VIEW FROM BULBULE TAAL, BIRENDRANAGAR
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TAYAR NEPAL – IMPROVED DISASTER RISK MANAGEMENT PROJECT

DEVELOPMENT OF RISK SENSITIVE LAND USE PLANNING FOR FOUR MUNICIPALITIES – PHASE I

Multi Hazard, Vulnerability and Risk Profile – Birendranagar Municipality

April 2022

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EXECUTIVE SUMMARY

Birendranagar Municipality is located in Surkhet district of Karnali Province of Nepal. It covers an area of 245.06 sq. km. it is located in the Siwalik physiographic (Chure) region of Nepal and lies 665 m above the mean sea level. The municipality is surrounded by Chingad rural municipality in the east, Barahatal Rural Municipality in the west, Dailekh district in the north and Bheriganga Municipality in the south.

The landscape of the municipal region is dominated by forest area (54 percent) and agriculture area (22 percent) with existing built-up and settlement area of 6 percent only, though the urban growth has been steadily seen at the annual growth rate of 0.19 percent over the last decade. The growth is increasing in and around the main market areas in wards 3, 4, 5, 6, 7 and 8 indicating both outward and infill development in and around the market centers as well as linear development along the major thoroughfare. The population of the municipality is 114,451 with female/male ratio of 1.04 with growth rate of 4.57 percent.

In the municipality, there are no records of devastating earthquakes in the past. It seems, there was no major earthquake since 1505 in western Nepal. Based on the current study, the seismicity is analyzed as VIII-X in Modified Mercalli Intensity (MMI) in different scenario earthquake, with MHT scenario having the highest intensity of X. These scales indicate that the municipal region is susceptible to high intensity earthquakes, which could result in significant loss of lives and properties, owning to the fact that the majority of constructions are not earthquake resistant, lack of adequate preparedness as well as lack of resources and capacities.

The entire municipal region is composed of steep sloping terrain and dissected topography, where landslides, debris flow and gully erosions are common phenomenon. . There are altogether 303 active landslides identified in the municipality. The landslide susceptibility analysis showed about 19 percent of municipal area falls under "High" susceptibility, 41 percent "Moderate" susceptibility and 40 percent "Low" susceptibility to rainfall triggered landslides. Similarly, under earthquake triggered landslides, 9 percent of municipal region falls under "High", 49 percent under "Moderate" and 42 percent under "Low" susceptibility.

The municipal region lies in Bheri river watershed. The Bheri River originate from the snow peaked mountains in North and flow downstream to confluence with Karnali River. The settlements built near to the Khorke, Itram khola, Neware Khola are at risk of flooding. There are risks of flooding in downstream area by these streams and there is a high possibility of inundation of large area of land at the confluence of those all small rivers downstream at inlet to the Nikashe Khola due to improper drainage provisions and urban settlements and urbanization at upstream area.

The municipality region also suffers from periodic forest fires. There have been 175 occurrences of forest fires between 2010 and 2021, with highest number of forest fires occurring in 2016. Forested areas in Ward 9 and 2 are the hotspots. The settlements and villages near to the forested areas and along the edges are in risk of the spread of forest fires. The forest fires are likely linked with the change in temperature pattern over the last decade. The heat wave analysis showed that there is an increasing trend of temperature per year as well as increase in the length of the heatwave days. The increase in temperature will likely increase the climate hazards such as extreme precipitation, extreme temperatures and heat wave and climate induced hazards such flood, flash flood, landslide, forest fires etc.

Few incidents of lightening have occurred in the municipality. Focus group discussion showed that past two incidents occurred in wards- 15 (Ratu settlement area had frequent lightening and in 2019 ward 16. Human Wildlife Conflict contribute to the loss of crop products in the conflict zone. Deers from the nearby forest have been causing loss of crops in the area. Communities in Kuirt, Kakre Bihar etc are affected by HWC.

In terms of industrial hazards, there are no such industries or industrial sites with potentiality of hazards, especially related to the industrial fires, material or chemical spills, toxic plumes or other forms of potentially hazardous events. However, there are several petrol stations/pumps with potential of explosion and fire hazards in case of accidental release and ignitions including Vapor Cloud Explosion which can cause damages within the blast radius of 100m.

The findings from VCA shows the wards in Birendranagar Municipality fall into mid to high level of vulnerability status. Though most of the wards have relatively higher adaptive capacity, their ranking shows 8 out of 16 wards in relatively higher vulnerability zone with a score from 0.6 to 0.9. Ward 9 & 12, has been identified as the most vulnerable ward in the indexing, while wards 14 and 16 have scored the least in the vulnerability. It is also evident that ward 9 is highly exposed to flood hazards, and with high susceptibility of the HHs, their resilience to shocks is low. Although, wards 14 and 16 have scored low in the vulnerability indexing but are equally exposed to hazards like rainfall induced landslide with almost 37%, 43% and 33% HHs exposed to landslide hazard respectively. With the given scenario, the RSLUP for Birendranagar should focus on identifying specific policies and programs to mitigate the disaster risk ward-wise and enabling better preparedness at local level.

Contents

LIST OF MAPS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOGRAPHS

ACRONYMS AND ABBREVIATIONS

ADSL	Asymmetric Digital Subscriber Line
APF	Armed Police Force
CAO	Chief Administrative Officer
CBD	Central Business District
CCA	Climate Change Adaptation
CDMA	Code-division multiple access
CGI	Corrugated Iron
DRM	disaster risk management
DRR	disaster risk reduction
DRRM	disaster risk reduction and management
DUDBC	Department of Urban Development and Building Construction
Eco-DRR	Ecosystem based Disaster Risk Reduction
EWS	Early Warning System
GDP	Gross Domestic Product
GESI	Gender equality and social inclusion
GIS	Geographical Information System
GoN	Government of Nepal
HEOC	Health Emergency Operation Centers
HFT	Himalayan Frontal Thrust
HOS	Humanitarian Open Space
HVRA	Hazard, Vulnerability and Risk Assessment
INGOs	International Non-Governmental Organizations
IPCC	Intergovernmental Panel on Climate Change
LGOA	Local Government Operation Act
LULC	Land use land cover

LUP	Land Use Plan
Km	Kilometer
MBT	Main Boundary Thrust
MCT	Main Central Thrust
MFT	Main Frontal Thrust
MoFAGA	Ministry of Federal Affairs and General Administration
MoFE	Ministry of Forests and Environment
MoHA	Ministry of Home Affairs
MoLMCPA	Ministry of Land Management, Cooperatives and Poverty Alleviation
MOUD	Ministry of Urban Development
NDRRMA	National Council, Executive Committee, and National Disaster Risk Reduction and Management Authority
NBS	Nature Based Solutions
NGOs	Non-Governmental Organizations
NTC	Nepal Telecom
NTPCO	New Town Project Coordination Office
NUDS	National Urban Development Strategy
PHCC	Primary Health Care Center
PGA	Peak Ground Acceleration
PWD	Person with Disabilities
RCC	Reinforced Cement Concrete
RS	Remote Sensing
RSLUP	Risk Sensitive Land Use Plan
SLC	School Leaving Certificate
SOP	Standard Operating Procedures
SOWC	Strength, Opportunities, Weakness and Challenges
STDS	South Tibetan Detachment System

Tayar Nepal	USAID/Nepal's Tayar Nepal – Improved Disaster Risk Management project
TOR	Terms of Reference
TWG	Technical Working Group
UNDP- CDRMP	United Nations Development Programme's Comprehensive Disaster Risk Management Programme
UNDRR	United Nations Office for Disaster Risk Reduction
USAID	United States Agency for International Development
VDCs	Village Development Committees
VCA	Vulnerability Capacity Assessment
WHO	World Health Organization

GLOSSARY

Building Code	A set of ordinances or regulations and associated standards intended to control aspects of the design, construction, materials, alteration, and occupancy of structures that are necessary to ensure human safety and welfare, including resistance to collapse and damage.
Capacity	The combination of all the strengths, attributes, and resources available within a community, society or organization that can be used to achieve agreed goals.
Critical infrastructure	The physical structures, facilities, networks, and other assets that support services that are socially, economically or operationally essential to the functioning of a society or community.
Disaster	A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.
Disaster Risk Reduction	The concept and practice of reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including through reduced exposure to 11 hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.
Elements at risk	People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.
Exposure	The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.
Geo-hazards	A geological state that may lead to widespread damage or risk. Geohazards are geological and environmental conditions and involve long-term or short-term geological processes. Geohazards include earthquakes, landslides, tsunamis, etc. and can range from local events such as a rock fall or gully erosion, landslide to events that threaten humankind such as a large earthquake.
Hazard	A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.
Land Use Act	An act formulated to regulate the land that is developed based on the land use plan.

Land use plan	A document or set of documents which provide a clear policy and strategic instructions for sustainable and effective spatial development for an area.
Land use planning	Systematic and iterative process carried out to create an enabling environment for sustainable and equitable development of land and land resources to meet people's needs and demands. It assesses the physical, social, economic, institutional, and legal potential and constraints with respect to the optimal and sustainable use of land and land resources and empowers people to make collective decisions on how to allocate and utilize those resources.
Land Use Policy	A policy formulated to regulate the land that is developed based on the land use plan.
Multi-hazard	More than one potential physical damaging event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.
Municipality	City or town with its own local government including metropolitan city and sub-metropolitan city as is provisioned by the Constitution of Nepal.
Planning and Building Bylaw	Legal tools to achieve orderly development. Planning Bylaws regulate the growth and development of a city and the Building Bylaws regulate coverage, height, building bulk, architectural design and construction aspects of buildings.
Resilience	The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.
Risk	The combination of the probability of a hazardous event and its consequences which result from interaction(s) between natural or man-made hazard(s), vulnerability, exposure and capacity.
Risk sensitive land use planning	Integrated and mainstreamed disaster risk land use plan.
Rural	Sparsely populated area outside of the limits of a city or town or a designated commercial, industrial, or residential center. Rural areas are characterized by farms, vegetation, and open spaces.
Seismic hazards	Seismic hazard is the hazard associated with potential earthquakes in an area.
Urban	Pertaining to city with dense population, heterogeneity, commercial activities, mobility and developed buildings, services, and infrastructure.

Vulnerability	The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.
Ward	Administrative sub-division of a rural municipality or municipality as is provisioned by the Constitution of Nepal.

SECTION 1 BACKGROUND

INTRODUCTION

1.1 BACKGROUND

Nepal is prone to myriad of disasters caused by geophysical, hydro-meteorological, climatological hazards and biological hazards. Earthquakes, floods, landslides, glacier lake outburst flood (GLOF), landslide dam outburst flood (LDOF), drought, wildfires, extreme storms, heat/cold waves and epidemic outbreaks are the most prevalent and recurring hazards impacting socio-economic fabric and development gains of the country.

Nepal is also highly vulnerable to climate change impacts mainly due to challenging topography and diversity of climate zones, fragile socio-economic conditions and sensitive ecosystems. Poverty and social disparity as well as people's dependency on natural resources for livelihood have made Nepal more vulnerable to the impacts of climate change. The Global Climate Risk Index (Eckstein, Künzel, and Schäfer 2021) ranks Nepal among the 10th most affected countries from 2000 to 2019 in terms of climate long term climate risk. The combination of political, geographic and social factors have contributed to the increasing vulnerability (World Bank and Asian Development Bank 2021), as indicated by the ND-GAIN vulnerability score1 ranking of 138th out of 181 countries.

More than 60 percent of Nepal's population is urban population residing in 293 municipalities compared with just 17 percent in 2011. Most of 293 newly declared municipalities have inherent rural characters with prevalence of various natural and human-induced hazards. The population of the municipalities are highly exposed due to unregulated settlements in hazard prone areas; unsafe, sub-standard buildings and infrastructure; lack of open spaces; unplanned urban growth; lack of or inadequate planning and weak implementations of the plan; ineffective enforcement mechanisms; environmental mismanagement; unsustainable land use practice; and poverty.

In this context, Tayar Nepal aims to build the capacity of its partner municipalities to establish **stronger DRRM systems** needed to prepare for and respond to disasters and promote **safer settlements** by helping municipalities understand their hazard risk profiles and holistically improve risk-informed urban land use planning in its program municipalities and replicate to other municipalities.

1.2 OBJECTIVE OF WORK

The overarching objective of the task order is "to prepare and develop Risk Sensitive Land Use Plan (RSLUP) for Birendranagar Municipality". The specific objectives of the overall RSLUP process as stipulated are:

- Undertake actionable multi hazard risk assessment and multi-sectoral vulnerability assessment at the municipal level.
- Develop draft RSLUP by contextualizing the scenario of the municipality and through consultative and multi-stakeholder engagement processes.
- Identify and recommend disaster risk reduction measures.

[1] University of Notre Dame (2019). Notre Dame Global Adaptation Initiative. URL: https://gain.nd.edu/our-work/country-index/. Higher ND-GAIN vulnerability score indicating high vulnerability.

- Support municipal governments to develop key policy decisions (Planning regulations and building bylaws) to reduce and manage risks using land use and urban planning techniques.
- Develop RSLUP associated manuals, guidelines, tools, SOPs, communication materials others as required.
    - Undertake necessary activities to build local knowledge and capacitate the municipalities to implement, regulate RSLUP related activities and building bylaws.

1.3 SCOPE AND OUTLINED OF THE DOCUMENT

Under the first objective of the work, a comprehensive Multi-Hazard Vulnerability and Risks Assessment (MHVRA) was done to assess the trend and susceptibility of prevalent hazards in the municipal region, their potential impacts to the communities and economic activities in the municipality.

This report presents the technical details and outcomes of the MHVRA along with the supporting results of the extensive field and lab testing works undertaken for various processes undertaken. This report entitled "Multi Hazard, Vulnerability and Risk Profile of Birendranagar Municipality" is organized in five different sections with related chapters.

Section 1 Background presents the background of the works, the general concept and context of the hazard, vulnerability and risk used, the mainstreaming of MHVRA in the context of Sendai Framework, UNFCC/IPCC and other international conventions including cross cutting national policies.

Section 2 Municipal Profile presents the spatial profile of the municipality focusing on the urban bio-physical environment, urban system, and elements-at-risk from multi-hazards.

Section 3 Multi-Hazards in Birendranagar Municipality includes chapters presenting the technical details of the methodology implemented for assessing various hazards and the results of hazard modelling, assessment, and mapping.

Section 4 Multi-Sectoral Vulnerability Capacity section presents the vulnerability capacity assessment undertaken for physical vulnerability, community level socio-economic vulnerability, economic and environmental vulnerabilities including critical infrastructures and services.

Section 5 Multi-Hazards Risks presents the probabilistic risk assessment and the results portraying the context of risks in terms of prevalent hazards in the municipality.

Section 6 Mainstreaming HVRA in DRRM and RSLUP Processes recommends the pathway to integrate and mainstream the outcomes of MHVRA into the risk sensitive land use planning (RSLUP), land use policy and implementation Planning Regulations and Building Bye-Laws.

1.4 LIMITATIONS OF THE STUDY

The primary objective of this study was to develop a baseline information of prevalent multi-hazards and their risks in the municipality to facilitate development of risk sensitive land use policy and plan. All the activities have been undertaken in accordance with the terms of reference and the contract. However, certain unforeseen issues related to COVID-19 situation and ensuing restrictions limited effective undertaking of few activities that attributed to the limitations in some of the non-critical outputs. Following were the limitations of the study:

- Due to COVID-19 situation and available time, each and every community in the wards could not be incorporated in the vulnerability capacity assessment (VCA) study. VCA study was done at ward level with representative communities. Additionally, separate community based VCAs were done in the targeted most vulnerable communities. The representation of the communities and the selection of the most vulnerable communities were done by the municipality.
- Due to the COVID-19 situation and resulting economic crisis in the municipalities, the field based Key Informant Interviews (KIIs) with relevant economic sector actors in the municipality could not be conducted effectively and in many cases cancelled. This resulted in incomplete and skewed information, hence a comprehensive study of economic vulnerabilities of the municipality could not be done. Similar issue inhibited comprehensive study of environmental vulnerabilities as the key agriculture sector, forestry sector and other environmental sector actors could not be consulted. However, both the economic and environmental vulnerability of the communities have been assessed during the community level VCA process and incorporated in this study report.

In the technical aspects, there were several limitations including:

- Non-availability of building typology and structure type data to undertake comprehensive building seismic vulnerability and risk assessment, therefore, damage-loss estimation of building stock and critical infrastructures could not be done effectively. Alternatively, representative samples (different types) of building stocks were done through rapid visual screening and their seismic vulnerability assessed in terms of observed structural vulnerabilities. This gives an indicative assessment of the conditions of the building stock in the municipality to support formulation of land use policy and risk sensitive land use plan activities.
- Due to the lack of damage-loss (physical vulnerability curve) for landslides, floods and other hazards for building and physicals structures appropriate to Nepalese conditions, a detailed probabilistic risk assessment for these hazards could not be undertaken. Risk were assessed in terms of elements "at-risk" in relevance to the risks sensitive land use planning context.

CONCEPT AND CONTEXT OF HAZARDS, VULNERABILITY AND RISK

1.5 HAZARD, VULNERABILITY AND RISK

Hazards are potentially damaging physical events, phenomena, or human activities that cause loss of life, injury, property damage, social and economic disruption, or environmental degradation (UNDRR). Hazards are threat of a stress or perturbation to a system and what it values (Stockholm Environment Institute -SEI). They are external factors that affect the society or elements at risk, whereas vulnerabilities are the internal factors that affect the transformation of hazards into disasters. Vulnerabilities actually determine the impact of the hazard on society or elements at risk. Hazards are either natural that occur as part of our environment or human induced hazards that arise directly from human activity. The location of natural hazards primarily depends on natural processes, including movement of tectonic plates, the influence of weather systems, and existence of waterways and slopes. But processes such as urbanization, climate change, and environmental degradation also influence the location, intensity and occurrence of natural disasters.

The classification of hazards varies across different institutions and government, but can be broadly divided into following categories:

- Biological hazards originating from biological vectors, including pathogenic organisms, toxins or bioactive substances. Examples include bacteria, virus, parasites as well venomous plants and insects.
- Environmental hazards are created by environmental degradation or physical or chemical pollution in the air, water, or soil.
- Geological or Geophysical hazard originate from internal earth processes like earthquakes, volcanic activity, emissions etc. Hydro meteorological factors also contribute to some of the processes like mud flow, landslide etc.
- Hydro meteorological hazards of atmospheric, hydrological, or oceanographic origin. Examples are tropical cyclones (also known as typhoons and hurricanes); floods, including flash floods; drought; heat waves and cold spells; and coastal storm surges.
- Technological hazards originate from technological or industrial conditions, dangerous procedures, infrastructure failures or specific human activities. Examples include industrial pollution, nuclear radiation, toxic wastes, dam failures, transport accidents, factory explosions, fires, and chemical spills.

Human control over the occurrence of natural hazards is very limited, necessitating a focus on the mitigation, preparedness, and response and recovery actions for natural hazards than prevention. The most important step in hazard assessment is identification of relevant hazard (specific to a location) and collection of hazard related data. The most essential data define the date, geographical location and extent, and maximum intensity of historical events. A collection of the spatial, intensity, and temporal characteristics for events in an event set is termed a hazard catalogue. Hazard catalogues can be used with risk models in a deterministic or probabilistic manner. Historical events should also be analyzed to understand the impact of past events with current exposure, but can also be used to estimate the probability of a hazard occurring at a location with a specific intensity (www.preventionweb.net).

Vulnerability is defined as degree to which a person, system or unit is likely to experience harm due to exposure to perturbations of stresses. In past, vulnerability was limited to physical susceptibility, however, the concept has now become more comprehensive to include susceptibility, exposure, coping capacity, adaptive capacity, social inequities, and physical, social and economic weaknesses.

If vulnerability is considered from hazard perspective, it is possible to define it as "the likelihood that an individual or group will be exposed to and adversely affected by a hazard.

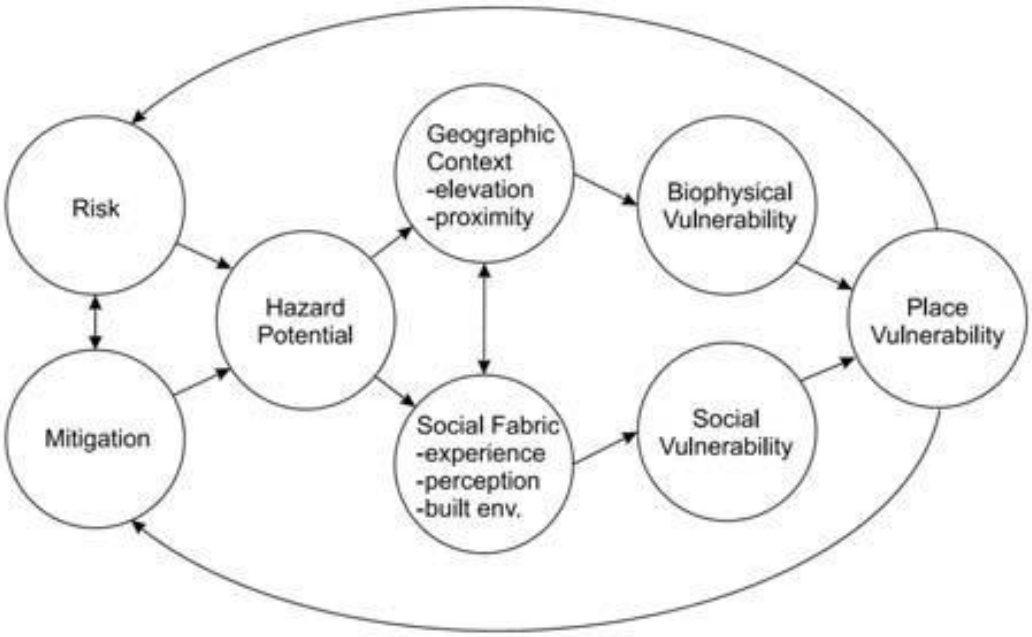


Figure 0-1: The Hazards-of-place model of Vulnerability

Cutter in 1996 developed a hazards-of-place model of vulnerability. According to this figure, risk and mitigation interact to produce the hazard potential, which is filtered through the social fabric to create social vulnerability and geographic context to produce biophysical vulnerability. These two together form the overall place vulnerability. The hazards-of-place model of vulnerability has an explicit focus on locality since it depicts the overall situation and elements contributing to the vulnerability of a specific geographical area.

Vulnerability assessment is a broad concept that can be discussed in several different contexts e.g., vulnerability to climate change, disasters, wetlands etc. Vulnerabilities vary according to hazards, human ecology and social changes involved. Every disaster and every geographical location have unique circumstances; as a consequence, it is not possible to propose a single vulnerability assessment methodology. Each hazard poses different risk to communities at different levels.

Risk is the conditional probability and magnitude of harm attendant on exposure to a perturbation or stress. It is basically the likelihood of something happening and consequences if it happens. It is a combination of three components: hazard, exposure and vulnerability which can be represented by three sides of a triangle, also called risk triangle. If any one side of the triangle increases, the area of the triangle increases, hence the amount of risk also increases and vice-versa.

Figure 0-2: The Risk Triangle

1.6 DEFINATION USED FOR HAZARD, VULNERABILITY AND RISK ASSESSMENT

Hazards, vulnerability and risk have been defined and understood differently in different context and different domain. There exists a vast set of literatures and practices defining these terminologies in different context. Two different but interrelated domains viz. the DRR given by the UNDRR framework and Climate change given by the IPCC framework have defined these terminologies respective to their science and domain context, albeit the differences in the understanding and definitions are now getting narrower with overlapping context and analogous use of the terminology. It is now well established that both the DRR and CC domains are intrinsic and intersects across vertically and horizontally in terms of the drivers of hazards, hazards, their impacts, vulnerability of the system and probability of risk.

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. (IPCC, 2014).

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC, 2014).

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2014).

Sensitivity: The physical predisposition of human beings, infrastructure, and environment to be affected by a dangerous phenomenon due to lack of resistance and predisposition of society and ecosystems to suffer harm as a consequence of intrinsic and context conditions making it plausible that such systems once impacted will collapse or experience major harm and damage due to the influence of a hazard event (IPCC, 2012).

Adaptive capacity: The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC, 2014). The combination of the strengths, attributes, and resources available to an individual, community,

society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities (IPCC, 2012).

Risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values (IPCC, 2014). Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur.

The term 'risk' is often used to refer to the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and infrastructure.

Box 1: UNDRR Definition of DRR Terminologies

Hazard: A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.

Hazards may be natural, anthropogenic or socio-natural in origin. Natural hazards are predominantly associated with natural processes and phenomena. Anthropogenic hazards, or human-induced hazards, are induced entirely or predominantly by human activities and choices. This term does not include the occurrence or risk of armed conflicts and other situations of social instability or tension which are subject to international humanitarian law and national legislation. Several hazards are socio-natural, in that they are associated with a combination of natural and anthropogenic factors, including environmental degradation and climate change.

Exposure: The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.

Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability and capacity of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest.

Coping Capacity: the ability of people, organizations and systems, using available skills and resources, to manage adverse conditions, risk or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks.

Vulnerability: The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

Risk: The combination of the probability of an event and its negative consequences. Risk Assessment is a methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend.

1.7 CONTEXT OF HVRA IN THE NATIONAL DRR ACT, DRR POLICY AND DRR-NATIONAL PLAN OF ACTION

Nepal's DRRM landscape is guided by Constitution of Nepal-2015 and the Disaster Risk Reduction and Management (DRRM) Act of 2017. The Constitution of Nepal stipulates that disaster risk reduction and management is sole responsibility of the local government, and also shared responsibility amongst federal, provincial and local governments.

The Government of Nepal endorsed the Disaster Risk Reduction and Management Act in 2017 with necessary provisions for effective disaster risk management throughout the disaster management cycle – preparedness, response, rehabilitation and mitigation. The DRRM Act sets out formal structures, roles and responsibilities at federal, provincial, district and local levels. At federal level there is provision for a DRRM National Council, Executive Committee, and National Disaster Risk Reduction and Management Authority (NDRRMA). The First Amendment of the DRRM Act in 2019 also included provision for a Provincial Disaster Management Council (Chapter 6, Clause 13 'Ka') and further specifies the structure and functions of Provincial Disaster Management Executive Committee, though these are yet to be constituted. The Act also stipulates a structure (a Disaster Management Committee) and DRRM functions for the local governments. Local governments are also guided by the Local Government Operations (LGO) Act of 2017 AD, which provides for execution of disaster management structures and functions for each local government and their ward units. In Chapter 1 (clause 2), the act has provided definition of disaster, natural disaster, disaster risk reduction, disaster response, disaster recovery, disaster search and rescue team and disaster management. The act however doesn't highlight the concept of risk, vulnerability and hazard. The chapter 3 highlights the constitution of the executive committee under the chairmanship of the home minister and key tasks to be executed by this committee. Some of the key tasks with respect to Hazard, Vulnerability and Risk Analysis include– identification of vulnerable locations and mapping of vulnerabilities and risk; risk sensitive development and land use planning and implementation; risk assessment of public infrastructure, relocation of vulnerable settlements located on river bank, landslide prone areas, or at risk of being inundated; special plans and programs for women, children, old age citizen, dalit and other marginalized communities who are at risk; and disaster mitigation in communities at highest risk. Similarly, in Chapter 4 (clause 11), the tasks of NDRRMA have been described. The key tasks with respect to HVRA includes- research and studies on reasons for disasters and their mitigation; developed of national information system on disaster and collection of data related to disaster; awareness program on DRR; research and use of technology like remote sensing, hydro metrological date etc. Chapter 7 (clause 17) stipulated the key tasks to be carried out by the local government. However, it does not highlight tasks related to HVRA at the municipal level or local level.

Nepal's overarching framework for DRRM is guided by the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 (UNDRR, 2015). The four priority actions of the SFDRR to prevent new disasters and reduce existing disaster risks, are: (i) understanding disaster risk; (ii) strengthening disaster risk governance to manage disaster risk; (iii) investing in disaster reduction for resilience, and; (iv) enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction. Aligning with the principles and framework of the SFDRR, the GoN endorsed the National Policy for DRR 2018 and the Disaster Risk Reduction National Strategic Action Plan (2018-2030). These documents provide a comprehensive planning framework for disaster risk reduction and management, encompassing different priority areas and guiding government actors and stakeholders to achieve targets by adopting appropriate processes.

The mission of the National Policy for DRR is to substantially reduce the disaster risk and losses in lives, livelihoods and health as well as in the economic, social and physical infrastructure and cultural and environmental assets of persons, communities and nation and to increase their resiliency by implementing disaster risk reduction and management activities in a balanced way. Some of the policy points in line with HVRA comprises of monitoring of disasters' development of disaster risk assessment and mapping system in areas of health, education, agriculture, industry, tourism, energy, housing, transportation, water supply, sanitation, and cultural heritage; use of appropriate technology for DRR through research and study of geology, seismology, GIS, remote sending and early warning systems; management and dissemination of disaster information; development and

management of safer settlement and RSLUP based on multi-hazard risk assessment as directed by the National Land Use Policy, adoption of risk reduction policy for conducting study on impact of disaster risk and climate change in planning, designing, construction and management of mega projects; and monitoring of natural hazards and forecast on a regular basis.

The Disaster Risk Reduction National Strategic Action Plan (2018-2030) proposes priority actions for 2018 to 2020 in the short-term, 2018 to 2025 in the medium-term, and 2018 to 2030 in the long-term, assigning responsibilities within relevant federal, provincial and local governments. The strategic action plan has identified four priority areas with 18 priority actions with strategic activities for each priority actions. Hazard, Vulnerability and Risk Assessment has been included in Priority Action 1 – Hazard-wise Assessment of Risk under Priority Area 1 – Understanding Disaster Risk. The priority area 1 clearly states on conducting risk assessment and mapping in Nepal for each hazard including risk related information covering knowledge on vulnerability, capacity, and social, economic and demographic information. The disaggregated data should be collected based on gender, age, disability, and other indicators. Land use zoning based on Risk Sensitive Land Use Plans is also necessary as part of risk assessment. The Hazard wise Risk Assessment includes list of strategic activities, expected outcome, time-frame, responsible and supporting agency for Road accidents risk, Epidemics risk, Earthquake risk, Landslide risk, Flood risk, Snowstorm, avalanche and glacial lake outburst risk, climatic risk (drought, thunderbolt, windstorm, heat wave, cold wave), Fire and wildlife risks, and Industrial risk.

1.8 MAINSTREAMING HVRA IN THE SENDAI FRAMEWORK, UNFCC/IPCC AND OTHER INTERNATIONAL CONVENTIONS

Risk assessments are fundamental for risk-informed planning. The methodologies to conduct risk assessments are very diverse and the literature in this regard is extensive. The Priority 1 of the Sendai Framework: Develop common grounds for standing risk to inform policy making sufficiently discusses VCA including the other risk assessment tools. Depending on the purpose of the assessment, a different methodology will be applied, but the final objective remains the quantification of present and future risks.

The Sendai Framework acknowledges that the Vulnerability-centered approaches have gained attention in both DRR and CCA communities in the recent years. Considering that vulnerability varies over time and space, some vulnerability assessments present rather a snapshot of the situation than a dynamic evolution of the conditions that make some social groups more susceptible to natural hazards or the impacts of climate change (UNDRR, 2019). Herein lies one of the key challenges for long term planning for risk reduction and climate change adaptation. It is very difficult to get a dynamic picture of the evolution of vulnerability conditions to match them with the evolution of climate parameters, in other words, temporal scales differ. The Framework highlights the dynamics aspects of vulnerability which should be considered with priority in the vulnerability research arena. Projections on GDP, population growth and urbanization serve as vulnerability proxies to be combined with climate projections. Depending on the final objective of the risk assessment, it will be necessary to decide if we draw upon projected socio- economic pathways combined with predictions of climate parameters or focus on localized aspects of vulnerability such as results of household surveys, knowledge on EWS, risk perception, conditions of built environment among others.

Without greater attention to collecting, analyzing, and using data, countries will be unable to track progress on reducing climate and disaster risks, and lack the evidence to make sound future decisions related to development and economic growth. The Sendai Framework therefore

emphasize the need to invest and dedicate resources to data collection at the local level and to the development of risks assessments which can inform policymaking. In addition to the use of risk assessments to inform coherent policymaking, knowledge of risk should be enhanced at all levels of the society through formal and informal education, public awareness and citizen participation. Further, it is strongly recommended to-

- map data available for hazard and vulnerability assessments, to identify gaps and enhance data availability, data sharing and data repositories,
- develop joint methodologies for hazard and vulnerability assessments,
- conduct risk assessments and share results to enhance knowledge, discussion and feedback
- enhance availability of local data and strengthening of local institutions dealing with risk and disaster loss data

1.9 CONTEXT OF HVRA IN CROSS CUTTING NATIONAL POLICIES

While talking about the history of Nepal in relation to land and its management, several laws and policies have been developed and formulated to regulate manage land resources. Nepal has tried to address the land management issues through various policy measures at different time periods. The issue of policy making becomes more complex when the demand for land increases requiring innovative strategies and methods to address the issues. In the earlier period, government did not require strong regulatory policies to manage the land though unavailability of land was not a problem and land is basically a resource to produce subsistence. Later on, state land policies began to emerge in Nepal as early as 300 AD during Lichhavi era when a law for recording of land ownership records was introduced. Since then the state powers had introduced land policies to mostly regulate the agricultural and residential land use and raise land tax. Now there are only two types of ownership namely Raikar (Private ownership) and Guthi (Trust land, normally owned by public institution of religious group). Now, over 66 Acts and bylaws guide land management and administration in Nepal. These acts and bylaws stipulate certain procedures, terms and conditions related with land ownership, tenancy, land registration, inheritance, land transfer, land revenue, mortgage agreement, leasing and renting of land (Shrestha, R.et.al, 2020).

Nepal has introduced many acts and policies regarding land ownership and land use but they do not speak much about in favour of women and other socially excluded vulnerable groups. There are very rare cases of policies formulated which are friendly to women and excluded groups. In Nepal, Land Policy was introduced in 2013 A.D (2069 BS) as a "The National Land Use Policy, 2013 A.D) which prioritized the protection of arable lands ensuring food security (GoN, 2013). Later on, The Land Use Policy 2015 (GoN, 2015 (a) has come into existence upon making a review over the Land Use Policy 2013 A.D. The Land Use Policy 2015 clearly talks about the participation of women and other socially excluded vulnerable groups while making Land Use Planning. In Policy no 2 (strategy 7) clearly mentioned that "while making Land Use Plans and implementation thereof, the stakeholders participation shall be sought ensuring of gender and inclusiveness particularly, in devising of land use plans in local levels, local community`s involvement shall be ensured. This indicates positive message to ensure the gender and inclusive perspectives in land use planning process. Different land related laws, act, regulations, policy and constitution which are listed and reviewed below.

1.10 REVIEW OF LAND USE POLICY, LAND USE ACT, LAND POLICY

Land related policy guidelines and legislatures in Nepal have been directed by various acts, legislatures and government gazettes at different periods, notably the Land Act 2021 (and its recent amendment). However, these acts and legal provisions do not specifically address the context of

land use in terms of disaster risk reduction and climate change adaptation. The recent Land Act (Sixth Amendment) 2072 has specifically recommended identification and delineation of hazard prone areas as one of the recommended categories of land use. The subsequent Land Use Policy, Land Use Act and other related policies and legislatures have recognized and highlighted the importance of identification of hazard-risk areas and incorporation in the land use plan at all levels. Cross sectoral policies, strategies and acts including the Climate Change Policy 2076, National Policy for Disaster Risk Reduction 2019, Local Government Operation Act 2075 and the National Urban Development Strategy have also recognized the importance of hazard risk informed planning and development.

Preliminary review of various policies and legislatures were done in order to get an insight on the policy and legal provisions on land and land use in the context of DRR/DRRM. The relevant paragraphs, articles and sub-articles are presented hereunder in Nepali language for clarity and brevity of the policy and legal provisions.

1.10.1 LAND USE POLICY, 2015

The policy was drafted in 2069 B.S and updated in 2015 to regulate and direct the use of land. The broader objective of this policy is to direct the use of land according to its classification. The policy is expected to protect, manage and use the land according to its use. The Policy is also expected to manage and guide the land subdivision to encourage planned urbanization. The policy also directs to prepare land use plan of and area and prepare help to conserve the environment sensitive, religious, cultural, tourism and other important sites.

Legal and institutional management for Lands and Land Resources (LLRs), and protection, use and management thereon are done under this Policy.

Policy 1: Entire lands of the country shall be basically classified into following Land Use Zones (LUZs). Those zones could be sub-classified into Land Use sub-Zones as per necessity:

(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.

(The vulnerable zones shall be identified on the basis of geological study and such vulnerable/hazardous zones shall be denoted in the land use map.)

Strategy 1: Bases for land use zoning shall be as follows:

(a) Bases of Land composition, capability and appropriateness

(b) Land composition (geographical and geological), capability and appropriateness shall be considered as the main bases for land use zoning.

(c) Existing land use base: In the case of particular places, existing land use, land-composition, capability and appropriateness shall be the main bases for land use zoning.

Strategy 2: In the urban areas, keeping in view of comparative sensitivity, sub-classification shall be determined through micro-zoning.

Policy 2: According to federal structure, level wise (Federal, Provincial and Local Levels) Land Use Plans (LUPs) shall be devised of and be executed.

Strategy 1: While preparing Federal Land Use Map, it shall be done based on national priority and policy.

Strategy 2: Federal land use plan should be taken into account as general directives before devising of Provincial/Regional and zone-wise plans.

Strategy 3: In devising of Land Use Plans (LUPs), following objectives shall be considered into account:

(a) To consolidate lands for protection of Agricultural Zone,
(b) To ensure of a hygienic, beautiful, well-facilitated and safe human settlement, sustainable and planned urbanization of the country;
(c) To maintain a balance between physical infrastructure development and environment;
(d) To conserve historical, religious, cultural and tourist hubs;
(e) To identify all types of vulnerable zones on the basis of geographical and geological study;
(f) To optimum utilize of 'non-use land', 'under-use land', 'misused land', and 'land use under exploitation';
(g) To ensure of protection and promotion of biodiversities;
(h) To mitigate the impact of climate change;
(i) To control unmanaged development and extension of industrial, commercialized or business zones;
(j) To develop in minimum a green belt, open space, and areas for gardening, playgrounds and entertainment venues in the urban or rural areas of residential settlements;
(k) To develop green belts and open spaces along with rivers, roads, both sides of canals, among others;

Strategy 4: In devising of level wise Land Use Plans (LUPs), lower level plans shall be made in conformity with upper level Land Use Plans (LUPs).

Strategy 5: In devising of rural and urban Land Use Plans (LUPs) in local levels, they shall be done separately in an extended form and then be implemented.

Strategy 6: In devising of Land Use Plans (LUPs) and implementation thereof in the Kathmandu Valley, coordination shall be done with the Kathmandu Valley Development Authority (KVDA) and in the case of other areas of implementing town development plans with the stake holding agencies.

Strategy 7: While making Land Use Plans (LUPs) and implementation thereof, the stakeholders' participation shall be sought ensuring of gender and inclusiveness. Particularly, in devising of Land Use Plans (LUPs) in local levels, local community's involvement shall be ensured.

Strategy 8: In devising of Provincial/Regional and local level Land Use Plans (LUPs), Central Agency shall provide directions, technology and technical assistance as required.

Policy 3: The use of Land and Land Resources (LLRs) shall be ensured of on the basis of Specific Land Use Zones (SLUZs) and Land Use Plans (LUPs).

Policy 4: Level wise Land Use Plans (LUPs) compatible with physical infrastructure development projects shall be devised of and be implemented.

Policy 5: Optimum use and protection of arable lands shall be ensured of upon discouraging of non-agricultural use of arable lands and the trend of keeping land fallow and rampant fragmentation.

Strategy 1: In order to protect and promote agricultural sector, grants, facility/subsidy and compensation shall be ensured by discouraging non-agricultural use of arable lands and changes thereto.

Strategy 2: High lands of mountainous region classified under agricultural zone shall be developed into a zone of valuable herbals, fruits, animal husbandry and pasture.

Strategy 3: Lands now availing of irrigation facility and under Command Area of a planned irrigation project shall be classified into agricultural zones and those lands shall be ensured of such facility.

Strategy 4: Upon specifying a minimum area of the land plot on the basis of Specific Land Use Zones (SLUZs), no one shall be allowed to make fragmentation of the land into a smaller piece.

Strategy 5: In order to encourage commercial agricultural/business farming in a classified agricultural zone, criteria relating to Land Consolidation shall be framed and be implemented.

Strategy 6: A provision shall be made where no one is allowed to leave fallow of agricultural lands in a classified agricultural zone without believable reasons for three consecutive years.

Strategy 7: Government may reduce grants, facilities/subsidies and assistance to the landlord not doing agriculture in a classified agricultural zone but rather may impose additional tax.

Policy 6: A hygienic, beautiful, well-facilitated and safe human settlement, as well as a planned and sustainable urbanization of the country shall be ensured of.

Policy 7: Conservation and optimum use of forests and other natural heritages shall be ensured of.

Policy 8: Incentive-oriented programs shall be operated in order to motivate people for the use of Land and Land Resources (LLRs) in accordance with Land Use Zones (LUZs) or Land Use Plans (LUPs).

Policy 9: Keeping lands under conditions of 'non-use' or 'under-use', 'misuse and 'excessive use' shall be discouraged.

Policy 10: In order to keep balance between development and environment for the mitigation of natural and human created-hazards, vulnerable zones shall be identified and the provision thereof shall be made to ensure of operating of certain activities only in those zones.

Policy 11: Protection and optimum use of natural heritages, tourist hubs and historical, cultural and religious, archaeological zones including lands belonging to Government, the public and trust shall be ensured.

Policy 12: Minimum valuation and land tax system shall be developed as per a plot based land records upon referring Land Use Zones (LUZs) on the basis of specific land use.

Policy 13: Information system on Land Use Plans (LUPs) shall be developed.

Policy 14: Institutional structure shall be established in course of the execution of land use policy, plans and programs thereto.

Policy 15: Public awareness shall be enhanced on land use and long term impact thereto.

1.10.2 LAND SURVEY AND MEASUREMENT ACT

The Land Survey and Measurement Act came in force from 1963 A. D (2019 B.S) when the cadastral survey of whole Nepal was carried out. The act gives a legal basis for conduction land survey and measurement and also classify land according to different categories (Ailani, Parti, Bhir, Pahara etc). The land taxes have been assigned according to the land categories. It describes land position and defines public land, government land, land owner and tenant and sets provision for surveying and measuring all or any section of land throughout the country. The Ministry of Land Reform and Management is made responsible for land use planning.

Under the section 11C the Government of Nepal may make, or cause to be made, survey and measurement for the plotting or integrated development of any private, governmental or public lands.

1.10.3 NATIONAL URBAN POLICY (2064)

The national Urban Policy is a guiding document to respond the uncontrolled urbanization and urban problem. The issues of urban sectors like development of infrastructures, generation of employment, management of environment and balanced urban regional growth has been pointed in National Urban policy. The policy basically has three main objectives,

- To development of infrastructure services and direct investment to achieve balanced urban form

- To improve the livelihood of urban population through the creation of clean, secure and prosperous urban environment

- To make the local bodies capable of managing urban issues effectively through delegation the power, institutional strengthening and cooperation between agencies working in urban issues.

1.10.4 LOCAL GOVERNMENT OPERATION ACT 2074

Local governance operation act is based on Constitution of Nepal 2074. The act allows the local government bodies to exercise their rights, implement the federal, state level and local cooperation, coexistence and coordination with public participation, transparency, accountability, easy and quality services. The acts are related to the operation of local governments; local service formation and operation; incentives for office bearers of local units; conducting meeting of village councils and municipal councils; arrangement of central, provincial and local governance; taxation by municipalities and rural municipalities; expenditure of the deposit funds of municipalities and rural

municipalities; projection of income and expenditures; formation, management and work assignment of district coordination committee; educational management at local level; regulation and management of cooperative institutions; intergovernmental financial management; national natural resources and financial commission; and federal economic procedure.

The Local Government Operation Act 2074 has provisioned legal mandate to the municipalities:

- To formulate policy, act, regulations related to the urban development, settlement development and building constructions including the planning, identification of projects, study, implementation and regulations.
- To formulate policy, plan, program related to the safer settlements including implementation, monitoring, regulation and evaluation of the program.
- Formulation and implementation of local level land use policy, plan, program in accordance with the federal and provincial policy and legislations.
- Formulation and implementation of regulated settlement development program, land readjustment and management for integrated settlement development, and management of unplanned settlement at the local level.

The LGOA, under Paragraph 7, Article 27 (2) has also provisioned:

- Municipalities shall establish land use bye-lays in accordance to the risk sensitivity of the land and shall allow building construction in designated area only in accordance to the land sue bye-law.
- Fragmentation of re-development (plotting) of land shall not be done without formal approval by the municipality.

1.10.5 NATIONAL POLICY FOR DISASTER RISK REDUCITON 2075

The National Policy for Disaster Risk Reduction (NPDRR) has provisioned:

- Development of planned and safe settlements shall be done through the formulation of risk sensitive land use planning by evaluating multi-hazard risks at the local levels in accordance to the national land use policy.
- All the development activities shall be implemented and managed to minimize the potential risks based on the sensitivity to the multi-hazard risks.

1.10.6 NATIONAL LAND POLICY 2075

The National Land Policy has defined its Objective 3 Ensuring optimum use and management of land for sustainable environment, food security, well-managed infrastructure development and safe settlements and has provisioned policy for:

- Zonation of land according to different land uses for sustainable and well-managed usages of land and land resources in the entire country.
- Formulation and implementation of land use plans in accordance with the federal structure for the effective management of land usages.
- Identification of hazard prone areas and implementation of mitigate measures for the use of land in such areas.

1.10.7 LAND USE ACT 2076

The Land Use Act 2076 is the prevailing law governing the use of land in the country. The act has explicitly provisioned legal basis for the use of land and land resources as:

- The federal, provincial and local governments shall prepare approach paper for long term land use plan on the basis of study on existing status of land, population growth, requirements for food security and habitation, economic growth and infrastructure development and future land demands prior to the formulation of any land use plan.
- Every municipalities shall formulate local land use plans on the basis of land use zone maps along with the consideration of economic, social and infrastructure development aspects and in accordance with the federal and provincial plans.
- The land use plan formulated shall be approved by the Municipal Land Use Council and implemented.
- Municipalities can prepare land use plans for urban and rural areas separately as necessary.

The Land Use Act has also provisioned institutional structure for the legally implementation the land use plan. The provisions made for institutional structure and governance is summarized as:

- Every municipalities shall establish Local Land Use Council for the formulation and implementation land use zonation and land use plan along with the definition of the work, responsibilities and mandates for the council.
- Every municipalities shall establish Local Land Use Implementation Committee to implement, regulate and monitor the implementation of land use plan and its programs.

