalamukhi have the following safe settlements are as Majhuwatar and Majhitar in ward 1, Batasemaidi and Majhukot Satdobato in ward 2, Bicharihatiya in ward 3, Aryal Gaun and Purshuk in Ward 4, Chhapthok, Bhaduwar, Tripura Sundari, and Dhulimaidan are in ward 5, Jyamiretar, Rampurgaun and Pakhagaun in ward 7 where commercial and residential area are proposed for the future use.

4.4 Land Use Zone in the study area

The result shows the most of the land in Jwalamukhi Rural Municipality consist under Agriculture zone and Forest zone cover 48.29% and 41.94% of the total land. Similarly, Residential zone consist (5.16%), Public Use Zone (2.80%) and Riverine stream lake and marsh (1.56%). Another land use zoning class like Commercial, Mines and Minerals, Industrial and Cultural and Archeological have occupied less area having percentage 0.13%, 0.072%, 0.041% and 0.012% respectively. Others zone is not defined area in this rural municipality. Details of the land use has been shown in the below land use zoning map.

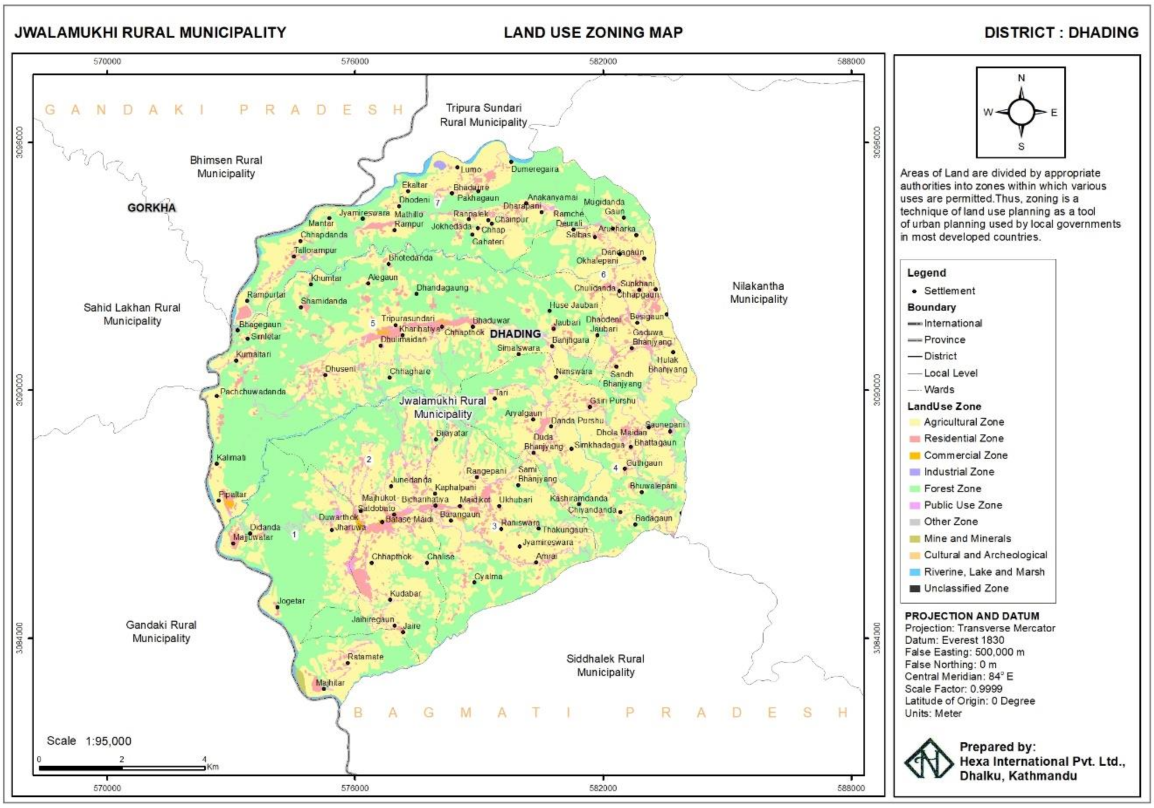

Figure 4-1: Land Use Zoning Map of Jwalamukhi Rural Municipality

4.5 Land Use Zoning GIS Database

The GIS database of land use zoning has been prepared following the TSLUMD specification in the structure as given in the table below:

Table 4-2: Structure of Land Use Zoning GIS Database

Field	Data Type	Description
OBJECTID	Object ID	Feature
SHAPE	Geometry	Geometric Object type
Class	Short Integer	Land Use Zoning Class
ZoneNO	Text	ZoneNO
ZoneType	Text	ZoneType
ZSubtypes	Text	ZSubtypes
Remarks	Text	Remarks
FYY	Text	Fiscal year
CONSULTING	Text	Consulting Firm
DISTRICT	Text	District
MP_RMP	Text	Municipality/Rural Municipality
Transmission	Text	Transmission Risk

Field	Data Type	Description
Industry	Text	Industry Risk
Fire	Text	Fire Risk
Flood	Text	Flood Risk
BankCut	Text	BankCut Risk
Fault	Text	Fault Risk
Liquifac	Text	Liquifac Risk
Seismic	Text	Seismic Risk
LandSL	Text	Landslide Risk
Right_of_way	Text	Right_of_way of Road, Canal, Transmission
Area_H	Double	Area (Hectare)
SHAPE_Length	Double	Length (Default)
SHAPE_Area	Double	Area (Default)

CHAPTER 5 : CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Land use zone map of this Rural Municipality has been prepared, based on multi criteria decision analysis, i.e., various data layers and setting appropriate and established criteria that best suits the locality.

Result shows the most of the land in Jwalamukhi Rural Municipality consist under Agriculture zone and Forest zone cover 48.29% and 41.94% of the total land. Similarly, Residential zone consist (5.16%), Public Use Zone (2.80%) and Riverine stream lake and marsh (1.56%). Another land use zoning class like Commercial, Mines and Minerals, Industrial and Cultural and Archeological have occupied less area having percentage 0.13%, 0.072%, 0.041% and 0.012% respectively. Others zone is not defined area in this rural municipality.

Risk analysis have done with different parameter using different model. Soil erosion and landslide risk is main risk in this rural municipality.

Based on knowledge base multi criteria decision analysis, i.e., various data layers and setting appropriate and established criteria that best suits the locality. These data layers are primarily the soil structure, topography and drainage, and moisture regime incorporated in the land capability classes, and the socio-economic and cultural features such as population, road access, distance from river and proximity or contiguity to existing urban or semi-urban settlements. In proposed land use zones, areas under exiting bush or shrubs and flood prone areas has been proposed for the forest, and the new areas for residential, commercial and industrial and public utility zone has been proposed on the existing agricultural land which lie adjacent to existing major settlement on main roads and highway, road crossings or those at the fringe of urban residential built-up areas.

This rural municipality is rich in cultural diversity. Most of the people are from Brahmin Kshetri Community and others hilly community. All caste and ethnic group have own culture and tradition. Beautiful religious Jwalamukhi, Chitre Kalika, Kailash Temple, Kag Kot, Maju Kot, Maidi Kot, Mandali Temple, Baraha Kalika, Chainpur Kot, Sthanpati, Bangkot Ghat, Khari Kot and Mahadevasthan etc. are religious place which can be promote as tourist destination.

5.2 Recommendations

Jwalamukhi Rural Municipality is situated in Middle West of the Dhading district with having diverse geomorphic features. Geomorphology of the Rural Municipality comprises gentle slopes to elevated hill-slopes with river valleys, terraces, sloping lands, ridges, spurs and saddles. Land yielding low agriculture production is allocated for new residential and commercial zones. Prime agriculture lands are preserved for better food production. Human settlements should be far from the potential risks like fire, flood, and landslide as much as possible. The new settlements are recommended near the existing settlements, so that the government could focus their services on those already existing clusters. Business areas are proposed at equidistance from all major clusters of settlements.

Based on the finding of this study, the following recommendation could be made for future undertaking of similar projects.

1. Policies and Programs should be made and public should be made aware and implied for sustainable use of land resources.
2. As the most of the area of Rural Municipality is covered by Agriculture land, Rural Municipality may make major sources of income from the cash crops, cereal crops and horticulture with taking modern technologies.
3. Being a hilly area, medical herbs, animal husbandry, and horticulture, and fruits which are proposed in this rural municipality based on land capability and soil nutrient, may take advantage by farmers which should be given priority.
4. Jwalamukhi can encourage the public for commercial livestock as it has enough feeding sources i.e. forest, but with sustainable handling.
5. As a hilly rural municipality this area consist highly sloping area with land capability class II, III and IV. III Class consist the highest area of the total land. So medium capability recommended for vegetables and herbs citrus based fruits like lemon, orange nibuwa etc. However Prime Minister Agriculture Modernization Project didn't selected this rural municipality as pocket, zone and super zone, high yield agriculture crops should promote.
6. The land use in this Rural Municipality is still not deteriorated so far. Therefore, land use planning should be started based on this study as soon as possible. Land use act is the most important tool to take this policy in action. So, it is recommended to formulate land use act and enact it as soon as possible.
7. Settlements in the risky area should shift from current location to safe settlement area.
8. Zoning criteria are subjective, which may lead to ambiguous zoning and inconsistency amongst different consultants. Therefore, it is recommended to have a discussion and develop scientific guideline as much as possible. Therefore, it is suggested to develop a micro zoning by the local government based on to this report/maps/database/ document for further implementation.
9. Possibility of Animal Husbandry especially Cow, Buffalo Goat, seems high, so farmers should be motivated for livestock farming. This rural municipality can be sustain itself in dairy product.

REFERENCE

- National Land Use Policy, 2072.
- Land Use Act 2076.
- Land Use Specification, 2019
- CBS, Dhading District Profile
- District Coordination Committee, Dhading
- Rural Municipality Profile and Website of Jwalamukhi.
- Prime Minister Agricultural Modernization Project, Government of Nepal. 2073/074

FINAL REPORT

Present Land Use

Jwalamukhi Rural Municipality, Dhading District

Package No.: TSLUMD/CS/QCBS/01/07/2077/078

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CHAPTER 1: INTRODUCTION

1.1 Background and Rationale

Land use involves the management, development and modification of natural environment into a manageable ecofriendly built environment in the form of settlements and semi-natural habitats such as arable fields, pastures and managed forest. Land use and land cover patterns in the few decades have begun as a global phenomenon and probably the most noteworthy to the environmental changes it brings with it. Towards this realm, human activities and perception regarding urbanization, industrialization, and agriculture have been identified as a major cause of this dramatic change in land cover and land use patterns globally. Dramatic land cover and land use changes that would have once required centuries now take place within a few decades (Ademiluyi et al., 2008). The increasing concern for the management of natural resources in recent times has been necessitated by the increasing demographic pressures and its associated man-made activities which have led to serious environmental stress and ecological instability. In the last 300 years, the impacts of land use change have increasingly assumed significant to threatening proportions (Briassoullis H, 1999).

Land use planning is a process by which the society, through its institutions, decides where, within its territory, different socioeconomic activities such as agriculture, housing, industry, recreation and commerce to name a few should take place. FAO (1993) states that the systematic assessment of the land and water potential, alternatives for land uses and economic and social conditions in order to select and adopt the land use of all economic activities. The land use/ land cover pattern of a region is an outcome of sustainable management and proper utilization of land resources-an essence of land use planning. That is to say, it is about maximizing economic and social benefits, and maintaining or enhancing the ecological support functions of land resources. Land is the only natural resource that is at the center natural and socioeconomic factors and their utilization by man in time and space. It turn out that land has become a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use / land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. In the context of rapidly growing human population, the demand for land for agriculture, grazing, wildlife, tourism, and urban development, is conflicting and greater than it is available.

In Nepal, eighty-one percent of the active population of Nepal rely on the agriculture and related activities such as forestry and pasture which constitute almost ninety-seven percent of the total land use area (FAO. 2019). Since the country is producing insufficient food, the demand for arable land is increasing. In addition, the problem has become much severe due to increasing land demand for urbanization, industrial uses, infrastructures development, mining, and recreation. The forces that would change their nature and availability such as climatic change and natural disaster makes the task to preserve the land quality and its availability for the future generation a challenging task. Therefore, land use planning is required to best utilize the limited land resources based on inherent qualities. This will address the issues of food security, land degradation, forest and wild life protection, hazard mitigation, and physical development. 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 polices and national planning efforts. The Ninth and Tenth Five Year plans (2002/03 - 2006/07) of Nepal highlighted on the formulation and implementation of land use policy to discourage to use arable land for non-agricultural purposes. Comprehensive Rural Municipality/Municipality level land use planning has been felt necessary by the Government of Nepal to address the issues of food security, land degradation, forest and wild life protection, hazard mitigation, and physical development. At the national and local scale of land use management and planning, information on the current land use, soil characteristics, land capability, land system, land use zoning, and cadastral maps as well as that of people perception and available services are required. In the Tenth Five Year Plan, implementation of land use program was included. So, the National Land Use Project (NLUP) initiated its work to update existing land resources maps that included the preparation of land use zoning data, creating profile at local level for Rural Municipality/Municipality, and mapping land use, land cover, soil and risk areas.

Space borne remote sensing has long been an appropriate and effective data source for land cover mapping due to its wide coverage and repetitive observations. Remote sensing methods are used now to generate base maps to analyze the urban environment relying predominantly on digital sensor data from space-borne platforms. Development of new sources of spatial data (multispectral and multi-temporal) and sophisticated statistical and geospatial methods have given privilege to the researchers to work even with the smallest pixel size based spectral information and classify the diverse surface of landscape and quantify statistically the surface diversity while improving overall classification accuracy (Myint, S.W., 2006a).

Global cities have been experiencing rapid urban growth in recent decades causing loss of arable land, habitat destruction, a decline in wetland and natural vegetation cover (Alphan, 2003); this has been the case that could be generalized to Nepal as well. Land use areas are comprised of a heterogeneous patchwork of land covers and land uses that are juxtaposed to each other are of significant importance in land classification of any nature be it priori or posteriori. Therefore, implication of any classification techniques, however, does not imply that one method is better than another. As with the type of satellite remote sensing data that are employed for analyses, the application of a specific algorithm for classification of urban land cover and land use is dependent upon what the user’s objectives are, and what level of detail, frequency, and sensors are required for the anticipation of the resulting output products. The emerging tools and techniques of Geographic Information Systems (GIS) and Remote Sensing (RS) are powerful and cost-effective tools for assessing the spatial and temporal dynamics of land use/ land cover (Hathout. S., 2002). Remote sensing data provide valuable multispectral data on the processes and patterns of land use / land cover change, and GIS is useful tool for mapping and analyzing these patterns (Liu, A., et al. 2006). Geographic Information system (GIS) and Remote Sensing (RS) tools are most effective tool for spatial analysis. This study will use these tools to identify the land use\land cover of Jwalamukhi Rural Municipality and analyze their level of accuracy and significance for statistical appropriations from satellite image obtained from ZY-3 sensor in 2018.

This project of selected Rural Municipality/Municipality of Dhading district is a part of the series of functions to achieve the objectives of the TSLUMD. Analysis and interpolations of high resolution satellite images supported with field observations for the soil data and other related details for the preparation of the Rural Municipality/Municipality level existing land use maps, soil maps, land capability maps, land use zoning maps in large scale using Remote Sensing and Geographic Information System techniques is the present state of art to execute the project. The spatial information that comes with this project is intended to provide valuable insight to the land resources planners, urban/infrastructure planners, environmentalists, foresters, scientific researchers as well as local municipal authority and other agencies that would benefit them to implement effective land use plans in the future.

The TSLUMD under the Ministry of Land Reform and Management, Government of Nepal offered the task to prepare Rural Municipality/Municipality level (present land use maps, soil maps, risk layer maps, land capability maps, land use zoning maps, profile, databases and report for Jwalamukhi Rural Municipality of Dhading District (TSLUMD/CS/QCBS/01/07/2077/078) to Hexa International Pvt. Ltd.

1.2 Objectives of the Study

The long term approach of the Government of Nepal is to make optimum use of available land and land resources in pursuit of sustainable social, economic and ecological developments and prosperity of the Nation with a mission to manage lands in a sustainable manner by developing specific land use system through various Land Use Plans. To do this, government has set objectives to classify entire lands of the country based on the nature of the land use such as capability, type, risk etc. so that the use of land and the available land resources could be protected. Also objectives, by the government, are set to well-facilitate settlement; ensure sustainable urbanization; protect and promote heritage sites, biodiversity, forest, and cultural and archeological area; mitigate natural and human created disastrous hazards; evaluate property; and assess and apply with ease the progressive taxation on land.

On the basis of the government approach, goal, and implication on the land use, the objective of this TSLUMD project is to prepare a comprehensive Rural Municipality/Municipality level present land use maps at 1.10,000 scales, database and reports in order to formulate and implement sustainable land use planning of Jwalamukhi Rural Municipality of Dhading District. The specific objective of this study is to present Land Use Maps, GIS Database and Reports for the Jwalamukhi Rural Municipality in seven hierarchical levels as specified in the Term of Reference provided by the TSLUMD and National Level Specification for the Preparation of Rural Municipality/Municipality Level Land Resource Maps, Database and Reports, 2021. The gathered information acts as land resource inventory of the Jwalamukhi Rural Municipality, that includes the study of existing land use with cropping pattern in cultivated area, forestry information, hydro graphic information, soil characteristics, and rural urban facilities, that are useful parameters for various functional purposes such as land use zoning. This study shall take following objectives as a reference to complete the preparation of the land use resource mapping in Jwalamukhi Rural Municipality.

- Preparation of Rural Municipality/Municipality level present land use maps,
- Preparation of Rural Municipality/Municipality level soil maps,
- Preparation of Rural Municipality/Municipality level land systems maps,
- Preparation of Rural Municipality/Municipality level land capability maps,
- Preparation of Rural Municipality/Municipality level Risk Layer
- Preparation of Rural Municipality/Municipality level land use zoning maps,
- Preparation of Rural Municipality/Municipality profile for land use zoning, and
- Superimposition of cadastral layers with land use zoning maps.

In fulfilling the mentioned objectives, this report should ensure the consolidation and protection of agricultural land; sustainable, planned and safe human settlement; balance between infrastructure development and environment; conservation and identification of historical, religious, cultural and tourists destinations; identification of vulnerable areas both related to human and nature; optimum utilization of land for cultivation and other use; protection and promotion of biodiversity; mitigation of climate change impact, development and expansion of unmanaged industrial and commercial land; and development of open space such as green belt, playgrounds, entertainment venues and gardening areas to mention a few in Jwalamukhi Rural Municipality.

1.3 Study Area

Jwalamukhi is one of the 11 rural municipalities of the Dhading district. The rural municipality is named after the sacred Jwalamukhi Temple, located in one of the wards. The municipality was established on 10th March 2017, merging four VDC units i.e. Khari, Dhola, Nepal, Maidi and Chainpur from the previous administrative structure. Sadhbhyanjang is the administrative center of the municipality.

Jwalamukhi municipality shares border with three municipalities each in Dhading and Gorkha District. In the Dhading district, the municipality shares its border with Tripurasundari, Neelkantha and Siddhalek. Additionally, Shahid lakhan, Bhimsen and Gandaki municipality of Gorkha district are connected to the municipality. Geographically it extends from 84º 44' 3.07" E to 84º 51' 22.92" E and 27º 51' 25.51" N to 27º 58' 52.45" N. The total area of the municipality is 112.90 sq.km with the altitudinal elevation ranging from 333.84 m to 1343.14 m (Figure 1-1). The Jwalamukhi Municipality is divided into 7 wards. As of census 2011, the population of the municipality is 32922. The geological makeup of the rural municipality is dominated by Ranimatta Formation. Almost 62 % of landscape has slope between 15 and 30 degrees. Major area of the municipality is suitable for agriculture. The major produces are cereal, cash-crop, fruits and vegetable. The major cereals are paddy, maize, millet and wheat. Additional, the area is equally known for producing ginger and honey.

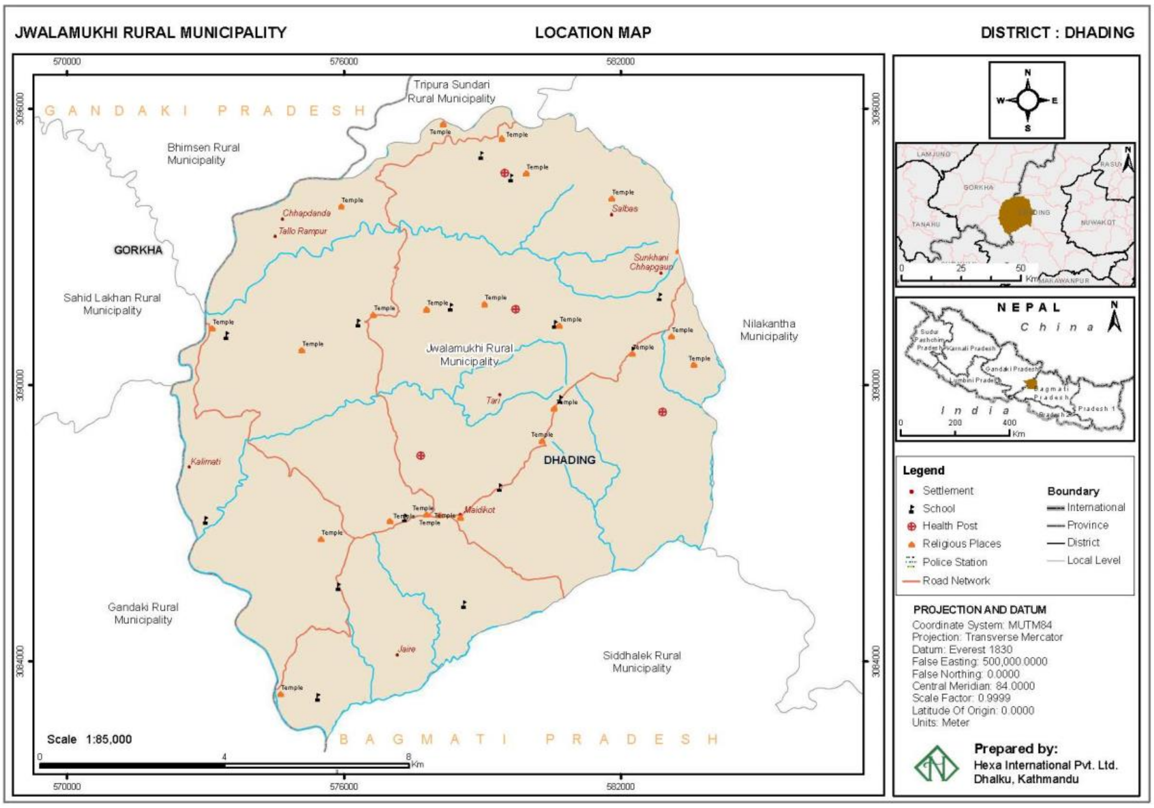

Figure 1-1: Location Map of Jwalamukhi Rural Municipality

The total population of this Rural Municipality is 23966 of which male population is 10573 (44.1%) and female population is 13393 (55.9%). The total households are 5730 and the average family size of the Rural Municipality is 4.2. The Ward wise population distribution of the Rural Municipality has presented in Table 1-1.

Table 1-1: Population distribution by ward and sex in Jwalamukhi Rural Municipality

Ward No.	Household	Population						
		Total	Male	Female	Male %	Female %	Ward %	Density (sq.km)
1	729	3,285	1,472	1,813	44.8%	55.2%	13.7%	250.95
2	693	2,796	1,275	1,521	45.6%	54.4%	11.7%	195.14
3	745	3,122	1,363	1,759	43.7%	56.3%	13.0%	243.08
4	998	4,033	1,772	2,261	43.9%	56.1%	16.8%	219.33
5	1,051	4,381	1,944	2,437	44.4%	55.6%	18.3%	144.95
6	802	3,439	1,477	1,962	42.9%	57.1%	14.3%	424.14
7	712	2,910	1,270	1,640	43.6%	56.4%	12.1%	182.85
Total	**5,730**	**23,966**	**10,573**	**13,393**	**44.1%**	**55.9%**	**100.0%**	**237.21**

Source: CBS 2011

Table 1-1 shows that the ward wise population distribution pattern varies across the rural municipality. The highest population is in ward 5 (18.3%) % whereas the ward no 2 have lowest percentage i.e. of population 11.7 %. Similarly, Ward 1 have highest household size i.e. 4.5 and the ward no 2 and 4 have the lowest household size i.e. 4.0. The population density of Jwalamukhi rural municipality is varied. The average density of the rural Municipality is recorded 237.21 person / sq. km.

CHAPTER 2: CONCEPTUAL BASIS OF LAND USE CLASSIFICATION

2.1 Classification System and Criteria

Land-use classification schemes typically address both land use and land cover and exists no ideal land use classification system because the subjectivity and objectivity of the classification are interchangeable and depends on the nature of the available data and the users' demand. The land use classification process demands more logical reasoning and factual information about the ground since the land use and land cover patterns changes with the change of natural resources. For this reason, land use classification in general is performed with the user need and interest in mind at a particular time frame and it demands frequent update. In an attempt to develop a classification system based on remote sensing technique that provides a framework to satisfy the needs of the majority of users, certain guidelines of criteria for evaluation must first be established.

One basic concept of the land use refers to the nature and characteristics of land that are directly related to the man's activities (Clawson & Stewart, 1965). Whereas, land cover, on the other hand, refers to, the vegetation and artificial constructions covering the land surface (Burley, 1961). By looking at these concepts we can say that land use is a series of operations on land, carried out by humans, with the intention to obtain products and/or benefits through using land resources whereas land cover is the vegetation (natural or planted), water, ice, bare rock, sand or man-made constructions (buildings, etc.) which occur on the earth surface. This signifies that the land use and land cover are closely related and in many cases have been used interchangeably despite the fact that they have some fundamental differences. Land use refers to the purpose the land serves, for example, recreation, wildlife habitat or agriculture; it does not describe the surface cover on the ground. For example, a recreational land use could occur in a forest, shrub land, grasslands or on manicured lawns. Land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil or other; it does not describe the use of land, and the use of land may be different for lands with the same cover type. For instance, a land cover type of forest may be used for timber production, wildlife management or recreation; it might be private land, a protected watershed or a popular state park.

In short, land use indicates how people are using the land, whereas land cover indicates the physical land type. Understanding the significance of the meaning of the land use and land cover would provide a comprehensive picture of a particular area and serves as a fundamental component of the planning and decision-making processes for many communities because it helps them to understand better where to plan for different types of growth and where to preserve. It also helps them to understand the connectivity or fragmentation of various land features in their community in terms of their association with the land cover whether they are forest, agricultural, residential, or industrial among others.

Data related to both land use and land cover are mostly obtained from the analysis of either satellite or other form of images. Remote sensing devices do not record activity directly instead acquires a response which is based on many characteristics of the land surface, including natural or artificial cover. The interpreter uses patterns, tones, textures, shapes, and site associations to derive information about land use activities as a basic information about land cover. Some activities of man, however, cannot be directly related to the type of land cover. Extensive recreational activities covering large tracts of land are not particularly agreeable to interpretation from remote sensing image. For example, hunting is a very common and pervasive recreational use of land, but hunting usually occurs on land that would be classified as some type of forest, range, or agricultural land either during ground survey or image interpretation. Consequently, supplemental information is needed to identify lands used for hunting. Supplemental information such as land ownership maps also is necessary to determine the use of lands such as parks, game shelters, or water conservation districts, which may have land uses coincident with administrative boundaries not usually discernible by inventory using remote sensing image. For these reasons, types of land use and land cover identifiable primarily from remote sensing image are used as the basis for organizing this classification system. Agencies requiring more detailed land use information may need to employ more supplemental data.

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 flats, 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 and Kuhn, 2008).

The problem of classifying multiple uses occurring on a single parcel of land has not been easily solved. Multiple uses may occur simultaneously, as in the instance of agricultural land or forest land used for recreational activities such as hunting or camping. Uses may also occur alternately, such as a major reservoir providing flood control during spring runoff and generating power during winter peak demand periods. This same reservoir may have sufficient water depth to be navigable by commercial shipping the year round and may additionally provide summer recreational opportunities. Obviously all of these activities would not be detectable on a single aerial photograph or a satellite image. However, interpreters have occasionally related flood control activities to drawdown easements around reservoirs detectable on imagery acquired during winter low-water levels. Similarly, major locks at water-control structures imply barge or ship traffic, and foaming tailraces indicate power generation. Pleasure-boat marinas, as well as the wakes of the boats themselves, can be detected on high-altitude photographs. Although each of these activities is detectable at some time using remote sensing, many other multiple-use situations cannot be interpreted with the same degree of success. The example of the reservoir does provide insight into another facet of the problem's solution, however, and that is the possibility and need for acquiring collateral data to aid in the understanding of a multiple-use situation.

The vertical arrangement of many uses above and below the actual ground surface provides additional problems for the land use interpreter. Coal and other mineral deposits under croplands or forests, electrical transmission lines crossing pastures, garages underground or on roofs of buildings, and subways beneath urban areas all exemplify situations which must be resolved by individual users and compilers of land use data.

The size of the minimum area which can be depicted as being in any particular land use category depends partially on the scale and resolution of the original remote sensing image or other data source from which the land use is identified and interpreted. It also depends on the scale of data compilation as well as the final scale of the presentation of the land use information. In some cases, land uses cannot be identified with the level of accuracy approaching the size of the smallest unit map able, while in others, specific land uses can be identified which are too small to be mapped.

Classification is an abstract representation of the situation in the field using well-defined diagnostic criteria: example would be the order or arrangement of objects into groups or sets on the basis of their relationships. A classification describes the systematic framework with the names of the classes and the criteria used to distinguish them, and the relation between classes. Classification thus necessarily involves definition of class boundaries that should be clear, precise, possibly quantitative, and based upon objective criteria. A classification should therefore be i) scale independent, meaning that the classes at all levels of the system should be applicable at any scale or level of detail and ii) source independent, implying that it is independent of the means used to collect information, whether satellite imagery, aerial photography, field survey or some combination of them is used.

A legend is the application of a classification in a specific area using a defined mapping scale and specific data set. Therefore, a legend may contain only a proportion, or subset, of all possible classes of the classification. Thus, a legend is i) scale and cartographic representation dependent (e.g., occurrence of mixed mapping units if the elements composing this unit are too small to be delineated independently) and ii) data and mapping methodology dependent (e.g., an aerial photograph shows different features compared to a satellite false color composite image).

A land use and land cover classification system which can effectively employ high-resolution remote sensing image should meet the following criteria (Anderson *et al*., 1976):

i. 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.
ii. The accuracy of interpretation for the several categories should be about equal.
iii. Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.
iv. The classification system should be applicable over extensive areas.
v. The categorization should permit vegetation and other types of land cover to be used as surrogates for activity.
vi. The classification system should be suitable for use with remote sensing image obtained at different times of the year.
vii. 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.

viii. Aggregation of categories must be possible.
ix. Comparison with future land use data should be possible.
x. Multiple uses of land should be recognized when possible.

Some of these criteria are applicable to land use and land cover classification in general, but some of the criteria apply primarily to land use and land cover data interpreted from remote sensing image.

2.2 Land Use Hierarchy and Description

Classification systems are predominantly two types in nature; one a priori or a posteriori and the other is a hierarchical or a non-hierarchical. In an a priori classification system the classes are abstractions of the types actually occurring. The approach is based upon definition of classes before any data collection actually takes place. This means that all possible combinations of diagnostic criteria must be dealt beforehand in the classification. Basically, in the field, each sample plot is identified and labeled according to the classification adopted. The advantage is that classes are standardized independent of the area and the means used but the disadvantage, however, is that this method is rigid, as some of the field samples may not be easily assignable to one of the pre-defined classes.

A posteriori classification differs fundamentally by its direct approach and its freedom from preconceived notions. The approach is based upon definition of classes after clustering similarity or dissimilarity of the field samples collected. The Braun-Blanquet method (Kuechler and Zonneveld, 1988) - a floristic classification approach using the total species combination to cluster samples in sociological groups- is an example of such an approach. The advantage of this type of classification is its flexibility and adaptability compared to the implicit rigidity of the *a priori* classification. This type of classification better fits the collected field observations in a specific area. At the same time, since *a posteriori* classification is specific area dependent is unable to define standardized classes and hence the clustering of samples in defining the classes can only be done after data collection and dependent of space i.e., cannot be used in various region.

In hierarchically structured classification system classes offer more consistency owing to their 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, i.e., lower level.

Non-hierarchical system begins with some suboptimal partitioning of objects into groups and iterate by moving objects from one group to another so as to optimize some measurement of within-group homogeneity and between-group heterogeneity. These methods are designed to produce a partitioning of objects into a set of groups but give no direct information as to how the groups, or the individuals within them are related.

In the specification provided by the National Land Use Project (TSLUMD) hierarchical classification system has been prescribed. A hierarchical classification system is a multi-tiered abstract representation of the situation using well-defined diagnostic criteria, the 'classifiers'. Hierarchical classification system aggregates objects into groups or sets on the basis of their relationship with each other and with the objects in the higher order.

Hierarchical classification system offers more realistic output because of its ability to accommodate different levels of information, starting with structured broad-level classes which allow further subdivision into more detailed sub-classes.

ToR and subsequent specification of TSLUMD prescribes the following classifications scheme for the present land use map (Table 2):

Table 2-1: Land use categories as per specifications of TSLUMD

S.N.	Land Use Classes	Description
1.	Agriculture	Includes area being used for or suitable for agricultural production (Corn crops, cash crops. horticulture etc.), animal and birds husbandry, fishery, farm house, bee keeping, silk farm, Natural parks, private plantation and orchards. Any other area of agro-forest or such land suitable for it.
2.	Residential	Includes area land used by human beings for habitat, which includes houses, cattle sheds, garage, grain-storage, well, home-garden. This term also denotes shed, *bhakari* (large bamboo bin used to store crops), stable, water tap, fruits garden, vegetable garden, yard or the land used for other such purpose whether the land is adjoined to a house or not. This term also indicates colony home, apartment constructed by a business company or institution by a business company or institution, and any specific land declared as residential area by Government of Nepal among others.
3.	Commercial	Includes areas covered by Banks, Cooperatives, financial institutions, shops, hotels, exhibition hall, go down, show rooms, petrol pump, cinema hall, swimming pool, Health, Communication, Entertainment Services, place where services or goods related to health, communication and entertainment are traded; or place where services, information or consultations related to literature, scientific or technical is provided; or areas covered by houses built for any other commercial purposes and tourist areas, literature, scientific, Technical, information, and Counselling. Also includes land declared or segregated by law for expansion of commerce and trade.

S.N.	Land Use Classes	Description
4.	Industrial	Includes land covered by house, hut, or workshop constructed for establishment of industry that produces goods or to be operating thereof including the land having separated for the purpose. Also includes area declared by the government as industrial corridor, industrial village, industrial cluster, special export zone or special economic zone for promotion of industry, among others.
5.	Forest	Includes government, community, leasehold forest covered fully or partially by trees and vegetation including wild life conservation, preserved areas, bushes, nursery plant and the place which is declared as forest area by government even in non-existence of tree including lands with all types of forest. It also denotes any specific geographical area declared by the government as forest area for expansion of forest area or green area among others.
6.	Public use	Includes areas used for academic institutions including School, College, Vocational Education Centre, university, Hostels; Security Body; public health institution including Health Center, Health Post, and Community Hospital; government office responsible for Telecommunication; Drinking Water; Electricity and other energy supply; Community Building; Library; Elder's Home and House; Hut; Paati (resting inn/house) constructed for public use and the land covered by thereof, hostel, pilgrimage, funeral sites, well, *Chautari* (platform under a tree), ground, picnic spot, highway, district road, village road, airport, cargo area, dry port, railway, ropeway, waterway, cable car, electrical transmission line,, parks, and bus park. Also any open area declared by the government as public use area.
7.	Mine and Minerals	Includes land where mines and minerals are excavated, produced, processed, refined, and stored or any specific geographical area which is declared as mines and minerals by Government of Nepal. This term also denotes any area where any mine is found or mines industry is operated or where industry of excavation, production, processing and purification of minerals is located, house and hut used for the same propose and the land used for operation of the industry of the same purpose, among others.
8.	Cultural and Archaeological	Includes area of historic and archeological importance such as, palaces; religious buildings including churches, cloister, temple, shrines, mosque, and monastery, *mane*

S.N.	Land Use Classes	Description
		(the prayer wheel). This term also indicates any specific geographical area that is declared by law as cultural and archaeological area by Government of Nepal, among others.
9.	Riverine, Stream, Lake and Marsh Area	Includes areas of river, brooklet, territorial stream, canal, streams, pond, lake and wetland, among others.
10.	Others	Includes areas which are not existed in any of the above mentioned geographical areas but seems deem necessary to mention specific type of land use. This area denotes the land with mixed type that will be available in various `towns, residential and business area located in highway area in the time being at present which is mixed with each other in an inseparable way and cannot be separated from each other. This area shall be applied only for the purpose of regulating the previous settlement and market area.
Note: Description of Land Use Classes is according to National Land Use act, 2076		

For the purpose of detailed classification of major land use categories, TSLUMD has prepared following classification scheme in detail:

2.2.1 Agricultural Land Use

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, topography, soil) and social/cultural believes of the particular region. LRMP has broadly categorized cultivated land based on physiography of Nepal, namely Terai, Hill, Mountain and Valley cultivation. The Terai 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 level 6. Based on above information, TSLUMD has provided hierarchy of agricultural land for this study as follows.

Table 2-2: Hierarchies of Agriculture land use

Level 1	Level 2	Level 3	Level 4	Level 5 - Cropping pattern	Level 6
Agriculture	**Terai Cultivation**	Wet land cultivation	Low khet land cultivation	**(Monsoon-Winter-Dry Season)** 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; 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	**Cropping intensity** Intense (75%-100% cultivated) medium(50 %-75% cultivated) Light (25%-50% cultivated)
			Upper khet land cultivation –Tari Khet		
		Dry land cultivation	*Unclassified*		
		Mixed land cultivation			
	Hill Cultivation	Level terraces	Level terraces Khet land cultivation		
			Level terraces upland / Pakho land cultivation		
		Sloping terraces	Sloping upland / Pakho land cultivation		
	Mountain cultivation	Level terraces upland cultivation	*Unclassified*		
		Slopy upland			
	Valley cultivation	Level terraces Khet land cultivation	*Unclassified*		
		Level terraces upland / Pakho cultivation			
		Valley slope upland / pakho cultivation			
		Valley riverbeds (lower footslope) Alluvial fans cultivation			

2.2.2 Residential Land Use

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: Hierarchy of Residential Land Use

Level1	Level2	Level3	Level4
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, Apartment/Multi-storeys, Oldage care place, Hostel, Dharashram, Quarters, Infrastructure developed area, Other

2.2.3 Commercial Land Use

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 Rural Municipality.

Table 2-4: Hierarchy of Commercial Land Use

Level 2	Level 3	Level 4
Service Areas	Government service Area (G)	Agriculture Office – ag; CBS - b5; Civil Aviation – ca; Communication – cm; Court – co; Cultural Office – cu; District Administration office - a1; Doildar – do; Education – en; Electricity office – eo; Forestry office - f2; Health office - h5; Irrigation office - i1; Land Transaction Office –lt; Local Development office - l2; Mining and Geology – mg; Other - o5; Petroleum – pm; Post Office – po; Road Office - r4; Soil Conservation – sc
	Market Area with specific categories, like:	

Level 2	Level 3	Level 4
Business Areas	Market (M)	Shop - s1; Boutique - b2; Departmental Store - d1; Retail Business - r2; Supermarket - m1
	Hotel (H)	Hotel - h1; Guest House -g1; Fast-food -f1; Restaurant - r1; Bar - b1; Travel Agency - t1; Other hotel - o1
	Recreation (R)	Cyber cafe - y1; Cinema Hall - c2; Concert Hall - h2; Theatre - t2; Dance Hall - d2; Night Club - n1; Gaming Hall - g2; Gambling Hall - l1; Exhibition Centre - e1; Gym House - m2; Other Entertaining area - x2
	Utility (U)	Water Reservoir - w1; Hydropower Area - h4; Cable Car - c5; Gas Plant - g3; Oil Storage - o4; Other storage - x3
	Storage (T)	Storage house/ area - s3; Consultancy service area - c4; Business house - b4
	Service (S)	Bank/Money Exchange - b3; Private Post office - p1; Private Communication Area - c3; Broadcast Studio - d3; Private School Area - e2; Private Health Service Area - h3; Petrol Pump - m3; Radio Station - r3; Service centre - s2; TV Station - t3; Other Service - o3

2.2.4 Industrial Land 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: Hierarchy of Public Land Use

Level1	Level2
Industrial	Small Scale including Cottage Industry Medium Scale Industry Large Scale Industry

2.2.5 Forest Land 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 is 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.

Bushes/Shrubs are classified as a category of forest. These are different from trees due to their multiple stems and lower height. Bushes generally have dense foliage and many small leafy branches growing close together. Shrubs are generally found in the gardens, narrow gullies, along the river bank as well as on bare unattended land during rainy season. Bushes are not categorized into lower levels. The hierarchy of forest land use is shown in Table.

Table 2-6: Hierarchy of Forest Land Use

Level 1	Level 2 (*Climatic Vegetation Zone)*	Level 3 *(Cover Type)*	Level 4 *(Species Type)*	Level 5 (*Crown Density)*	Level 6 (*Maturity Class)*	Level 7 (*Forest Ownership Category or Use Rights)*
Forest	**Tropical Forest** (<1000m) **Sub-tropical** (1000-2000/2100m) **Temperate** (2000/2100-3000/3100m) **Sub-alpine** (3000/3100-4000/4100m) **Alpine** (4000/4100-4500m)	**Hardwood** **Coniferous** **Mixed** **Other**	Sal: Shorea R7obusta Or Dalbergla Sissoo etc Pr: Pinus Rosburghii Quercus (Oak) all species Pinus (wallchian) Blue Pine etc	**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)	***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	Private Protected Government Managed Community Leasehold Collaborative Religious Others
		Shrub				

2.2.6 Public Services Area Land Use

Public services are those services 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, Recreational facility, Institution and other. School, Colleges and Universities are placed in Educational class. Police station 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. Recreational facility includes Park, Picnic spot, Open Spaces, Stadium, Playground etc. Institutional service includes Government and Public institutions. The hierarchy of public services is given below:

Table 2-7: Hierarchy of Public Service Land use

Level 1	Level 2	Level 3	Level 4
Public Services	Educational	School, College and Universities	Designated Name
	Security Services	Police, Armed Police, Military	
	Transportation Infrastructure	Road, trail, airport, bus park, Railway, Ropeway, etc.	
	Utility Places	Telephone booth, Crematory, Electricity office, Fire station, Landfill site, Water tank, Electric pole etc.	
	Health Service	Hospital, Health Post, Polyclinic	
	Recreational Facility	Park, picnic spot, open spaces, stadium, playground, etc)	
	Institution	Government, Public, Private, NGOs, INGOs etc.	
	Snowy Mountain	Snow covered Area (s)	
	Other	Other public use - o4.	

2.2.7 Mine and Minerals Area Land Use

Mines and minerals in their original position are part and parcel of the land. The common law presumption is that a landowner owns everything below the surface down to the center of the earth. Unworked mines and minerals are the property of the surface owner. This class also includes areas of aggregate material such as gravels, sand, clay and occupied area.

This class includes areas being mine reserve and extraction area; house, hut and the land which is occupied by mining project. Also aggregate material for construction and decoration such as gravels, sand, clay, pebbles, Lime stones, quartz, River boulders, Slates, granites, marbles, colored sandstone and other excavation materials falls under this category in Level 3. Likewise, fuel minerals such as coal, methane, petroleum etc., various gemstone, such as Kyanite, Ruby, Sapphire, Tourmaline etc. and metallic and nonmetallic Magnesite, Mica, Phosphorite, Quartz, Silica sand, Talc, Iron, Copper, Zinc, Lead, Cobalt, Nickel, Gold, Silver, Tin, Tungsten, Molybdenum, Uranium, Lithium, Lepidolite (Mica), Tantalum, Bismuth, Arsenic, Cadmium, Chromium, Mercury, Titanium etc. fall in this category. Under sub category level 4 and level 5 these materials under construction, trade, or business that are licensed, not-licensed, reserved or banned, under operation, closed, and/or not operated are classified.

Table 2-8: Hierarchy of Mine and Minerals Area

LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5
Mine and Minerals Area	Metallic Minerals Nonmetallic Minerals Gemstones Construction Minerals (Materials) Fuel Minerals Decorative and Dimension Stones Other Minerals	**Construction (Materials) Subcategory (CNSM)** Sands, Cobbles, Flaggy quartzite Limestone, Pebbles, Quartzite, River boulders, Schist, Slates, Other Construction Minerals	**Licensed** Not-Licensed Reserved Banned	Not Operated So Far Currently under Operation Closed Other Operation Status
		Decorative and Dimension Subcategory (DCDEM) Basalt, Colored sandstone, Granites, Marble, Quartzite, Other Decorative and Dimension Minerals		
		Fuel Sub category (FUEL) Coal, Hot springs, Methane, Petroleum, Other Fuel Minerals, Natural Gas		
		Gemstones Subcategory (GM) Aquamarine, Beryl, Garnets, Gem, Kyanites, Quartz crystals, Ruby, Sapphire, Tourmaline, Other Gemstone Minerals		
		non-metallic category (NM) Clay, Dolomite, Limestone, Magnesite, Mica, Phosphorite, Quartz, Silica sand, Talc, Other Non-Metallic, Phyllite		
		Metallic Sub category (MTL) 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		

2.2.8 Cultural and Archaeological Area Land Use

These are institutions or establishments related to religious, culture and history. This class includes areas of Temple, palace, buildings, Mosque, Stupa, Mane and other cultural buildings and areas.

Table 2-9: Hierarchy of Cultural and Archaeological Area

LEVEL1	LEVEL 2
Historical and Archeological	Historical, Archeological and Religious Sub category Heritage Site (h), Durbar Square (d), Gadh (g), Archeological Site (a), Cultural Site (c), Fort (f), Temple(t), Stupa/Monastary(s), Mosque(m), Church(c), Bahal(b), Patis(p), Bihar(v), Other(o)

2.2.9 Riverine, Stream, Lake and Marsh Land Use

All water related natural and man-made features are categorized as hydrography. This class includes pond, lake, canal, glacier, snow area, wetland, river, spout, Kulo, sand and other hydrography.

Table 2-10: Hierarchy of Riverine, Stream, Lake and Marsh Land Use

LEVEL1	LEVEL2
Riverine, Stream, Lake and Marsh Area	Pond (p), Lake (l) Canal (c) Glacier (g) Snow Area (s) Wetland (w) River (r) Spout (t) Well (e) Kulo (k) Other (o) Sand (d)

2.2.10 Other Land Use

Others land use includes a type of land that does not belong to the above mentioned categories. Grazing 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).

Table 2-11: Hierarchy of Others Land Use

Level 2	Level 2	Level 3 (Climatic vegetation zone)
Others	Grazing land (G)	Tropical (<1000 m), Sub-tropical (1000-2000/2100 m), Temperate (2000/2100 m-3000/3100 m), Sub-alpine (3000/3100-4000/4100 m), Alpine (4000/4100 m-4500 m)
	Others(X)	

CHAPTER 3: METHODOLOGY

3.1 Data Sources

Data provides essential information that helps in monitoring various applications such as image fusion, change detection and land cover classification. Various data sources that were used to delineate and analyze the land use, land cover and land use pattern of Jwalamukhi Rural Municipality form two groups- primary and secondary- based on their nature and occurrence. Primary data sources were drawn from ground survey, satellite images, and ground control points (GCPs), whereas secondary data source were obtained from topographical maps, cadastral maps and other relevant land use land cover maps. Recently, with the development of Remote sensing technology, high resolution satellite images that comes from sensors such as IKONOS, Quickbird, World view, GeoEye, ZY-3 etc. are the primary source of preparing LULC map within the private and public sectors. Image interpretation technique is one of the widely used technique in classifying land use from the satellite images. Image interpretation technique with feature extraction tool as a classifier in preparing land use classification from these high resolution images seeks less technological knowhow and does not have to deal with legal obstacles such as permits and rules. Whereas, incomplete data coverage, varying data age and tedious job to aggregate the data for a broad hierarchical classification systems are few shortcomings to name few in using interpretation technique.