1.10.8 NATIONAL POLICY FOR CLIMATE CHANGE 2076

The National Policy for Climate Change 2076 has provisioned several cross-cutting policies addressing the impacts of climate change induced hazards as well as adaptation to the climate change through sustainable use of land and land resources. The provisions made by the policy are discussed as:

- Designation of land use zones for forest, agricultural, settlement and industrial development shall be done with due consideration of climate change induced hazards during the formulation of local level land use plans.
- Implementation of adaptation programs for reduction of climate change impacts to the unplanned urban and rural communities and the communities living in climate induced hazard prone areas.
- Inclusion of climate change adaptation and low GHG emission programs in the urban development plans.

1.10.9 NATIONAL URBAN DEVELOPMENT STRATEGY 2076 (NUDS 2017)

- Strategy 50: Promote multi-hazard approach in dealing with disasters including climate change.
- Strategy 51: Promote integrated safer settlement.
- Strategy 52: Establish system of periodic review to strengthen building code, building regulations and guidelines and planning by-laws.
- Strategy 53: Build back better after any disaster.

1.10.10 GENDER EQUALITY AND SOCIAL INCLUSION (GESI) PERSPECTIVES IN RECENT POLICIES

Gender equality and social inclusion (GESI) is the concept where it addresses unequal power relations between women and men and between different social groups. The GESI approach to development focuses on the need for action to re-balance these power relations and ensure equal rights, opportunities and respect for all individuals regardless of their social identity. Therefore,

mainstreaming and institutionalizing the Gender Equality and Social Inclusion (GESI) component is prime to ensure the voice of excluded and vulnerable groups to address their key issues and to bring them in development initiatives and engage them in decision making process for the sustainable use of land and land resources.

In many communities, gender disparities with regard to land, its ownership and access to resources was rampant, and somehow it intimately linked to women`s poverty and exclusion. This is very common practice in Nepali society which enforces patriarchy in different forms of daily activities. In earlier days, there were several discriminatory policies related to property rights to women. There are only a few traditional ways that women may get access to property which is called *Stridhan* (Women`s property) or *pewa* (One`s own) which may illustrate women`s own earnings, gifts from her parental households, her husband or from any other sources (Adhikari, J., 2008). The latest legal provision related to property and other rights seems nondiscriminatory against women and other socially excluded vulnerable groups. This has been clearly mentioned in Constitution of Nepal 2015. In Part 3 of Constitution which is on "Fundamental Rights and Duty", it has been clearly stated that every woman has equal right to lineage without any gender discrimination. According to Constitution of Nepal 2015 (GoN, 2015 (b), in Article 38, it has clearly mentioned that:

- Every woman shall have right to safe motherhood and reproductive health.
- No physical, mental, sexual, psychological or other forms of violence on grounds of religion, social, cultural tradition shall be committed to any woman.
- Women shall have the right to participate in all bodies of the state on the basis of the principle of proportional inclusion.
- Women have the right to obtain special opportunity in education, health, employment and social security on the basis of positive discrimination.
- Husband and wife both shall have equal right to property and family affairs.

Similarly, in Article 18, it talks about Right to Equality- it is stated that all citizens are equal. No discrimination shall be made on grounds of origin, religion, race, caste, tribe, sex, physical condition, marital status, pregnancy, economic condition, language and ideology, no discrimination shall be made on the basis of gender in relation to remuneration and social security for the same work. On the other hand, Constitution of Nepal clearly talks about the Rights of Dalit in Article 40.

- The state shall once provide land to the landless Dalit in accordance with law
- The state shall, in accordance with law, arrange settlement for Dalit who do not have housing
- Article 41 (Rights of Senior Citizens) - The Senior Citizens shall have the right to special protection and social security from the state.
- Article 42 (Right to Social Justice) - The socially backward women, Dalit, indigenous people, Madhesi, Minorities, Persons with Disabilities, marginalized communities, Muslims, Gender and Sexual minorities, Youth, Farmers, Laborers have the right to participate in the state bodies on the basis of inclusive principle.
- People with Disabilities shall have the right to live with dignity and honor, with the identity of their diversity, and have equal access to public services and facilities.
- Every farmer shall have the right to take access to lands for agro activities, select and protect local seeds and agro species which have been used and pursued traditionally, in accordance with law.

Besides that, Land Use Policy 2015 clearly talks about the participation of women and other excluded groups in land use planning by ensuring the gender and inclusiveness in every level. Such efforts are really encouraging to mainstream the GESI aspects in each development activities. It is also noticed that 50 % reduction in land tax for registration of land if the title holder is women, as

in land distribution, husband and wife`s name will be written in land ownership certificate as title holders, this is indeed good impact on women`s empowerment. Similarly, to increase the access of farm laborers to land Dalits, Indigenous peoples, Janajatis, Madhesis (Terai Groups) and women will be given priority while distributing land. It seems that there is a good impact of the policy giving priorities to women, Dalits, indigenous peoples, Janajatis, Madhesis and other socially backward most vulnerable groups.

1.10.11 CONTEXTUAL SCENARIO OF MUNICIPALITIES IN REGARD TO DRRM AND GESI POLICIES AND PROVISIONS

Birendranagar Municipality is located in a valley and surrounded by hills which established in 2033 BS. Like other municipalities, Birendgranagar is also facing different kinds of disasters like flood, earthquake, and landslide. As guided by the Constitution 2015 AD and Disaster Risk Reduction Management Act 2017 AD, Birendranagar Municipality has developed some documents by focusing the issue of DRR and Gender Equality and Social Inclusion (GESI) which are listed below:

- Jagga Prapti Karyabidhi 2075
- Mahila Swarojgar Karyakram Karyabidhi 2076
- Bhumigat Swrot ko Pani nikalna tatha Upayog garna Anumati Patra Jari garne sambandhi Nirdeshika 2076
- Bipad Jokhim Nyunikaran Tatha Bebasthapan Ain 2076
- Nagar Bipad Purba Tayari tatha Pratikarya Yojana 2077
- Bipad Jokhim Nyunikaran Sthaniya Niti Tatha Rananitik Karya Yojana 2020-2030

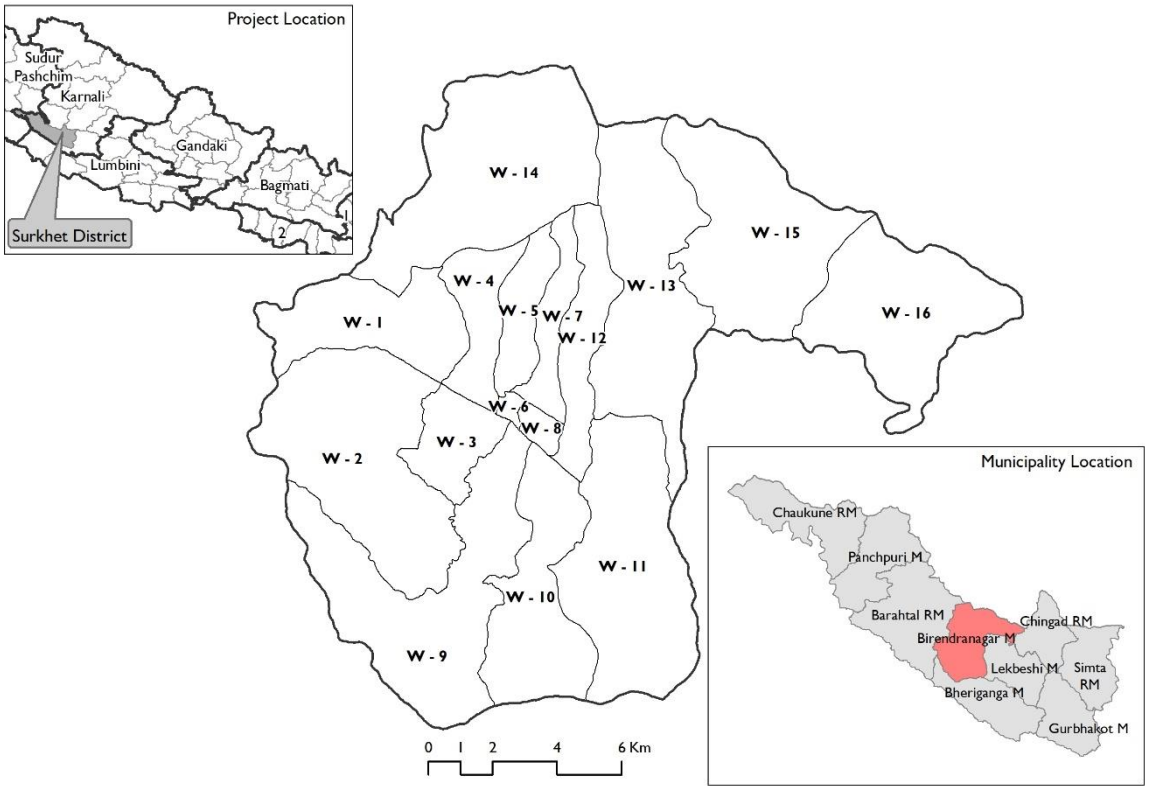
Office of Birendranagar Municipality has introduced ***Mahila Sworajgar Karyakram Sanchalan Karyabidhi, 2076*** to make women self-dependent by creating entrepreneurship so that their economic and social status can be changed and bring positive changes in their life. This effort has really added value to make women empowered and sustained. In contrary to GESI related provisions, plans, Birendranagar Municipality has brought more Acts, Plans including 10 years Strategic Plans (Draft) on DRRM which seemed good but need to analyse its implementation part. Specific GESI focused provisions and plans needs to be carried out in coming days to mainstream and make women and other vulnerable groups' voice more meaningful in each level of development.

SECTION 2 MUNICIPAL PROFILE

ADMINISTRATION

1.11 LOCATION OF MUNICIPALITY

Birendranagar Municipality is located in Surkhet district of Karnali Province of Nepal. It covers an area of 245.06 sq. km. The municipality's coverage was recently consolidated merging three VDCs - Gadi, Ratu, Garpan VDCs and into the existing Birendranagar Municipality. The municipality has altogether 16 wards. Geographically it extends from 81°32'57.3" to 81°46'41.4" east longitude and from 28°30'19.94" to 28°41'31.68" north latitude in the Siwalik physiographic (Chure) region of Nepal. It lies 665 m above the mean sea level. The municipality is surrounded by Chingad rural municipality in the east, Barahatal Rural Municipality in the west, Dailekh district in the north and Bheriganga Municipality in the south.



Map 0-1: Locaton Map

1.12 ADMINISTRATION UNITS

Birendranagar Municipality was established in 2033 B.S and has been a number of times. It was first restructured on 25th Baisakh 2071 B.S. merging Latikoili and Uttarganga VDCs. It was again restructured on 16th Mangsir 2071 B.S. by merging Jarbuta VDC and later on 10th March 2017 and again restructured on 10 March 2017 by merging Gadhi, Ratu and Garpan VDCs. The municipality is divided into 16 wards.

Table 0-1: Wards with previous VDCs

WARDS NUMBER	AREA (KM2)	PREVIOUS VDC/ MUNICIPALITY
1	6.1	Birendranagar Municipality 1,2
2	29.2	Birendranagar Municipality 19,20,25
3	6.62	Birendranagar Municipality 18
4	7.1	Birendranagar Municipality 3,4
5	5.8	Birendranagar Municipality 5
6	0.6	Birendranagar Municipality 6
7	5.2	Birendranagar Municipality 7,8
8	1.4	Birendranagar Municipality 9,10
9	28.82	Birendranagar Municipality 15,17
10	17	Birendranagar Municipality 14,16
11	26.7	Birendranagar Municipality 13,21
12	8.82	Birendranagar Municipality 11,12
13	25.9	Birendranagar Municipality 22,23,24
14	28.96	Gadhi VDC – 1 to 9
15	24.61	Ratu VDC – 1 to 9
16	22.23	Garpan VDC 1 to 9
Total	245.06	

Source: Rajpatra

PHYSICAL ENVIRONMENT

1.13 GEOLOGY

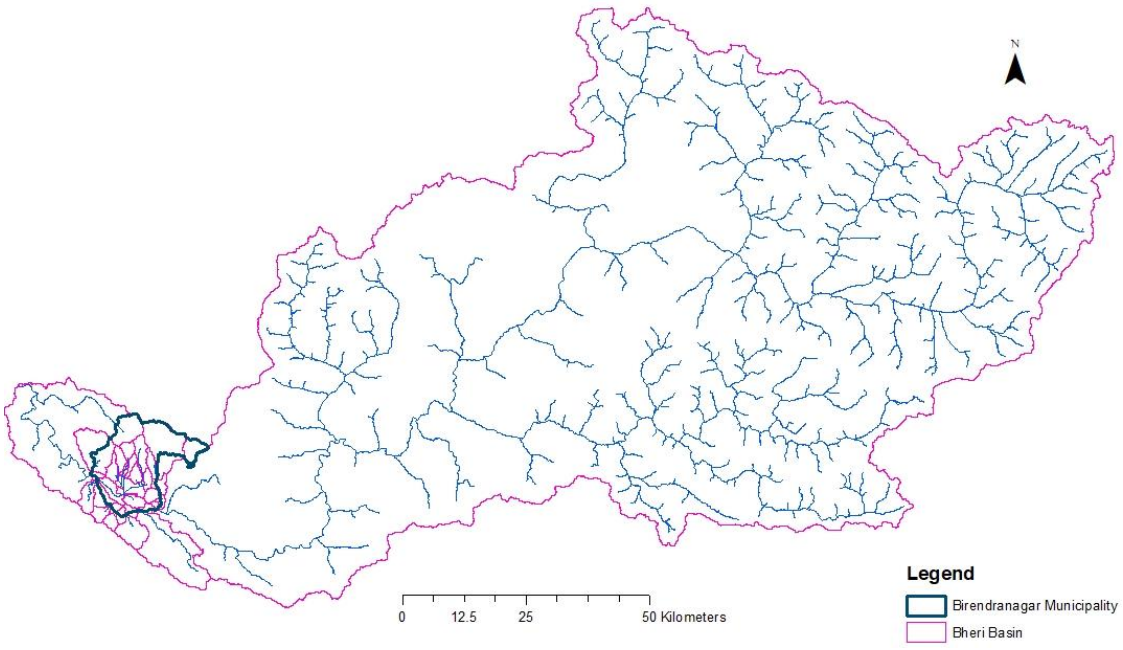
The Birendranagar Municipality lies in the Western Nepal Himalaya that covers Siwalik, Intermontane basin of Surkhet Valley and Lesser Himalaya. The municipality comprises entire intermontane basin of Surkhet, which is physiographically called as Dun Valley. This intermontane basin was formed due to tectonic activities during the upliftment of Siwaliks. There is a wide variation in rock type in the municipality that comprises sedimentary rocks, meta-sedimentary rocks, and low to medium-grade metamorphic rocks of Pre-Cambrian to Neogene time. The valley is filled with loose and unconsolidated alluvial deposits belonging to Quaternary Deposits. These deposits are mainly characterized by rounded to sub-rounded boulders, cobble, and gravels with sand and clay layers. The metasedimentary rocks of Lesser Himalayan Zone in the north are separated with Siwalik by Main Boundary Thrust (MBT). Besides, there are three other regional thrusts that control the geomorphology of Birendranagar Municipality. The Surkhet Valley is surrounded in east, south, and west by sedimentary rocks such as sandstone, mudstone, siltstone,

and conglomerate, which are main lithology of Siwalik. In the northern part of municipality, metasandstone, quartzite, phyllite, slate, dolomite, and limestone are dominant rock types.

The valley field sediments have formed different terraces and geomorphic landscapes. There is variation in sediment texture, size, and mode of origin. There is an isolated hillock composed of sedimentary rocks of Siwalik Group within the intermontane basin surrounded by sedimentary deposits. Stratigraphically, the lithological units of Lesser Himalaya can be divided into three groups, namely Surkhet Group, Lakharpata Group, and Dailekh Group in the municipality. Similarly, sedimentary rocks belonging to all three units of Siwalik Group are found in the municipality. In case of sedimentary deposits of Surkhet Valley, there are six different units belonging to Quaternary Deposits.

1.14 WATERSHED AND RIVER SYSTEM

Birendranagar Municipality is situated in Bheri river watershed. The Bheri Watershed originate from the snow peaked mountains in North and flow downstream to confluence with Karnali River. The Bheri River is a major tributary to Karnali River. The drainage area of Bheri River up to the hydrological station at Samaijighat is 12200 square km (DHM). Bheri River flows along the southern boundary of the Municipality. Jhupra khola and Girighat khola flows along eastern and western boundary of the municipality. There are other numerous streams flowing throughout the valley of Birendranagar such as Itram, Khorke, Neware, and Sot Khola. Most of them are dry in winter season and they are flow in monsoon season. These rivers are originating from the Siwalik region and the river system of Siwalik is flashy type of flow.



Map 0-1:Watershed area Bheri Basin

DEMOGRAPHY AND POPULATION

1.15 POPULATION DISTRIBUTION AND DENSITY

According to the municipal profile the population of Birendranagar Municipality as of 2075 B.S is 115,451 with 56,392 male inhabitants and 58,994 female inhabitants. According to the municipality profile 2075, ward 3 has the maximum household with 3426 and minimum number is at ward 15 with 356 households.

Table 0-1: Population Distribution and Density

WARD NO	HOUSEHOLD	MALE POPULATION	FEMALE POPULATION	TOTAL POPULATION	AREA (SQ. KM)	DENSITY (PERSON PER SQ KM)
1	2124	4144	4523	8667	6.1	1421
2	2126	4297	4652	8949	29.2	306
3	3426	7232	6771	14003	6.62	2115
4	2027	4109	4021	8130	7.1	1145
5	1165	2385	2526	4911	5.8	847
6	2731	3711	3734	7445	0.6	12408
7	1344	2713	2889	5638	5.2	1084
8	1760	3021	2961	5982	1.4	4273
9	2099	4246	4429	8675	28.82	301
10	2724	5288	5908	11225	17	660
11	2217	3871	4314	8185	26.7	307
12	2804	5317	6058	11375	8.82	1290
13	1215	2784	2811	5595	25.9	216
14	660	1411	1490	2901	28.96	100
15	356	860	840	1700	24.61	69
16	438	1003	1067	2070	22.23	93
Total	29216	56392	58994	115451	245.06	471

Source: CBS 2001 and 2011

1.16 POPULATION GROWTH TREND AND PROJECTION

Average population growth trend of Birendranagar Municipality is 4.57% from 2001 to 2011, which more in comparison to the national growth rate i.e. 1.35%. Geometric growth rate has been assumed for Birendrangar and projected for the next three decades. The actual growth rate of ward 14 and 16 are negative therefore the minimum growth rate i.e. 0.24% has been taken for the projection of these wards, which is the minimum and overall growth rate in the municipality. It is

expected that the municipality population will be 155984, 252045, 421933 and 728887 in the year 2021, 2031, 2041 and 2051 respectively.

Geometric Growth Pn=Po (1+r) ^t

Table 0-2: Population growth trend and projection

WARD NO	TOTAL POPULATION		R=(1/T)*LN(PN/PO)	POP 2021	POP 2031	POP 2041	POP 2051
	2001	2011					
1	4092	6,554	0.0482	10,497	16,813	26,929	43,131
2	5893	8,057	0.0318	11,016	15,061	20,591	28,153
3	4307	9,204	0.0789	19,669	42,032	89,822	191,948
4	4350	7,421	0.0549	12,660	21,598	36,845	62,857
5	3694	4,992	0.0306	6,746	9,117	12,320	16,649
6	6705	7,598	0.0126	8,610	9,757	11,056	12,529
7	4670	6,848	0.039	10,042	14,725	21,593	31,663
8	3254	6,358	0.0693	12,423	24,273	47,427	92,669
9	4580	7,227	0.0467	11,404	17,995	28,395	44,805
10	5255	8,883	0.0539	15,016	25,382	42,906	72,528
11	4729	7,085	0.0413	10,615	15,903	23,826	35,696
12	4616	8,143	0.0584	14,365	25,341	44,703	78,860
13	4389	5,348	0.02	6,517	7,940	9,675	11,789
14	3413	3,050	0.0024	2,726	2,436	2,177	1,945
15	1639	1,679	0.0024	1,720	1,762	1,805	1,849
16	2063	2,011	0.0024	1,960	1,911	1,863	1,816
	46800	73142	0.0457	155,984	252,045	421,933	728,887

Source: CBS 2001/2011

1.17 ETHNICITY

Due to the migration from different places, there is a variety of customs and culture in this municipality. 20.61 % Brahmins, 26.95 % Chhetri, 12.62 % Magar, 11.18 % Kami, 6.23 % Thakuri, 6.14 % Tharu, 4.22 % Damai/Dholi, 2.82 % Sarki, 2.54 % Dasnami/Sanyasi and other castes reside in the municipality.

1.18 ECONOMICALLY ACTIVE POPULATION

Economically active population ranges from 15 to 59 years. According to the household survey carried out in 2075 by the municipality there are 64.09 % of the economically active population with

34592 males i.e. 61.34 % of total male population and 39362 female population i.e. 66.72% of total female population.

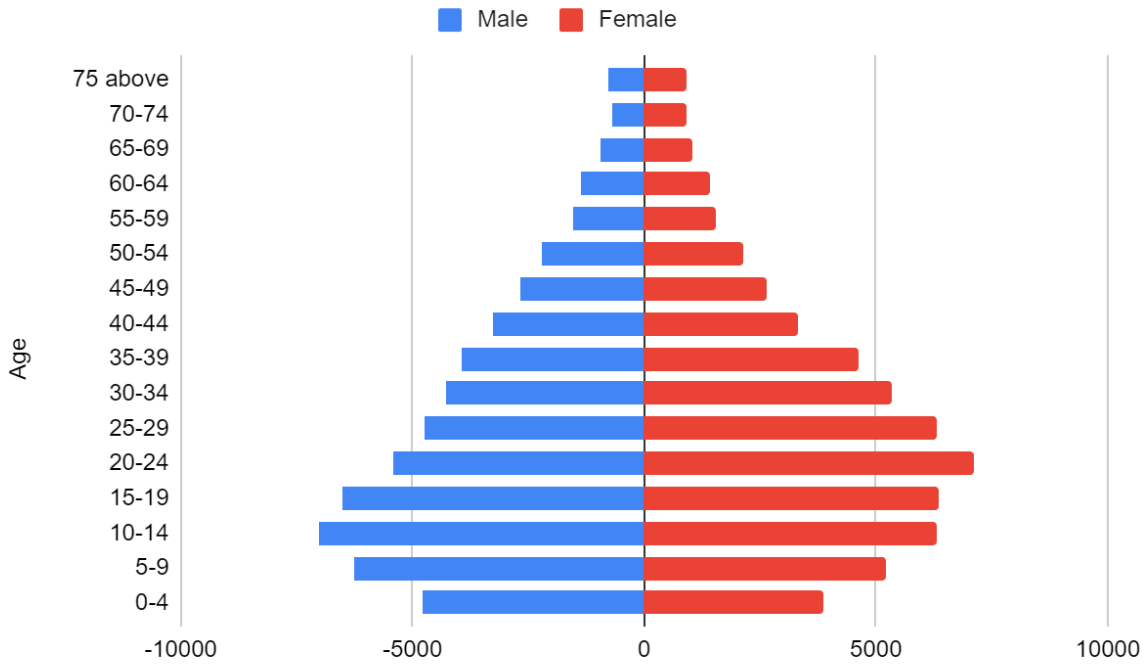


Figure 0-1: Age-Sex Pyramid (Source: Municipality Profile)

1.19 SOURCE OF INCOME

Among the total of households in Birendranagar Municipality major source of income is service with 28.23% household, followed by agriculture 18.91%, business 17.68%, and daily wages 17.35% household. Other sources of income are remittance, pension, rent and industries.

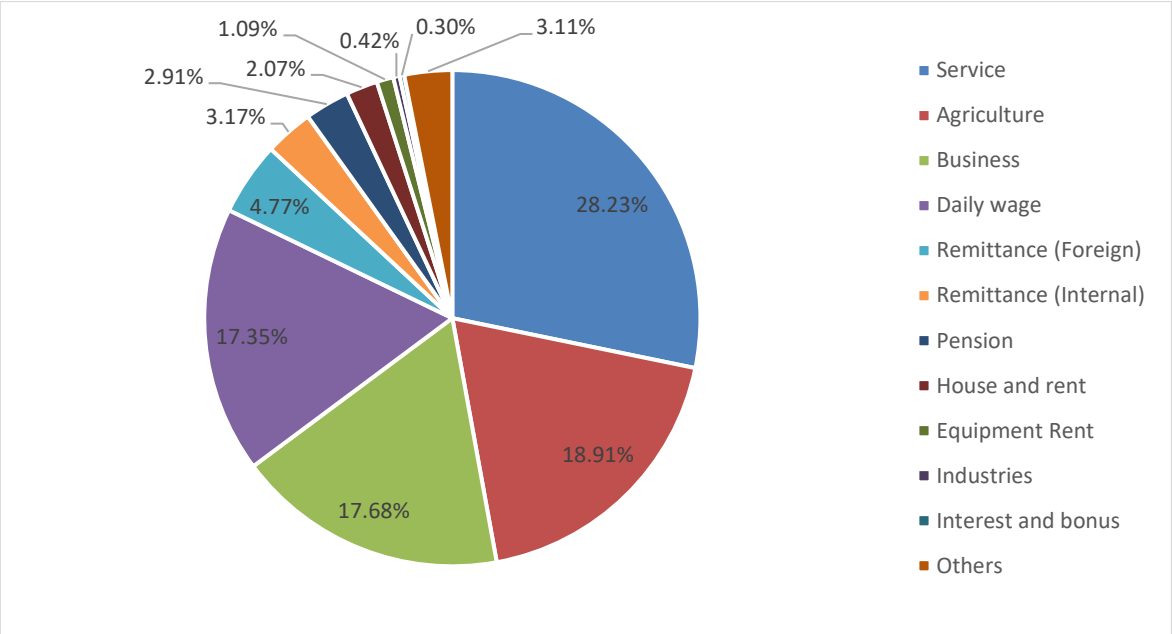


Figure 0-2: Source of income (*Source: Municipal Profile 2075)*

1.20 ECONOMIC ACTIVITIES

All activities related with production, distribution, marketing, and sales of goods or services are referred to as economic activities. Nepal Standard Industrial Classification (NSIC) has been developed on the basis of International Standard Industrial Classification (ISIC). The information on economic activities is collected, tabulated on the basis of NSIC, in National Economic Census 2018. The results of economic census 2018 based on the NSIC broad classifications has been presented below.

Table 0-3: NSIC broad classification

SYMBOL	DESCRIPTION
A	Agriculture, forestry fishing 3)
C	Manufacturing
B+D+E+F	Mining, Electricity Gas, Water supply & Construction
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
H+J	Transportation, storage, Information, communication
I	Accommodation and food service activities
K	Financial and insurance activities
P	Education
Q	Human health and social work activities
L+M+N+R+S	Real estate, Professional, scientific, Administrative, Arts, entertainment and Other

According to the National Economic Census 2018, the number of wholesale and retail trade is highest, 61.54% of all the total establishment, followed by Accommodation and food service activities i.e. 14.92%.

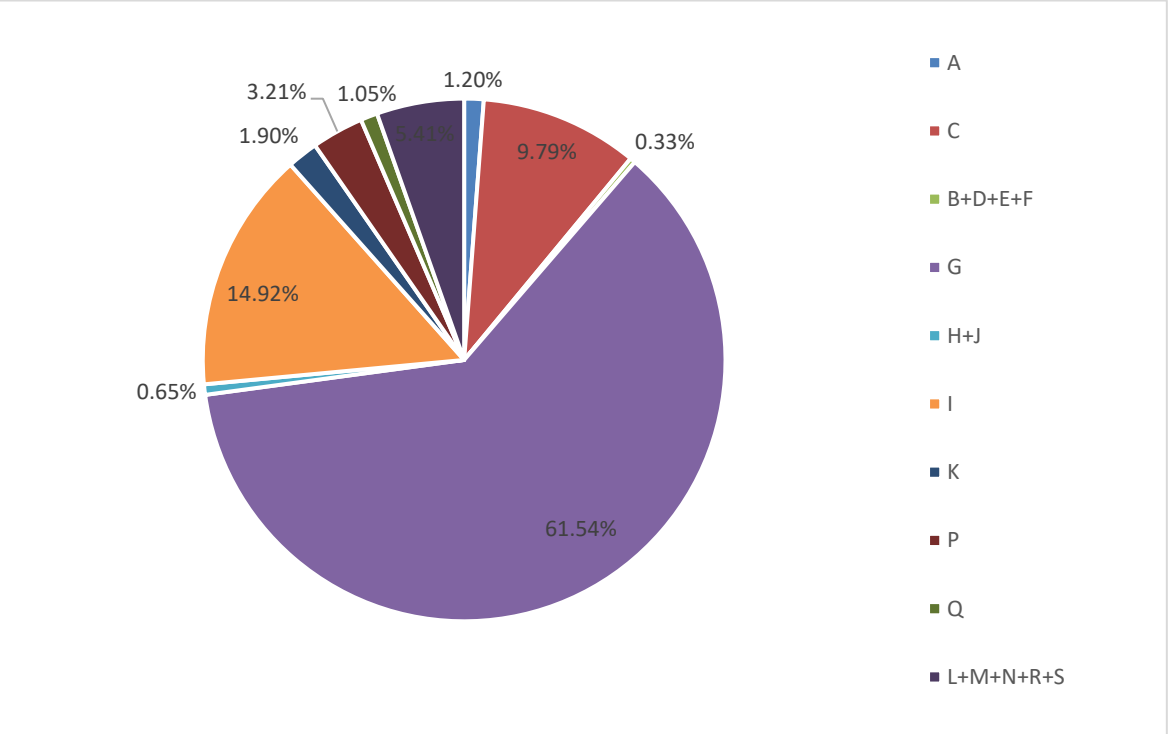


Figure 0-3: Number of Establishments in Birendranagar municipality

(Where A =Agriculture, forestry fishing , C = Manufacturing, B+D+E+F = Mining, Electricity Gas, Water supply & Construction, G= Wholesale and retail trade; repair of motor vehicles and motorcycles, H+J = Transportation, storage, Information, communication, I = Accommodation and food service activities, K = Financial and insurance activities, P = Education, Q = Human health and social work activities, L+M+N+R+S = Real estate, Professional, scientific, Administrative, Arts, entertainment and Other)

Table 0-4: Numbers of Establishments by NSIC, Municipality and Ward

Wards	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, Professional, scientific, Administrative, Arts, entertainment and Other
1	1	19	-	164	1	26	3	7	-	3
2	3	13	-	114	-	17	3	7	-	2
3	1	27	1	237	1	54	6	12	6	15
4	3	38	-	249	-	81	1	10	3	13
5	1	11	-	59	-	3	-	7	-	3
6	2	234	11	1,217	28	301	69	36	20	188
7	1	23	2	179	3	46	1	12	1	4
8	-	21	-	214	1	55	3	21	2	15
9	-	20	1	149	-	44	4	8	4	11
10	4	28	-	235	-	63	3	17	3	15
11	2	34	-	241	-	54	7	12	3	17
12	11	50	-	300	2	63	2	12	10	9
13	11	10	2	84	-	18	4	6	3	4
14	7	9	1	34	-	23	1	6	1	6
15	3	2	-	17	-	4	1	6	1	2
16	19	22	1	34	1	3	1	5	3	3
Birendranagar	69	561	19	3527	37	855	109	184	60	310

Source: National Economic Census (2018)

According to the National Economic Census 2018, the largest number of people are involved in wholesale and retail trade i.e. 34% followed by people's engagement in education 16%.

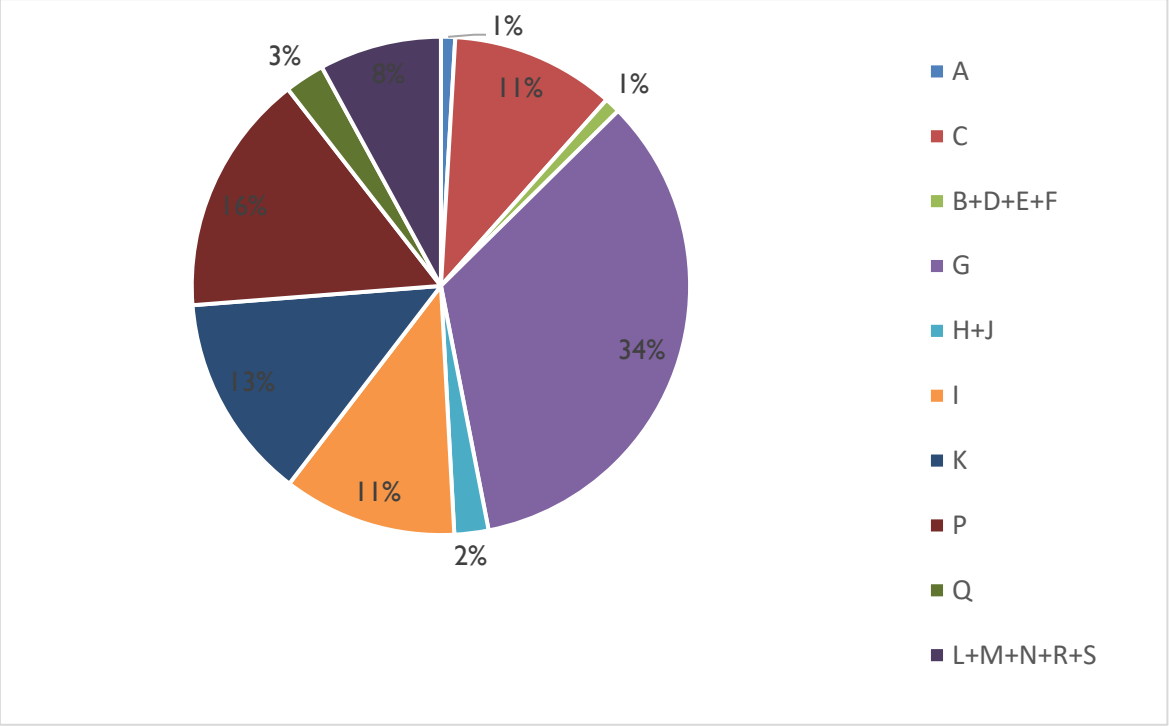


Figure 0-4: People Engaged in Economic Establishments

(Where A =Agriculture, forestry fishing , C = Manufacturing, B+D+E+F = Mining, Electricity Gas, Water supply & Construction, G= Wholesale and retail trade; repair of motor vehicles and motorcycles, H+J = Transportation, storage, Information, communication, I = Accommodation and food service activities, K = Financial and insurance activities, P = Education, Q = Human health and social work activities, L+M+N+R+S = Real estate, Professional, scientific, Administrative, Arts, entertainment and Other)

Table 0-5: Numbers of Persons Engaged by NSIC, Municipality and Ward

Wards	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, Professional, scientific, Administrative, Arts, entertainment and Other	Total
1	1	27	-	235	29	38	16	139	-	3	488
2	9	38	-	181	-	27	11	78	-	2	346
3	3	145	2	491	7	205	50	215	44	36	1198
4	11	113	-	552	-	171	14	197	156	88	1302
5	3	37	-	109	-	6	-	97	-	4	256
6	27	928	66	2,901	335	999	2,587	559	209	545	9156
7	2	64	109	355	69	151	2	194	10	6	962
8	-	68	-	417	1	133	7	571	31	326	1554
9	-	319	30	345	-	131	41	203	25	273	1367
10	12	106	-	456	-	150	13	408	5	242	1392
11	8	70	-	401	-	108	13	184	9	23	816
12	28	229	-	473	16	122	7	220	14	79	1188
13	24	24	2	98	-	31	6	59	13	4	261
14	21	13	2	40	-	56	2	44	6	9	193
15	6	3	-	21	-	6	1	43	6	2	88
16	36	26	2	49	2	4	1	50	9	4	183
Birendranagar	191	2210	213	7124	459	2338	2771	3261	537	1646	20750

Source: National Economic Census (2018)

The number of person engaged in the establishment gives the scale of the establishment. Details of the person engaged is given in the table below.

Table 0-6: Number of Establishments by Size of Persons Engaged, Municipality and Ward

WARDS	1 PERSON	2 PERSONS	3 - 9 PERSONS	10 PERSONS OR MORE	TOTAL
1	153	52	14	5	224
2	74	59	23	3	159
3	127	142	73	18	360
4	109	192	80	17	398
5	26	42	11	5	84
6	452	905	643	106	2106
7	52	134	72	14	272
8	69	200	42	21	332
9	44	113	64	20	241
10	119	149	80	20	368
11	186	126	49	9	370
12	211	176	55	17	459
13	97	28	15	2	142
14	49	23	14	2	88
15	20	8	6	2	36
16	58	21	10	3	92
Birendranagar	1846	2370	1251	264	5731

In Birendranagar Municipality, among the total population engaged in any establishment, 59 % are male and only 41% are female. The details of the person engaged are given in table below.

Table 0-7: Number of persons engaged by Sex

WARD	MALE	FEMALE	TOTAL
1	235	253	488
2	170	176	346
3	649	549	1198
4	727	575	1302
5	131	125	256
6	5,704	3,452	9156
7	524	438	962
8	994	560	1554
9	798	569	1367
10	870	522	1392
11	424	392	816
12	629	559	1188
13	139	122	261
14	116	77	193
15	45	43	88
16	122	61	183
Birendranagar	12277	8473	20750

1.21 POPULATION DISTRIBUTION AND COMPOSITION

WARD	TOTAL HOUSEHOLDS	POPULATION
1	2300	8667
2	3000	8949
3	3500	14003
4	2000	8130
5	1600	4911
6	2000	7445
7	1600	5638
8	1760	5982
9	2300	8675
10	3250	11225
11	2265	8185
12	3000	11375
13	1500	5595
14	700	2901
15	380	1700
16	870	2070
Total	32025	115451

Here in the table below it illustrates that out of total ward, ward no.3 is thickly populace with 14003 numbers of people followed by ward no.10 consist of 11375 inhabitants reside there and ward no 15 has the lowest number of population which is about 1700 only. Where in terms of household's data, 3500 households reside in ward 3 which is uppermost in comparison to other wards. Subsequently ward no.10 consist 3250 households followed by ward no.2 and 12 with 3000 households with same ratio and ward no.15 has least number of households which is only about 380.

Table 0-8: Total Household and Population

Source: VCA 2021/Municipal profile

1.22 LITERACY RATE

The given table elaborate the literacy status of the Birendranagar municipality where the number of literate percentage is high in ward no.6 and 7 regarding 98 percent in equivalent quotient and the number of illiterate percent is high in ward no.5 and 7 with 20 percent. The uppermost 97.82 percent of the student from ward no.9 had got education up to secondary level where 76.66 percent of the student from ward 12 had passed the higher secondary level. The highest number of student who are graduate are from ward no.11 which is about 56.19 percent and 15.45 percent of student from ward no.11 has post graduate degree which is utmost in appraisal to other wards.

Table 0-9: Literacy rate

WARD	ILLITERATE-H%	LITERATE-H%	SECONDARY LEVEL-H%	HIGHER SECONDARY LEVEL-H%	GRADUATE-H%	POST-GRADUATE-H%
1	6.52	26.08	21.73	19.56	13.04	6.52
2	10	13.33	40	31.66	5	100
3	4	80	51.42	42.83	17.14	5.71
4	6	90	60	45	20	5
5	20	85	90	60	30	15
6	0	98	20	40	20	20
7	20	98	10	40	25	25
8	8.52	90.9	79.54	76.7	36.93	11.36
9	1.3	9.56	97.82	56.52	26.08	10.86
10	0	98	15.38	46.15	21.53	12.3
11	1.76	83.88	92.71	61.81	56.19	15.45
12	10	90	96.66	76.66	36.66	13.33
13	0	95	20	40	10	5
14	0	90	28.57	35.71	21.42	14.28
15	0	95	20	40	15	5
16	5.17	10.34	17.24	20.69	4.59	2.29

Source: VCA 2021/Municipal profile

1.23 ETHNICITY

Out of entire inhabitants of the municipality 50 percent of janajati households reside in ward no. 9 and 15 which is utmost among all wards and in ward no. 4 and 6 there are no janajati households were found according to field survey report. Where ward no.6 has highest percent of Dalit inhabitation with 40 percent and smallest percent of Dalit exist in ward no.8 regarding 10 percent only. The number of Brahmans inhabitants are high in ward no.3 and 8 with 32 percent in same quotient and only 4 percent reside in ward no.9 which is lowest in comparison to others wards. Like Brahmans inhabitants, 61 percent of the Cheetri populace be inherent in ward no.4 which is highest number of chetrri households among all wards and only 13 percent are in ward no.11 which is the lowermost in comparison to other wards of the Birendranagar municipality.

Table 0-10: Ethnic group

WARD	JANAJATI-H	DALIT-H	BRAHMAN-H	CHETTRI-H	OTHERS-H
1	40	28	11	21	0
2	26	34	5	35	0
3	15	22	32	31	0
4	0	20	19	61	0
5	40	20	11	29	0
6	0	40	25	35	0
7	26	12	30	32	0
8	20	10	32	38	0
9	50	25	4	21	0
10	40	13	17	30	0
11	44	13	30	13	0
12	20	20	30	30	0
13	30	20	25	25	0
14	45	20	15	20	0
15	50	11	9	30	0
16	15	30	15	40	0

Source: VCA 2021/Municipal profile

1.24 FEMALE FAMILY HEAD

As shown in the above table 20 percent out of total households from ward no.2 and 3 in same proportion has the highest number of female headed households and ward no.10 has the lowest regarding 10 percent among all other wards. Further exemplifying the table, it shows that ward no.8 has the most percentage (12%) of the households that are regulated by single female headed households and ward no.2, 6 and 10 has lowest in same quotient with 2 percent only. In terms of joint family, concerning 60 percent of the households are from ward no.4 which is utmost amongst all wards and only 20 percent of the households are categories as joint family in ward no.16 which is bottommost amongst all wards. In addition, 69 percent of the households have elementary households structure in ward no.16 and ward no.4 is in least with just 32 percent.

Table 0-11 Female Family Head

WARD	FEMALE-HEAD -H	SINGLE FEMALE-H	JOINT FAMILY-H	ELEMENTARY FAMILY-H
1	18	4	38	40
2	20	2	40	38
3	20	8	32	40
4	5	3	60	32
5	7	5	33	55
6	5	2	33	60
7	12	3	28	57
8	12	12	31	45
9	10	3	32	55
10	3	2	40	55
11	8	10	30	52
12	7	2	41	50
13	9	4	35	52
14	10	6	26	58
15	10	7	31	52
16	7	4	20	69

Source: VCA 2021/Municipal profile

1.25 PHYSICALLY/MENTALLY CHALLENGE POPULATION

The physically challenge individuals are those persons who can't do their everyday work effortlessly as a normal individuals do. They can be challenged in their daily life by physically, sometimes mentally etc. The given table depict more about dissimilar kind of physically/mentally challenge population of both genders. Here, the survey data shows that out of total households from all over the municipality 0.77 percentage households from ward no. 11 are recorded as the person living in those households are physically disable which is the highest among all wards. In further the physical disability are categories in different kind of disability where from ward no.7 around 0.63 percent of person living in a households are suffering from blindness and low vision followed by 0.43 percent from ward no.2 with deaf and hearing problems, 0.04 percent from ward no.1, 2, 6, 7 and 11 in equal ratio with intellectual disability, in ward no.3 regarding 0.96 percent are enduring by speech problems. In addition, 0.43 percent from ward no.3 with metal disability and 0.39 percent of ward 9 people are listed as both deaf and blind disability.

Table 0-12 Physically/Mentally Challenged Population

WARD	PHYSICAL DISABLE-H	BLINDNESS/LOW VISION-H	DEAF/HARD TO HEARING-H	INTELLECTUAL DISABLE-H	SPEECH PROBLEM -H	MENTAL DISABLE-H	DEAF/BLIND-H
1	0.17	0.39	0.13	0.04	0.35	0.26	0.13
2	0.14	0.50	0.43	0.04	0.35	0.26	0.13
3	0.06	0.43	0.22	0.09	0.96	0.43	0.22
4	0.07	0.25	0.02	0.00	0.02	0.02	0.02
5	0.07	0.05	0.01	0.00	0.04	0.00	0.22
6	0.10	0.02	0.01	0.04	0.22	0.22	0.00
7	0.09	0.63	0.35	0.04	0.26	0.52	0.13
8	0.03	0.34	0.13	0.00	0.39	0.35	0.00
9	0.11	0.04	0.03	0.00	0.01	0.00	0.39
10	0.12	0.03	0.02	0.02	0.01	0.02	0.01
11	0.77	0.22	0.04	0.04	0.22	0.39	0.13
12	0.13	0.02	0.03	0.01	0.02	0.01	0.01
13	0.06	0.04	0.03	0.01	0.01	0.03	0.02
14	0.10	0.20	0.01	0.01	0.07	0.08	0.01
15	0.21	0.28	0.08	0.00	0.03	0.09	0.00
16	0.09	0.05	0.01	0.22	0.13	0.22	0.00

Source: VCA 2021/Municipal profile

URBAN MORPHOLOGY AND LANDUSE

1.26 LAND USE

Land use of Birendranagar Municipality was classified into three levels- Level 1, Level 2 and Level 3. As per the essence of National Land Use Policy 2072 which mandate different number of Land Use Classes, the general land cover class is represented by Level 1 which is classified into Level 2 to represent the subclass of Level 1. Level 2 is further classified into Level 3 to represent sub-units of level 2. Similarly, Level 4 and Level 5 to represent sub-units of Level 3 and level 4 respectively. The land use pattern in this Municipality has been classified as agriculture land (5602.33 hectares), commercial area (238.30 ha), forest (13758.17 ha), residential (561.36 ha), public service (497.89

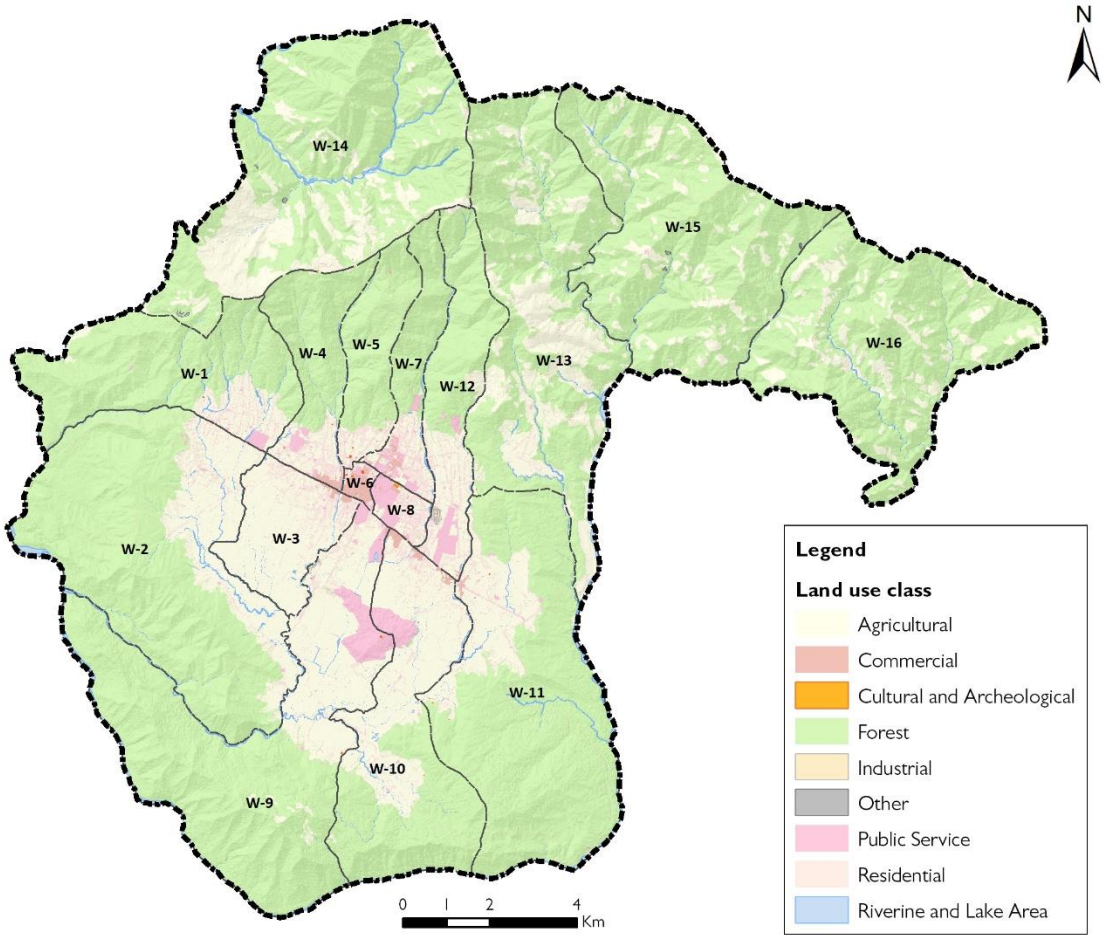
ha), riverine and lake (403.57 ha), cultural and archaeological (13.57 ha), industrial (12.11 ha) and other area (4257.73 ha).