For the present land use analysis, both primary and secondary types of data were used. Satellite image from the ZY-3 sensor (that has four spectral bands with 5.8 meters spatial resolution and a panchromatic band with 2.1 meters spatial resolution), ground survey, and GCPs are the major primary sources of data whereas, topographic maps related to Land utilization, Land Capability, and Land cover, cadastral data, previous digital maps of the location and various local and central government reports are the major secondary data used for enhancing data accuracy and interpreting the classification of land use maps. These collected data sets were analyzed and tallied with the field visit information and then later used in the interpretation of satellite imagery. Information and data regarding land use types and risk factor associated with it, cropping pattern and its appropriateness, and forest types and its management etc. were collected during the field work applying intensive field data collection technique such as formatted questionnaires and interviews. All data and information obtained from secondary sources related to the land resources were verified during field work.

3.1.1 ZY-3 Satellite Imageries

ZY-3/ZiYuan-3/Resource-3 (ZY-3. 2019) is a Chinese Earth observation multispectral satellite with high-resolution stereo mapping capability launched in January 2012. ZY-3 is lunched by Stereoscopic Earth Observation Program in China with the overall objective of creating large-scale, three-dimensional maps, and delivering relevant parameters for environmental monitoring, resource management, disaster relief, urban planning and national security. Development of the ZY-3 satellites began in 2008 and the first spacecraft launched in 2012 for a five-year mission.

ZY-3 satellites supports agile and accurate pointing up to 32 degrees off nadir at a typical accuracy of 0.1°. Drift correction is employed to permit the satellite to keep pointing to its target. The remote sensing payload of the ZY-3 satellites is comprised of two instruments- the Three-line Array Camera and a Multispectral Camera. The Three-line Array Camera is comprised of three high-resolution panchromatic cameras, one facing directly nadir and the other two offset by 22 degrees forward and backward in the along-track direction. This enables the simultaneous collection of stereoscopic imagery of the same scene with a minimal period of time between the collections of the stereo images. The TAC instrument consists of the three cameras and telescopes, a common control unit, and signal processing units, all integrated onto a single frame serving as optical bench. The along-track stereo images of ZY-3 allow the generation of digital elevation models (DEMs) for various mapping applications.

The spectral image of the study area comes with 4 bands with wave length of the bands ranging from 450nm to 890nm. Red, Green and Blue bands are of visible range whereas NIR is of nonvisible range. One panchromatic image was also used with spatial resolution of 2.1m. The sensor characteristic and scene details of ZY-3 is described in Table 3-1 and Table 3-2.

Table 3-1: Specification of ZY-3 Image

Specifications	Characteristics		
Processing Level	Standard Radiometric Corrected		
Sensor	ZY-3		
Product Type	Standard		
Image Type	NAD/MUX		
Imaging Mode	Mono		
Image Format	Geo TIFF		
Interpolation Method	Cubic Convolution		
Band/Resolution	Panchromatic	500-800nm	2.1m
	Red	630-690nm	5.8m
	Green	520-590nm	5.8m
	Blue	450-520nm	5.8m
	NIR	770-890nm	5.8m
Scan Direction	Reverse		
Map Projection	Universal Transverse Mercator		
Datum	WGS 84		
Zone	45N		

Table 3-2: Scene Description of ZY-3 Image

Scene Description(Panchromatic)							
SN	**Description**	**zy302a_nad_024708_072154**	**zy302a_nad_024708_072155**	**zy302a_nad_024632_073154**	**zy302a_nad_024632_073155**	**zy302a_nad_024632_073156**	**zy302a_nad_024708_072156**
1	Orbit Id	24708	24708	24632	24632	24632	24708
2	Scene Id	796231	796232	791778	791779	791780	796233
3	Scene Row/Path	154/72	155/72	154/73	155/73	156/73	156/72
4	Acquisition Date/Time (GMT)	2020-10-11 13:03	2020-10-11 13:03	2020-11-05 13:05:29	2020-11-05 13:05:35	2020-11-05 13:05:41	2020-11-10 13:04:04
5	Production Time	2020-11-11 20:09	2020-11-11 20:07	2020-11-11 16:03:59	2020-11-11 16:01:04	2020-11-11 16:02:25	2020-11-11 20:11:10
6	Product Integrity	Complete	Complete	Complete	Complete	Complete	Complete
7	Number of Bands	1	1	1	1	1	1
8	Geometric Accuracy Check	Yes	Yes	Yes	Yes	Yes	Yes
9	Cloud Cover	0	0	8	0	1	0

Scene Description(Multi-spectral)							
SN	**Description**	**zy302a_mux_024708_072154**	**zy302a_mux_024708_072155**	**zy302a_mux_024708_072156**	**zy302a_mux_024632_073154**	**zy302a_mux_024632_073155**	**zy302a_mux_024632_073156**
1	Orbit Id	24708	24708	24708	24632	24632	24632
2	Scene Id	796231	796232	796233	791778	791779	791780
3	Scene Row/Path	154/72	155/72	156/72	154/73	155/73	156/73
4	Acquisition Date/Time (GMT)	2020-10-11 13:03	2020-10-11 13:03	2020-11-10 13:04:04	2020-11-05 13:05:29	2020-11-05 13:05:35	2020-11-05 13:05:41
5	Production Time	2020-10-11 20:10	2020-11-11 20:13	2020-11-11 20:09:10	2020-11-11 16:05:24	2020-11-11 16:01:53	2020-11-11 16:03:25
6	Product Integrity	Complete	Complete	Complete	Complete	Complete	Complete
7	Number of Bands	4	4	4	4	4	4
8	Geometric Accuracy Check	Yes	Yes	Yes	Yes	Yes	Yes
9	Cloud Cover	0	0c	0	8	0	1

In order to visibly identify the land use entities that confuses the image analyst with the similar color identification problem (True Color Deficiency), NIR band was used to visibly detect the land use based on the signatures captured by it. In this image, for example, red color is vegetation unlike green in True color image. Representation of the Satellite image in the form of False Color Composite (FCC) of the study area is shown in Figure 3-1.

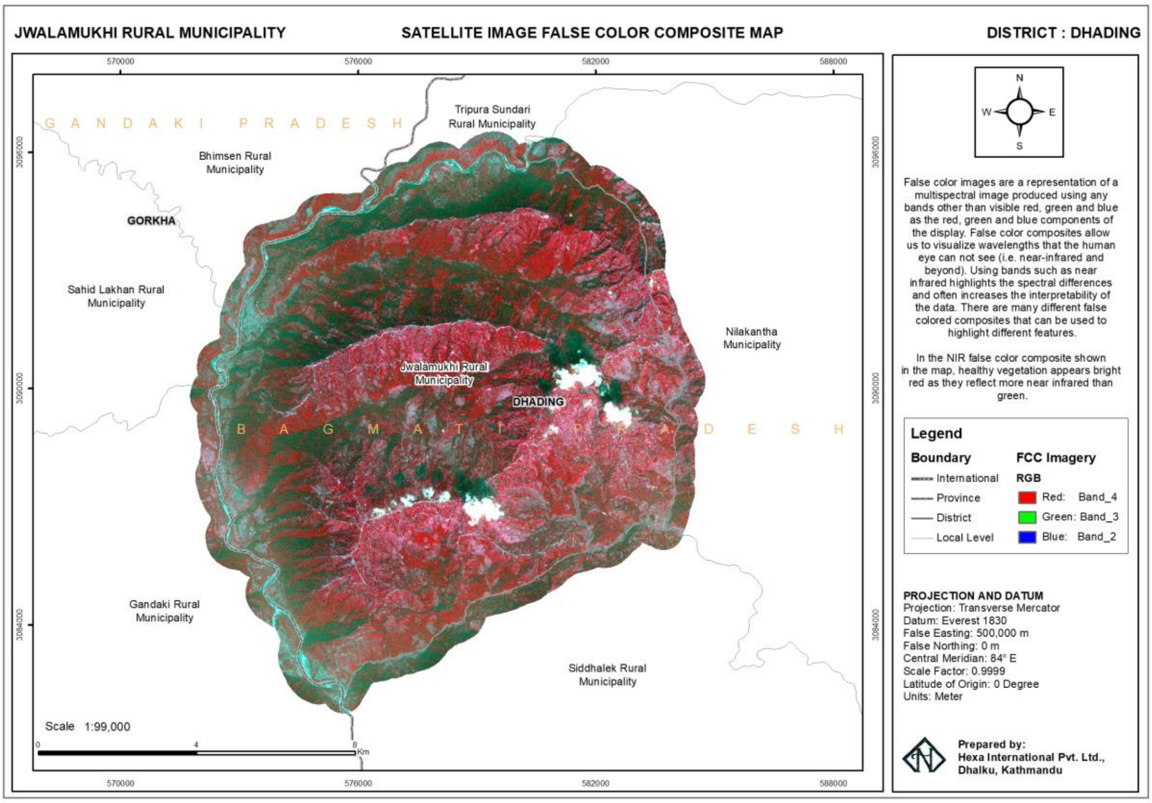

Figure 3-1: Satellite Image (FCC) of the Jwalamukhi Rural Municipality

3.1.2 Topographical Map/Digital Data

Topographical maps covering the study area, Dhading of the package TSLUMD/CS/QCBS/01/07/2077/078 includes Sheet No. 2884-16, 2885-09/13, 2784-03B/03D/04A/04B/04C/04D, 2785-01A/01C/01D, 2784-07B/08A/08B, and 2785-05A/05B respectively in 1:25000 scale with 20m contour interval prepared in 1996 that were compiled from 1:50000 scale aerial photography of 1992 by the Survey Department, Government of Nepal, were used as a base data for GIS analysis. Also, digital GIS datasets including contour, land cover, river features and other topographic features were used as additional data for GIS based analysis and for the study of existing land use pattern. The topographic maps were used as a reference source in planning the allocation of GCPs location using DGPS survey and for identifying the land use coverage (forest area, agriculture area, open area, commerce area etc.) that were used later for classifying the land resources.

Digital Elevation Model (DEM) was generated from the digital topographic map of 20m contour interval using ANUDEM algorithm with *topo to raster* tool in ArcGIS Desktop. The Topo to Raster tool is an interpolation method specifically designed for the creation of hydrologically correct digital elevation models (DEMs). This DEM (Figure 3-2) data was used to rectify the satellite image obtained from ZY-3 sensor and also used to create various DEM derivatives such as slope, aspect, relief and hill shade using terrain analysis techniques in ArcGIS Desktop.

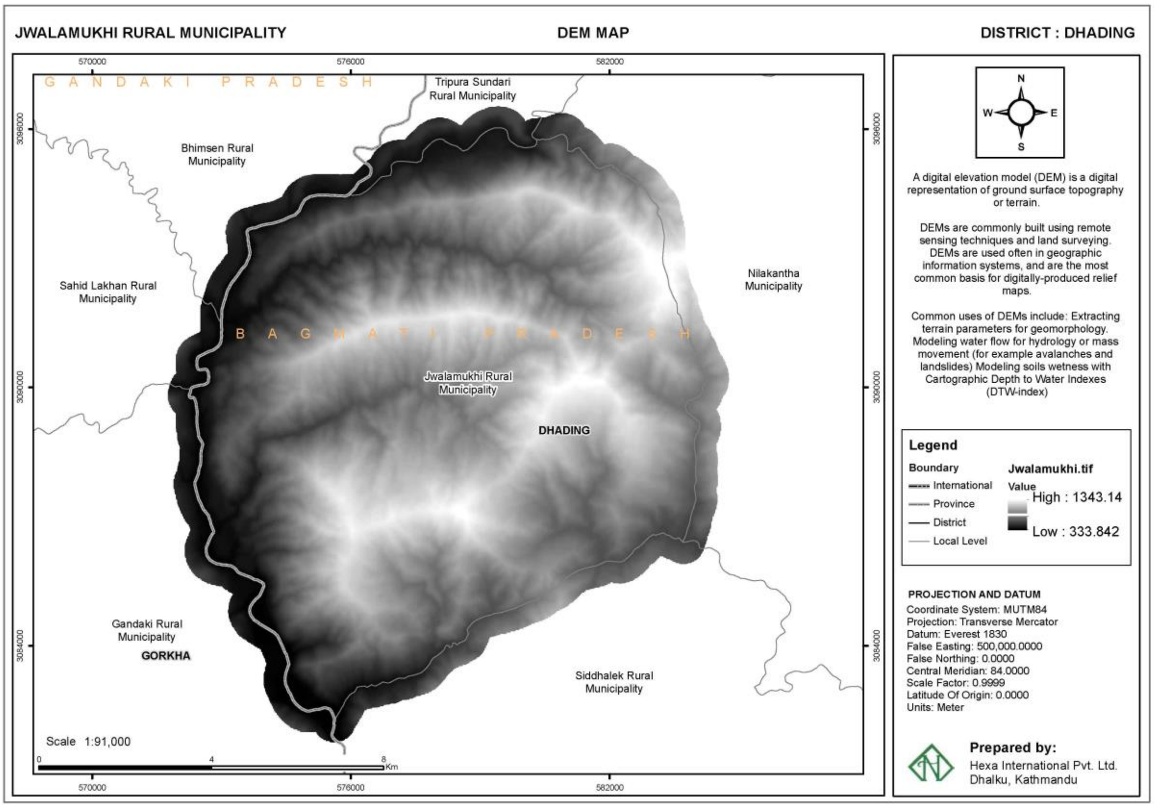

Figure 3-2: Digital Elevation Model (DEM) of Jwalamukhi Rural Municipality

3.1.3 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 identifying land use patterns and for planning land use classification. These maps and reports were studied in detail in order to get an in-depth insight of existing land use classification schema and zonal system of Nepal. Physiography, land use, land form type, climatic conditions as well as zonal capability of the area were reviewed. Annual progressive report published by District Forest Office, Dhading, and Annual Agricultural Census Report and Population Monograph published by Central Bureau of statistics were of paramount importance in reviewing land use pattern, commercial situation, and cultural information about the area.

3.1.4 Ground Control Points

With aerial photography and satellite imagery, sometimes the location information delivered with them is inadequate, and the data does not align properly with other data at hand. Thus, in order to use satellite image in conjunction with other spatial data at hand we need to georeferenced them to a given map coordinate system with specified map projection. During georeferencing a raster data, it is necessary to define its location using map coordinates and assign the coordinate system of the data frame. Georeferencing raster data allows it to be viewed, queried, and analyzed with other geographic data.

Georeferencing a raster data using a GCPs requires identification of a series of ground control points with known x,y coordinates that link locations on the raster dataset with locations in the spatially referenced data (target data). These Control points are locations that can be accurately identified on the raster dataset with real-world coordinates. Ground control points are large marked targets on the ground, spaced strategically throughout the area of interest with high accuracy GPS coordinate that are corresponding to the location of the GCP. The accuracy of the GPS device is directly related to the spatial accuracy of the data from GCPs. Many different types of features can be used as identifiable locations, such as road or stream intersections, the mouth of a stream, rock outcrops, the end of a jetty of land, the corner of an established field, street corners, or the intersection of two hedgerows. These control points are used to build a polynomial transformation that will shift the raster dataset from its existing location to the spatially correct location. The connection between one control point on the raster dataset (*the from point*) and the corresponding control point on the aligned target data (*the to point*) is a link of such transformation.

The Ground Control Points (GCPs) including check points for this study were obtained from the Differential Global Positioning System (GPS) during the field survey in Dhading district under package TSLUMD/CS/QCBS/O1/07/2077/078. DGPS survey was carried out using instrument Geomax Zenith 35 that uses three GPS receivers in order to collect GCPs. During the surveys external batteries has been chosen in order to power the receivers with energy. The DGPS stations were established on the locations identifiable in the ZY-3 image as well as on the ground covering entire study area covering whole range of elevation. For this package, 24 GCPs were measured, from which 6 were assigned as control point for DGPS observation. DGPS readings were later processed using post processing Geo-max Geo-Office Software to get adjusted coordinates of GPS points, which were later transformed into national coordinate system. The coordinate list of GCPs is presented in Table 3-3 and the distribution of GCPs point location overlay on the study area image is shown in Figure 3.3. Alignment to be corrected was almost 20 percent of a pixel size in our satellite image and for this reason the transformation selected for georectification was third order polynomial transformation. In georectification, the established theory is that the higher the transformation order, the higher the correction level of the complex distortion.

Table 3-3: Coordinate list of GCPs in Dhading District

SN	X	Y	Z (ELLIPSOIDAL)	Z (ORTHOMETRIC)
GCP -1	283297.67	3047908.76	236.33	293.77
GCP -2	325636.92	3041004.77	949.90	1004.60
GCP -3	309217.27	3058179.05	1726.67	1778.80
GCP -4	284849.47	3071251.27	518.38	571.08
GCP -5	315777.25	3085437.09	445.55	491.74
GCP -6	330993.57	3060126.67	1196.54	1246.15
GCP -7	324917.73	3069257.96	1187.03	1235.30
GCP -8	333170.97	3098039.53	1885.46	1925.25
GCP -9	296000.69	3097206.38	1088.15	1134.80
GCP -10	335142.77	3114573.48	1457.39	1493.69
GCP -11	305542.29	3112486.47	1165.61	1217.74
GCP -12	314665.88	3118026.93	2154.06	2208.76
GCP -13	340933.00	3128421.49	1749.81	1783.52
GCP -14	277771.83	3077239.12	318.68	371.12
GCP -15	259971.38	3083569.30	242.76	295.40
GCP -16	265883.47	3099819.20	1083.95	1132.78
GCP -17	285913.65	3103095.50	650.13	696.64
GCP -18	291298.04	3109064.40	1492.43	1536.66
GCP -19	262934.95	3114720.95	936.88	982.02
GCP -20	268963.33	3124679.50	1966.83	2008.31
GCP -21	292236.45	3130965.60	1965.50	2003.53
GCP -22	301270.32	3150661.05	2431.19	2464.38
GCP -23	294358.03	3119466.79	2227.81	2268.75
GCP -24	294044.97	3142350.09	1558.03	1593.41

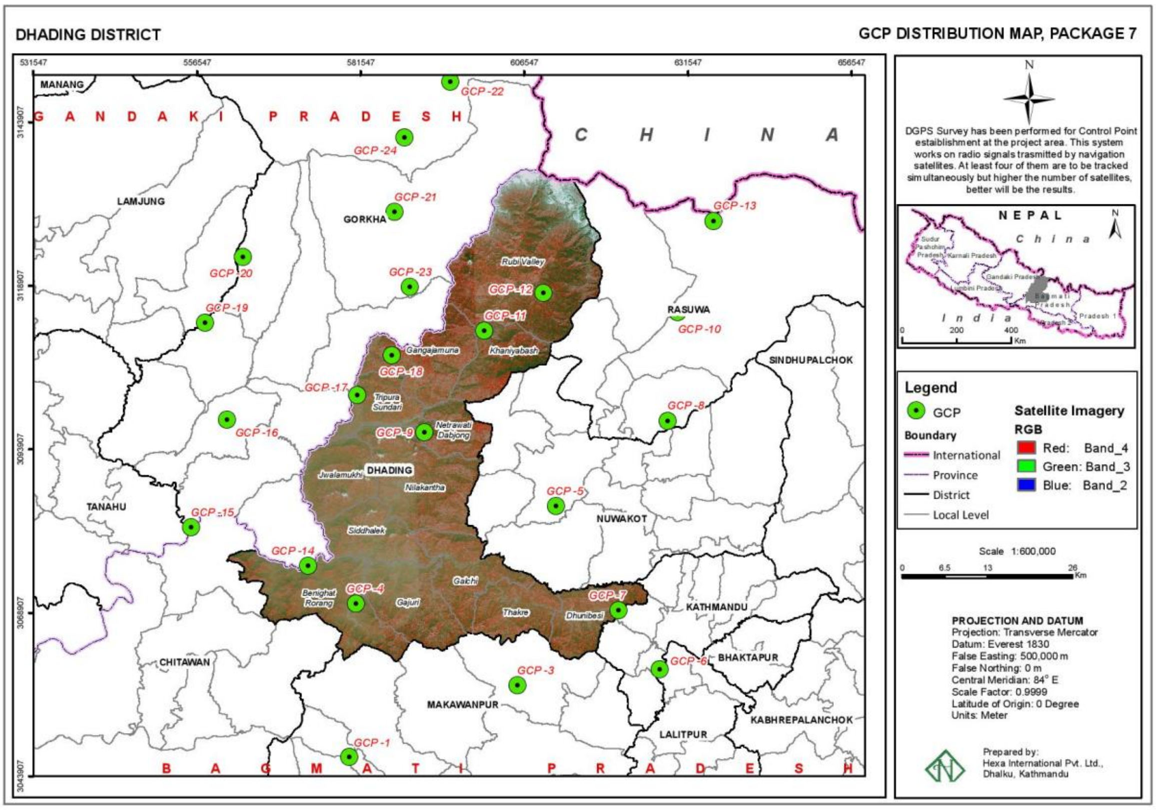

Figure 3-3: Location Map with GCPs Overlaid

3.2 Methods Adopted

Step by step procedures and methods adopted in generating the Present Land Use Map of the Jwalamukhi Rural Municipality is explained briefly with the following work flow diagram (Figure 3-4).

Flow Chart:

Methodology Used to Prepare Land use Map in Jwalamukhi Rural Municipality

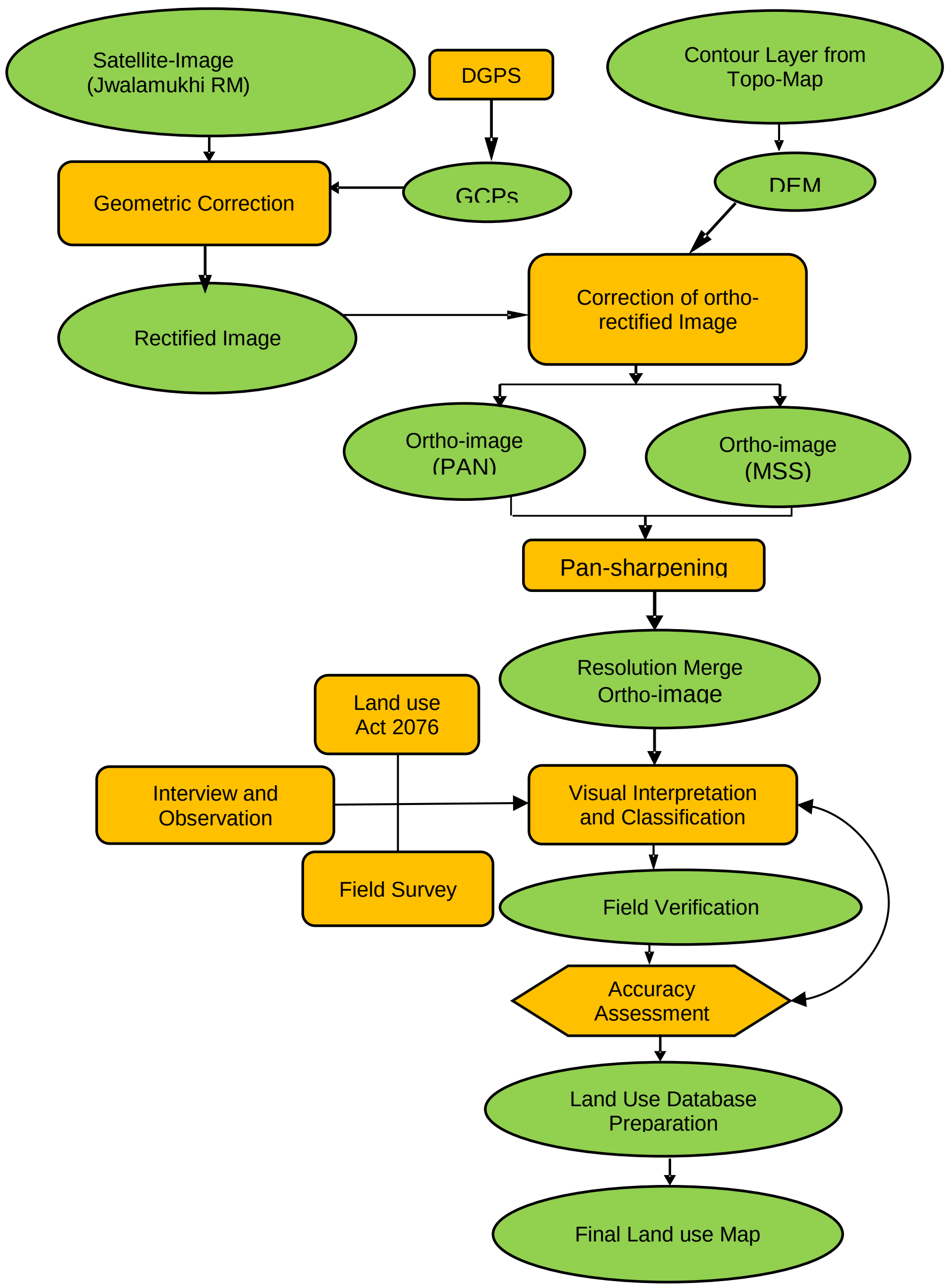

Figure 3-4: Work Flow Diagram

The overall procedural methods adopted in generating the present land use map of the study area is explained under following sections.

3.2.1 Ortho-rectification of satellite Image

The image taken from high resolution satellite ZY-3 with push broom sensor has its own perspective projection model for each image taken at different instance of time or scan line.

On this sensor, there is GPS receiver along with gyros and sensor for positioning and determining satellite camera position with respect to time. The sensor camera position and altitude angle plays important role in geo-rectifying the images produced by these sensors, which is all about a geometric correction of an image.

Satellite images with only good amount of resolution but not geo-referenced are of little use in mapping land use data. Geometric corrections mean corrections for geometric distortions (image coordinates of the object with respect to the ground coordinates of such object in the image) due to sensor-earth geometry variations, and conversion of the data to real world data. 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. 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, 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 orthorectification 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 orthorectification (Schenk, 1999). Without performing orthorectification, 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 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 are eliminated or reduced by orthorectification using high quality DEM, but only DEM is not sufficient to eliminate the effect of elevated objects and occlusion caused by it completely. The quality of ortho-image is based on the quality of GCPs, check points and the quality of DEM used in the process of orthorectification.

For the geometric correction of images, there are two mathematical models are proposed –Rigorous Sensor Model (RSM) and Rational Polynomial Co-efficient Model(RPCM). The RSM is based on satellite orbital parameters and is used in direct geo-referencing techniques that 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 establishes relationship between the point on the image and the corresponding point on the ground (Kaveh and Mazlan, 2011).The RSM builds a correlation between the pixels (2D image space) and their ground locations (3D object space) using any other sensor model. This model is termed as rational polynomial functions (RPFs). This correlation is based on ratios of polynomials. For the ground-to-image transformation, the defined ratios of polynomials takes the form of equation 1.1:

$$x = \frac{p_1(X,Y,Z)}{p_2(X,Y,Z)} \quad \text{and} \quad y = \frac{p_3(X,Y,Z)}{p_4\,(X,Y,Z)} \tag{1.1}$$

Where x and y are the row and column in the image respectively. X, Y, and Z are the coordinates of points in object space, and, Pi (i = 1, 2, 3, and 4) is a polynomial function in the general form of equation 1.2.

$$pi = a_{1_i} + a_{2_i}X + a_{3_i}Y + a_{4_i}Z + a_{5_i}XY + a_{6_i}XZ + a_{7_i}YZ + a_{8_i}X^2 + a_{9_i}Y^2 + a_{10_i}ZY^2 + a_{11_i}XYZ + a_{12_i}X^3 + a_{13_i}XY^2 + a_{14_i}XZ^2 + a_{15_i}X^2Y + a_{16_i}Y^3 + a_{17_i}YZ^2 + a_{18_i}X^2Z + a_{19_i}Y^2Z + a_{20_i}Z^3 \quad (1.2)$$

Usually, rational functions having third order polynomials i.e. the rational function model (RFM) is used in general rational functions with some variations, as is the case with terrain-dependent rational functions. The rational functions are expressed by third order polynomials as shown in Equation 1.2, though the number of coefficients in the polynomials can be reduced gradually. 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 et al., 2010). Exterior and interior orientation can be implicitly encoded in the form of RPFs using third order polynomials for numerator and denominator for a row and column is given by the ratio of two polynomials of third order with normalized ground coordinate (ƛ, ɸ and h) with 20 coefficients.

The second mathematical model (RPCM) is a nonparametric or generic model. In the RPCM, co-ordinate transformation can be solved using an object grid with its nodes coordinates determined using the physical sensor model (Tao and Hu, 2001) and also termed as physical sensor model or universal sensor models, which provide a standardized and easy to use mathematical model to transform map object coordinates to image column and row values of the original image. The RPC model 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. This method can be applied without GCPs (because of that it is called terrain-independent), although the accuracy obtained is not very good and generally not applied in the actual geometric correction of the satellite images. A very interesting possibility of this method is that users can update or improve the accuracy of the rational function model, refining the image vendor coefficients by a few GCPs. In very high-resolution satellite imagery, the RPCM may be refined directly or indirectly (Hu et al., 2004). Direct refining methods update the original RPCM themselves (Hu and Tao, 2002), while the indirect refining introduces complementary transformation (usually polynomial) in image or object space, and they do not change the original RPCM.

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

$$row = a_0 + a_1 .\ rpc_r + a_2 .\ rpc_c$$
$$col. = b_0 + b_1 .\ rpc_r + b_2 .\ rpc_c$$

Where rpcr and rpcc are the originally rational polynomial coefficients provided by satellite image provider or vendors. The RPCM mathematical model is universally used for geo-referencing the wide range of satellite 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 plan metric features or objects as a map (Toutin, 2004). So, it is a map with geometric properties i.e. orthogonal projection with earth reference terrestrial 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.

In this project both geometric rectification and radiometric normalization were performed in the phase of image preprocessing. The georeferencing strategy adopted here was actually an image to image registration using topographic map. First, the 2012 ZY-3 satellite image was rectified using TSLUMD 1:2500 digital topographic maps using GCPs and later georeferenced to Everest 1830 coordinate system. Details of this co-ordinate system 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 81^0 E, Latitude 0 0 N (Equator)

False Coordinate: 500000m Easting, 0m Northing

Scale Factor: 0.9999 at Central Meridian

An intensive pre-processing steps such as mosaicking, clipping and layer- stacking were carried out in order to rectify the satellite images. Six tiles of study area were first merged to form a single tile via mosaicking in EARDAS IMAGINE 15. Using the same software the image is pan sharpened to increase visual clarity. Ortho-rectification was done based on geometric corrected images and DEM generated from topographical contours. Finally, the study area image was extracted by clipping the satellite image using clip function. The details of the pre-processing of the image is described below.

The process of Digital Elevation Model (DEM) creation began with the scanned and geo-referenced topographic map. Contour Lines, elevations, hill shade and bodies of water from the raster image are extracted, converted to digital vectors and were given elevation values. Once a digital image has been fully vectorized and attributed, a raster representation of the map is created based on those vector features. After editing and testing, the resulted file is then projected to the specified projection as an output. DEM was generated from this digital topographic map of 20m contour interval using ANUDEM algorithm with *topo to* raster tool in ArcGIS Desktop. To achieve the desired quality output, the following steps were carried out in reoccurring manner.

a. The vector data is directly compared to the Topographic Map so as to ensure that the lines accurately represent the source map and the vectors have the proper elevation values.
b. The DEM is put through an edge matching process that verifies a visibly smooth transition from one DEM (one map sheet) to another. This portion is done manually to assure the information from the source Topographic Maps are transferred to the DEM and there is no loss of accuracy.
c. Root Mean Square Error (RMSE) is checked to ensure that the creation of DEM is with less error induced. This steps provides the level of accuracy in creating DEM in comparison to the source Topographic Map by comparing a DEMs elevation values to the estimated horizontal and vertical values and control points that have accurate elevation data associated to them.
d. The control points are an important component in checking the DEM Quality. Control points range from spot heights to points along index contours. A minimum of 24 control points selected throughout the study area. Several different elevation values are used to spread the checked points evenly throughout the entire map. 6 control points were chosen near the edges and corners of the DEM to account for edge matching. Two RMSE tests and an average deviation test are performed to ensure the quality of the DEM. The processing resulted value less than that of the value of the contour interval and passed the quality check.
e. GCPs were overlaid on the final mosaicked and rectified image of the study area. The ranges of positional residual entered in orthorectification processes are minimum -1.139m to maximum 0.891m in X and minimum -1.518m to maximum 1.226m in Y having the overall root mean square error (RMSE) of 0.95m (Table 3-4).

Table 3-4: RMSE Table

GCP	X INPUT	Y INPUT	X REF	Y REF	TYPE	X RES	Y RES	RMSE
GCP 1	283288.757	3047927.368	283297.667	3047908.759	Control	-0.124	0.811	0.821
GCP 2	325628.08	3041017.901	325636.919	3041004.769	Control	-0.034	1.77	1.77
GCP 3	309208.354	3058196.1	309217.269	3058179.049	Control	-0.26	0.234	0.35
GCP 4	284840.209	3071272.363	284849.468	3071251.27	Control	-0.159	-0.811	0.827
GCP 6	330984.203	3060141.464	330993.571	3060126.669	Control	0.186	0.406	0.446
GCP 5	315767.409	3085456.426	315777.247	3085437.09	Control	0.22	-1.518	1.534
GCP 7	324908.261	3069274.459	324917.732	3069257.955	Control	0.131	-0.301	0.328
GCP 8	333162.303	3098055.811	333170.97	3098039.532	Control	-1.139	0.356	1.193
GCP 9	295990.172	3097227.807	296000.694	3097206.384	Control	0.686	-1.122	1.315
GCP 10	335132.957	3114591.906	335142.769	3114573.479	Control	-0.266	-1.27	1.297
GCP 11	305531.832	3112506.684	305542.291	3112486.472	Control	0.382	-0.196	0.43
GCP 12	314655.867	3118047.017	314665.884	3118026.927	Control	-0.141	-0.742	0.755
GCP 13	340921.809	3128437.936	340933	3128421.49	Control	0.891	0.738	1.157
GCP 14	277762.379	3077260.934	277771.825	3077239.123	Control	-0.079	-0.563	0.569
GCP 15	259961.111	3083592.151	259971.379	3083569.295	Control	0.618	0.441	0.759
GCP 16	265873.18	3099843.379	265883.468	3099819.202	Control	0.375	-0.761	0.849
GCP 17	285903.926	3103117.542	285913.651	3103095.498	Control	-0.219	-0.482	0.53
GCP 18	291287.786	3109086.36	291298.043	3109064.396	Control	0.221	-0.679	0.713
GCP 19	262925.33	3114745.179	262934.949	3114720.948	Control	-0.542	0.127	0.557
GCP 20	268953.616	3124702.467	268963.334	3124679.503	Control	-0.601	1.226	1.366
GCP 21	292225.887	3130987.062	292236.449	3130965.597	Control	0.165	0.681	0.701
GCP 22	301260.296	3150682.175	301270.321	3150661.048	Control	-0.687	0.976	1.194
GCP 23	294348.274	3119488.194	294358.028	3119466.786	Control	-0.451	0.025	0.452
GCP 24	294033.558	3142371.902	294044.968	3142350.094	Control	0.827	0.653	1.054
			RMSE	**0.9578**				

RMS error is a residual error that shows the difference between where *the from point* ended up as opposed to the actual location that was specified *the to point* position. The total error is computed by taking the root mean square (RMS) sum of all the residuals to compute the RMS error. This value describes how consistent the transformation is between the different control points. When the error is particularly large, you can remove and add control points to adjust the error. The RMSE in our study is 0.957m which shows that the image is georeferenced with high accuracy and the error falls within the limit of half pixel size of the image. Two more necessary steps were also carried out before classifying the land use resource of the study area namely Visualization of different Color Composite and Pan sharpening.

I. Visualization of different Color Composite: Enhancing of the spatial resolution was carried out by fusing 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. This allowed the visualization of the final image clearer than earlier. The process was conducted in the ERDAS IMAGINE 15.
II. Pan-sharpening (Data Merging for clarity) is a process of merging high-resolution panchromatic and lower resolution multispectral imagery to create a single high-resolution color image. It is a technique by which a visual clarity of an image is acquired by the fusion process of high resolution panchromatic data with lower resolution multispectral data. There are various types of algorithms available to pan sharpen the image such as Brovey transform, Multiplicative technique, Principal Component Analysis (PCA), Intensity Hue Saturation (IHS) transform, Gram-Schmidt transform, Subtractive Resolution Merge etc. In this study, pan-sharpening was done with Subtractive Resolution Merge technique. This technique uses a subtractive algorithm to pan sharpen multi-spectral (MS) images. It is capable 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). The input consists of overlapping panchromatic (pan) and MS image. The output is an MS image that retains the colors of the MS image while maintaining the spatial detail of the pan image. This algorithm was designed specifically to provide a solution that was fast, yet produced quality results for the most common types of merges. It uses a 3x3 sharpening convolution kernel and selects lowest central values of the pixels so as to increase the sharpening level. In general, smaller center value creates more sharpening, while larger center values creates less sharpening. Processing this algorithm, our multispectral image acquired clarity significantly than before and allowed us to extract land features with ease and high accuracy.

3.2.2 Classification

Classification of land use based on the feature extraction technique plays an important role in recognition of feature characters that falls within the same class/category. Feature extraction is a method that eases the task of identifying characters uniquely and with high accuracy. It also helps in finding the shape contained in the pattern. Feature extraction can be understood as the process of extracting differentiating features from the pool or matrices of digitized characters. This topic describes the improved procedural method for the present land use land cover classification, which was built upon the hierarchical system designed by the TSLUMD.

To comply with the specification guidelines provided by the TSLUMD, extraction based image processing techniques were performed to extract the information from the satellite imagery to generate our land use classes. An image scene was separated into various categorical regions such as forest, agriculture, commercial etc. early in the classification. Each spectral cluster was assigned into one of the 10 land use classes using visual inspection of the original base image, the reference map/data and the familiarity of the study area (via field visit). To identify and label the clusters, the original image in false color composite and the clustered map were displayed side by side and the displays were spatially linked. A targeted spectral class was highlighted in color and its corresponding image pixels were examined by moving the cursor across the screen. The class assignment for individual clusters was based on an examination of the targeted cluster at two different levels of details. At the large-scale level, the individual image color was mainly used in decision making. At the small-scale level, however, other image elements such as association and field information were utilized to improve classification accuracy. In spatial reclassification, image interpretation procedures, auxiliary vector data and a variety of Geographical Information System (GIS) functions were synthesized to resolve spectral confusion and improve mapping accuracy.

The initial land-use and land-cover maps after hierarchical classification came with the accuracies of approximately 75 percent. To achieve higher accuracy, therefore, further research effort was attempted to reduce image classification errors and improve accuracy. For this purpose, a spatial reclassification procedure has been developed to recode those pixels being labeled wrongly. Spatial reclassification was implemented through the use of image interpretation procedures, auxiliary data and a variety of GIS functions. It consists of several steps as described below.

a. Raster modal filtering: A 3*3 modal filter was used to reduce boundary errors at class boundaries due to the occurrences of intra-pixel spectral mixing and signal noises. Pixels identified as boundary errors are generally in the form of salt and pepper and they were replaced with classes of their surroundings through a modal filter.
b. Iterative image interpretation: The level of spectral confusion was substantially suppressed after hierarchical classification. However, a varying degree of spectral confusion was still observable in some areas. These areas were identified with an image interpretation procedure through which spectral and spatial contextual contents as well as human wisdom and experience were synthesized. Image interpretation was incorporated effectively into a digital classification procedure with the use of on-screen digitizing, multiple zooming, area of interest functionality and other relevant GIS tools such as overlaying and recoding. With the above methods, four major types of spectral confusion were identified:(i) low density urban (mostly residential)/mixed forest (sparse trees); (ii) low density urban (scattered

residential)/agricultural land (sparse crops or grasses); (iii) mixed forest (sparse forest and shrubs)/agricultural land (cropland or grassland); and (iv) high density urban (large roof buildings, highways)/ barren land (large barren landmass, clear outs, and fallowed land). These pairs of land-use and land-cover types were spectrally similar to varying degrees. Whenever any spectrally confused cluster was identified, an area of interest layer was created through on-screen digitizing to define a 'mask' by which the problematic cluster was split and then recoded into a correct land use and land cover class. This process was iterative until an acceptable accuracy was reached.

c. GIS data overlay enforcement: Several GIS data layers were overlaid with the image classification product after the above procedures were completed, which included: (i) Drainage Network; (ii) road network and (iii) landmarks (these entities were generated from the topographic map of the location). These procedures ensured our confidence that the feature extraction during classification was without any alignment error.

Following the above mentioned methods and procedures, 10 categories of land use/land cover map was generated from the satellite image. This classification resulted into a satisfactory overall classification error within half a pixel of the image data and accuracy more than 90 percent and is thus accepted for this study. After the classification was done, the final land use classes and subclasses in the 10 categories of land use were identified and classified as below.

3.2.2.1 *Agricultural Land Use Area*

Agricultural land denotes the land suitable for agricultural production , both crops and livestock . On the satellite imagery, the chief indications of agricultural activity are distinctive geometric field and road patterns on the landscape and the traces produced by livestock or mechanized equipment. However, in our image, pasture and other lands where such equipment is used infrequently did not show as well defined shapes as other areas. These distinctive geometric patterns are also characteristic of urban or built-up lands because of street layout and development by blocks. Distinguishing between agricultural and urban or built-up lands are possible on the basis of urban-activity indicators and the associated concentration of population. The number of building complexes is smaller and the density of the road and highway network is much lower in agricultural land than in urban or built-up land. Some urban land uses, such as parks and open area, however, may be mistaken for agricultural land, especially when they occur on the periphery of the urban areas.

The interface of agricultural land with other categories of land use may sometimes be a transition zone in which there is an intermixture of land uses at first and second levels of categorization. Where farming activities are limited by wetness, the exact boundary also may be difficult to locate, and agricultural land may grade into wetland. In this study, the production of agricultural crops unhindered by wetland conditions are also included in the agricultural category. This latter stipulation also includes those cases in which agricultural crop production depends on wetland conditions, such as the flooding of rice fields. Similarly, the wetlands that are drained for agricultural purposes are also included in the agricultural land category. In the case when such drainage enterprises were not used anymore for agricultural purpose and is reestablished as wetland vegetation again, such land is again classified as wetland category.

In this study, under hierarchical system, cultivation land use is classified into various levels based on terrain morphology/physiography of the area, cropping pattern and intensity. Based on terrain morphology, cultivation land is classified into wetland cultivation, dry land cultivation and mixed land cultivation. Wet land cultivation is further sub-divided into Low Khet Land Cultivation and Upper Khet Land Cultivation. These cultivation land types are further categorized into subclasses based on cropping pattern and intensity. The cropping pattern is designated for monsoon-winter-dry season crops. Cropping intensity is classified as intense, medium and light.

In the map layout, only level 1 class have been shown in different colors whereas other sub-classes are given in map label as specified by TSLUMD. However, all the information's are included in the attribute database as per TSLUMD's specification. Information drawn from the satellite imagery, field observation and information gathered from the local people were compared with the existing land use database (LRMP, 1986), which helped and supported to a great extent to designate the cropping pattern in the study area.

3.2.2.2 *Residential Land Use Area*

A residential area is a land use in which housing predominates, as opposed to industrial and commercial areas . Residential land use includes area consisting of houses, cattle sheds, horse-stable, garage, grain-storage, well, home-garden. It also includes area declared as residential by the government.

As development progresses, land having less intensive or nonconforming use may be located in the midst of urban or built-up areas and will generally be included in this category. Agricultural land, forest, wetland, or water areas on the fringe of urban or built-up areas are not included in this category except when they are surrounded and dominated by urban development. The urban or built-up category takes precedence over others when the criteria for more than one category are met. For example, residential areas that have sufficient tree cover to meet forest land criteria are placed in the residential category.

Residential area are classified hierarchically following density of houses (dense, moderate, low), age of residential area (old area, newly developed unplanned and planned residential area); and lastly by purpose (residential cluster, apartment/multi-storeys, old-age care place, hostel, dharmashala ashram, quarters, Infrastructure developed area and others). Field visit information, and topographic maps played vital role in identifying and locating these entities during classification.

3.2.2.3 *Commercial Land Use Area*

Commercial land use includes area consisting of shops, hotels, show rooms, petrol pump, storage, cinema hall; or place where services or goods related to health, communication and entertainment are traded; or place where services, information or consultations related to literature, scientific or technical is provided; or areas covered by houses built for any other commercial purposes and tourist areas. It also includes areas declared by government for city expansion or establishment of new city.

Commercial land is further classified into different hierarchies based on nature of commerce (service oriented, business oriented), government service area and other commercial areas. It is further classified based on office type/name and business type. Field visit information, and topographic maps played vital role in identifying and locating these entities during classification.

3.2.2.4 *Industrial Land Use Area*

Industrial land use includes areas being used as workshops and for production of goods/materials. It also includes areas declared by the government as areas of special economic zone for promoting industrial activities in a designated area.

Industrial lands are further classified based on their size and nature as: small scale industry, medium scale industry, large scale industry, and special economic zone, industrial state and other industrial category. Field visit information, and topographic maps played vital role in identifying and locating these entities during classification.

3.2.2.5 *Forest Land Use Area*

Forest land includes areas completely or partially covered by trees and vegetation; and forest areas not included in any of above-mentioned classes including governmental, community, leasehold and other forest areas. It also includes areas declared by government for forest area expansion in designated area.

Forest land has been further classified based on climatic vegetation zone, cover type, dominant species type, crown density, maturity class and finally the ownership or use rights. Bushes/Shrubs are classified as a category of forest. These are different from trees due to their multiple stems and lower height. Bushes generally have dense foliage and many small leafy branches growing close together. Shrubs are generally found in the gardens, narrow gullies, along the river bank as well as on bare unattended land during rainy season. Bushes are not categorized into lower levels. Field visit information, and topographic maps played vital role in identifying and locating these entities during classification.

3.2.2.6 *Public Land Use Area*

Public Use land includes areas being used for public purposes including school, college, hostel, pilgrimage, funeral sites, well, *Chautari*, parks, bus-park, airport, and other public use. It also includes area declared by the government as public use area. Field visit information, and topographic maps played vital role in identifying and locating these entities during classification. One campus, and few primary and secondary schools including few heath related establishment were located and mapped for classification.

3.2.2.7 *Mines and minerals Area*

These are the areas that include areas of aggregate material such as gravels, sand, clay and occupied area. Jwalamukhi Rural Municipality does not contain establishments related to mines and minerals and this study is not able to map this land use. Information regarding few locations of mines and minerals is published by the Department of Mines and Geology (http://gis.dmgnepal.gov.np/dmg/) but the area lacks establishments or any areal coverage and hence this study was not able to map this category.

3.2.2.8 *Cultural and Archaeological Area*

These are institutions or establishments related to culture, history and religion. This class includes temple, stupa, monastery, mosque, church, *Bahal, Patis, Bihar* and other related to any kind of religious activities. In this Rural Municipality, few areas of churches, temples and gumbas were located, classified and mapped.