Forest is the major land use class of Birendranagar which covers 54.28% of total municipal area followed by Agricultural land use that covers around 22.10% of the total area. Public Service and Residential area covers around 1.96% and 2.21% of the total area. Similarly, Riverine and lake area occupies around 1.59% of the municipal area. Commercial area, Cultural and archeological area, and industrial area occupies less than 1% of the municipal area.

Table 0-1: Distribution of Landuse Classes

LAND USE	AREA (HA)	PERCENTAGE
Forest	13758.17	54.28
Agriculture	5602.33	22.10
Others	4257.73	16.80
Residential	561.36	2.21
Public Service	497.89	1.96
Riverine and Lake Area	403.57	1.59
Commercial	238.30	0.94
Cultural and Archeological	13.57	0.05
Industrial	12.11	0.05
Mines and Minerals	0.80	0.003
Total	25345.84	100.00

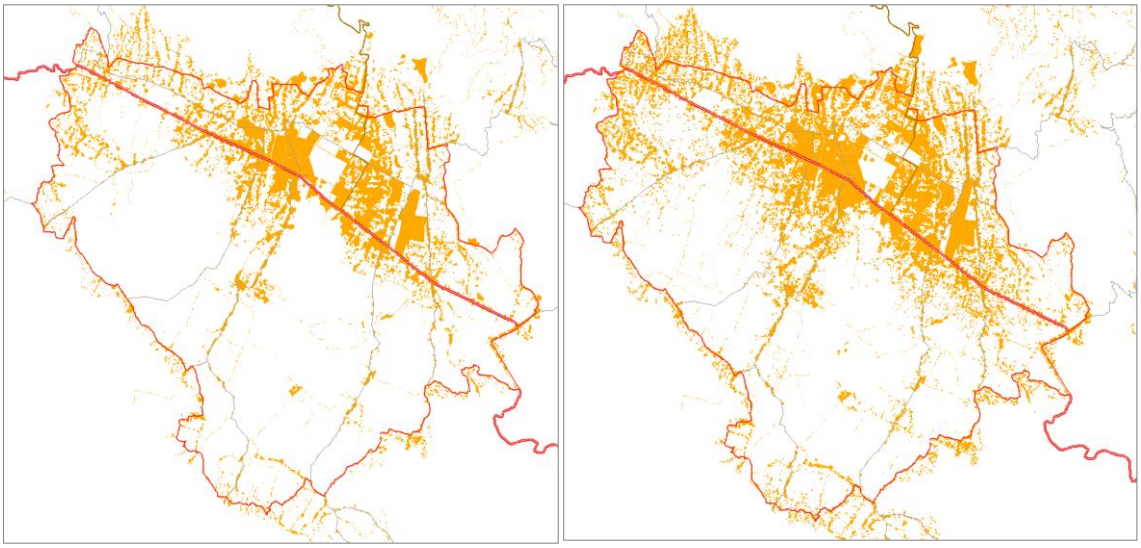
Source: Field Survey data 2021, Geoeye Satellite Image 2018



Map 0-1: Land use class of Birendranagar municipality

1.27 SETTLEMENT PATTERN

Birendranagar Municipality is rapidly urbanizing due to high migration rates from the surrounding rural municipalities in search of better quality of life and opportunities (Rijal, Rimal, & Sloan, 2018). It is a major socio-economic hub and administrative center and an important gateway to Karnali zone. So urban development is seen as haphazard due to absence of urban plans and policies and weak implementation of existing plans. The new urban development is characterized as spatially dispersed frequently rising over the prime agricultural lands and linear development along the Highway, Ring road and other major road networks. The trend analysis shows that from 2011 built up area was 980.73 ha which was increased to 1323.24 ha in 2018. About 342.51 ha built-up area has been increased.



Map 0-2: Settlement growth inside ring-road during 2010 (left) and 2018 (right) *(Source: DUDBC, 2020)*

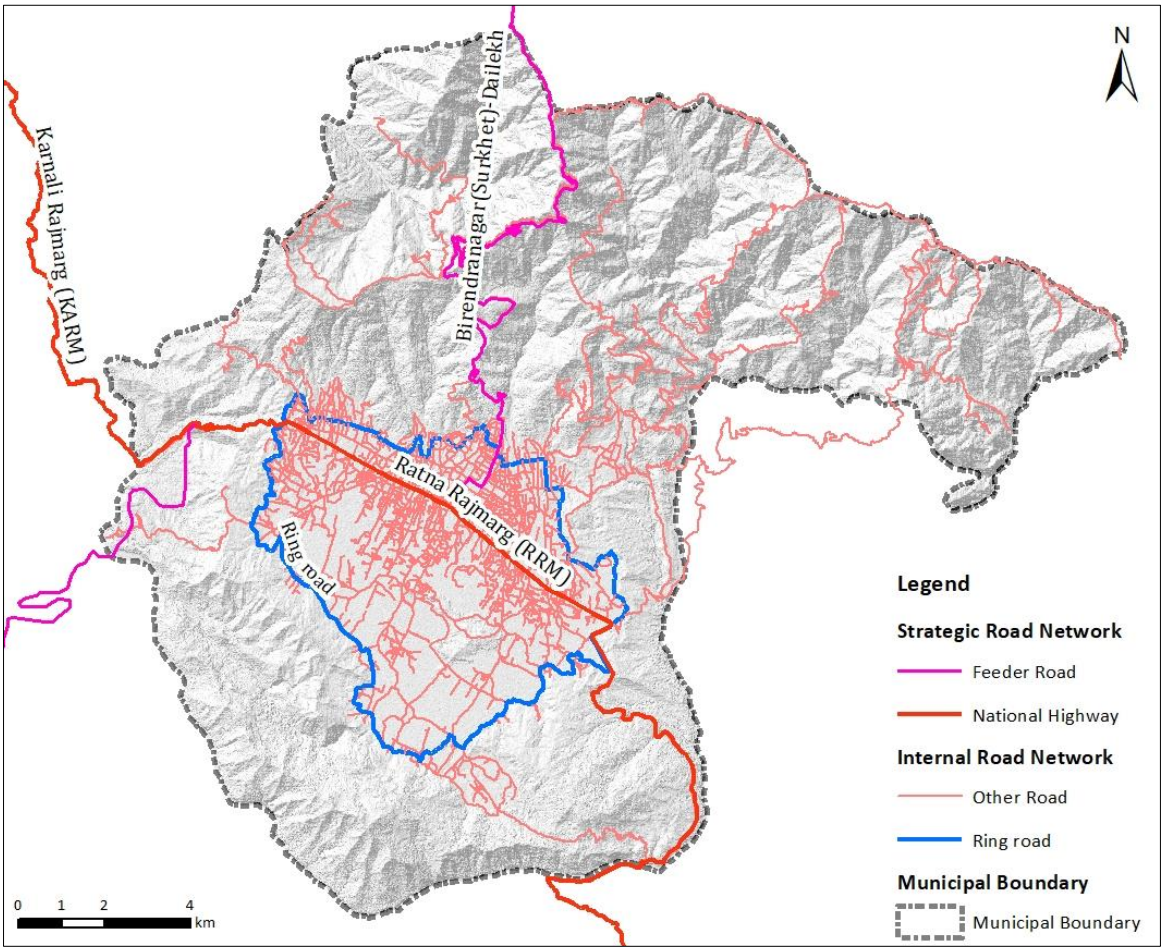
1.28 INTERNAL ROAD AND TRANSPORTATION

Birendranagar Municipality is connected to other part of the country through Ratna highway. The highway connects the municipality to east west highway at Kohalpur of Banke district. Karnali highway is the other highway that connects the municipality with other districts: Dailekh, Kalikot, Jumla and Mugu of the Karnali Province. A total length of 656.02 km road has been constructed in Birendranagar Municipality out of which 142.56 km is black topped, 113.40 km is graveled and 400.06 km is earthen. *Source: Strategic Urban Infrastructure Development of Surkhet Valley, 2020*

Photograph 0-1: Khorka Pul (left) and Khajura Pul (right)

Photograph 0-2 : Birendra Chowk (left) and Pepera Chowk (right)

Birendranagar Airport is another major transport hub in province 6. It serves most of the remote sectors of the country such as Jumla, Humla, Kalikot, Mugu and Dolpa. The surface of the runway is paved and has a length of 4118 ft.



Map 0-3: Internal road in Birendranagar Municipality

Table 0-2: Types of road networks

S. N.	TYPE OF ROAD	LENGTH (KM)	PERCENTAGE (%)
1	Black Topped	142.56	21.73
2	Gravel	113.4	17.29
3	Earthen	400.06	60.98
Total		656.02	100

Source: Strategic Urban Infrastructure Development of Surkhet valley, 2020

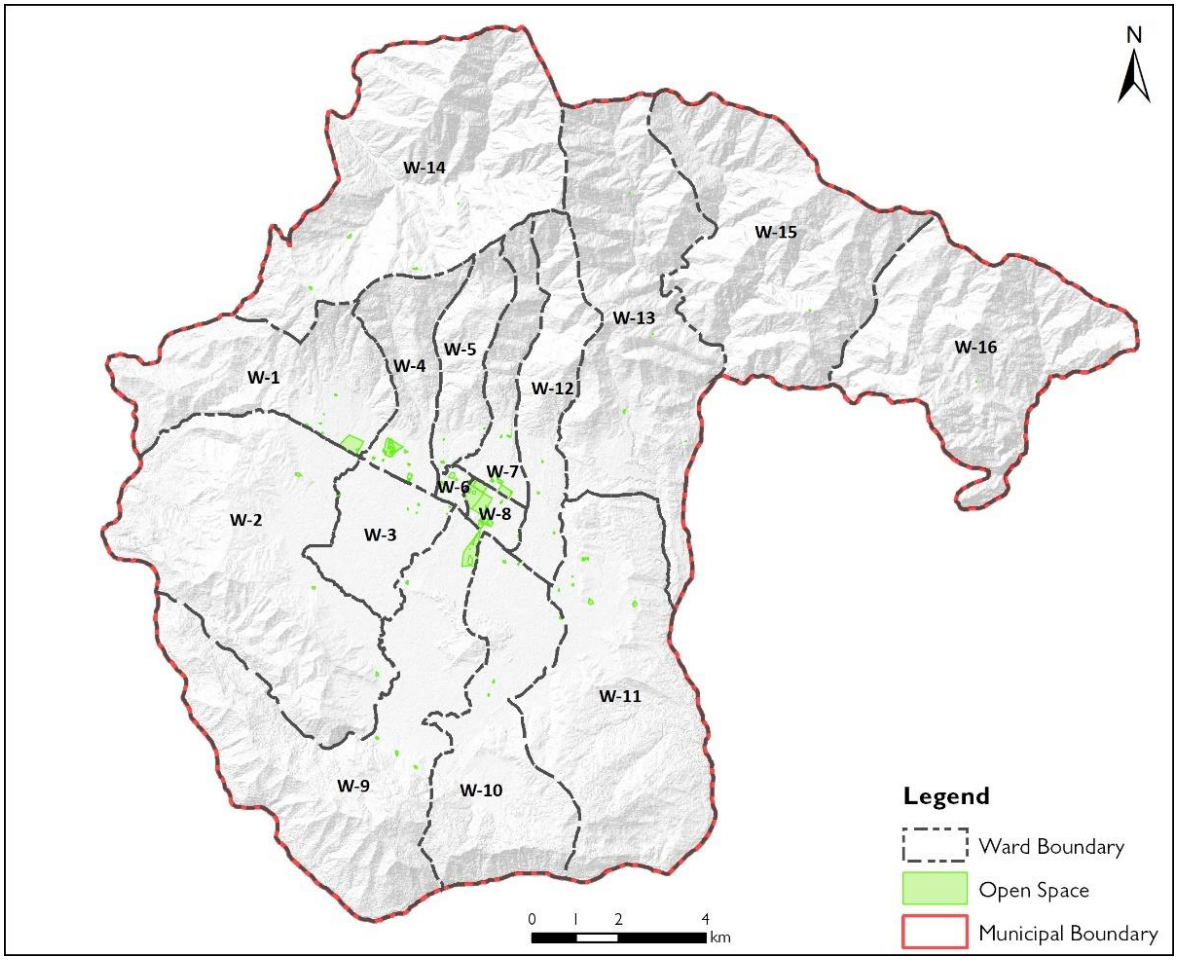
1.29 OPEN SPACE

There are number of public parks, open spaces and recreational spaces within Birendranagar Municipality. Apart from public open spaces it has a number of institutional (government and private) open spaces including the grounds of school and college, government institution ground, private institution ground etc. The recreational area covers 176.93 hectares in the Municipality. There are total 164 recreational areas in the Municipality.

Table 0-3: Ward wise information of open space

WARD NO	MUSEUM	OPEN SPACE	OTHER	PLAY GROUND	STADIUM	TOTAL
1			1	9		10
2		2	1	7		10
3				13		13
4		3	1	6		10
5			1	5		6
6		3	1	9		13
7		1		33		34
8	1	6	2	13	2	24
9			1	8		9
10		1	1	5		7
11			1	7		8
12				5		5
13				5		5
14		1		6		7
15				1		1
16				2		2
Total	1	17	10	134	2	164

Source: Field Survey data 2021, Geoeye Satellite Image 2018



Map 0-4: Distribution of open spaces in Birendranagar Municipality

Photograph 0-3: Open Spaces of Birendranagar Municipality

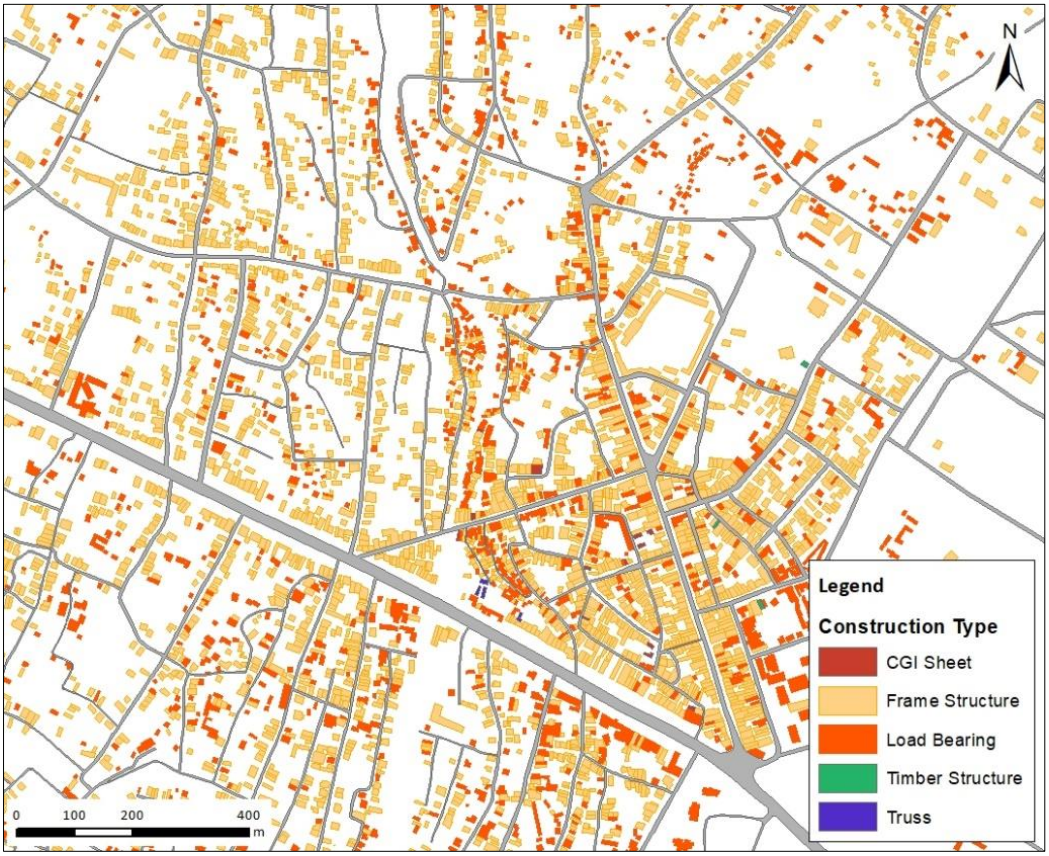
1.30 BUILDING TYPOLOGY

Birendranagar Municipality has altogether 32596 buildings with different typologies such as- roof type, no. of floors, construction type and functional type and construction materials. Data on

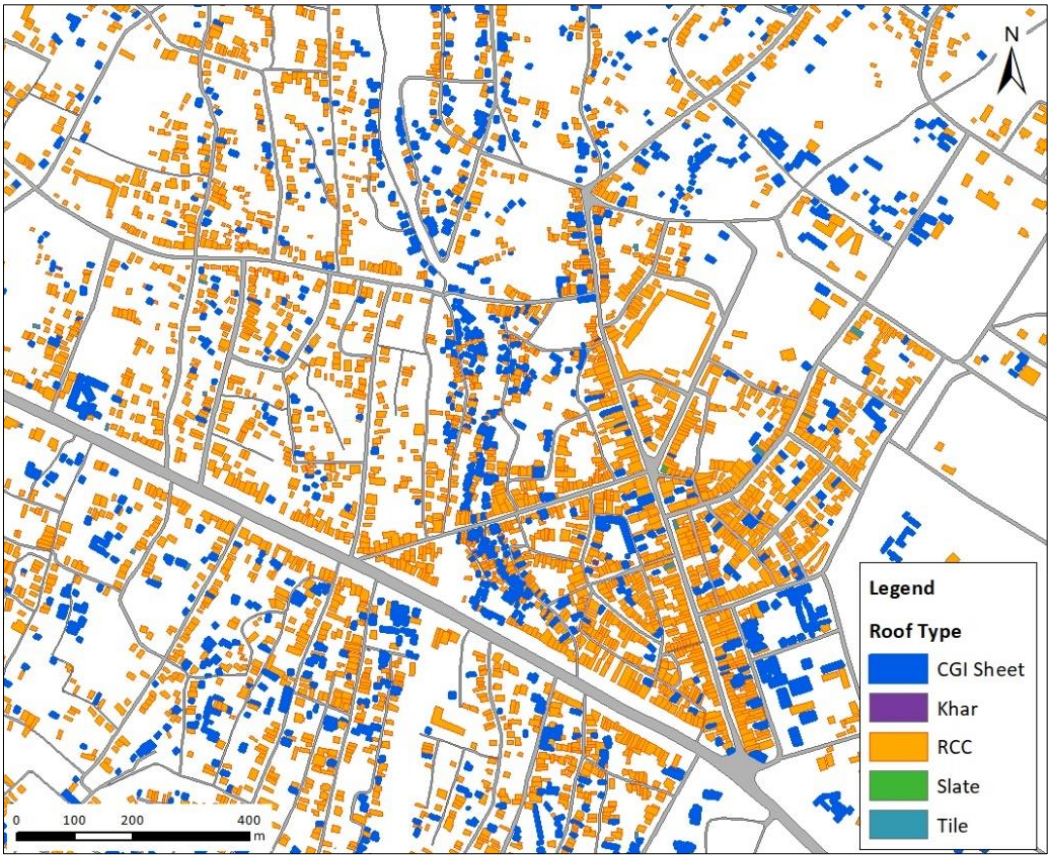
building construction type shows that both load bearing and frame structure are very common in the municipality with 56.1% and 43.36% of total number of building. Remaining 0.5% are constructed with CGI sheet, Timber and Truss.

Similarly, data on roof type indicates that CGI Sheet and RCC roof type are very common in the municipality with total coverage of 47.1% and 46.5%. Remaining 6.3% buildings have roofs constructed with Khar, Tile and Slate.

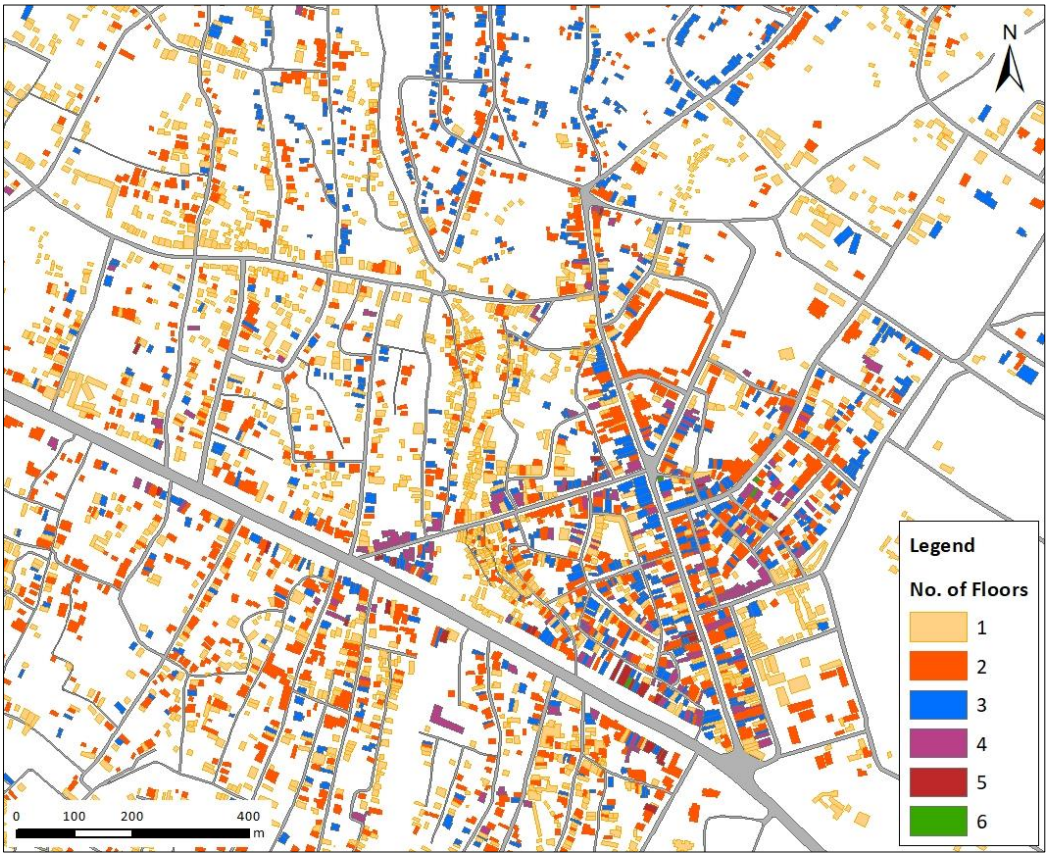
Out of total buildings, around 48.8% are of single story and 44.6% are of two stories. Remaining 6.6% have greater than two stories. Figures below show the distribution of construction type, roof type and no. of floors in urban center of the Birendranagar Municipality. (*Source: Strategic Urban Infrastructure Development of Surkhet Valley, 2020)*



Map 0-5: Distribution of building construction type



Map 0-6: Roof type in Birendranagar municipality



Map 0-7: No. of floors in Birendranagar Municipality

URBAN ENVIRONMENT

Predominantly, Nepal has been an agrarian economy with a rural setting. Though in recent times, this situation has gradually been changing. The rural populations are gradually opting out of subsistence agriculture by migrating, either to urban parts of the country, or to the foreign countries. Both of these migrations are the major drivers of urbanization in Nepal. In the meantime, the government has also been declaring new urban municipalities, which is exponentially boosted by the recent administrative restructuring. However, till date the majority of these urban municipalities still have the rural settings – meaning absence of basic services, amenities and opportunities that are commonly anticipated in the urban areas. As a result, though Nepal has a low level of urbanization, the pace of urbanization is one of the fastest in the world.

The environmental challenges of urbanization are mainly because of, either the existing urban centres not having adequate facilities and infrastructures to accept the migrating population, or inadequate preparation and planning of newly growing urban areas. As a result, the urban centres are facing environmental challenges, like solid waste management, water pollution, air pollution, noise pollution, encroachment of natural and sensitive environmental area/resources on one hand, and on the other hand, the urban areas are increasing being exposed to the environmental hazards such as floods, landslides, droughts etc.

Birendranagar Municipality is located in one of the Dun Valleys (Inner Terai) of the Mid-Western Nepal, which is surrounded by the Siwalik range, which has been declared as the "Environmental Protection Area", by the government. Any urban expansion into the environmentally fragile and sensitive zone requires extensive consideration of environmental consequences. Thus, most of the urban expansions are occurring at the loss of the fertile and finite agriculture lands of the valley.

CULTURAL AND ARCHAEOLOGY

1.31 EXISTING ARCHAEOLOGICAL SITES/MONUMENTS

Birendranagar Municipality has a number of archeological sites and monuments that attracts number of domestic tourists every year. Kakrevihar is one of the popular site with rich historical masterpieces. It is adorned with artefacts made in ancient times in the forests. Deuti Bajai temple is another major site that attracts lots of religious tourism in the municipality. It is national heritage that is located around 2.5km southeast of Surkhet bazar. Similarly, Bulbule Lake is another popular site located in the south of Surkhet Bazaar. This lake not only serves as recreational park but also serves as constant source of fresh drinking water. There are other historical places of tourism importance like Bayalkanda Gadhi, Mangalgadhi, however, the forts have been demolished and bear unknown history.

Photograph 0-1: Kakrebihar temple

Photograph 0-2: Bulbule Taal

Photograph 0-3: Sava Temple (left) and Deuti Bajai Temple (right)

1.32 CULTURE ASPECTS (TANGIBLE/INTANGIBLE)

Birendranagar Municipality is very rich in tangible and intangible heritages. It has heterogeneous community with different ethnic groups living together. Hinduism and Christian are the two major religion in the city. Each ethnic communities have their own tradition, customs, values, and norms.

Dashain, Tihar, Teej, Krishna Janmashtami, Maha Shivratri, Holi, and Maghe-Sankranti etc. are the major festivals of Hindu people. Ramjan, Eid, is the major festival celebrated by Muslim community whereas; Christmas is the festival of Christian people. Specific cultural dance of indigenous Tharu and Magar community people have added to the cultural value of the city (MoUD, 2020).

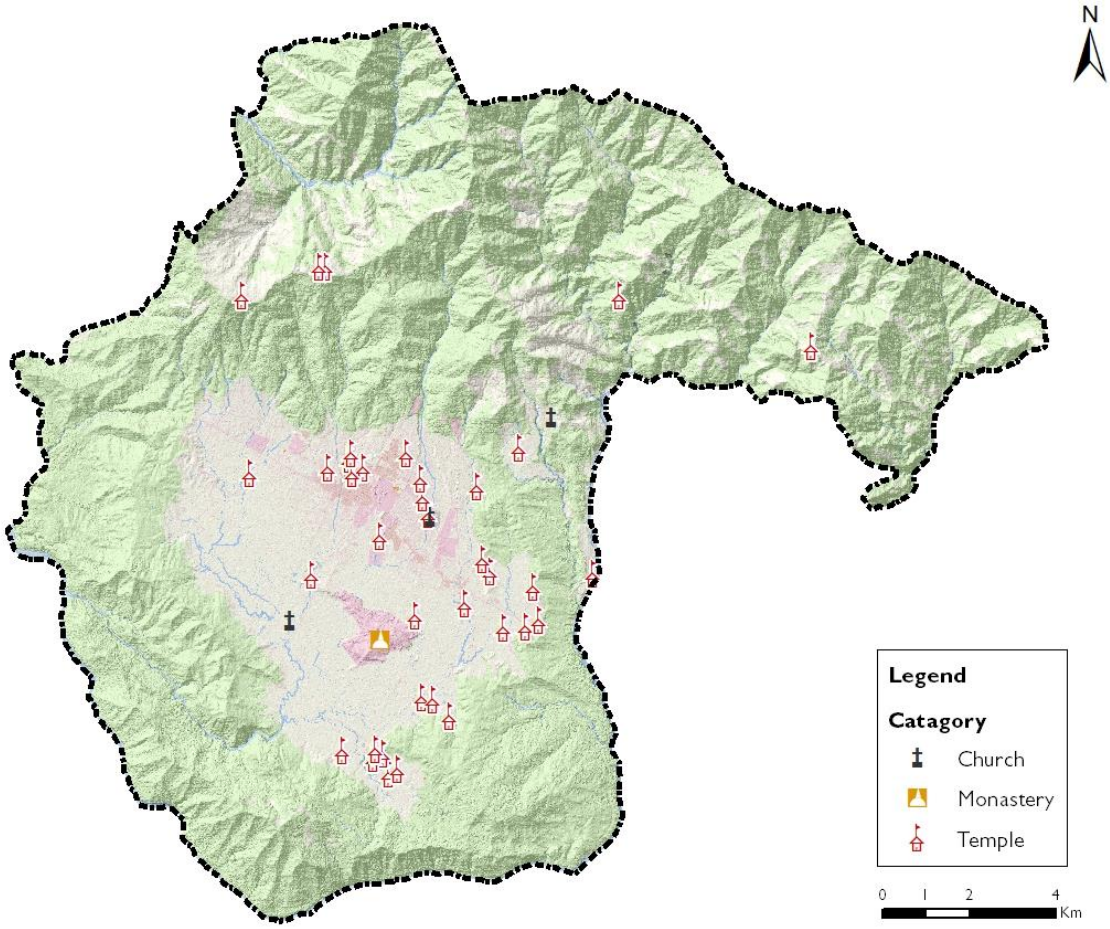
1.33 CULTURAL AND RELIGIOUS SITES

There are numerous cultural and religious sites in the Municipality. According to the field data 2021, it has altogether 1 Archeological sites, 1 Bihar, 6 Church, 12 cultural sites, 1 mosque, 9 other, and 6 monasteries and 71 temples. Map below shows the spatial location of cultural and religious sites in Birendranagar Municipality. Total area cover by Cultural and Religious sites is 13.57 hectares.

Table 0-1: Ward wise information of Cultural and Religious site

WARD NO	ARCHEOLOGICAL SITE	BIHAR	CHURCH	CULTURAL SITE	GADH	MOSQUE	OTHER	STUPA/MONASTARY	TEMPLE	TOTAL
1							2		3	5
2	1			2			1		5	9
3									6	6
4				1			1		4	6
5								1	8	9
6			2			1			8	11
7									3	3
8							2		1	3
9		1		1			2	2	11	17
10								1	3	4
11			1	1					9	11
12			1							1
13			2	2				2	3	9
14				2	2		1		6	11
15				1					1	2
16				2						2
Total	1	1	6	12	2	1	9	6	71	109

Source: Field Survey data 2021, Geoeye Satellite Image 2018



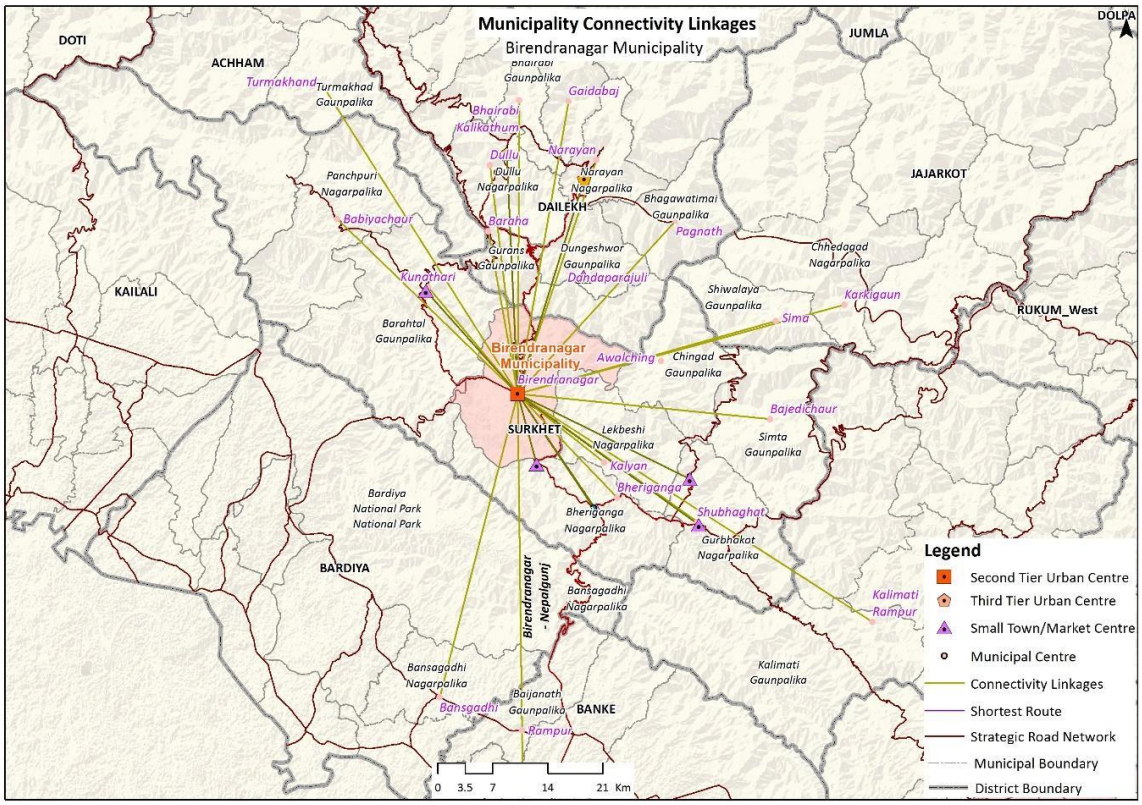
Map 0-1: Location of Cultural and Religious Sites

REGIONAL SCENARIO AND CONNECTIVITY

1.34 REGIONAL URBAN NODES, HINTERLAND AREA AND LINKAGES

NUDS has categorized Birendranagar Municipality as a Second-Tier urban center, whose major regional urban node is Nepalgunj Sub Metropolitan City. Within a radius of 20 km from the municipality, there are 2 third tier urban center - Dullu municipality and Narayan municipality, 2 Small towns – Chhinchu and Gumi- and 4 Market Centers-Bandichour, Ramghat, Mehelkuna and Abalparajal (MoUD, 2017) and 21 municipal centers.

Birendranagar is directly linked with the capital city that has added up the opportunity of trade and business in regional and national level. The municipality is the major distribution and the service center for the surrounding rural area along with other districts of the Karnali Province including the number of smaller towns and rural developments, in a regional economy based upon agriculture, primarily grains and cattle. Agriculture, forest-product (herbs), animal and animal products, honey, mushroom are major exports from the municipal trading and collection centers. And goods like agriculture, grocery, clothes, utensils, construction materials fertilizer etc. are imported from outside. Major exporting and importing destinations are Kathmandu, Nepalgunj, Butwal, Kailali etc. and others.



Map 0-1: Regional Nodes and Economic connectivity

Table 0-1: Urban Centers around Birendranagar Municipality

MAJOR URBAN AREA	SECOND TIER URBAN CENTRE	THIRD TIER URBAN CENTRE	SMALL TOWN	MARKET CENTRE	MUNICIPAL CENTRE
Nepalgunj Sub Metropolitan City	Birendranagar Municipality	Dullu Municipality	Chhinchu	Bandichour	Rampur (Baijanath Rural Municipality)
		Narayan Municipality	Gumi	Ramghat	Bansgadhi (Bansagadhi Municipality)
				Mehelkuna	Pagnath (Bhagawatimai Rural Municipality)
				Abalparajal	Bhairabi Kalikathum (Bhairabi Rural Municipality)
					Dullu (Dullu Municipality)
					Dandaparajuli (Dungeshwor Rural Municipality)
					Baraha (Gurans Rural Municipality)
					Gaidabaj (Mahabu Rural Municipality)
					Narayan (Narayan Municipality)
					Karkigaun (Chhedagad Municipality)
					Sima (Shivalaya Rural Municipality)
					Kalimati Rampur (Kalimati Rural Municipality)
					Kunathari (Barahatal Rural Municipality)
					Bheriganga (Bheriganga Municipality)
					Awalching (Chingad Rural Municipality)
					Shubhaghat (Gurbhakot Municipality)
					Kalyan (Lekabeshi Municipality)
					Babiyachaur (Panchapuri Municipality)
					Bajedichaur (Simta Rural Municipality)

MAJOR URBAN AREA	SECOND TIER URBAN CENTRE	THIRD TIER URBAN CENTRE	SMALL TOWN	MARKET CENTRE	MUNICIPAL CENTRE	
					Turmakhand (Turmakhand Municipality)	Rural

Source: National Urban Development Strategy (NUDS), MoUD (2017) and field survey 2021

1.35 ROAD NETWORK CONNECTIVITY AND ECONOMIC CONNECTIVITY

Ratna Highway connects Birendranagar Municipality to other parts of the country, it connects the municipality to east west highway at Kohalpur of Banke District. Karnali highway connects the municipality with Dailekh, Kalikot, Jumla and Mugu. Birendranagar Airport is one of the hub airports in province 6 and serves most of the remote sectors of the country such as Jumla, Humla, Kalikot, Mugu and Dolpa. With the establishment of the Airport and connectivity through Ratna Highway and Karnali highway, the urbanization in municipality has been accelerated with growth rate greater than 5% in last decade.

The municipality is the main food supplier to the rural areas of Karnali province. It also supplies products from livestock and forest to the different regions of the province. It is the main shopping destinations of Dailekh, Jajarkot and Acham districts. The municipality imports the goods and products from Lakhnow of India, Kathmandu and Nepalgunj.

UTILITIES AND SERVICES

1.36 HEALTH SERVICES

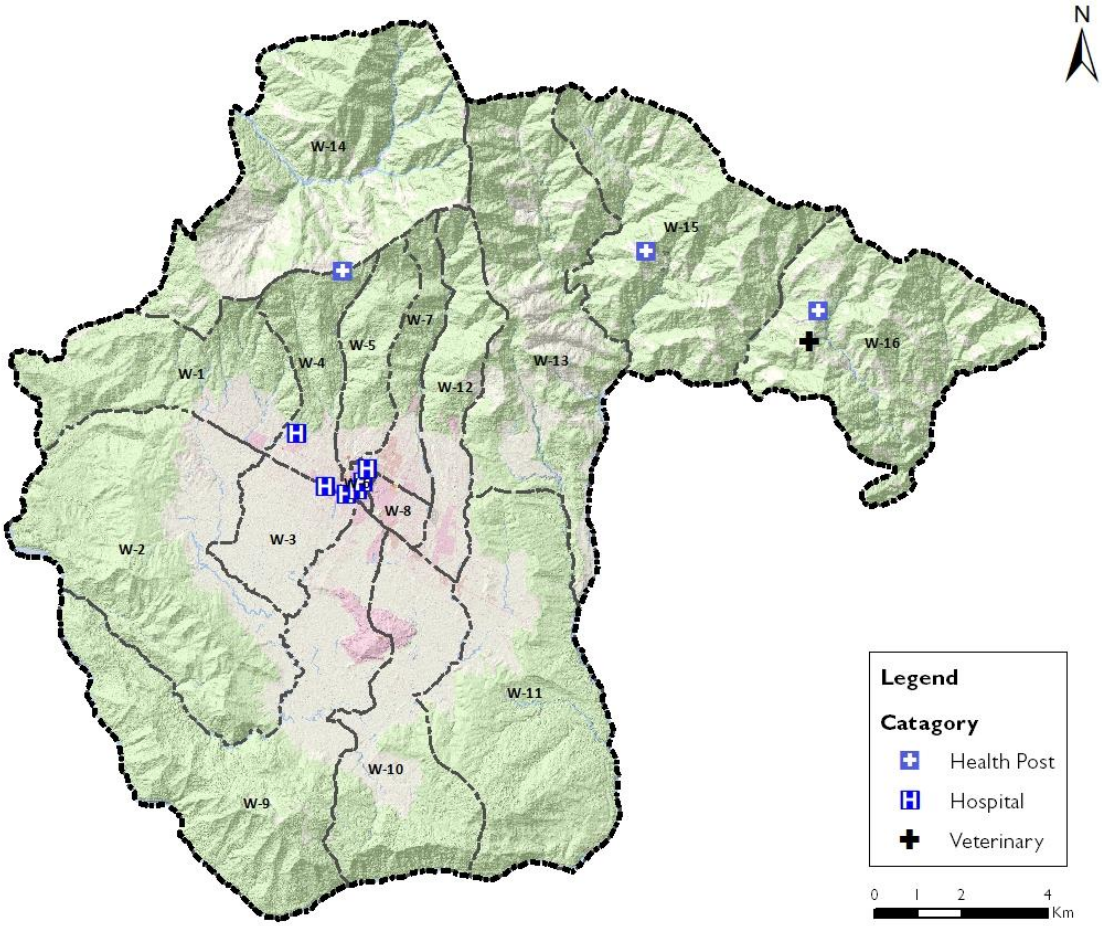
Birendranagar is main health centre in the western hilly and mountainous region of Nepal. It is also developing as a hub of health services in Karnali province. There is one district hospital, one province hospital, one Ayurveda hospital and nine health posts providing basic health facilities to the urban and rural people. Besides there are number of private hospitals, polyclinics and nursing homes mainly concentrated in the municipal center. Majority of health centers with better facilities are located in municipal center due to which people in the rural area of the municipality are sometimes deprived of basic health facilities despite the availability of health posts (MoUD, 2020).

According to the field survey 2021 total area covered by hearth sector is 3.73 hectares. There are total 31 health services in the municipality.

Table 0-1: Ward wise information of Health services

WARD NO	HEALTH CENTRE	HOSPITAL	NURSING HOME	OTHER	PHARMACY	TOTAL
1	1					1
2					1	1
3						0
4	4	6				10
5				1		1
6		1	2			3
7						0
10	1					1
15	1					1
16	1					1
Total	8	7	2	1	1	19

Source: Field Survey data 2021, Geoeye Satellite Image 2018



Map 0-1: Location of Health facilities in Birendranagar Municipality

1.37 EDUCATION

The Municipality bears different types of educational facilities including- preschools, childcare, primary schools, secondary schools and colleges. There are altogether 64 community school and 76 private schools providing Basic and Secondary level education (MoUD, 2020). Also there are 176 Child development centers among which 99 are Community and 77 are under Private management. Besides, there are 2 Government College and 4 Private colleges along with 2 Madrasa. (MoUD, 2020).

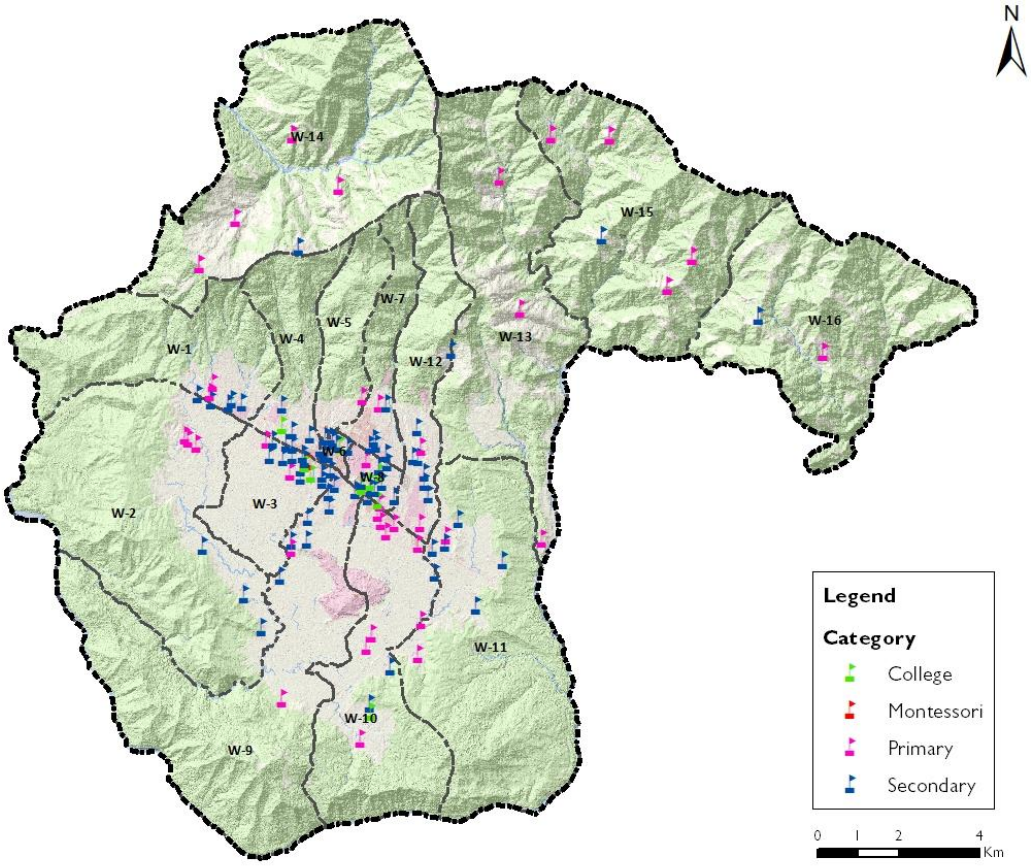
Table 0-2: Education Institutions of Birendranagar Municipality

S. N.	TYPES	GOVERNMENT	COMMUNITY	PRIVATE	TOTAL
1	Children Development Center	-	99	77	176
2	Primary School	-	31	21	52
3	Lower Secondary School	-	14	16	30
4	Secondary School	-	19	39	59
5	Campus	2	2	4	8
6	Madrasa	-	2	-	2
7	Others	Technical School	12	-	12
		Skill Development Training Center	5	-	5
		Community Children Development Center	11	-	11

According to the field survey 2021 total area covered by education sector is 18.91 hectares. There are total 163 educational services in the Municipality.