3.2.2.9 *Riverine, Lake and Marsh Area*

All water related natural and man-made features are categorized as hydrography. These include pond, lake, canal, glacier, snow area, wetland, river, spout, Kulo, sand and other hydrography. In this rural municipality, waterbodies are the main supporting resource for agriculture and ecological balancing. There are many small and big rivers flows in this area such as Aankhu Khola and Budi Gandaki River and their respective tributaries and are located, classified and mapped.

3.2.2.10 *Other Land Area*

This class includes grazing lands and other land use which are not represented by any of the above. It covers a large area covered by grass species and is primarily used for cattle grazing. It has been further divided into five classes based on climatic vegetation zone. This class could not be sub-classed into grazing land or other type based on the function or climatic zones. So we could only classify this class as ‘other’ as a level 1 classification. This demands for more field knowledge, good digital data, and good resolution satellite image to locate, identify and map this class into various subclass if any such variation exists in this class.

3.2.3 Image Interpretation

The common visual interpretation technique was used that includes the parameters like tone, texture, color, pattern, form, shadow, association etc. This technique is preferred while classifying the high resolution satellite images by experienced user so that they have more control on the classification process. It includes assigning the pixels in a multispectral image to classes and sub-classes, extracting thematic information from the image using visual interpretation keys. Visual interpretation takes advantage of the human skills to recognize data "content" by combining several elements of image interpretation. It relies on experience, a prior knowledge and skilled analysts qualities to produce excellent results. Availability of high resolution remote sensing data and sufficient a prior knowledge of a small area to be mapped, with adequate ground trothing allows the analysts to extract information about cover (physical dimension) and the use (functional dimension) of the land.

Interpretation keys such as tone, color, shape, size, pattern, texture, shape, association were applied for predicting land use and land cover types in using both true and infrared color composite images. Common image enhancement techniques such as contrast enhancement, intensity-Hue-Saturation processing, de-correlation stretching and color composites were applied. The spectral bands of ZY-3 image, which are useful for detecting various land features land was reviewed from the reports and previous studies. Accordingly, the spectral bands were included in producing various color composite imageries to be used for visually interpreting land use and land cover types.

There are wide range of classification options developed and used in classifying land use area- spectral-based, object-oriented, and other advanced classification methods. Jensen (2005) argued that spectral-based classifications are often not capable of extracting information at high spatial resolutions. Nevertheless, it has been observed that current object-oriented classification (OOC) is still incapable of effectively utilizing the information within High Resolution (HR) satellite images (Zhang, 2008). Given such options, the visual classification approach based on experience, familiarity of the study area and skill of analyst offer advantage over classification based on features extraction and is used in this study as a method of classification of land use.

The land use classification based on feature extraction was carried out by visual interpretation of the satellite image aided by the field observation and other reference maps. Most intuitive way to extract feature from high resolution satellite images is in depth class hierarchy level with visual image interpretation. The objects or feature of land use land cover has been identified with the help of interpretation keys by the experienced image interpreter from prior knowledge and the study of the images. The identified features were verified with extensive field verification and finally, the features of land use classes were extracted from the image.

Two extremely important issues were addressed before undertaking task of image interpretation for determining and delineating land use classes. The first step was to define the criteria to distinguish the various categories of features occurring in the images. For this, the interpreter carefully checked and ascertained that what specific characteristics may determine and separate the proper land use classes as described in classification hierarchy which is described in section 2.2 guided by Land Use Policy, 2072. The second important issue for determining and delineating of discrete areal units on photographs was the selection of the minimum mapping unit (MMU) to be employed in the process. This refers to the smallest size areal entity to be mapped as a discrete area. The minimum mapping unit (MMU) for delineating of land use category was one fourth of a hectare. However, important and essential features smaller than the MMU were also mapped. For the purpose of this study, the MMU was taken as 0.25 ha as specified in land use specification for mapping in scale 1:10000. Interpretation of elements based on tone, size, shape, texture, shadow, 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. The object or feature such as forest, agriculture, road, residential area or commercial area in one category, industrial area, river etc. which was easily identified was classified with interpretation element incorporate with expert knowledge. These features were included in the classification hierarchy. Further, these classified features were verified with intensive field verification using raw classified map. After visual interpretation and desk study based classified feature were verified in the field. If any modification at the first level classification was found; these correction was immediately modified in classified map. For lower level classification, object or features within the hierarchy of first level was done based on actual ground information. In this way, classified feature such as public use, commercial and industrial feature was categories by remote sensing expert. Similarly, agriculture land was categorized based on the cropping pattern and its intensity up to six level classification hierarchy schemas. Forest land was also categorized based on species cover, type, crown density, maturity status and ownership right of forest in seven level classification hierarchy schema. This intensive detail field verification increase the quality of land use classes. Thus, the land use classes yield better accuracy because the classes are designated manually based on ground knowledge rather than automatic classification.

3.2.4 Accuracy Assessment

Validation of 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. Accuracy assessment was done to evaluate classification performance and usefulness of the image classified. 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 (Lillesand et al., 2008).There are several methods for evaluating accuracy. In general, one method compares 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 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). It is a measurement of the argument between a standard that is assumed to be correct and a classified image of unknown quality. 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 samples with visual interpretation of original images and classification result classes at Level-1. A total of 832 sample points in package TSLUMD/CS/QCBS/O1/07/2077/078 were taken for confusion matrix generation. 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. 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*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).

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

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 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 kappa coefficient of agreement summarizes the outcomes of an accurateness of the calculation to assess the sorting of land use or land cover obtained using remote sensing technique. The kappa coefficient standard estimator together with this estimator's standard error requires a sampling model approximated by simple random sampling. Kappa = 1, perfect agreement exists. Kappa = 0, agreement is the equal as would be expected by chance. Kappa < 0, agreement is weaker than expected by chance.

These methods were used for sample schema and evaluation process was 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. It shows the degree of correctness of a map or classification in comparison to the actual ground features. Accuracy assessment in terms of class specific producer’s and user’s accuracy, overall accuracy and Kappa coefficient are subsequently computed after generating confusion matrix. The producer's accuracy relates to the probability that a reference sample is correctly mapped and measures the errors of omission. In contrast, the user's accuracy indicates the probability that a sample from land cover map actually matches what it is from the reference data and measures the error of commission. The classification made at the present study is more realistic as the image interpretation was followed by the intensive field verification. 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.

This study followed TSLUMD hierarchical classification schema in classifying land use and land cover into ten classes and adapted up to seven level of subclasses for further categorization of the land use assets. The Confusion Matrix table or popularly referred to as the Error Matrix table provides key image classification information and enables the researchers to verify its accuracy. The overall accuracies with KIA (kappa statistics) were found 96.99% and 0.97 respectively for the classified objects. The Kappa index illustrated in confusion matrix is shown in Table 3-5.

Table 3-5: Confusion Matrix showing Accuracy Assessment and Kappa Index

	Agriculture	Forest	Residential	Commercial	Industrial	Public Use	Mine And Minerals	Cultural And Archaeological	Riverine, Stream, Lake and Marsh	Other	Total	User Accuracy
Agricultural	414	3	0	0	0	1	0	0	2	0	420	98.57
Forest	1	14	0	0	0	1	0	0	0	0	16	87.50
Residential	0	0	319	2	1	3	0	0	0	0	325	98.15
Commercial	0	0	1	14	0	1	0	0	0	0	16	87.50
Industrial	0	0	0	1	4	0	0	0	0	0	5	80.00
Public Use	0	0	1	0	0	16	0	0	1	0	17	94.12
Mines and Minerals	0	0	0	0	0	0	0	0	0	0	0	0.00
Cultural and Archaeological	0	0	2	1	0	0	0	5	0	0	8	62.50
Riverine, Stream, Lakes and marsh	1	1	0	0	0	1	0	0	21	0	24	87.50
Others	0	0	0	0	0	0	0	0	0	0	0	0.00
Total	416	18	323	18	5	23	0	5	24	0	832	
Producers Accuracy	99.52	77.78	98.76	77.78	80.00	69.57	0.00	100.00	87.50			

Overall Accuracy **96.995%**

Kappa **0.97**

Accuracy assessment table shows that classification process has also acquired good amount of accuracy in all classes. For example user's accuracy and producer's accuracy for Agriculture class is 98.57 percent and 99.52 percent, which means out of 420 samples 414 are counted as agriculture and 6 samples were counted as some other classes. Similarly, the user accuracy and producer accuracy for Residential class is 98.15 percent and 98.76 percent and for commercial class is 87.50 percent and 77.78 percent. Overall class performance of the classification is achieved with 96.99 percent, which means 96.99 percent of the classification area covers the real ground area coverage. Kappa index is acquired at 0.97, which means classification has achieved perfect level of agreement than the agreement would have happened by random or change i.e. a good agreement has been established in classifying the land use area in 10 classes.

CHAPTER 4: PRESENT LAND USE PATTERN IN THE STUDY AREA

This chapter describes in detail the hierarchical level of the present land use pattern based on priori classification schema at 1:10,000 scales as per the land use specification 2015, provided by TSLUMD. In this section, the study has focused on the land use type, cultivation pattern, and area covered by the land use so that the relationship between the cultivation of crops and land type could be established. Similarly, the land cover present on the land, its conditions at present and future prospectus on its usage could be forecasted for proper land utilization in this area. The following section analyses the broad hierarchy level present land use pattern of the Jwalamukhi Rural Municipality at first and describes the details of the different hierarchical level of each broad categories of land use at later part.

4.1 Land Use Pattern

Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (Chaudhary & Jansen, 1999). Land use is a broader aspect of land management including knowledge about land use and land cover that becomes increasingly important as the Nation plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss of fish and wildlife habitat.

This chapter describes the present land use pattern in the Jwalamukhi Rural Municipality. Among the prescribed 10 land use category agriculture dominates the land use pattern of the area. Seven classes were identified in this Rural Municipality where, Agriculture and Forest land use cover 49.98 percent and 42.34 percent of the total land use area as shown in Table 4-1.

Table 4-1: Areal Coverage of Different Land Use practices

S.N.	Description	Area(ha)	Percentage
1	Agriculture	5642.54	49.98
2	Residential	542.97	4.81
3	Commercial	3.24	0.03
4	Industrial	0.00	0.00
5	Mines and Minerals	0.00	0.00
6	Forest	4780.03	42.34
7	Riverine, Stream, Lake and Marsh Area	184.42	1.63
8	Public Service	135.11	1.20
9	Cultural and Archaeological	1.31	0.01
10	Others	0.00	0.00
	Grand Total	**11289.63**	**100.00**

Agriculture predominantly is a driving force of the land and the people and occupies area larger than any other land use area. The present land use Table 4-1 shows that the Agriculture area covers maximum area (49.98 percent) followed by Forest land use (42.34 percent). Next significant land use area is Riverine, Stream, Lake and Marsh Area (1.63 percent). Out of total 11289.62 hectare of area only 5642.54 hectare is used for agricultural purpose. The Seven categories of present land use in Jwalamukhi Rural Municipality is shown in Figure 4-1 and its present land use map is shown in Figure 4-2.

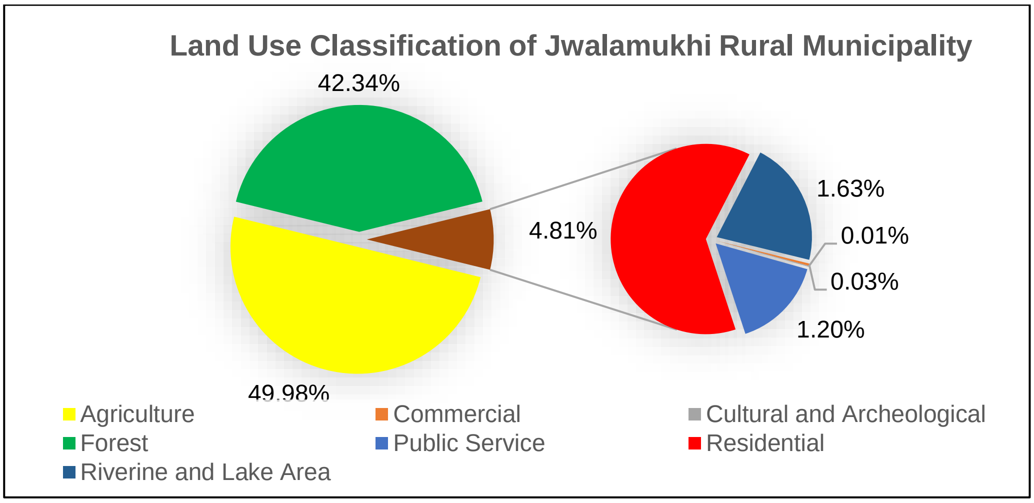

Figure 4-1: Area Coverage by different Land Use Practices in Jwalamukhi RM

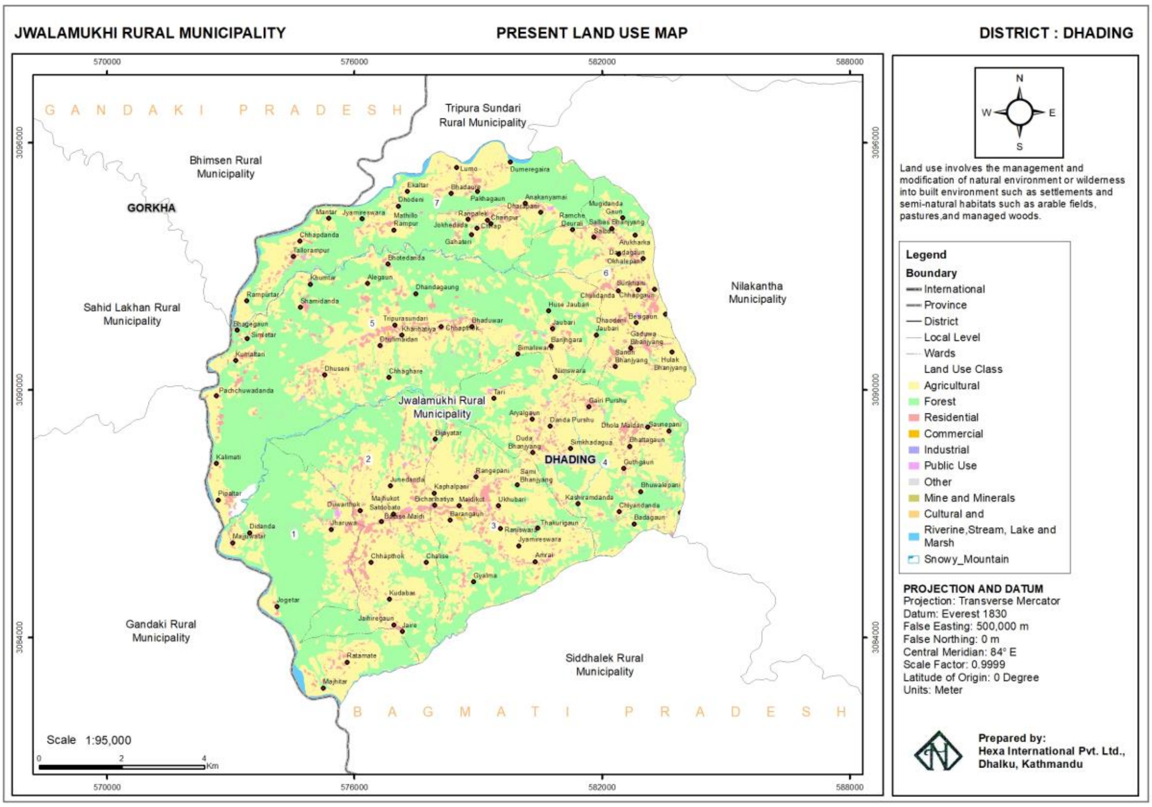

Figure 4-2: Present Land Use Map of Jwalamukhi Rural Municipality

4.1.1 Agricultural Area: Land Use Pattern

Based on the physiography of the land, cultivation is classified into four different classes- Terai Cultivation, Hill Cultivation, Mountain Cultivation and Valley Cultivation. Agriculture is predominantly practiced in hilly area in Jwalamukhi Rural Municipality and is a primary economy covering total agriculture land use area (Table 4-2).

Table 4-2: Categories of Agriculture land use at classification at level 2

S.N.	Description	Area(ha)	Percentage
1	H-Hill Cultivation	5642.54	100.00
	Grand Total	**5642.54**	**100.00**

Based on the land type and crops type, at level 3 the cultivation area is further divided into 3 subclasses as shown in the Table 4-3 where dominant area of cultivation is level terraces covering all of the agricultural land. These areas favor cultivation of maize, wheat, millet, vegetables and rive including other crops such as vegetables and few pulses.

Table 4-3: Categories of Agriculture land use at classification at level 3

S.N.	Description	Area(ha)	Percentage
1	Level Terraces	5642.54	100.00
	Grand Total	**5642.54**	**100.00**

The Hill Cultivation at level four could only be classified as Level Terraces khet land and Level Terraces Upland/Pakho cultivation. Under this category, these lands are cultivated with hard labor. Maize, millet and wheat are the primary crops cultivated in the lower region where as potato, pulses, and few vegetables are some of the crops cultivated in the upper region of the hill. In Jwalamukhi Rural Municipality, cultivation is done on the level terraces khet and upland/pakho where, khet and plain pakho is developed on terraces by levelling the land-a labor intensive job- to maximize the farming capacity of an arable land. Other benefit it brings is it reduces soil erosion and water loss. These terraces are low in nature and built on flat ridge to channelize runoff water for the crops. Usually terraces are built on a slight grade so that the water caught in the channel moves slowly toward the terrace outlet. Khet land is suitable for rice, vegetables, pulses and wheat whereas upland pakho is suitable for local breed of rice, millet, buckwheat and potato. According to the elevation and slope, the land in classification level 4 is shown in (Table 4-4).

Table 4-4: Categories of Agriculture land use at classification at level 4

S.N.	Description	Area(ha)	Percentage
1	Level Terraces Khet Land Cultivation	314.87	5.58
2	Level Terraces Upland/Pakho Land Cultivation	5327.68	94.42
	Grand Total	**5642.54**	**100.00**

The cropping pattern of the Rural Municipality varies with the cultivation land type available along with the availability of the irrigation canal or water from rain water. As for the agricultural land, analysis of cropping pattern shows that Rice-Maize-Vegetables, Rice-

Potato-Vegetables and Rice-Wheat-Pulses are the dominant cropping pattern each occupying the cultivation area of 1884.01 hectare, 928.86 hectare and 599.49 hectare of the total agriculture land respectively. Maize-Millet, Maize-Potato and Maize-Pulses are also practiced to some extent covering less than a percent of the land. The agriculture land use pattern at the hierarchical Level 5 has shown in the Table 4-5 and Figure 4-3.

Table 4-5: Categories of Agriculture land use at classification at level 5

S.N.	Description	Area(ha)	Percentage
1	Garlic-Vegetable	2.80	0.05
2	Maize - Vegetable	147.29	2.61
3	Maize-Millet	217.51	3.85
4	Maize-Oilseeds	10.56	0.19
5	Maize-Potato	10.84	0.19
6	Maize-Pulses	27.42	0.49
7	Maize-Wheat	511.40	9.06
8	Rice-Buckwheat	182.42	3.23
9	Rice-Maize-Vegetable	1884.01	33.39
10	Rice-Potato-Vegetable	928.86	16.46
11	Rice-Wheat-Pulses	599.49	10.62
12	Rice-Wheat	523.96	9.29
13	Shrub from non-forest area	432.20	7.66
14	Vegetables-Others	2.89	0.05
15	Vegetables-Vegetable	160.89	2.85
	Grand Total	**5642.54**	**100.00**

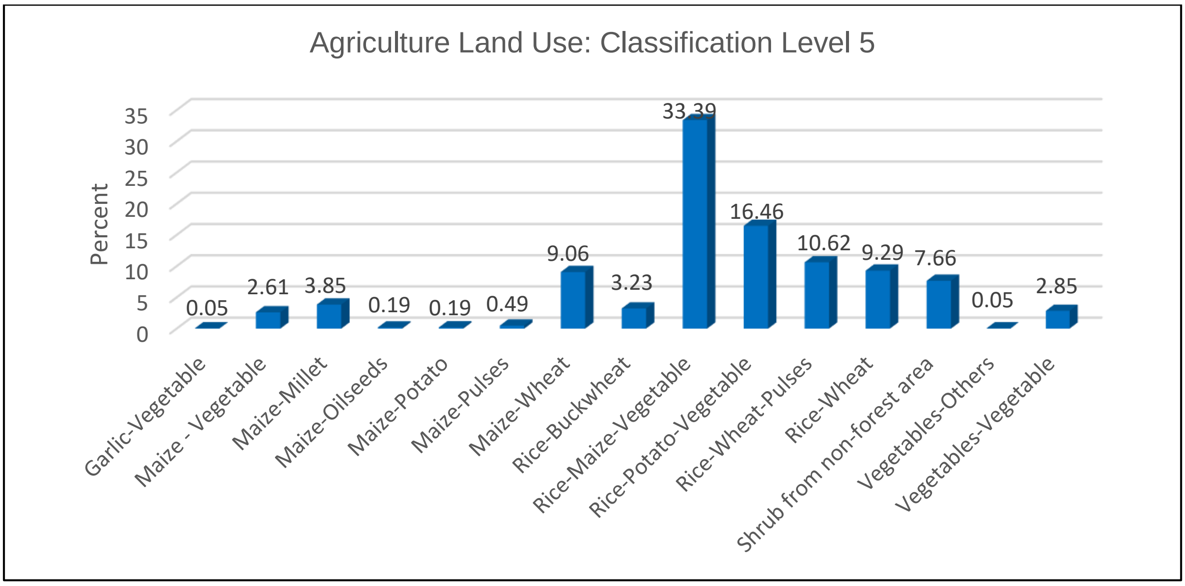

Figure 4-3: Agricultural Land Use Pattern: Classification Level 5

Cropping density is the major factor for classification of the land that signifies the production capability of the land and its fertility. The land in this category is divided into three sub classes on the basis of farming intensity namely light cropping density (25%-50% cultivated), medium cropping density (50%-75% cultivated) and intense cropping density (75%-100% cultivated). Most of the land of this Rural Municipality falls under Intense cropping (60.48 percent) cultivation followed by medium cropping (31.86 percent) cultivation (Table 4-6).

Table 4-6:Categories of Agriculture land use at classification at level 6

S.N.	Description	Area(ha)	Percentage
1	Intense	3412.37	60.48
2	Medium	1797.97	31.86
3	Not Applicable	432.20	7.66
	Grand Total	**5642.54**	**100.00**

In this Rural Municipality, intense cropping practices should be encouraged to increase the production with the help of modern agricultural means and modes. Maize, Rice, Wheat and Vegetables are cropped in intensely whereas millet, oilseeds and potato area produced in medium intensity. Figure 4-4 shows the detailed description of cropping intensity at classification level 6.

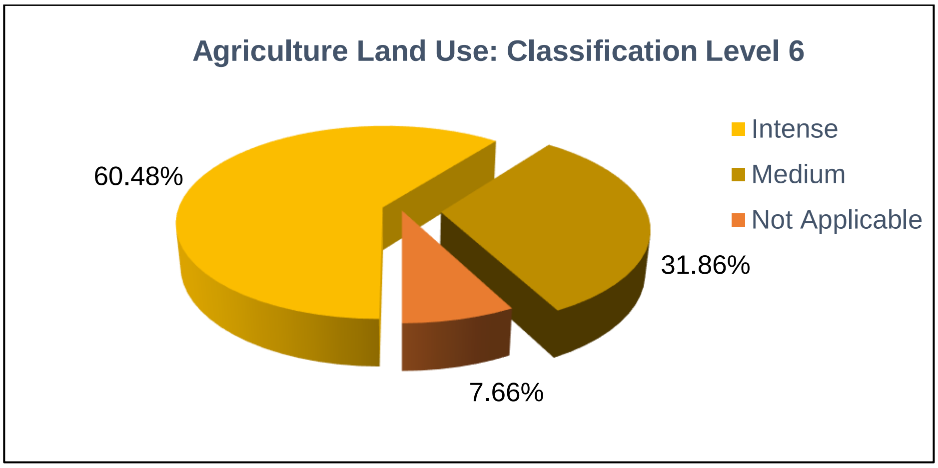

Figure 4-4: Agricultural Land Use Area (Crop Density): Classification Level 6

Potential agriculture production

Jwalamukhi RM	**PMAMP Vegetable Zone Ward No. 1-10**
Staple Crops	Maize, Wheat, Potato, Rice, Millet, Buckwheat, Vegetables
Fruits	Citrus Fruits, Kiwi, Apricot, Peach, Banana
Horticulture	Orchard sites
Action	Vegetable area expansion, Nursery establishment for seeds
Walnut	elevation above 1500 m

4.1.2 Residential Area: Land Use Pattern

Residential area covers 4.81 percent (542.97 ha) of the total land use area. Residential area is further divided into different category on the basis of factors such as density, development state, and cluster among others. According to the population density, settlement is divided into dense, moderate and sparse. Almost all of the residential area of the Rural Municipality is densely populated covering 478.67 hectare land which is 88.16 percent of the total residential area (Table 4-7).

Table 4-7: Categories of Residential area at classification level 2

S.N.	Description	Area(ha)	Percentage
1	Densely Populated-D	478.67	88.16
2	Moderately Populated-M	63.40	11.68
3	Sparsely Populated-S	0.90	0.17
	Grand Total	**542.97**	**100.00**

Only 0.17 percent of the residential area is sparsely populated. This shows that large area of land that is being occupied by the densely and moderately populated area are in old area i.e. no new land has been exploited so far for other land use purposes. If this population could be settled in a planned area or smart city area, the Rural Municipality can have spare land on hand to use for other land use need of the people. According to the development of settlement it is further classified as newly developed area, old area and planned area. All of the residential area is an old settlement in this Rural Municipality which means cultivated land has not been exploited so far. The classification of residential area type at level 3 classification for this Rural Municipality is shown in the Table 4-8.

Table 4-8: Categories of Residential area at classification level 3

S.N.	Description	Area(ha)	Percentage
1	Old Area	542.97	100.00
	Grand Total	**542.97**	**100.00**

Residential nature in this Rural Municipality is 100 percent residential cluster type. Cluster development is a design technique or zoning strategy that involves grouping houses on smaller lots in one area of a development while preserving the remaining land on the site for recreation, common open space, or protection of environmentally sensitive areas. The major benefit of cluster settlement is that the close proximity makes communication quicker and easier than in linear and dispersed settlements. Because people are closer together, it is also easier to perform joint tasks such as the buying and selling of goods and services. Nature of residency in Jwalamukhi predominantly forms a residential cluster and covers 542.97 hectares of land as shown in the Table 4-9.

Table 4-9: Categories of Residential Area: Classification Level 4

S.N.	Description	Area(ha)	Percentage
1	Residential cluster	542.97	100.00
	Grand Total	**542.97**	**100.00**

4.1.3 Industrial Area: Land Use Pattern

Jwalamukhi Rural Municipality does not contain any large industries. Accessibility to the market, excavation of raw materials, priority from the government, and skilled labor market are few hurdles for the growth of industry in this area. Despite this, there are few family based home industries run by family such as medicinal herbs based industry, bamboo based industry, and woolen based industry etc. and are by large functional at present but could not be mapped in this study in lack of their proper designated establishments.

4.1.4 Forest Area: Land Use Pattern

Forest area that accounts for 42.34 percent of the total land use area of Jwalamukhi Rural Municipality is a gifted natural resource for the people of this area. Almost all of the forest available in this Rural Municipality is tropical in nature leaving only 0.01 percent of area for subtropical forest (Table 4-10).

Table 4-10: Forest Land Use at Classification Level 2

S.N.	Description	Area(ha)	Percentage
1	Sub-tropical	0.52	0.01
2	Tropical	4779.51	99.99
	Grand Total	**4780.03**	**100.00**

Field survey confirms that the alnus woods, pines trees, sals, and various hardwood trees are the dominant vegetation in the tropical region in this Rural Municipality. Also during field survey, it is noticed that some dwarf bamboo are available on the exposed ridge along with some twisted juniper on the dry slopes. At classification level 3, hardwood forest and mixed forest are the large area covering forest found in this rural municipality. As the Rural Municipality falls in the low hilly region, tropical forest contains primarily hardwood and mixed type of forest (Table 4-11).

Table 4-11: Categories of Forest land use at classification at Level 3

S.N.	Description	Area(ha)	Percentage
1	Bushes	310.68	6.50
2	Coniferous	22.03	0.46
3	Hardwood	3613.87	75.60
4	Mixed	833.45	17.44
	Grand Total	**4780.03**	**100.00**

Bushes which occupies only 6.50 percent are a plant community characterized by vegetation dominated by shrubs, often also including grasses, herbs and geophytes. Bushes and shrubs may either occur naturally or be the result of human activity. It may be a mature vegetation type in a particular region and remain stable over time, or a transitional community that occurs temporarily as the result of a disturbance, such as fire. Various species of bushes belonging to the family of Hippophae and Vaccinium scrub are the dominant scrub in this region. Deodar, chiuri and khayer, jaamum and sal are the hardwood available among others in this area that covers only 75.60 percent of the land (Figure 4-5).

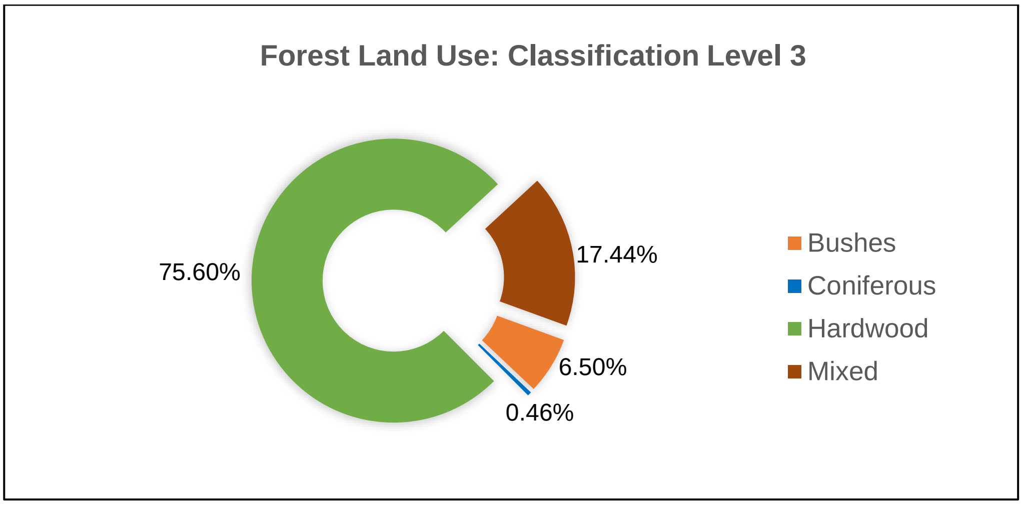

Figure 4-5: Forest Land Use: Classification Level 3

Alnus Woods and Pinusroxburghii Forest cover 25.66 percent and 53.92 percent whereas subtropical evergreen forest covers only 0.31 percent of the total forest area. Because of the highest concentration of hardwood and Pinusroxburghii forest in this Rural Municipality, rainfall is sufficient for the agricultural cropping and animal husbandry as it brings lot of growth of grass and bushes in the season. Table 4-13 shows the classification level 4 of forest land use at the Jwalamukhi Rural Municipality.

Table 4-12: Categories of Forest land use at classification level 4

S.N.	Description	Area(ha)	Percentage
1	Abiesspectabilis Forest	84.92	1.78
2	Alnus Woods	1226.50	25.66
3	Pinusroxburghii Forest	2577.48	53.92
4	Quercus lamellose Forest	39.99	0.84
5	Quercusdilata Forest	310.68	6.50
6	Quercussemecarpifolia Forest	3.41	0.07
7	Rhododendron Forest	132.24	2.77
8	Schima-Castonopsis Forest	390.07	8.16
9	Sub-tropical Evergreen Forest	14.74	0.31
	Grand Total	**4780.03**	**100.00**

Though the forest is standing tall in this region with 88.86 percent of the forest in the state of good crown density but are found in a state of high maturity (93.50%). Harvesting this matured forest could bring lot of revenue to the local government with proper management. Few area of forest in this Rural Municipality are found to be in a sparse state which is not good for the land as it does not bring sufficient rain in a season for timely cultivation. Forest covering 532.64 hectare of land is found to be in a sparse state.

Table 4-13: Categories of Forest land use at classification level 5

S.N.	Description	Area(ha)	Percentage
1	Dense	4247.39	88.86
2	Sparse	532.64	11.14
	Grand Total	**4780.03**	**100.00**

Some reviving measure can be taken to increase the crown density of a forest in this Rural Municipality. Management of soil quality, insect and disease damage, or other environmental factors such as drought, wind, competition, or soil compaction can be some effective measures that can speed the crown density rate.

For the sake of this report, maturity of a tree is defined as a state of a tree those have reached at least the estimated rotation age or saw timber size as specified. Any trees below this age or size is immature tees and trees that are in state of new generation to the pole size is Generation tree. 93.50 percent of the total forest in the Jwalamukhi Rural Municipality are in a mature state that could be harvested replacing with new plantation. Huge revenue could be generated with these tree logs for the Rural Municipality. Immature trees cover 14.45 percent of the forest area. Table 4-14 shows the maturity state of a forest as a classification level 6 in Jwalamukhi Rural Municipality in the term of their age and size.

Table 4-14: Categories of Forest land use at classification level 6

S.N.	Description	Area(ha)	Percentage
1	Mature	4469.35	93.50
2	Not Applicable	310.68	6.50
	Grand Total	**4780.03**	**100.00**

Based on the forest ownership and use right at classification level 7, community owned forest and government owned forest covers 32.05 percent and 67.72 percent of the total forest land (Table 4-15). It means cooing fuel, fodder and bread and butter comes from community owned forest for the residents of this Rural Municipality.

Table 4-15: Categories of Forest land use at classification level 7

S.N.	Description	Area(ha)	Percentage
1	Community	1531.80	32.05
2	Government	3237.22	67.72
3	Private	11.01	0.23
	Grand Total	**4780.03**	**100.00**

These community-owned forests need specifically precise control mechanism to protect on the basis of use right and management. Private owned forest covers only 0.23 percent of the total forest. Figure 4-6 shows the forest ownership at classification level 7 in the Jwalamukhi Rural Municipality.

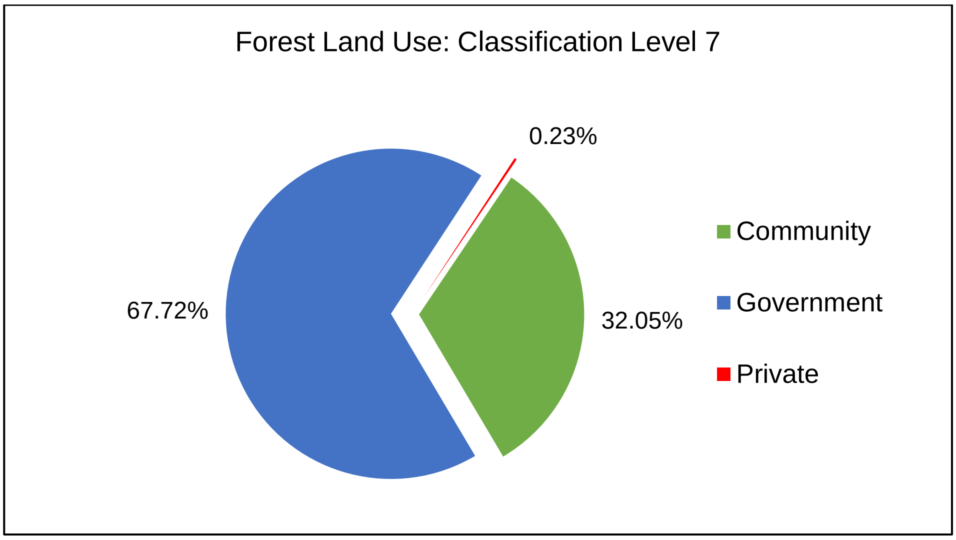

Figure 4-6:Forest Ownership: Classification Level 7

4.1.5 Commercial Area: Land Use Pattern

Commercial Area in Jwalamukhi Rural Municipality is classified into two primary areas namely Service Areas and Business Areas based on their features and market needs and covers 65.71 percent and 34.29 percent of the commercial land use. There is huge scope for business in this Rural Municipality in terms of Storage Facility, educational facilities and banking facilities among others. Lots of efforts, plans, and programs need to be establish from both public and private sectors in order to boost the business area by tapping the use local resources to raise the local taxes and revenue in this Rural Municipality. Table 4-16 shows the category of commercial land use as a classification level 2 in Jwalamukhi Rural Municipality.

Table 4-16: Categories of Commercial land use at classification level 2

S.N.	Description	Area(ha)	Percentage
1	Business Area	1.11	34.29
2	Service Area	2.13	65.71
	Grand Total	**3.24**	**100.00**

Furthermore, at classification level 3, government service area covers 24.38 percent of the commercial area. Similarly, storage house covers 30.77 percent of the land. Service related to banking, schools and post office etc. covers 44.86 percent of the total commercial land. (Table 4-17).

Table 4-17: Commercial land use at classification level 3

S.N.	Description	Area(ha)	Percentage
1	Government Service Area	0.79	24.38
2	Service	1.45	44.86
3	Storage	1.00	30.77
	Grand Total	**3.24**	**100.00**

Area for recreational facility is nil in this area and shows strong upmarket and demand. Banking service is provided by few establishments and cover 20.56 percent of the land. Storage house covers larger area than any form of commercial services. Area occupied by local development office, post office, private schools, telecommunication and electricity is less than a hectare (Table 4-18).

Table 4-18: Categories of Commercial land use at classification level 4

S.N.	Description	Area(ha)	Percentage
1	Bank/Money Exchange	0.67	20.56
2	Electricity office	0.04	1.37
3	Government Service Area	0.05	1.66
4	Local Development office	0.18	5.50
5	Post Office	0.03	1.05
6	Private School Area	0.47	14.65
7	Services Subcategory	0.66	20.31
8	Storage house/ area	1.00	30.77
9	Telecommunication Office	0.13	4.15
	Grand Total	**3.24**	**100.00**

There is a lot of scope of business areas expansion in the form of tourism, market expansion, recreation utility services, storage facility for agro industry so that the Rural Municipality can increase its revenue and the quality of life of her residents. Figure 4-7 show the land use at classification level 4 in the Jwalamukhi Rural Municipality.

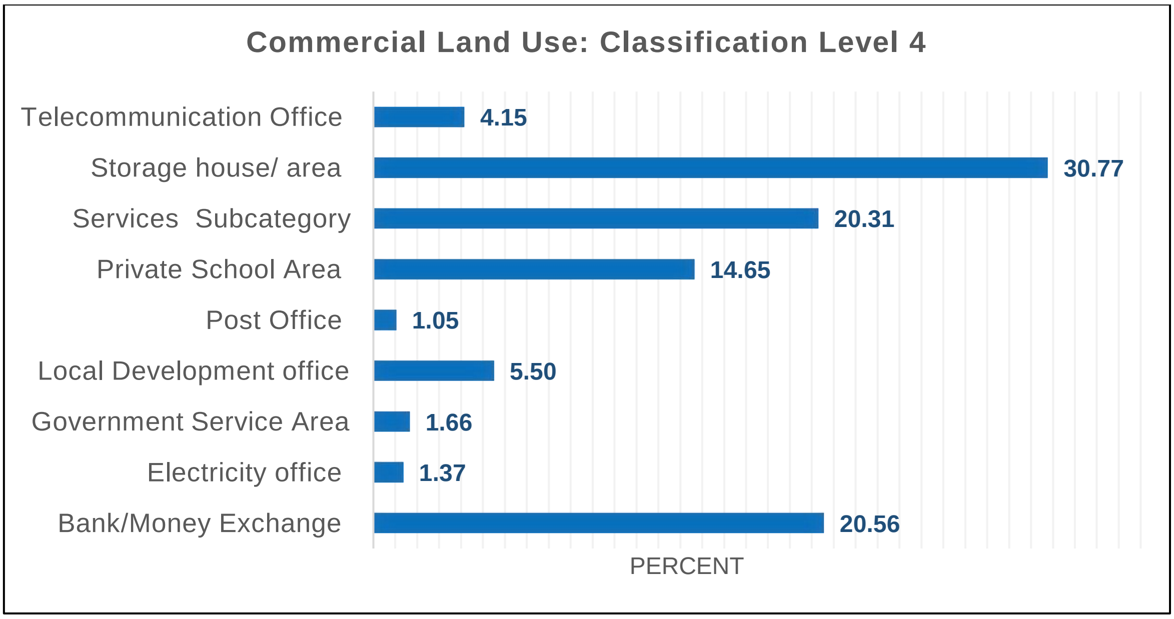

Figure 4-7: Commercial Land Use: Classification Level 4

4.1.6 Public Service Area: Land Use Pattern

Public service is a service intended to serve all members of a community. It is usually provided by government and/or by private sector to people living within its jurisdiction, either directly or by financing provision of services. The term is associated with a social consensus that certain services should be available to all, regardless of income, physical ability or mental acuity. Examples of public services includes education, health, security, transportation, recreation and utility places. Public service area covers nominal area in Jwalamukhi Rural Municipality i.e. only 1.20 percent of the total land area. In this classification, Transportation Infrastructure covers 85.77 percent of the public service area (Table 4-19).

Table 4-19: Public service at classification level 2

S.N.	Description	Area(ha)	Percentage
1	Educational	11.63	8.61
2	Health Service	0.86	0.64
3	Recreational Area	6.32	4.68
4	Security Service	0.41	0.30
5	Transportation Infrastructure	115.89	85.77
	Grand Total	**135.11**	**100.00**

Next to transportation, the larger land use coverage are educational area (8.61 percent) and recreational area (4.68 percent). There is a dire need for expansion of health service area in this Rural Municipality as it covers less than a hectare of land to serve the total population. Category of public service area at a classification level 2 is shown in Figure 4-8.

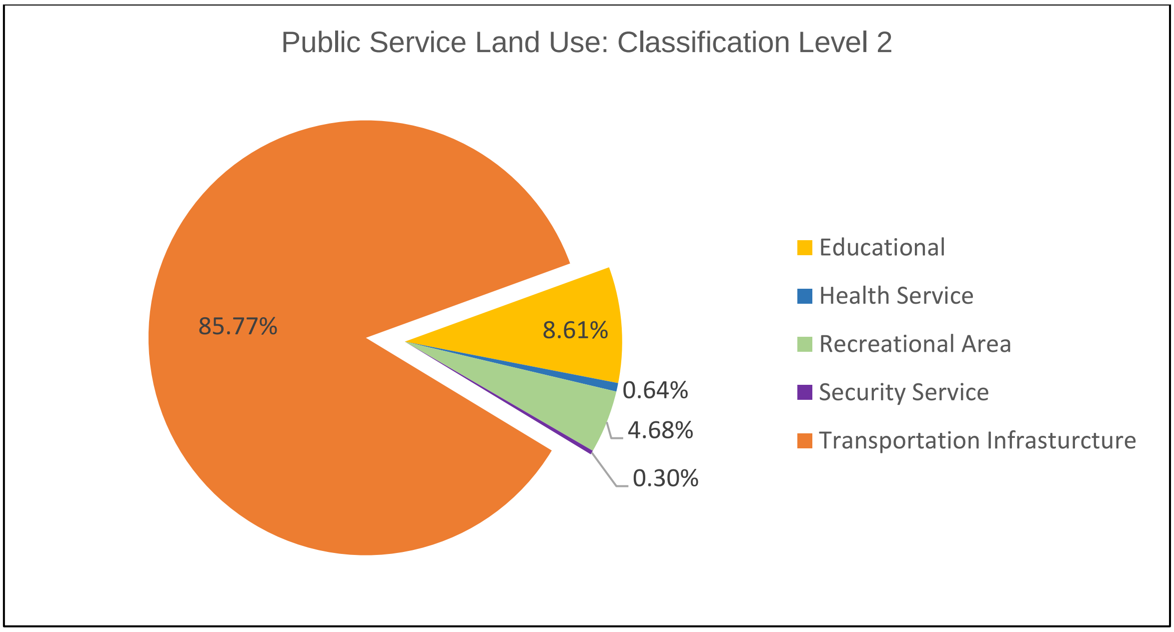

Figure 4-8: Public Service Area: Classification Level 2

Public service is further classified on the basis of their functional use. Table 4-20 shows that most of the public service of this Rural Municipality covered by local road (78.24 percent) followed by other road (7.06 percent), and secondary education (3.35 percent). Likewise, health centers cover 0.55 percent, and police station covers 0.30 percent of the total public service land use area.

Table 4-20: Categories of Public service at classification level 3

S.N.	Description	Area(ha)	Percentage
1	Bridge	0.06	0.04
2	Campus	0.94	0.70
3	Health Centre	0.74	0.55
4	Hospital	0.12	0.09
5	Local Road	105.71	78.24
6	Other Road	9.54	7.06
7	Play ground	6.32	4.68
8	Police Station	0.41	0.30
9	Primary	6.17	4.56
10	Secondary	4.52	3.35
11	Transportation	0.58	0.43
	Grand Total	**135.11**	**100.00**

Demand for more educational infrastructures is high in this Rural Municipality to serve the increasing population. Also the demand of health infrastructure is of primary concern of the population as the residential pattern is pretty much densely populated throughout the region. Public service categories at the classification level 3 in Jwalamukhi Rural Municipality is shown in Figure 4-9.

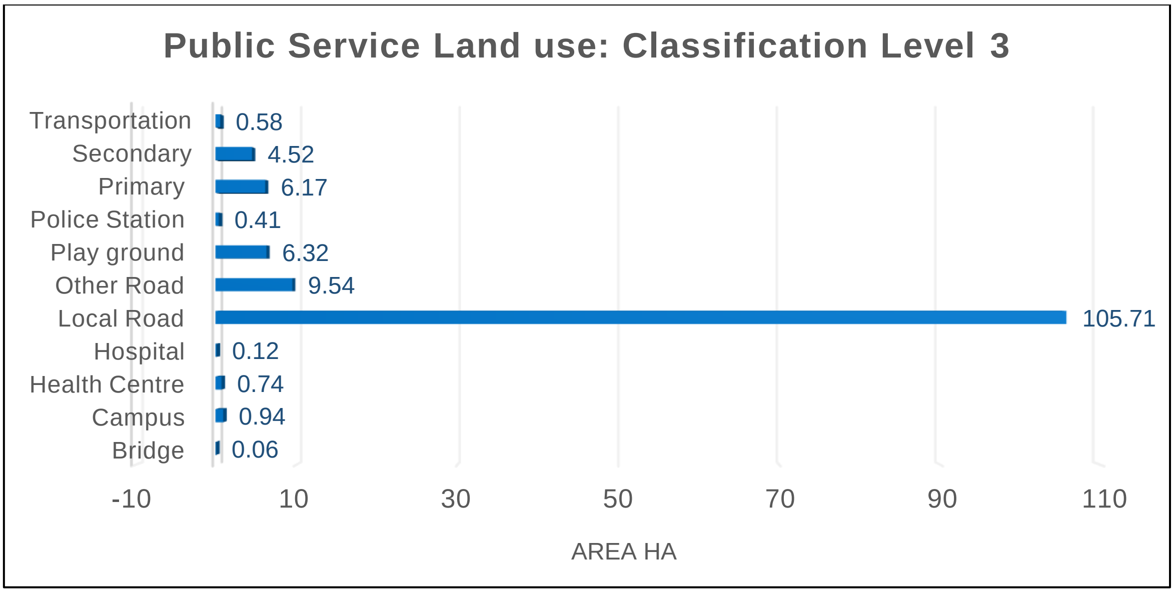

Figure 4-9: Public Service Area: Classification Level 3

4.1.7 Cultural and Archeological Area: Land Use Pattern

Cultural and archaeological area resembles the distinct ethnic, cultural and religious entity of a society based on their material use. These could be the institutions or establishments related to their respective culture, religion, and practices. In this Rural Municipality this category includes entities such as churches, temples and stupas/monasteries and other such establishment related to any kind of religion, culture and practices. Church sites cover 40.65 percent whereas temples cover 39.83 percent of the total Cultural and Archeological land use area (Table 4-21).