WARD NO	CAMPUS	PRIMARY	SECONDARY	UNIVERSITY	TOTAL	PRIVATE SCHOOL AREA
1	0	6	0		6	2
2	0	5	0		5	6
3	1	12	1		14	8
4	0	2	4		6	4
5	0	1	1		2	0
6	1	2	4	1	8	4
7	0	4	1		5	5
8	3	10	0		13	2
9	0	10	1		11	1
10	0	10	0		10	0
11	0	12	1		13	2
12	0	6	0		6	1
13	0	11	0		11	
14	0	5	1		6	
15	0	6	1		7	
16	0	4	1		5	
Total	5	106	16	1	128	35

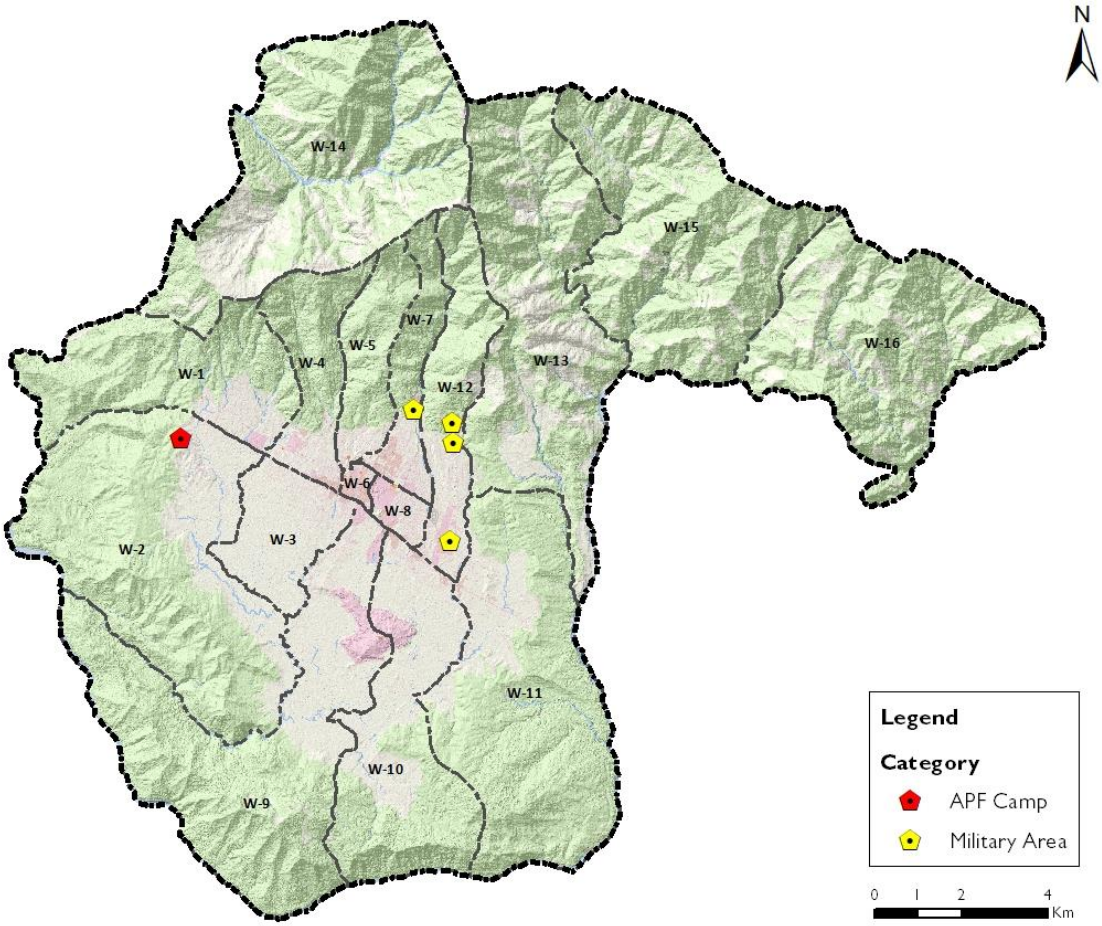
Table 0-3: Ward wise Educational sector information



Map 0-2: Location of Education facilities in Birendranagar Municipality

1.38 SECURITY SERVICES

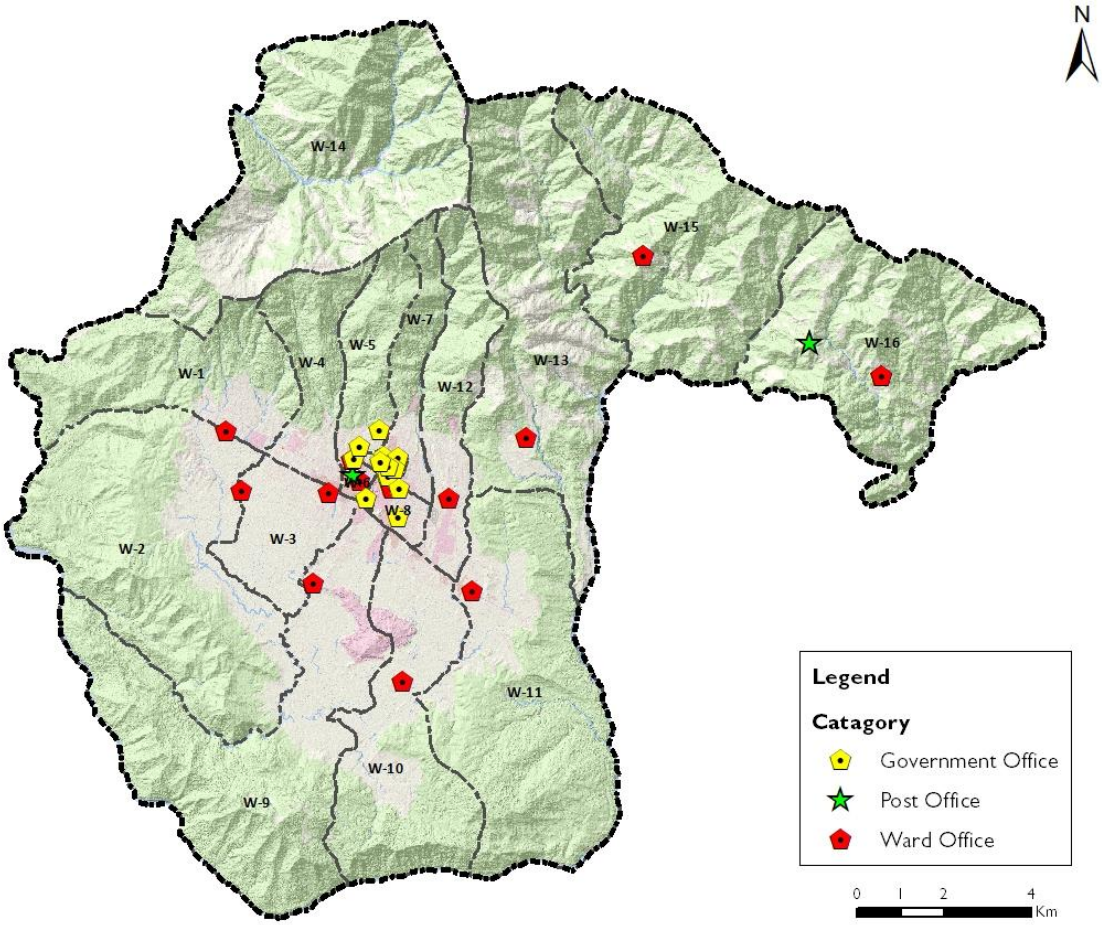
The municipality has 3 military area (including Nepal Army Mid-Western Division) and one APF camp along with number of police stations distributing across the valley. Karnali province traffic police office and District police office is also located in the municipality. According to field survey 2021 there are 17 Security services among them 1 Mid-Western Regional Police Office in ward 7, 1 Surkhet Jail in ward 5 rest of the other are Military area and Police Stations. The area occupied by security services is 57.69 hectares in the Municipality. Map below shows the location of military area and APF camp in the municipality.



Map 0-3: Military area and APF camp location

1.39 ADMINISTRATIVE SERVICES

As a capital city of province 6, Birendranagar Municipality serves as a main economic and administrative center to all the districts of Karnali Province. Government services such as-Regional administrative office, District administrative office, Tax service office, District court, Mid-western road division office, etc. are located in the main bazar area of the municipality. Besides ward offices are located in each ward of the municipality. Map below shows the distribution of administrative service of Birendranagar municipality.



Map 0-4: Distribution of Administrative Services in Birendranagar Municipality

According to field 2021, there are 79 Government services areas which occupied 16.38 hectares of total area of the Municipality.

Table 0-4: Ward wise Government Service Areas

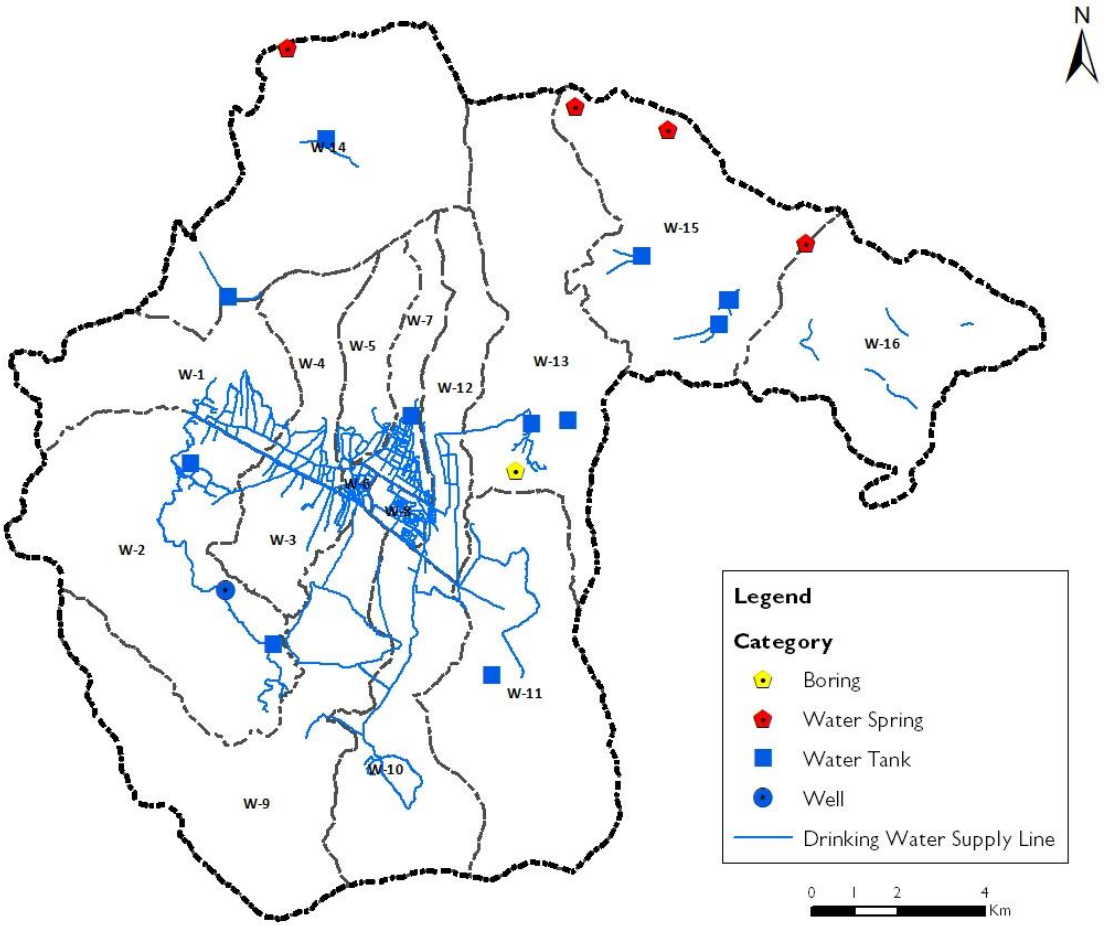
WARDS NO	1	4	5	6	7	8	9	10	12	13	15	16	TOTAL
Agriculture Office						1							1
Civil Aviation									1				1
Court					2								2
District Administration Office					4	1							5
Education					1								1
Electricity Office					1			1					2
Forestry Office		1			1								2
Health Office			1		1							1	3
Land Reform					1								1
Local Development Office	1		1		3	1			1	1	1	1	10
Other				1	21	6	2	2	6				38
Post Office												1	1
Road Office				2	1	2							5
Survey Office					1								1
Tax			1										1
Tele Communication Office					1								1
Water Induced Disaster					1								1
Water Supply Office		1			2								3
Total	1	2	3	3	41	11	2	3	8	1	1	3	79

Source: Field Survey data 2021, Geoeye Satellite Image 2018

1.40 UTILITY SERVICES

Drinking Water

The main source of water in Birendranagar Municipality is rivers and streams such as- Ittram Khola, Bulbule, Jhupra Khola and Khorke Khola. The water from these sources is supplied through pipeline after filtration (MoUD, 2020). Besides, water from well, spout and other sources are used for drinking purpose. As an emerging city of Karnali Province, the average daily demand for drinking water in the Municipality is likely to increase in near future. According to the municipal profile, the total population of the municipality is around 181,500 who require nearly 560 liters of water per second. But according to Surkhet Upatyaka Khanepani Sanstha (SUKS), which has been supplying drinking water in Birendranagar, can hardly supply 149 liters in normal seasons which reduced to 99 liters per second in the dry season. So considering the ever increasing population, the municipality has already identified Bheri River as an alternative source of drinking water. Map below shows the different types of water sources in the municipality.



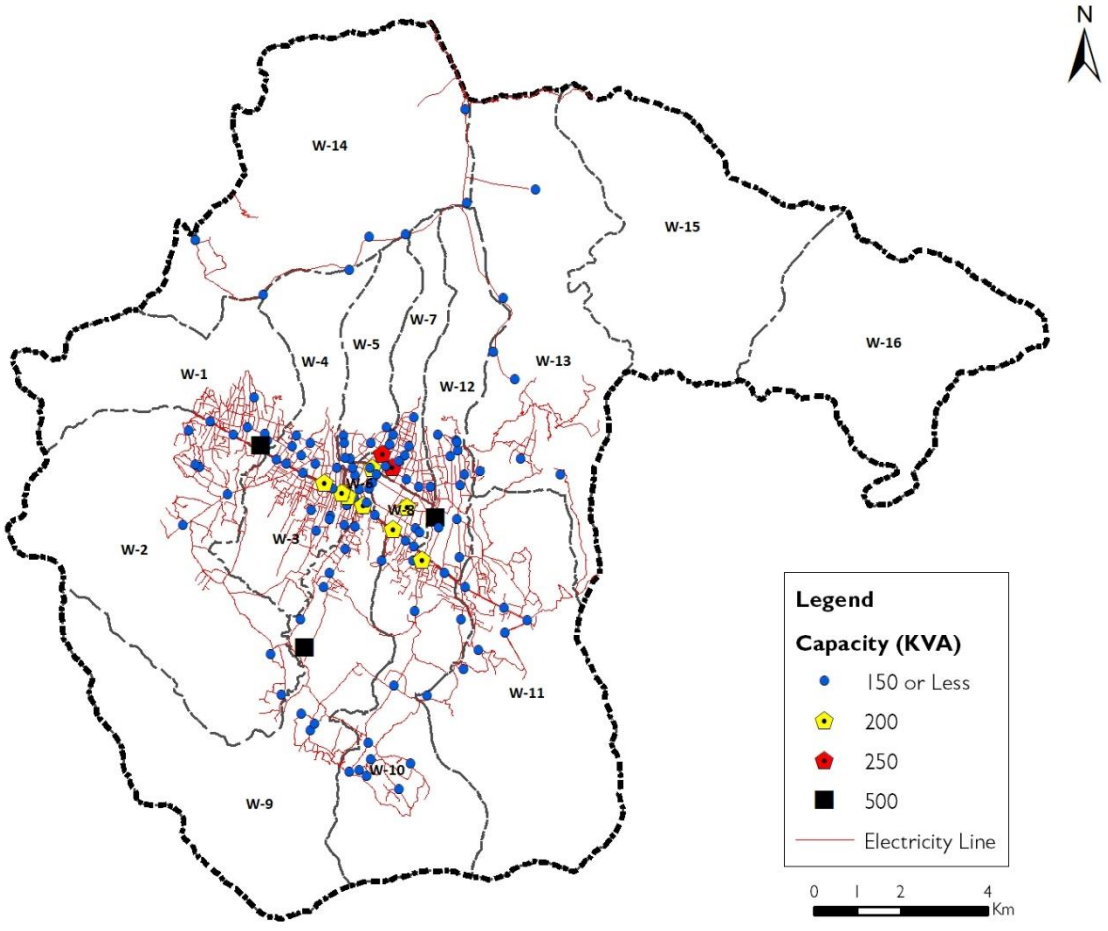
Map 0-5: Distribution of Water supply Services in Birendranagar Municipality

According to field data survey 2021 there are two water tanks in ward 1. Other water sources are natural water sources and 20 spouts. The "Jupra Brihat Khanepani Sansthan" is the main water supply office in ward 7 in the Municipality.

Electricity

Birendranagar Municipality is connected to National Grid and electricity has been distributed throughout the municipality except ward 16. Some households are still deprived of electricity supply in all the wards. Within the municipality 27,306 households (93.46%) are facilitated by electricity supply whereas 6.52 % of household are deprived of electricity (MoUD, 2020).

Ward 1 to ward 13 has good access to electricity while ward 14, 15 and 16 are deprived of electricity due to uninstallation of electric poles till date. Solar panel is an alternative source for those household who are deprived from electricity. Till date, 128 transformers have been installed in Birendranagar municipality with voltage between 25 KVA to 500 KVA. Ramghat and Dailekh substation supply electricity in the municipality.



Map 0-6: Distribution of Electricity Services in Birendranagar Municipality

Drainage System

Proper Municipal Drainage system is not available in Birendranagar municipality. Only storm water drains are constructed along the roads in most of the settlement. Most of these drains are masonry and uncovered. Storm water during monsoon and waste water from the adjoining households too flow through these drains. The outlet of these drains is in the rivers and streams (MoUD, 2020).

Whereas the solid waste is dumped in dumping site, there are two landfill sites in ward 1 with the area of 0.60 hectare and 0.66 hectare respectively.

Information and Communication

Information and Communication service is well developed in Birendranagar municipality. However, there is a distinct gap between rural areas and urban areas of the municipality due to poor infrastructures and less opportunities in rural areas.

Postal service, mobile, landline, internet, television, FM radio, newspaper, magazines etc. are the major means of information and communication in the municipality. FM radio stations are also available here with one government FM and various private FM. Postal services are serving the municipality since long years back but postal service users are decreasing at present (MoUD, 2020).The radio Nepal station is in ward 1 and the Tele communication office is in ward 7 of the Municipality.

COMMERCIAL AND FINANCIAL

1.41 COMMERCIAL SERVICES AND FINANCIAL SERVICES

The main economic activities of the municipality are Agricultural (including livestock and poultry), cottage industries and trade. The municipality is served by 30 banking and financial institutions including 253 saving and credit cooperatives and multipurpose cooperatives. Besides, there are various business units in the municipality including grocery shops, clothing stores, utensils, showrooms and other value generating business. Major 5 trading centers have been facilitating import, export and collection of agriculture goods to the municipality. However, there is no cold store, formal collection center and large storage house in the municipality (MoUD, 2020).

According to Field survey 2021 data there are 1080 commercial multi-purpose building among them 11 are banks and finances, 892 shops, 16 hotels, restaurant and 151 retail business. Rest of other are storage houses, business houses, other services and gaming hall. Most of the commercial buildings are in ward 3, ward 4, ward 6, ward 8, and ward 9 along the highway of Birendranagar-Surkhet. Total area of commercial and financial area is 215.19 hectares in the Municipality.

1.42 HOSPITALITY/TOURISM SERVICES

Tourism can be major economic source since the municipality bears many places having cultural and religious importance. Similarly, there are many other places for viewing large range of Himalaya, sceneries, highest elevation rhododendron jungle wildlife natural habitats, attracting natural destination and many more. All these sources can help the municipality to uplift its economy. The regional Museum Surkhet, Sahid Park, Adheri Gufa, Chamera Gufa and Bulbule Tal are an attraction for tourism.

CRITICAL INFRASTRUCTURES

1.43 HUMANITARIAN OPEN SPACES

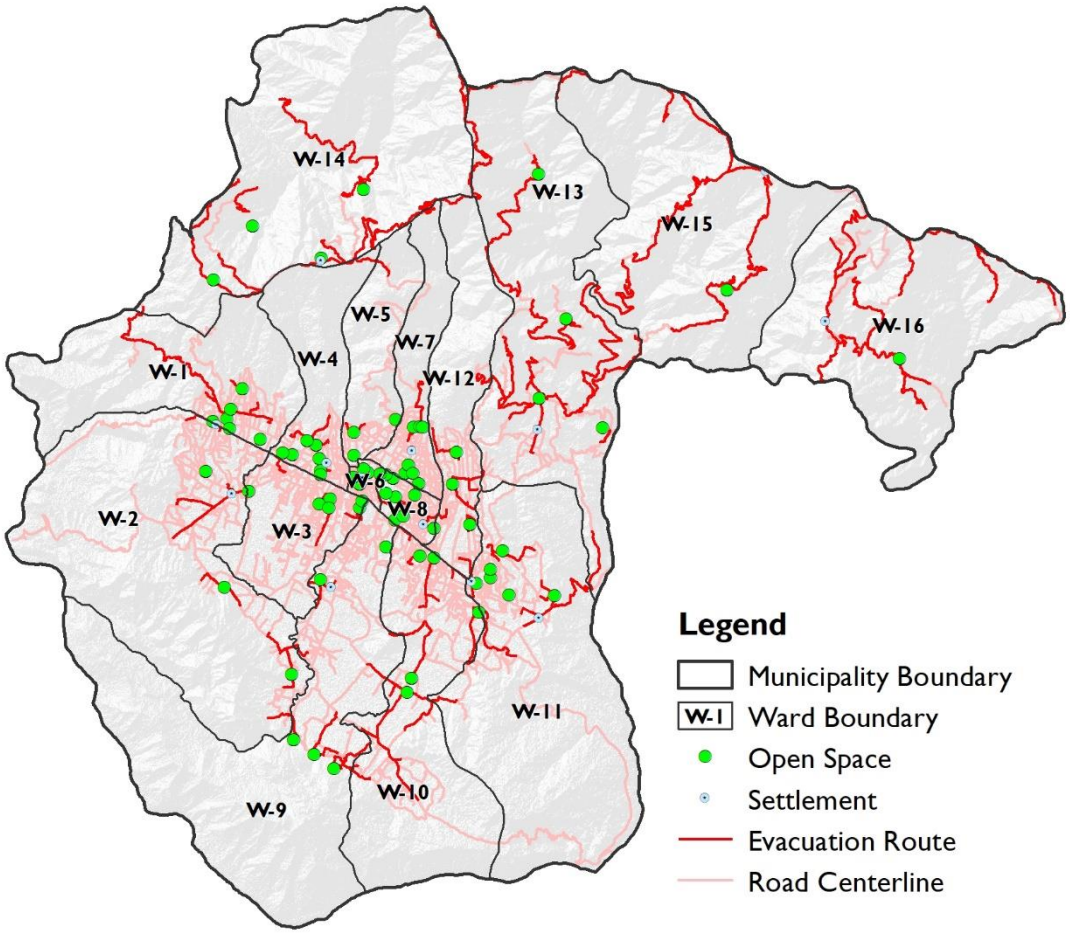
There are altogether 164 open spaces in Birendranagar Municipality including school ground and institutional grounds. The selection of Humanitarian open spaces out of these open spaces will be based on following criteria:

- Slope (less than 5°),
- Accessibility to road
- Availability of critical facilities and other resources,
- Environmental suitability

Table 0-1: Wardwise distribution of open spaces

WARD NO	MUSEUM	OPEN SPACE	OTHER	PLAY GROUND	STADIUM	TOTAL	AREA IN HA
1			1	9		10	14.77
2		2	1	7		10	1.87
3				13		13	1.46
4		3	1	6		10	12.46
5			1	5		6	1.24
6		3	1	9		13	24.85
7		1		33		34	28.80
8	1	6	2	13	2	24	46.44
9			1	8		9	19.97
10		1	1	5		7	18.76
11			1	7		8	3.31
12				5		5	0.70
13				5		5	0.60
14		1		6		7	1.48
15				1		1	0.10
16				2		2	0.11
Total	1	17	10	134	2	164	176.93
Area in ha	0.81	17.89	64.43	77.18	16.61	176.93	

Source: Field Survey data 2021, Geoeye Satellite Image 2018



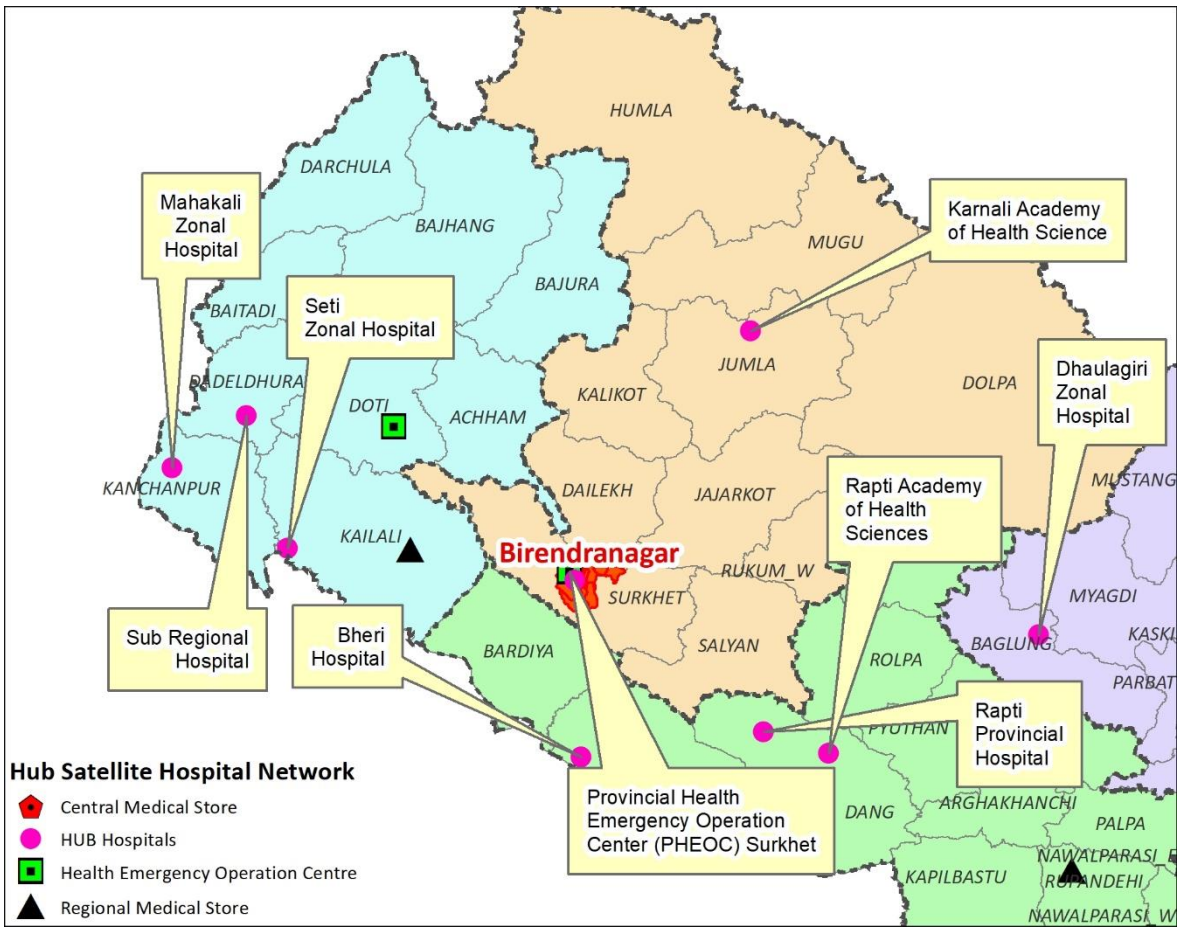
Map 0-1: Humanitarian Open Space and Evacuation Route

1.44 EMERGENCY OPERATION CENTERS

An Emergency Operation Center (EOC) is a physical infrastructure as well as a functional mechanism for coordination of information and resources to support incident management activities that may be located at a temporary facility or established in a permanent site (MoHP, 2021). The National Emergency Operation Center (NEOC) was established in 2010 as a coordination and communication point for disaster information across Nepal, including government agencies and other response and recovery stakeholders (UN agencies, INGOs and NGOs).

The Ministry of Health and Population (MoHP), identifying the importance of such an operation center for the health sector, requested the World Health Organization (WHO) for its support in establishing a high-level operational command center for disaster and emergencies management (MoHP, 2021). Accordingly, MoHP has designated the Health Emergency Operation Centers (HEOC) and area specific Hub and Satellite hospital network across the country to enable the strategic and structured sharing of the resources and capacities. There are altogether 4 HEOC and 25 hub hospitals throughout the country. Currently, HOEC/MoHP-Nepal has been reporting and

spreading awareness of covid-19 and actively updating through different media and official community groups. Map below shows the location of Birendranagar Municipality and HEOC and Hub Hospitals around it.



Map 0-2: Distribution of HEDC and Hub Hospitals of Birendranagar Municipality

1.45 LIFELINE SERVICES

There is no fire engine in Birendranagar. The fire cases are usually handled by security personnel of Nepal Army, Armed Police Forced and Nepal Police.

URBAN GROWTH TREND AND PROJECTIONS

1.46 LAND USE CHANGE TRENDS (OF LAST 10-15 YEARS)

Urban growth change and trend

The annual urban growth rate from 2011 to 2018 was calculated using following equation.

$$AGR = \frac{UAn+i - UAi}{nTAn+i} \times 100\%$$

Where, AGR is annual urban growth rate, UAn+i and UAi are urban areas in target unit at time i+n and i respectively, n is number of year, and TAn+i is the total land area of the target unit to be calculated at the time of i+n.

In Birendranagar Municipality, the annual urban growth rate from 2011 to 2018 was 0.19 percent.

Table 0-1: Annual Urban Growth Rate

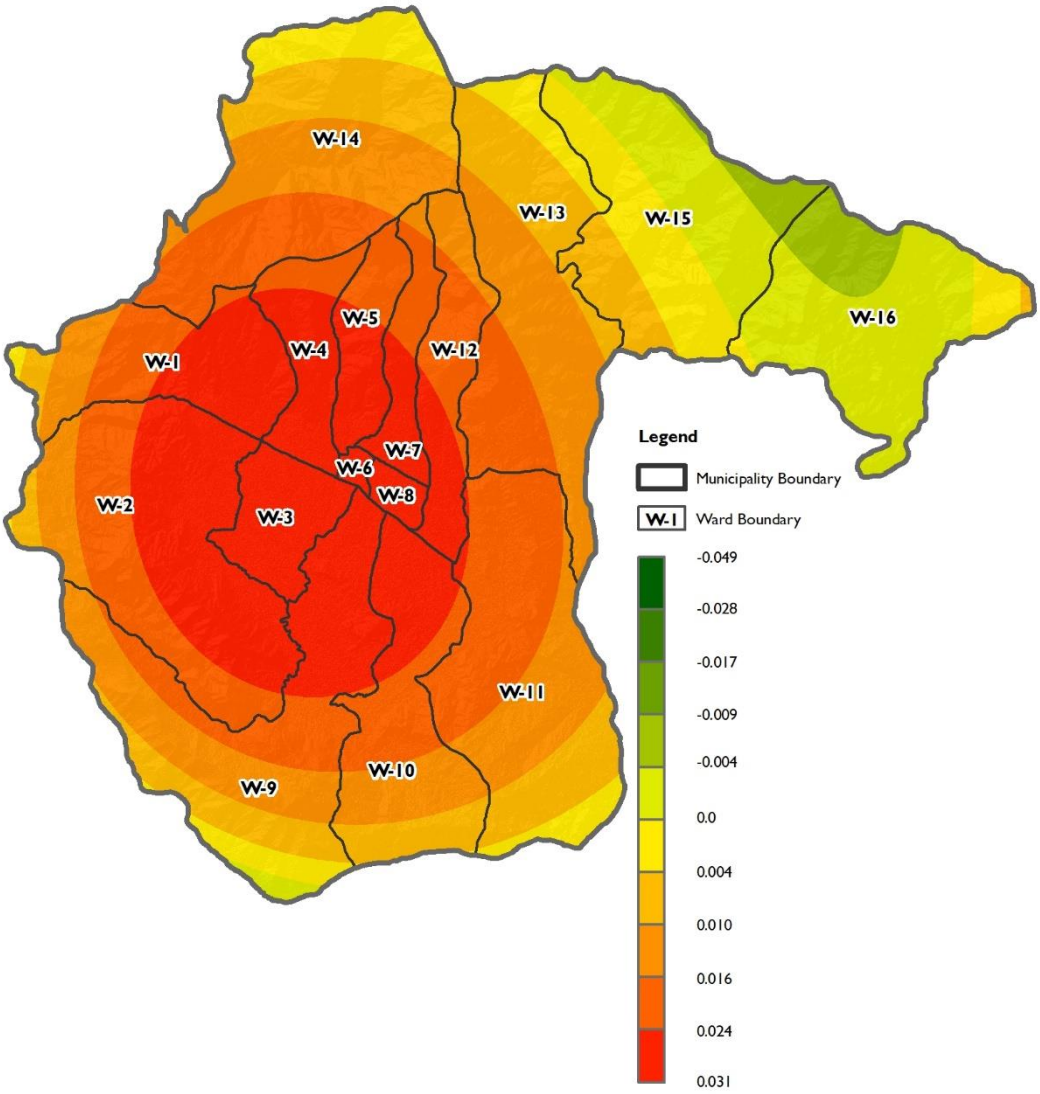
SN	LULC	2011 (HA)	2018 (HA)	ANNUAL GROWTH RATE
1	Built-up	980.73	1323.24	0.19

Source: DUDBC, 2020

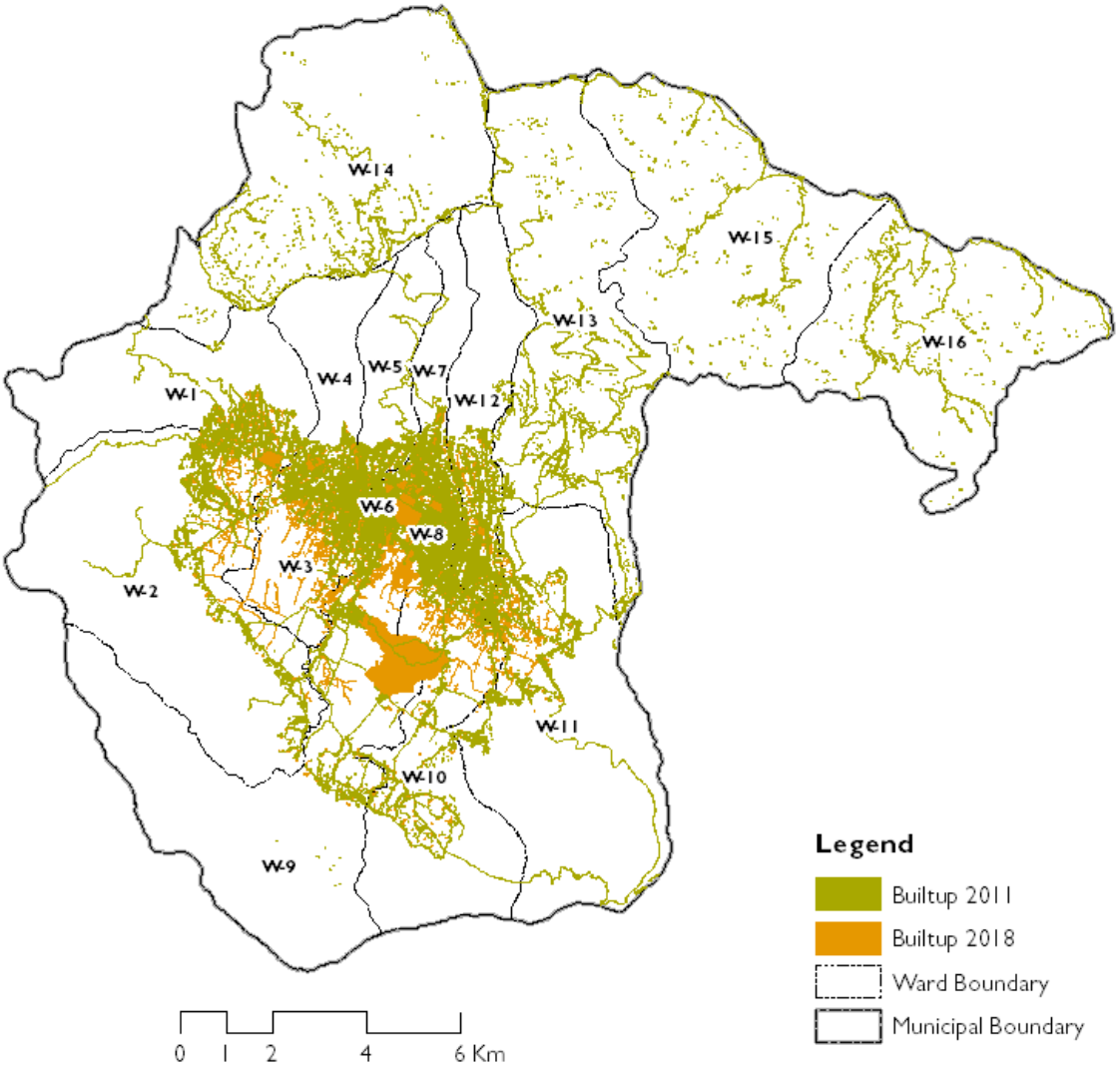
The urban growth trend was analyzed using a best fit polynomial trend surface equation as following, Third order polynomial was used to identify the trend.

$$Z = \sum_{i=0}^{k} \sum_{j=0}^{i} b_{ij} x^{i-j} y^{j}$$

Where b is the coefficient *k* is the maximum order to be fitted; both *i* and *j* are iteration variables associated to *k*, in which *i = 0..k* and *j = 0..i*.



Map 0-1: Urban Growth Trend (2011-2018)



Map 0-2: Urban Growth Change (2011-2018)

1.47 POPULATION GROWTH

1.47.1 DRIVERS OF CHANGE

Identifying the major drivers of urbanization is a fundamental prerequisite for sustainable urban growth and effective environmental planning (Rijal et al. 2020). There are a number of factors that influence the growth rate. These factors are also called drivers of urban growth "or variables responsible for change. The key drivers of changes in land use/land cover (LULC) in Nepal have been found to be natural hazards, urbanization, climate change, population growth, economic activities and development, along with poor government planning and policies. (Li et al. 2017) (Rijal et al. 2020).

NATURAL ENVIRONMENT (BIO-PHYSICAL CONDITION)

Bio-physical characteristics refer to characteristics and processes of the natural environment such as landforms, topography, soil type, natural resources and drainage pattern. These characteristics usually affect settlement growth patterns based on the suitability of land for specific purposes.

Parameters such as slope, reserved forest and water bodies are taken as site specific characteristics, which can either restrict or accelerate the growth rate.

Built-ups are generally discouraged in the slopes greater than 30 degrees, areas vulnerable to liquefaction, landslides and other natural hazards. Therefore, slopes greater than 30 degrees, water bodies and areas vulnerable to natural hazards have been identified as constraints for growth. From a real estate perspective, the land value close to water fronts, rivers, lakes, green belt and open spaces tend to be higher than the value of land more distant from the amenities. (Ewing 2008).

BUILT ENVIRONMENT

Considering built environment- related factors transportation (distance to roads, highways, public transportation), land use (distance to settlement, land use, distance to urban centers, cities, residential areas), and job opportunities (distance to settlement, Central Business District (CBD), commercial area) are closely related to commuting time and cost and therefore affecting the settlement growth.

TRANSPORT NETWORKS

It is assumed that whether a place is urban or not is highly correlated to accessibility of that place. Therefore, transport related variables such as roads are included as predictors of urban growth. This variable is widely mentioned in most of the literature because of the fact that the area which is at closer proximity of transport related variables have greater tendency to grow in future due to potential benefits such as ease of access, economic opportunities and social services.

Highways connected in Birendranagar Municipality are Ratna Highway and Karnali Highway. Other major roads in the municipality are hotline road, Latikoli, Surkhet Dailekh road, Mangalgadi- Ganesh chowk, etc. Birendranagar Airpot is one of the hub airport in the Karnali Province. The major development has been observed in the peripheral area of Airport, Tempo chowk and Mangalgadi chowk.

ACCESS TO INFRASTRUCTURE AND SERVICES

Availability of facilities and infrastructure in an area will be an attraction for residents to choose the location as a residential area. (Pigawati, Yuliastuti, and Mardiansjah 2018). Accessibility to public facilities and institutions will attract settlement growth. Birendranagar is also facilitated with hospitals and health posts for health facilities and different private and community schools for education facilities. Most of the future growth potential area are around such facilities.

EXISTING SETTLEMENT

Urban expansion is caused by continuous population growth and migration, (Li et al. 2017) existing settlements trigger the growth of new settlements in the surrounding area. Infrastructure development (e.g., sewage, water lines) is a key implication for future development. (Lapping 2000). Public facilities providing community service and value become attractive for development and redevelopment.

POLITICAL SCENARIO

Political conditions have an important role in determining settlement growth as they determine the migration trend. Political situation in the country in the last decade influenced the migration pattern from rural areas to the district headquarters and more significantly from district headquarters to major cities for safety and security reasons. This had a negative impact on settlement growth in the region. Though political condition governs social and commercial growth attributing to the

settlement growth, it is not included while modelling the growth due to complexity of modelling political situation into spatial form.

Birendranagar served as the headquarters for the Surkhet District and now it has also been declared as capital city of Karnali Province. Therefore, it is more likely to grow in future due to these changes.

ECONOMIC ACTIVITY

The level of urbanization and level of development is closely related with accessibility to market, infrastructure and services such as drinking water, electricity, education, market, health facilities. Therefore, settlements in areas facilitated with proper infrastructures tend to grow. The presence of infrastructures and services is also likely to affect the future growth pattern of a place because it enhances the thrust towards urbanization of rural-urban fringes, which eventually increase the settlement areas at their proximity.

POLICIES

The implementation of relevant government policies also directly or indirectly affected land cover. In 1956, the Nepalese government promulgated the Forest Protection Law to implement compulsory management measures for state-owned forests. For agricultural land, the government has implemented a series of agricultural development measures to promote the increase in cropland areas, such as agricultural loans, promotion of fine varieties, expansion of irrigation systems, pesticide and fertilizer application.

Industrial Policy in 1992 and Foreign Investment and One-Window Policy, had increased both foreign and domestic investment for industrial development; these actions have led to population migration and urban development (Li et al. 2017).

The summary of drivers discussed in the focus group discussion in the municipality and wards is provided below:

Table 0-2: Drivers of change

DRIVERS	WARD 3,6,8	WARD 1,2,9,10,11	WARD 4,5,7,12	WARD 13,14,15,16
Transport Network	4	1	2	1
Access to infrastructure and services	5	2	4	
Existing Settlement	1	3	2	
Policy	2	4	1	3
Economic Activities		6	4	5
Plans and policies and their implementations	3	5	6	1
Others (River bank management)				

Providing weighted ranking to all the responses and discussion final ranking for the drivers of change was obtained as follows:

Table 0-3: Drivers of change with rank

DRIVERS	RANK
Transport Network	1
Access to infrastructure and services	2
Policy	3
Plans and policies and their implementations	4
Existing Settlement	5
Economic Activities	6
Others (River bank management)	7

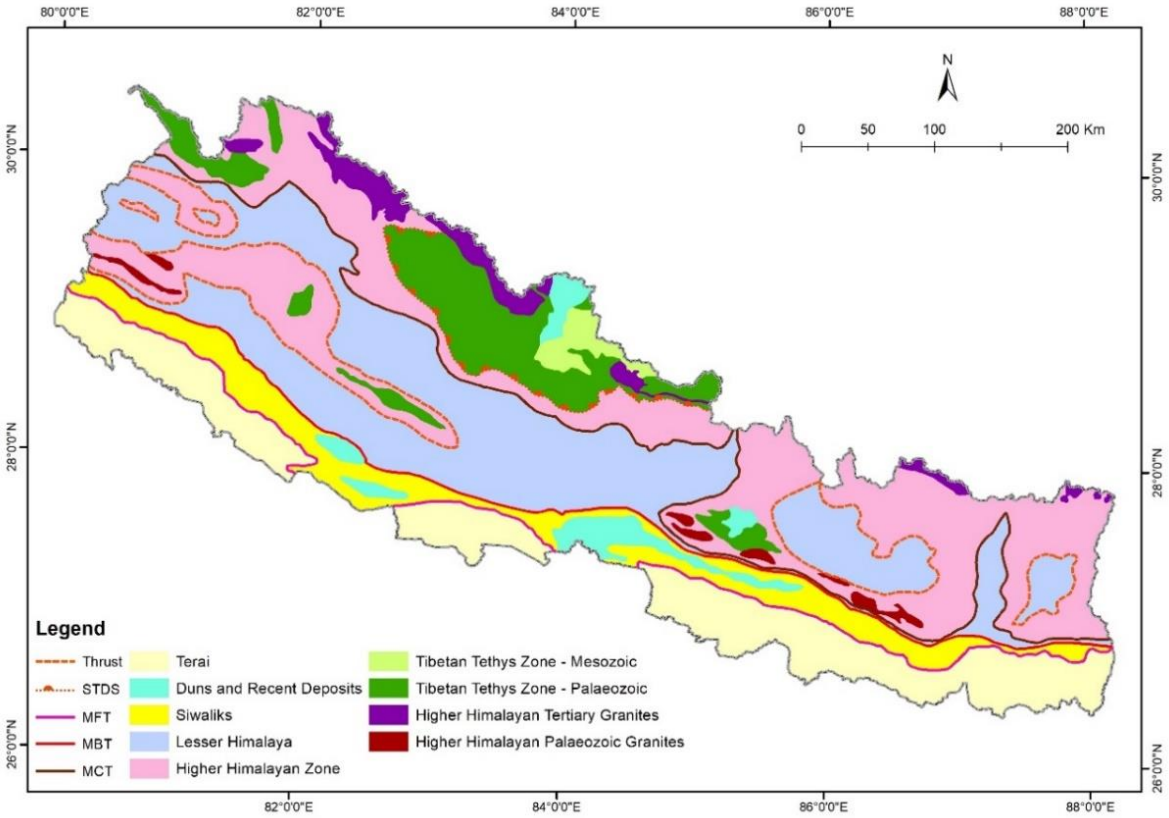
REGIONAL GEOLOGY AND SEISMOTECTONICS

1.48 REGIONAL GEOLOGY

The geological features of the entire Himalayan region are simply defined as regional geology. It describes the rock types, their origin of formation, their composition, and structures present on these rocks in a regional level. The study of regional geology is important because it determines the seismic activities in the whole Himalayan range and also determines the local geological setting. The entire range of Himalayas extends for about 2400 km from Nanga Parbat (8126m) in the west to Namcha Barwa (7782m) in the east with 200 – 250 km width. The Himalayan range shows a convex southward bend and terminates on both east and west ends with two remarkable syntaxes (Sharma, 1990). Gansser (1964) divided the Himalayas into five divisions from west to east following geographical as well as political boundaries (Gansser, 1964), namely, Punjab Himalaya (550 km), Kumaon Himalaya (320 km), Nepal Himalaya (800 km), Sikkim-Bhutan Himalaya (400 km), and NEFA (North-East Frontier Assembly) Himalaya (400 km). Among these, the Nepal Himalayas covers about one-third of the total length of entire Himalayan range extending from Mahakali River in the west to Mechi River in the east.

Like the entire Himalayan range, the Nepal Himalaya is divided into following five major geological zones from south to north, respectively (Amatya & Jnawali, 1994; Hagen, 1969, Dhital 2015)

- Indo-Gangetic Plain (Terai)
- Sub Himalayan (Siwaliks) Zone
- Lesser Himalayan Zone
- Higher Himalayan Zone, and
- Tibetan-Tethys Zone



Map 0-1: Geological map of Nepal (Modified for the Limpiyadhura region from Amatya & Jnawali 1994)

Indo-Gangetic Plain: It is the southernmost geological unit of Nepal Himalaya. It is characterized by the fluvial sediments that are derived from the northern mountainous region. It is also defined as the northern extension of the Indo-Gangetic Plain. It is called as Terai Plain in Nepal. It comprises three different units: Bhavar Zone, Middle Terai, and Southern Terai from north to south, respectively.

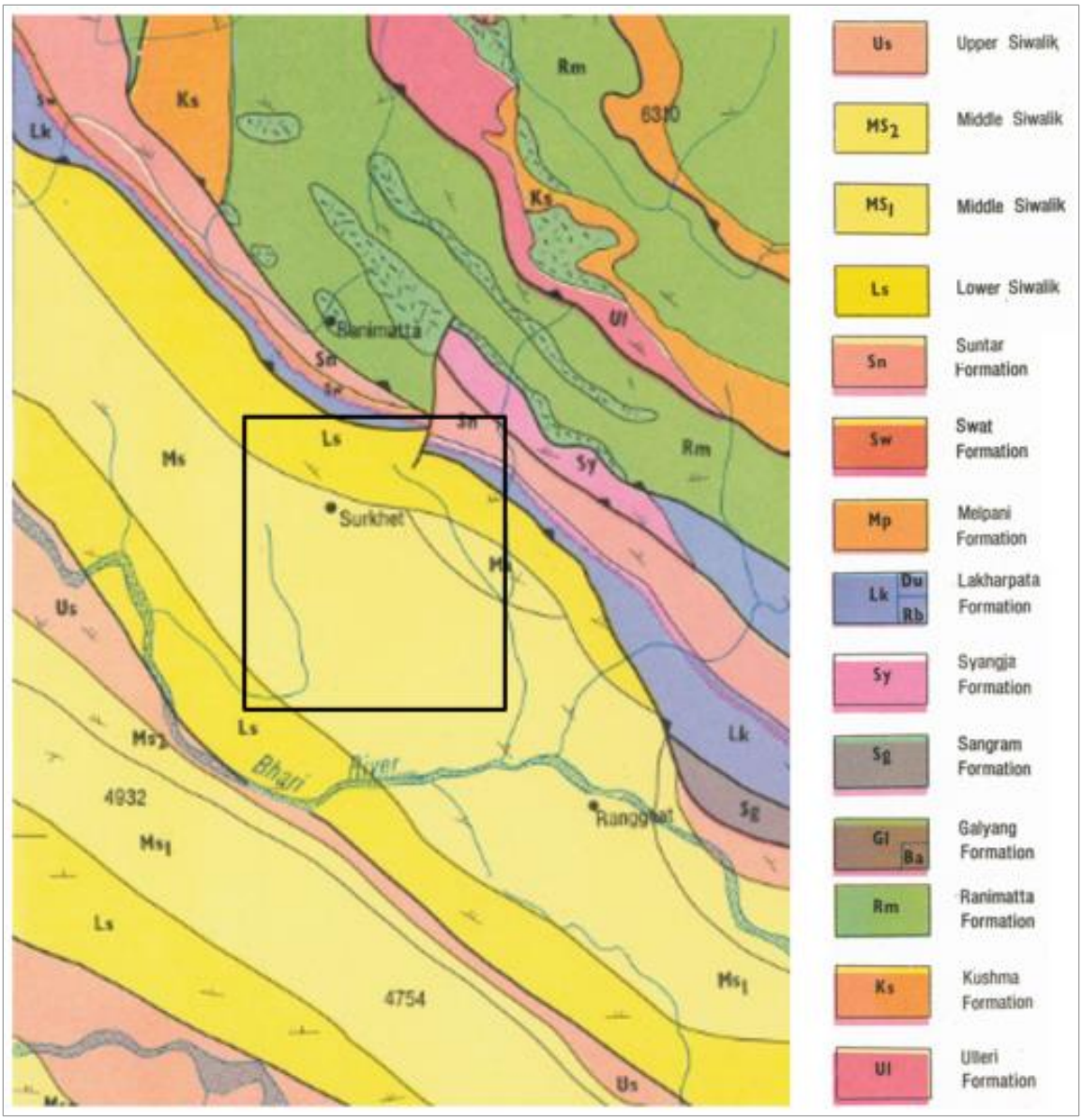
i. **Siwaliks:** It extends throughout the country from east to west, and demarcated by the Main Frontal Thrust (MFT) to the south and by the Main Boundary Thrust (MBT) to the north, respectively. The Siwaliks is wide in western Nepal and it pinches out in the east. It splits in Dang and Chitwan area forming dun valleys. The Siwaliks consists of sedimentary rocks made up of fine to very coarse sized molasses-like fluvial sedimentary deposits demonstrating the uplifting history of the Himalaya (Gansser, 1964). It is broadly classified into three groups: Lower Siwaliks, Middle Siwaliks, and Upper Siwaliks based on the proportion of sandstone, mudstone, and conglomerate. There is an intermontane basin formed between Siwalik and Lesser Himalaya, which is filled with alluvial deposits. The Birendranagar Municipality geographically covers the intermontane basin, Siwalik, and Lesser Himalaya.

ii. **Lesser Himalayan Zone:** This zone lies between the Siwaliks and Higher Himalaya and forms the hanging wall of the MBT and the footwall of the Main Central Thrust (MCT). It comprises Precambrian low- to medium-grade metamorphic rocks, also called as metasedimentary rocks. Phyllite, quartzite, limestone, and dolomite are pre-dominantly occurring rocks in the Lesser Himalaya. Granitic intrusions are also occurred in this zone. This zone also comprises many complex structures such as folds, faults, nappes, and *klippes* showing a complicated geological setting.

iii. **Higher Himalayan Zone:** It is separated from the Lesser Himalayan Zone by the MCT in the south and extends to the Tibetan-Tethys Zone in the north running throughout the country. This zone comprises medium to high-grade metamorphic rocks such as banded and augen gneiss, marble, quartzite, and migmatites. In many places, the Higher Himalayan rocks are thrust over the Lesser Himalayan rocks forming nappe and *klippe*. The South Tibetan Detachment System (STDS) separates it from the Tibetan-Tethys Zone in the north. The project area lies in this zone.

iv. **Tibetan-Tethys Zone:** It begins from the top of the Higher Himalayan Zone and reaches to the north in Tibet. This zone comprises highly fossiliferous calcareous sedimentary rocks of Palaeozoic to Miocene age. In Nepal, the Tibetan Tethys rocks are well exposed in the Thak Khola (Mustang), Manang, and Dolpa area. Due to thrust, some rocks belonging to the Tibetan Tethys Zone are also exposed on the top of southern hills of the Kathmandu Valley.

The Birendranagar Municipality covers some portion of Lesser Himalaya and Siwalik that comprises rock sequences of Cambrian to Neogene age along with entire intermontane basin of Surkhet, which is filled with fluvial sediments. Based on the stratigraphy of DMG (1987), the northern part of the Birendranagar Municipality comprises bedrocks of Dailekh Group, Lakharpata Group, and Surkhet Group. Similarly, sandstone, mudstone, siltstone, and conglomerate beds are observed in the eastern, southern, and western part of the municipality. These rocks are belonging to Lower, Middle, and Upper Siwalik. The MBT passes through the central part of the municipality, which edges with the northern hills (DMG 1993). Additionally, there are Ranimatta Thrust, Bheri Thurst, and Surkhet Thrust also pass through the municipality.



Map 0-2: Geological map of Mid-Western Nepal showing the location of Birendranagar Municipality (DMG 1987)

1.49 REGIONAL TECTONICS AND STRUCTURAL SETTING

The tectonic setting refers to the different tectonic condition at a particular place of the earth. The regional tectonics describes the processes shown by the movement of lithospheric plates in the Himalayan region. If there is continuous movement of lithospheric plates in their boundary, it is called as active tectonics. The regional tectonics and structural settings of the Himalayan Range are determined by the submergence of Indian Sub-Continent under the Eurasian Plate. Due to continuous movement of these two lithospheric plates, the Himalayan Range shows an active tectonic setting. As a result, a diverse geographical setting has been formed in the entire Himalayan region. As a part of the entire Himalaya, this region has also been characterized by diverse landforms that varies from lowlands in the southern part to high towering mountains in the north. A diverse geographical setting has been formed that varies from low lands in the southern part to high mountains in the north. These diverse setting were developed due

to the different types of folds, faults and thrust ranging from local scale to the regional scale extending throughout the country. Among these, there are four major thrusts/faults that divides the whole region into different longitudinal geological zones. These major thrusts from south to north are;

- Main Frontal Thrust (MFT)
- Main Boundary Thrust (MBT)
- Main Central Thrust (MCT)
- South Tibetan Detachment System (STDS)

Main Frontal Thrust (MFT) – It is also known by Himalayan Frontal Thrust (HFT) which separates the unconsolidated loose sedimentary deposits of Terai Zone in the south with young and immature sedimentary rock sequence of Siwaliks in the north. It is the youngest tectonic unit existed in the Himalayan range.

Main Boundary Thrust (MBT) – It separates the Siwaliks in the south with comparatively matured sedimentary and meta-sedimentary rocks of the Lesser Himalaya in the north.

Main Central Thrust (MCT) – It separates the Lesser Himalayan rocks with highly metamorphosed Higher Himalayan rocks. The MCT does not look to be extended from west to east in a linear trend like MBT and HFT. Instead, windows, nappes, and klippes have been developed by the MCT.

South Tibetan Detachment System (STDS) – It is not a single thrust /fault like other three thrusts, but it comprises several normal faults that are developed from west to east of Nepal. It separates the sedimentary rocks formed in the Tethys basin during the formation of Himalayas from the high-grade

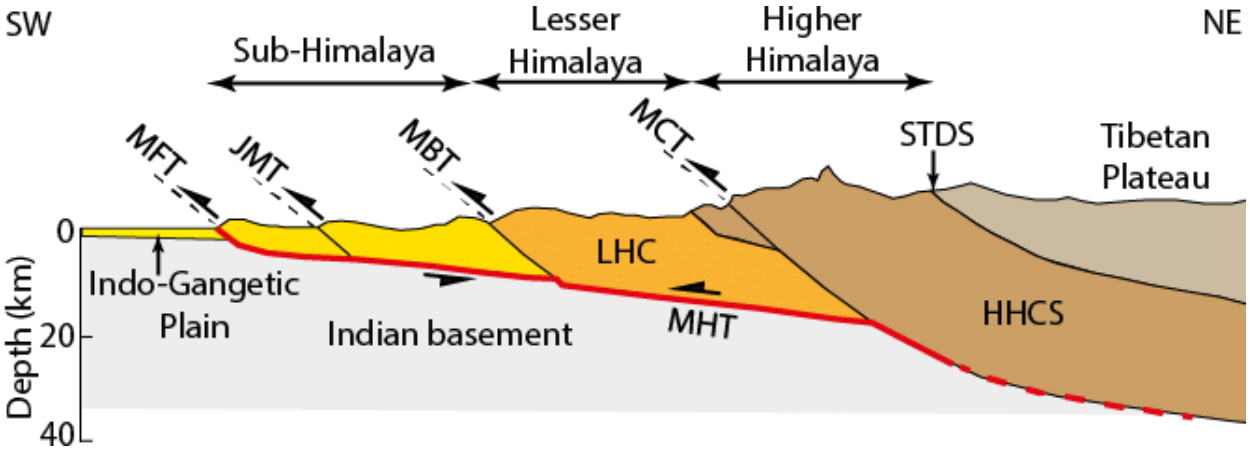


Figure 0-1: Major Himalayan Thrusts (LHC: Lesser Himalayan Crystalline Sequence, HHCS: Higher Himalayan Crystalline Sequence, MHT: Main Himalayan Thrust)

1.50 LOCAL GEOLOGY AND STRUCTURAL SETTINGS

The geology of Birendranagar Municipality covers Siwalik and Lesser Himalaya of mid-western Nepal. There is a wide variation in rock type in the municipality that comprises sedimentary rocks, meta-sedimentary rocks, and low to medium-grade metamorphic rocks of Pre-Cambrian to Neogene time. The valley is filled with loose and unconsolidated alluvial deposits belonging to Quaternary Deposits. These

deposits are mainly characterized by rounded to sub rounded boulders, cobble, and gravels with sand and clay layers. The metasedimentary rocks of Lesser Himalayan Zone in the north are separated with Siwalik by Main Boundary Thrust (MBT). Besides, there are three other regional thrusts that control the geomorphology of Birendranagar municipality. The Surkhet Valley is surrounded by sedimentary rocks such as sandstone, mudstone, and conglomerate, which are main lithology of Siwalik. In the northern part of municipality, metasandstone, quartzite, phyllite, slate, dolomite, and limestone are dominant rock types.

The characteristics of rock types and distribution of thrust show there are five different geological groups namely, Dailekh Group, Lakharpata Group, Surkhet Group, Siwalik Group, and Quaternary Deposits. The Bheri Thrust passes through southernmost part of the municipality being parallel to Bheri River. It is equivalent to Central Churia Thrust of Western Nepal, which thrust the Lower Siwalik over the Upper Siwalik. There is another thrust, named as Surkhet Thrust, which also passes through Siwalik Zone and separates Lower Siwalik and Middle Siwalik. The rocks of Lakharpata Group and Surkhet Group are thrust over the Siwalik on Main Boundary Thrust (MBT), which passes through north of Surkhet Valley. The Ranimatta Thrust passes through northern part of municipality, where the Pre-Cambrian metamorphic rocks of Dailekh Group are thrust over the sedimentary rocks of Surkhet Group. Due to these thrusts and weak lithological condition of Siwalik, there are several shallow landslides and severe gully erosions in the municipality. Based on the type of lithology, distribution of geological structures, and age of rocks, the local geology can be sub-divided into nine formations.

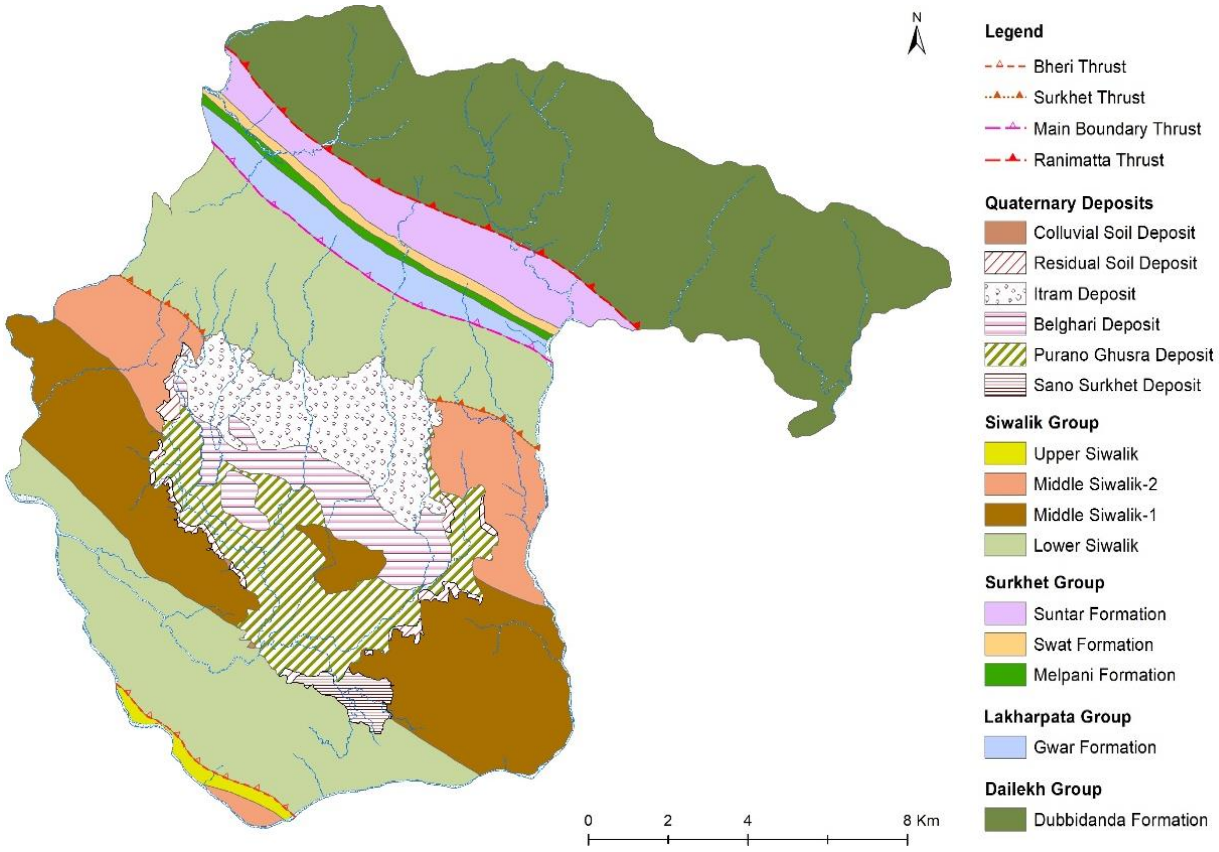


Figure 0-2: Geological map of Birendranagar Municipality

1.50.1 QUATERNARY DEPOSITS

i. Itram Deposit

This geological unit is characterized by sub-rounded boulder, peddle, and gravel dominant sedimentary deposit, which is mixed with silt and sand as matrix. The deposit is distributed in Itram and the northern part of Surkhet valley. The soil is compact and has high bearing capacity showing greater N-value than 50. There is low earthquake hazard and low liquefaction potential. The groundwater table is high and the sediments have high permeability.

ii. Belghari Deposit

This lithological unit is characterized by dark grey to yellowish brown silt clay, clayey silt, and sand with sub-rounded gravels, pebbles, and boulders. However, the size of sediments is smaller than in the Itram Deposit. This kind of sedimentary deposits can be observed in the central part of valley to the south of Karnali Highway trending east-west through Bulbule Tal. In general, the upper layers of deposit comprise light grey to brown clayey silt, where the sediments are densely packed. The groundwater table can be reached down to 2 m. depth in general. At some places, the groundwater is flowing as springs such as in Bulbule Tal area. There is moderate to high liquefaction potentiality in the area comprising Belghari Deposit. The bearing capacity of the land is medium.

iii. Purano Ghushra Deposit

The southern part of Surkhet Valley is mainly characterized by grey to dark grey silty clay and black carbonaceous clay that is named as Purano Ghushra Deposit. Intercalation of fine sand and silty sand layers are most common in this lithological unit. The unit comprises predominantly lacustrine deposits that has greater than 5m thickness. The soil is very soft to soft and intermediate to high plastic in nature. There is moderate to high liquefaction potentiality in most of the part of this unit. The allowable bearing capacity is low and most of the area goes under local inundation. The groundwater table is very low in most of the area.

iv. Sano Surkhet Deposit

There are coarse sedimentary deposits that has dominance of boulders, conglomerate with less sandstones and sandy clay zone in a small valley in the south-eastern corner of Surkhet Valley. The groundwater table can be reached at more than 6 m. depth. There is low to moderate liquefaction potentiality in Sano Surkhet area, where the allowable bearing capacity varies widely from low to high.

1.50.2 SIWALIK GROUP

i. Upper Siwalik

The upper Siwalik is the youngest litho-stratigraphical unit of Siwalik, which is the youngest mountain range of the Himalaya. It is characterized by coarse boulders beds and conglomerates with less sandstones and sandy clays as binding materials. The Upper Siwalik covers only about 1.67% of the municipality. It is exposed in the southernmost part of the municipality. The Upper Siwalik comprises immature and poorly consolidated conglomeratic beds that can be disintegrated easily due to high water content. As a result, debris flows are originated from this zone.

There is Bheri Thrust between Upper Siwalik and Lower Siwalik within this municipality, on which the rocks of Lower Siwalik thrust over the Upper Siwalik. The thrust passes trending east-west at very close to Bheri River. This lithological unit is also prone to surface erosion.

ii. Middle Siwalik

In the Birendranagar Municipality, the Middle Siwalik has covers about 44 sq. km of the entire municipality. In general, the Middle Siwalik comprises fine-to medium-grained pebbly sandstone with occasionally silty sandstone. The Middle Siwalik has been divided into two sub-units: lower and upper Middle Siwalik based on characteristics of lithology found there.

The Lower Middle Siwalik Formation consists of medium grained sandstone interbedded with mudstone and siltstone. Sandstone is found as dominant over mudstone. In this formation, the sandstones are characterized by salt and pepper like texture due to presence of dark colored biotite and light-colored quartz and feldspars and muscovite. The Lower Middle Siwalik Formation is exposed in both side of valley in the southern part, i.e., in the vicinity of Latikoili and Uttarganga. The Kakrebihar also lies in this formation.

The Upper Middle Siwalik Formation consists of medium to coarse grained and pebbly grey sandstone with some light grey mudstone, siltstone, and shale. Pebbly sandstones show layers of pebbles in the upper part. In the Birendranagar Municipality, the Upper Middle Siwalik Formation is distributed in Satakhani and Jarbuta area in the east and Bangesimal area in the west of valley. The Middle Siwalik Formation is comparatively less prone to surface erosion but there is possibility of rock block failure in steep slope.

iii. Lower Siwalik

In Birendranagar Municipality, the Lower Siwalik Formation is distributed in northern part of Surkhet Valley in the vicinity of Chisapani and north, and also to the south of the valley around Saktekanda. In this formation, the lithology is mainly fine-grained, hard grey sandstones inter-bedded with purple shale and claystone. In the southern part of valley, the Lower Siwalik Formation is thrust over the Upper Siwalik by the Bheri Thrust. In the northern part, the Gawar Formation of Lakharpatha Group thrust over the Lower Siwalik by Main Boundary Thrust (MBT).

1.50.3 LAKHARPATA GROUP

There are two groups, namely Lakharpata Group and Surkhet Group in this area that comprise Lesser Himalayan sedimentary and low grade metamorphic rocks. Rocks belonging to Gawar Formation of Lakharpata Group are only observed within the boundary of Birendranagar Municipality. The Gawar Formation is distributed in the northern hilly area of municipality that comprises grey stromatolitic dolomite, limestone with white sandstone and shale. It is thrust over the Siwalik rocks by MBT.

1.50.4 SURKHET GROUP

In the Birendranagar Municipality, the northern hilly region comprises sandstone, shale, quartztic sandstone, and fossiliferous limestone belonging to Surkhet Group. The rocks of Surkhet Group are placed over the Gawar Formation of Lakharpata Group and separated by an unconformity. There are three formations of this group in the Birendranagar Municipality, which are categorized based on the rock type found there. Melpani Formation is the oldest geological unit of this group in this area that comprises white to grey ferruginous quartzitic sandstone and grey to dark grey shale. It is overlaid by Swat Formation that

comprises grey to dark grey shale with fossiliferous limestone. The Suntar Formation is youngest lithological unit of Surkhet Group in this area that comprises green and greenish grey sandstone and purple shale with occasional marl beds.

1.50.5 DAILEKH GROUP

Low grade metamorphic rocks predominantly grey, green grey cholritic phyllites, gritty phyllite are observed in the northernmost part of the municipality. These rocks are main lithology of Dubbidanda Formation of Dailekh Group. These rocks are thrust over the Surkhet Group by Ranimatta Thrust, which is equivalent to Main Central Thrust (MCT) of Central Nepal Lesser Himalaya.

Table 0-1: Geological distribution in Birendranagar Municipality

S.N.	GEOLOGICAL GROUP	GEOLOGICAL UNITS	MAJOR LITHOLOGY
1	Quaternary Deposits	Colluvial Soil Deposit	Alluvium, mixture of boulder, gravel, sand, and clay
		Residual Soil Deposit	Alluvium, mixture of boulder, gravel, sand, and clay
		Itram Deposit	Sub-rounded cobble and gravels to boulder size sediments with silt and sand in matrix
		Belghari Deposit	Dark grey to yellowish brown silty clay, clayey silt and sand with subrounded gravels
		Purano Ghusra Deposit	Grey to dark grey silty clays and black carbonaceous clays
		Sano Surkhet Deposit	Alluvium, mixture of boulder, gravel, sand, and clay
2		Upper Siwalik	Coarse boulders conglomerates with less sandstones and sandy clays
3		Middle Siwalik	Fine- to medium-grained pebbly sandstone with occasionally silty sandstone
4		Lower Siwalik	Fine-grained, hard grey sandstones inter-bedded with purple shale and claystone
5		Suntar Formation	Green and greenish grey sandstone and purple shale with occasional marl
6		Swat Formation	Grey to dark grey shale with fossiliferous limestone
7		Melpani Formation	White, grey, ferruginous quartzitic sandstone and grey to dark grey shale
8	Lakharpata Group	Gawar Formation	Grey stromatolitic dolomite, limestone with white sandstone and shale
9	Dailekh Group	Dubbidanda Formation	Grey, green grey cholritic phyllites, gritty phyllite with amphibolite

Source: PEPP/DMG 1993; DMG 2011

SEISMIC HAZARD ASSESSMENT

1.51 SEISMIC HAZARD ASSESSMENT APPROACH

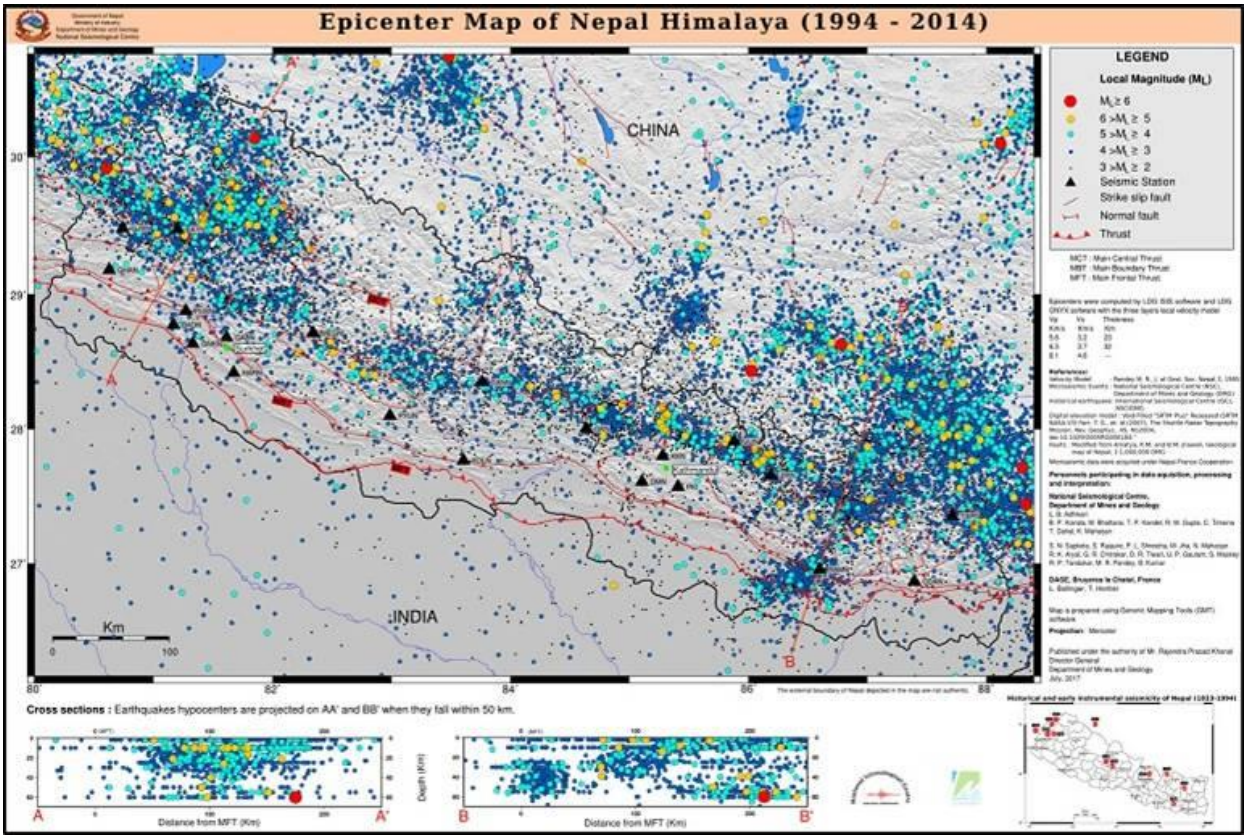
Seismic hazard is any phenomenon associated with an earthquake that may affect normal activities of people. The seismic hazard does not limit to vibration on the ground it includes landslide, ground deformation, surface faulting, cracks on the ground, liquefaction, lateral spreading, tectonic deformation, tsunamis, floods and other earthquake-related hazards. Seismic hazard assessment is a process to quantify seismic hazard and its uncertainty in a certain place in certain time and to estimate seismic hazard.

The entire Himalayan range is dynamic zone of active deformation due to continuous moving of the Indian plate beneath the Eurasian plate. The collision of those two plates has started about 50 Ma (million years) ago and produced a giant mountain range with thickened crust and lateral tectonic setting (Molnar and Tapponnier 1975). Powell and Conaghan (1973) proposed an evolutionary model presenting two phases of orogeny in the formation of Himalaya (Powell and Conaghan 1973). At first, an active subduction zone presented along the present-day Indus-Tsangpo suture zone in Mesozoic - early Tertiary time. That phase ended in Eocene by collapsing the suture zone after collision of two plates occurred. The second phase is characterized by the formation of the intracontinental thrusts from Miocene to the present in the Indian plate where the Indian plate is sub ducting under the Eurasian plate since middle Tertiary to the present. At present, the Indian plate is converging to the Eurasian plate at the rate of 5 mm/yr (Patriat and Achache 1984). GPS measurements show that a part of this convergence (about 2 mm/yr) is still being absorbed by a horizontal shear and crustal shortening in the Himalaya (Bilham et al. 1997, Jouanne et al. 2004). The crustal shortening processes are still active in the Himalayan range that are exhibited by large earthquakes (Mw>8.0), e.g., the Nepal-Bihar Earthquake (1934), the Kangara Earthquake (1905), or the Pakistan Earthquake (2005). Apart from the convergence of Indian plate, the shortening of the Himalayan crust is being occurred due to southward propagation of the thrusts. To the north of the Himalaya, entire Tibetan Plateau comprises extensional tectonics characterized by movement along E–W trending strike-slip faults and N–S trending normal faults associated with several grabens. In recent studies (Elliot et al 2016) explain about the geometry of the MHT as (1) the upper ramp, ranging from the surface to about 5 km depth with a dip of 30°, (2) a nearly flat section from 5 km up to about 14 km depth with a slope of 7°, (3) the mid-crustal ramp from 14 km to about 28 km depth with a 20° slope, and (4) a flat deep crustal zone at 30 km beneath the northern Nepalese political boundary.

In the Birendranagar Municipality, there are no records of devastating earthquakes in the past. It seems, there was no major earthquake since 1505 in western Nepal. In the central and eastern part of Nepal, many devastating earthquakes were recorded those earthquakes severely affected central Nepal including Kathmandu. Some notable past earthquakes in central and eastern Nepal are Gorkha and Kodari earthquake 2015, If we go more past, 80 years ago that a massive earthquake called Nepal Bihar earthquake at Udayapur of magnitude 8.3. Similarly, there was another huge earthquake hit central Nepal in 1833 having epicenter at Sindhupalchok. There are earthquakes of interval about 80 years in the central and eastern region but It shows that there is long seismic gap in the western Nepal that is about 500 years. It proves that any kind of event could be hit western Nepal any time in the near future. Therefore, seismic hazard assessment in different scale (National, prefectural, zonal, municipal etc.) being essential for the country.

1.52 SEISMICITY

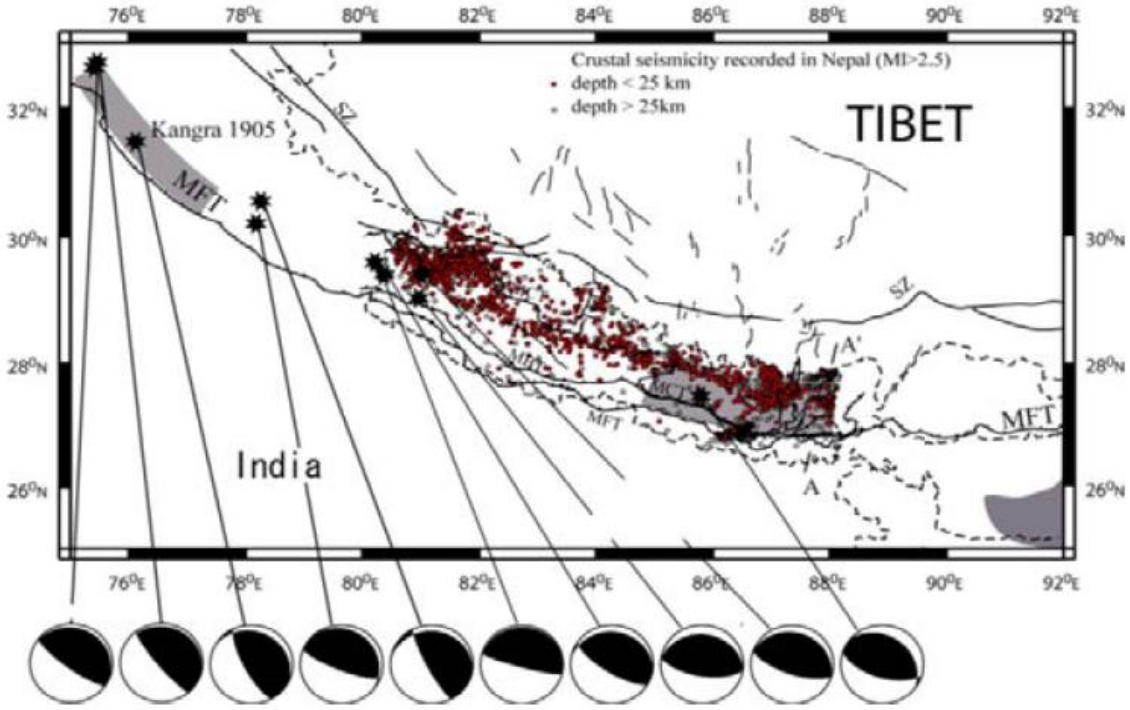
During the past few decades, the entire Himalayan range has been recognized as an active seismic zone that is supported by historical and recent earthquakes (e.g., Gorkha earthquake 2015; Kodari Earthquake 2015; Pakistan earthquake, 2005; Sikkim earthquake, 2011). Historical records show that Nepal has experienced numbers of large earthquakes in the past centuries. The most devastating earthquakes had been recorded in 1255, 1408, 1681, 1803, 1810, 1833, 1866, and 1934 (Chitrakar and Pandey 1986, Pandey et al. 2002, Pandey and Molnar 1988). Due to lack of seismic instruments, the magnitude and intensity of each previous earthquake are unknown.



Map 0-1: Seismic Catalogue of Nepal Himalaya (data from 1994 to 2014) (*Source: DMG Nepal)*

The 1934 Nepal-Bihar earthquake (Mw = 8.3) is thought to be a repetition of 1833 Rasuwa-Sindhupalchok earthquake, which had a magnitude of 7.8 (Bilham 1995). National Seismological Center (NSC) has been continuously monitoring the earthquake events since 1978; however the seismic data are available only after 1994 Map 0-1.

The overall characterization of Himalayan range is solely based on the measured magnitudes of the earthquakes experienced in this belt. Historical catalogue Map 0-1 of earthquake shows that most of the seismic events are located on the front part of the Higher Himalaya trending east to west. Likewise, other region, the Nepal Himalaya is characterized by a very intense micro seismic activity to keep it seismically active. Map 15-2 shows that the micro seismic activity is particularly intensified in the Eastern and Far-Western Nepal, while some patches of seismicity are also detected in the southern part of Tibet. In Nepal, a narrow belt of seismicity follows approximately the topographic front of the



Map 0-2: Focal mechanism and microseismicity for the Nepal Himalaya and adjacent region (Jouanne et al., 2004)

Higher Himalaya as a main feature of micro seismicity in Nepal Himalaya, which was recognized in Central Nepal from the analysis of the 1994-2014 earthquake data recorded around the Kathmandu (DMG 2017).

In case of Siwalik, there are very few earthquakes recorded throughout the Himalaya. The Udayapur earthquake in 1988 (Magnitude 6.5) is the most noticeable earthquake observed in this range that occurred in the depth of 50 km beneath the Siwalik. It has no equivalent earthquake along the entire arc. The focal mechanism Map 15-2 of the Nepal himalaya shows the potential future earthquakes in the Nepal himalayas.

1.53 GROUND MODEL

The preparation of different maps is part of the hazard analysis. Surface faulting map (Geological map), Ground shaking map (PGA), Earthquake intensity map, Shear wave velocity (VS30) distribution map, Liquefaction susceptibility map, Landslide hazard map, earthquake-related hazard flooding map or other regional maps of earthquake-related hazards. Active faults with small scales zones where surface faulting has been observed several times in the project area. The different geological formations, local faults/thrusts

and soil types are presented as in the geological map of the study area. The slope aspect map, topographic map, morphological maps were also presented in this geological portions.

The Vs30 value of the study area were measured at selected locations within the study area. The locations were selected based on type of geology, topography, slope aspect, soil type, size of settlement and potential for future extension of settlements, relative importance of the area etc. Multichannel Analysis of Surface Wave (MASW) and Downhole seismic methods has been applied to measure VS30 at selected locations. Distribution of VS30 within whole area has been estimated by Geo-statistical methods.

Another important information for Probabilistic Seismic Hazard Analysis is Peak Ground Acceleration (PGA). PGA value for a station has been estimated by considering scenario earthquakes, fault model, distance from the fault to study area, potential magnitude of the earthquake etc. (equation 1) (Boore et al. 1997).

$$Log_e Y = b_1 + 0.527(M_w - 6) - 0.778 Log_e r - 0.571(\log e \frac{V_s}{1396}) \ldots\ldots\ldots (1)$$

Where, Y = Acceleration (g)

b_1 = Fixed number (-0.313 for strike slip, -0.117 for reverse slip, -0.242 for mechanism not specified)

Mw = moment magnitude

$r = \sqrt{r_{ib}^{\ 2} + 5.57^2}$ where, r_{ib} = Horizontal distance from the station to an epicenter (Km)

Vs = average shear wave velocity of surface 30 m (m/s)

PGA from three different scenario earthquakes Main Himalayan Thrust (MHT) (Mw 9.0), Main Boundary Thrust (MBT) (Mw 8.5), and Local Thrust (Mw 6.5) has been considered for the study. All the scenario earthquakes have been separately calculated and mapped by using Geostatistical method.

The earthquake intensity map also prepared for these earthquakes and presented in the maps. Three different earthquake scenarios has been considered for the study area. Recent studies show, Main Himalayan Thrust (MHT) is a thrust plane beneath the Nepal Himalaya which has the potential to generate earthquake of magnitude Mw 9. This is considered as the most devastating events in the Himalayan region. Other events are taken from Main Boundary Thrust (MBT) passes east to west from north of study area. Similarly, another scenario earthquake has been considered from the geological map, a local thrust passing along east to west at central part of the study area. The magnitude from these earthquakes has been estimated as 8.5 and 6.5 respectively.

1.54 PROBABILISTIC SEISMIC HAZARD

Two approaches, probabilistic seismic hazard analysis (PSHA) and deterministic seismic hazard analysis (DSHA), are commonly used for seismic hazard assessment. In this study probabilistic approach has been used to prepare hazard maps.

In the present study, the seismicity of the Birendranagar municipality is modelled by taking the epicenters of three scenarios earthquakes of different magnitudes. The magnitude of these earthquakes are Mw9 Main Himalayan Thrust (MHT) and Mw 8.5 Main Boundary Thrust (MBT) and Mw 6.5 local Thrust (LT). That active thrust is Main Himalayan Thrust (MHT) a regional thrust plane that passes under the whole Nepal Himalayas through east to west. The potential magnitude of the earthquake from this thrust is calculated based on 10% probability of exceedance in 50 years that is 475 years. Maximum magnitude of this earthquake is calculated as Mw 9. Similarly, there are three local thrusts Ranimata thrust, Surkhet thrust and veri thrust passes through the study area. One local thrust Surkhet thrust passes through the central part of the city has been considered as a local thrust for this study and the approximate magnitude is considered as 6.5.

The Vs30 value for the study are has been estimated by measuring shear wave velocity at selected locations. Multichannel Analysis of Surface Wave (MASW) has been used to measure shear wave velocity. Similarly, PGA at the sampled point been calculated based on equation proposed by Boore et al 1997. The strength of an earthquake is generally measured in two ways, based on two different approaches: (1) the magnitude of an earthquake event is a quantity defining the energy released by this event (in form of earthquake waves), and is calculated from recorded seismograms. (2) The intensity of an earthquake event is a quantity defining the severity of ground shaking on the basis of observed effects in a limited area. As a tool to define the intensity levels, it is recommended that the Modified Mercalli Intensity (MMI) scale be used. This defines twelve intensity degrees from intensity I to intensity XII as in Table 0-1.

Table 0-1: Modified Marcalli Intensity Scale (MMI) (Source: Okamoto 1973)

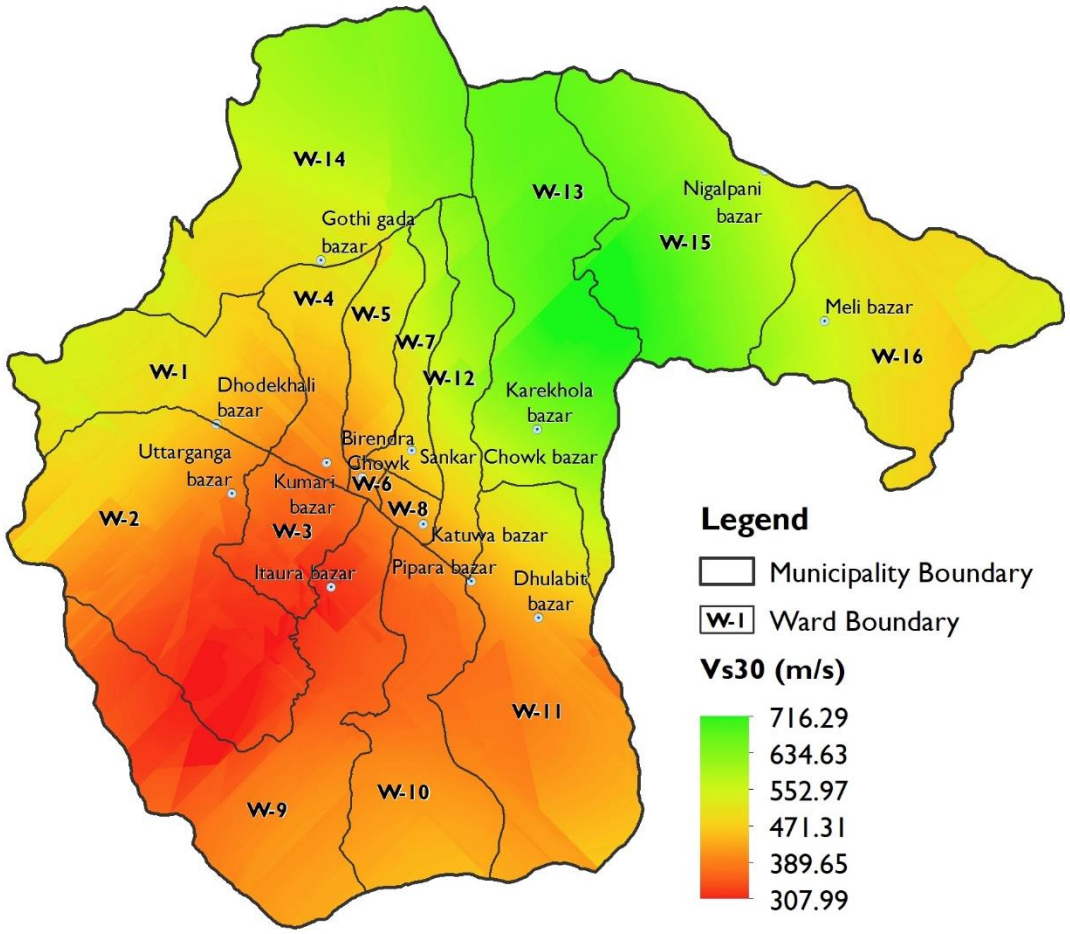
SCALE	DESCRIPTION
I	**Not felt except by a few under especially favorable conditions**
II	Felt only by persons at rest in places such as upper floors of buildings. Delicately suspended objects may swing.
III	Felt only by persons at rest in places such as upper floors of buildings but of a degree that most persons do not recognize it as an earthquake. Standing automobiles may rock slightly as if from vibration caused by passing truck, duration may be measured.
IV	In daytime, felt by many indoors but by only a few outdoors. Dishes, windows, doors disturbed and walls crack. Sensations like a heavy truck striking a building. Standing automobiles rocked considerably.
V	Felt by all, many awakened. Some dishes and window glasses broken, wall plaster may crack. Unstable objects overturned. Disturbance of telephone poles, trees and other tall objects sometimes noticed. Pendulum clocks stopped.
VI	People are frightened and run outdoors. Heavy furniture may be moved, some instances of fallen plaster and topping of chimneys. Slight damages.
VII	Everybody runs outdoors. Damages negligible in buildings of good design and construction, slight to moderate in ordinary structures and considerable in poorly built of badly designed structures. Chimneys broken. Felt by moving automobiles.
VIII	Some damages even in building of good design and construction. Considerable damage in ordinary building with some collapsing. Great damage in poorly constructed buildings. Panel walls thrown out of frame structures. Falling of houses and factory chimneys, columns, monuments and walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Hinders driving of automobiles.
IX	Damage considerable in building of good design and construction. Structures thrown out of alignment with foundations. Ground cracked conspicuously. Underground pipes damaged.
X	Wooden houses of good design and construction collapse. Most masonry and frame structures destroyed with foundations. Ground cracked causing damage. Rails bent. Slopes and embankments slide. Water surface rises.
XI	Almost all masonry structures collapse. Bridges destroyed. Fissures over entire surface of ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent prominently.
XII	Damage total. Waves seen transmitted at ground surface. Topography changed. Objects thrown into air.