Table 4-21: Categories of Cultural and Archeological land use at classification level 2

S.N.	Description	Area(ha)	Percentage
1	Church	0.53	40.65
2	Stupa/Monastery	0.26	19.52
3	Temple	0.52	39.83
	Grand Total	**1.31**	**100.00**

Jwalamukhi Rural Municipality contains a historical Maalika temple which is considered a real old and various other temples such as Anakunyumai temple, Thani Devi Mandir, Krishna Mandir, Swota Devi Mandir, and Shivalaya Pashupati Mandir amaong others. Various establishments related to church are also located in this rural municipality such as Khaurum Church, Tari Church and Bedsalam Church and few sites of Gumbas such as Dhola Gumba and Nyaki Gumba. Festivals related to every month ‘purnima’ and various ‘jatras’ are enjoyed at various occasions by the local people. These festivals, jatras and temples needs promotion and protection to develop as a tourist destination. This could also add to the local economy of the Rural Municipality.

4.1.8 Riverine, Lake and Marsh Area: Land Use Pattern

Rivers, lakes and wetlands are the main attractions of most ecotourism spots in Nepal. These areas have high potential of the vast natural habitat and wildlife that provide access for tourists and locals alike to enjoy the quality of life experience. These are not well tapped to generate enough revenue by the Rural Municipality since this area is not well known to the both domestic and international tourists. Also there has to put high priority in developing this area by the government. Lake and Marsh area covers only 1.63 percent (184.42 ha) of the total land use area in Jwalamukhi Rural Municipality (Table 4-22).

Table 4-22: Riverine, Lake and Marsh at classification level 2

S.N.	Description	Area(ha)	Percentage
1	River	149.19	80.90
2	Sand	35.22	19.10
	Grand Total	**184.42**	**100.00**

The major river that flows in this Rural Municipality are Aankhu River and Budhi Gandaki River and their respective tributaries. These rivers make lot of impact in the local economy of this Rural Municipality by providing irrigation to the agricultural land, which is yet to be established. These rivers have also deposited lot of sand as a resource of construction material for the area that covers 35.22 hectare of land.

4.1.9 Mines and Mineral Area: Land Use Pattern

The mining industry is one of the important driving forces in the national economy. In the case of Nepal, mining and minerals brings direct economic benefits significantly to the country by increasing its revenue through taxes, foreign investment, exports, and employment. In this category, the land use area Includes areas reserved for mine excavation and extraction area including houses, warehouses, hut and land occupied by the mining site. In the case of Jwalamukhi Rural Municipality, we could not locate any establishment related to this category, however there are few mining and mineral sites identified by the Department of Mines and Geology, Government of Nepal, in a state of Approved License. These sites are the possible excavation area of Kyanite, tourmaline, and limestone mining. Government of Nepal including private sector should excavate these minerals and established a processing plant so that it could boost the economy of the country. This study could not locate any establishments related to mines and minerals for mapping.

4.1.10 Other Area: Land Use Pattern

This category includes geographical areas other than mentioned above; areas such as mixed area declared by law by the Government of Nepal reserved and regulated for urbanization, grazing reserve, highway expansion, protected forest etc. This area is hard to differentiate as it has mixed purpose within the same area coverage. Such area of land would play major role in ecological balance (forest reserve) and commercial livestock rearing. In the case of Jwalamukhi Rural Municipality, study could not locate such areas for mapping.

4.2 Land Use GIS Database

4.2.1 Data base for Present Land Use

The GIS database of present land use area has been prepared as per the specification provided by TSLUMD, where land use data is stored in vector 'feature data class' format in geo database as shown in the Table 4-23.

Table 4-23: 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 7	String	Land Use Class	LEVEL 7
Year	String	Fiscal Year of Data	YEAR
AREA	Double	Area in Square meter	AREA
AREA_HA	Double	Area in Hectare	AREA_HA
FYY	String	Fiscal Year of Date	FYY
Consulting	String	Name of the Consultant	Consulting
Shape Length	Double	Length in Meters	LENGTH
Shape Area	Double	Area in Square Meters	AREA
RM/M	String	Name of Rural Municipality/Municipality	NAME

Where,

Feature ID : automatically generated integer that uniquely identifies the feature class within a geodatabase
String : characters
Double : double precision floating point numbers (fractional data)
Geometry : point, line, polygon, multipoint, or multi-patch
Long : long integers (whole number data)

4.2.2 Symbol used in preparation of Land Use Map

The symbols used in the map for the corresponding land use theme while mapping the land use information are listed as shown in the various tables below with their categories and respective level of classifications.

Table 4-24: Symbols used in Commercial Land Use Classification

Symbols used in Commercial Land Use Classification					
Classification Level 4					
Market Subcategory	M	Recreation Subcategory	R	Government Service Area Subcategory	G
Shop	s1	Cyber cafe	y1	Agriculture Office	ag
Boutique	b2	Cinema Hall	c2	CBS	b5
Departmental Store	d1	Concert Hall	h2	Civil Aviation	ca
Retail Business	r2	Theatre	t2	Communication	cm
Supermarket	m1	Dance Hall	d2	Court	co
		Night Club	n1	Cultural Office	cu
Hotel Subcategory	H	Gaming Hall	g2	District Administration office	a1
Hotel	h1	Gambling Hall	l1	Doildar	do
Guest House	g1	Exhibition Centre	e1	Education	en
Fast-food	f1	Gym House	m2	Electricity office	eo
Restaurant	r1	Other Entertaing area	x2	Forestry office	f2
Bar	b1			Health office	h5
Travel Agency	t1	Services Subcategory	S	Irrigation office	i1
Other hotel	o1	Bank/Money Exchange	b3	Land Transaction Ofice	lt
		Private Post office	p1	Local Development office	l2
Storage Subcategory	T	Private Communication Area	c3	Mining and Geology	mg
Storage house/ area	s3	Broadcast Studio	d3	Other	o5
Consultancy service area	c4	Private School Area	e2	Petroleum	pm
Business house	b4	Private Health Service Area	h3	Post Office	po
		Petrol Pump	m3	Road Office	r4
Utility Subcategory	U	Radio Station	r3	Soil Conservation	sc
Water Reservoir	w1	Service centre	s2		
Hydropower Area	h4	TV Station	t3		
Cable Car	c5	Other Service	o3		
Gas Plant	g3				
Oil Storage	o4				
Other storage	x3				

Table 4-25: Symbol used in Public Land Use Classification

Symbol used in Public land Use Classification			
Classification Level 3			
Sub-Category Transportation	T	Sub-Category Institutional	I
Highway	h2	Private Institution	r3
Feeder Road	f2	Public Intuition	p6
District Road	d3	NGO	n2
Local Road	i1	INGO	i4
Other Road	o5	Other intuitional	o8
Bus park	b1	Sub-Category Recreational	F
Airport	a2	Public Theatre	c8
Railway	r2	Drama House	d4
Car Park	c4	Stadium	s3
Port	p3	Play ground	g4
Pavement	v1	Open space	o9
Cart Track	t3	Other	x2
Other Transportation	x1	Zoo	z1
Bridge	g3	Rest-point-Chautari	r4
		Museum	m1
Sub-Category Education	E	Sub-Category Security Service	S
Primary	p5	Police Station	p8
Secondary	s2	Military Area - m2 Military Area	m2
Campus	c5	Armed Force	a3
University	u2	Other Security	o10
Other educational area	o6		
Sub-Category Health	H		
Hospital	h3		
Nursing Home	n1		
Health Centre	c7		
Pharmacy	f3		
Polyclinic	i2		
Other	o7		

Table 4-26: Symbol Used in Agricultural Land Use Classification

Symbol used in Agricultural Land Use Classification					
Classification Level 5 (Including Cropping Pattern)					
Maize-Oilseeds	m2	Rice-Potato	r8	Rice-Buckwheat	r14
Maize-Pulses	m4	Rice-Potato-Vegetable	r9	Rice-Wheat-Maize	r15
Maize-Wheat	m5	Rice-Maize	r10	Bamboo	b3
Maize - Vegetable	m6	Rice-Vegetable-Vegetable	r11	Pond for Fish farming	p3
Maize-Millet	m7	Rice-Maize-Vegetable	r12	Beekeepig	b4
Maize-Potato	m8	Garlic-Vegetable	v2	Cotton	c3
Maize-Others	m9	Vegetables-Vegetable	v3	Floriculture	f5
Pulses-Fallow	p1	Fruit+Potato/Vegetable/Buckwheat	f2	Barren Cultivable land	b5
Pulses-Others	p2	Banana	b2	Livestock Grazing area	g2
Rice-Fallow	r0	Tea	t1	Maize-Rice-Cereal	m3
Rice-Rice	r1	Coffee	c1	Rice-Others	r13
Rice-Wheat	r2	Cardamom	c2	Sugarcane-Sugarcane	s1
Rice-Wheat-Pulses	r3	Amriso	a1	Potato-Vegetable Crops	v1
Rice-Oilseed	r4	Ginger	g1	Others	o1
Rice-Pulses	r5	Livestock/Cattle/buffalo Farm	l1	Shrub from non-forest area	s3
Rice-Rice- Vegetable	r6	Turmeric	t2	Vegetables-Others	v4
Rice-Vegetable	r7	Fruits	f4	Sugarcane-Others	s2
				Barley-Buck Wheat	b1
				Fruit-Fruit	f1
				Fruit-Others	f3
				Others-Others	o2
				Others-Others-others	o3
				Maize-Rice-Fallow	m1

Table 4-27: Symbols Used in Forest Land Use Classification

Symbol used in Forest land use Classification			
Classification Level 4			
Sal forest	Sl	Cedrusdeodara Forest	Cd
Pinusroxburghii Forest	pb	Cupressustorulosa Forest	Ct
Quercusincana-Q. lanuginose Forest	Qq	Larix Forest	La
Quercusdilata Forest	Qd	Tropical Evergreen Forest	Te
Quercussemecarpifolia Forest	Qs	Alnus Woods	Aw
Castanopsistribuloides-C.hystrix Forest	Cc	Populus ciliate Woods	Pc
Quercus lamellose Forest	Ql	Hippophae Scrub	Hp
Lithocarpuspachyphylla Forest	Lp	Moist Alpine Scrub	Ma
Aesculus-juglans-Acer Forest	Aa	Dry Alpine Scrub	Ds
Lower Temperate Mixed Broadleaved Forest	Lm	Juniper wallichiana Forest	Jw
Upper Temperate Mixed Broadleaved Forest	Um	Wetland area	Wl
Tropical Deciduous Riverain Forest	Tr	Rock outcrops/ barren lands	Ro
Rhododendron Forest	Rh	Sub-tropical Evergreen Forest	Se
Betulautilis Forest	Bu	Terminalia Forest	Tn
Abiesspectabilis Forest	As	Dalbergiasissoo-Acacia catechu Forest	Da
Tsugadumosa Forest	Td	Sub-tropical Deciduous Hill Forest	Sd
Pinusexcelsa Forest	Pe	Schima-Castonopsis Forest	Sc
Piceasmithiana Forest	Ps	Sub-tropical Semi-evergreen Hill Forest	Ss
Abiespindrow Forest	Ap	Other Forest Species	Of

Table 4-28: Symbol used In Cultural and Archeological Land Use; Riverine, Lake and Marsh Land Use Classification

Symbol used in Cultural and Archelogical Land use Classification		Symbol used in Riverine and Lake land use Classification	
Classification Level 2		Classifcation Level 2	
Heritage Site	h	Pond	p
Durbar Square	d	Lake	l
Gadh	g	Canal	c
Archeological Site	a	Glacier	g
Cultural Site	c	Snow Area	s
Fort	f	Wetland	w
Temple	t	River	r
Stupa/Monastary	s	Spout	t
Mosque	m	Well	e
Church	c	Kulo	k
Bahal	b	Other	o
Patis	p	Sand	d
Bihar	v		
Other	o		

CHAPTER 5: CONCLUSIONS

5.1 Conclusions

The project report of Jwalamukhi Rural Municipality was conducted using satellite image obtained from ZY-3 sensor and Geographic Information System as a tool along with visual interpretation supplemented by extensive field verification. During the visual image interpretation, the knowledge of experienced image interpreter along with ancillary data such as LRMP maps/data, DEM, DEM derivatives (slope, hillshade, aspect) and ground based first hand data were used. Present land use map is developed in larger map scale (1:10000) containing the accurate and specified information of land use classes and subclasses in a hierarchical structure.

Report finds high variation in land use pattern in this Rural Municipality with much of the land is used for agricultural cropping that accounts for 49.98 percent of total land use. Analysis of cropping pattern shows that level terraces upland/pakho land cultivation is heavily practiced in the hilly region. Level terraces khet cultivation covers much less area (5.58%) compared to the level terraces upland/pakho cultivation. Rice-Maize-Vegetables, Rice-Potato-Vegetables and Rice-Wheat-Pulses are the dominant cropping pattern whereas, Maize-Oilseeds, Maize-Potato and Maize-Pulses are the least practiced cropping pattern found in the study. The level of cropping intensity in Jwalamukhi Rural Municipality is found to be in intense state (60.48%) and medium state (31.86%) that needs some boost up with proper land management practices such as smart water management, good varieties selection of seeds, conservation tillage, efficient use of nitrogen and farm management software including others.

Forest is a life line of this Rural Municipality that supports ecological balancing of the area for good agricultural conditions and risk management. Subtropical and tropical forests are the two primary forest found in this rural municipality where, mixed forest and hardwood forest are found in abundance with high percentage of Pinusroxurghii trees (53.92%). Analysis of crown density shows that forest health is in dense state but are in a state of maturity. Only 32.05 percent of the forest is managed by the community itself and rest is government and private owned. Wood log from the mature trees could generate sufficient revenue for the local government as the area has high number of matured trees. Also the area is rich in herbs, fruits and vegetables. Commercial production of these herbs, fruits, and vegetables and the access to the market is of prime concern of the residents in this Rural Municipality. Human pressure on the forest is high particularly in proximity to settlement and highway as evidenced by the shrubs and grazing land developed at the fringe of the forest in piedmont area.

Benighat Rorang Rural Municipality does not contain any industrial areas except few home based industries managed by family. Lack of employment oriented manufacturing and industrial establishment and production of raw materials for the industrial and manufacturing industry is identified by the Rural Municipality as a foremost challenge to overcome for industrial development in the area. When it comes to commercial land use, there is huge scope and opportunity for business expansion in this Rural Municipality with small area covered by banking sector, private schools and storage areas. No establishments related to mines and minerals could be located and mapped in this rural municipality, despite the fact that the municipality has potential area of quartz crystals, kyanite, limestone, and tourmaline etc. according to the local authorities.

Health and educational service need more establishments as it covers only 0.74 ha and 6.58ha of land of the total public service land use area to cope with the increasing demand of the population. Likewise there is only 0.06 ha of area covered by bridge in this location and is one of the hurdles for the market access to the local production. Residential area in this Rural Municipality is densely populated, unplanned and old, which signifies the importance of the development of compact city/smart city concept launched by the government of Nepal. The excess land after establishment of smart city could be used to serve back the population in term of agricultural and commercial benefit. Rivers in this Rural Municipality are in their natural state, and nothing has been done to benefit from them economically; they could be a source of water for agriculture or a tourist destination.

This study has categorized the land use plan up to seven levels with each land use class delineated with high accuracy of 96.99 percent with KIA coefficient of 0.97. Despite the good result, it is felt that more accurate and better result would have been obtained, have we had a ‘real time and error free’ satellite imagery. Time frame of the project months and changing nature of the cropping pattern cycle might have had influenced the study and the result but cannot be said with certainty.

The land use data and map produced can be used in the future to formulate land use planning to control land fragmentation, to manage unplanned settlements, and to reduce and control encroachment of public and government land via interaction and negotiation among planners, stakeholders and decision makers at local and national levels. This report assumes that the presented database would be useful in attaining optimal benefit of the land sustainably, equitably and economically within the jurisdiction of this Rural Municipality.

5.2 Recommendations

Based on the finding of this study, the following recommendation could be made for future undertaking of similar projects for implementation of the government land use plans and policies.

This Rural Municipality have citrus fruits, maize, rice, vegetables, wheat, pulses and potato pocket area that lacks access to the market, so the Rural Municipality should give more attention to develop it largely at specified and designated area assisted by the local/national government. More bridges, banking security, scientific agricultural land and water resource management could help raise the overall agriculture production of the area.

This area provides very good climatic condition for potato, wheat, millet, walnut, ginger, kiwi, oranges, and various kind of vegetables, so the Rural Municipality should promote towards organic farming and market through subsidy, training, and education program. For forest management, care should be taken to harvest the mature log and replantation in the area. Report shows that high percentage of matured trees are in dense state.

Also there is need to raise public awareness towards sustainable utilization of land resources through displaying the land use maps of various time interval and explaining the changes (positive and/or negative) so that the local people can visualize and understand the scenario and of the present land use and the causes and effects for its situation thereby easing for implementation of the plans.

With few cultural sites, churches, gumbas and temples, Jwalamukhi Rural Municipality need to promote their cultural and archeological sites with renovation and protection to attract local and national tourist.

Although most of the residential areas found to be in the old area, while developing onto a new land, encroachment on the flood prone areas or on highly arable areas should not be encouraged in the future.

In this rural municipality, there are few risk areas both on settlement and agricultural location. Since, the residential area has old establishments and is sparsely populated, therefore planned community settlement such as smart city through land zoning and/or plotting could put less pressure and reduce encroachment of forest and agriculture land and helps make the community in the less risk zone.

Potential Agriculture Production

Jwalamukhi RM	PMAMP Vegetable Zone Ward No. 1-10
Staple Crops	Maize, Wheat, Potato, Rice, Pulses, Buckwheat, Vegetables
Fruits	Citrus Fruits, Kiwi, Apricot, Peach, Banana
Horticulture	Orchard sites
Action	Vegetable area expansion, Nursery establishment for seeds
Walnut	elevation above 1500 m

Potential Medicinal Plants

Local Name	Scientific Name	Location
Panch Aunle	*Dactylorbiza batagirea*	Mountain and High hill
Kutki	*Picrorhizo*	Mountain
Walnut	*Juglans regia*	Mahabharata range
Timur	*Zanthoxy lumarmatum*	Hill
Chiraito	*Swertia chirayita*	Hill
Tetepati	*Indianwormwood*	Hill
Majitho	*Rubia manjith*	Hill
Stuwa	*Paris polypyllasmith*	High hill and mountain
Bhojo	*Sweet flag*	Mountain and hill
Tulsi	*O-cinum sarictum*	Hill
Lichens	*Parmilia nepalensis*	Mountain

Local Name	Scientific Name	Location
Chirpine	*Pinus raxoxburghill*	High hill and mountain
Bel	*Aegle marcios*	River basin
Sarpa-gandha	*Rauvolfia serpentine*	Hill
Neem	*Azadirachtandica*	Hill and river basin
Kurilo	*Asparegus recemosus*	Hill and river basin
Black berry	*Syzigium cumini*	Hill
Pipal	*Ficus Religiora*	Hill
Tejpat	*Cinama mumtamala*	Hill and mountain
Jatamanshi	*Nardostachys grardifiora*	Hill
Amala	*Phyllanthus emblica*	Hill and river basin
Alaichee	*Amomum subulatum*	Hill

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FINAL REPORT

Profile of the Study Area

Jwalamukhi Rural Municipality, Dhading District

Package No.: TSLUMD/CS/QCBS/01/07/2077/078

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CHAPTER 1 : INTRODUCTION

Jwalamukhi Rural Municipality of Dhading District, a part of Bagmati Pradesh of federal Nepal, is located west of Kathmandu, the capital city of Nepal. Jwalamukhi is one of the 11 rural Municipality. The Rural Municipality was formed merging four village development committee from the past administrative structure. Administratively, it is divided into seven wards. Politically, the rural Municipality is placed under constituency no 2 for federal parliament and 2 (ka) for provincial parliament. The Rural Municipality is attributed to a wide spectrum of social, cultural, economic, ecological, and political characteristics.

The Rural Municipality covers nearly 6 percent of the geographical area of the Dhading district. The altitude of the Rural Municipality ranges from 333 m to 1343 m. Geology and landforms in Jwalamukhi Rural Municipality characterize the rocks of midland Zone. Forest covers about 42% of the land, the forest is largely tropical, and the remaining part is sub-tropical. Pinusroxburghii Forest and Alnus wood are the dominant one, the combination of the two makes almost 79.58 % of the forest diversity.

According to the Hegan physiography the rural Municipality falls entirely on the midland zone. The Rural Municipality comprises of single formation i.e., Ranimatta. Almost 76% of the land in the Rural Municipality exceeds the gradient of 15 degrees. The geographical landscape of the municipalities is shaped by a steep and gentle slope, hundreds of big and small watersheds, and flatlands. The adjoining municipalities in the north and east of the have higher elevation hence the Rural Municipality is also the route of several perennial and seasonal river and rivulets flowing south and south-west.

Climatically, the Rural Municipality has tropical climate. The Rural Municipality is susceptible to number of hazards. Particularly the houses and the agricultural areas closer to the river are under threat during rainy season. Most of the wards in the Rural Municipality has been identified with mid-level and low risk to the landslide, however there are multiple high-risk landslides in 6,7,5,3 and 2 wards. Industraial risk are not observed in this Rural Municipality. Multiple areas in nearly all ward no 6 and 7 were found with high risk of fire. In terms of earthquake, the entire Rural Municipality has two-gal value between i.e., 250-300 & 300-350.

The Rural Municipality is populated by almost 7% of the district population. The population density of the Rural Municipality is 237 per sq kilometer. The ethnic demographic diversity is equally high, mostly dominated by Brahmin, Newar, Magar, Chhetree. Whilst the number of Musalman, Hajam/Thakur and Teli in the Rural Municipality is negligible. Eight languages are spoken across and within the multicultural society. The Rural Municipality has impressive literacy rate of 60%. There are 42 community school. The Rural Municipality is well connected with the communication system i.e., mobile, FM radio and local newspaper, etc.

The residential area covers about 4.81% of the total land, 98% of the house are privately owned and 59% of the homes have access to the piped water.

Farming, trade, and tourism are the main economic resources of the Rural Municipality. Though most of the inhabitants of the Rural Municipality depend on agriculture, it has subsistence and traditional agriculture. Agricultural practices in performed in 50% of the land of the Rural Municipality. The Level Terraces Cultivation covers about 94 % of Agricultural land. The most important crops are rice, maize, wheat, and millet. Other products include fruits, vegetables, legumes, and oilseeds. The cultivation pattern of Rice-Maize-Vegetable; Rice-Potato-Vegetable and Rice-Wheat-Pulses accounts for the more than 60%. The livestock rearing is also a popular sector which is dominated by cattle, and buffalo which accounts for 39% of the total rearing. Foreign employment is the principal employment of youth. Malaysia, Qatar, UAE, Saudi Arabia, America, Japan, Canada, Korea, and India are a few of the main destinations. The remittance received has contributed as one of the major financial activities of the Rural Municipality. Private schools, hotels and restaurants, shops and shops, medical centers, and polyclinics multiply daily. Moreover, access to the road has fostered the development of mini settlements outside the villages influencing its economic activities. Under the Prime Minister Agriculture Modernization Project (PMAMP), 10 years starting from FY 2073 to 2082 , the Rural Municipality is chosen as the vegetable and maize zone.

Transportation infrastructure accounts for the 85% of the land under the public service. Almost all the wards of the Rural Municipality are connected by the road, however, still many of them are seasonal roads. It is quite challenging to travel on those roads during the rainy season.

The Rural Municipality have several places of religious and historical values. Many of them can be developed into tourist places.

1.1 Context/Naming and Origin of the Rural Municipality

The rural Municipality is named after the sacred Jwalamukhi Temple, located in one of the wards.

A historic decision, on 10th March 2017, taken by the federal ministerial cabinet resulted in the formation of several municipalities across the country. One of such a newly formed Rural Municipality was Jwalamukhi, it was formed by merging four VDC units i.e., Khari, Dhola, Nepal, Maidi and Chainpur from the previous administrative structure. Sadhbhyanjang is the administrative center of the Rural Municipality.

Important / highlighted features of the Rural Municipality

Jwalamukhi Rural Municipality is connected to the capital city Kathmandu through metaled and dirt road connects, the journey to administrative center depends on road condition. The Rural Municipality is integral part of national highway thus connected to a different part of the country. major land cover constitutes of rocked topography, hillocks, hilltops, hills, ridges, and river basins covered by thin and scattered upper and lower mixed forest which is geologically highly erosive and unstable land, and some river basins, tars, and lowlands are fertile for crop farming which supplement high yield of a variety of food crops and cash crops per annum. The Rural Municipality has been an agrarian society from the time innumerable hence agriculture continues to be the dominant sector of livelihoods. The 18 different ethnically diverse people live in the Rural Municipality. The varying elevation shapes the river system. The river pattern in the Rural Municipality looks like tree branches, technically called dendritic drainage patterns. Along with major rivers, there are several small rivulets, some season coming to life during the rainy season, are the tributaries to the permanent drainages.

1.2 Location

Jwalamukhi Rural Municipality shares border with three municipalities each in Dhading and Gorkha District. In the Dhading district, the Rural Municipality shares its border with Tripurasundari, Neelkantha and Siddhalek. Additionally, Shahid lakhan, Bhimsen and Gandaki Rural Municipality of Gorkha district are connected to the Rural Municipality. Geographically it extends from 84º 44' 3.07'' E to 84º 51' 22.92'' E and 27º 51' 25.51'' N to 27º 58' 52.45'' N. The total area of the Rural Municipality is 112.90 sq.km with the altitudinal elevation ranging from 333.84 m to 1343.14 m The Rural Municipality is stretched 12.02 km east-west and 13.78 km north-south

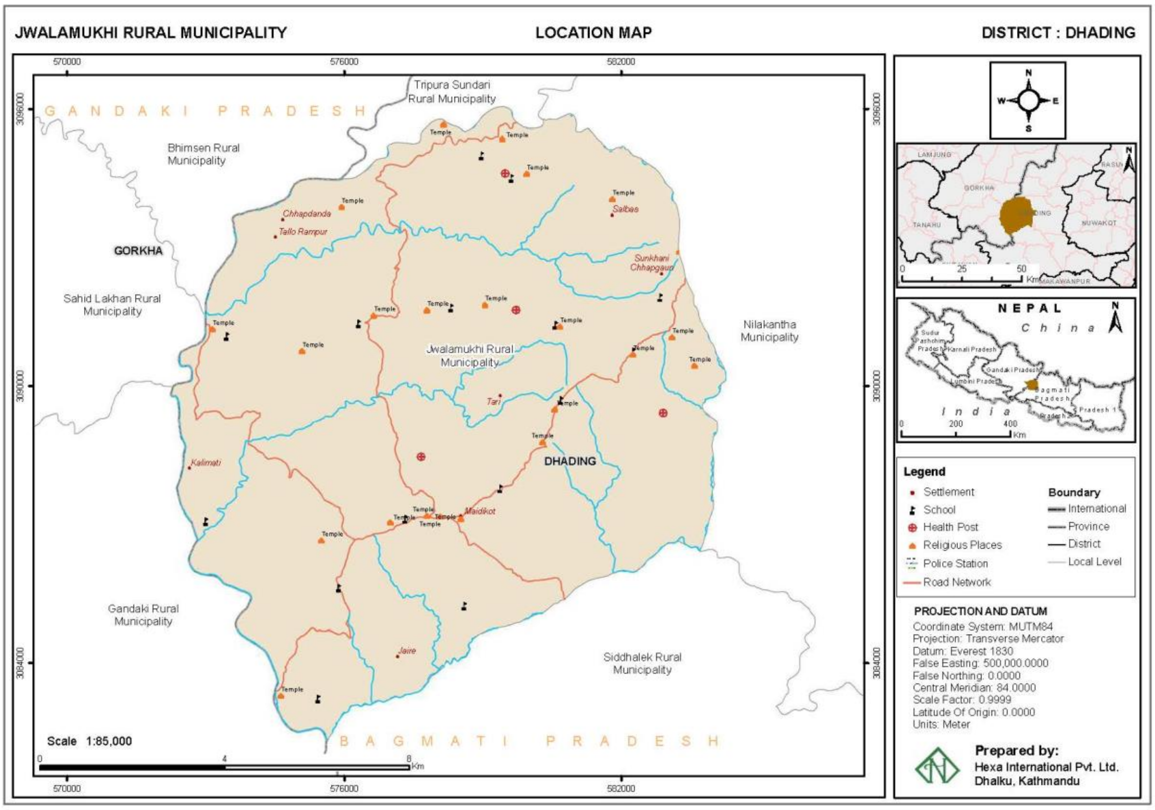


Figure 1-1: Location Map of the Study Area

1.3 Settlements and Administrative Units

Jwalamukhi Rural Municipality is divided into wards, communities, village/ tole, and households. Administratively, the Rural Municipality is divided into 7 wards. The wards vary in their land area and population size. Wards are made up of several settlements and hamlets. Most of the settlements of Rural Municipality are in scattered form and thinly distributed. The hamlets of the Rural Municipality are referred to as tol, bazaar, Gaun, and Nagar. Generally, settlement like hamlets is located along the crossroads are referred as *chowk*. Likewise, the linear settlements observed along the roads and riversides i.e., *bagar*. Other isolated or agglomerated settlements are normally distributed in scattered from in and outside the cropland area. The major settlements of the Rural Municipality are presented in table 1.

Table 1-1: Settlements in different wards

Ward No.	Village/Tole
1	Jaire, Ratamate, Majhitar, Didanda, Majjuwatar, Duwarthok, Jharuwa, Jogetar
2	Bijayatar, Junedanda, Kaphalpani, Bicharihatiya, Majhukot Satdobato, Batase Maidi, Chhapthok, Chalise, Kudabar, Jaihiregaun
3	Duda Bhanjyang, Rangepani, Sami Bhanjyang, Maidikot, Ukhubari, Barangaun, Thakurigaun, Raniswara, Jyamireswara, Amrai, Gyalma
4	Sandh Bhanjyang, Nimswara, Tari, Gairi Purshu, Aryalgaun, Danda Purshu, Dhola Maidan, Saunepani, Bhattagaun, Simkhadagua, Guthgaun, Bhuwalepani, Kashiramdanda, Chiyandanda, Pipaltar, Badagaun
5	Simletar, Kumaltari, Pachchuwadanda, Bhotedanda, Alegaun, Khumtar, Dhandagaung, Shamidanda, Huse Jaubari, Tripurasundari, Chhapthok, Bhaduwar, Jaubari, Dhaodeni Jaubari, Kharihatiya, Dhulimaidan, Banjhgara, Simalswara, Dhuseni, Chhaghare
6	Mugidanda Gaun, Salbas Bhanjyang, Ramche Deurali, Arukharka, Salbas, Okhalepani, Dandagaun, Chhapgaun, Sunkhani, Chulidanda, Kauledanda, Besigaun, Gaduwa Bhanjyang
7	Rampurtar, Dumeregaira, Lumo, Pakhagaun, Ekaltar, Bhadaure, Anakanyamai, Dhodeni, Dharapani, Mantar, Jyamireswara, Jokhedada, Ranpalek, Chainpur, Chhap, Mathillo Rampur, Gahateri, Chhapdanda, Tallorampur

CHAPTER 2 : PHYSICAL SETTINGS

2.1 Physiography

The physical condition, geological structure, topographic features, and visible terrain indicate the Jwalamukhi rural Municipality falls under midlands. The foundation of the Rural Municipality is made up of single formation i.e., Ranimatta. The Ranimatta covers 100% of the land. 15 % of the land i.e., 17677 ha, is south facing and 76 % of land has slope greater than 15 degrees.

This Rural Municipality has the elevation range from 333 to 1343 m. Topography of the Rural Municipality varies from river basin and tar and low land with gentle slope to hills, ridge, middle hills, and hilltop and high hills with steep slope. The relief features of the Rural Municipality appear in complex form from lowland with gentle slope to hills and hillocks with steep slope. Due to the relief feature variations number of micro topographic features are also apparent in the terms of shaded relief, slope gradient, and digital elevation.

2.2 Geomorphology

Jwalamukhi Rural Municipality is situated in Midlands of the Nepal Himalaya with having diverse geomorphic features and its elevation varies from 333 to 1343 m. Geomorphology of the Rural Municipality comprises gentle slopes to elevated hill-slopes with river valleys, terraces, sloping lands, ridges, spurs, and saddles. Drainage system greatly varies from valley floor to mountain slopes and the drainage pattern is dendritic. Budhi Gandaki River is on western side of the Rural Municipality. Besides many tributaries, there are other prominent streams such as Anderi Khola, Angtar Khola, Ankhu Khola, Bhalu Khola, Chhargandi Khola, Chisopani Khola, Chyandu Khola, Dhawa Khola, Gamnsur Khola, Gyalma Khola, Jyadul Khola, Kalopani Khola, Maste Khola, Pipaltar Khola, Sand Khola, Sang Khola etc. Topography is reflected as geomorphic landform expressions depending on differential weathering conditions with respect to rock types. Landslides, debris flows, and soil erosions are common processes that shape the geomorphic surfaces. Soils are formed by weathering processes that have resulted the spatial distribution of colluvial and residual soils. The residual soils are found in gentle slopes whereas colluvial soils are seen as thin cover in steep slopes and are mostly confined to base of the hillslopes. Recent sediments are also found to be deposited in valley flat of riverbank terraces which varies from 1 to 4.5 m height than riverbed and the terraces are sloping towards the river-courses. The riverbank terraces comprise gravel, sand, and silt with some boulders.

2.3 Geology

Geology and landforms in Jwalamukhi Rural Municipality characterizes the rocks of Dailekh Subgroup which consists of Ranimatta Formation. Rocks are dipping towards south to southwest. A geological map is given in Figure 2-1 and geology of the area can be represented from Table 2-1. Lithology in the formation is given as:

Ranimatta Formation: Greenish grey gritty phyllites grit-stones with conglomerates and white massive quartzites in the upper parts

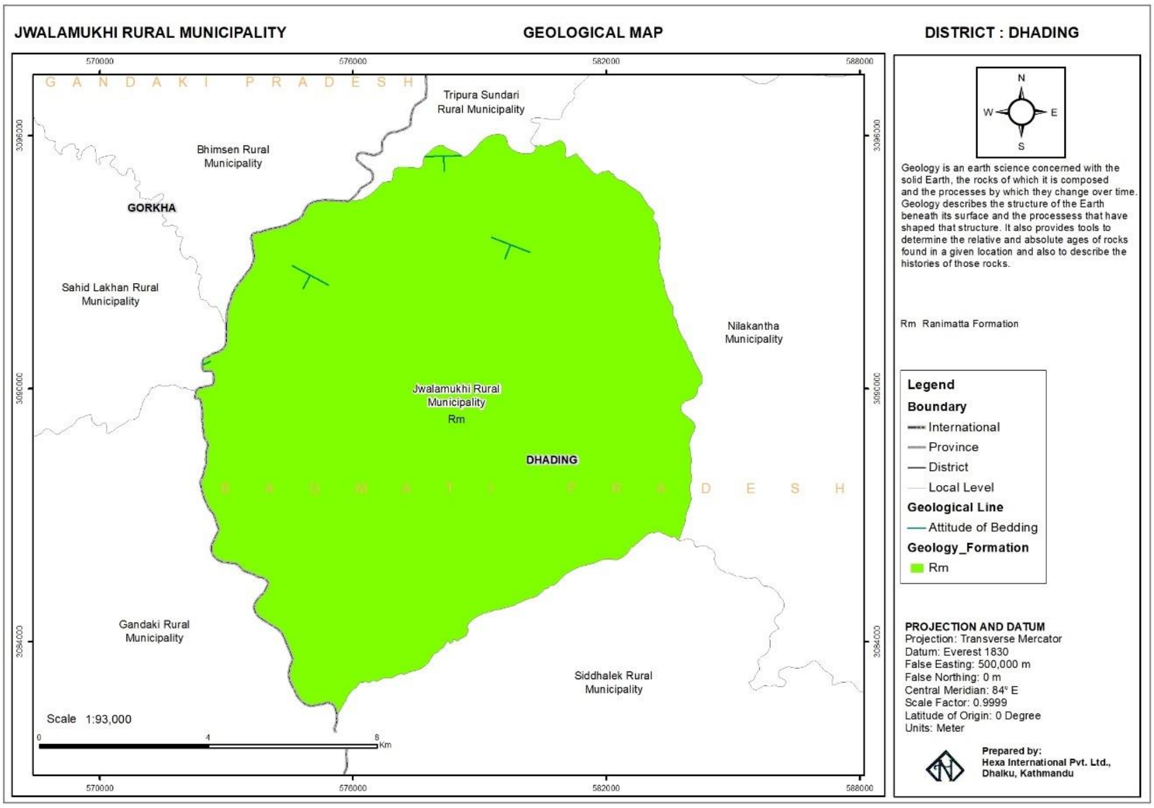


Figure 2-1: Geological Map of Study Area.

Table 2-1: Geology (lithostratigraphy) of Dhading District. (Source: Department of Mines and Geology)

Zone	Group	Subgroup	Formation	Code	Rock types
QUATERNARY			Quaternary deposit	Q	Alluvium, boulders, gravel, sands, clays
LESSER HIMALAYA	Gneiss			Gn	Augen gneisses, banded gneisses
	Dadeldhura Group		Intrusive Granite	Gr	Biotite-tourmaline granites
	Basic rocks			Br	Metamorphosed gabbroic rocks
	Mid-land Group	Lakharpata Subgroup	Lakharpata Formation	Lk *(Rb)*	Fine-grained, light blue, grey limestones, dolomites with thin interactions of grey shales, white, pink dolomite limestones, purple quartizes, green shales at the top. Algal structure & stromatolites are present
			Syangja Formation	Sy	White pale orange pinkish or purplish or calcareous quartzites, quartzitic limestones intercalated with dark grey purple & green shales, strongly ripple marked quartzites at the base
			Sangram Formation	Sg	Black, dark grey to greenish grey shales with interaction of limestones & quartzites

Zone	Group	Subgroup	Formation	Code	Rock types
			Galyang Formation	Gl	Dark grey slates intercalated with thin grey calcareous slates & lamellae of carbonates. Thick beds of grey siliceous dolomites are found at place (Baitadi beds)
			Ghan Pokhara Formation	Gp *(Cr)*	Black to grey carbonaceous slates & green shales. Carbonates, white to grey compact dolomite & dolomitic limestones interbedded with shales beds
			Naudanda Formation	Nd	White massive fine to medium grained quartzites with ripple marks interbedded with green phyllites. Basic intrusions are noted
		Dailekh Subgroup	Ulleri Formation	Ul	Augen gneisses muscovite biotite gneisses feldspathic schists
			Ranimatta Formation	Rm	Grey greenish grey gritty phyllites grit-stones with conglomerates & white massive quartzites in the upper parts. Basic intrusions are abundant
	Kathmandu Group	Phulchoki Subgroup	Chitlang Formation	Ch	Dark slates with white quartzites at the base. Impure limestones & ferruginous beds with trilobites
			Chandragiri Formation	Ca	Light fine grained crystalline limestones partly siliceous thick to massively bedded white quartzites in upper parts. Wavy limestones contain Ordovician schinoderms
			Sopyang Formation	So	Augen gneisses muscovite biotite gneisses feldspathic schists
			Tistung Formation	Ti	Dark grey slates intercalated with thin grey calcareous slates & lamellae of carbonates. Thick beds of grey siliceous dolomites are found at place (Baitadi beds)
		Bhimphedi Subgroup	Markhu Formation	Mr	Massive coarse to medium grained, crystalline marble changing northward to dark fine biotites schists interbedded with impure marbles & quartzites, stromatolites are found
			Tawa Khola Formation	Ta	Coarse-grained dark grey garnetiferous muscovite biotite quartz schists interbedded with grayish impure quartzites pandrang quartzite member light green quartzites
			Udayapur Formation	Ud	Coarse-grained crystalline marbles with intercalated schists
			Sarung Khola Formation	Sk	Fine grained dark green grey biotite and quartzitic mica schists occasionally garnetiferous interbedded with impure strongly micaceous quartzites
			Maksang Formation	Mk	White fine grained quartzites cross bedded

Zone	Group	Subgroup	Formation	Code	Rock types
			Shiprin Khola Formation	Sp	Coarsely crystalline garnetiferous muscovite-biotite-quartz schists, quartzites, green chlorite schists at the base
			Undifferentiated Schist	Sh	Undifferentiated schists, quartzites gneisses and calcareous silicate rocks with various stages of migmatization

2.4 Drainage/Hydrology

The drainage/hydrology of Jwalamukhi rural Municipality determined by its relief features and drainage pattern that consists of streams, Gads, and source points of water in the different watersheds of Rural Municipality. Drainage system greatly varies from valley to steep mountain slopes and the drainage pattern is dendritic. Budhi Gandaki River is on western side of the Rural Municipality. Besides many tributaries, there are other prominent streams such as Anderi Khola, Angtar Khola, Ankhu Khola, Bhalu Khola, Chhargandi Khola, Chisopani Khola, Chyandu Khola, Dhawa Khola, Gamnsur Khola, Gyalma Khola, Jyadul Khola, Kalopani Khola, Maste Khola, Pipaltar Khola, Sand Khola, Sang Khola etc. Gads have high volume of water with high velocity then streams so that all of the stream flow in the area of the Rural Municipality which has great importance for irrigation, water supply. Several tributaries flow into chhargandi khola in center and ultimately to Budhi Gandaki. Due to the weak geological structure of the area and high speed with water velocity the drainage pattern caused to high landslide and riverbank cutting hazard prone area. Thus, the drainage pattern and hydrological condition of the rural Municipality seems from north-east to south-west which governed by the existing watersheds of the Rural Municipality. Number of small streams meet together and confluence into their higher order streams and then into gads and flow to west south part of the district. The drainage pattern/hydrology of the Rural Municipality has shown in Figure 2-3.

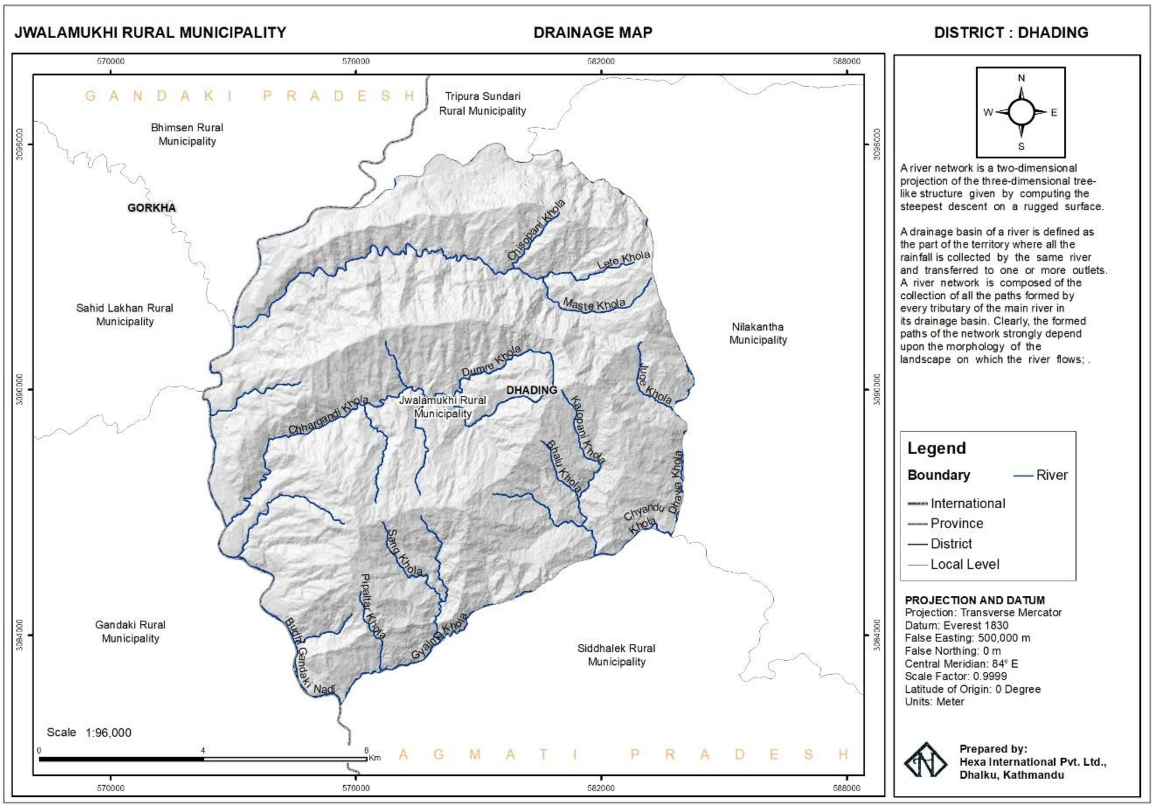


Figure 2-2: Drainage map of the study area

The drainage pattern and geological features of the Rural Municipality indicate favourable conditions for the recharge capacity of the groundwater in the southern low-lying area. So, the hydro geological condition appears suit for irrigation and power production.

2.5 Terrain

Terrain of Jwalamukhi rural Municipality comprises low lying river basins, tars, foothills, ridge, middle hills, hilltops, high hills range. Fore Himal range and mountainous area hillslopes, middle hill terraces, micro-ridge, spurs and alluvial deposits, gravel, boulders and sand complex, and flood fan are main topographical features of the Rural Municipality. All these topographical features are in changing forms due to regular landslides, soil erosion, flood havoc, river shifts and sedimentation. The topography comprises dissected to rolling topography in high land to piedmont region and very gentle with poor drainage conditions. The terrain covers the mix up barren land, rocky hillslopes, forests, settlements, and agricultural land. Therefore, there is an extremely complex landscape, heavy sculptured by fluvial erosion and has been a catastrophic production of sediments and development of badland topography. The relative relief slope of the range has been increasing throughout the past hundred years or so because stream down cutting has exceeded lowering of the local interfluves. Riverside slopes, therefore, have progressively lengthened and their parallel retreat affected by stream down cutting and land sliding. Debris mobilized on the steep slopes flows directly into river/stream giving an extremely high sediment-delivery ratio, and subsequently moved out on the river basin by flooding.

As a result, the steep hill slope area found to be sensitive for the large-scale landslides and mud flow which composed of unconsolidated earth materials like low grade metamorphic and sedimentary rocks with residual soil in red and brown color.

2.5.1 Slope

The study Rural Municipality consists of mountains and tars and mostly they have <7 to >30-degree slope. About 82.87% lands are moderately to steeply sloping (5 to 30 degree), nearly 14% are steeply to very steeply sloping (>30 degree), and small fraction (3.08%) of the lands are relatively flat to gently sloping (1 to 5 degree). The steeper slopes slope of the lands in the Jwalamukhi Rural Municipality has been presented in Map XX. are less stable, all other factors being constant. The steeper the slope, the shallower the unconsolidated material on the slope, which is likely to be removed by erosion processes. Conversely, landscape on the gentle slopes is stable and hence the soil forming processes is relatively less hindered. The slope of the lands in the Jwalamukhi Rural Municipality has been presented in figure .