The Vs30 value for the study are has been estimated by measuring shear wave velocity at selected locations. Multichannel Analysis of Surface Wave (MASW) has been used to measure shear wave velocity. Similarly, PGA at the sampled point been calculated based on equation proposed by Boore et al 1997. The strength of an earthquake is generally measured in two ways, based on two different approaches: (1) the magnitude of an earthquake event is a quantity defining the energy released by this event (in form of earthquake waves), and is calculated from recorded seismograms. (2) The intensity of an earthquake event is a quantity defining the severity of ground shaking on the basis of observed effects in a limited area. As a tool to define the intensity levels, it is recommended that the Modified Mercalli Intensity (MMI) scale be used. This defines twelve intensity degrees from intensity I to intensity XII.

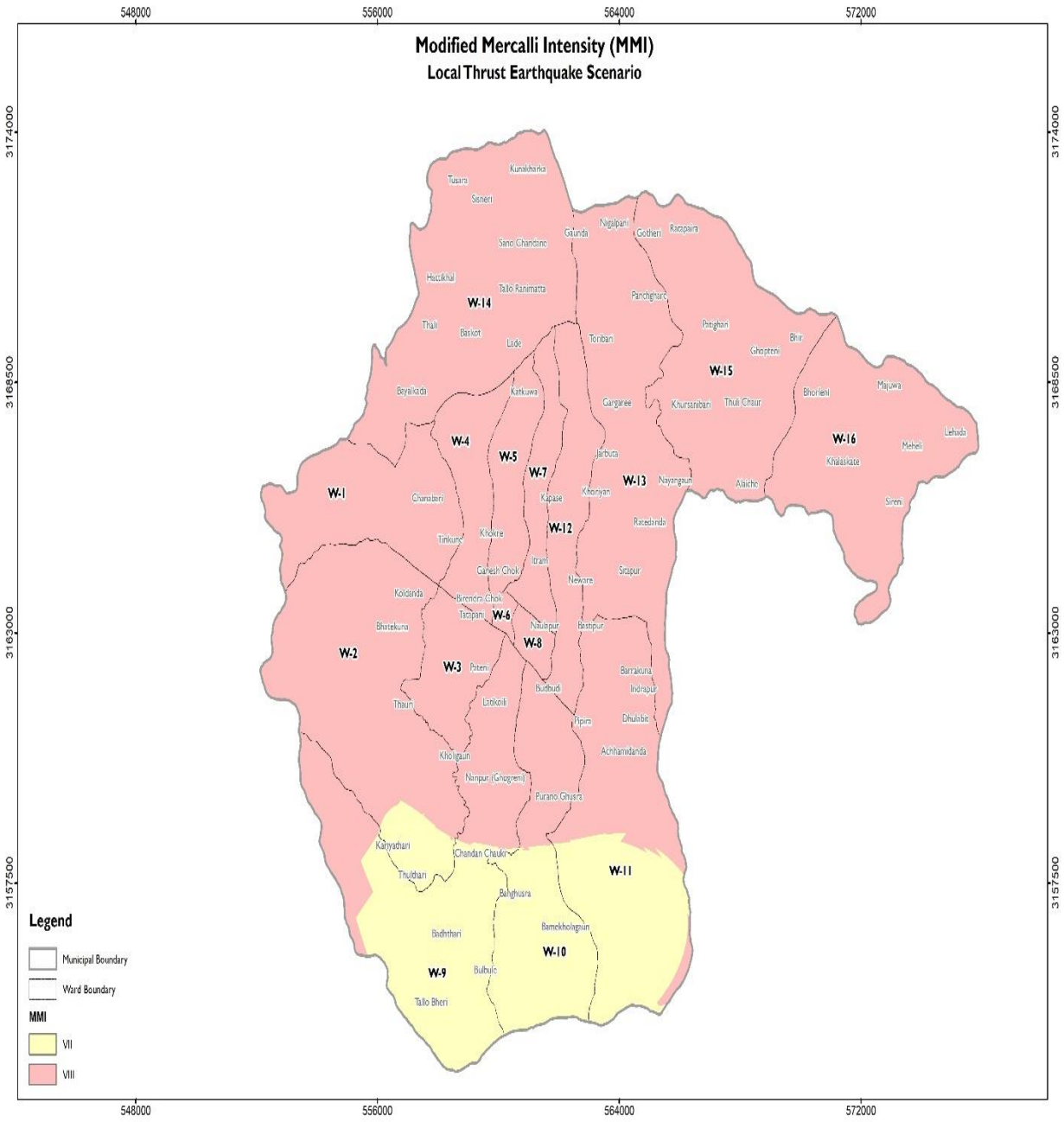
1.55 DISTRIBUTION OF VS30, PGA AND MMI

The Vs30 value for the study area were measured by downhole seismic and MASW method. The Global Vs30 map based on slope prepared by USGS has been incorporated with measured Vs30 value in the site. A statistical method has been applied to prepare Vs30 zoning map. The spatial distribution of shear wave velocity are shown in Map 0-3**Error! Reference source not found.** . Where, Vs30 value varied from 250 to 780 m/s within study area. The southern part has low shear wave velocity than northern part it could be the reason of shallow bed rock at the northern part. Similarly, PGA at the sampled point been calculated based on equation proposed by Boore et al 1997 and zoned by using geostatistical methods Map 0-9 in these figures the PGA for MHT has very narrow range of 400 to 600 gal.

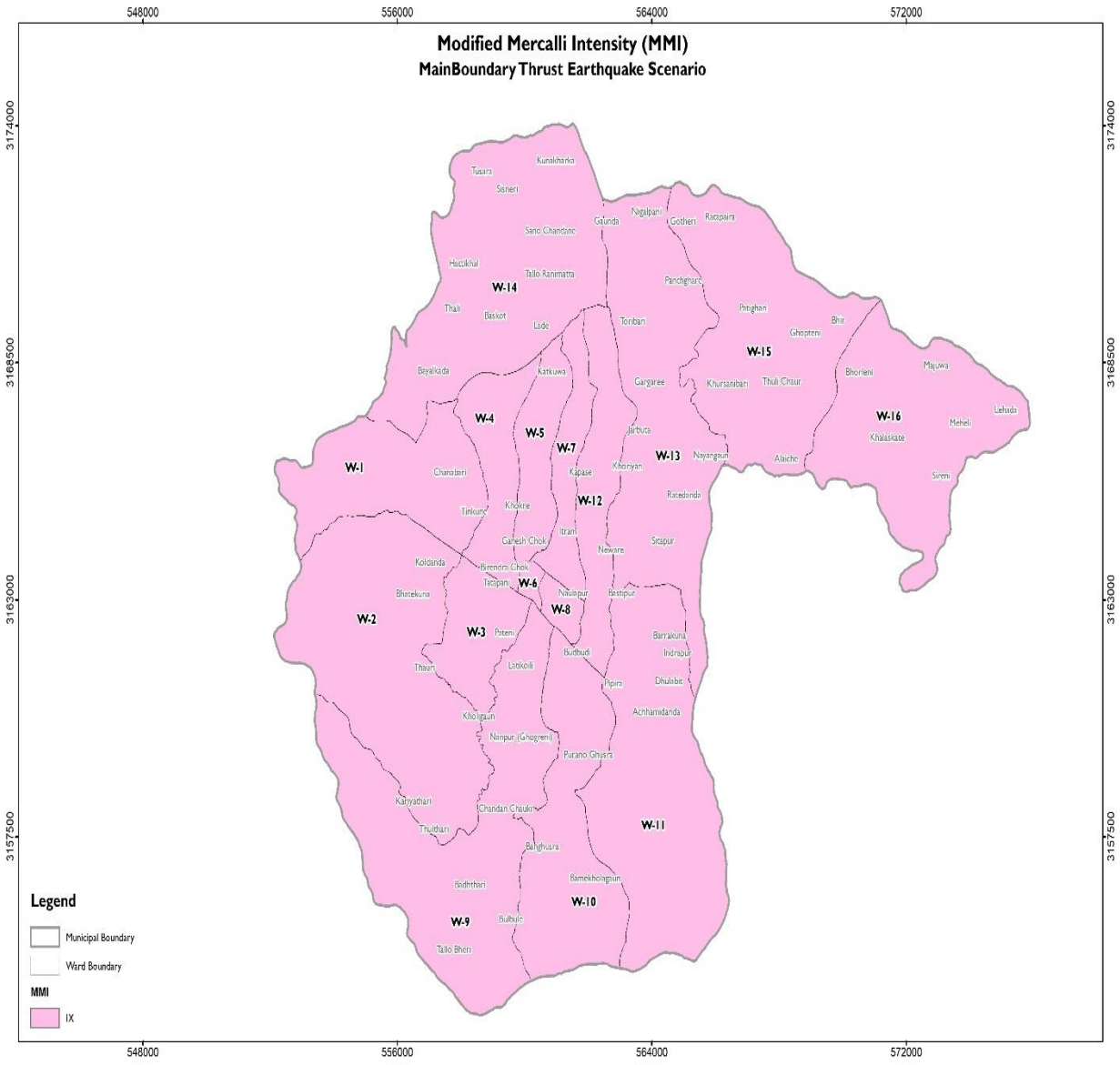
The Birendranagar municipality has diverse topography, with varied geology within municipality and different soil properties. Similarly, the PGA for MBT has also within small range of 400 to 500 gal, Map 0-8. On the other hand, local thrust can generate the PGA value of 150 to 180 gal, Map 0-7. The intensity scale (MMI) three different scenario earthquakes are shown in Map 0-6, Map 0-5, Map 0-4 .it shows (MMI) X for MHT and IX for MBT and VIII for local Thrust.



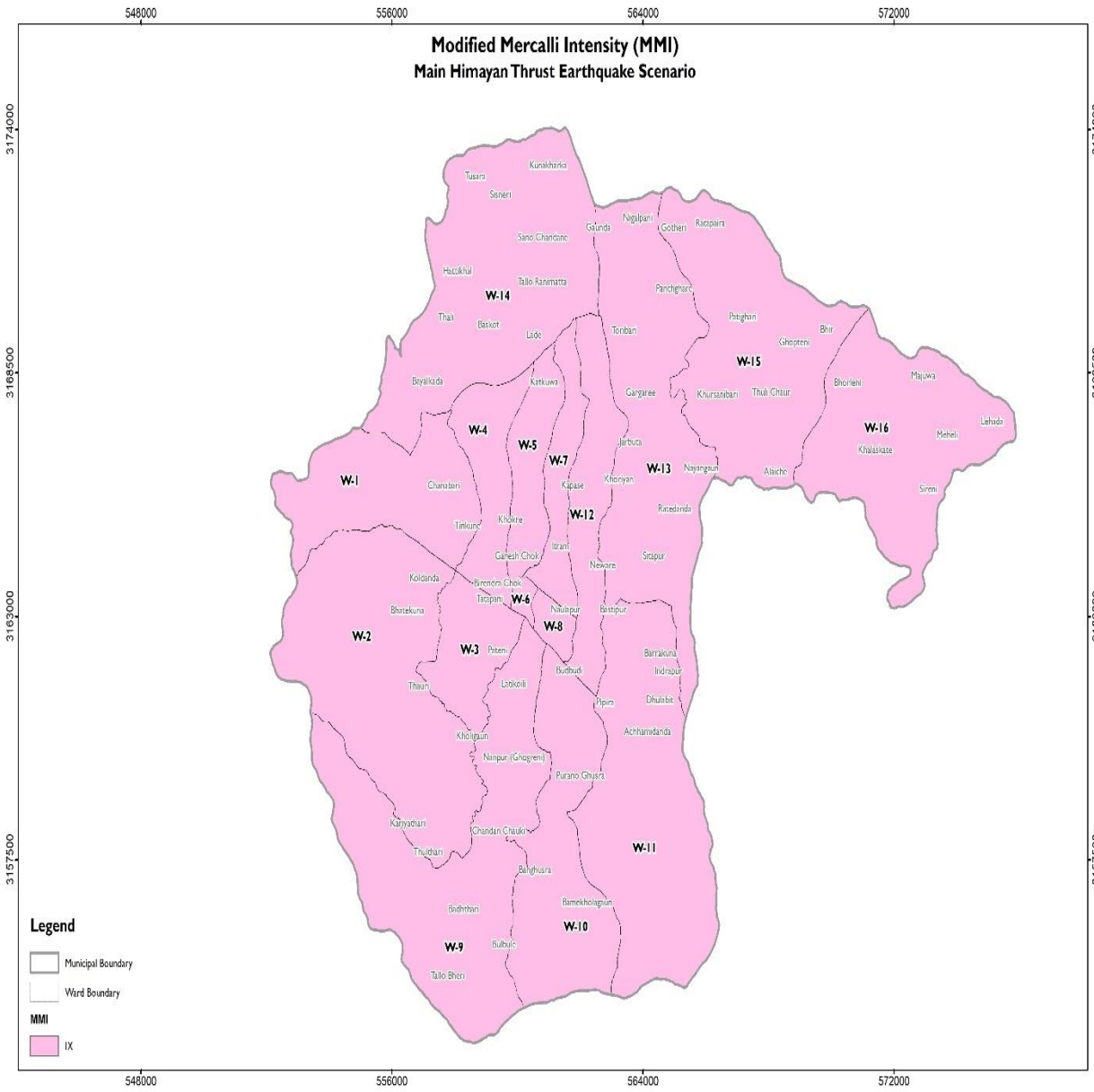
Map 0-3: Shear wave velocity Vs30



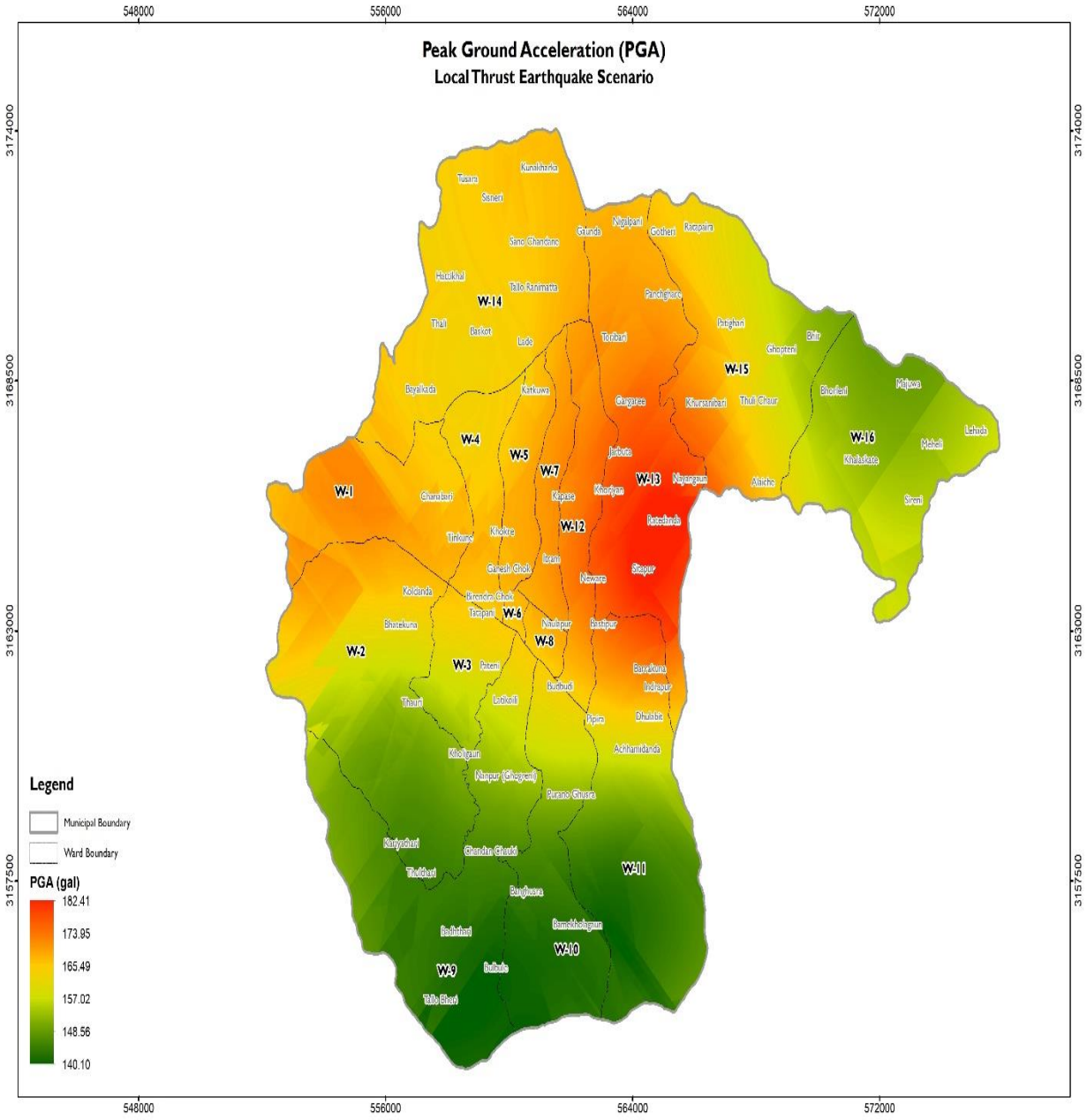
Map 0-4: : Modified Mercalli Intensity (MMI) Local Thrust



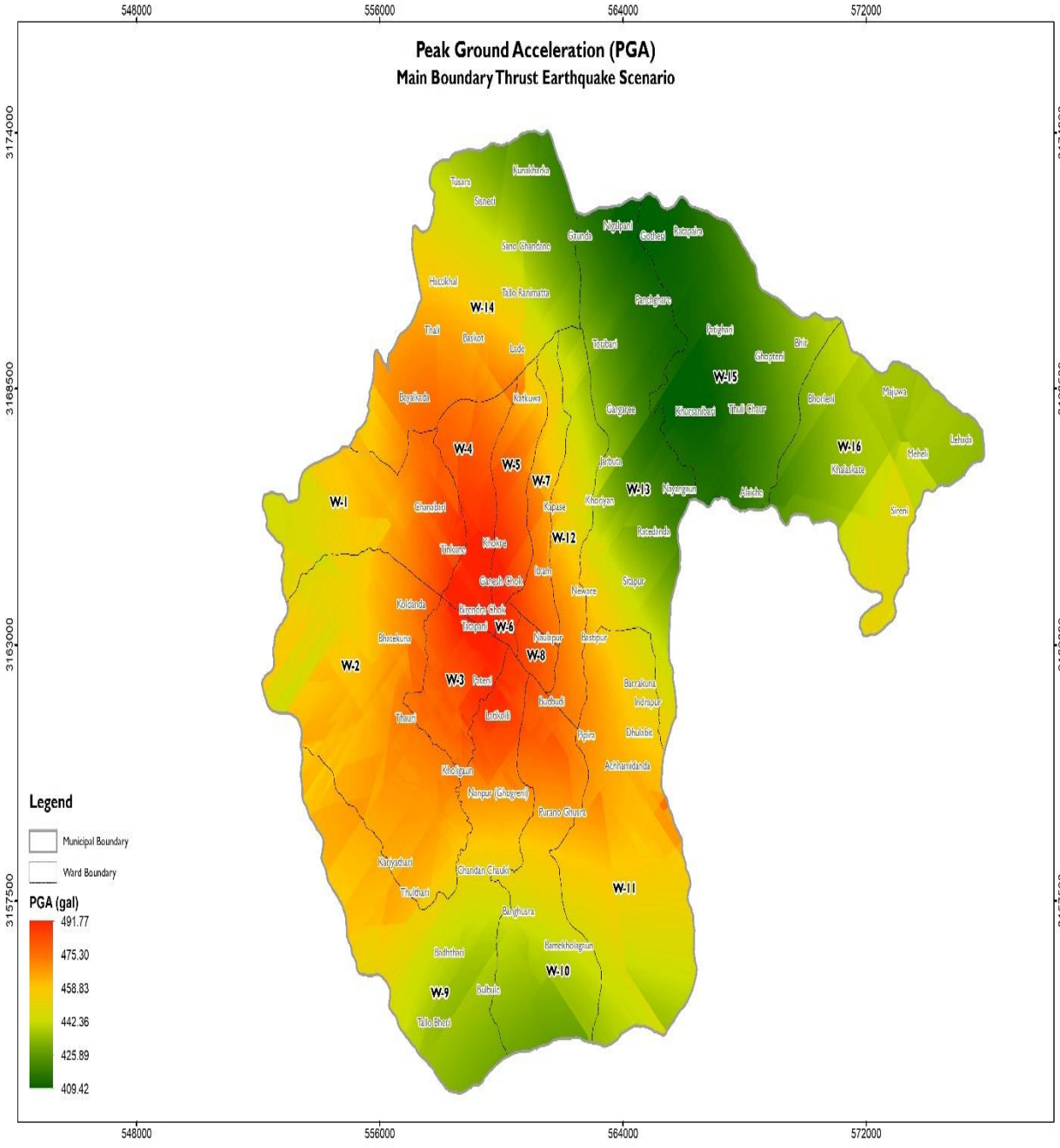
Map 0-5: Modified Mercalli Intensity (MMI)) Main Boundary Thrust



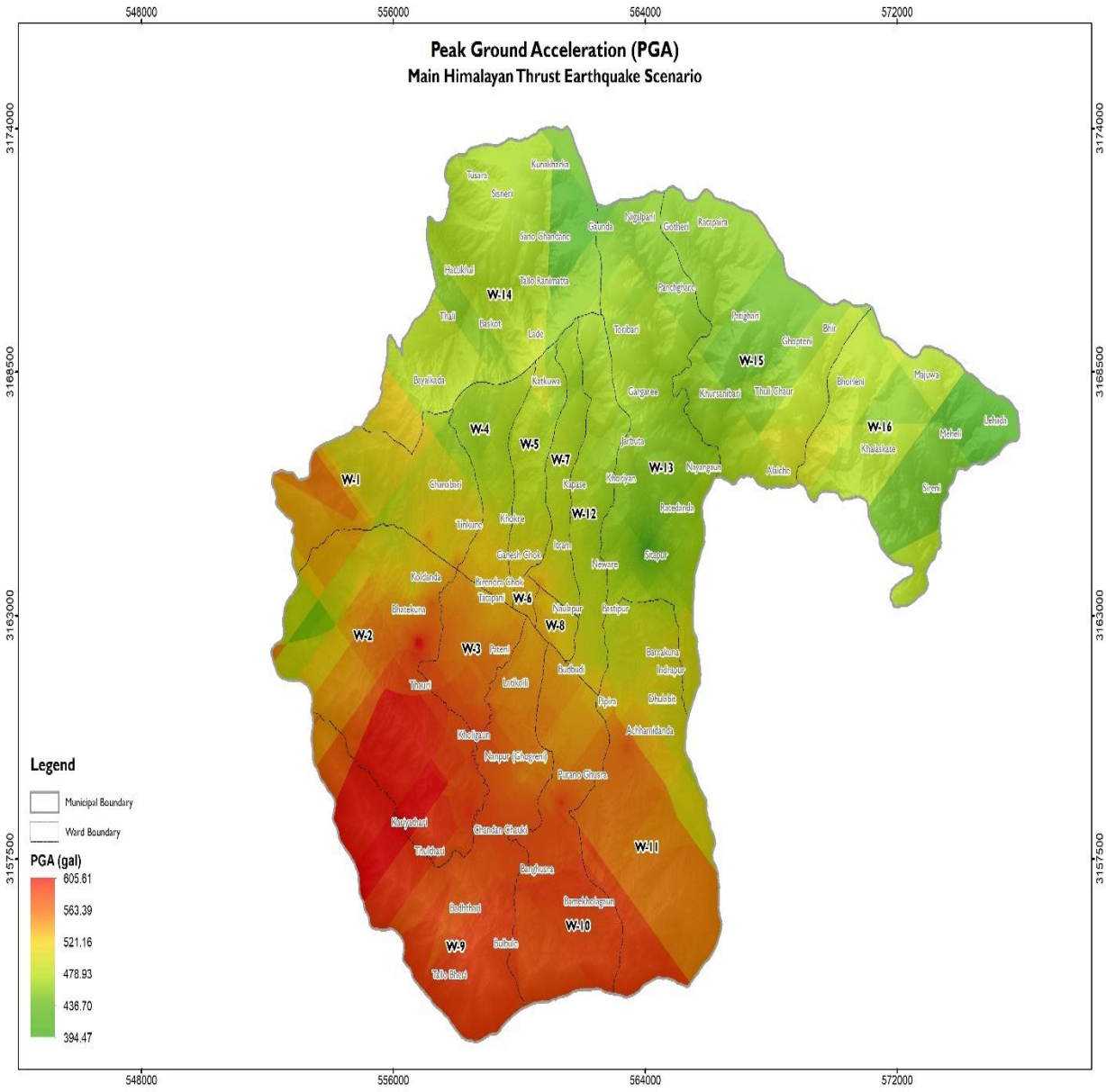
Map 0-6: Modified Mercalli Intensity (MMI) Himalayan Frontal Thrust



Map 0-7: Peak Ground Acceleration (PGA) Local Thrust (gal)



Map 0-8: Peak ground acceleration (PGA) Main boundary Thrust (gal)



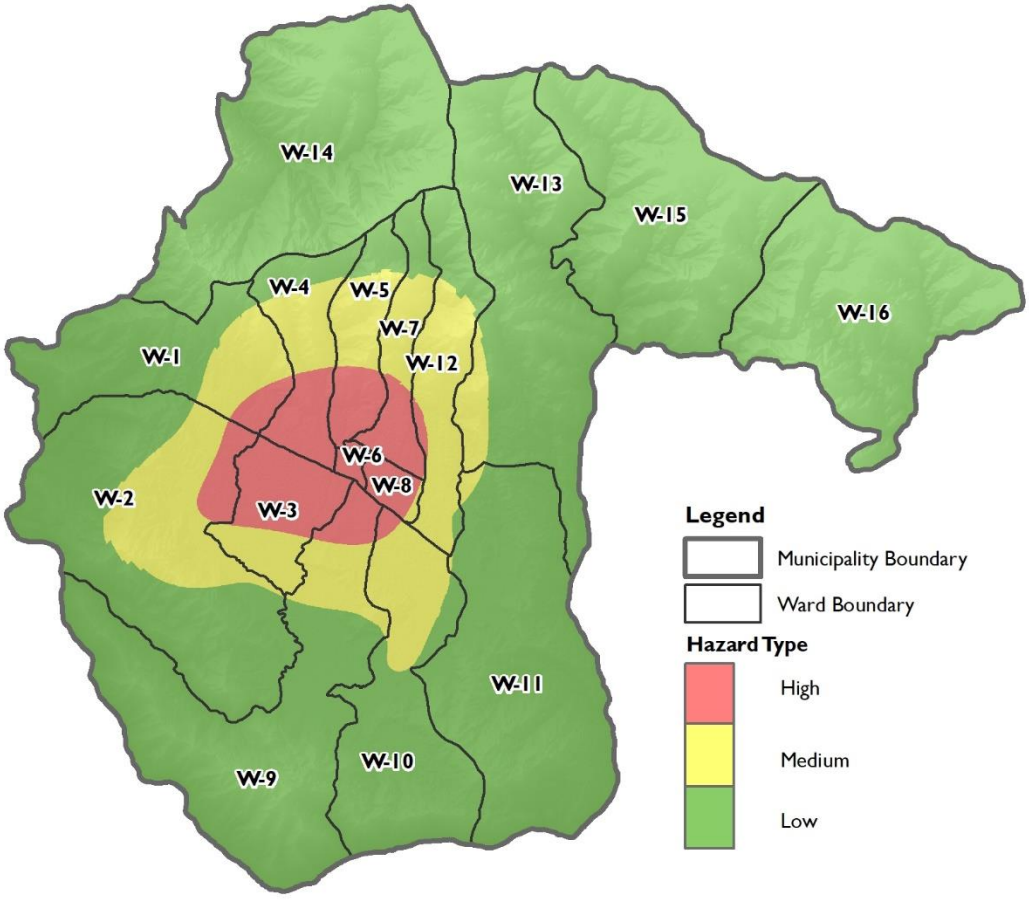
Map 0-9: : Peak ground acceleration (PGA) Main Himalayan Thrust (gal)

1.56 LIQUEFACTION HAZARD ASSESSMENT APPROACH

Liquefaction is a process by which water-saturated sediment temporarily loses strength and stiffness and acts as a fluid. Liquefaction takes place when loosely packed, waterlogged sediments at or near the ground surface lose their strength in response to strong ground shaking. This reduction of strength is due to the fact that during dynamic excitation, pore water pressures in the sediment tend to increase, if above conditions are fulfilled. The increase of pore water pressures causes the effective stress to decrease, which in turn affects the soil strength and stiffness.

1.57 LIQUEFACTION SUSCEPTIBILITY

Liquefaction is the phenomenon in which certain soils below the water table lose strength when shaken and become like a liquid. Liquefaction alone does not cause damage, but if the liquefied soil can flow, the ground surface may settle or spread apart, damaging structures, roads, and infrastructure networks. Liquefaction is most likely to occur in sandy soils in area of high ground water table along rivers, creeks, lakes and other bodies of water or in areas of hydraulically placed sand fills. Our current study area Birendranagar Municipality is lies in the dun valley and drained and deposited by local rivers and lakes, therefore there are thick sandy soil in the study area. Geotechnical properties of soil show, the properties of the soil is highly liquefiable during shaking. Presence of soil with low SPT value, low shear wave velocity and sandy soil proves the soil is highly liquefiable. The liquefaction potential map for the Birendranagar Municipality has been prepared based on the limited number of collected data and presented below in the The central part of the city has highly liquefiable then the peripheral part.



Map 0-10: Liquefaction Susceptibility

Table 0-2 Wardwise Distribution of Liquefaction Suspetibility

WARD	AREA (HA)	LOW (HA)	LOW %	MEDIUM (HA)	MEDIUM %	HIGH (HA)	HIGH %
1	1423.55	993.31	69.78	332.30	23.34	97.98	6.88
2	2909.42	1939.57	66.67	804.32	27.65	165.56	5.69
3	660.28	0.00	0.00	216.76	32.83	443.52	67.17
4	703.99	193.11	27.43	258.02	36.65	252.85	35.92
5	576.14	117.64	20.42	265.29	46.05	193.21	33.53
6	58.99	0.00	0.00	0.00	0.00	58.97	99.98
7	523.46	117.20	22.39	212.68	40.63	193.63	36.99
8	140.79	0.00	0.00	15.83	11.25	124.97	88.77
9	2876.51	2464.19	85.67	276.26	9.60	136.02	4.73
10	1697.18	1227.92	72.35	439.28	25.88	30.03	1.77
11	2664.87	2630.38	98.71	34.49	1.29	0.00	0.00
12	880.32	263.83	29.97	589.06	66.91	27.39	3.11
13	2585.00	2405.37	93.05	179.66	6.95	0.00	0.00
14	2969.04	2969.13	100.00	0.00	0.00	0.00	0.00
15	2456.86	2456.90	100.00	0.00	0.00	0.00	0.00
16	2219.45	2219.42	100.00	0.00	0.00	0.00	0.00

GEO-HAZARD ASSESSMENT

1.58 HISTORICAL DISASTER ASSESSMENT

Historical disaster events were obtained from Nepal disaster risk reduction portal (http://drrportal.gov.np/). The data showed that there were 1 incidents of strong wind, 50 incidents of fire, 6 incidents of thunder, 8 incidents of flood and 6 incidents of heavy rainfall in the municipality. The incidents have resulted in death and injuries to people. The details of type of incidents and fatalities are presented in Annex.

1.59 GEO-HAZARDS SCENARIO IN BIRENDRANAGAR MUNICIPALITY

The Birendranagar Municipality comprises three different physiographic divisions: towering hills and steeply sloping terrain of Mahabharat Range at north, small hillocks and rugged terrain of Chure at south and gentle to flat fluvial terraces of a small Dun Valley at central part. Major streams such as Itram Khola, Khorke Khola, Dwari Khola, and Neware Khola, originate in northern Chure and Mahabharat Range and flow towards south through the Surkhet Valley. In addition, the Bame Khola and its tributaries originate in southeastern Chure Hills and flows to meet the collective stream of valley. Finally, all the valley water drains to Bheri River in south through a stream called as Nikas Khola. All these valley streams are flash flood bearing that carry high discharge in rainy season only and create flooding on banks and in the lowland of southern part of the valley. Besides these, the eastern part of the municipality drains through Karre Khola, Jhupra Khola, and their tributaries. The Jhupra Khola collects all these streamlets and flows to meet the Bheri River to the south. The upper catchments of these tributaries are experiencing landslide, debris flow, and severe erosion, while the downstream part create bank cutting, river shifting, and flooding within the municipality.

Based on an analysis of present and past scenario of disasters occurred in the municipality, the most potential geo-hazards in the Birendranagar Municipality are:

- rainfall-induced landslide
- earthquake-induced landslide
- rock fall
- debris flows, surface erosion, and gully erosion
- bank cutting and river channel shifting

Table 0-1: Geo-hazard and risk scenario in Birendranagar Municipality

Ward No.	Name of the risk places	Major Hazard	Level of risk
1	Bangesimal	Bank Cutting	High
	Bangesimal	Flood, bank cutting	High
	Aapkhori	Flooding	High
2	Bhate Kuna	Inundation	High
	Phalate	Inundation	High
	Bhureli	Inundation	High
	Bhureli	Inundation	High
	Bhureli	Inundation	High
	Thauri	Inundation	High
	Thauri	Bank Cutting	High

Ward No.	Name of the risk places	Major Hazard	Level of risk
	Daulatpur	Cutting and flash flooding	High
	Company Khola Dobhan	Flood and Inundation	High
	Nikas Area	Flood	High
3	Yari Chowk	Flooding	High
	Downstream from Yari Chowk bridge	Flooding	Very High
	Sukumbashi tol	Flooding, bank cutting	Very High
4	Sahid Park	Flooding	Moderate
	Upstream from Sahid Park	Flooding	High
	Zero Dam	Flooding and Landslide	High
	Gunapani	Flooding	High
	Kalagaun tol	Bank Cutting	Moderate
	Upstream from Yeri Chowk bridge	Bank Cutting	High
	Upstream from Yeri Chowk bridge	Flooding	High
5	Bhute Pokhari	Landslide	High
	Shrinagar	Flooding	High
6	Birendrachowk	Flooding	High
	Yari Chowk	Flooding	High
	Upstream from Yari Chowk bridge	Flooding	High
7	Dailekh Road	Landslide	High
	Dailekh Road	Complex Landslide	High
	Dailekh Road	Landslide	High
	Sagarmatha tol	Flooding	High
8	Birendranagar Industrial Area	Flooding	High
	Pangeni chowk	Bank cutting	High
	Airport	Flooding, bank cutting	Moderate
	Airport	Flooding, bank cutting	Moderate
9	Itaura	Flood and Bank cutting	High
	Itaura	Bank Cutting	High
	Ghogreni	Inundation and Bank cutting	High
	Khorke Khola and Parseni Khola confluence	Flood and Bank cutting	High
	Mathilo Parseni	Flood and Bank cutting	High
10	Bame Kholagaun	Bank Cutting	High
	Bame Kholagaun	Flood	High
	Budbudi	Flood	High
	Raharpur	Bank Cutting and Inundation	High
	Manikapur	Inundation	High
11	Jhupra Khola	Flood and Bank cutting	High
	Gagre Tal (Barrakuna)	Bank cutting, Bank scouring and landslide	High
	Bastipur	Flood	High
12	Basghari (Culvert)	Flood	High
	Jhykri Tole	Bank cutting	High
13	Guptipur, Subedi Tole	Flood	High
	Guptipur, Subedi Tole	Flood, Bank cutting	High
	Guptipur	Bank cutting	High
	Nikas Khola, Pragatishil Tol	Rock slide	High
	Jumlakot	Soil Slide	High
14	Gothikada	Debris slide	High
	Darnakot	Debris slide	High
	Sal Danda	Landslide	Moderate
	Chedda	Complex Landslide	High
	Sano Chandane	Landslide	Moderate
15	Kapase	Landslide	High
	Damai Tol	Landslide	High
	Laure Dada	Landslide	High

Ward No.	Name of the risk places	Major Hazard	Level of risk
	Bhir	Landslide	High
	Kamere	Landslide	High
	Pagali Dada	Landslide	High
	Bhalu Khola Gau	Landslide	High
	Chuli	Landslide	High
16	Gothikada	Complex Landslide	High
	Darnakot	Debris flow	High
	Sal Danda	Landslide	High
	Chedda	Landslide	High
	Sano Chandane	Landslide	High
	Pokhaaribata	Landslide	High
	Jugepani	Landslide	High

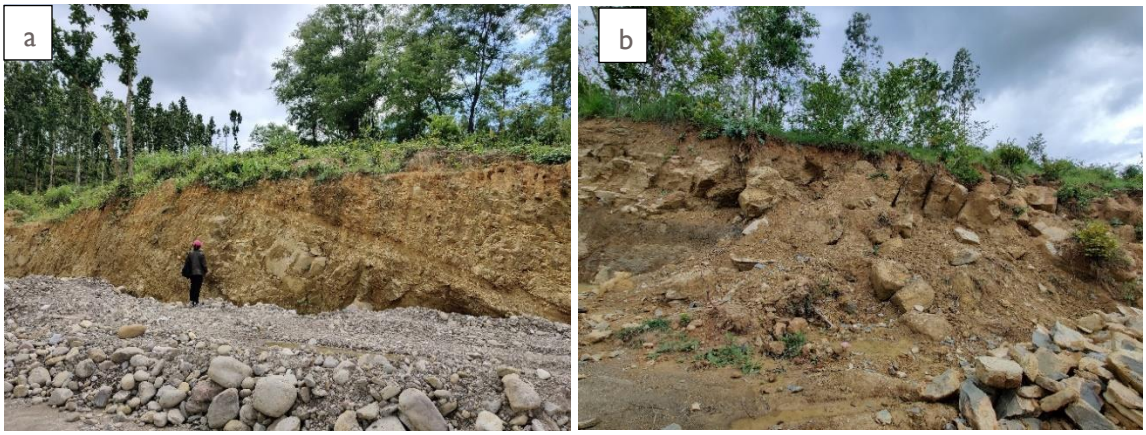
(Source: Information based on field visit and discussion)

1.60 ENGINEERING GEOLOGICAL SETTING OF MUNICIPALITY

Birendranagar Municipality covers entire valley of Surkhet Dun Valley along with Chure Hills, Mahabharat Range, and partially Midland. The Mahabharat Range and Midland are characterized by presence of metasedimentary and low-grade metamorphic rocks of Lesser Himalaya. Due to presence of moderate to highly weathered phyllite and highly fractured quartzite as dominant lithology, the terrain has been dissected severe gully erosion and characterized by presence of small to large landslides. In the northern part, there are also weak sedimentary rocks belonging to Gondwana age that are characterized by presence of fissile slate, sandstone, and fossiliferous limestone. These rocks are also weak in terms of slope instability. Presence of Ranimatta Thrust (equivalent to Main Central Thrust) and Surkhet Thrust has made the northern part of the municipality more susceptible due to mass movements. The high elevated ridge and spurs are covered by thin residual soil, while the sloping terrain comprises thick colluvium covered with forest. Immediate north edge of the valley comprises lithology of Lower Siwalik, which comprises dominance of mudstone and sandstone. That area is more potential to surface erosion and gully erosion and stands as one of the prime sources of sediments to the streams flowing through the valley.

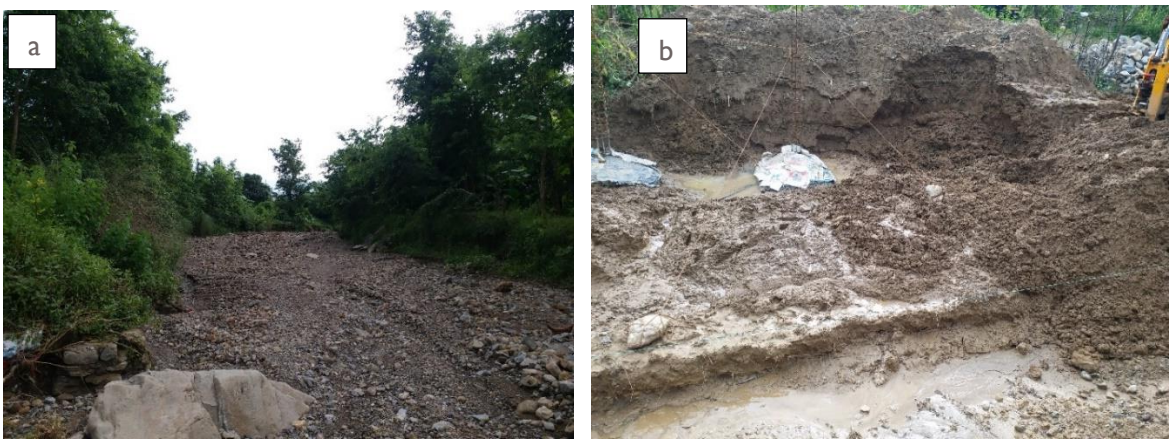
The southern part of the municipality comprises geologically young and immature sedimentary rocks belonging to Siwalik. Variegated mudstones with siltstones beds belonging to the Lower Siwalik Unit, are facing the problem of deep gully erosion. The Middle Siwalik hills characterized by moderate to highly weathered, alteration of competent beds of sandstone and incompetent mudstone beds, are responsible for shallow slides around low elevated hill side areas. The colluvium soil deposits, and residual soils has covered the gentle to moderate slope hills while thick alluvium deposits are frequent in foothill area.

The valley has gentle to flat topography formed by dominance of fluvial sediments. The streams originated in immediate northern sloping hills are main contributors for flash flooding, sedimentation, flooding and bank cutting activities in the valley. In most of the places in valley, the soil has low bearing capacity in the Birendranagar Municipality. Moreover, hydrogeological assessment based on the well inventory and location of spring, pond and stream shows that the acquirable groundwater table is at very deep beneath the surface.



Photograph 0-1: a. Alternating sandstone and mudstone beds, b. highly fractured and weathered sandstone

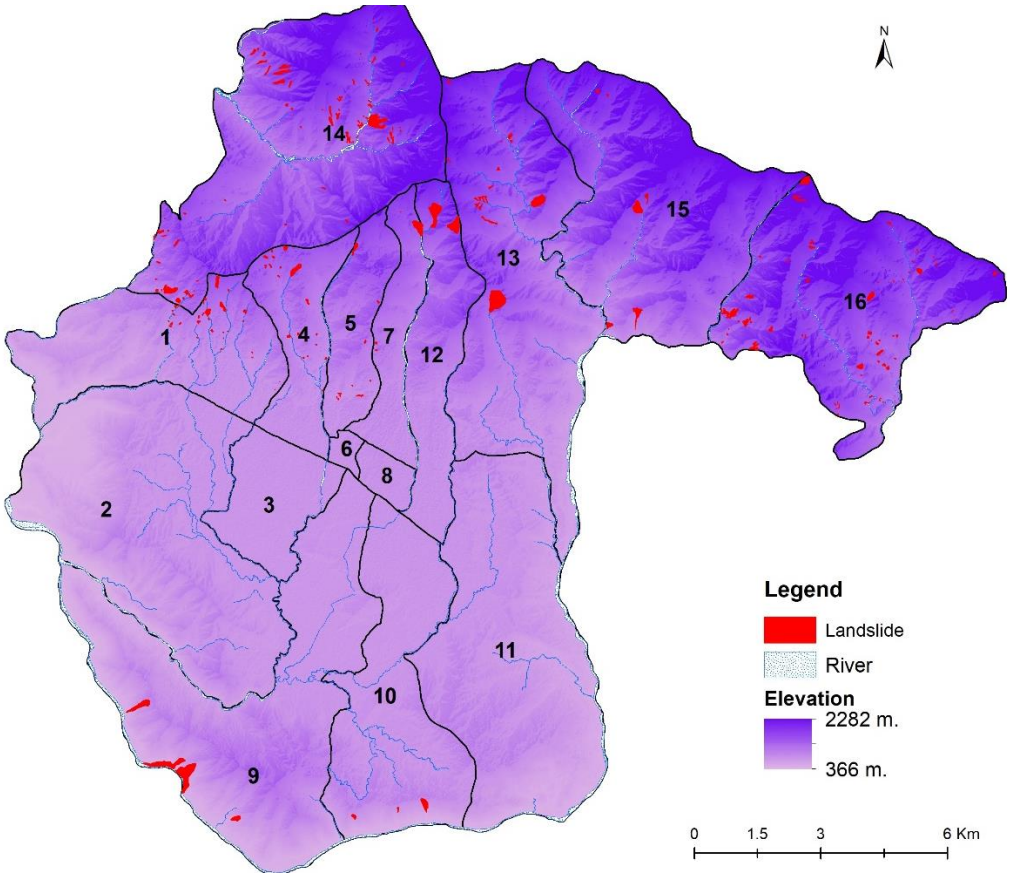
Photograph 0-2: a. weathered quartzite rock, b. Weathered red purple shale, c. and d. Cut slope failures and colluvium soil along Chanabari to Maikal Road, e and f. Excavated alluvial deposits showing potentiality of slides



Photograph 0-3: a. Debris flow at Chanabari Khola, and b. Silty clay soil at Solighoptegaun

1.61 LANDSLIDE DISTRIBUTION IN THE BIRENDRANAGAR MUNICIPALITY

Landslide is one of the major geo-hazards observed in the northern part of the Birendranagar Municipality. The landslide commonly includes all types of mass movements such as slide, topple, fall, debris flows, creep, and other activities that lead the earth mass towards down on the sloping terrain. Geomorphic and engineering geological characteristics of some important landslides from the Birendranagar Municipality were studied for their existing status and chance of reoccurring in the future. The study of landslides not only helps to understand the mechanism of slope failure in the similar terrain within the sub-metropolitan city but also guides to select appropriate mitigation measures for these landslides. A landslide distribution map has been prepared by delineation of landslides in satellite image and verified by field work. There are altogether 303 active landslides identified in the Birendranagar Municipality that range in size from about 30 to 141000 m^2 in area. Besides these existing landslides, there are some places with landslide marks indicating the occurrence of landslides in historical time.



Map 0-1: Spatial distribution of landslides in Birendranagar Municipality

1.62 SCENARIO OF LANDSLIDES AND DEBRIS FLOWS IN THE MUNICIPALITY

Rainfall is one of the major triggering factors of landslide occurrence in the Birendranagar Municipality. Already the rocks in this area are weathered, highly jointed, and fractured and most of the municipality comprises thick colluvial soil. So, the intense rainfall triggers landslides and debris flows in this terrain.