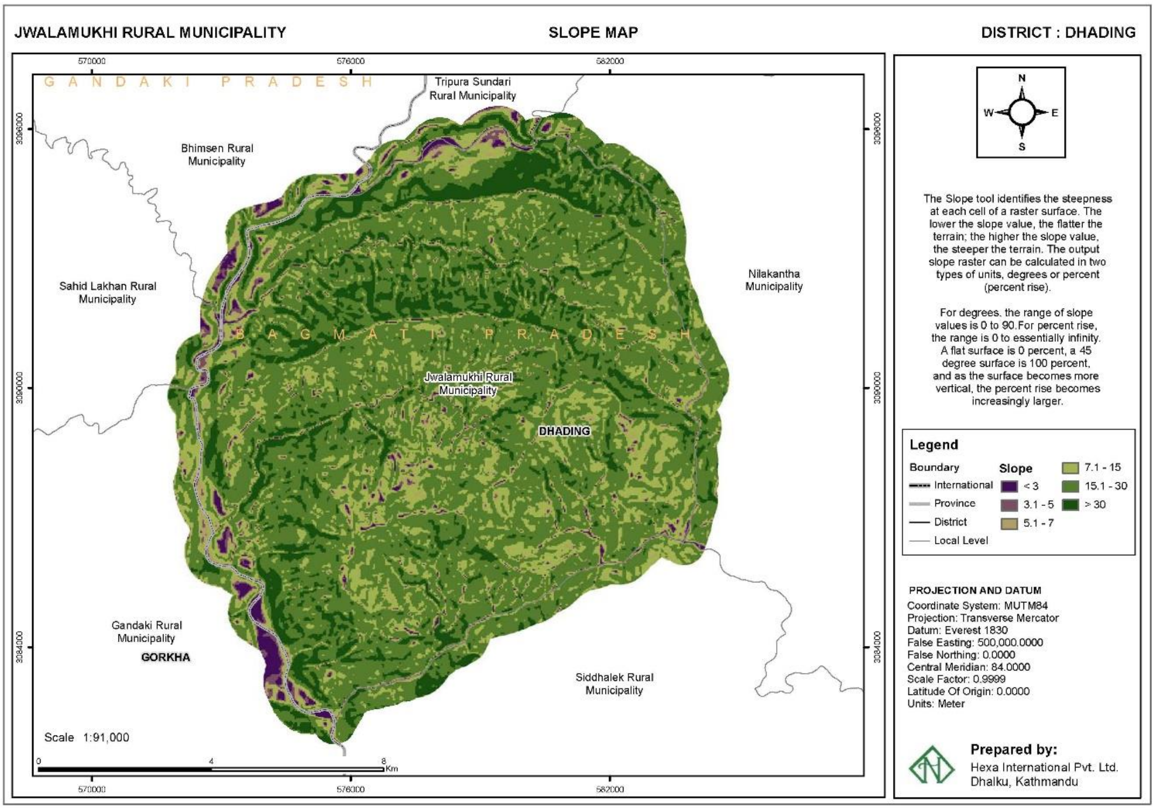


Figure 2-3: Slope of the study area

2.5.2 Elevation

Jwalamukhi rural Municipality is located midlands and its elevation ranges from 333 to 1343 m. The region is geologically fragile and geomorphologically unstable and overly sensitive in terms of natural hazards like landslides, soil erosion and watershed degradation. Major land-cover in the Rural Municipality constitutes the rocky topography, hillocks, hilltops, hills, F ridges and river valley. Thins soils distributed in this region are highly susceptible to erosion along the active streams and gullies

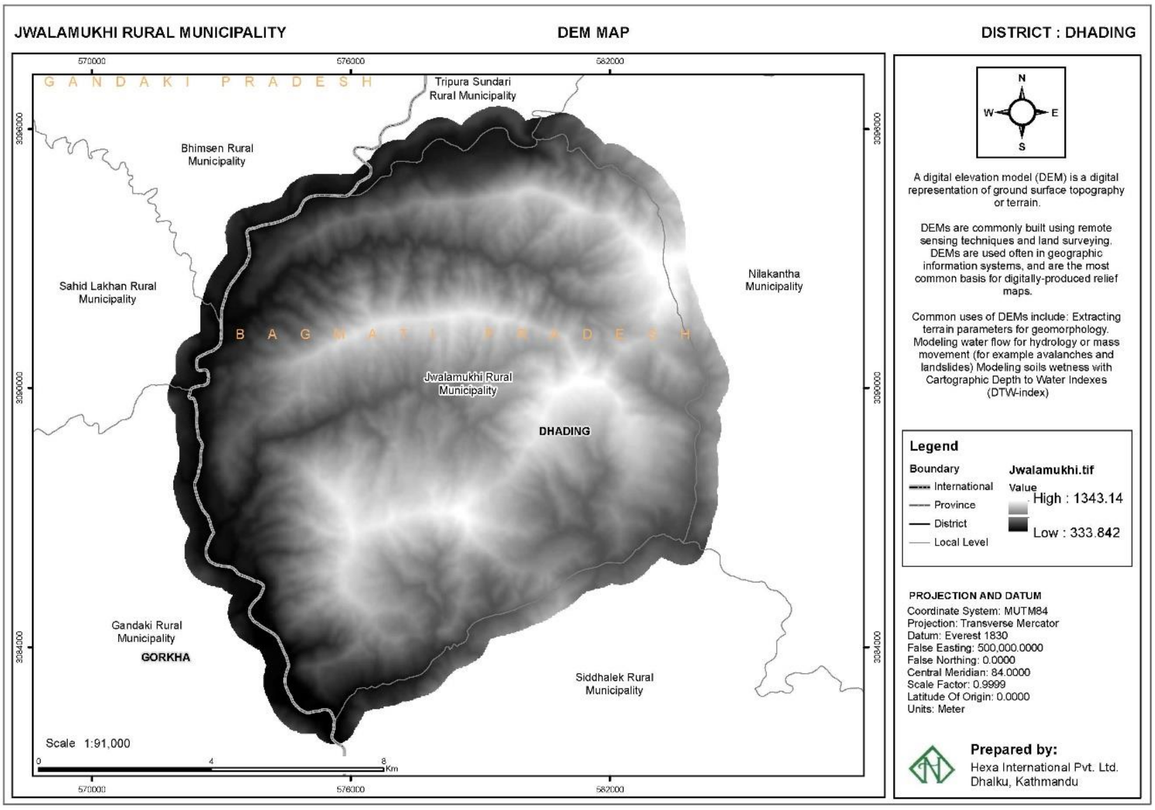


Figure 2-4: Elevation of the study area

2.6 Climate

Rainfall data were analyzed in monthly and annual rainfall basis over the project area by surfer software and plot by kriging methods the spatial rainfall distribution present in the isohyet's method over the Dhading district. The spatial analysis result of 18 number stations in 7 nearest district annual rainfall (125 to 350 mm) received in the entire area of Dhading district. However, the observed temporal (1991-2014) annual average rainfall 1790 mm received in Dhading district, there is significantly decreasing order in Dhading station no.1005, which is closed with the Jwalamukhi Rural Municipality. Similarly, the temporal average maximum monthly rainfall 213 mm received in the month of July and the minimum monthly rainfall (6 mm) received in the month of November.

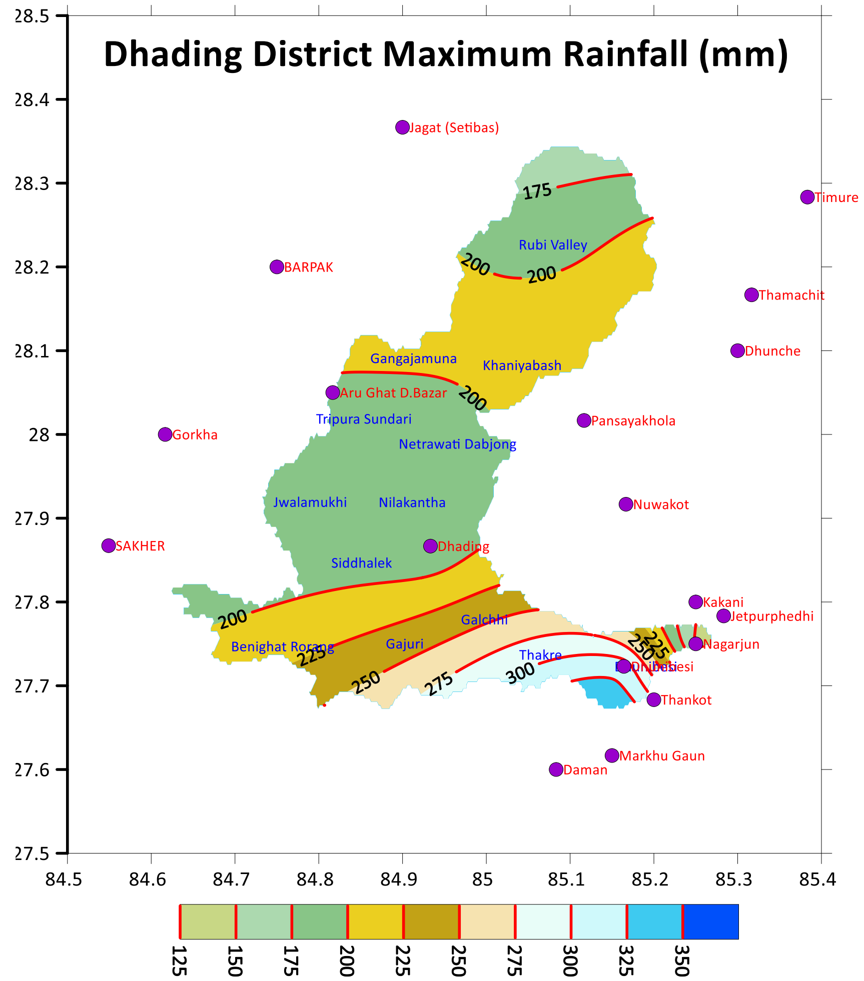


Figure 2-3: Spatial monthly maximum rainfall of Dhading district

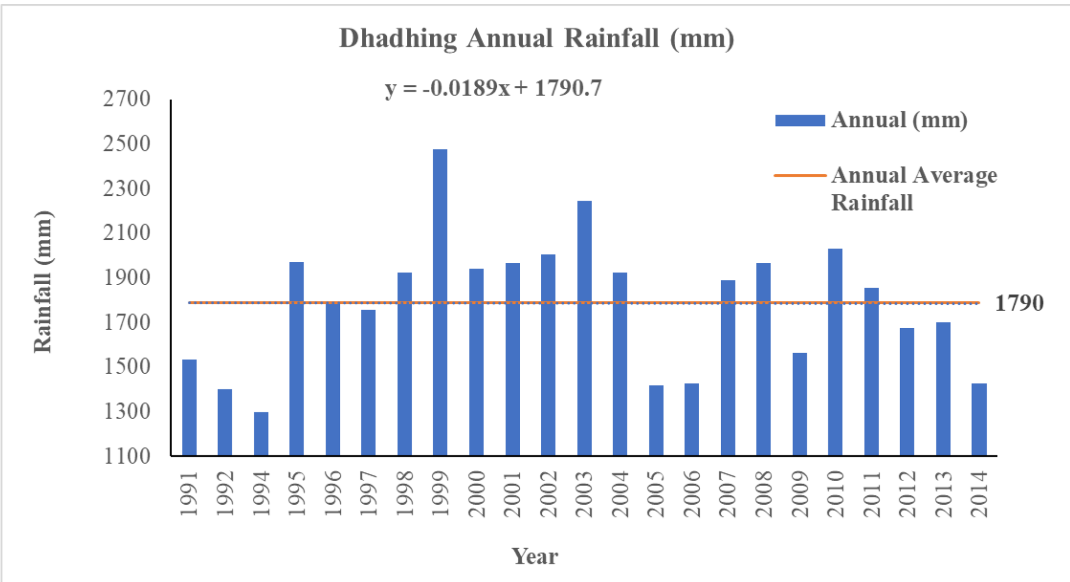
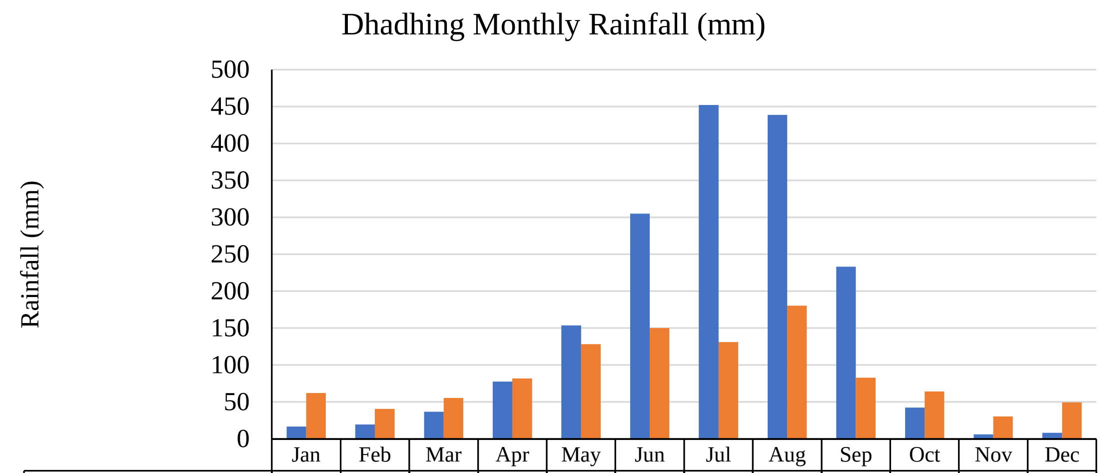


Figure 2-4: Annual average rainfall of Dhading District



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Rainfall (mm)	17	19	37	78	154	305	452	439	233	42	6	8
Maximum Rainfall (mm)	62	41	56	82	128	150	131	180	83	64	31	49

Figure 2-5: temporal average monthly and maximum rainfall Dhading district

2.7 Forest and Biodiversity

Forest resources are main source of life and continuing of ecosystem services of the Rural Municipality. The total forest area is 4780 ha which accounts 42.34 percent of total land area of the Rural Municipality. The forest of the area is mix up of sub-tropical and Tropical Forest. The types of forest with species presents in table 2-3.

Table 2-2: Categories of Forest land use

S.N.	Types of forest	Area(ha)	Percent
1	Sub-tropical	0.52	0.01
2	Tropical	4779.51	99.99
	Grand Total	12765.55	12765.55

Most of the forest is found as dense. The dense forest makes up about 89 % of forest coverage. More than 93 % forest was found matured. The detail has been given in table below.

Table 2-3: Status of forest cover

SN	Class	Area_Ha	Area (%)
1	Dense	4247.39	88.86
2	Sparse	532.64	11.14
	Grand Total	4780.03	100.00

The diversity among the species in the forest is equally high mostly dominated by the Pinusroxburghii, alnus, schima-castonopsis and Quercusdilata. They in combine makes of 94% of diversity. The detail has been given in table below.

Table 2-4: Classification of species

SN	Class	Area_Ha	Area percentage (%)
1	Abiesspectabilis Forest	84.92	1.78
2	Alnus Woods	1226.50	25.66
3	Pinusroxburghii Forest	2577.48	53.92
4	Quercus lamellose Forest	39.99	0.84
5	Quercusdilata Forest	310.68	6.50
6	Quercussemecarpifolia Forest	3.41	0.07
7	Rhododendron Forest	132.24	2.77
8	Schima-Castonopsis Forest	390.07	8.16
9	Sub-tropical Evergreen Forest	14.74	0.31
	Grand Total	4780.03	100.00

2.8 Natural hazards and environment

Jwala Mukhi Rural Municipality is not exceptional from the general impacts of adverse effects of climate change as impacted to the district. Since the decades farmers had got low production and have been faced high risk of drought and floods. Due to very few sporadic rainfall flash floods and riverbank and crop land cutting problems, and massive landslides are in rising trends. Every year the villagers lost huge amount of property and human life due to the adverse effects of natural hazards. Faced with immediate survival needs, with few options, and have no choices the poor have over harvested natural resources and have further aggravated the undesirable ecological conditions in Rural Municipality area. Similarly, unscientific road track open practices in and around the Rural Municipality exposed for landslide debris flow and flooding and river side cutting. Free grazing by larger family with larger herds also become one of the reasons to heavy soil erosion and degradation of bio-resources in the area. It is reported that rich households use more natural resources in larger quantities and natural resources like land (soil), water and forest have been depleting continuously since the last decades. This has created a dynamically unstable vicious circle amongst population, poverty, and environmental resource degradation. Recently, deforestation, soil erosion, landslides, desertification, resource scarcity and the adverse effects of climate change appear as the challenging issues in all sectors of the Rural Municipality.

Most of the area of Rural Municipality which lies in the hill and high hills by the aggressiveness of its climate is strongly exposed to the phenomena of landslides, mudflow, soil erosion, flood, and drought. The erosive of rainfall is of major importance among the natural factors that affect erosion. The erosive of rain represents the interaction between the kinetic energy of the rain and the soil surface. This is corroborated by the study of Andoh, H.F.; Antwi B.O., & et.al, (2012) in Algeria. Erosion and land degradation in the Rural Municipality are the subject of many factors which reveal the speed and severity of the hazards due to the unfavorable weather conditions marked by contrasts in the seasons with torrential rains high vulnerability of fragile lands coupled with pressures from inappropriate road construction, uncontrolled grazing, illegal collection of forest products (NTFPs and TFPs) conversion of forest land into croplands and road open without scientific alignment and geophysical feasible. People having experienced the change over the year fear that almost all area of the Rural Municipality is facing the problems of climate change adverse effects. Due to the direct impacts of climate change number of water springs were disappeared. Water scarcity for drinking and irrigation purposes is in rising trends. Number of local plant species was vanished and the productivity and production of cereal, cash and NTFPs decreased drastically since the last twenty years. Local elites argues that if locals do not care it and try to adopt the climate change and not manage locally available resources sustainably, and not control nonalignment road construction works, the whole area of the Rural Municipality will face the great challenges of acute scarcity of livelihood resources and ecological instability with ill environment of public spheres. Community people perceived that short period rainfall amounts in September and August and road track construction is the main cause of high risk of landslides, erosion, drought, and vanished water springs and gradually declining of bio-resources including farm production. Therefore, the economy, ecology, and land resources i.e., soil; forest and water are strongly threatened by the risk of natural hazards which is conceived as a climatic and environmental risk.

An effort is made to collect their opinions on their accountability to save the forest and environment, local said that the government duty is to manage and conserve the forest resources and they (local people) have only right to collect, consume and use forest products. They are not responsible to protect the surrounding areas forests. As for the public awareness, different clubs and user groups have formed but no programs were implemented for the conservation of the common property like public land, riversides, roadsides, and their importance for the future. Grassland is the open spaces inside or boundary of the forest having less crown cover. Sometimes it is vegetated with grasses and promptly used for the grazing cattle. In the context of biodiversity, different kinds of natural species and domestic animals are found including different kinds of birds, butterfly, reptiles' insects, and mammals.

The assessment has found most of the area with medium and low risk to the landslide. Significant part of ward no 5 and 7 were found with medium risk, whereas significant part of wards 2,3 and 4 were found with low risk. However big area in ward 2 and multiple area in ward 5 were found with high risk with the landslide.

CHAPTER 3 : SOILS AND LAND CHARACTERISTICS

3.1 Land System and Soil Characteristics

LRMP Land Systems have categorized land units of this area into 3 broad land system units namely, Active and Recent alluvial plain; Fans, aprons and ancient river terraces and Depositional basins. For the preparation of land system map at Rural Municipality level, the generic and pragmatic approach that was adopted by LRMP was followed in this chapter. Based on LRMP, 1986 a total of 17 land systems from 1 to 17 were identified.

Analysis of land systems based on standard methodology showed that the majority area is occupied by land unit 11 (52.42%) followed by 12 (39.80%) and 9 complex (2.65%). Figure 4-1 and figure 4-2 depicts the spatial distribution of land system type of this Rural in graphical form and map. Hence, majority of the terrains are moderately to steeply sloping mountainous. However, some of the areas are alluvial plains and fans and tars (6.13%) which are suitable for the production of agricultural crops.

In Jwalamukhi Municipality, most of the area (52.03%) were high and 25% land were low in organic matter content but 21.17% area were medium for this soil trait (Figure 6-8 and figure 6-9; table 6-6). While the average value of OM was 3.76%, the value ranged from 1.07 to 6.44%.

3.2 Land Capability

Land capability assessment provides the ranking of the land on the basis of its ability to sustain a range of agricultural land uses without degradation of land resources on sustainable basis. It was originally developed by United States, Department of Agriculture and has been used in identifying appropriate land usages and required management practices that can sustain its productivity for long run.

Of the total area (11289.62 ha), Class II comprise 7.98 % and III comprise 52.46 percent, suited to mostly upland crops with limited choices for diversification. Topographic deficiency and altitudinal limits are major constraints.

3.3 Present Land Use

Rice-Maize-Vegetables, Rice-Potato-Vegetables and Rice-Wheat-Pulses are the dominant cropping pattern whereas, Maize-Oilseeds, Maize-Potato and Maize-Pulses are the least practiced cropping pattern found in the study. The level of cropping intensity in Jwalamukhi Rural Municipality is found to be in intense state (60.48%) and medium state (31.86%) that needs some boost up with proper land management practices such as smart water management, good varieties selection of seeds, conservation tillage, efficient use of nitrogen and farm management software including others.

Forest is a life line of this Rural Municipality that supports ecological balancing of the area for good agricultural conditions and risk management. Subtropical and tropical forests are the two primary forest found in this rural municipality where, mixed forest and hardwood forest are found in abundance with high percentage of Pinusroxurghii trees (53.92%). Analysis of crown density shows that forest health is in dense state but are in a state of maturity. Only 32.05 percent of the forest is managed by the community itself and rest is government and private owned. Wood log from the mature trees could generate sufficient revenue for the local government as the area has high number of matured trees. Also the area is rich in herbs, fruits and vegetables. Commercial production of these herbs, fruits, and vegetables and the access to the market is of prime concern of the residents in this Rural Municipality. Human pressure on the forest is high particularly in proximity to settlement and highway as evidenced by the shrubs and grazing land developed at the fringe of the forest in piedmont area.

Jwalamukhi Rural Municipality does not contain any industrial areas except few home based industries managed by family. Lack of employment oriented manufacturing and industrial establishment and production of raw materials for the industrial and manufacturing industry is identified by the Rural Municipality as a foremost challenge to overcome for industrial development in the area. When it comes to commercial land use, there is huge scope and opportunity for business expansion in this Rural Municipality with small area covered by banking sector, private schools and storage areas. No establishments related to mines and minerals could be located and mapped in this rural municipality, despite the fact that the municipality has potential area of quartz crystals, kyanite, limestone, and tourmaline etc. according to the local authorities.

Health and educational service need more establishments as it covers only 0.74 ha and 6.58ha of land of the total public service land use area to cope with the increasing demand of the population. Likewise there is only 0.06 ha of area covered by bridge in this location and is one of the hurdles for the market access to the local production. Residential area in this Rural Municipality is densely populated, unplanned and old, which signifies the importance of the development of compact city/smart city concept launched by the government of Nepal. The excess land after establishment of smart city could be used to serve back the population in term of agricultural and commercial benefit. Rivers in this Rural Municipality are in their natural state, and nothing has been done to benefit from them economically; they could be a source of water for agriculture or a tourist destination.

This study has categorized the land use plan up to seven levels with each land use class delineated with high accuracy of 96.99 percent with KIA coefficient of 0.97. Despite the good result, it is felt that more accurate and better result would have been obtained, have we had a 'real time and error free' satellite imagery. Time frame of the project months and changing nature of the cropping pattern cycle might have had influenced the study and the result but cannot be said with certainty.

The land use data and map produced can be used in the future to formulate land use planning to control land fragmentation, to manage unplanned settlements, and to reduce and control encroachment of public and government land via interaction and negotiation among planners, stakeholders and decision makers at local and national levels. This report assumes that the presented database would be useful in attaining optimal benefit of the land sustainably, equitably and economically within the jurisdiction of this Rural Municipality

3.4 Agriculture Pattern

On the reference of physiographic regions Cultivation area is classified into four different classes- Terai Cultivation, Hill Cultivation, Mountain Cultivation and Valley Cultivation. Agriculture is predominantly practiced in hill area and is a primary economy in Jwalamukhi RM covering 50 percent of the land use area. Rice, Millet, maize, vegetables and wheat are the primary crops cultivated in the lower region where as barley, pulses and buck wheat are some of the crops cultivated in the upper region of the hill area. In Jwalamukhi RM, Level terraces farming is practiced- a labor intensive method of growing crops on the side of the mountains by planting on graduated terraces built into the slope- to maximize arable land area. Other benefit it brings is it reduces soil erosion and water loss. These terraces are low in nature and built on flat ridge to channelize runoff water for the crops. Usually terraces are built on a slight grade so that the water caught in the channel moves slowly toward the terrace outlet.

The cropping pattern of the Jwalamukhi RM varies with the cultivation land type available along with the availability of the irrigation canal or water from rainfall. As for the agricultural land, analysis of cropping pattern shows that Rice-Maize-Vegetable and Rice-Potato-Vegetable are the dominant pattern of cultivation each occupying the cultivation area of 1884 hectare and 928 hectare of land respectively

3.5 Land Use Zones

Land Use Zoning is the process of designating legalized uses of certain parcels of land by governments. The government will designate various zones for different uses of land, such as agricultural, residential, commercial, industrial, public use etc.

Result shows that the most of the land in Jwalamukhi Rural Municipality consist under Agriculture zone and Forest zone cover 48.29% and 41.94% of the total land. Similarly, Residential zone consist (5.16%), Public Use Zone (2.80%) and Riverine stream lake and marsh (1.56%). Another land use zoning class like Commercial, Mines and Minerals, Industrial and Cultural and Archeological have occupied less area

3.6 Cadastral Data

3.6.1 Cadastral land parcel based on land use.

A total of 28469 parcels were recorded in Gangajamuna Rural Municipality. Total 24601 parcels (86.41% parcel number) are found to be occupied by Agricultural zone. With 3576 parcels (12.56% parcel number)..

3.6.2 Cadastral and Parcel based on Land use Zoning.

In the resulting zones the maximum area of parcels lies in Agriculture zone (82.76% by parcel area) followed by Residential zone (13.29% by parcel area). ६

CHAPTER 4 : SOCIO-ECONOMIC SETTINGS

4.1 Social settings

The social components and its built structure signal the social dynamics and state of the society in terms of art, science, technology, and life standard too. Therefore, in this chapter, the social aspects and their dynamism are discussed. Population size, its growth rate, distribution pattern, composition by age and sex, caste/ethnicity, language, religion, and educational status are the main aspects that dealt with the social conditions of the Rural Municipality. In general, in the Hindu dominant society of the Rural Municipality, all caste/ ethnic groups' people are found to live together by maintaining social harmony. Agro-based economy and its allied activities are found as the main livelihood of the people who reside in the Rural Municipality. As a newly declared Rural Municipality based on population threshold, the urban features as built area, non-agricultural economic activities, and level of physical infrastructures facilities are in negligible condition. However, the lifestyle and livelihood act as main factors to strengthen the social relation and social cohesion at the settlement level.

4.1.1 Population distribution and density

The total population of this Rural Municipality is 23966 of which male population is 10573 (44.1%) and female population is 13393 (55.9%). The total households are 5730 and the average family size of the Rural Municipality is 4.2. The Ward wise population distribution of the Rural Municipality has presented in table 4-1.

Table 4-1: Population distribution by ward and sex

Ward No.	Household	Population						Ward
		Total	Male	Female	Male %	Female %	Household size	
1	729	3,285	1,472	1,813	44.8%	55.2%	4.5	13.7%
2	693	2,796	1,275	1,521	45.6%	54.4%	4.0	11.7%
3	745	3,122	1,363	1,759	43.7%	56.3%	4.2	13.0%
4	998	4,033	1,772	2,261	43.9%	56.1%	4.0	16.8%
5	1,051	4,381	1,944	2,437	44.4%	55.6%	4.2	18.3%
6	802	3,439	1,477	1,962	42.9%	57.1%	4.3	14.3%
7	712	2,910	1,270	1,640	43.6%	56.4%	4.1	12.1%
Total	5,730	23,966	10,573	13,393	44.1%	55.9%	4.2	100.0%

Source: CBS 2011 / Updated 218

Table 4-2 shows that the ward wise population distribution pattern varies across the rural Municipality. The highest population is in ward 5 (18.3%) % whereas the ward no 2 have lowest percentage i.e., of population 11.7 %. Similarly, Ward 1 have highest household size i.e., 4.5 and the ward no 2 and 4 have the lowest household size i.e., 4.0.

Population density

The population density of Jwalamukhi rural Municipality is varied. The average density of the rural Municipality is recorded 237.21 person / sq. km. The detail ward wise population density of the rural Municipality has presented in Table 4-2.

Table 4-3: Population density by wards

Ward	Area (sqkm)	Population	Density (pop / sqkm)
1	13.09	3,285	250.95
2	14.33	2,796	195.14
3	12.84	3,122	243.08
4	18.39	4,033	219.33
5	30.22	4,381	144.95
6	8.11	3,439	424.14
7	15.91	2,910	182.85
Total	112.90	23966	237.21

Souce :CBS 2011 / Updated 2018

Table 4-2 shows that across the seven wards of the rural Municipality, ward 6 has the highest population density (424.14 Person / sq. km) and ward no 1 has the lowest population density 144.95 Person / sq. km).

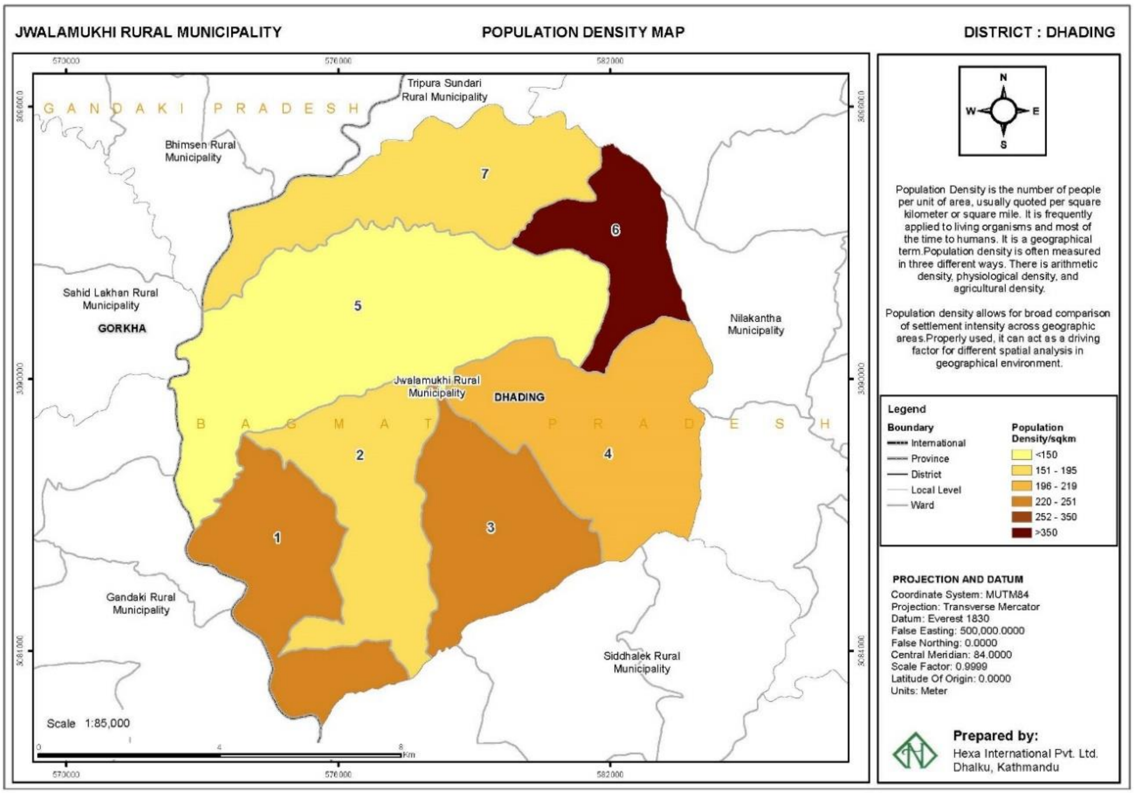


Figure 4-1: Population density

Population composition

Population composition is an important factor that determines the stage of resource development in the right direction and equitable basis. It means it is an indicator of a balanced development approach. Age and sex, ethnic groups, language, and educational status are the major aspects of socio-demographic characteristics and the index of population composition of an area. The age and sex composition of the population in Jwalamukhi Rural Municipality have been presented in Table 4-3.

Table 4-3: Population composition by age & sex

Age Group	Male	Male %	Female	Female %	Total	Total %	Sex ratio
00 - 04	1076	18.40	1032	14.95	2108	16.53	1.04
05 - 09	1414	24.18	1294	18.75	2708	21.24	1.09
10 - 14	1635	27.96	1686	24.43	3321	26.05	0.97
15 - 19	1163	19.89	1595	23.11	2758	21.63	0.73
20 - 24	457	7.82	1128	16.34	1585	12.43	0.41
25 - 29	403	6.89	935	13.55	1338	10.49	0.43
30 - 34	371	6.35	790	11.45	1161	9.11	0.47
35 - 39	394	6.74	779	11.29	1173	9.20	0.51
40 - 44	522	8.93	789	11.43	1311	10.28	0.66
45 - 49	500	8.55	661	9.58	1161	9.11	0.76
50 - 54	568	9.71	664	9.62	1232	9.66	0.86
55 - 59	448	7.66	488	7.07	936	7.34	0.92
60 - 64	429	7.34	453	6.56	882	6.92	0.95
65 - 69	432	7.39	380	5.51	812	6.37	1.14
70 - 74	300	5.13	305	4.42	605	4.75	0.98
75 +	461	7.88	414	6.00	875	6.86	1.11
Total	10573	180.83	13393	194.05	23966	187.98	0.81

Source: CBS, 2011, Updated 2018

The Rural Municipality has quite a young population, the table 4-3 reveals that almost 40% of the inhabitants are below 19 years. While the population of the age group above 60 less than 10%. The better ratio of the young over the aged population is promising from the economic perspective. The average sex ratio is .81.

4.1.2 Population by Caste/Ethnicity

Jwalamukhi Rural Municipality has a multi-ethnic society and is inhabited by more than 25 ethnic groups. The major castes of this Rural Municipality are Brahman, Newar and Magar, while Hajam, Teli and Musalman are in minority. The caste/ethnic population composition of Jwalamukhi Rural Municipality is given in Table 4.4.

Table 4-4: Caste/ ethnic population composition

S.N	Cast-Ethnic Group	Population	Percentage
1	Brahman - Hill	4706	19.64
2	Newar	4147	17.30
3	Magar	3555	14.83
4	Chhetree	3331	13.90
5	Sarki	2103	8.77
6	Tamang	1373	5.73
7	Gurung	1130	4.72
8	Kumal	1063	4.44
9	Kami	935	3.90
10	Damai/Dholi	657	2.74
11	Sanyasi/Dashnami	267	1.11
12	Gharti/Bhujel	240	1.00
13	Thakuri	184	0.77
14	Thakali	66	0.28
15	Others	66	0.28
16	Majhi	61	0.25
17	Hajam/Thakur	43	0.18
18	Teli	20	0.08
19	Musalman	19	0.08

4.1.3 Population by Religion

Religion is another important component of the population of an area. Primarily, religion is the basis for all people to determine their lifestyle, social value traditions, and culture. All the progress and changes are to be valued on religious beliefs and practices. People living in Jwalamukhi Rural Municipality are mainly Hindu and Buddhist. The followers of Islam Christianity, Prakriti, and Bon religions people are also settled in Jwalamukhi Rural Municipality. The composition of the population by religions of the Rural Municipality is presented in Table 4-5.

Table 4-5: Population composition by religion

Ward	Hindu	Buddha	Muslim	Christian
1	3717	8	0	156
2	3051	4	0	576
3	4670	31	6	392
4	5245	250	0	306
5	5568	1	0	277
6	4053	723	0	57
7	3700	19	0	112

Source: Jwalamukhi RM Profile, 2075

It is seen from table 4-5 that more than 90 percent of people of the Rural Municipality are Hindu. It followed Buddha (7.5 %), Christian (1.68%), Muslim (0.61%) and others (0.1%).

Language

Jwalamukhi Rural Municipality is multiethnic groups and multilingual as well as the multi-religious area where different caste/ethnic groups, religious communities, and different mother tongue people reside in mutual understanding with social cohesion to each other. Being a multiethnic group and a mutual relationship between and among the community people in the Rural Municipality there are different types of languages are spoken. Major languages spoken in Jwalamukhi Rural Municipality are Nepali, Tamang, Magar. The population composition of the Rural Municipality by language is given in Table 4-6

Table 4-6: Population composition by language

Language	Population	Percentage
Nepali	20043	83.63
Magar	1450	6.05
Tamang	1329	5.55
Newar	518	2.16
Kumal	506	2.11
Others	55	0.23
Gurung	42	0.18
Maithili	12	0.05
Not Reported	11	0.05

Source: CBS, 2012, Updated 2018

Table 4.6 shows that the Nepali language is the mother tongue of more than 80% of the population of the Rural Municipality.

4.1.4 Literacy rate

Education is an important indicator of the human development index of an area. Level of education and literacy rate are the main determinants of educational status to synopsis the resource development capacity of a society. Here an attempt has been made to deal with the literacy rate of the Jwalamukhi Rural Municipality and resource development trends and human capacity development to maximize the utilization rate of available resources. The data relating to the literacy rate of the Rural Municipality was calculated based on CBS data (2012) and available information at the Rural Municipality office. The average literacy rate of the Rural Municipality was only 60.49 percent, which is lower to the national level literacy rate of 64. The sex-wise literacy rate of age groups 5 and above has presented in the following table.

Table 4-7: Literacy rate population aged 5 years & above by sex.

Total population	Population aged 5 years & above	Population who						Literacy not stated	Literacy rate
		Can read & write	%	Can read only	%	Can't read & write	%		
Male	21,858	13,222	60.49	487	2.23	8,128	37.19	21	60.49
Female	9,497	6,524	68.70	228	2.40	2,736	28.81	9	68.70
Total	12,361	6,698	54.19	259	2.10	5,392	43.62	12	54.19

Source: CBS, 2012, Updated 2018

Table 4-7 shows a big gap between male and female literacy as almost 69 % percent of the male are literate compared to 54 percent female.

4.2 Economic Settings

The local economy is mainly focused on Agriculture, employment, industries, remittance. Most of the locals grow their own food, though many of them consume their products, few of them sell in the market. Families have engaged in multiple economic activities i.e. same family or the family members in addition to the agriculture also are employed elsewhere. Some of the families receive remittance in addition to the other occupation. Many of the people who have less or no land work as the daily wages labor in both agriculture and non-agricultural sector. Regarding the selling, the pattern is not consistent as the production plan are not made. If there is a surplus, they choose to sell in the market. Local governments are focusing on improving the infrastructure i.e. irrigation and market center.

4.2.1 Agriculture

The main occupation of the people of the rural municipality is agriculture. The agriculture practice however is primitive, traditional, and substantive. Not very many are interested in stepping up agriculture commercialization. Several houses across in wards are food insecurity. The following table 4-7 illustrates the status of food security.

Table 4-7: Status of food security

Ward no	Less than 3 months	3 to 6 months	6 to 9 months	9 to 12 months	Surplus food
1	93	125	176	195	258
2	56	261	212	64	133
3	147	191	462	78	137
4	225	404	394	184	112
5	165	300	404	194	113
6	145	90	247	232	299
7	128	203	236	75	170
Total	959	1574	2131	1022	1222

The table illustrates that almost 14% of population either do not have land or don't practice agriculture 23 % of family have food security less than 3 month, while the maximum 31 % of the family have food security lasting 4 to 6 month.

4.2.1.1 Food Production

The total agricultural land in Rural Municipality accounts 49.98 percent (5642 ha) out of that portion less percent of cultivable land is cultivated in which soil quality is suit for food and cash crops farming. But there is a lacking irrigation facility and most of the cultivated land is irrigated by rain fall. Most of the area of the Rural Municipality is fertile. The main cereal crops which grown in the area are rice, maize, wheat millet, pulses, and buckwheat. Similarly, mustard/ oil seeds, potato summer, winter and offseason vegetables, fruits like mango, banana, walnut, are main cash crops that need to the irrigation facility, organic farming methods and organic manure for obtaining maximum production annually. But no irrigation facility is available from managed irrigation system in limited area particularly in river basins and low-lying area. However, farmers have managed traditional irrigation system with own investment in negligible scale. Now, the Rural Municipality has initiated to lunch different irrigation projects in different stream/river basins. Thus, government and development partners must seek managed irrigation facility for enhancing the production of cultivated crops and productivity of per unit of agricultural land. Main cropping pattern with cultivated area of Rural Municipality has been presented in Table 4-10

Table 4-4: Main cropping pattern by area

SN	Class	Area_Ha	Area (%)
1	Garlic-Vegetable	2.80	0.05
2	Maize - Vegetable	147.29	2.61
3	Maize-Millet	217.51	3.85
4	Maize-Oilseeds	10.56	0.19
5	Maize-Potato	10.84	0.19
6	Maize-Pulses	27.42	0.49
7	Maize-Wheat	511.40	9.06
8	Rice-Buckwheat	182.42	3.23
9	Rice-Maize-Vegetable	1884.01	33.39
10	Rice-Potato-Vegetable	928.86	16.46
11	Rice-Wheat-Pulses	599.49	10.62
12	Rice-Wheat	523.96	9.29
13	Shrub from non-forest area	432.20	7.66
14	Vegetables-Others	2.89	0.05
15	Vegetables-Vegetable	160.89	2.85
	Grand Total	**5642.54**	**100.00**

Level Terraces Upland/Pakho Land Cultivation is done in 94% (5328 hectare), while Level Terraces Khet Land Cultivation 6% (314hectare). The cropping pattern is dominated by Rice-maize-vegetable. The existing cropping pattern clearly indicates that rice, maize, potato, and vegetables are main food crops.

4.2.1.2 Production of High Value Crops

The production is mainly divided into crop, pulses, and oilseed. According to the RM profile the cereal total crop production was 3665 quintals. The total maize production was 1555 quintal, wheat production was 72.69 quintal, millet production 709 quintal. Regarding the pulses, 31 quintal was produced. The oil seed was production was 463 kg. Regarding the vegetable 124.98 quintal was produced. Finally, 14.87 quintal of cash crop i.e., Mushroom, ginger, onion was produced.

4.2.1.3 Livestock farming

Livestock is an integral part of economy in Jwalamukhi Rural Municipality. The farmers of the Rural Municipality practices traditional subsistence mix crop farming and cattle rising.

However, the livestock farming is still subsistence. The livestock population by their types and number are presented in Table 4-12.

Table 4-5: Livestock population by types and number

Types of livestock	Number	Percentage
Cattle	9013	20.4
Buffalo	8196	18.6
Yak/ Nak/ Chauri	86	0.2
Sheep	4	0.0
Goat	26141	59.3
Pig	672	1.5
Total	44112	100.0

Source: Ministry of Agricultural Development, 2018; Field Study, 2019

From the Table 4-12 reveals that total number of livestock at Jwalamukhi Rural Municipality is 44112. Regarding the types of livestock that kept in the Rural Municipality, goat being in highest percentage (59.3%).

4.2.1.4 Poultry and Fish Farming

The food habit has changed towards increased consumption of poultry and fish production. To meet the increasing demand, local production is gaining a momentum. The farming is being done on smaller level. The household along the side of several rivers are increasing getting interest for the fish farming, whereas people with the less fertile land are opting for the poultry farming. This is one of the highly potential areas which can lure businesspeople. According to the RM profile, the fish farming is done in 5, 6 and 7 and the annual production is 1210 kg.

4.3 Employment/Occupation

National Economic Census was conducted in 2018 to assess the nature of the economic structure of the Nepali economy at preset and to provide comprehensive statistical information for policy makers, planners, researchers, business communities, and other users for policy formulation and development planning, research, and study. The findings of the study at Galchi RM have been listed below which explains the number of engagements.

Table 4-10: Status of people engaged in various sector.

Agriculture, forestry fishing 3)	Manufacturing	Mining, Electricity, Gas, Water supply & Construction	Wholesale and retail trade; repair of motor vehicles and motorcycles	Transportation, storage, Information, communication	Accommodation and food service activities	Financial and insurance activities	Education	Human health and social work activities	Real estate, Professi-onal, scientific, Administrative, Arts, enter-tainment and Other
519	216	7	512	7	144	111	507	130	50
23.56%	9.80%	0.32%	23.24%	0.32%	6.54%	5.04%	23.01 %	5.90%	2.27%

Source: National Economic Census, 2018

The above table shows that about 519 (24%) and 512 (23%) people are engaged in agriculture and wholesale and retail trade, respectively.

4.4 Industries

The study also explored for the sector and number of the establishment at employs people.

Table 4-11: Status of sector

Agriculture, forestry fishing)	Manufacturing	Mining, Electricity, Gas, Water supply & Construction	Wholesale and retail trade; repair of motor vehicles and motorcycles	Transportation, storage, Information, communication	Accommodation and food service activities	Financial and insurance activities	Education	Human health and social work activities	Real estate, Professi-onal, scientific, Administrative, Arts, enter-tainment and Other
74	123	2	267	2	71	19	47	24	19
11.42%	18.98%	0.31%	41.20 %	0.31%	10.96%	2.93%	7.25%	3.70%	2.93%

The study document 648 different establishment. The highest number of the establishment is wholesale and retail trade, whereas accommodation and manufacturing establishment were also found in significant number.

4.5 Remittances

Youth from across the wards have opted for the foreign employment. Annually, they send back remittances to their families. The remittance data are collected at the municipal level and not in the ward level. The discreet record of the remittance not available. Most the remittance are used for meeting rudimentary household needs i.e., food, education etc. Very few have used the remit money in the productive sector.

4.6 Source Income

The source of income is from a different source however finding from the assessment shows that the income is connected to the agricultural and related business dominates overall income. Nevertheless, no records are kept at the household level regarding the actual input and the income from the agricultural sector. Other sources of income are from government and private jobs. Now, there is an increasing trend of foreign employment and families back home are being supported with remittance. The following table illustrates different sectors.

Table 4-12: Source of income

Source	Income (NRs)	Percentage
Agriculture	7608	46.01%
Business/establishment	1060	6.41%
Jobs/Pension	3623	21.91%
Daily wages	1369	8.28%
Foreign employment	1653	10.00%
Professional work	78	0.47%
Unemployed	1143	6.91%

4.7 Potential Income Opportunities

There are several income opportunities in the municipal areas. The access to the road and the river holds several potential opportunities. The muncipality have big cities in the close proximity, so can be developed as the hinterland to cash to ever widening demand of the big cities. Other potential includes in the herbal exports and the tourism. To realize the potential, they have to overcome several challenges, some key challenges are unorganized settlements, depleting work force, poverty, poor awareness, poor infrastructure, lack of policy, high expectation, and unidentified sources.

CHAPTER 5 : INFRASTRUCTURE AND SERVICES

5.1 Road

The Rural Municipality have different type of road network. They are asphalt road, gravel road, earthen (dirt road) mule road and pedestrian one. The local road accounts for 78.24% area of the public services. The Rural Municipality reliable asphalt road connected with the district center nevertheless all wards of the Rural Municipality are connected by the earthen road. Travelling in those roads in rainy season is quite difficult.

Table 5-1: Status of various road

S.N.	Type	Length (km)
1	Black topped	0
2	Paved	0
3	Earthen road	125
4	Foot trail	35

5.2 Health

The Rural Municipality have health post and sub heath post. The health post is located in ward no 2 and 7, whereas sub health post is in ward no 4 and 5.

The status of health facilities is illustrated below.

Table 5-2: Status of various health facilities

S.N.	Type	Number
1	Govt Hospital	0
2	Maternity / Birthing center	2
3	Aurvedic hospital	0
4	Natural rehabilitation center	0
5	Health post	4
6	Primary Health Center	3
7	Private hospital	0
8	Pharmacy	0
9	Vet Hospital	0
10	Vet Center	0

The household sanitation level of the Rural Municipality is satisfactory. The status of toilet use in the Rural Municipality is illustrated below.