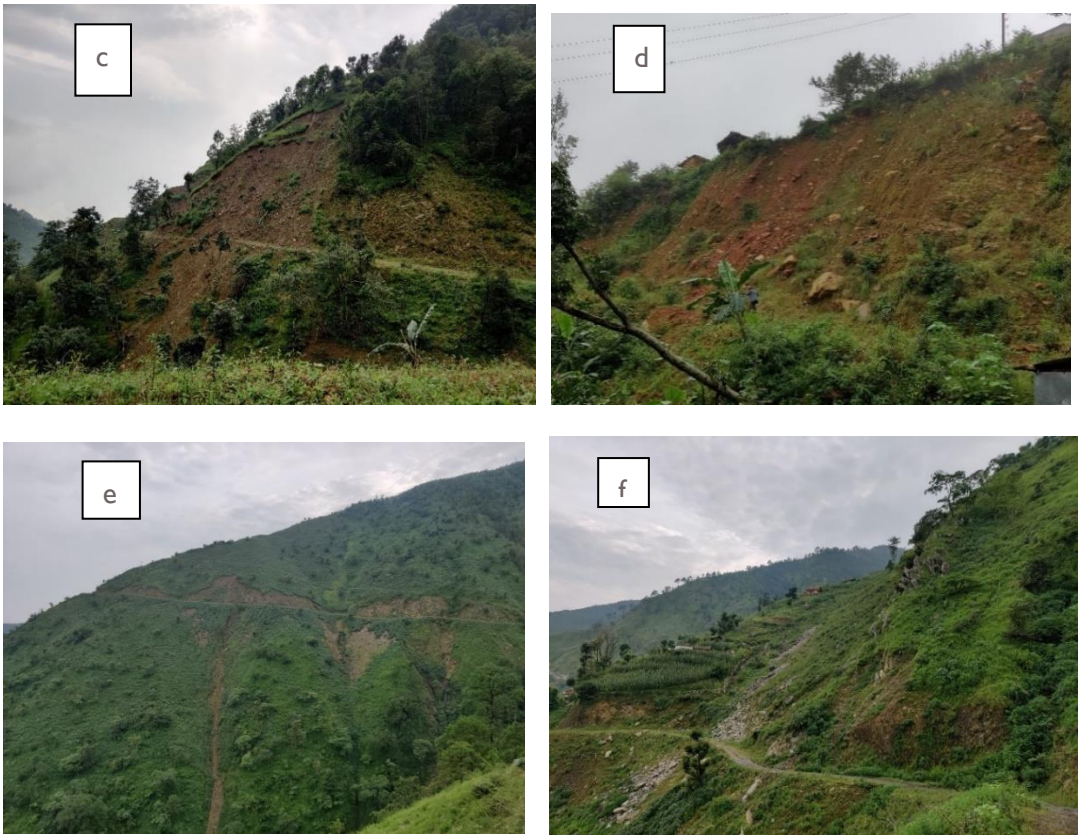
Most of the landslides and debris sites are located on the northern hill slopes of the Municipality while few are located at the bank side of Bheri River. The majority of the mass movement activities have been instigated by road cut along the weak and fragile and steep terrain. The landslides of varying scale ranging from shallow to large, are primarily at the hilly wards; ward 13, 14, 15 and 16. However, few landslides are presented on the immediate valley hills which are responsible for sedimentation over the foot hill side.

Landslides at different places on the northern hills of Lower Siwalik within ward 1, 4 and 7 created higher menace of damming Dharapani Khola, Bhureli Khola, Khorke Khola, Baspani Khola and Itram Khola, which ultimately could bring flash flood immensely affecting the downstream settlement. The mass movement in these regions had triggered flash flood in past years. Also, landslide located at Bhute Pokhari at foothill of ward 5 seems hazardous as the expansion of the slide area may keep 6 houses lying upslope region under the threat of the hazard. The site is mainly composed of alternation of mudstone and sandstone. Old landslide mass and few active sites for rock fall at different places are found along the road section of Dailekh Sadak, which have made the transportation very difficult and hazardous during rainy season. Despite of risk, no much mitigation measures have been implemented to protect the region from further

sliding. Slope stability analysis, construction of mitigation structures such as gabion wall, masonry wall should be constructed to prevent the mass wasting phenomena in this region.

Photograph 0-4: Landslide located at a) Bhute Pokhari and b) on the uphill slide of Surkhet-Dailekh Sadak

Many shallow to large landslides, mostly soil slides, creep and few rock slides are presents on the way to Jumlakot (Ward 13). These landslides are mainly on the slopes where basement is highly weathered rock and at the area having thick soil deposits. The rainfall induced landslide of Jumlakot is most problematic one, which made the 2 houses located at immediate crown section at very high risk situation. The highly jointed and weathered beds of Quartzite and slate as excavated during road construction, slope got failed. Though there are gabion walls at toe part, sliding activity is still present. However, trimming of slopes along with bio-engineering technique could control the sliding. Moreover, shallow slides with frequent rock fragments are present along the road section on the way to Pragati Tol. The uphill slope of the road should be modified in gentle and proper drainages must be constructed along the road. In addition, construction of footwalls and application of bioengineering measures in the downhill slope of the road are required.



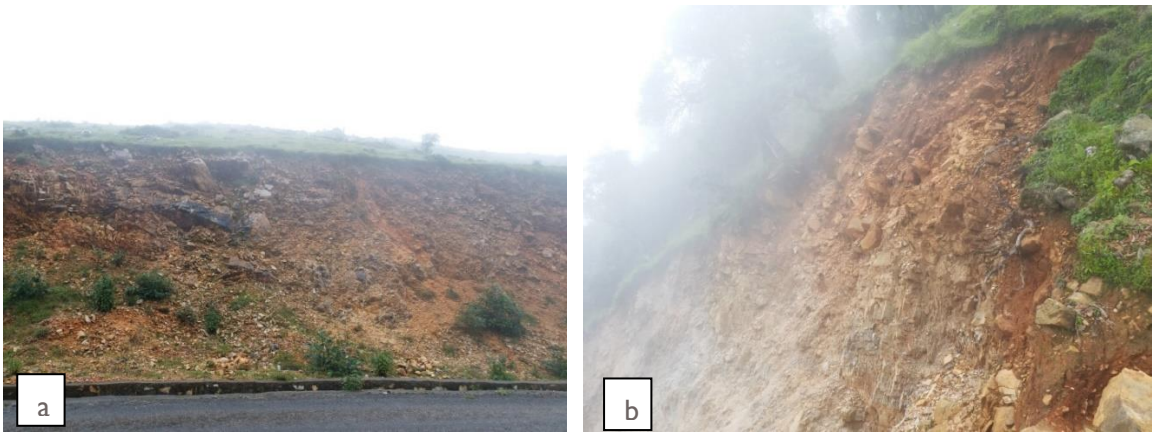
Photograph 0-5: Houses under threat due to debris slide at Bhalumare Pragati Tol, b. Close view of slide, c. and d. Soil slides induced by road cut at Pragati Tol, e. Debris flows due to lack of road drain, f. Debris fall above a road

In ward 15, numerous landslides are present in different locations namely, Kapase, Damai Tol, Laure Dada, Downslope of Chuli, and Kamere. The presence of moderate to highly weathered steep slope of quartzite not only made the lands to slide, but also made inaccessible during the monsoon season. Many landslides can be seen on the satellite images. At Bhalu Khola Gau, 1 house has already been migrated to community forest and Saraswati Primary School is under very high-risk situation due to the landslide initiated in 2020.

Complex landslides located at Gothikada constitutes highly weathered interbedded red-purple shale, sandstone and residual soil. The slide mass can obstruct the spring water located down slope within the boundary of ward 4. Continuation of sliding has damaged the gabion wall placed for the mitigation. One of the most potential sliding regions within ward 14 lies at Darnakot. Ganga Adharbhut School and 7 houses located around the crown portion of the slide and settlements at the foothill are at greater threat. Highly weathered weak rock and road cut excavation seems to be major factor causing mass movement. Landslides initiated along the motorway at Chedda, Sal Danda, Sano Chandane, which are dominated by colluvial soil pose disturbance in the motorway during rainy season. The uphill slope of the road should be modified in gentle and proper drainages must be constructed along the road. In addition, construction of footwalls and application of bioengineering measures in the downhill slope of the road are required.

Photograph 0-6: Landslide location a) at Gothikada and b) at Darnakot ,c) Chedda and d) Sal Danda

Most of the mass movement activities within ward 16 are initiated due to the road cut excavation carried out along the weak and fragile geology. Landslides and debris flow are initiated from many places along the road cut section at Garpan and Bhalukharka. Majuwa, Awalching, Syala, Bara Gaule Basti. Complex type of landslide initiated at Ghyupokhari after road cut had damaged watermill down slope, affected agricultural land and Lifting water system facilitating Bhitri Khola Basti and Tin Ghare is under high. Debris flow sites at Ratangaira, which is dominated by highly weathered rocks and colluvial soil seems very hazardous as 600 houses which have been receiving water supply from 6 springs located about 200m downslope from the crown position of landslide is under high risk. Landslide commenced at Tin Ghare has affected agricultural land, spring water 60-70m downslope from the crown and settlements on the other side of the sliding slope. Similarly, settlements at Syala, Pokharibata and Jugepani are also at risk of landslides.



Photograph 0-1Road cut and rainfall induced landslides located at a) Ghyu Pokhari, and b) Ratangaira

1.62.1 APPROACH AND METHODS OF HAZARD MAPPING

There are some controlling factors besides the rainfall to induce landslides in an area. Topographic, geologic, hydrologic and anthropogenic factors are considered in the preparation of rainfall-induced landslide hazard map. Since there is not enough existing landslide distribution in the municipality, the hazard map has been prepared by following a semi-quantitative scientific approach called Analytical Hierarchical Process (AHP). Each controlling factor is assigned with weightage obtained from a comparative matrix at first. Then, the weightage of particular factor map has been again distributed among factor classes based on their role on landslide triggering. An overlay of all these factor maps in GIS environment results a landslide susceptibility map of the municipality. The landslide susceptibility map has been categorized in to three relative classes: High, Moderate, and Low. The general methodological approach is presented in following figure.

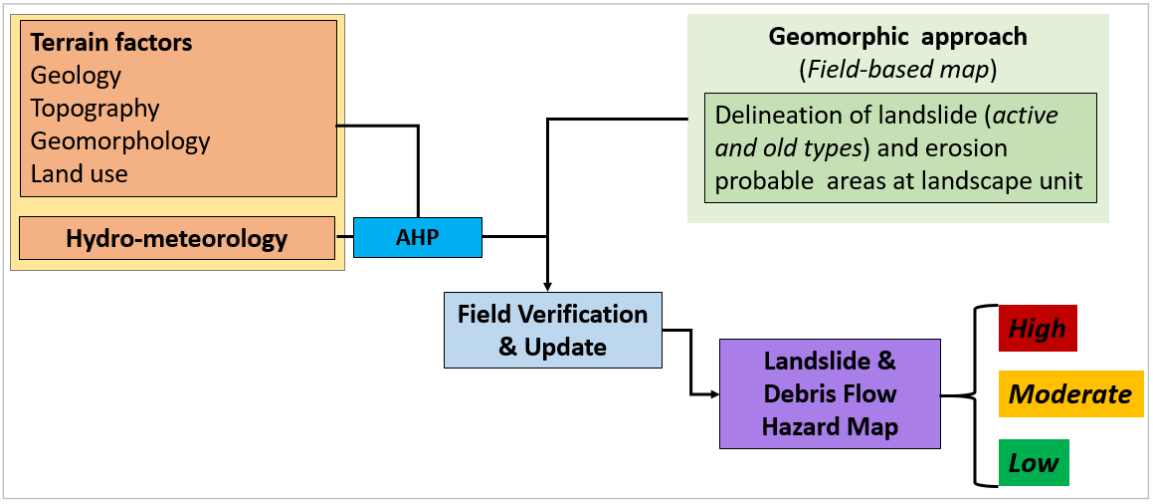


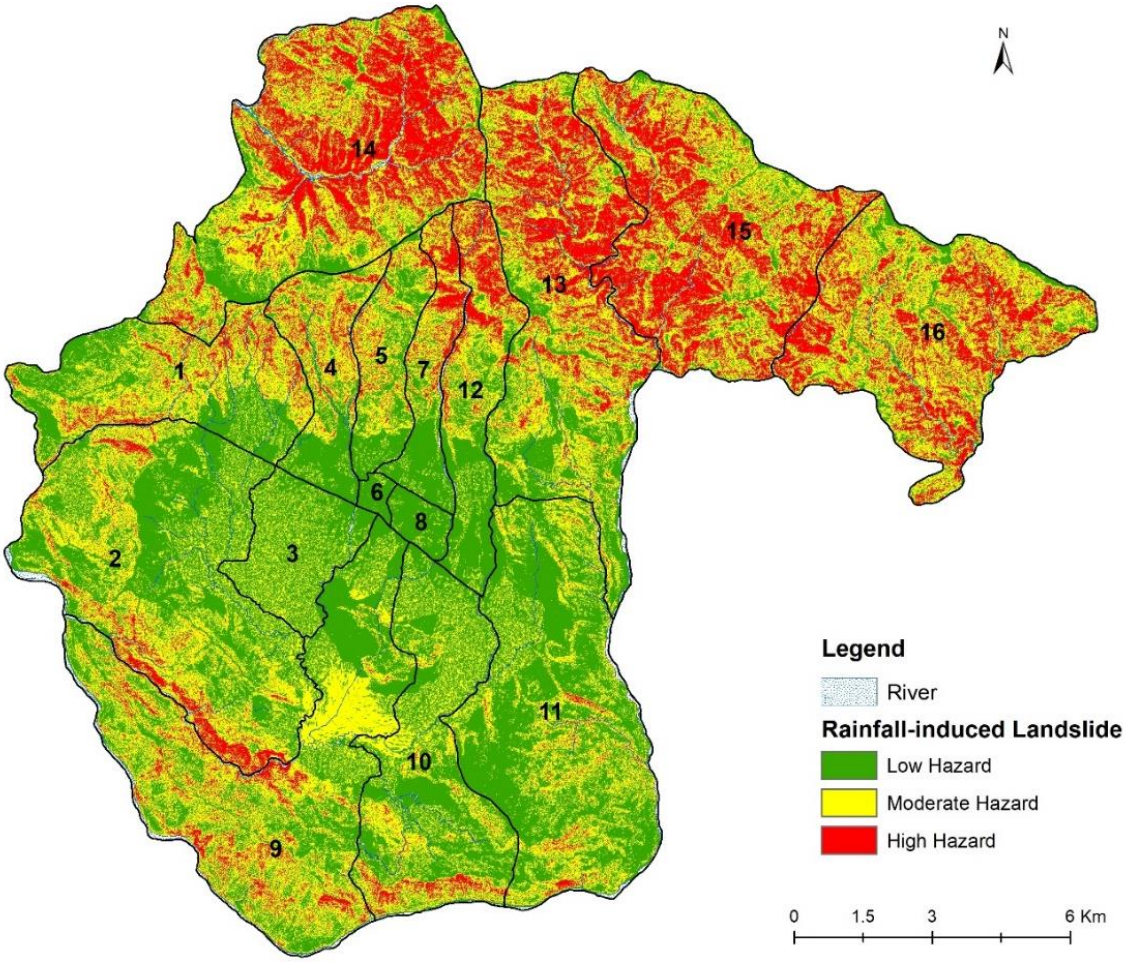
Figure 0-2: Methodological approach for preparation of rainfall-induced landslide in Birendranagar Municipality

1.62.2 RESULT

Following the AHP approach as described above, the rainfall-induced landslide hazard map has been prepared for the Birendranagar Municipality. The rainfall-induced landslide hazard map shows the susceptible zone of occurring small to large landslides, debris flows, and creeping. The map shows relative degree of susceptibility as low, moderate, and high hazard zones. The high susceptibility of rainfall-induced landslides is distributed in northern hilly region of the municipality. Thus, some settlements of northern part of ward nos. 13, 14, 15, and 16. Similarly, some northern part of Ward no. 7 and 12 are also rainfall-induced landslide susceptible. In the southern part of municipality, some parts of ward no. 2 and 9 seem highly susceptible to rainfall-induced landslide. There is about 20% of the municipality falls under high susceptible zone in terms of rainfall-induced landslide. The area in the northern uphill slope seems more favorable to rainfall triggering landslides.

Table 0-2 Wardwise Distribution of Rainfall Triggered Landslides

WARD	AREA (HA)	LOW (HA)	LOW %	MEDIUM (HA)	MEDIUM %	HIGH (HA)	HIGH %
1	1423.55	614.92	43.20	646.20	45.39	162.07	11.39
2	2909.42	1523.11	52.35	1167.39	40.12	218.62	7.51
3	660.28	450.71	68.26	209.55	31.74	0.01	0.00
4	703.99	305.99	43.47	300.15	42.64	97.83	13.90
5	576.14	260.57	45.23	254.73	44.21	60.84	10.56
6	58.99	56.37	95.57	2.60	4.41	0.00	0.00
7	523.46	228.26	43.61	184.61	35.27	110.65	21.14
8	140.79	130.29	92.54	10.43	7.41	0.09	0.06
9	2876.51	1296.62	45.08	1327.53	46.15	251.61	8.75
10	1697.18	986.49	58.13	634.63	37.39	75.77	4.46
11	2664.87	1752.81	65.77	842.18	31.60	69.58	2.61
12	880.32	403.13	45.79	303.84	34.51	173.31	19.69
13	2585.00	691.57	26.75	1109.19	42.91	783.96	30.33
14	2969.04	482.91	16.26	1279.96	43.11	1205.32	40.60
15	2456.86	301.08	12.25	1078.42	43.89	1076.76	43.83
16	2219.45	345.34	15.56	1120.34	50.48	752.32	33.90



Map 0-2: Rainfall-induced landslide hazard map of Birendranagar Municipality

1.63 EARTHQUAKE-INDUCED LANDSLIDE HAZARD

Landslides can occur due to strong shaking on sloping terrain during an earthquake. Earthquake-induced landslides are also crucial geo-hazards that could destruct and change the landscape of a terrain. There were several landslides occurred in mountainous region during the huge earthquakes in the history. Recently, the Gorkha Earthquake 2015 also induced number of small and large landslides in central and western Nepal. The western region (Bheri to Mahakali River section) of Nepal has frequently experienced small to medium-magnitude earthquakes since historical time. Though there is not any earthquake-induced landslide reported in Birendranagar yet, there is possibility of earthquake-induced landslides in the towering hills of Mahabharat Range in the northern part of the municipality.

1.63.1 APPROACH AND METHODS

Literatures and cases reported in field show the earthquake-induced landslides are mainly based on the slope of terrain, peak ground acceleration (PGA), and shear wave velocity (Vs30) of the ground. Thus, the susceptibility to earthquake-induced landslides has been predicted by using Rapolla's method. Rapolla et al. (2010, 2012) proposed a heuristic approach based on three factors to predict the susceptibility to

earthquake-induced landslides. The geotechnical behavior of rock/soil (expressed by means of Vs), the slope steepness of terrain, and the seismic action at surface (PGA). The first two factors are in-situ characteristic of earth, while the seismic action is triggering factor for landslide occurrence. In the Rapolla's development, S_a, S_b, and S_c are three indices, respectively: Lithology Index (S_a), the Slope Index (S_b), and the Seismic Index (S_c). All these indices are comprised between 0 and 1.

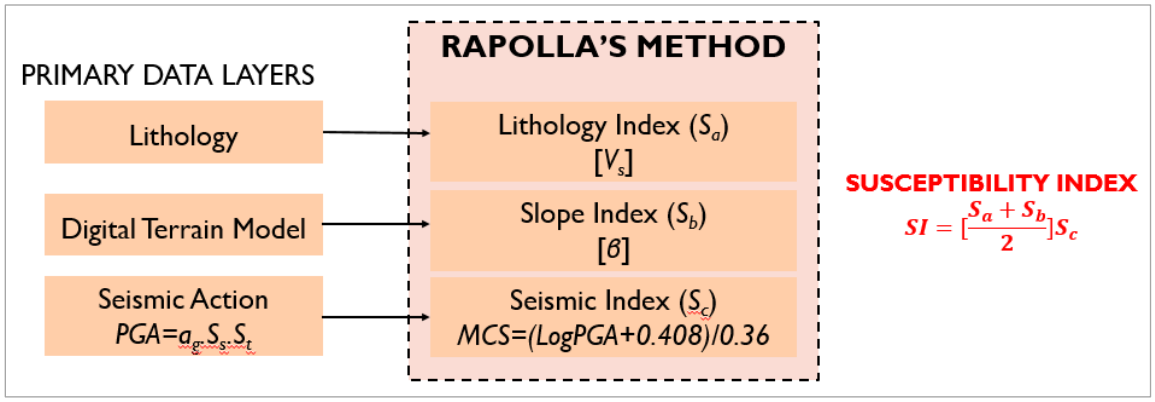


Figure 0-3: Methodological chart for earthquake-induced landslide susceptibility mapping

According to Rapolla et al. (2012), the S_a can be computed as a linear function of the inverse of Vs. Here Vs is average Vs30 computed at the site.

$$S_a = \frac{0.2045}{V_s} - 0.1363 \quad \begin{cases} S_a = 0 \; for \; V_s \geq 1500 \; ms^{-1} \; (compact, non-fractured \; rocks) \\ = 1 \; for \; V_s < 180 \; ms^{-1} \; (cohesionless \; clayey \; materials) \end{cases}$$

According to some additional studies by Keefer (1984), Mora and Vahrson (1994), Rodriguez et al. (1999), and Wasowski et al. (2002), the Slope Index (S_b) is computed on the basis of soil and rock slopes as:

$$S_b = 0.04\beta \;\; (for \; soils)$$

$$S_b = 0.04\beta - 0.6 \;\; (for \; rocks)$$

Where β = slope (in degrees). On soil slopes, the value of S_b ranges from 0 to 1 that increases linearly from 0 to 25o of slope, over which the value of S_b becomes constant at the maximum value. On rock slopes, S_b is 0 for slope gradient less than 15o and increases linearly up to 40o, over which it remains constant. The seismic index S_c is expressed in terms of the local maximum Mercalli-Cancani-Sieberg (MCS) intensity. The MCS can be derived from PGA using the formula proposed by Ambraseys (1975):

$$MCS = \frac{(log_{10}PGA + 0.408)}{0.36}$$

Then, the S_c is assumed by the following equation:

$$S_c = 0.6667 \; (MCS) - 0.8333$$

Finally, the seismically induced landslide susceptibility index (SI) is obtained by the following equation:

$$SI = \frac{S_a + S_b}{2} \times S_c$$

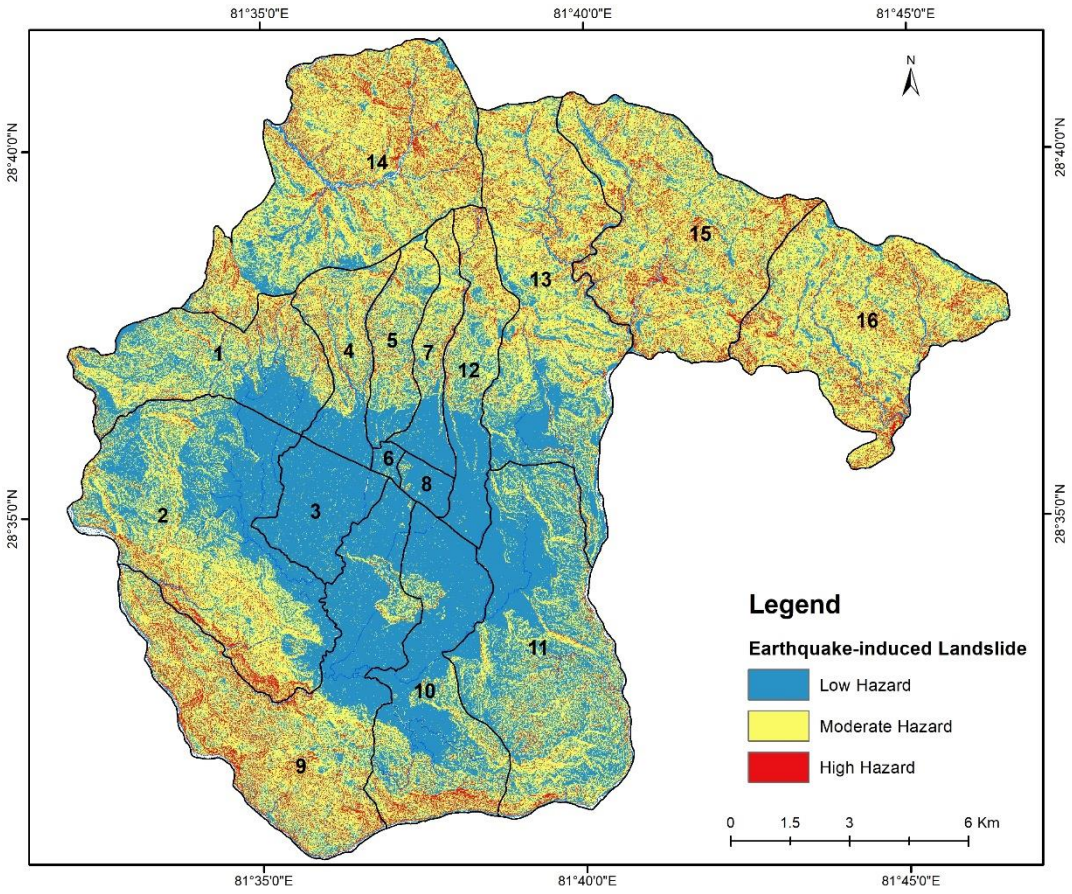
The obtained map of seismically induced landslide susceptibility index has been classified in three classes showing the relative degree of hazard as low, moderate, and high.

1.63.2 RESULT

The earthquake-induced landslide hazard map of the Birendranagar Municipality shows the spatial distribution of different level of landslide susceptible zones within the sub-metropolitan city. Some places of the northern hilly area along with only few places of southern hills are looking high susceptible due to earthquake-induced landslides. There is nearly about 9% of the municipality falls under high susceptible zone in terms of earthquake-induced landslide. The area in the northern uphill slope seems more favorable to landslide occurrence during strong earthquakes.

Table 0-3 Wardwise Distribution of Earthquake Induced Lanldslide

WARD	AREA (HA)	LOW (HA)	LOW %	MEDIUM (HA)	MEDIUM %	HIGH (HA)	HIGH %
1	1423.55	680.47	47.80	658.03	46.22	84.62	5.94
2	2909.42	1516.68	52.13	1223.21	42.04	169.20	5.82
3	660.28	639.81	96.90	20.47	3.10	0.00	0.00
4	703.99	316.05	44.89	334.09	47.46	53.93	7.66
5	576.14	246.58	42.80	293.49	50.94	36.03	6.25
6	58.99	53.64	90.94	5.32	9.02	0.01	0.02
7	523.46	262.76	50.20	229.97	43.93	30.71	5.87
8	140.79	131.84	93.65	8.39	5.96	0.57	0.40
9	2876.51	1241.09	43.15	1273.83	44.28	360.87	12.55
10	1697.18	1146.07	67.53	457.15	26.94	93.58	5.51
11	2664.87	1601.39	60.09	972.44	36.49	90.65	3.40
12	880.32	460.52	52.31	359.78	40.87	60.04	6.82
13	2585.00	891.18	34.47	1482.10	57.33	211.43	8.18
14	2969.04	641.14	21.59	1906.03	64.20	420.79	14.17
15	2456.86	454.94	18.52	1636.38	66.60	364.74	14.85
16	2219.45	357.51	16.11	1526.44	68.78	333.91	15.04

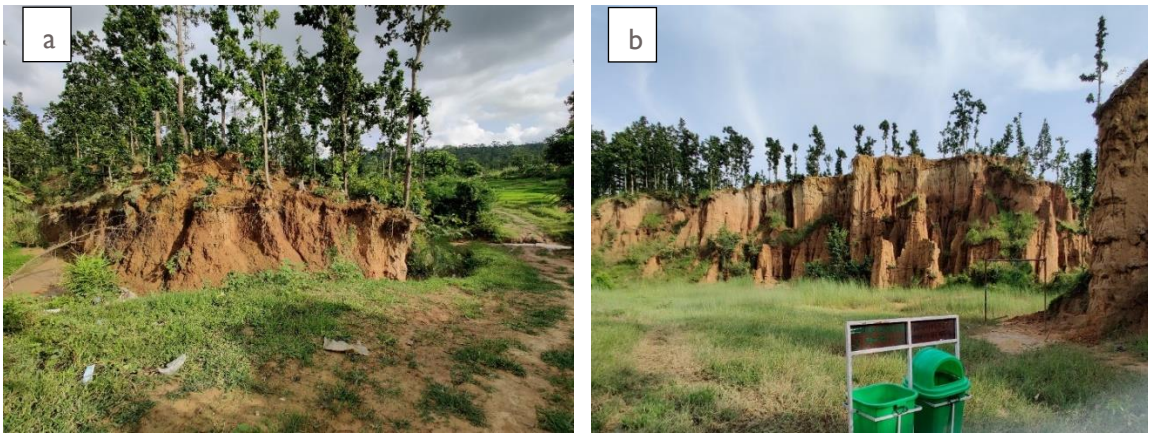


Map 0-3: Earthquake-induced landslide hazard map of Birendranagar Municipality

1.64 SCENARIO OF SURFACE EROSION AND GULLY EROSION IN MUNICIPALITY

The main erosional agent of surface erosion and gully erosion on the study area is intense rainfall. When the volume of water increases and starts to flow towards downhill slope on sloping terrain of barren land, depositional masses of old landslides, and cultivation land, the surface water concentrates in a path to form gullies. Besides gully erosion, a large slope face of land also undergoes erosion of topsoil. The erosion takes place based on some geomorphic and geological factors beside the rainfall. The thickness of soil, weathering grade of rocks, higher slope gradient, land cover and land use practices, cropping pattern on the cultivated land, deposition of old landslides, and amount of rainfall are some of the main factors that control surface and gully erosion. During the field observation, the higher erosion rate has been reported in more thickness of soil in the Birendranagar Municipality.

Deep gullies are present in the mudstone rocks belonging to Lower Siwalik Unit. Gully erosion is a major problem in most of the southern hills lying in ward no. 2, 9 and 10, where the gentle to moderate steeply dipping hills comprised of mudstone and siltstone. As the piles of weathered mudstone are eroded away by the gullies during the monsoon, deep gullies (depth > 5m) are formed. Not only on mudstone bed, the siltstone beds also have gone to erosional process and resulted the multiple gullies of varying depths. This phenomenon is significant in Pantale Darbar area.



Photograph 0-7: Gully erosion at a. Sano Surkhet area and b. Pantale Darbar area

1.64.1 APPROACH AND METHODS

Gully erosion are associated with slope gradient, soil thickness, and stream order. Therefore, the potential gully erosion sites are delineated from the digital terrain model and stream distribution in GIS environment. Similarly, the potential surface erosion has been modeled by using land cover and slope gradient obtained from DEM. A brief methodological scheme has been shown as follow:

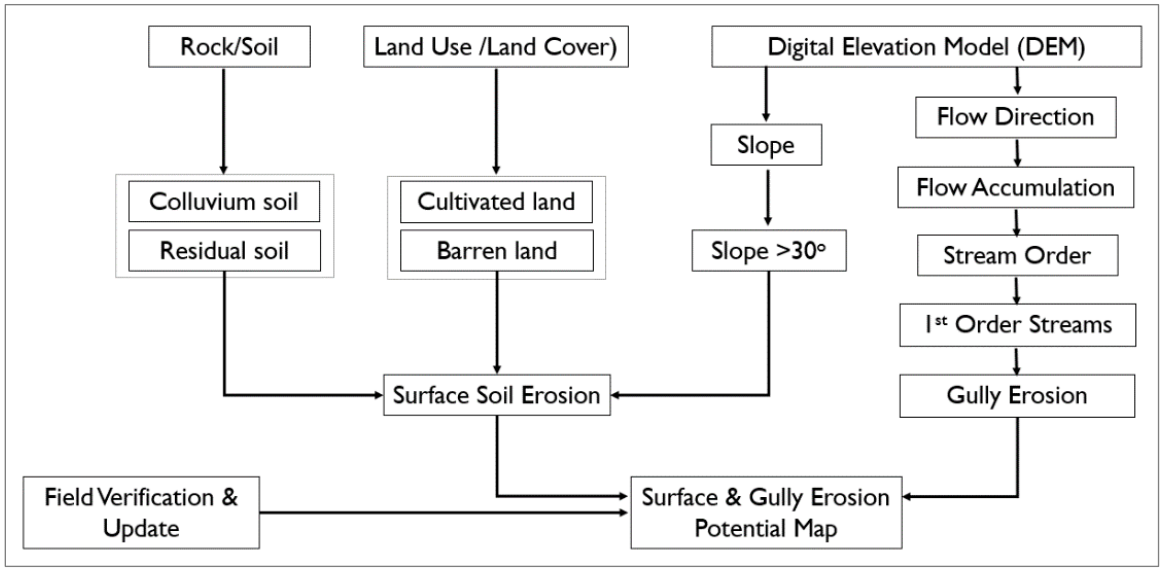
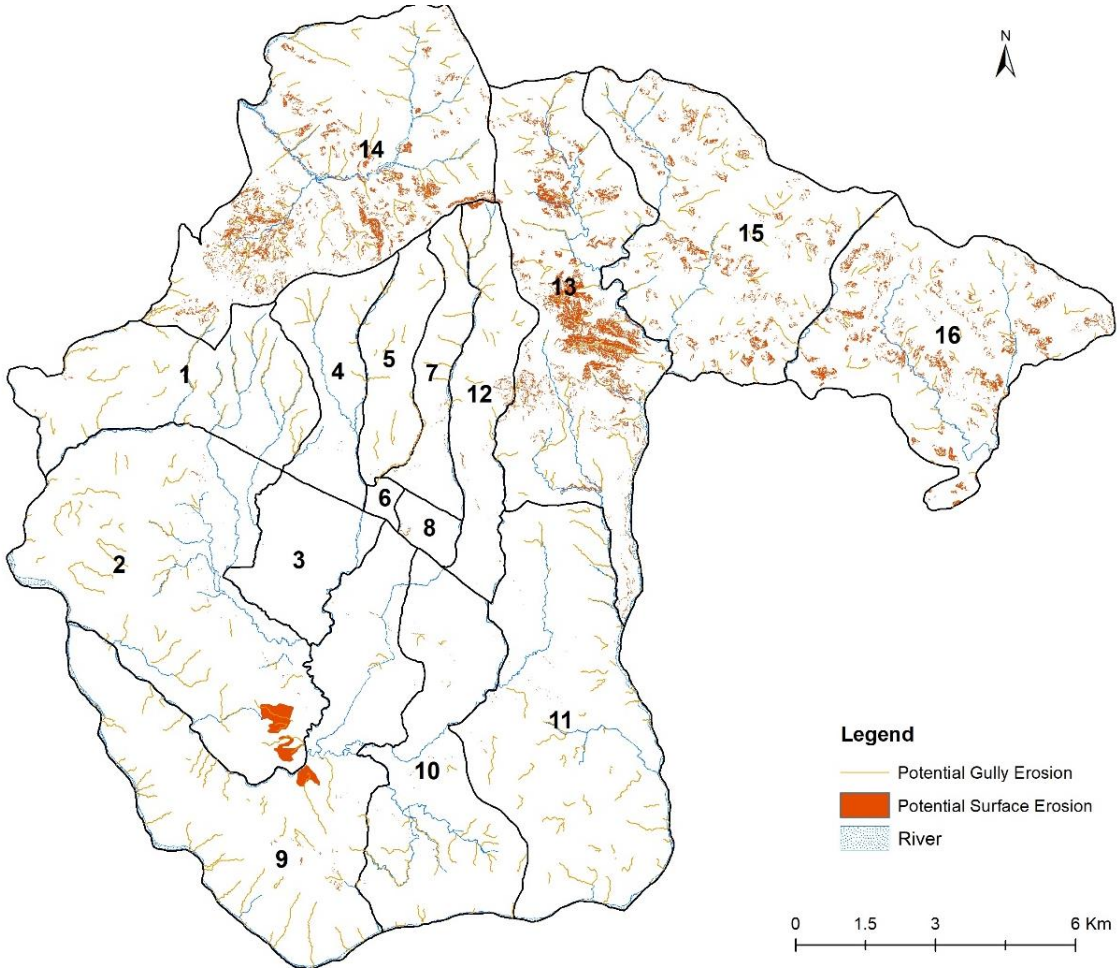


Figure 0-4: Methodological chart for surface and gully erosion hazard mapping in Birendranagar Municipality

1.64.2 RESULT

The integrated map of surface soil and gully erosion of the Birendranagar Municipality shows the erosion potentiality is concentrated in northern part of Ward no. 13, 14, 15, and 16. Similarly, there is severe

surface and gully erosion in southeastern part of Ward no. 2 and in Ward 9. Besides, the hilly terrain with thick soil cover are potential to gully erosion.



Map 0-4: Potential surface soil and gully erosion map of the Birendranagar Municipality

1.65 ROCK FALL AND ROCKSLIDE HAZARD

1.65.1 APPROACH AND METHODS

The rockslides and rock falls are highly associated with steepness of terrain. So, the potentiality of rock falls and rockslides has been calculated using slope angle and internal relief of terrain from the DEM. Then, a susceptibility map has been prepared for Birendranagar Municipality.

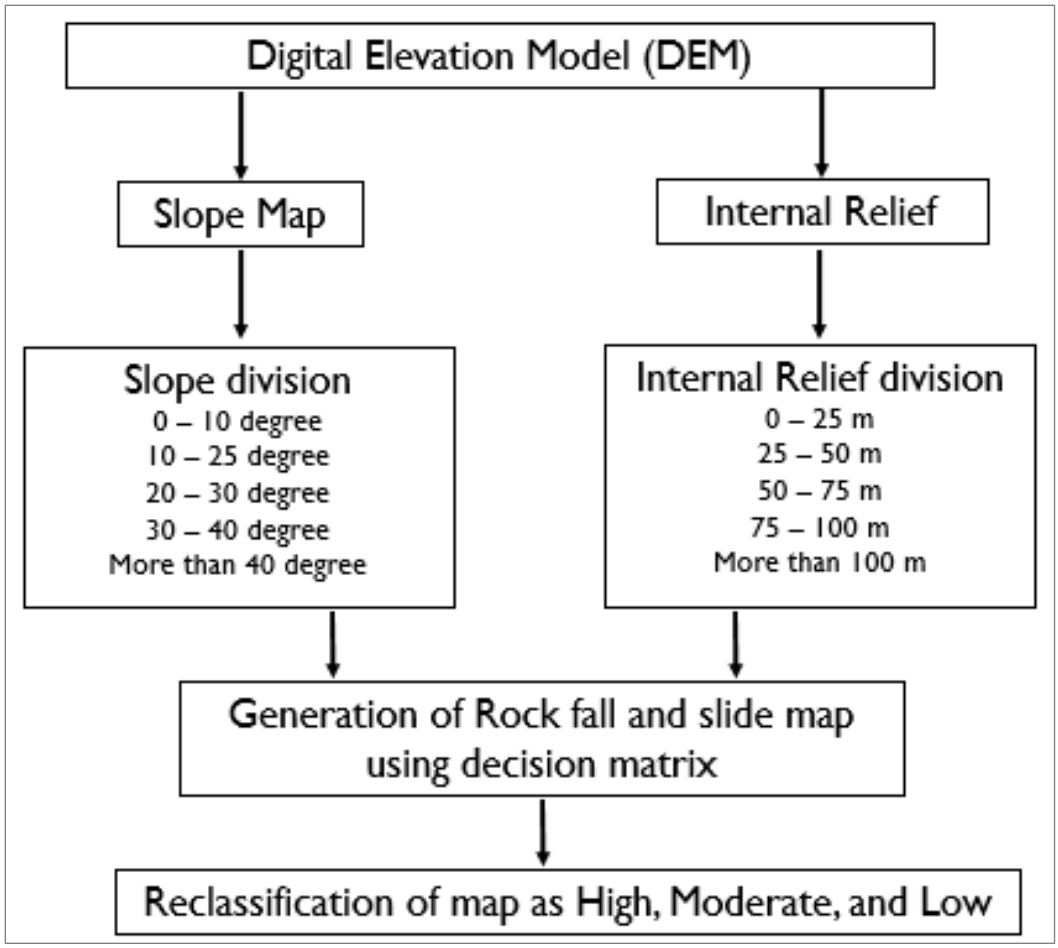


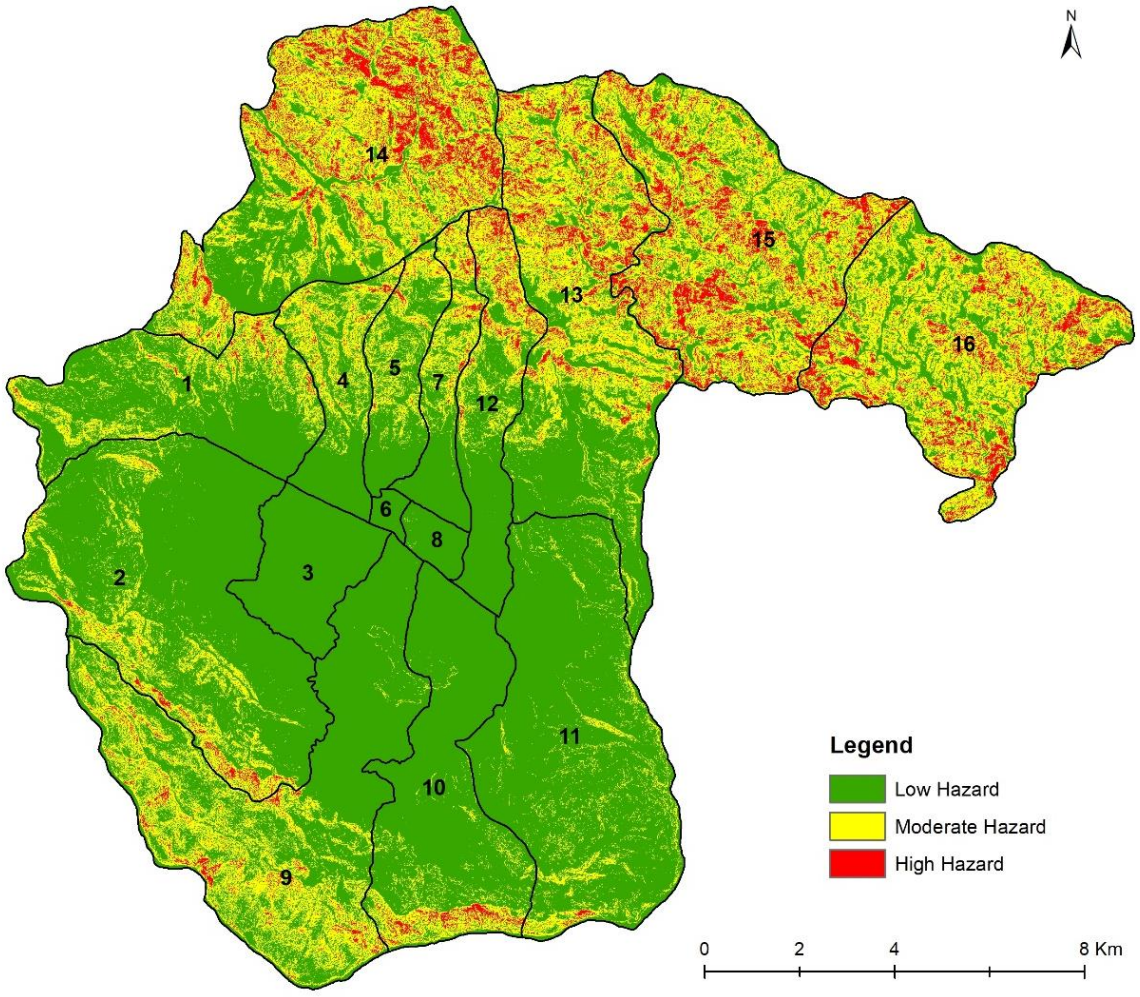
Figure 0-5: Methodological chart for rock fall and rockslide hazard map in Birendranagar Municipality

Attribute		Rock fall susceptibility class				
		Slope (degrees)				
Internal relief (m)		0–15	15–25	25–35	35–40	>40
	0–25	LS	LS	LS	LS	MS
	25–50	LS	LS	LS	MS	MS
	50–75	LS	LH	MS	MS	MS
	75–100	LS	MS	MS	MS	HS
	>100	MS	MS	MS	HS	HS

Figure 0-6: Decision matrix used to define the rock fall and rockslide hazard map

1.65.2 RESULT

The rockslide and rock fall hazard map of Birendranagar Municipality shows the higher potentiality rock fall/slide is on the northern part of ward no. 13, 14, 15, and 16, where the Mahabharat Range has towering hills and comprises bedrock exposures on surface. There is only about 7% of the municipality falls under high susceptible zone in terms of rock fall and rockslide. The area in the northern uphill slope seems more favorable to rockslide and rock fall.



Map 0-5: Rock fall and rockslide hazard map of Birendranagar Municipality

Table 0-4 Warwise Distribution of Rockfall

WARD	AREA (HA)	LOW (HA)	LOW %	MEDIUM (HA)	MEDIUM %	HIGH (HA)	HIGH %
1	1423.55	1058.21	74.34	343.86	24.15	20.80	1.46
2	2909.42	2417.93	83.11	455.80	15.67	35.38	1.22
3	660.28	660.28	100.00	0.00	0.00	0.00	0.00
4	703.99	457.51	64.99	233.36	33.15	13.11	1.86
5	576.14	390.03	67.70	176.81	30.69	9.31	1.62
6	58.99	58.97	99.98	0.01	0.01	0.00	0.00
7	523.46	329.22	62.89	174.31	33.30	19.93	3.81
8	140.79	140.25	99.62	0.56	0.40	0.00	0.00
9	2876.51	1961.55	68.19	851.67	29.61	63.03	2.19
10	1697.18	1464.22	86.27	193.90	11.42	39.03	2.30
11	2664.87	2418.96	90.77	240.15	9.01	5.71	0.21
12	880.32	558.52	63.45	256.46	29.13	65.28	7.42
13	2585.00	1199.72	46.41	1121.15	43.37	263.84	10.21
14	2969.04	976.66	32.89	1478.35	49.79	512.63	17.27
15	2456.86	617.35	25.13	1367.50	55.66	471.12	19.18
16	2219.45	646.91	29.15	1253.31	56.47	318.15	14.33

1.66 RIVER SHIFTING AND BANK CUTTING HAZARD

1.66.1 APPROACH AND METHOD

River shifting and bank cutting are the major problem that the Surkhet Valley lying in central part of the municipality has been facing since decades. The ephemeral streams are flowing on gentle sloping terrain of valley, so they naturally tend to shift during high discharge. In case of Surkhet Valley, these streams have narrow water channel, which cannot confine the river discharge within the natural levees. As a result, they cut their either bank and also tend to migrate from the original course.