Table 5-3: Status of Toilets

Total HH	HH without toilet facility	HH with toilet facility of Flush toilet	Ordinary toilet	Toilet facility not stated
5730	951	2635	2130	14

CBS 2011 (updated 2018)

5.3 Drinking Water

In the Rural Municipality 59 % of the house have access to the piped drinking water. However, significant number of house access water from well, sprout and stream, such sources could get contaminated during the rainy season which could trigger water borne diseases. The following table illustrate the status.

Table 5-4: Status of Drinking water

Total household	Tap/ piped water	Tubewell / hand pump	Covered well/kuwa	Uncovered well/kuwa	Spout water	River /stream	Others	Not Stated
5730	3391	0	317	205	1637	99	67	14

CBS 2011 (updated 2018)

5.4 Electricity

The use of the electricity across the municipalities are on raise. In the Rural Municipality the use of electricity and other energy sources as follows

Table 5-5: Status of Electricity

Total HH	Electricity	Kerosene	Biogas	Solar	Others	Not Stated
5730	2758	1383	3	1109	463	14

CBS 2011 (updated 2018)

5.5 Education Institution

There are number of education institution in the municipalities. The education institution accounts for 8.61% area of public services the status of various institution is as follows.

Table 5-6: Status of education institution

Ward no	Basic	High secondary
1	9	0
2	1	2
3	2	2
4	5	1
5	4	3
6	4	2
7	3	2
Total	**28**	**12**

Source: RM Profile 2075

5.6 Financial institution

There are number of financial institutions providing the services in the Rural Municipality. There are several big and small financial institutions throughout the Rural Municipality. In addition to that, there are several single and multipurpose cooperatives actively engaged in the commodity and service sector.

- Bank – 1
- Microfinance – 1
- Cooperative - 29

CHAPTER 6 : HERITAGE, CULTURE AND TOURISM

6.1 Heritage

The heritage of the rural muncipality is mainly shaped by the religion and scared places. The demography is a mix-up of several cast, religion and culture i.e. Tamang. Brahmin, Chhetree and Christian also lives in the rural municipality. Several cultural events are celebrated with great enthusiasm by various religion. The municipalities is also famous for traditional wear of the inhabitants.

Some of the places in the rural municipality that people pay tribute are Chitre Kalika, Jwalamukhi Mandir, Maidi kot, Chainpur kot, Kalika mandir, Bangot ghat, Stanpati, Mahadevestar and Mantar carnival.

6.2 Culture

The Rural Municipality offers the one of the diverse communities in the district. Hence, culturally the Rural Municipality is diverse. Brahmin, Chhetree and Newar are the dominant group celebrate hindu festival and Gurung and Magar celebrate Losar together. There are number of religious shrines across the Rural Municipality, those places are visited by hundreds of devotee visits in sacred day.

6.3 Tourism

Many places can be developed for attract the tourist . Some of the notable places are Jwalamukhi mai, Dhola Mandali, Chainpur kot. In addition to that, one can have majestic view of Ganesh and Pawil mountain.

CHAPTER 7 : RISK IN THE STUDY AREA AND SAFE AREAS FOR SETTLEMENT

7.1 Flood Risk

Flood is one of the disastrous and vulnerable water induced natural disasters which occurs frequently in plain land, river valley and Terai region. Since the study area lies in mountain and valley this region usually bank cutting and landslide problem. River banks and low-level terraces face flood and inundation during high-flood events. The nearby settlement areas of one major Trishuli River and Malehnu Khola may face greater risk bank cutting and few areas are flooding and inundation. Time series analysis of river morphology shows that the Trishuli River is shifting some time right and left from river bank as low-level terrace areas. Mostly in Trishuli River right and left bank areas having the deep gorges with river valley which threats for flooding and bank cutting problem.

Aakhu Khola, cover the high risk 8.03 -hectare land, Medium risk cover 18.89-hectare land and Low risk cover about 2.74-hectare areas . Finally, the inundation assessemnt found the Ward No 7 in the flood risk areas of Jwalamukhi Rural Municipality.

7.2 Fire Risk

Fire risk can be viewed as the possibility of an unwanted fire hazard in an uncertain situation, where loss or harm may be induced to the valued, typically life, property, business continuity, heritage, and/or environment (Meacham 2001 2002). The fire risk is critical concern in Nepal during hot and dry period as well as sometimes it is associated with any time accidental cases of inflammable objects or sparking phenomena.

The area is in some risk of fire due to presence of forested area. Result showed that the region with area of 12.51% is high, 51.55% is medium and 35.94% low risk levels of fire. The risky areas are seen in considerable portions of the area and the rest of area lies in medium and low risk zones. Water bodies cover 184.42 ha and Table 3-4 shows the statistics of fire risk in terms of land use.

7.3 Landslide Risk

Landslide risk evaluation aims to determine the expected degree of loss due to a landslide and the expected number of live lost, people injured, damage to property and disruption of economic activity (Varnes 1984). Landslide is one of the most serious slope movements risk in the mountainous terrain of Nepal due to fragile geology, frequent extreme weather events and rugged topography.

Study area is susceptible to landslide occurrence due to topographic variation in elevated region. The result showed that the region with area of 1.31% is high, 42.12% is medium and 56.58% low risk levels of landslide . As the area is located in mountainous terrain, both high and medium risk level zones are susceptible to landslides.

7.4 Seismic Risk

Seismic hazard and risk describes natural phenomena caused by an earthquake that have the potential to cause harm, such as surface rupture, ground motion, ground-motion amplification, liquefaction, or induced landslide (Wang 2008). The seismic hazard and risk are two particularly important concepts in engineering design and other policy considerations. Although seismic hazard and risk have often been used inter-changeably, they are fundamentally different. Furthermore, seismic risk is more important in engineering design and other policy considerations. Seismic hazard assessment is an effort by earth scientists to quantify seismic hazard and its associated uncertainty in time and space and to provide seismic hazard estimates for seismic risk assessment and other applications (Wang 2010).

PGA value of the area comprises the values ranging between 250 and 350 gals comprising three zones of DMG seismic map and interpreting such value has showed the area is situated in seismic risk of low value . However, lower PGA value does not mean that it lies in low to moderate seismic risk zone because Nepal is located in seismically very active zone and always possesses risk of frequent earthquakes and their aftershocks. Table 3-7 shows statistics of seismic risk in terms of land use.

7.5 Industrial Risk

The presence of factories for their production activities in the territory exposes the population and surrounding environment to industrial risk. An industrial accident can in fact cause harm to population and territory. The problem related to industrial hazard is that diversification of risk type has increased in recent times. People staying nearby industrial estates in developing countries are more vulnerable, particularly in the absence of governmental facilities to cope with disasters.

Industries are not present as the area is just in growing phase of development.

7.6 Soil Erosion Risk

The displacement of the upper layer of soil refers as Soil Erosion. Soil Erosion can also be defined as one of the form of soil degradation and it is considered a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing a serious loss of topsoil.

The area is in considerable risk of soil erosion due to sloping lands during rainy season. The result showed that the area with 9.09% is high, 49.97% is medium, and 40.94% low risk levels . Table 3-10 shows the statistics of soil erosion risk in terms of land use.

7.7 Other Risk in the study area

Other risk in the area can be due to high tension line (HTL) and Glacial Lake Outburst Flood (GLOF). The HTL passes through the region may produce electromagnetic field with causing health hazard and abnormal functionality of equipment. The effect of high tension line should be minimized by avoiding of settlement or utilities within the influence zone on either side from the central line. Prehistoric record of GLOF event affected zones along the river course is potential for future risk.

Health Institutional Waste: The risk of health care waste is always from the infectious component, which can be transmitted as result of improper management of health care waste. Among the various types waste management, local or conventional type of options are in practice. During field survey, it is found that this rural municipality partly sorts out various wastes depending on material properties whether they are risky to human health or surrounding environment.

7.8 Safe Areas for re-settlement

Jwalamukhi is exposed to multiple hazards, so future development undertakings must take reference from the comprehensive risk assessment. The assessment has found public use zone for 315 hector, these places can be used for the evacuation purpose. Dhading was one of the hardest district in the 2015 earthquake, hence apart from enforcing building code, the rural municipality must conduct comprehensive assessment to explore the area for resettlement for the re-settlement.

FINAL REPORT

Preparation of Cadastral Layer Superimpose

Jwalamukhi Rural Municipality, Dhading District

Package No.: TSLUMD/CS/QCBS/01/07/2077/078

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CHAPTER 1 : INTRODUCTION

1.1 Background and Rationale

The development of a country depends mainly on the land and land related resources and its effective and efficient management which is only possible by implementing land use policies. In Nepal most people have excessive reliance on land and economic growth depends vastly on land and the related resources. All developmental efforts made for the overall development including social and economic changes, land or land resource is to be directly or indirectly mobilized, and without its appropriate management, building of a prosperous nation can never be imagined. As Nepal has a growing economic development a lot of development activities are being carried on. So, there is a need to balance between the developmental activities and land conservation.

Although Nepal is an agricultural country with majority of population still dependent on agricultural activities for livelihood, the agricultural land is now being used for residential and other purposes. This have caused reduction in agricultural productivity along with agricultural activities thus increasing the risk of food security. Thus the establishment of National Land use Project for the implementation and preparation of data and maps for implementation of National Land use Policy has been the primary focus of Nepal Government. In the context for the data preparation purpose with scientific evidences the division of land according to the current use and the future capability is identified with scientific evaluations. Some efforts have been made in past to divide lands based on productivity in past during the time of cadastral survey in which private lands were divided based on *biraha* and *kisim* in early 1960s, although this proves the history of land use classification at parcel level but these information were based on the eye judgement and lacked scientific evidences.

Land classification according to various economic uses has been an important database for government, planners and policy maker for long time. These data base can reflects the available resources and local need at the country level. Land use classification is the classifying land uses based on their characteristics. The land use classification is classifying land uses by refining traditional categories into various categories, such as Agricultural area, Residential area, Commercial area, Industrial area, Forest area and Public use area, based on scientific evidences. In this background the Government of Nepal has adopted National Land use Policy 2015 with a vision of achieving sustainable social, economic and environmental development through optimum use of land resources. For this purpose, it has assigned a goal of classifying the lands into different classes on the basis of landscape characteristics, quality of soil, capability, and needs. The classes are agricultural, residential, commercial, industrial, forests, public use and others. As this land use policy is on its way of implementation, data which is the most important and necessary infrastructure is obviously required. Understanding that only data driven decision making are the most effective ones, the project has decided to build data inventory of its own comprising of these most important indicators for identifying the lands' current use, the capacity it holds and the zone it belongs to.

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 2012 envisages land-use planning to be applied at three broad levels: national, district and rural municipality/municipality. 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 Municipality/ Rural Municipality 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 Municipality/Rural Municipality level. Similarly, the Land use Act, 2076 is also drafted by the Government of Nepal for the optimum utilization of land and land related resources through classification of land and effective management to achieve the sustainable benefit for the country. The act is drafted for the implementation of the land use policies in the current scenario of federalism in the country. This act provides a clear guideline for it, as it specifies the responsible for the each of the steps. The Act 5 states that land use maps of all the local levels should be prepared and handed over to local levels by the Ministry within a year of the formulation of the act. Thus, the land use maps of the local levels are being prepared. This act defines the new classes of land use which are agricultural, residential, commercial, mines and minerals, industrial, forests, public use, rivers lakes and wetlands, cultural and archeological and others

Similarly, as guided by the constitution of the country, the Land use Act, 2076 is also drafted by the Government of Nepal for the optimum utilization of land and land related resources through classification of land and effective management to achieve the sustainable benefit for the country. The act is drafted for the implementation of the land use policies in the current scenario of federalism in the country. This act provides a clear guideline for it, as it specifies the responsible for the each of the steps. The Act 5 states that land use maps of all the local levels should be prepared and handed over to local levels by the Ministry within a year of the formulation of the act. Thus, the land use maps of the local levels are being prepared. This act defines the new classes of land use which are agricultural, residential, commercial, mines and minerals, industrial, forests, public use, rivers lakes and wetlands, cultural and archeological and others.

Land use information at cadastral level is very essential and useful in visualizing and implementing land use zoning regulations in an area. Land use zoning is the classification of land use as per the development of real state of that area. It is defined as "the segregation of land use into different areas for each type of use such as agricultural, vegetation (forest), industrial, residential and recreational" In practice, generally, as per the policy of the central government, land use zoning regulation and restriction are implemented by the local government bodies to control and direct the development of property within their boundaries. Similarly, according the Act 7 of Land Use Act 2076, the land use fields in land ownership certificates are to be updated based on the prepared land use maps. Thus, the information related to the present land use and the land use zones are to be updated in every parcel.

1.2 Objectives of the Study

The broad objective of Topographical Survey and Land Use Management Division (TSLUMD) Package No.: TSLUMD/CS/QCBS/01/07/2077/078 is to prepare Rural Municipality level land use maps, soil maps, land capability maps, land use zoning maps and preparation of profile for land use zoning and cadastral layer superimposing for Dhading District of Nepal.

In order to fulfill the broad objective, the present study aims to prepare report, map and database of the superimposing of cadastral layers with land use zoning map of the study Rural Municipality. The specific objectives of the study are to:

- Classification of the cadastral parcels of the Rural Municipality according to existing land use and potential land use zoning;
- Preparation of superimposed map of cadastral parcels on land use zoning map of the Rural Municipality at 1:10000 scale;
- Preparation of GIS inventory on cadastral parcels together with current land use and zoning characteristics as well; and
- Preparation data model and reports suggesting and recommending the changes to be applied.

1.3 Study Area

Jwalamukhi rural municipality is in mid-western part of the Dhading District in Bagmati Province of Nepal. The rural municipality was formed on 10th March 2017 (2073/11/27) by merging four VDC units i.e. Khari, Dhola, Nepal, Maidi and Chainpur. Administratively, it is divided into seven wards. Politically, the rural municipality is placed under constituency no 2 for federal parliament and 2 (ka) for provincial parliament.

Jwalamukhi rural municipality shares border with three municipalities each in Dhading and Gorkha District. In the Dhading district, the rural municipality shares its border with Tripurasundari, Neelkantha and Siddhalek. Additionally, Shahid lakhan, Bhimsen and Gandaki municipality of Gorkha district are connected to the rural municipality. Geographically it extends from 84º 44' 3.07'' E to 84º 51' 22.92'' E and 27º 51' 25.51'' N to 27º 58' 52.45'' N. The total area of the rural municipality is 112.90 sq.km with the altitudinal elevation ranging from 333.84 m to 1343.14 m (Figure 1-1).

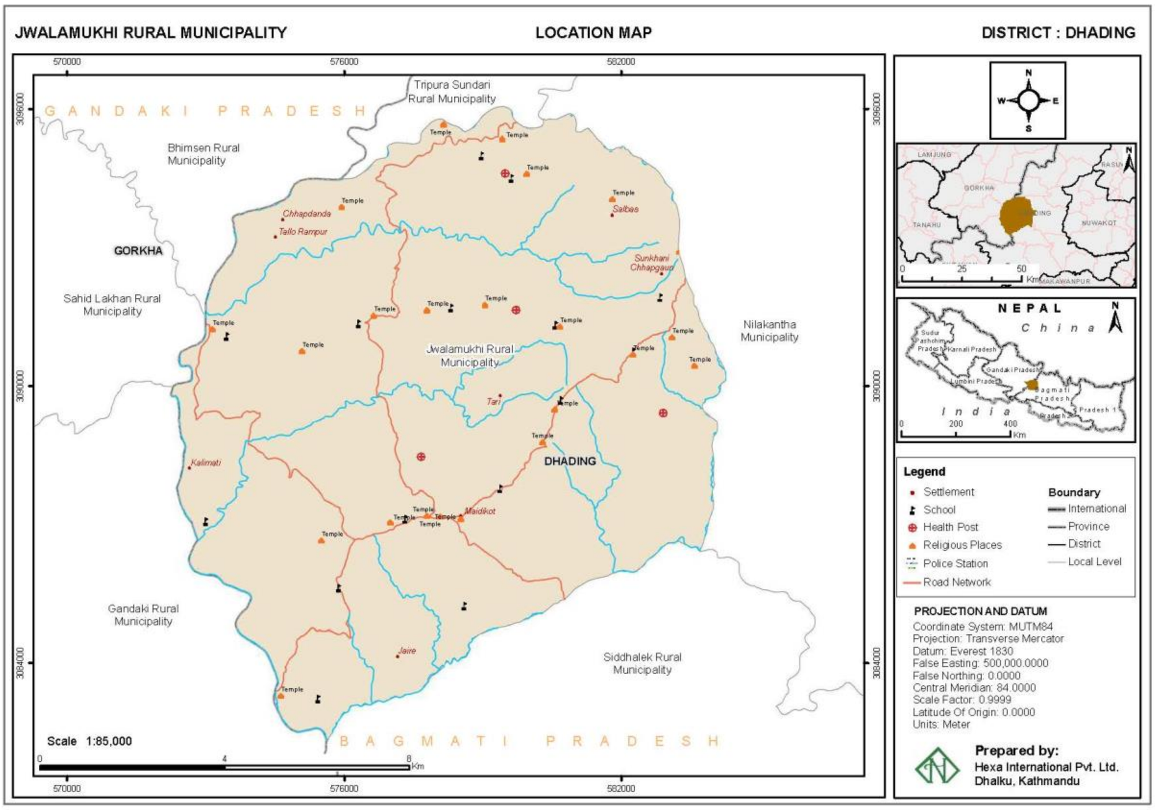


Figure 1-1: Location Map of the Study Area

As of census 2011, the population of the rural municipality is 32922. The total population of this Rural Municipality is 23966 of which male population is 10573 (44.1%) and female population is 13393 (55.9%). The total households are 5730 and the average family size of the Rural Municipality is 4.2. The Ward wise population distribution of the Rural Municipality has presented in Table 1-1.

Table 1-1: Population distribution by ward and sex

Ward No.	Household	Population						
		Total	Male	Female	Male %	Female %	Household Size	Ward
1	729	3,285	1,472	1,813	44.8%	55.2%	4.5	13.7%
2	693	2,796	1,275	1,521	45.6%	54.4%	4.0	11.7%
3	745	3,122	1,363	1,759	43.7%	56.3%	4.2	13.0%
4	998	4,033	1,772	2,261	43.9%	56.1%	4.0	16.8%
5	1,051	4,381	1,944	2,437	44.4%	55.6%	4.2	18.3%
6	802	3,439	1,477	1,962	42.9%	57.1%	4.3	14.3%
7	712	2,910	1,270	1,640	43.6%	56.4%	4.1	12.1%
Total	**5,730**	**23,966**	**10,573**	**13,393**	**44.1%**	**55.9%**	**4.2**	**100.0%**

Source: CBS 2011(Updated 2018)

Table 1-1 shows that the ward wise population distribution pattern varies across the rural municipality. The highest population is in ward 5 (18.3%) % whereas the ward no 2 have lowest percentage i.e. of population 11.7 %. Similarly, Ward 1 have highest household size i.e. 4.5 and the ward no 2 and 4 have the lowest household size i.e. 4.0.

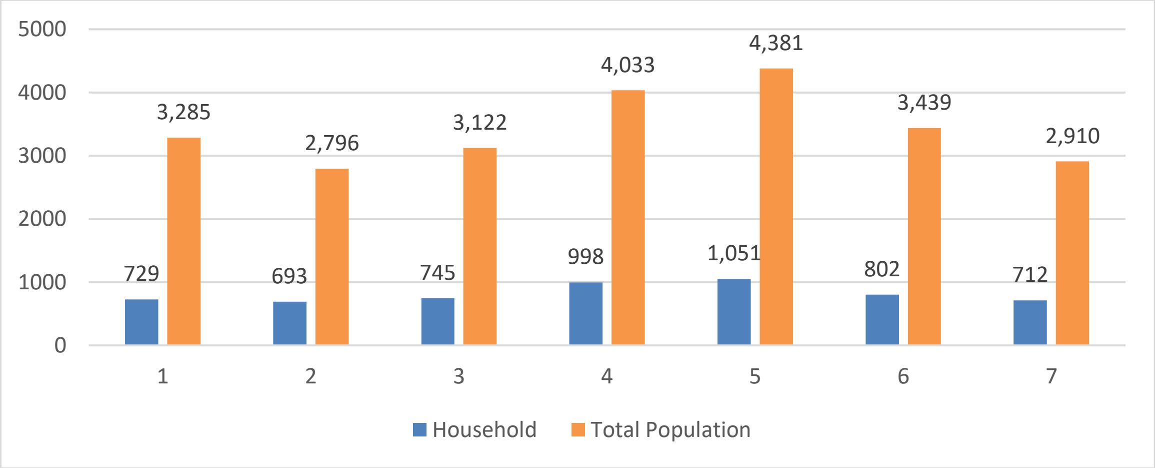


Figure 1-2: Population distribution by ward and sex

CHAPTER 2 : CONCEPTUAL BASIS OF CADASTRAL LAYER SUPERIMPOSE

2.1 Concepts

The present chapter describes the conceptual basis behind the superimposing of cadastral layer on land use zoning data.

The groundwork of superimposing the land use zoning in cadastral layer is useful for implementation of goals of land use policy. The goals express the government policies on land use, citizen's right, housing, natural resources, and local comprehensive planning. These national policies and law help local level bodies like Rural Municipality or Municipality of the county to develop a comprehensive plan and implementation of the plan. Local governments can do the planning and administer most of the land use regulations that 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 two components: a cadastral layer as base and a land use zoning layer for implementation of land use policy. The cadastral layer data and related land information show the spatial location of the land parcel and legal rights of land owners including the land fragmentation process within existing land-laws. Land use zoning determines the types of land use activities that occur on that land, such as agriculture, forest, residential, commercial, industrial and public activities. Land use zoning visualizes both the current situation of land and proper planning for future.

2.2 Spatial Functions related to Spatial Database

The overlay process of two digital spatial data layers such as cadastral and zoning map having same reference system would lead to the preparation of composite map and data bases (Figure 2-1). It leads to the generation of a new set of polygons (and attributes) that explain the relations existing between the two inputs of spatial data (i.e. Land use zone class and parcel id).

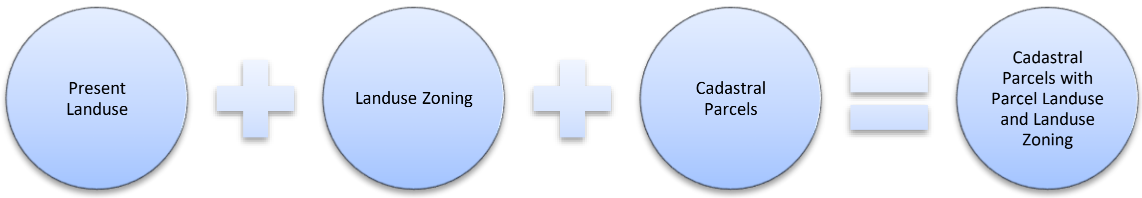


Figure 2-1: Spatial Function related to Spatial Databases

2.3 Attribute Data Management

Attribute database management is accomplished through establishing graphic/ alphanumerical relations between graphical and alphanumerical databases. This connection is based on the use of a GIS internal table as a linkage with other tables in external databases. The set or collection of data that describes the characteristics of real-world entities or conditions is too large to be stored in a single table associated with the graphic elements. This data are usually managed by a relational database management system (RDBMS). The usual procedures are based in the connection of each graphical element to a line of a column of the alphanumerical table containing its attributes (record). This action can be performed automatically or not depending on the use of GIS software. The schemas of attribute table used for superimposing land use zoning map on cadastral layers are prepared and managed in GIS environment.

In the DOLIA system, the schema of the cadastral parcel feature (spatial data) is as shown in the following table:

Table 2-1: Schema of Cadastral Parcel Feature Class in the database of DOLIA

Field Name	Data Type	Description
ObjectID	Object ID	Unique object ID
Shape	Geometry (Polygon)	Geometric object type e. g. Point, Line, Polygon etc.
PARCELKEY	String (Length = 23)	Unique parcel key
PARCELNO	Integer	Parcel number as in cadastral map
DISTRICT	Integer	District ID
RM/M	Integer	Rural Municipality /Municipality Code
WARDNO	String (Length = 3)	Ward number
GRIDS1	String (Length = 9)	Grid sheet number in case of Trig sheets, and in case of island map sheet e. g. Ka, Kha etc.
PARCELTY	Integer	Parcel type code as specified by DOLIA (e.g. river, track, ravine, pine etc.)
Shape_Length	Double	Number representing perimeter of the polygon
Shape_Area	Double	Number representing area of the polygon
ParcelNote	String	

Likewise, the database for cadastral parcel feature class for superimpose on present land use and land use zones, as per the specification of Survey Department, is as given in the table below:

Table 2-2: Schema of Cadastral Parcel Feature Class as per Survey Department Specification

Field	Data Type	Description	Remarks
FID	Object ID	Feature	
SHAPE	Geometry	Geometric Object type	
Id	Long	Unique Object ID	
PARCEL_NO	Integer	Parcel number as in cadastral map	DOLIA
AREA	Double	Parcel Area in m^2	DOLIA
DISTRICT	Integer	District Code	CBS
RM/M	Integer	Rural Municipality /Municipality Code	CBS
WARD	String	Ward number	DOLIA
GRID_SH	Integer	Grid sheet number	DOLIA
PARCEL_KEY	String	Unique parcel key	DOLIA
PARCEL_TY	String	Parcel type (i.e. government, private, etc.)	DOLIA
SHEET_NO	String	Sheet number (e.g. Sheet3ga)	DOLIA
PRE_LU	String	Present Land Use Type	
LU_ZONE	String	Land Use Zoning Type	
LAND USE_ZONE	String	Land Use Type and Land Use Zone	

CHAPTER 3 : METHODOLOGY

3.1 Cadastral Maps

The cadastral data for the former VDCs of Dhading district were obtained from the survey Department. The digital copies of island cadastral maps in digitized vector format with the attribute database having schema as stated earlier. The digital cadastral maps were available in national co-ordinate system. The methodology of the adjustment and overlay is presented in Figure 3-1.

Similarly, the land use zoning maps for the study area is prepared under the separate components of the project (refer land use zoning report for detail). The land use zoning map of the Jwalamukhi Rural Municipality contains a detailed category of zones.

3.2 Scanning

Scanning is the process to convert hard-copy paper maps into digital format so that it can be further processed in the computer. Once scanned, the image is converted into digital raster file which can be processed in specialized software like GIS to convert the map features into vector files. For this purpose, the cadastral maps acquired were scanned in high resolution so as to get maximum details to facilitate heads-up digitizing and ensure maximum accuracy.

3.3 Geo-referencing of Cadastral Data

Since the cadastral maps of the former VDCs in the Rural Municipality were in National coordinate system, the overlay analysis was easily performed using GIS tools. No adjustments were necessary for these map sheet as they already possessed the geo-reference. These coordinate systems exactly match the coordinate system used for the land use and land use zone data. The details of the coordinate system used are presented in Table below.

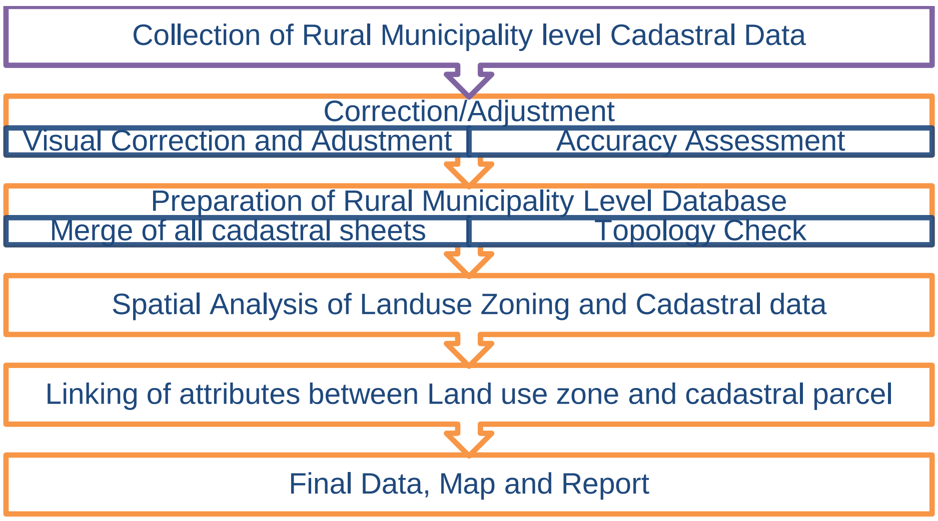


Figure 3-1: Schematic Diagram of Methods Adopted

Table 3-1: Parameters used for Geo-referencing of Cadastral Layers

S.N.	Parameters	Description
1	Projection	Modified Universal Transverse Mercator
2	Spheroid	Everest 1830 (Adjustment 1937)
3	Semi-Major axis	a=6377276.345m
4	Semi-Minor axis	b= 6356075.413
5	1/f	300.8017
6	Central Meridian	81°E
7	False Coordinate at origin	500,000 m E, 0 m N
8	Scale Factor at Central Meridian	0.9999

3.4 Digitization and Preparation of Digital Data

It is used for checking and cleaning up the vector layer cadastral data so that the cleanup data should always be valid. Examination of it can be used to give a measure of the overall data quality in vector layer of the cadastral data. Thresholds for data quality may be set for acceptance criteria and it may state the type for particular object in cadastral dataset. Examination of it can be applied to various aspects of the data held in GIS; be that topology, connectivity, position or attribute information. If the data validation is acceptable then these data are used for preparing seamless dataset of Rural Municipality level, otherwise there is need for repeating the process.

3.5 Accuracy Assessment of the prepared Dataset

The prepared and geo-referenced cadastral maps are assessed to check their correctness to the ground features through two level of assessments. The first stage of assessment being the check of important features like parcel corners of larger parcels, roads, rivers by overlaying them on the satellite images. The second stage of verification is done for the map sheets which couldn't be verified through satellite image-based method. This method of verification is field based verification method where field maps are prepared by printing the adjusted cadastral maps and the measurements are made based on features clearly identified on map. The adjusted maps will be re-adjusted if required according to the measurements from field.

3.6 Preparation of Rural Municipality Level Seamless Cadastral Dataset

A ward level seamless cadastral dataset of vector cadastral layer is prepared by spatial analysis process of merging in GIS environment. Similarly, Rural Municipality level seamless cadastral dataset is prepared with ward wise seamless cadastral datasets. Overlapping and gap between the individual cadastral island maps have occurred in the spatial merging. However, these errors are eliminated with the building topology within the permissible limit of threshold.

3.7 Superimpose of Rural Municipality Level Seamless Cadastral Dataset on Land Use Zoning Map

Rural Municipality level land use zoning map of the study area and Rural Municipality level seamless cadastral datasets are overlaid using the overlay spatial analysis function in GIS environment. At the time of overlay process, caution is taken to maintain three different topology functions. These are:

- Must not overlap
- Must not intersect
- Must not contain

Production of data, map and report: The whole process described in this section has resulted in a composite data base and maps and the elaboration is documented in the form of report.

3.8 Linking Attribute of Land Use Zoning and Present Land Use with Cadastral Parcel

The attribute of land use zoning and present land use were linked with the cadastral parcels so as to understand which parcel belong to which land use and land use zone classes. The details are described in next section.

CHAPTER 4 : CHARACTERISTICS OF THE SUPERIMPOSE OF CADASTRAL DATA

4.1 Cadastral Parcel Superimpose on Present Land Use

A total of 28469 parcels were recorded in Gangajamuna Rural Municipality. Total 24601 parcels (86.41% parcel number) are found to be occupied by Agricultural zone. With 3576 parcels (12.56% parcel number). All other Land Use areas are scarcely present.

Table 4-1: Cadastral Parcels with respect to Present Land Use

S.N.	Land Use	Parcels	Percentage
1	Agricultural	24601	86.41
2	Residential	3576	12.56
3	Commercial	25	0.09
4	Industrial	0.00	0.00
5	Mines and Minerals	0.00	0.00
6	Forest	104	0.37
7	Riverine, Lake and Marsh	56	0.20
8	Public Use	102	0.36
9	Cultural and Archeological	5	0.02
10	Others	0.00	0.00
	Total	**28469**	100

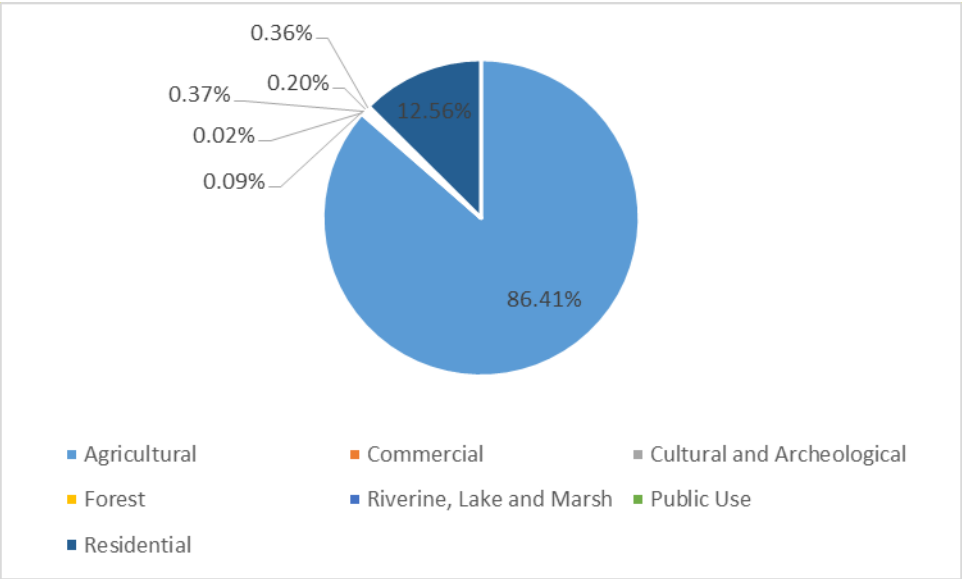


Figure 4-1: Parcel Area under various Present Land Use

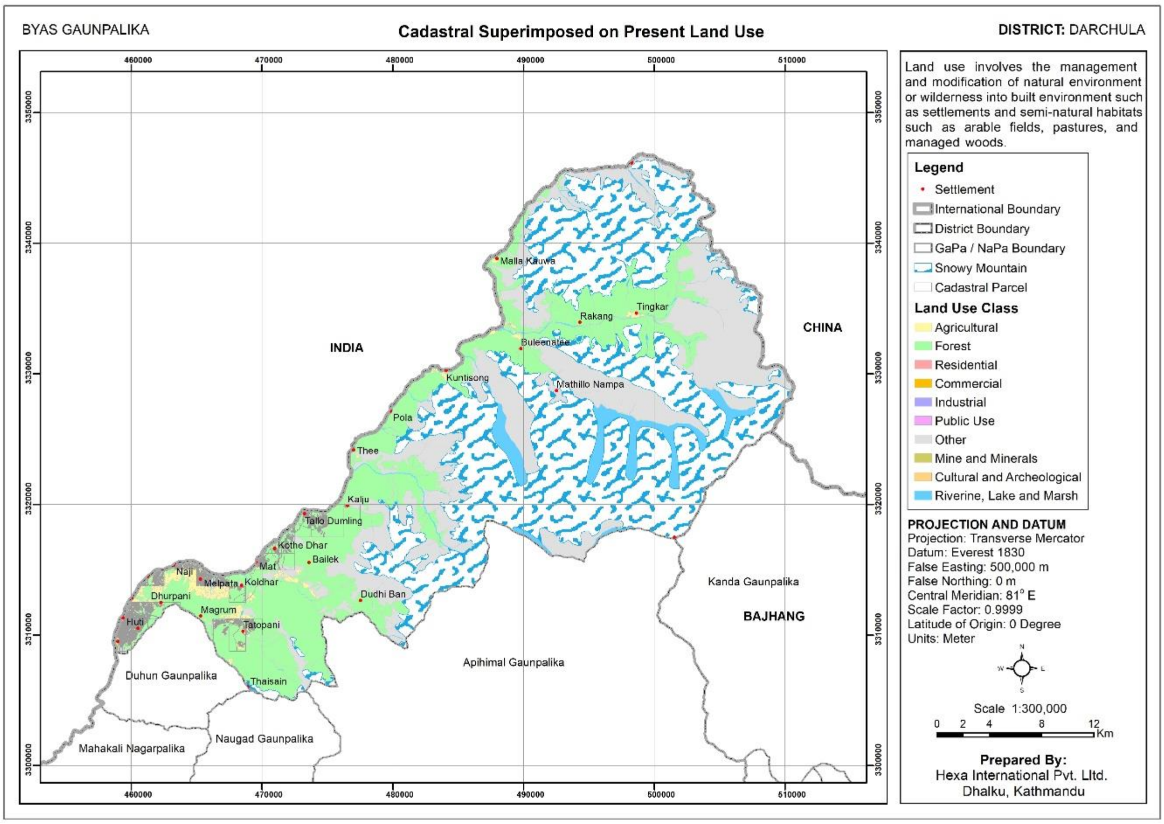


Figure 4-2: Cadastral Parcels Superimposed on Present Land Use Map

4.2 Cadastral Parcel Superimpose on Land Use Zoning

In the resulting zones the maximum area of parcels lies in Agriculture zone (82.76% by parcel area) followed by Residential zone (13.29% by parcel area). The number of parcels in different land use zones is shown in following table.

Table 4-2: Cadastral Parcels with respect to Land Use Zoning

S.N.	Land Use Zoning	Parcels	Percentage
1	Agricultural	23561	82.76
2	Residential	3783	13.29
3	Commercial	113	0.40
4	Industrial	34	0.12
5	Industrial	0.00	0.00
6	Forest	104	0.37
7	Riverine, Lake and Marsh	57	0.20
8	Public Use	812	2.85
9	Cultural and Archeological	5	0.02
10	Others	0.00	0.00
	Total	**28469**	**100**

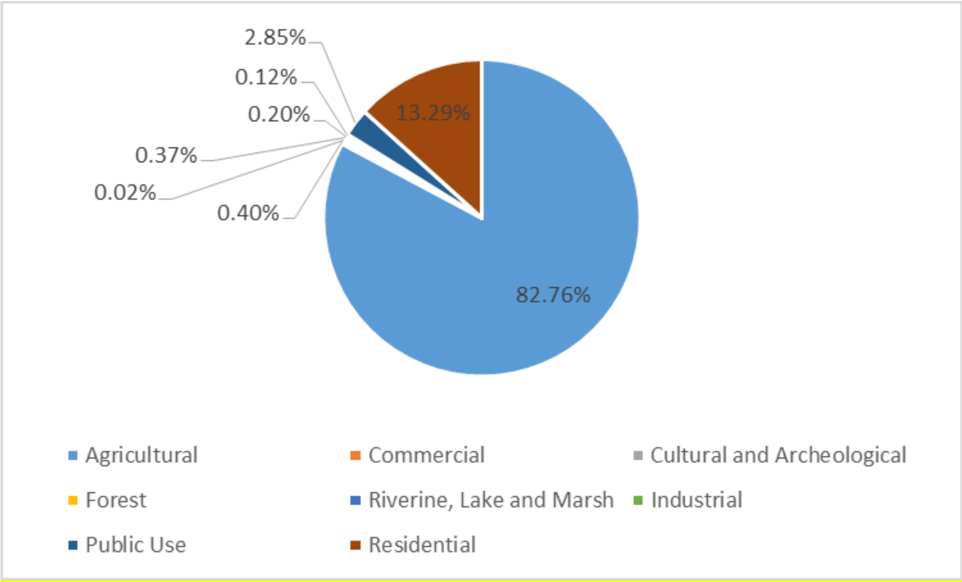


Figure 4-3: Area of Cadastral Parcels under various Land Use Zones

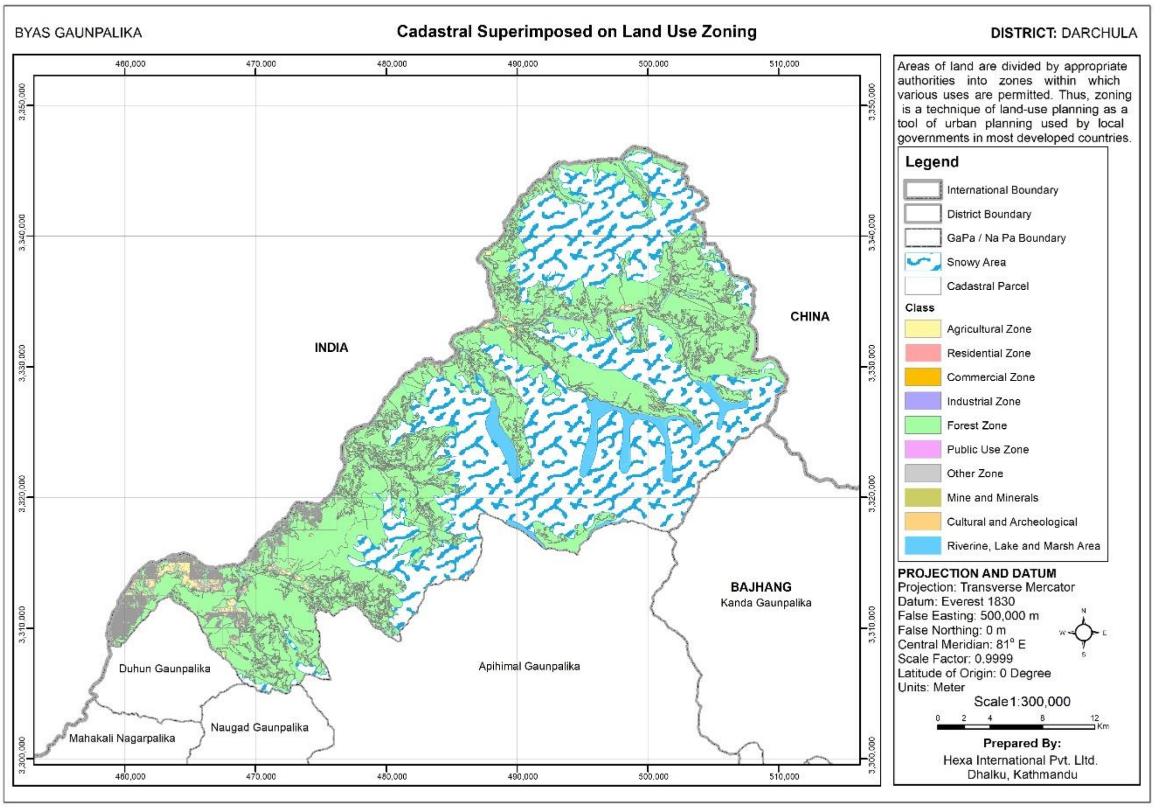


Figure 4-4: Cadastral Parcels Superimposed on Land Use Zoning Map

The list depicting the change from present land use to land use zoning is given below.

Table 4-3: Change of Present Land Use to Land Use Zoning

Classes (Landuse/Zoning)	Area (ha)	Parcels
AGR	**4563.71**	**24601**
AGR	4428.63	23544
COM	1.05	16
FOR	3.17	1
HYD	0.29	1
IND	4.91	34
PUB	45.88	417
RES	79.79	588
COM	**1.15**	**25**
COM	1.07	19
PUB	0.09	6
CULARCH	**0.34**	**5**
CULARCH	0.34	5
FOR	**829.35**	**104**
AGR	11.44	1
FOR	817.91	103
HYD	**17.31**	**56**
HYD	17.31	56
PUB	**7.29**	**102**
PUB	7.29	102
RES	**307.80**	**3576**
AGR	2.01	16
COM	4.53	78
PUB	21.33	287
RES	279.92	3195
Grand Total	**5726.96**	**28469**

CHAPTER 5 : CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

As guided by the Land Use Act 2076, the implementation of the land use at the local levels a detailed plan of cadaster-based land use and land zone is very essential and for this parcels-based land use and land use zone are to be identified. To achieve this purpose initially the cadastral maps were identified, adjusted, overlay analysis was performed and then verified with accuracy assessment. The parcels are categorized to their respective land use and land use zone. Similarly, the change of the parcels from one land use to other land use zone are noted and reported. The implementation of the National Land use Policy and the Land Use Act 2076 is supported by these data and reports.

Although the identification of a parcel’s current land use and land use zone the overlay of cadastral parcel is very important over the present land use and land use zone for the implementation purpose but some cadastral parcels don’t necessarily lie within same present land use and land use zone. This situation is very likely as majority of parcels have more than one use and are possible to lie in more than one land use zone, thus the statistics showing the number of parcels lying in certain land use/land use zone doesn’t necessarily provide the exact figure.

Similarly, the administrative boundaries have been changing time and again due to the restructuring of the state. Hence since the time of cadastral survey, the names as well as boundaries doesn’t match with the current administrative boundaries which creates problems in adjusting the cadastral sheets. Similarly, there lacks the proper documentation indicating the name of the current administrative units and older administrative units. In addition to this cadastral survey has not been done for the areas like Forest, River basins etc. The situations of land are changed considerably at present that at the time of cadastral survey and those changes have not been accommodated in the cadastral system.

5.2 Recommendations

The following are some of the recommendations drawn from this study that will be helpful in implementation purpose:

- A mechanism of development of the updating the parcels along with the transaction of the parcels is required for the time before the implementation by the local level, similarly after the implementation the parcel fragmentation should be guided by the zones the parcel lies on the data which also supports the government's decision to restrict the parcel split for the parcels lying in the agricultural land, to prevent the loss in agricultural land and thus for food security, it is recommended to identify the agricultural lands through these datasets. As in practice the *biraha* and *kisim* listed during the time of survey is being used as reference.
- A single parcel doesn’t necessarily lie in a single land use or land use zone thus the classification of a parcel into a single class is very difficult and currently the weighted values are considered. Instead all the classes should be listed in that parcel’s attribute which only can signify the true meaning of cadastral superimpose. To

overcome the problem a detailed parcel-based land use map per local level is to be prepared taking these data and maps as base and verified on the field.

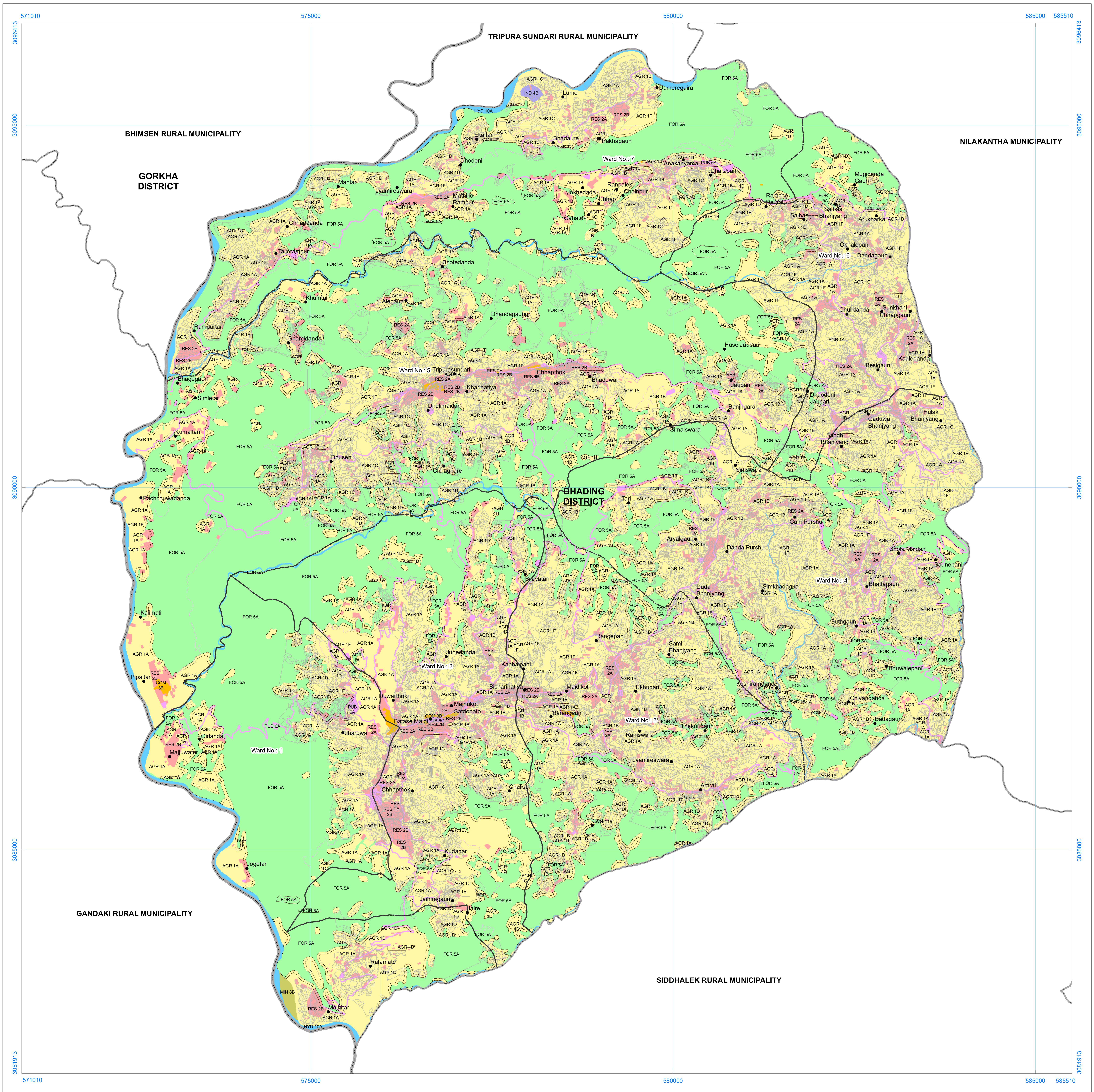
- Cadastral survey has been done in the late 60s and yet to be done for the areas like Forest, River basins etc. The situations of land are changed considerably at present than that of the time during cadastral survey and those changes have not been accommodated in the cadastral system. For example, the newly constructed roads have not been updated in cadastral maps and thus in data. Upcoming cadastral survey and mapping should be integrated with national geodetic control network also including the present land use as per the ground reality in the map itself, similarly also updating the land use condition upon any update in field by respective local levels.
- For the cadastral level administration of the land use policy the maps and reports prepared are to be used. If the implementation takes more time than expected it is recommended to revisit the present land use of the project area along with the updates on the cadastral data. As the land use zone is also depended on the present land use thus land use zone data is also recommended to be revisited.

TABLE OF CONTENTS

JWALAMUKHI RURAL MUNICIPALITY

CADASTRAL SUPERIMPOSED ON LAND USE ZONING

DHADING DISTRICT



Legend

Land Use Zones

- Zone 1 - Agricultural
- Zone 2 - Residential
- Zone 3 - Commercial
- Zone 4 - Industrial
- Zone 5 - Forest
- Zone 6 - Pubic Use
- Zone 7 - Other Zone
- Zone 8 - Mine and Minerals
- Zone 9 - Cultural and Archeological
- Zone 10 - Riverine,stream, Lake and Marsh Area
- Snowy Mountain Area

Boundaries

- International
- District
- GaPaNaPa
- Ward
- Settlement
- Mines Location
- Cadastral Parcel

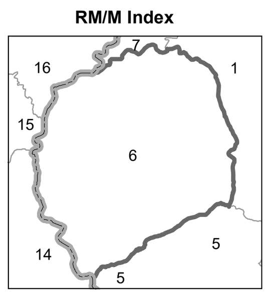
Note: Land Use Classes are classified according to Land Use Act 2076.

*Snowy Mountain Area stands for area of mountaineous region, with 12 months of snow coverage. It should be understood as public use area explained in Land Use Act 2076 and Land Use Policy 2072.

Risk Boundaries

Flood	Landslide	Fire	Seismic	Other
High	High	High	High	High
Medium	Medium	Medium	Medium	Medium
Low	Low	Low	Low	Low

RM/M Index



1. Nilakantha Municipality
5. Siddhalek Rural Municipality
6. Jwalamukhi Rural Municipality
7. Tripura Sundari Rural Municipality
14. Gandaki Rural Municipality
15. Sahid Lakhan Rural Municipality
16. Bhimsen Rural Municipality

District Index

Province Index

Land Use Zone 1 Sub-class	Land Use Zone 2 Sub-class	Land Use Zone 3 Sub-class	Land Use Zone 4 Sub-class	Land Use Zone 5 Sub-class	Land Use Zone 6 Sub-class
Cereal Crop Production Area -1A Cash Crop Area -1B Horticultural Area -1C Animal Husbandry Area -1D Fish Farming Area -1E Agro Forestry Area -1F Other Agriculture Area -1G	Existing Residential Zone - 2A Potential Area for Residential Zone - 2B	Service Areas - 3A Business Area - 3B	Areas under Industrial Use - 4A Potential Area for Industrial Use - 4B	Existing Forest - 5A Potential Area for Forest Including Barren Lands, Wet Lands - 5B	Areas Under Roads, Railways etc. - 6A Areas Under Hydrography - 6B Cultural, Archeological and Religious Areas etc. - 6D Public Health, Education Library, Police Station, Fire Station, Telephone, Electricity Areas etc. - 6E Grazing Land - 6F Open Spaces, Picnic Spots, Recreational etc. - 6C Government Instutional Area - 6G
	Land Use Zone 7 Sub-class Other Areas	**Land Use Zone 8 Sub-class** Existing Mine and Mineralsl Zone - 8A Potential Area for Mine and Minerals - 8B	**Land Use Zone 9 Sub-class** Existing Cultural and Archeological Area - 9A Potential Cultural and Archeological Area - 9B	**Land Use Zone 10 Sub-class** Areas Under Riverine Stream, Lake and Marsh - 10A Potential Riverine Stream, Lake and Marsh Area - 10B	

Criteria Applied in Delineating Land Use Zoning Boundary

-Existing (present) land use

-Land capability and land system identified by the analysis of soil characteristics (PH value, Nitrogen, Phosphorous, Potash etc), soils moisture, temperature, drainage, irrigation, slope, elevation, aspect, topography etc

-Suitability identified on the basis of the neighborhood and spatial analysis (distance from roads, markets, settlements, river and stream, and hazards like landslide, flood, seismic, fire, industrial etc.)

Concept Applied in the Zoning:

- Classification of land into Agricultural area, Residential area, Commercial area, Industrial area, Forest area, and Publicuse area .
- 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.

TYPE LEGEND SAMPLE

Land Use Zone Classification

2A 2B

Existing Residential Area Potential Residential Area

Scale 1:29000

0 800 1600 3200 4800 Meters

Land Use Zoning map is based on the ortho-rectified satellite image produced through the fusion of ZY-3 MSS 5.8 meter and Panchromatic 2.1 meter spatial resolution acquired on 2020. Basically the zoning was based on subjective analysis of Present Land Use, Land capability and Socio-economic setting of the study area. Land capability map was produced based on the Soil analysis, Land System and Present Land Use. Soil information for Land Capability was collected from the soil samples which were chemically analyzed in the soil laboratory. Location for the soil pit for sample collection was identified by defining the land unit which were defined by delineating the Land System over the high resolution satellite imagery data. Present Land Use was also considered while defining the boundary of land zoning. Extensive field study was carried prior to delineating to have better understanding of the social setting of the study area. The minimum mapping unit adopted is 0.25 hectare.

Projection and Datum Information
Projectiion: Modified Universal Trasnverse Mercator
False Easting: 500000 m
False Northing: 0 m
Central Meridian: 84 Degree East
Scale Factor: 0.9999
Latitude of Origin: 0 Degree
Linear Unit: Meter
Datum: Everest 1830

Government of Nepal
Ministry of Land Management, Cooperatives and Poverty Alleviation
Survey Department, Topographical Survey and Land Use Management Division
Kathmandu

Prepared by:
Hexa International Pvt. Ltd., Dhalku, Kathmandu

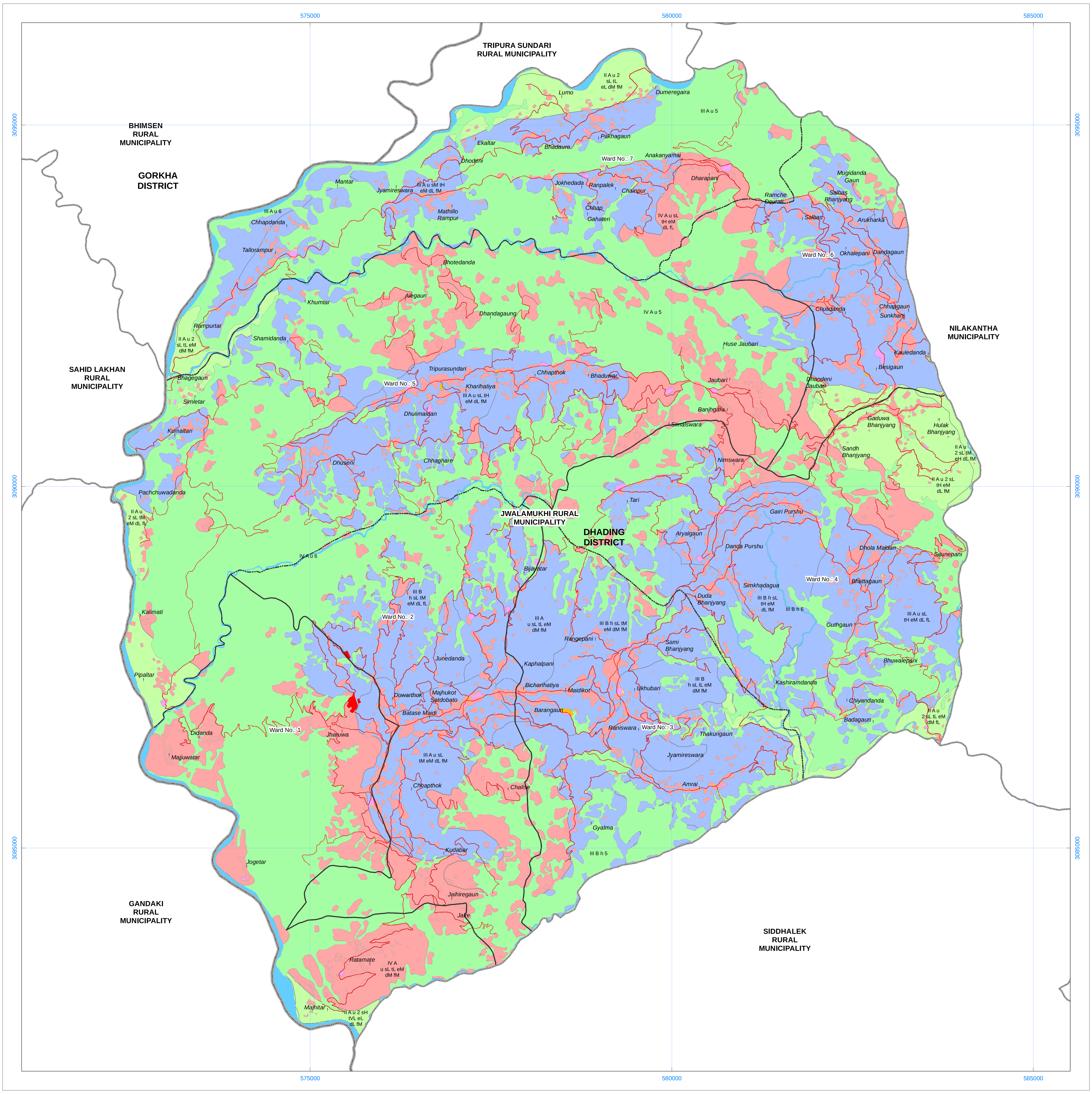
N W E S

International boundary shown in this map series does not suffice for validating the actual boundary line that exists on the ground.

Jwalamukhi Rural Municipality

LAND CAPABILITY MAP

DHADNG DISTRICT

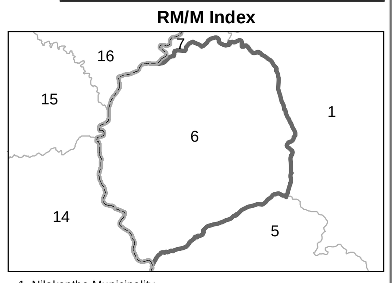


Legend		
Land Capability Class		
I	Non Arable	
II		Forest
		Residential
		Commercial
III		Mine and Minerals
		Public Use
IV		Industrial
		Snow Area
V		Sand
		Road
VI		Cultural and Archeological
VII		Riverine Stream, Lake and Marsh Area
Unclassified		

Settlement and Boundaries

- Settlement
- International Boundary
- District Boundary
- RM/M Boundary
- Ward Boundary

RM/M Index



1. Nilakantha Municipality
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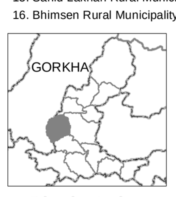
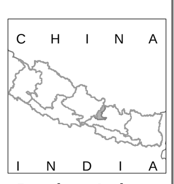


District Index



Province Index

Land Capability Sub Classes	Land Capability Sub Divisions	Crop Suitability
Subtropical areas- A	Arid moisture regime- a	Diversified Crops – Arable- 1
Warm temperate areas- B	Semiarid moisture regime- s	Diversified crops - Arable (Moderately Suitable)- 2
Cool temperate areas- C	Subhumid moisture regime- u	Wetland Rice-Arable (Suitable)- 1R
Alpine areas- D	Humid moisture regime- h	Wetland Rice – Arable (moderately suitable)- 2R
Arctic areas -E	Perhumid moisture regime- p	Non-Arable (Tentative)- 5
		Non-Arable- 6

Soil Deficiency (s)*

Range	Suitability Level
Very High Soil Deficiency (sVH): 0-18:	Very Low Suitability
High Soil Deficiency (sH): 18-36:	Low Suitability
Medium Soil Deficiency (sM): 36-54:	Medium Suitability
Low Soil Deficiency (sL): >54:	High Suitability

Topographic Deficiency(t)*

Range	Suitability Level
Low Deficiency (Flat to gently sloping [< 3°]: tL):	High Suitability
Medium (Sloping to moderately steep [3°- 14°]: tM):	Medium Suitability
High Deficiency (Steep [14° - 28°]: tH):	Low Suitability
Very High Deficiency (Very steep [> 28°] :tVH):	Very Low Suitability

Drainage Deficiency(d)*

Range	Suitability Level
Very High Deficiency (Poorly Drained = dVH):	Low Suitability
High Deficincey (Drained = dH):	High Suitability
Moderate Deficiency (Moderately Drained = dM):	Medium Suitability
Low Deficiency (Moderate to Well = dL):	Low Sutability
Very Low Deficinecy (Well Drained = dVL):	Very High Suitability

Erosion Deficiency(e)*

Range	Suitability Level
Sheet & Splash erosion (Low Deficiency: eL):	High Suitability
Rill erosion (Medium Deficiency : eM):	Medium Suitability
Rill/Gully erosion (High Deficiency : eH):	Low Suitability
Soil slump/Mass movement (Very High Deficiency: eVH):	Very Low Suitability

Soil - Fertility Rating(f) *

Range	Suitability Level
High Soil Deficiency (fH): <36:	Low Suitability
Medium Soil Deficiency (fM): 36-46:	Medium Suitability
Low Soil Deficiency (fL): >46:	High Suitability

Land Capability Description

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). 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. Lands are grouped into seven classes and five sub-divisions according to their opportunities, limitations and hazards for different sustainable usages in LRMP land capability classification system. Land suitability for arable agriculture and forestry uses are emphasized; thus the class arrangements shows the decreasing suitability/opportunities for use as well as decreasing intensity of use. There are seven classes assigned as “Class I” to “Class VII”, according to the order of opportunity each class offers. For example, Class I land has the very less limitations for arable agriculture or forestry development usages. The categorization of classes are influenced by the land system and soil units.

The subclasses of land capability are based on distinct temperature regimes according to elevation breaks. The subclasses are categorized into five climatic regime groups’ viz. sub-tropical, warm temperature, cool temperature, alpine, and arctic. These subclasses are further differentiated to represent major climatic moisture regime zones, which are arid, semiarid, sub-humid, humid, and per-humid.

Each land capability unit for Class I and Class II is further designated with irrigation suitability. By applying the United States Bureau of Reclamation (USBR) land classification framework, modified for local conditions, the irrigation suitability classification is done. Irrigation suitability classes are further sub-classified on the basis of deficiency in soil, topography or drainage conditions, which attributes to the arability of land.

Class I
This land 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 or forestry land uses. 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. 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, the erosion mitigation and river embanking works are required.

Class II
Class II is characterized as gently sloping (1-5 degrees) and soil stratum is deep and well to moderately well drained. No limitations exist in this class for well managed forestry for timber, fuel wood and fodder production or pasture development. When land of this class is used for arable agriculture, terracing and contouring are required to control soil erosion and suitable provisions are required for controlling surface runoff and drainage waters. Major 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.

Class III
Land in this class is characterized as moderately to steeply sloping (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 flow and river bank failures. There are few limitations in this class of land for the forest development 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 arable agriculture, terrace is compulsory to control erosion. Class III land cultivation is done making terraces, which is 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.

Class IV
Class IV lands are characterized by soils more than 20cm deep and well to imperfectly drained lands which are too steep (>30o slopes) to be profitably terraced and cultivated, too cold to be cultivated or prone to gully erosion and flooding. These lands are best suited for all 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.The major area 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.

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 meters, the natural steppe country in the shadow of the Himalayas and active flooding alluvial plains are the three major Class V lands in Nepal. 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.

TYPE LEGEND SAMPLE

Land Capability Classification

II	A	h	1R	tH	sL	dL	eH	fH
Land Capability Class	Land Capability Sub Class	Land Capability Sub Divisions	Crop Suitability Arability	Topographic Deficiency	Soil Deficiency	Drainage Deficiency	Erosion Deficiency	Fertility Rating

Class VI
Class VI lands are characterized by steep slope (40–50 degrees), severe gully erosion with less than 20 cm 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. Class VI 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.

Class VII
Class VII 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.

Weightage Value
Soil Depth (Weight: 4)
Organic Matter (Weight: 3)
PH (Weight: 3)
Drainage (Weight: 3)
P2O5 (Weight: 2)
K2O (Weight: 2)
Nitrogen (Weight: 2)
Permeability (Weight: 1)

Non Arable (5/6)
Areas covered by existing infrastructure like canal, road, industry residential, commercial area or public areas cannot be used for agriculture purpose. Such lands have been indicated by 5 or 6 in the map.

Soil Fertility Calculation Equation
Calculated Fertility Value =
[Soil Depth Rank Value * 4 + PH Rank Value * 3 + OM Rank Value * 3 + Drainage Rank * 3 + P2O5 Rank Value * 2 + K2o Rank Value * 2 + Nitrogen Rank Value * 2] + Permeability * 1

* Deficiencies and Rankings are generally shown in terms of High, Medium and Low, with symbol H, M and L respectively. Its class range value indicated in the legend indicates the level of deficiencies used in the classification of Land Capability in this map.

Scale 1:29000

0 900 1800 3600 M

Land capability map based on the ortho-rectified satellite image produced through the fusion of ZY-3 MSS 5.8 meter and Panchromatic 2.1 meter spatial resolution acquired on 2020. Soil information for land capability was collected from the soil samples which were chemically analyzed in the soil laboratory. Location for the soil pit for sample collection was identified by defining the land unit which were defined by delineating the land system over the over the high resolution satellite imagery data. Present land use was also considered while defining the boundary of land capability. Land capability classification is done on the basis of topography (slope), soil parameters (depth, texture, drainage, pH, OM, N, P, and K), climate, erosion hazard and land management. The minimum mapping unit is 0.25 hectare.

Projection and Datum Information
Coordinate System: Modified Universal Transverse Mercator
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 500000.0000
False Northing: 0.0000
Central Meridian: 84.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter

Government of Nepal
Ministry of Land Management,
Cooperatives and Poverty Alleviation
Survey Department,
Topographical Survey and
Land Use Management Division
Kathmandu

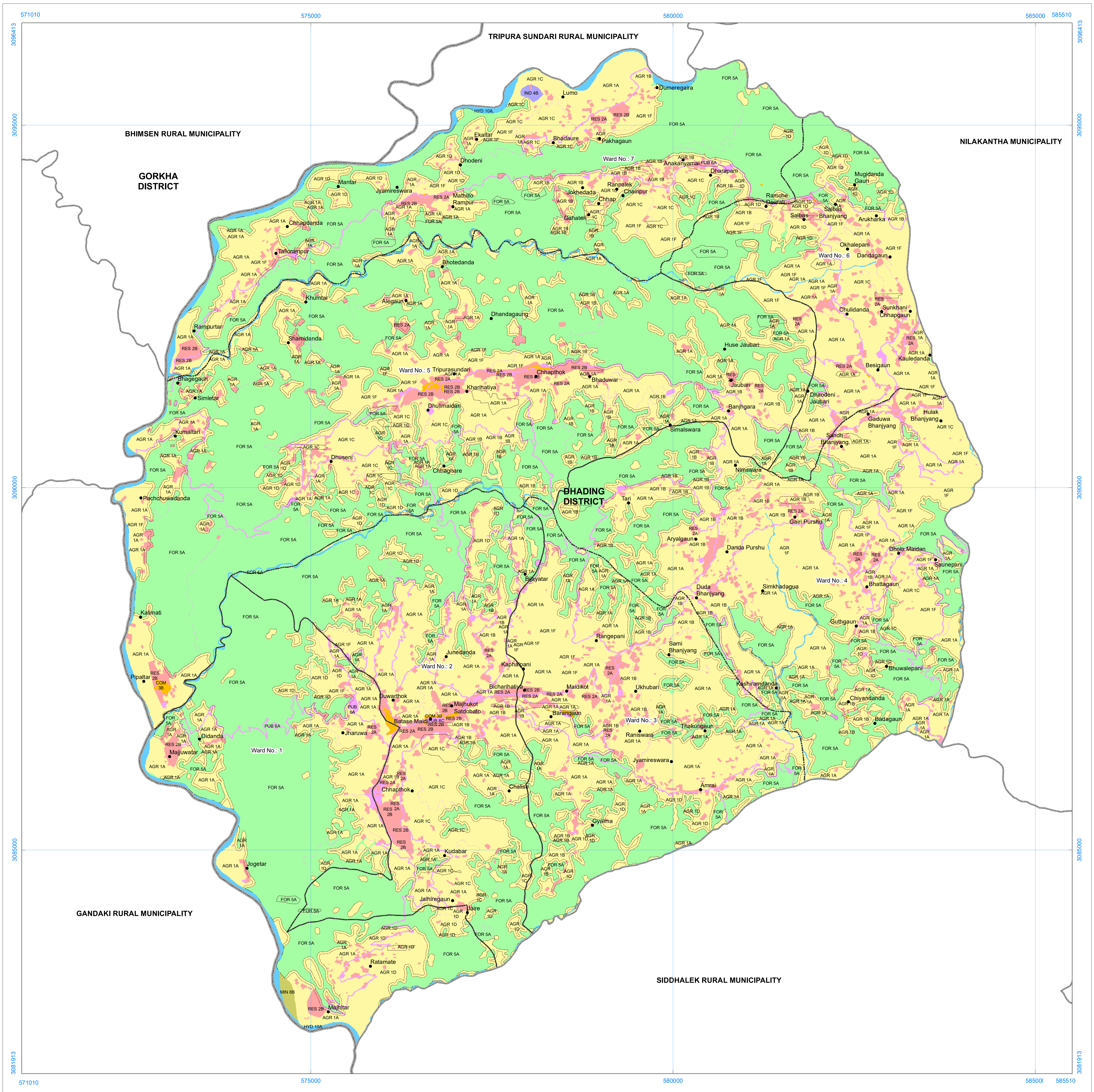
Prepared by:
Hexa International Pvt. Ltd.,
Dhalku, Kathmandu

μ

JWALAMUKHI RURAL MUNICIPALITY

LAND USE ZONING

DHADING DISTRICT



Legend

Land Use Zones

- Zone 1 - Agricultural
- Zone 2 - Residential
- Zone 3 - Commercial
- Zone 4 - Industrial
- Zone 5 - Forest
- Zone 6 - Pubic Use
- Zone 7 - Other Zone
- Zone 8 - Mine and Minerals
- Zone 9 - Cultural and Archeological
- Zone 10 - Riverine,stream, Lake and Marsh Area
- Snowy Mountain Area

Boundaries

- International
- District
- GaPaNaPa
- Ward
- Settlement
- Mines Location

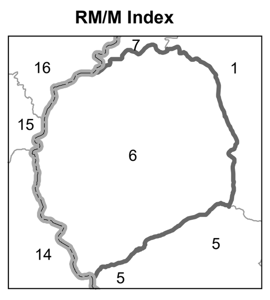
Note: Land Use Classes are classified according to Land Use Act 2076.

*Snowy Mountain Area stands for area of mountaineous region, with 12 months of snow coverage. It should be understood as public use area explained in Land Use Act 2076 and Land Use Policy 2072.

Risk Boundaries

Flood	Landslide	Fire	Seismic	Other
High	High	High	High	High
Medium	Medium	Medium	Medium	Medium
Low	Low	Low	Low	Low

RM/M Index



1. Nilakantha Municipality
5. Siddhalek Rural Municipality
6. Jwalamukhi Rural Municipality
7. Tripura Sundari Rural Municipality
14. Gandaki Rural Municipality
15. Sahid Lakhan Rural Municipality
16. Bhimsen Rural Municipality

District Index

Province Index

Land Use Zone 1 Sub-class	**Land Use Zone 2 Sub-class**	**Land Use Zone 3 Sub-class**	**Land Use Zone 4 Sub-class**	**Land Use Zone 5 Sub-class**	**Land Use Zone 6 Sub-class**
Cereal Crop Production Area -1A Cash Crop Area -1B Horticultural Area -1C Animal Husbandry Area -1D Fish Farming Area -1E Agro Forestry Area -1F Other Agriculture Area -1G	Existing Residential Zone - 2A Potential Area for Residential Zone - 2B	Service Areas - 3A Business Area - 3B	Areas under Industrial Use - 4A Potential Area for Industrial Use - 4B	Existing Forest - 5A Potential Area for Forest Including Barren Lands, Wet Lands - 5B	Areas Under Roads, Railways etc. - 6A Areas Under Hydrography - 6B Cultural, Archeological and Religious Areas etc. - 6D Public Health, Education Library, Police Station, Fire Station, Telephone, Electricity Areas etc. - 6E Grazing Land - 6F Open Spaces, Picnic Spots, Recreational etc. - 6C Government Instutional Area - 6G
	Land Use Zone 7 Sub-class	**Land Use Zone 8 Sub-class**	**Land Use Zone 9 Sub-class**	**Land Use Zone 10 Sub-class**	
	Other Areas	Existing Mine and Mineralsl Zone - 8A Potential Area for Mine and Minerals - 8B	Existing Cultural and Archeological Area - 9A Potential Cultural and Archeological Area - 9B	Areas Under Riverine Stream, Lake and Marsh - 10A Potential Riverine Stream, Lake and Marsh Area - 10B	

Criteria Applied in Delineating Land Use Zoning Boundary

-Existing (present) land use

-Land capability and land system identified by the analysis of soil characteristics (PH value, Nitrogen, Phosphorous, Potash etc), soils moisture, temperature, drainage, irrigation, slope, elevation, aspect, topography etc

-Suitability identified on the basis of the neighborhood and spatial analysis (distance from roads, markets, settlements, river and stream, and hazards like landslide, flood, seismic, fire, industrial etc.)

Concept Applied in the Zoning:

- Classification of land into Agricultural area, Residential area, Commercial area, Industrial area, Forest area, and Publicuse area .
- 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.

TYPE LEGEND SAMPLE

Land Use Zone Classification

2A — Existing Residential Area

2B — Potential Residential Area

Scale 1:29000

0 800 1600 3200 4800 Meters

Land Use Zoning map is based on the ortho-rectified satellite image produced through the fusion of ZY-3 MSS 5.8 meter and Panchromatic 2.1 meter spatial resolution acquired on 2020. Basically the zoning was based on subjective analysis of Present Land Use, Land capability and Socio-economic setting of the study area. Land capability map was produced based on the Soil analysis, Land System and Present Land Use. Soil information for Land Capability was collected from the soil samples which were chemically analyzed in the soil laboratory. Location for the soil pit for sample collection was identified by defining the land unit which were defined by delineating the Land System over the high resolution satellite imagery data. Present Land Use was also considered while defining the boundary of land zoning. Extensive field study was carried prior to delineating to have better understanding of the social setting of the study area. The minimum mapping unit adopted is 0.25 hectare.

Projection and Datum Information
Projectiion: Modified Universal Trasnverse Mercator
False Easting: 500000 m
False Northing: 0 m
Central Meridian: 84 Degree East
Scale Factor: 0.9999
Latitude of Origin: 0 Degree
Linear Unit: Meter
Datum: Everest 1830

Government of Nepal
Ministry of Land Management, Cooperatives and Poverty Alleviation

Survey Department, Topographical Survey and Land Use Management Division

Kathmandu

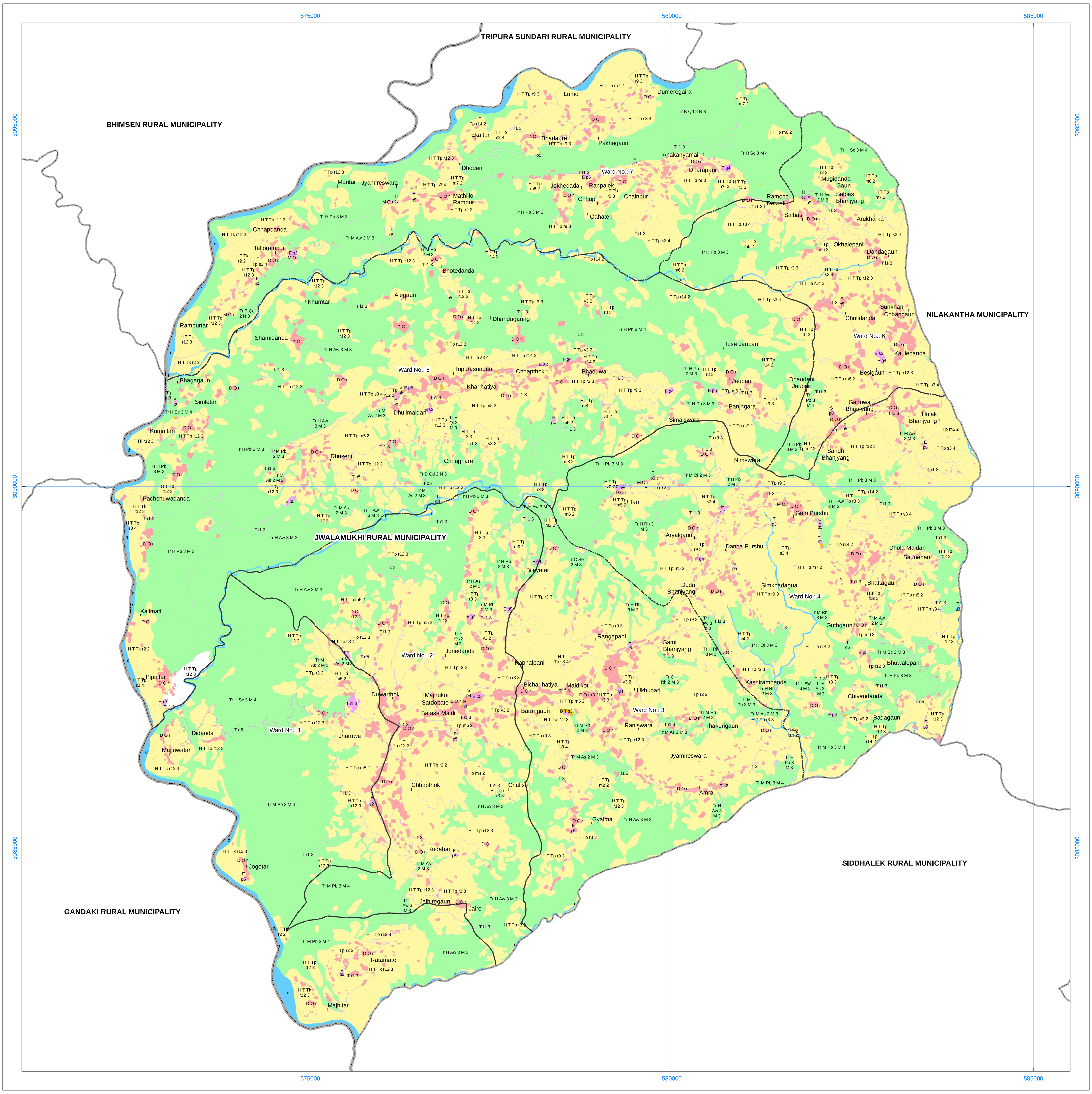
Prepared by:
Hexa International Pvt. Ltd., Dhalku, Kathmandu

N W E S

International boundary shown in this map series does not suffice for validating the actual boundary line that exists on the ground.

PRESENT LAND USE

JWALAMUKHI RURAL MUNICIPALITY — **DHADING DISTRICT**



Legend

Landuse Level 1

- Agricultural
- Public Use
- Forest
- Industrial
- Residential
- Other
- Commercial
- Riverine Stream,Lake and Marsh Area
- Cultural and Archeological
- Mine and Minerals
- Snowy Mountain Area

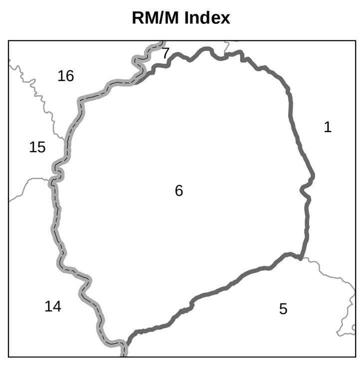
Settlement and Boundaries

- Settlement
- Mines Location
- International Boundary
- District Boundary
- RM/M Boundary
- Ward Boundary

*Snowy Mountain Area stands for area of mountaineous region, with 12 months of snow coverage. It should be understood as Public Use Area explained in Land Use Act 2076 and Land Use Policy 2072.

Note: Land Use Classes are classified according to Land Use Act 2076.

RM/M Index



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16. Bhimsen Rural Municipality

District Index

Province Index

Agriculture Level - 2

Teral Cultivation............T
Hill Cultivation...............H
Mountain Cultivation.... M
Valley Cultivation...........V
Other..............................O

Agriculture Level - 3

Wet Land Cultivation-W
Dry Land Cultivation - D
Mixed Land Cultivation - X
Level Terraces -T
Slopping Terraces - C
Level Terraces Upland Cultivation -Tu
Sloppy Upland - Cu
Valley Level Terraces Khet Land Cultivation - Vk
Valley Level Terraces Upland/Pakho Cultivation - Vu
Valley Slope Upland/Pakho Cultivation - Vs
Valley Riverbeds Alluvial Fans Cultivation -Vf
Other - Ot

Agriculture Level - 4

Low Khet Land Cultivation - Lk
Upper Khet Land Cultivation-TariKhet - Uk
Level Terraces Khet Land Cultivation - Tk
Level Terraces Upland/Pakho Land Cultivation -Tp
Slopping Upland/ Pakho Land Cultivation - Cp
Other - Ot
Unclassified - 0

Agriculture Level - 6

Cropping Intensity

Light - 1
Medium - 2
Intense - 3
Not Applicable - 4

TYPE LEGEND SAMPLE

Agriculture Landuse

T — Level 2 — Terai Cultivation
W — Level 3 — Wet Land Cultivation
Lk — Level 4 — Low Khet Land Cultivation
r2 — Level 5 — Rice-Wheat
2 — Level 6 — Medium

Agriculture Level - 5

Dominant Cropping Pattern (Monsoon-Winter-Dry)

Amriso - a1
Barley-Buckwheat - b1
Banana - b2
Bamboo - b3
Bee Keeping Area - b4
Barren Cultivable Land - b5
Coffee - c1
Cardamom - c2
Cotton - c3
Ginger - g1
Livestock Grazing Area- g2
Maize-Rice-Fallow - m1
Maize-Oilseeds - m2
Maize-Rice-Cereal - m3
Maize-Pulses - m4
Maize-Wheat - m5
Maize - Vegetable - m6
Maize-Millet - m7
Maize-Potato - m8
Maize-Others - m9
Pulses-Fallow - p1
Pulses-Others - p2
Pond for Fish Farming - p3
Rice-Fallow - r0
Rice-Rice - r1
Rice-Wheat - r2
Rice-Wheat-Pulses - r3
Rice-Oilseed - r4
Rice-Pulses - r5
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
Rice-Others - r13
Rice-Buckwheat - r14
Rice-Wheat-Maize - r15
Sugarcane-Sugarcane - s1
Sugarcane-Others - s2
Shrub from Non-forest Area - s3
Silk Farming - s3
Tea - t1
Turmeric - t2
Potato-Vegetable Crops - v1
Garlic-Vegetable - v2
Vegetables-Vegetable - v3
Vegetables-Others - v4
Others - o1
Others-Others - o2
Others-Others-Others - o3
Fruit-Fruit - f1
Fruit+Potato/Vegetable/Buckwheat - f2
Fruit-Others - f3
Fruits - f4
Floriculture- f5
Apple-a2
Maize-Buckwheat-m10
Uwa-u1

Forest Level - 2

Tropical - Tr
Sub-tropical - St
Temperate - Tm
Sub-alpine - Sl
Alpine - Al
Othr - O

Forest Level - 3

Hardwood Cover Type - H
Coniferous Cover Type - C
Mixed Cover Type - M
Bushes - B
Other Forest - Of

Forest Level - 4

Sal Forest - Sl
Pinusroxburghii Forest - pb
Quercusincana-Q. lanuginose Forest- Qq
Quercusdilata Forest- Qd
Quercussemecarpifolia Forest- Qs
Castanopsistribuloides-C.hystrix Forest- Cc
Quercus lamellose Forest- Ql
Lithocarpuspachyphylla Forest- Lp
Aesculus-juglans-Acer Forest(Aa)
Lower Temperate Mixed Broadleaved Forest- Lm
Upper Temperate Mixed Broadleaved Forest- Um
Tropical Deciduous Riverain Forest- Tr
Rhododendron Forest- Rh
Betulautilis Forest- Bu
Abiesspectabilis Forest- As
Tsugadumosa Forest- Td
Pinusexcelsa Forest- Pe
Piceasmithiana Forest- Ps
Abiespindrow Forest- Ap
Cedrusdeodara Forest- Cd
Cupressustorulosa Forest- Ct
Larix Forest- La
Tropical Evergreen Forest- Te
Alnus Woods- Aw
Populus Ciliate Woods- Pc
Hippophae Scrub- Hp
Moist Alpine Scrub- Ma
Medicinal Herbs- Mh
Dry Alpine Scrub- Ds
Juniper Wallichiana Forest- Jw
Wetland area- Wl
Rock outcrops/ barren lands- Ro
Sub-tropical Evergreen Forest- Se
Terminalia Forest- Tn
Dalbergiasissoo-Acacia Catechu Forest- Da
Sub-tropical Deciduous Hill Forest- Sd
Schima-Castonopsis Forest- Sc
Sub-tropical Semi-evergreen Hill Forest- Ss
Other Forest Species- Of

Forest Level - 5

Dense - 3
Sparse - 2
Degraded - 1
Not Applicable - 0

Forest Level - 6

Mature - M
Immature - I
Regeneration - R
Not Applicable - N

Forest Level - 7

Private - 1
Reserve - 2
Government - 3
Community - 4
Leasehold - 5
Collaborative - 6
Religious - 7
Other - 8

TYPE LEGEND SAMPLE

Forest Landuse

Tr — Level 2 — Tropical
H — Level 3 — Hardwood Cover Type
Sl — Level 4 — Species Type
2 — Level 5 — Sparse
I — Level 6 — Mature
4 — Level 7 — Community

Public Use Level - 2

Educational- E
Security Service- S
Health Service- H
Instutional Area- I
Recreational Area- F
Transportation Infrastructure- T
Utility Service Area- U
Other Public Use Area- O

Public Use Level - 3 (Sub-Categories)

Sub Category Education- E
Primary - p5
Secondary - s2
Campus - c5
University - u2
Other Educational Area- o6
Library- l3

Sub Category Health - H
Hospital - h3
Health Post - p4
Nursing Home - n1
Health Centre - c7
Pharmacy - f3
Polyclinic - i2
Other - o7

Sub Category Institutional- I
Private Institution - r3
Public Institution - p6
NGO - n2
INGO - i4
Other Institutional- o8

Sub-Category Transportation- T
Highway - h2
Feeder Road - f2
District Road - d3
Local Road - i1
Other Road - o5
Bus Park - b1
Airport - a2
Railway - r2
Car Park - c4
Port - p3
Pavement - v1
Cart Track - t3
Other - x1
Bridge - g3

Sub-Category Recreational- F
Public Theatre- c8
Drama House - d4
Picnic Spot - p7
Stadium - s3
Play Ground - g4
Open Space - o9
Other - x2
Zoo - z1
Restpoint-Chautari- r4
Museum - m1

Sub Category Security Service- S
Police Station - p8
Military Area - m2
Armed Force - a3
Other Security- o10

Sub Category Utility - U
Telephone Booth - t1
Crematory - c 2
Electricity Office - e1
Fire Station - f1
Landfill Site - l1
Water Tank - w1
Area by Electric Pole/Pylon- p1
Other - o2

Sub-Category Other- O
Other Public Use - o4
Snowy Mountain Area - Sm1

TYPE LEGEND SAMPLE

Public Use

E — Level 2 — Educational
p — Level 3 — Primary School

Commercial Level - 2

Business Area- B
Service Area- S

Commercial Level - 3

Market- M
Hotel- H
Recreation-R
Utility- U
Storage-T
Service- S
Government Service Area- G

Commercial Level - 4

Government Service Area Sub Category (S):

Agriculture Office - ag
CBS - b5
Civil Aviation - ca
Communication - cm
Court - co
Cultural Office - cu
Disctrict Administraion Office - a1
Doildar - do
Education - en
Electricity Office - eo
Forestry Office - f2
Helath Office - h5
Irrigation Office - i1
Land Transaction Ofice -lt
Local Development Office - l2
Mining and Geology - mg
Other - o5
Petrolium - pm
Post Office - po
Road Office - r4
Soil Conservation - sc
Survey Office - s4
Tax - tx
Telecommunication Office - tc
Land Reform - lr
Water Induced Disaster - d4
Water Supply Office - w2

TYPE LEGEND SAMPLE

Commercial Landuse

B — Level 2 — Business Area
M — Level 3 — Market
o — Level 4 — Open Market

Commercial Level - 4

Market Area Sub Category (M):
Shop - s1
Boutique - b2
Departmental Store - d1
Retail Business - r2
Super Market - m1
Dry Cleaners - c1
Kawadi - k1
Open Market - o2
Other - x1

Hotel Sub Category (H):
Hotel - h1
Guest House -g1
Fastfood -f1
Restaurant - r1
Bar - b1
Travel Agency - t1
Other Hotel - o1

Service Sub Category (S):
Bank/Money Exchange - b3
Private Post Office - p1
Private Communication Area - c3
Broadcast Studio - d3
Private School Area - e2
Private Health Service Area - h3
Petrol Pump - m3
Radio Station - r3
Service centre - s2
TV Station - t3
Other Service - o3

Storage House/ Area - s3
Consultancy Service Area - c4
Business House - b4
Utility Subcategory (U)
Water Reservoir - w1
Hydropower Area - h4
Cable Car - c5
Gas Plant - g3
Oil Storage - o4
Other storage - x3

Recreation Sub Category (R):
Cyber Cafe - y1
Cinemal Hall - c2
Concert Hall - h2
Theatre - t2
Dance Hall - d2
Night Club - n1
Gaming Hall - g2
Gambling Hall - l1
Exhibition Centre - e1
Gym House - m2
Other Entertaing Area - x2

Industrial Level - 2

Small Scale Industry - S
Medium Scale Industry - M
Large Scale Industry - L
Special Economic Zone - E
Industrial Estate - I
Other Industrial Category - O

TYPE LEGEND SAMPLE

Industrial Area Subtype

M — Level 2 — Medium Scale Industry

Cultural- Archeological Level - 2

Cultural-Historical- Archeological-C
Heritage Site - h
Cultural Site - c
Durbar Square - d
Gadh - g
Archeological Site - a
Other - o

Religious- R
Temple- t
Stupa/Monastary- s
Mosque- m
Church- c
Bahal- b
Patis- p
Bihar- v
Other- o

TYPE LEGEND SAMPLE

Cultural and Archeological Subtype

R — Level 2 — Religious
t — Level 3 — Temple

Residential Level - 2

Densely Populated - D
Moderately Populated - M
Sparsely Populated - S

Residential Level - 3

Old Area - O
Newly Developed Area - N
Planned Area - P

Residential Level - 4

Residential Cluster - r
Apartment/Multistoreys - a
Oldage Care Place - o
Hostel- h
Dharashram - d
Quarters-q
Infrastructure Developed Area- i
Other- x

TYPE LEGEND SAMPLE

Residential Landuse

D — Level 2 — Densly Populated
O — Level 3 — Old Area
r — Level 4 — Residential Cluster

TYPE LEGEND SAMPLE

Riverine Stream, Lake and Marsh Subtype

r — Level 2 — River

Riverine Stream, Lake and Marsh Level - 2

Pond - p
Lake - l
Canal - c
Glacier - g
Snow Area - s
Wetland - w
River - r
Spout - t
Kulo - k
Sand - d
Others - o

Mine and Minerals Level - 2

Construction Minerals (Materials) - CNSM
Decorative and Dimension Stones - DECDM
Fuel Minerals - FUEL
Gemstones - GEMS
Metallic Minerals - MTL
Nonmetallic Minerals - NMTL
Other Minerals - OTHM

Mine and Minerals Level - 3

Mine and Minerals (Construction)
Sands - Sands
Cobbles - Cobl
Flaggy Quartzite - Flgqz
Limestone - Lmstn
Pebbles - Pbles
Quartzite - Qrtz
River boulders - Rvbld
Schist - Schst
Slates - Slate
Other Construction Minerals - OthCM
Mine and Minerals (Decorative and Dimension)
Basalt - Bslt
Coloured sandstone - Clstn
Granites - Grnit
Marble - Mrble
Quartzites - Qartz
Other Decora/Dimension Minerals - ODcDm
Sandstone - Sn
Dolomite - Dol
Gneiss - Gne

Mine and Minerals (Non-Metallic) NM

Clay - Clys
Dolomite - Dlmte
Limestone - Lstn
Magnesite - Mgste
Mica - Mica
Phosphorite - Phspr
Quartz - Qurtz
Silica Sand - Silsn
Talc - Talc
Other Non-Metallic - ONM

Mine and Minerals (Gem Stone)

Aquamarine - Aqmrn
Beryl - Beryl
Garnets - Grnet
Gem - Gem
Kyanites - Kynte
Quartz crystals - Qcrst
Ruby - Ruby
Sapphire - Sphre
Tourmaline - Trmln

TYPE LEGEND SAMPLE

Mine and Minerals

MTL — Level 2 — Metal
Fe — Level 3 — Iron

Mine and Minerals (Metals)

Iron - Fe
Copper - Cu
Zinc - Zn
Lead - Pb
Cobalt - cb
Nickel - Ni
Gold - Au
Silver - Ag
Tin - Sn
Tungsten - Tn
Molybdenum - Mb
Uranium - Ur
Lithium - Li
Lepidolite (Mica) - Lp
Tantalum - Ta
Bismuth - Bi
Arsenic - Ar
Cadmium - Cd
Chromium - Cr
Mercury - Hg
Titanium - Ti
Other Metallic Minerals - OMM

Other Level - 2

Grazing Land - G
Others - X (Landslide)

Grazing Land Subtype

Tropical - Tr
Sub-tropical - St
Temperate - Tm
Sub-alpine - Sl
Alpine - Al

TYPE LEGEND SAMPLE

Other Landuse

G — Level 2 — Grass Land
Tr — Level 3 — Tropical

Scale 1:29000

1800 900 0 1800 Meters

Land use map based on the orthorectified satellite image produced through the fusion of ZY-3 MSS 5.8 meter and Panchromatic 2.1 meter spatial resolution acquired on 2020. This map is produced through the integrated approach: Classification of the remotely sensed imagery and Visual Interpretation. Field verification was carried out on 2020.

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Projectiion: Modified Universal Trasnverse Mercator
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Central Meridian: 84 Degree East
Scale Factor: 0.9999
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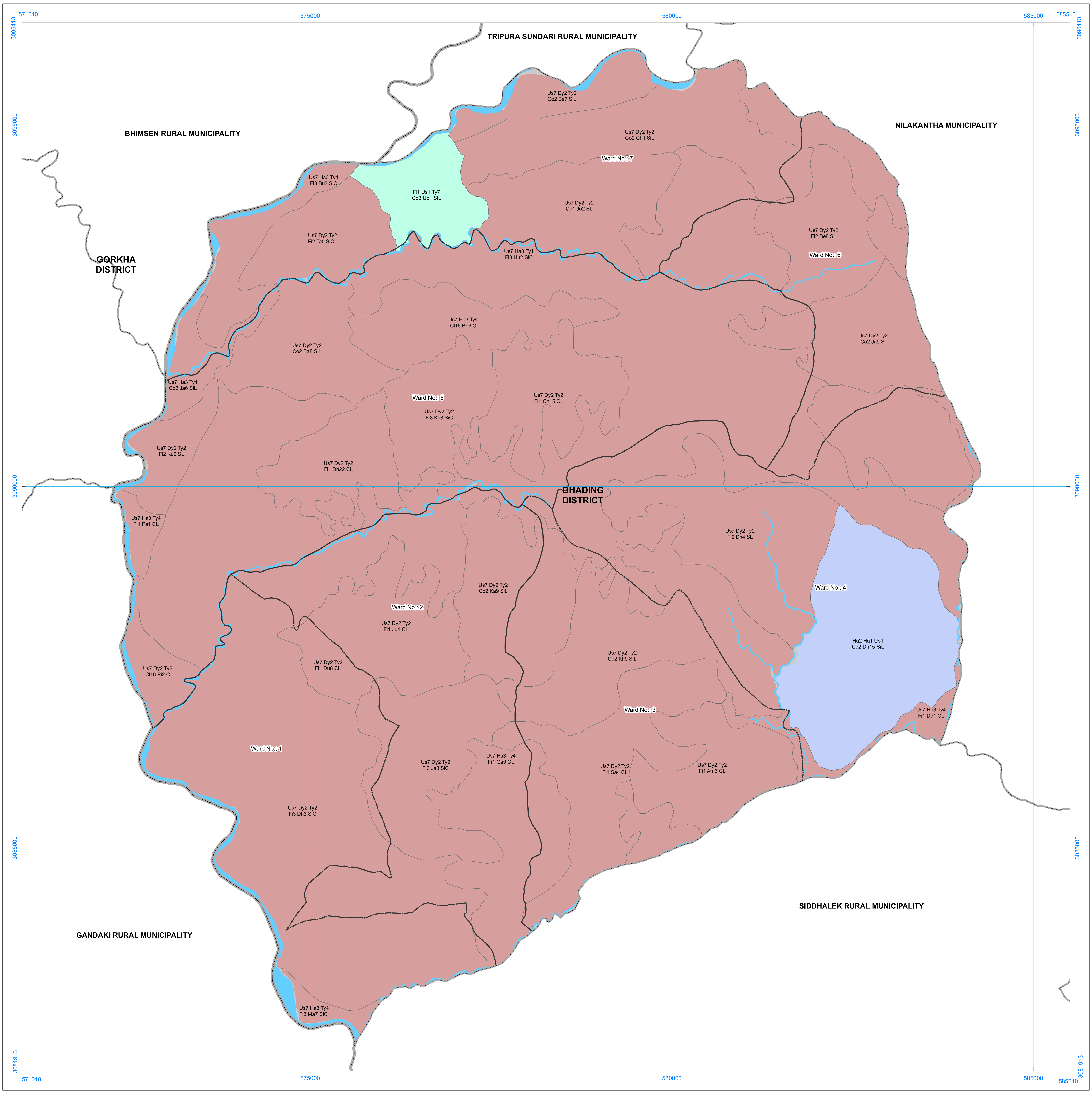
International boundary shown in this map series does not suffice for validating the actual boundary line that exists on the ground.

JWALAMUKHI RURAL MUNICIPALITY

SOIL MAP

DHADING DISTRICT



Legend

Soil Order

- Alfisols
- Andisols
- Aridisols
- Entisols
- Gelisols
- Histosols
- Inceptisols
- Mollisols
- Oxisols
- Spodosols
- Ultisols
- Vertisols
- Unclassified
- Waterbody
- International Boundary
- District Boundary
- GaPa/NaPa Boundary
- Ward Boundary
- Settlement

RM/M Index

1. Nilakantha Municipality
5. Siddhalek Rural Municipality
6. Jwalamukhi Rural Municipality
7. Tripura Sundari Rural Municipality
8. Netrawati Dabjong Rural Municipality
14. Gandaki Rural Municipality
15. Sahid Lakhan Rural Municipality
16. Bhimsen Rural Municipality

District Index (CHINA, GORKHA, RASUWA, DHADING, NUWAKOT, CHITAWAN)

Province Index (CHINA, INDIA)

Soil - Suborder

Sub Order of Aridisols
Calcids-Ca1
Cambids-Ca2
Durids-Du1
Gypsids-Gy1
Salids-Sa2
Orthids-Or4

Sub Order of Entisols
Aquents-Aq9
Arents-Ar1
Fluvents-Fl1
Orthents-Or3
Psamments-Ps1

Sub Order of Gelisols
Histels-Hi1
Orthels-Or1
Turbels-Tu1

Sub Order of Oxisols
Aquox-Aq3
Torrox-To2
Udox-Ud2
Ustox-Us2

Sub Order of Alfisols
Aqualfs-Aq7
Cryalfs-Cr3
Udalfs-Ud5
Ustalfs-Us6
Xeralfs-Xe5
Boralfs-Bo1

Sub Order of Andisols
Aquands-Aq2
Cryands-Cr5
Torrands-To1
Udands-Ud1
Ustands-Us1
Vitrands-Vi1
Xerands-Xe1

Sub Order of Spodosols
Aquods-Aq1
Cryods-Cr1
Humods-Hu1
Orthods-Or2

Sub Order of Ultisols
Aquults-Aq5
Humults-Hu2
Udults-Ud3
Ustults-Us4
Xerults-Xe3

Sub Order of Vertisols
Aquerts-Aq4
Torrerts-To2
Usterts-Us3
Xererts-Xe2

Sub Order of Histosols
Fibrists-Fi1
Folists-Fo1
Saprists-Sa1

Sub Order of Inceptisols
Anthrepts-An1
Aquepts-Aq8
Cryepts-Cr4
Udepts-Ud6
Ustepts-Us7
Ochrepts-Oc1
Umbrepts-Um1
Xerepts-Xe6

Sub Order of Mollisols
Albolls-Al1
Aquolls-Aq6
Cryolls-Cr2
Rendolls-Re1
Udolls-Ud4
Ustolls-Us5
Borolls-Bo2

* This part only uses the name and corresponding textual symbol used in this soil map.

For textual symbol, use the first two letters followed by one digit (if necessary, two digits) in a sequential manner to avoid duplication of the symbol. This method applies for Great group, Sub-group, Family and Series used in this particular map. The alphabet of the textual symbol should be in upper case and the second alphabet should be the lower case. This equally applies to the Texture as well.

For example: A soil sample under the Suborder: Fluvents can be symbolized as shown below.

Great Group: Torrifluvents	Textual Symbol: To1
Subgroup: Typic Torrifluvents	Textual Symbol: Ty1
Family: Fine-loamy	Textual Symbol: Fi1
Series: Jocity	Textual Symbol: Jo1
Texture: Loam	Textual Symbol: Lo1

Soil - Great Group*

Dystrochrepts-Dy1
Dytrustepts-Dy2
Haplohumults-Ha1
Haploxerepts-Ha2
Haplustepts-Ha3
Rhodustults-Rh1
Udochrepts-Ud1
Ustifluvents-Us1
Ustipsamments-Us2
Ustochrepts-Us3
Ustorthents-Us4

Soil - Texture*

Clay-C
Clay loam-CL
Sand-S
Sandy clay-SC
Sandy clay loam-SCL
Sandy loam-SL
Silt-Si
Silty clay-SiC
Silty clay loam-SiCL
Silty loam-SiL

Soil - Sub-group*

Aquic Ustifluvents-Aq1
Aridic Ustifluvents-Ar1
Integrade Dystrochrepts-In1
Intergrade Dystrochrepts-In2
Intergrade Rhodustults-In3
Intergrade Ustochrepts-In4
Intergrade Ustorthents-In5
Mollic Ustifluvents-Mo1
Oxyaquic Ustifluvents-Ox1
Typic Dystrochrepts-Ty1
Typic Dystrustepts-Ty2
Typic Haploxerepts-Ty3
Typic Haplustepts-Ty4
Typic Rhodustults-Ty5
Typic Udochrepts-Ty6
Typic Ustifluvents-Ty7
Typic Ustipsamments-Ty8
Typic Ustochrepts-Ty9
Typic Ustorthents-Ty10
Ustic Haplohumults-Us1

TYPE LEGEND SAMPLE

Soil Classification

Oc1	Cr1	Fl1	Sa1	Aa1	CL
Sub Order	Great Group	Sub Group	Family	Series	Texture

Soil - Family

Silty clay loam Typic Dystrochrepts-Si18
Silty clay loam typic ustochrepts-Si26
Silty clay Typic Dystrochrepts-Si19
Silty clay Typic Rhodustults-Si20
Silty clay Typic Ustochrepts-Si21
Silty clay Typic Ustochrthents-Si22
Silty clay Typic Ustorthents-Si23
Silty clayTypic Dystrochrepts-Si24
Silty mesic sypic Udochrepts-Si25
Typic Dystrochrepts-Ty1
Typic Ustochrepts-Ty2
Typic Ustorthents-Ty3

Soil - Family*

Sandy clay Typic Dystrochrepts-Sa1
Clay loam Intergrade Dystrochrepts-Cl1
Clay loam Intergrade Ustochrepts-Cl2
Clay loam Intergrade Ustorthents-Cl3
Clay loam mesic intergrade ustochrepts-Cl4
Clay loam mesic typic dystrochrepts-Cl5
Clay loam mesic typic ustorthents-Cl6
Clay loam Typic Dystrochrepts-Cl7
Clay loam Typic Rhodustults-Cl8
Clay loam Typic Ustochrepts-Cl9
Clay loam Typic Ustorthents-Cl10
Clay loamTypic Dystrochrepts-Cl11
Clay loamTypic Ustochrepts-Cl12
Clayey mesic sypic Udochrepts-Cl13
Clayey mesic sypic Utorthents-Cl14
Clayey mesic typic Ustorthents -Cl15
Clayey Superactive Mesic Ustic-Cl16
Coarse loamy Subactive Mesic Ustic-Co1
Coarse Silty Subactive Mesic Ustic-Co2
Coarse Silty Subactive Mesic Ustic Typic Ustifluv*-Co3
Fine loamy Active Mesic Ustic-Fi1
Fine loamy Semiactive Mesic Ustic-Fi2
Fine Silty Semiactive Mesic Ustic-Fi3
Fine Silty Subactive Mesic Ustic-Fi4
Fine Silty Typic Ustifluvents-Fi5
Intergrade Ustorthents-In1
Loamy mesic sypic Udochrepts-Lo1
Loamy sand Typic Dystrochrepts-Lo2
Sandy clay loam Intergrade Rhodustults-Sa2
Sandy clay loam Typic Dystrochrepts-Sa3
Sandy clay loam Typic Ustochrepts-Sa4
Sandy clay Typic Dystrochrepts-Sa5
Sandy loam Intergrade Dystrochrepts-Sa6
Sandy loam Typic Dystrochrepts-Sa7
Sandy loam Typic Ustochrepts-Sa8
Sandy mesic sypic Udochrepts-Sa9
Sandy Sandy Skeleton Mesic Ustic-Sa10
Sandy Subactive Mesic Ustic-Sa11
Sandy Typic Dystrochrepts-Sa12
Sandy Typic Ustorthents-Sa13
Silt loam Intergrade Dystrochrepts-Si1
Silt loam Intergrade Rhodustults-Si2
Silt loam Intergrade Ustochrepts-Si3
Silt loam intergrade Ustorthents-Si4
Silt loam mesic integrade dystrochrepts-Si5
Silt loam mesic typic dystrochrepts-Si6
Silt loam mesic typic ustorthents-Si7
Silt loam Typic Dystrochrepts-Si8
Silt loam Typic Rhodustults-Si9
Silt loam typic Ustorthents-Si10
Silt loamTypic Dystrochrepts-Si11
Silty clay Typic Dystrochrepts-Si12
Silty clay Intergrade Dystrochrepts-Si13
Silty clay Intergrade Rhodustults-Si14
Silty clay Intergrade Ustochrepts-Si15
Silty clay intergrade ustorthents-Si16
Silty clay loam integrade dystrochrepts-Si17

Soil Series *

Scale 1:29000

0 650 1300 2600 3900 5200 M

Soil map based on the ortho-rectified satellite image produced through the fusion of ZY-3 MSS 5.8 m and Panchromatic 2.1 meter spatial resolution acquired on 2020. Soil information was collected from the soil samples which were chemically analyzed in the soil laboratory. Location for the soil pit for sample collection was identified by defining the land unit which were defined by delineating the land system over the high resolution satellite imagery data. Present land use was also considered while delineating the land unit for soil pit identification. The minimum mapping unit is 0.25 hectare.

Projection and Datum Information
Projectiion: Modified Universal Trasnverse Mercator
False Easting: 500000 m
False Northing: 0 m
Central Meridian: 84 Degree East
Scale Factor: 0.9999
Latitude of Origin: 0 Degree
Linear Unit: Meter
Datum: Everest 1830

Government of Nepal
Ministry of Land Management,
Cooperatives and Poverty Alleviation
Survey Department,
Topographical Survey and
Land Use Management Division
Kathmandu

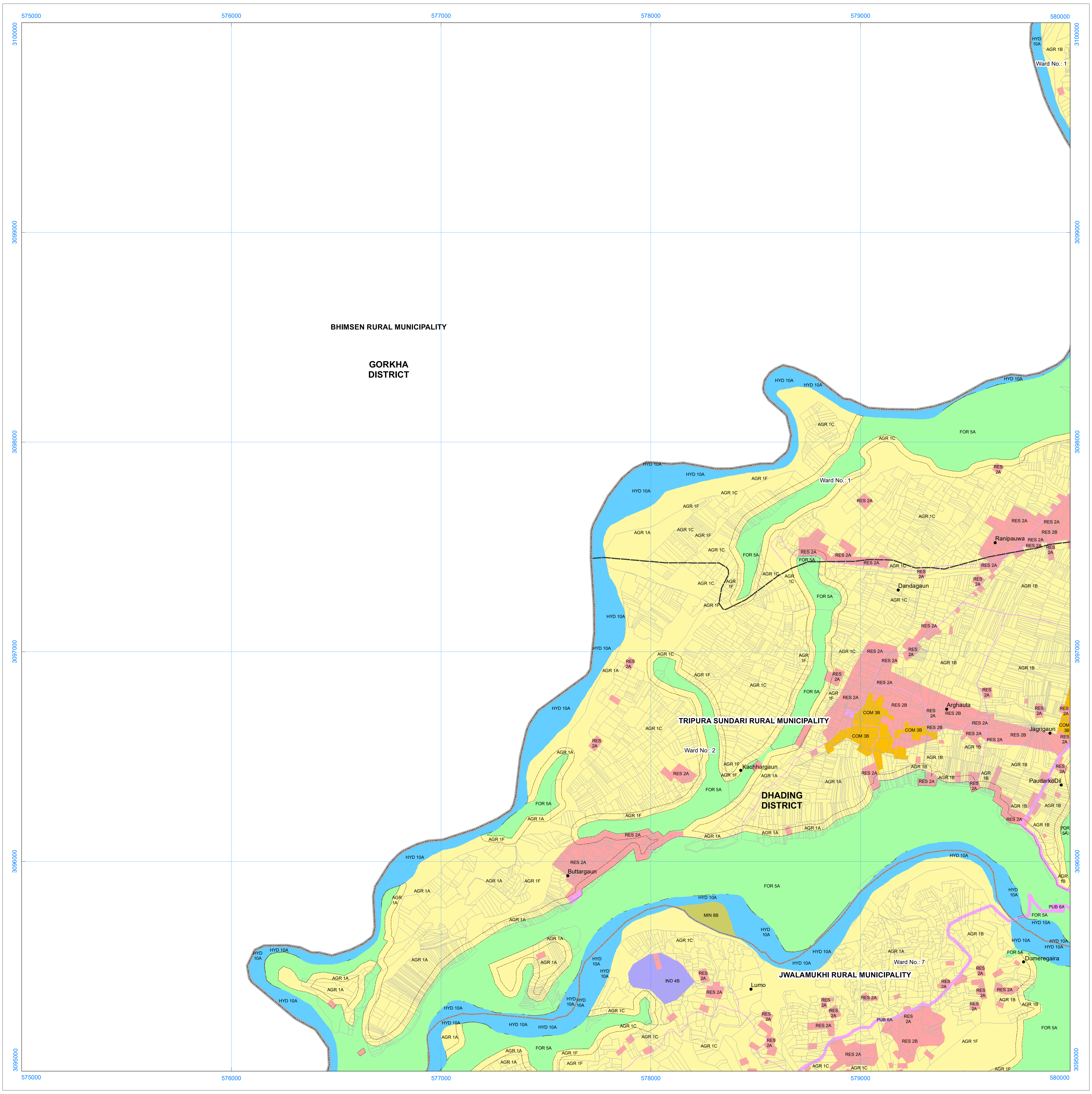
Prepared by:
Hexa International Pvt. Ltd.,
Dhalku, Kathmandu

International boundary shown in this map series does not suffice for validating the actual boundary line that exists on the ground.

CADASTRAL SUPERIMPOSED ON LAND USE ZONING

Sheet Number: 101-006

JWALAMUKHI RURAL MUNICIPALITY,TRIPURA SUNDARI RURAL MUNICIPALITY — **DHADING DISTRICT**



Legend

Land Use Zones

- Zone 1 - Agricultural
- Zone 2 - Residential
- Zone 3 - Commercial
- Zone 4 - Industrial
- Zone 5 - Forest
- Zone 6 - Pubic Use
- Zone 7 - Other Zone
- Zone 8 - Mine and Minerals
- Zone 9 - Cultural and Archeological
- Zone 10 - Riverine Stream, Lake and Marsh Area
- Snowy Mountain Area

Boundaries

- International
- District
- GaPaNaPa
- Ward
- Settlement
- Mines Location
- Cadastral Parcel

Note: Land Use Classes are classified according to Land Use Act 2076.

*Snowy Mountain Area stands for area of mountaineous region, with 12 months of snow coverage. It should be understood as public use area explained in Land Use Act 2076 and Land Use Policy 2072.

Risk Boundaries

Flood	Landslide	Fire	Seismic	Other
High	High	High	High	High
Medium	Medium	Medium	Medium	Medium
Low	Low	Low	Low	Low

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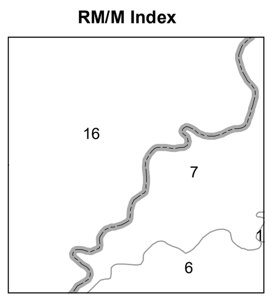
	101-016	101-017

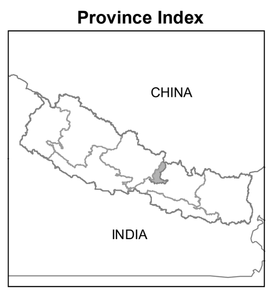
RM/M Index



1. Nilakantha Municipality
6. Jwalamukhi Rural Municipality
7. Tripura Sundari Rural Municipality
16. Bhimsen Rural Municipality

District Index

Province Index



Land Use Zone 1 Sub-class
- Cereal Crop Production Area -1A
- Cash Crop Area -1B
- Horticultural Area -1C
- Animal Husbandry Area -1D
- Fish Farming Area -1E
- Agro Forestry Area -1F
- Other Agriculture Area -1G

Land Use Zone 2 Sub-class
- Existing Residential Zone - 2A
- Potential Area for Residential Zone - 2B

Land Use Zone 3 Sub-class
- Service Areas - 3A
- Business Area - 3B

Land Use Zone 4 Sub-class
- Areas Under Industrial Use - 4A
- Potential Area for Industrial Use - 4B

Land Use Zone 5 Sub-class
- Existing Forest - 5A
- Potential Area for Forest Including Barren Lands, Wet Lands - 5B

Land Use Zone 6 Sub-class
- Areas Under Roads, Railways etc. - 6A
- Areas Under Hydrography - 6B
- Cultural, Archeological and Religious Areas etc. - 6D
- Public Health, Education Library, Police Station, Fire Station, Telephone, Electricity Areas etc. - 6E
- Grazing Land - 6F
- Open Spaces, Picnic Spots, Recreational etc. - 6C
- Government Instutional Area - 6G

Land Use Zone 7 Sub-class
- Other Areas

Land Use Zone 8 Sub-class
- Existing Mine and Minerals Zone - 8A
- Potential Area for Mine and Minerals - 8B

Land Use Zone 9 Sub-class
- Existing Cultural and Archeological Area - 9A
- Potential Cultural and Archeological Area - 9B

Land Use Zone 10 Sub-class
- Areas Under Riverine Stream, Lake and Marsh - 10A
- Potential Riverine Stream, Lake and Marsh - 10B

Criteria Applied in Delineating Land Use Zoning Boundary

-Existing (present) land use

-Land capability and land system identified by the analysis of soil characteristics (PH value, Nitrogen, Phosphorous, Potash etc), soils moisture, temperature, drainage, irrigation, slope, elevation, aspect, topography etc

-Suitability identified on the basis of the neighborhood and spatial analysis (distance from roads, markets, settlements, river and stream, and hazards like landslide, flood, seismic, fire, industrial etc.)

Concept Applied in the Zoning:

- Classification of land into Agricultural area, Residential area, Commercial area, Industrial area, Forest area, and Publicuse area .
- 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.

TYPE LEGEND SAMPLE

Land Use Zone Classification

2A — Existing Residential Area

2B — Potential Residential Area

Scale 1:10,000

Meters 200 100 0 200 400 600 800 1,000 Meters

Land Use Zoning map is based on the ortho-rectified satellite image produced through the fusion of ZY-3 MSS 5.8 meter and Panchromatic 2.1 meter spatial resolution acquired on 2020. Basically the zoning was based on subjective analysis of Present Land Use, Land capability and Socio-economic setting of the study area. Land capability map was produced based on the Soil analysis, Land System and Present Land Use. Soil information for Land Capability was collected from the soil samples which were chemically analyzed in the soil laboratory. Location for the soil pit for sample collection was identified by defining the land unit which were defined by delineating the Land System over the high resolution satellite imagery data. Present Land Use was also considered while defining the boundary of land zoning. Extensive field study was carried prior to delineating to have better understanding of the social setting of the study area. The minimum mapping unit adopted is 0.25 hectare.

Projection and Datum Information

Projectiion:	Modified Universal Trasnverse Mercator
False Easting:	500000 m
False Northing:	0 m
Central Meridian:	84 Degree East
Scale Factor:	0.9999
Latitude of Origin:	0 Degree
Linear Unit:	Meter
Datum:	Everest 1830

Government of Nepal
Ministry of Land Management, Cooperatives and Poverty Alleviation

Survey Department, Topographical Survey and Land Use Management Division

Kathmandu

Prepared by:
Hexa International Pvt. Ltd., Dhalku, Kathmandu

N W E S

International boundary shown in this map series does not suffice for validating the actual boundary line that exists on the ground.

CADASTRAL SUPERIMPOSED ON LAND USE ZONING

Sheet Number: 101-007

JWALAMUKHI RURAL MUNICIPALITY,NILAKANTHA MUNICIPALITY AND TRIPURA SUNDARI RURAL MUNICIPALITY — **DHADING DISTRICT**

Legend

Land Use Zones

- Zone 1 - Agricultural
- Zone 2 - Residential
- Zone 3 - Commercial
- Zone 4 - Industrial
- Zone 5 - Forest
- Zone 6 - Pubic Use
- Zone 7 - Other Zone
- Zone 8 - Mine and Minerals
- Zone 9 - Cultural and Archeological
- Zone 10 - Riverine Stream, Lake and Marsh Area
- Snowy Mountain Area

Boundaries

- International
- District
- GaPaNaPa
- Ward
- Settlement
- Mines Location
- Cadastral Parcel

Note: Land Use Classes are classified according to Land Use Act 2076.

*Snowy Mountain Area stands for area of mountaineous region, with 12 months of snow coverage. It should be understood as public use area explained in Land Use Act 2076 and Land Use Policy 2072.

Risk Boundaries

Flood	Landslide	Fire	Seismic	Other
High	High	High	High	High
Medium	Medium	Medium	Medium	Medium
Low	Low	Low	Low	Low

Land Use Zone 1 Sub-class	Land Use Zone 2 Sub-class	Land Use Zone 3 Sub-class	Land Use Zone 4 Sub-class	Land Use Zone 5 Sub-class	Land Use Zone 6 Sub-class
Cereal Crop Production Area -1A Cash Crop Area -1B Horticultural Area -1C Animal Husbandry Area -1D Fish Farming Area -1E Agro Forestry Area -1F Other Agriculture Area -1G	Existing Residential Zone - 2A Potential Area for Residential Zone - 2B	Service Areas - 3A Business Area - 3B	Areas Under Industrial Use - 4A Potential Area for Industrial Use - 4B	Existing Forest - 5A Potential Area for Forest Including Barren Lands, Wet Lands - 5B	Areas Under Roads, Railways etc. - 6A Areas Under Hydrography - 6B Cultural, Archeological and Religious Areas etc. - 6D Public Health, Education Library, Police Station, Fire Station, Telephone, Electricity Areas etc. - 6E Grazing Land - 6F Open Spaces, Picnic Spots, Recreational etc. - 6C Government Instutional Area - 6G
	Land Use Zone 7 Sub-class Other Areas	**Land Use Zone 8 Sub-class** Existing Mine and Minerals Zone - 8A Potential Area for Mine and Minerals - 8B	**Land Use Zone 9 Sub-class** Existing Cultural and Archeological Area - 9A Potential Cultural and Archeological Area - 9B	**Land Use Zone 10 Sub-class** Areas Under Riverine Stream, Lake and Marsh - 10A Potential Riverine Stream, Lake and Marsh - 10B	

Criteria Applied in Delineating Land Use Zoning Boundary

-Existing (present) land use

-Land capability and land system identified by the analysis of soil characteristics (PH value, Nitrogen, Phosphorous, Potash etc), soils moisture, temperature, drainage, irrigation, slope, elevation, aspect, topography etc

-Suitability identified on the basis of the neighborhood and spatial analysis (distance from roads, markets, settlements, river and stream, and hazards like landslide, flood, seismic, fire, industrial etc.)

Concept Applied in the Zoning:

- Classification of land into Agricultural area, Residential area, Commercial area, Industrial area, Forest area, and Publicuse area .
- 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.

TYPE LEGEND SAMPLE

Land Use Zone Classification

2A — Existing Residential Area

2B — Potential Residential Area

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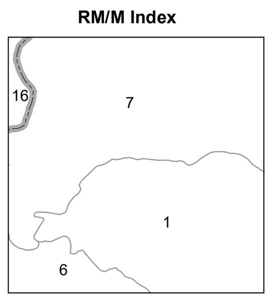
	101-017	101-018

RM/M Index



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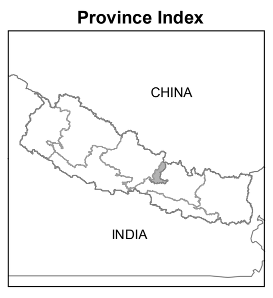
7. Tripura Sundari Rural Municipality
16. Bhimsen Rural Municipality

District Index

Province Index



Scale 1:10,000

Meters 200 100 0 200 400 600 800 1,000 Meters

Land Use Zoning map is based on the ortho-rectified satellite image produced through the fusion of ZY-3 MSS 5.8 meter and Panchromatic 2.1 meter spatial resolution acquired on 2020. Basically the zoning was based on subjective analysis of Present Land Use, Land capability and Socio-economic setting of the study area. Land capability map was produced based on the Soil analysis, Land System and Present Land Use. Soil information for Land Capability was collected from the soil samples which were chemically analyzed in the soil laboratory. Location for the soil pit for sample collection was identified by defining the land unit which were defined by delineating the Land System over the high resolution satellite imagery data. Present Land Use was also considered while defining the boundary of land zoning. Extensive field study was carried prior to delineating to have better understanding of the social setting of the study area. The minimum mapping unit adopted is 0.25 hectare.

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Projectiion: Modified Universal Trasnverse Mercator
False Easting: 500000 m
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Datum: Everest 1830

Government of Nepal
Ministry of Land Management, Cooperatives and Poverty Alleviation
Survey Department, Topographical Survey and Land Use Management Division
Kathmandu

Prepared by:
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N W E S

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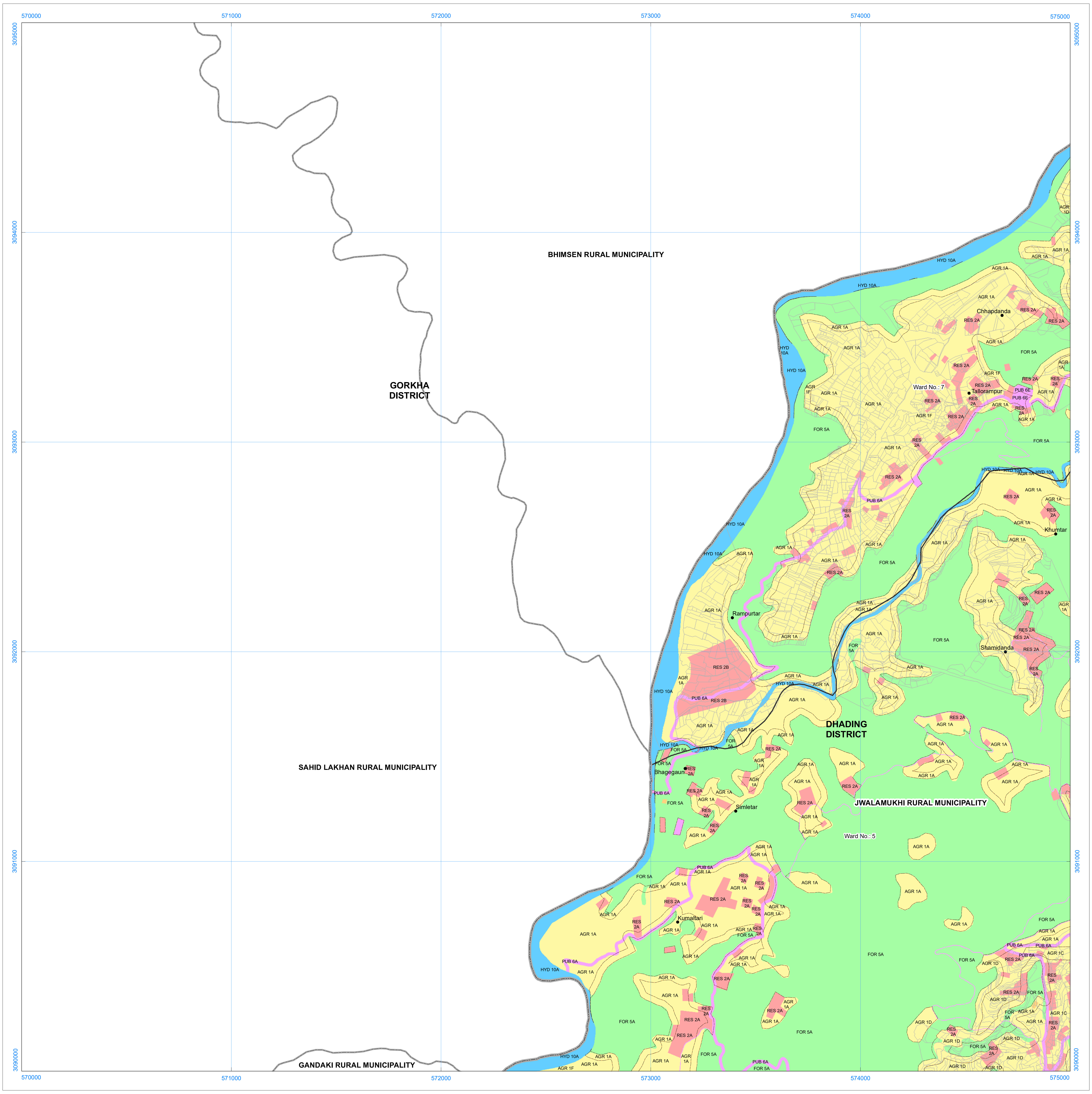
CADASTRAL SUPERIMPOSED ON LAND USE ZONING

Sheet Number: 101-015

JWALAMUKHI RURAL MUNICIPALITY | **DHADING DISTRICT**



Legend

Land Use Zones

- Zone 1 - Agricultural
- Zone 2 - Residential
- Zone 3 - Commercial
- Zone 4 - Industrial
- Zone 5 - Forest
- Zone 6 - Pubic Use
- Zone 7 - Other Zone
- Zone 8 - Mine and Minerals
- Zone 9 - Cultural and Archeological
- Zone 10 - Riverine Stream, Lake and Marsh Area
- Snowy Mountain Area

Boundaries

- International
- District
- GaPaNaPa
- Ward
- Settlement
- Mines Location
- Cadastral Parcel

Note: Land Use Classes are classified according to Land Use Act 2076.

*Snowy Mountain Area stands for area of mountaineous region, with 12 months of snow coverage. It should be understood as public use area explained in Land Use Act 2076 and Land Use Policy 2072.

Risk Boundaries

Flood	Landslide	Fire	Seismic	Other
High	High	High	High	High
Medium	Medium	Medium	Medium	Medium
Low	Low	Low	Low	Low

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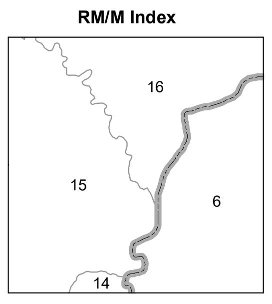
	101-025	101-026

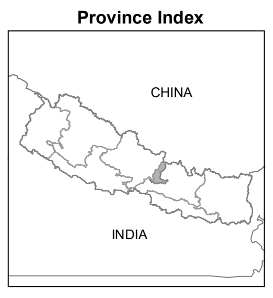
RM/M Index



6. Jwalamukhi Rural Municipality
14. Gandaki Rural Municipality
15. Sahid Lakhan Rural Municipality
16. Bhimsen Rural Municipality

District Index

Province Index



Land Use Zone 1 Sub-class	Land Use Zone 2 Sub-class	Land Use Zone 3 Sub-class	Land Use Zone 4 Sub-class	Land Use Zone 5 Sub-class	Land Use Zone 6 Sub-class
Cereal Crop Production Area -1A Cash Crop Area -1B Horticultural Area -1C Animal Husbandry Area -1D Fish Farming Area -1E Agro Forestry Area -1F Other Agriculture Area -1G	Existing Residential Zone - 2A Potential Area for Residential Zone - 2B	Service Areas - 3A Business Area - 3B	Areas Under Industrial Use - 4A Potential Area for Industrial Use - 4B	Existing Forest - 5A Potential Area for Forest Including Barren Lands, Wet Lands - 5B	Areas Under Roads, Railways etc. - 6A Areas Under Hydrography - 6B Cultural, Archeological and Religious Areas etc. - 6D Public Health, Education Library, Police Station, Fire Station, Telephone, Electricity Areas etc. - 6E Grazing Land - 6F Open Spaces, Picnic Spots, Recreational etc. - 6C Government Instutional Area - 6G
	Land Use Zone 7 Sub-class Other Areas	**Land Use Zone 8 Sub-class** Existing Mine and Minerals Zone - 8A Potential Area for Mine and Minerals - 8B	**Land Use Zone 9 Sub-class** Existing Cultural and Archeological Area - 9A Potential Cultural and Archeological Area - 9B	**Land Use Zone 10 Sub-class** Areas Under Riverine Stream, Lake and Marsh - 10A Potential Riverine Stream, Lake and Marsh - 10B	

Criteria Applied in Delineating Land Use Zoning Boundary

-Existing (present) land use

-Land capability and land system identified by the analysis of soil characteristics (PH value, Nitrogen, Phosphorous, Potash etc), soils moisture, temperature, drainage, irrigation, slope, elevation, aspect, topography etc

-Suitability identified on the basis of the neighborhood and spatial analysis (distance from roads, markets, settlements, river and stream, and hazards like landslide, flood, seismic, fire, industrial etc.)

Concept Applied in the Zoning:

- Classification of land into Agricultural area, Residential area, Commercial area, Industrial area, Forest area, and Publicuse area .
- 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.

TYPE LEGEND SAMPLE

Land Use Zone Classification

2A — Existing Residential Area
2B — Potential Residential Area

Scale 1:10,000

Meters 200 100 0 200 400 600 800 1,000 Meters

Land Use Zoning map is based on the ortho-rectified satellite image produced through the fusion of ZY-3 MSS 5.8 meter and Panchromatic 2.1 meter spatial resolution acquired on 2020. Basically the zoning was based on subjective analysis of Present Land Use, Land capability and Socio-economic setting of the study area. Land capability map was produced based on the Soil analysis, Land System and Present Land Use. Soil information for Land Capability was collected from the soil samples which were chemically analyzed in the soil laboratory. Location for the soil pit for sample collection was identified by defining the land unit which were defined by delineating the Land System over the high resolution satellite imagery data. Present Land Use was also considered while defining the boundary of land zoning. Extensive field study was carried prior to delineating to have better understanding of the social setting of the study area. The minimum mapping unit adopted is 0.25 hectare.

Projection and Datum Information
Projectiion: Modified Universal Trasnverse Mercator
False Easting: 500000 m
False Northing: 0 m
Central Meridian: 84 Degree East
Scale Factor: 0.9999
Latitude of Origin: 0 Degree
Linear Unit: Meter
Datum: Everest 1830

Government of Nepal
Ministry of Land Management, Cooperatives and Poverty Alleviation
Survey Department, Topographical Survey and Land Use Management Division
Kathmandu

Prepared by:
Hexa International Pvt. Ltd., Dhalku, Kathmandu

N W E S

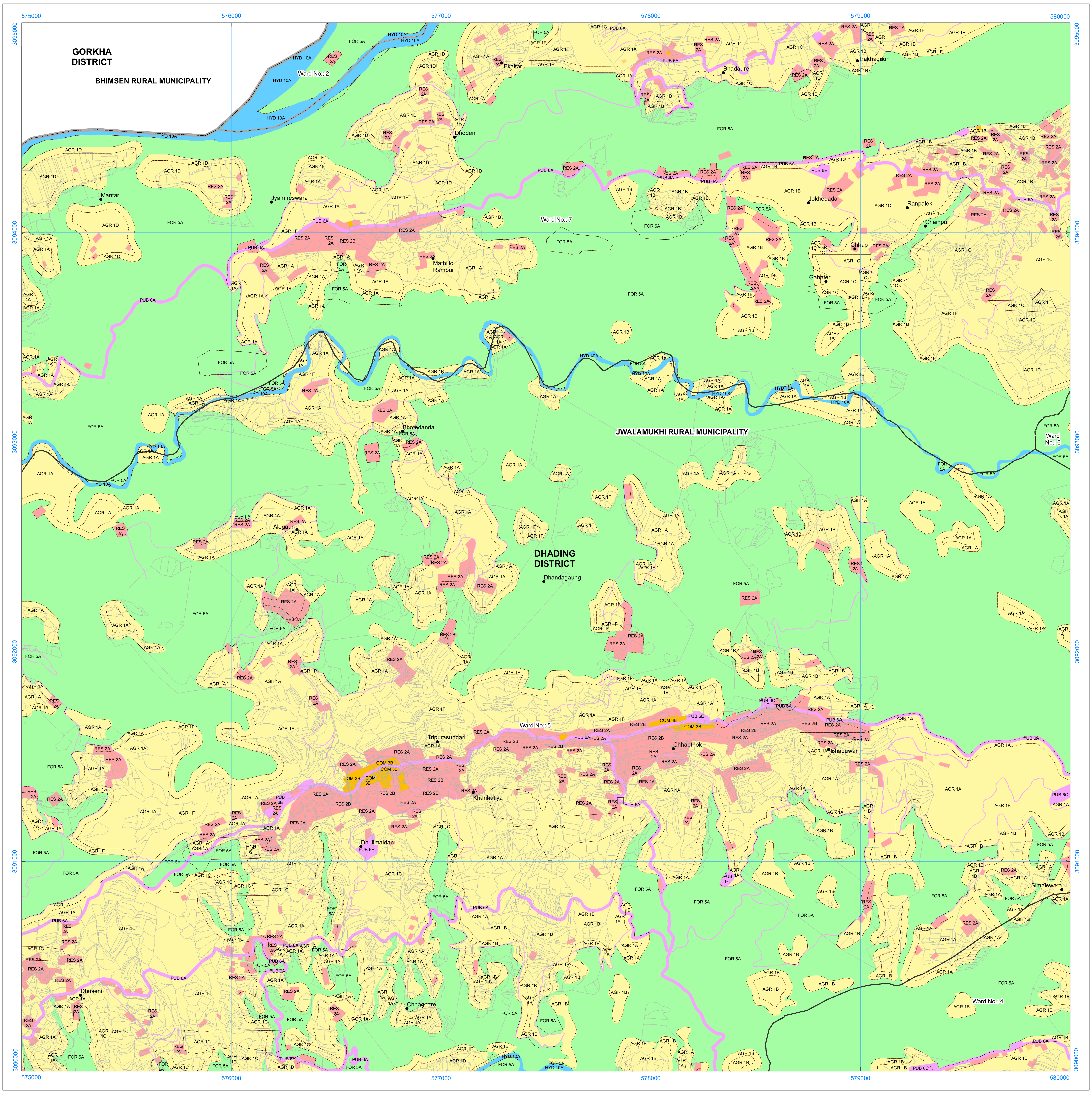
International boundary shown in this map series does not suffice for validating the actual boundary line that exists on the ground.

CADASTRAL SUPERIMPOSED ON LAND USE ZONING

Sheet Number: 101-016

JWALAMUKHI RURAL MUNICIPALITY,TRIPURA SUNDARI RURAL MUNICIPALITY

DHADING DISTRICT



Legend

Land Use Zones

- Zone 1 - Agricultural
- Zone 2 - Residential
- Zone 3 - Commercial
- Zone 4 - Industrial
- Zone 5 - Forest
- Zone 6 - Pubic Use
- Zone 7 - Other Zone
- Zone 8 - Mine and Minerals
- Zone 9 - Cultural and Archeological
- Zone 10 - Riverine Stream, Lake and Marsh Area
- Snowy Mountain Area

Boundaries

- International
- District
- GaPaNaPa
- Ward
- Settlement
- Mines Location
- Cadastral Parcel

Note: Land Use Classes are classified according to Land Use Act 2076.

*Snowy Mountain Area stands for area of mountaineous region, with 12 months of snow coverage. It should be understood as public use area explained in Land Use Act 2076 and Land Use Policy 2072.

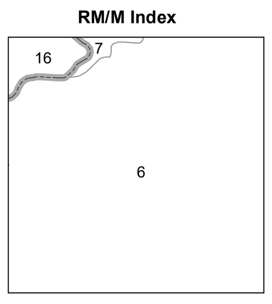
Risk Boundaries

Flood	Landslide	Fire	Seismic	Other
High	High	High	High	High
Medium	Medium	Medium	Medium	Medium
Low	Low	Low	Low	Low

Sheet Index

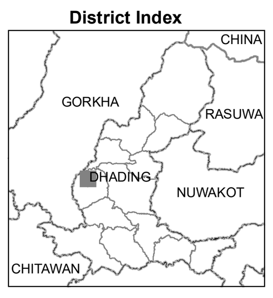
101-005	101-006	101-007
101-015	101-025 101-016	101-017
	101-026	101-027

RM/M Index

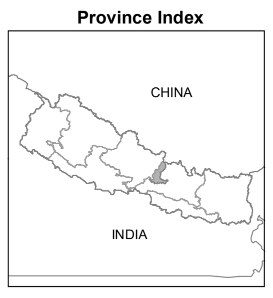


6. Jwalamukhi Rural Municipality
7. Tripura Sundari Rural Municipality
16. Bhimsen Rural Municipality

District Index



Province Index



Land Use Zone 1 Sub-class	Land Use Zone 2 Sub-class	Land Use Zone 3 Sub-class	Land Use Zone 4 Sub-class	Land Use Zone 5 Sub-class	Land Use Zone 6 Sub-class
Cereal Crop Production Area -1A Cash Crop Area -1B Horticultural Area -1C Animal Husbandry Area -1D Fish Farming Area -1E Agro Forestry Area -1F Other Agriculture Area -1G	Existing Residential Zone - 2A Potential Area for Residential Zone - 2B	Service Areas - 3A Business Area - 3B	Areas Under Industrial Use - 4A Potential Area for Industrial Use - 4B	Existing Forest - 5A Potential Area for Forest Including Barren Lands, Wet Lands - 5B	Areas Under Roads, Railways etc. - 6A Areas Under Hydrography - 6B Cultural, Archeological and Religious Areas etc. - 6D Public Health, Education Library, Police Station, Fire Station, Telephone, Electricity Areas etc. - 6E Grazing Land - 6F Open Spaces, Picnic Spots, Recreational etc. - 6C Government Instutional Area - 6G

Land Use Zone 7 Sub-class	Land Use Zone 8 Sub-class	Land Use Zone 9 Sub-class	Land Use Zone 10 Sub-class
Other Areas	Existing Mine and Minerals Zone - 8A Potential Area for Mine and Minerals - 8B	Existing Cultural and Archeological Area - 9A Potential Cultural and Archeological Area - 9B	Areas Under Riverine Stream, Lake and Marsh - 10A Potential Riverine Stream, Lake and Marsh - 10B

Criteria Applied in Delineating Land Use Zoning Boundary

-Existing (present) land use

-Land capability and land system identified by the analysis of soil characteristics (PH value, Nitrogen, Phosphorous, Potash etc), soils moisture, temperature, drainage, irrigation, slope, elevation, aspect, topography etc

-Suitability identified on the basis of the neighborhood and spatial analysis (distance from roads, markets, settlements, river and stream, and hazards like landslide, flood, seismic, fire, industrial etc.)

Concept Applied in the Zoning:

- Classification of land into Agricultural area, Residential area, Commercial area, Industrial area, Forest area, and Publicuse area .
- 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.

TYPE LEGEND SAMPLE

Land Use Zone Classification

2A — Existing Residential Area

2B — Potential Residential Area

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