The problem of river shifting is mainly in the central portion of valley. Khorke Khola and Itaram Khola are the major problematic streams responsible for channel shifting since decades. However, recent construction of embankment has limited the streams to shift only at the active flood plain area. Despite of presented structures, recently established settlements located at the old flood plain areas are still facing the problem of flooding as stream reached its maximum level during rainy season. The narrowing of the river due to increasing concentration of settlements have further aided the flood water to enter through nearby settlements. Mainly the area of ward no. 2, 3, 9, and 10 are facing these problems every year. Although few portion of ward no. 4, 5, 6, 7, 8, and 12 are also vulnerable to channel shifting problems.

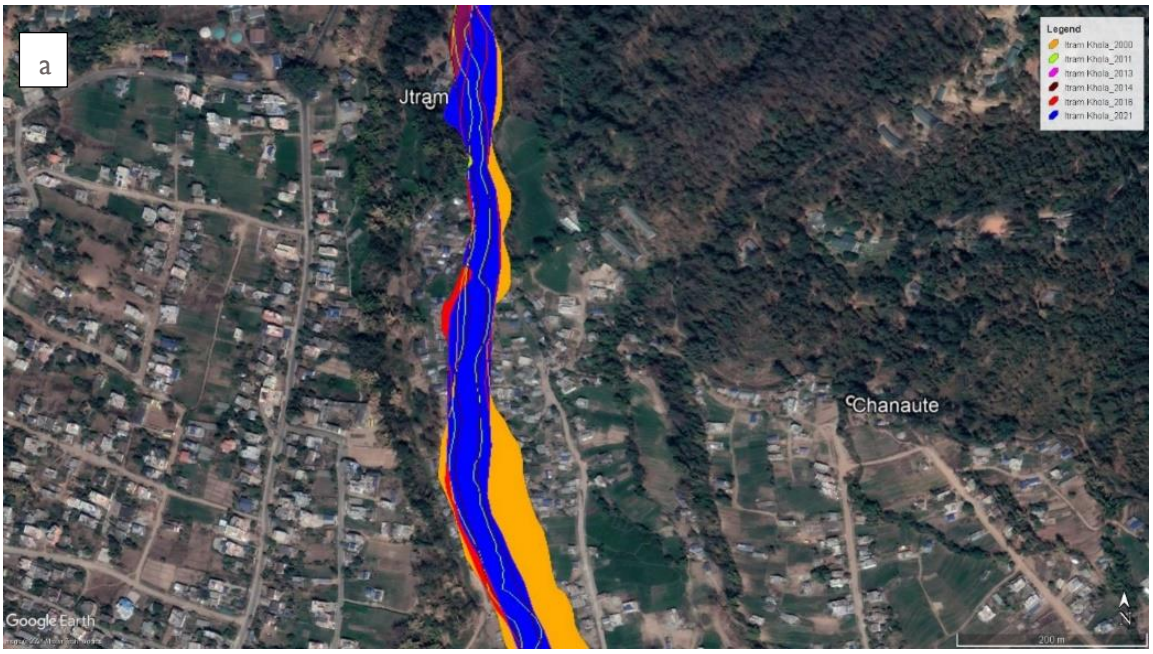
1.66.2 RESULT

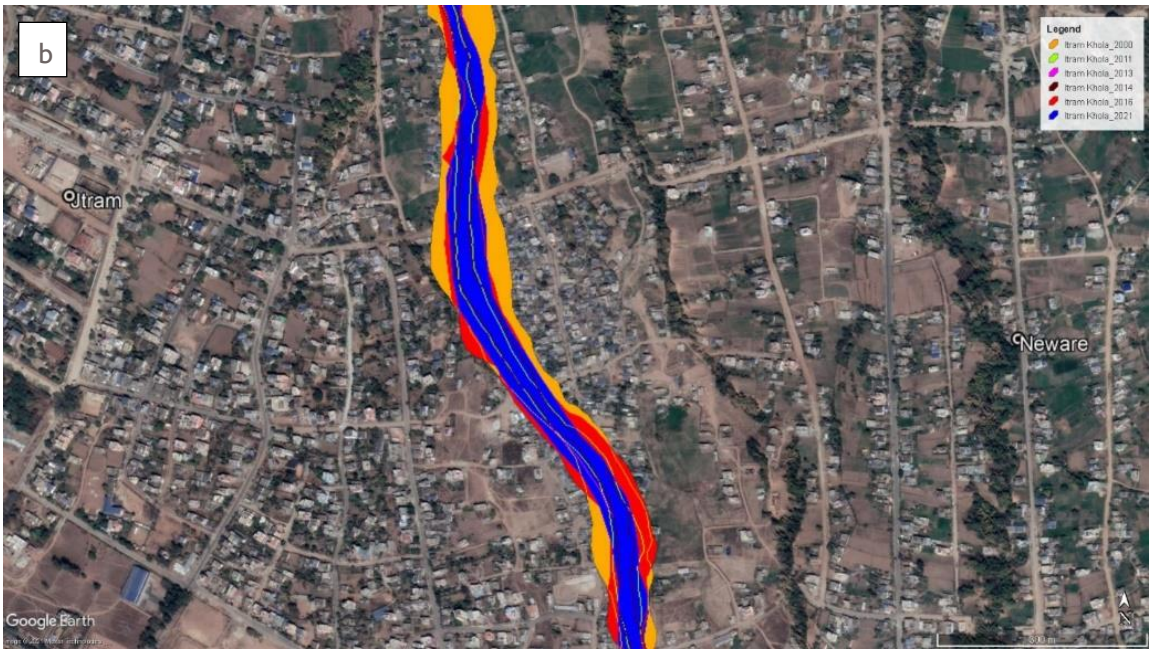
The overall shifting of active river channels is analyzed through the temporal satellite image analysis. On the basis of shifting nature of river and field condition, following rivers are the problematic one. The time series analysis of satellite images clearly shows the changes in river active channels. These problematic scenarios are explained on the following.

1.67 SCENARIO OF RIVER CHANNEL SHIFTING IN MUNICIPALITY

1.67.1 ITRAM KHOLA

Itram Khola is flowing from the North East direction towards South East. On analyzing the satellite images from 2000 to 2021 A.D, in 2014 A.D, this river had created a disastrous event at northern part of Kakrebihar Jungle. From the temporal image analysis, it was seen that before 2011 A.D, the river used to flow towards South West direction and drained into Khorke Khola. While after 2011, Itram Khola is flowing towards South East joining the Neware Khola. The river has become narrower in present days compared to 11 years back. Many recent settlements residing along the river banks are at old flood plain deposits. Due to which most of the settlements falls under high risk condition.


a
Jtram
Chanaute
Legend
Itram Khola_2000
Itram Khola_2011
Itram Khola_2013
Itram Khola_2014
Itram Khola_2016
Itram Khola_2021
Google Earth
200 m
N


b
Jtram
Neware
Legend
Itram Khola_2000
Itram Khola_2011
Itram Khola_2013
Itram Khola_2014
Itram Khola_2016
Itram Khola_2021
Google Earth
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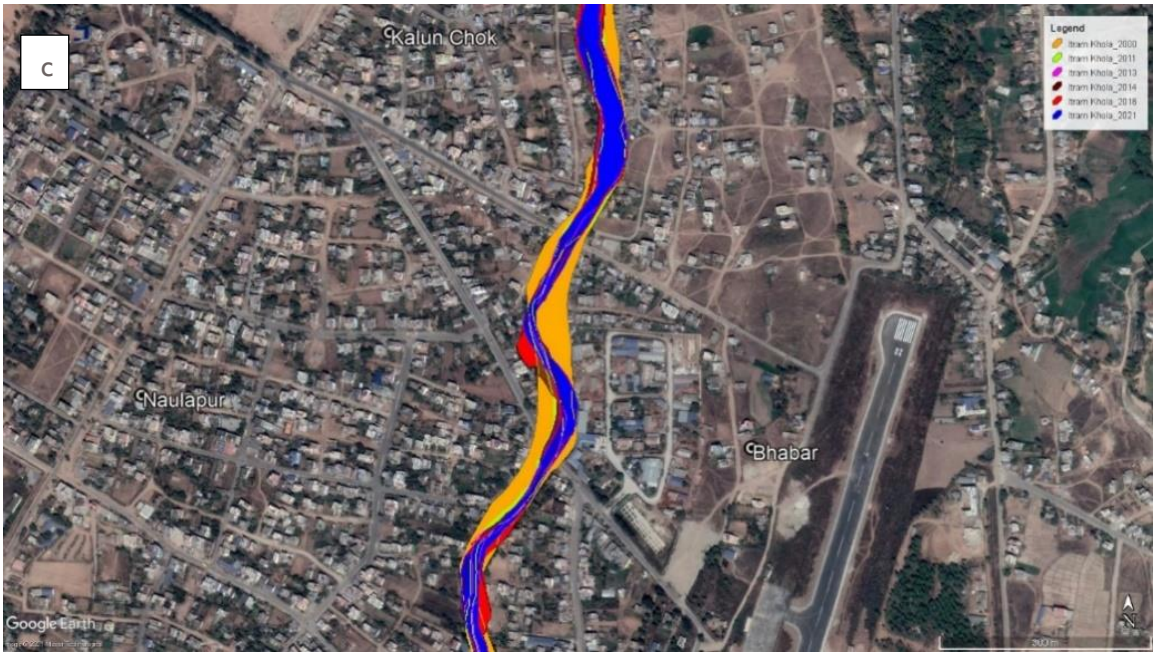
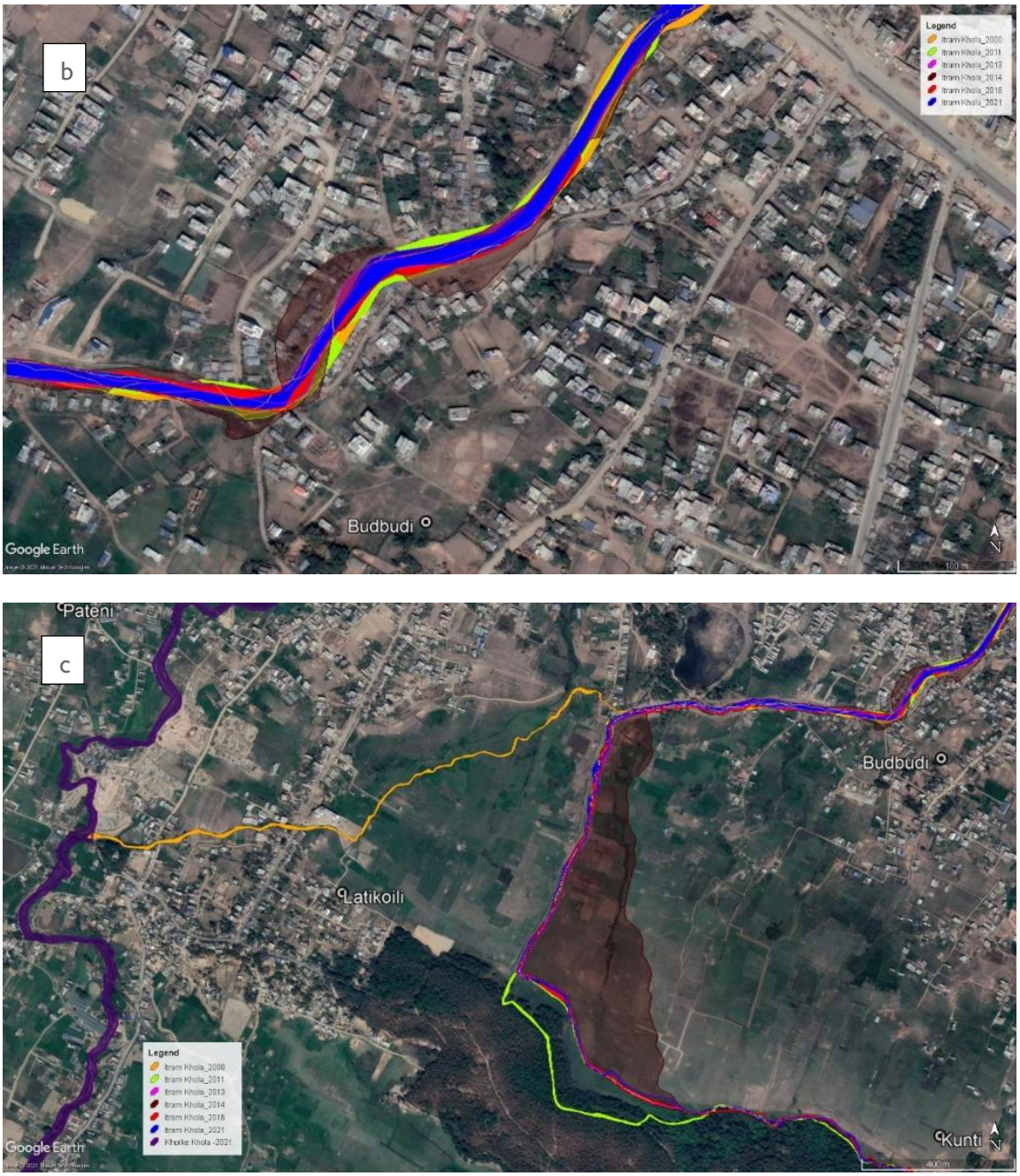


Map 0-6: River channel shifting of Itram Khola at different sections: a. On the foothill to the west of Chanaute, b. To the west of Neware and c. To the west of Surkhet Airport

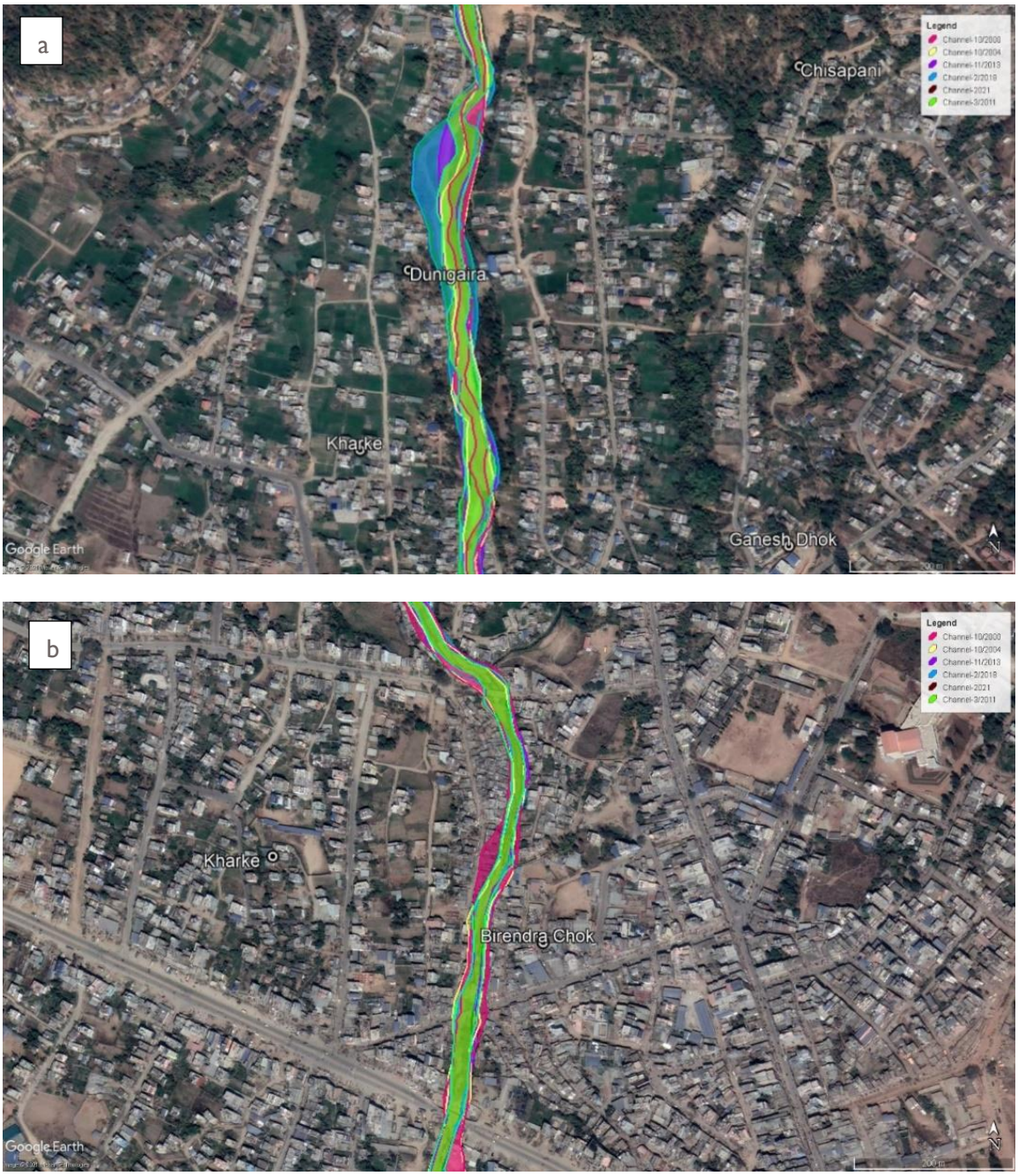


Map 0-7: River channel shifting of Itram Khola at different sections: a. Near to Khajura, b. Near to Budbudi (south of Highway), and c. Near to Latikoili (north of Kakrebihar)

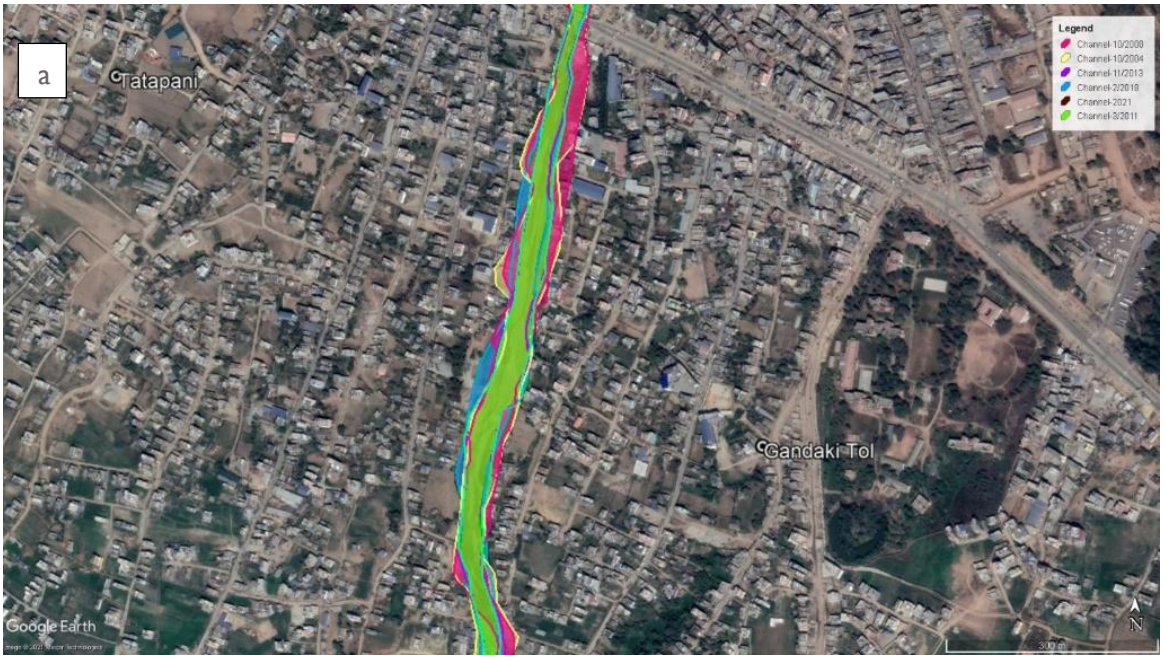
1.67.2 KHORKE KHOLA

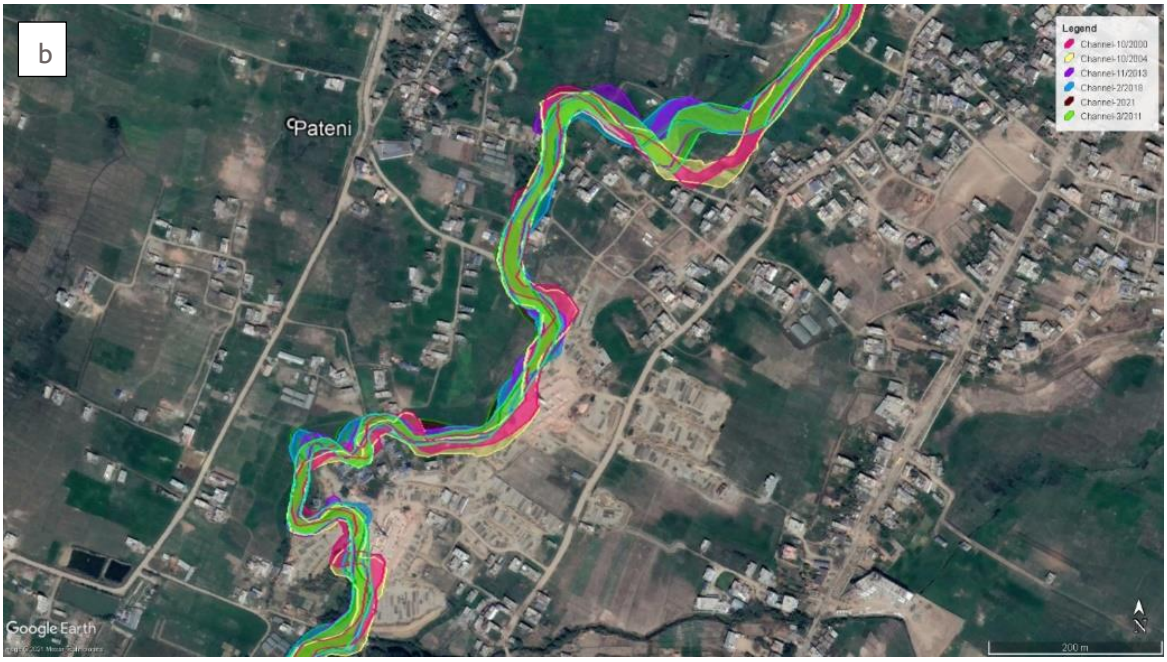
When analyzing the satellite image for Khorke Khola since 2000 to 2021 A.D, it is seen that Khorke Khola channel was narrowed significantly after 2011. The flood plain during 2000 was bigger as compared to the flood plain of present date. Most importantly, in the upper course area mainly settlements of Dunegaira, Kharke, Sukumbasi Tol, nearby area of Birendra Chowk and many other settlements located at either in the paleo channel or at vicinity of old flood plain. Most of the houses located over there are still at the

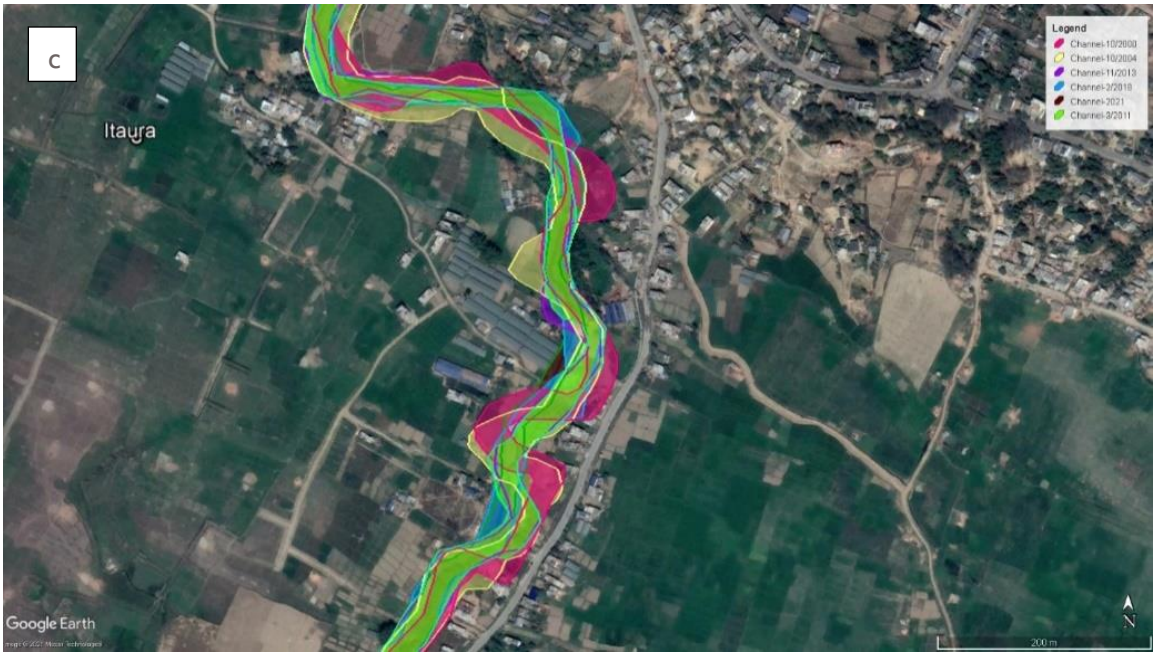
alarming situation. Not only this, the settlement at down course region like Pateri, Itaura also faced the shifting problem during past years.



Map 0-8: River channel shifting pattern of Khorke Khola at different sections: Near to Dungara area (upper) and Near to Birendra Chowk (lower)


a
Tatapani
Gandaki Tol
Legend
Channel-10/2000
Channel-10/2004
Channel-11/2013
Channel-2/2018
Channel-2021
Channel-3/2011
Google Earth
N


b
Pateni
Legend
Channel-10/2000
Channel-10/2004
Channel-11/2013
Channel-2/2018
Channel-2021
Channel-3/2011
Google Earth
N



Map 0-9: River channel shifting pattern of Khorke Khola at different sections: a. At downstream section from Birendra Chok, b. Near to Pateni, and c. Near to Itaura

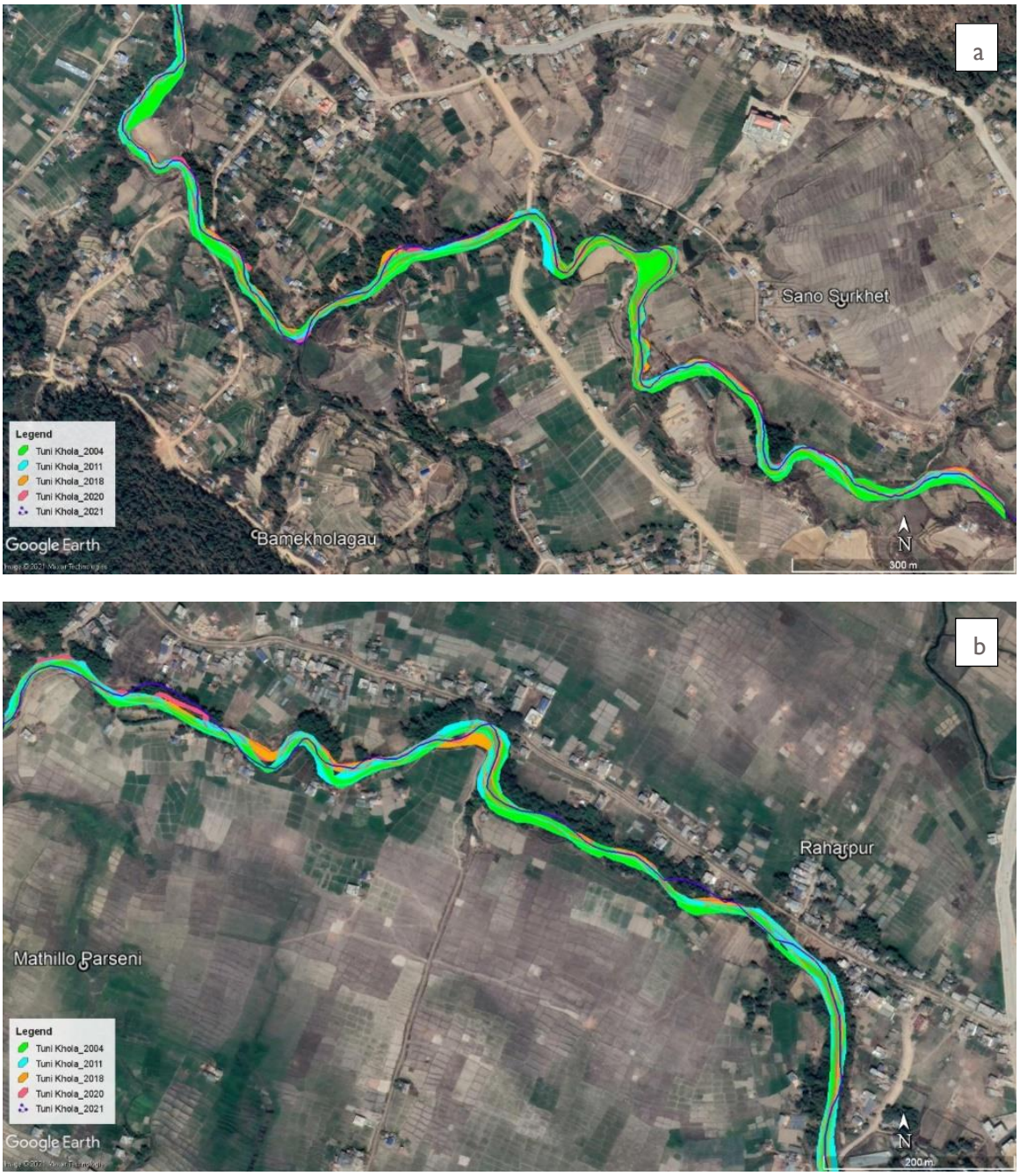
1.67.3 NEWARE KHOLA

The east-west flowing Neware Khola is shifting towards its right bank, which can be seen from the satellite image analyzed from 2004 to 2021 A.D. This river is creating a great problem in the Southern part of Birendranagar area, mostly at Tallo Parseni, Raharpur and Manikapur.

Map 0-10: Rives shifting analysis of Neware Khola since 2004 to 2021 A.D

1.67.4 TUNI KHOLA

Tuni Khola is flowing towards the South Eastern part of the valley. The river has become comparatively narrow than in the past years. This can be seen from the time series satellite image analyzed from 2004 to 2021 A.D. The reason for the narrow pathway is the vegetation i.e. bushes and lack of river training structures along the river. The whole settlement along the river i.e. Mathilo Parseni, Raharpur, Latikoili and Bame Kholagaun are under threat. In between Mathilo Parseni and Raharpur area, the river is sometimes hitting towards the right bank and sometimes towards the left bank.



Map 0-11: Significant shifting of Tuni Khola as seen on satellite image

1.68 SCENARIO OF BANK CUTTING IN THE MUNICIPALITY

The lower portion of the valley has a high level of bank cutting activities as compared to the upper portion of the valley and mountainous area. The lower section that consists of alluvial soil dominant of silts, silty clay, silts with gravel, has facing a high cutting activities during flash floods and flooding events. Itaram Khola, Khorke Khola, Neware Khola, Tuni Khola, Bhureli Khola, Chanabari Khola, and Sot Khola are the river whose most of their section are facing the bank cutting problem by each year.

1.68.1 ITRAM KHOLA

Along the Itaram Khola channel shifting and bank cutting, both are the major problems. Most of the settlements are under very high risk due to locating at the floodplain and paleo channel of Itaram Khola. Some of the major bank cutting areas along the Itaram Khola are Kunti, Budbudi, Kapase, Sukumbasi Tol, Industrial area, etc. Despite of presented river retaining structures, the nearby settlements are still facing the problem of cutting in every monsoon. In Budbudi, the flood of 2071 and 2076 B.S, not only swept the nearby lands but also 29 houses were totally damaged (a and b). Also, flood of 2071 damaged the 20 houses in Kunti.

Photograph 0-8: : Severe bank cutting sections of Itaram Khola: a. and b. At the Budbudi village, c. and d. Near to Itram village

1.68.2 NEWARE KHOLA

The cutting of Neware Khola range from 1-2 m every year. Many acres of land have been lost due to the cutting action of this river. The settlement area of Manikapur, Bastipur, Jhykri Tole and Guptipur are at high risk. Altogether 64 houses within these localities are at risk. In Guptipur area, the river has become deeper and wider. In the Pipira area (north of highway), where the Neware Khola had caused the destructive event when its flow was blocked in 2062 B.S. The blocking was due to the stocking of flood debris at the narrow section where its width is limited by the constructing of the buildings. In Basgadhi area, 15 houses located at the nearby bank area were damaged due to flood of 2062 B.S. Also, the situation is even worse at Jhyakri Tol where 20 house located at the right bank section are under very high threat of cutting.

Photograph 0-9: Bank cutting and flooding section of Neware Khola: At Basgadhi area (a, b, and c), At Jhakri Tol (d), At Tallo Parseni village (e), and At Guptipur village (f)

1.68.3 TUNI KHOLA

Bank cutting is the major problem along the Tuni Khola section. In 2072 B.S, the river had caused problematic scenario by affecting 14 houses in Raharpur area. Not only this, river had done many damages to the river section in Bame Kholagaun. The significant cutting had started since 2071 B.S. and many acres of agricultural land has been lost till date. The presence of slit dominant banks are mostly eroded away by the river. Currently, 8 houses located at nearby river section are under very risk situation due to the bank cutting action of Tuni Khola.

Photograph 0-10: Severe bank cutting sections by Tuni Khola in Sano Surkhet area: At the Bame Khola Gaun (a, b, c, & d), Risk houses of Bame Khola Gaun on the bank of Tuni Khola (e and f)

1.68.4 KHORKE KHOLA

Khorke Khola is causing the problem mainly in wards 3, 4, 5, 6 and 9. However, bank cutting problem is mostly concentrated at the downstream section. Many places of ward no, 2 and 9, the cutting action of Khorke Khola is a problem as compare to rest wards. The highly affected area because of the cutting phenomenon are Latikoli, Shivalaya Tol and Itaura. The approximate cutting rate is 3-4 m per year and till date 5 to 6 Bigha of agricultural land has been lost. Not only this, upper portion of ward 4 and lower portion of ward 3 are also affected areas even though the river training structures are built.

Photograph 0-11: Severe bank cutting and flooding section of Khorke Khola: a,b,c Sivalaya Tol, and d. Itaura

1.68.5 BHURELI KHOLA

In the southern section of the valley, Bhureli Khola have done significant damages to the agricultural land. Most significant bank cutting is seen in Jaypur, Daulatpur, Itaura and Phalate area. On those section, the bank height is generally ranges from 2 – 4 m and approximate cutting rate ranges from 1-2 m per year. The lithology of this area is clay and silty clay which is very weak and can easily eroded away by flood water. Till the date, around 4-5 m (laterally) land along the corresponding banks has been lost.

Photograph 0-12: Frequently bank cutting section by Bhureli Khola at Phalate area

1.68.6 NIKAS KHOLA

When all the rivers flowing from the valley portion meets to form one river, it is known by a Nikas Khola. It is only a way out for draining entire valley. The bank cutting by Nikas Khola is less significant as compare to other rivers. However, the bank slope of sandstone and mudstone rocks has failed frequently due to scouring action. The narrow course due to rocky banks, have favored the stocking of wooden debris brought by flood in 2014. However, the river course was more widened after that event.

Photograph 0-13: Slope failures on the rocky banks of Nikas Khola at the southern end of the municipality due to scouring

a. Jhupra Khola

There are 126 houses located along the left bank of Jhupra Khola section, nearby confluence with Bheri River. The settlement is residing on the flood plain and river terrace, are facing the problem of cutting and flooding every year. During the flood of 2014 AD, 62 houses were totally damaged. Currently, 20 houses located at the immediate to Jhupra Khola are at very high risk of bank cutting. The over excavation of the construction material from the river bed deposits had resulted the deepening of river and hence there by causing banks to scour every year. Moreover, the presence of landslide at immediate hills have further increased the risky scenario of the settlement

Photograph 0-14: Houses on either bank of Jhupra Khola under threat of severe bank cutting and flooding

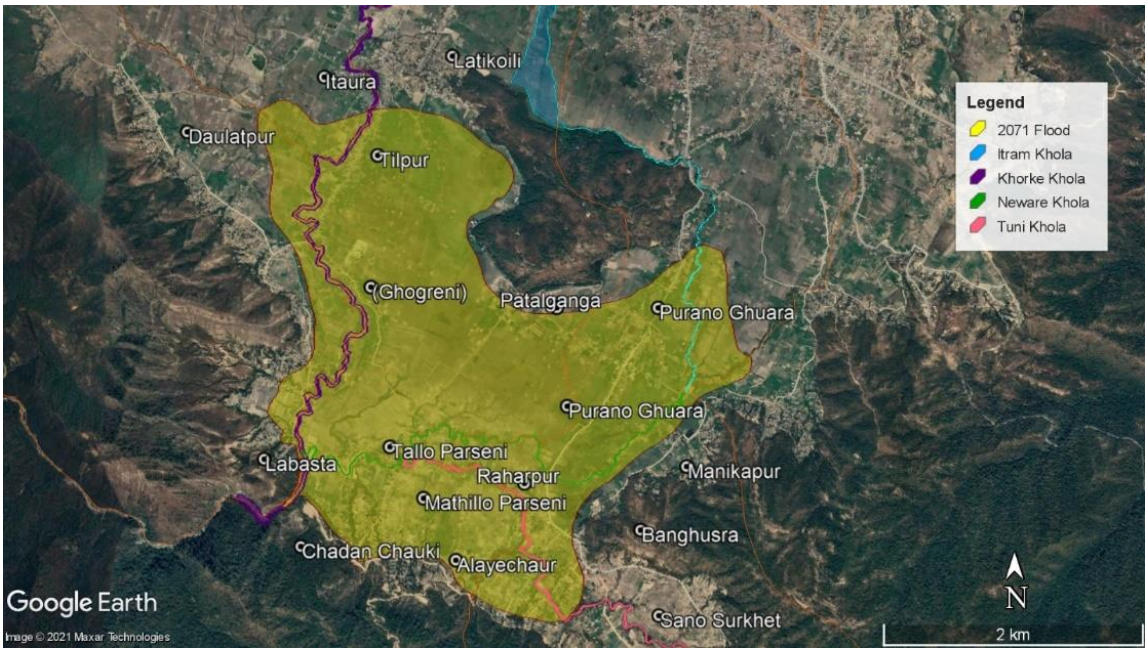
1.68.7 GAGRETAL KHOLA

Gagretal Khola area lies in the Lower Siwalik where mudstone and siltstone slopes has been cut out by the river. Mostly, the Barrakuna section is highly affected by bank cutting and bank scouring action by Gagretal Khola. The bank height is approximately 12-15 m composed of clay and silt which makes it easy to erode. The 2 houses in this area are under very high risk condition whic needs an immediate mitigation. Till date around 3 bigha of land has been lost due to bank cutting action of Gagretal Khola.

Photograph 0-15: Houses at Barrakuna settlement under threat due to bank cutting by Gagretal Khola

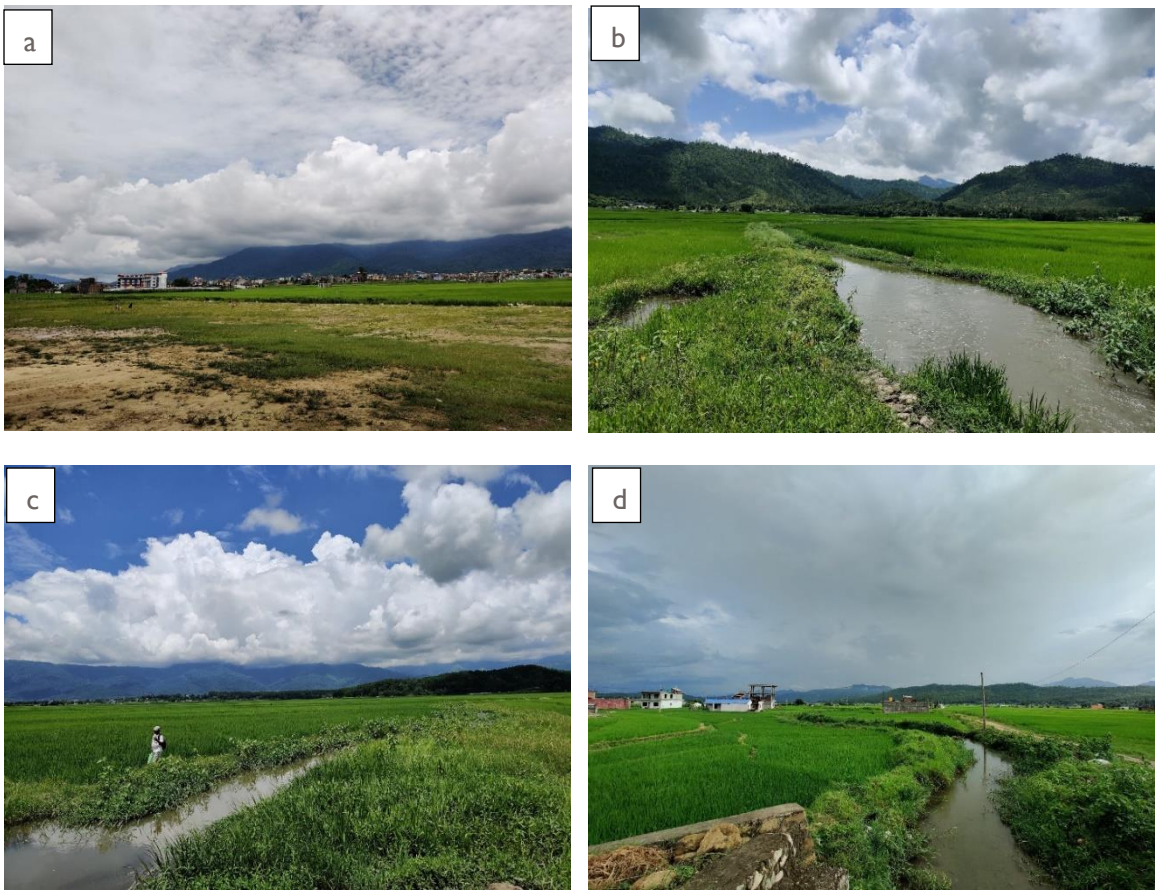
1.69 LOCAL INUNDATION HAZARD

The 2014 inundation is the most disastrous inundation recorded till the date. The blocking of Nikas Khola not only flooded the area but also destroyed more than 255 homes and damaged about 715 homes. Luckily, very few human lives were lost (<10) as compared to expected loss in that disastrous scenario. Almost all southern valley portions, mainly lower course areas of ward 2, 9 and 10 were inundated for a week. The most affected places were Mathillo parseni, Tallo Parseni, Raharpur, Nikas, Itaura, Labasta, Guptipur, Ghogreni, Purano Ghaura, Manikapur and Banghusra.



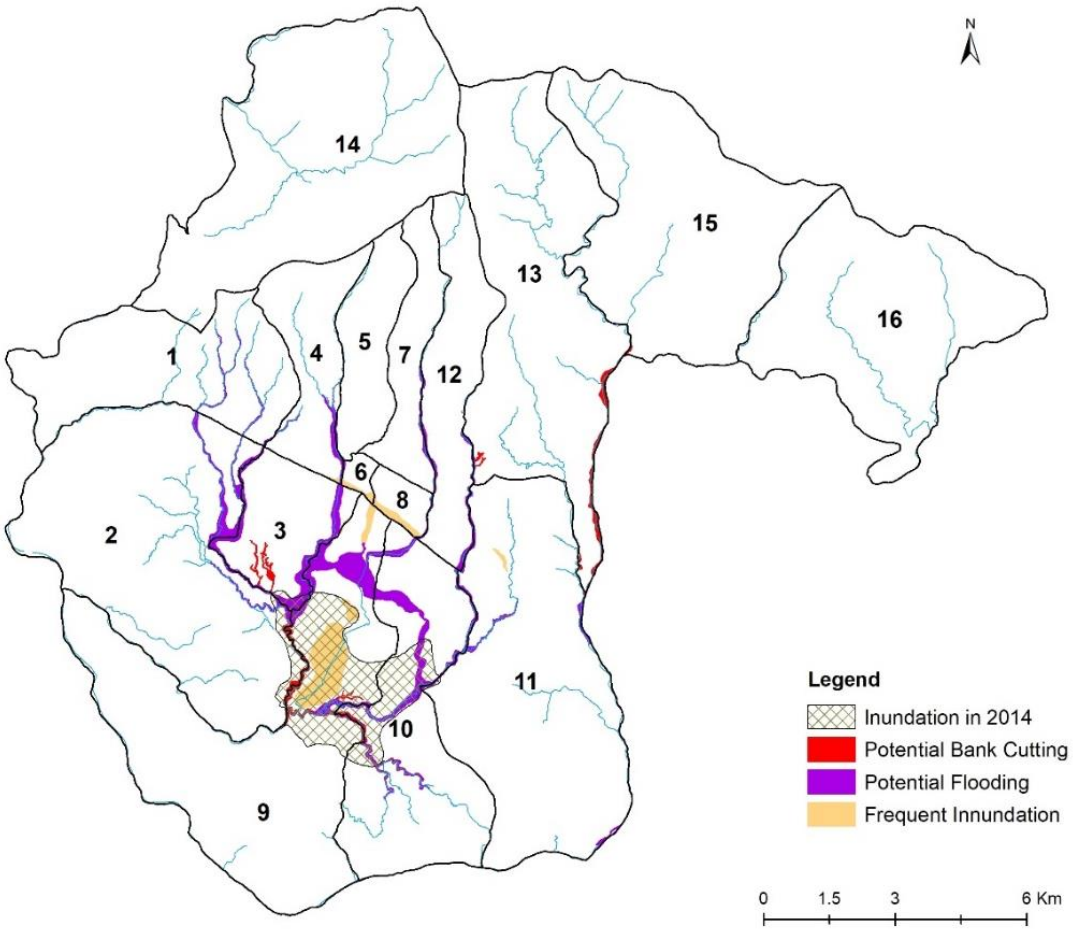
Map 0-12: Inundated area (approx.) in southern part of valley due to blockade of Nikas Khola in 2014 flood

In addition, the settlements located along the banks of Bhate Khola, Bhureli Khola, Itram Khola, Badigad Khola and Tuni Khola are also inundate every year. The inundation is the major problem of Ward 2, 9 and 10 with the depth ranging from <1 m to 3 m with an inundation period of 2-8 hours and 24 hours in case of heavy rainfall can be noticed over there. Moreover, the inundation is also resulted due to the narrow or no pass way of rainwater during the rainy season as well as the overflow of the river. A significant example of narrowing or river is seen at Thauri, where the actual river channel is of 40 m width but only about 2 m of its width is currently present, while rests are captured by bushes and bamboos. Because of which many wooden debris get stocked during flood and thereby causing the inundation of the area. The places affected by inundation in Birendranagar Municipality are Raharpur, Manikapur, northern and southern section (Ghogreni) of Kakrebihar and settlement of Tallo Parseni and Mathilo Parseni.



Photograph 0-16: Local Inundation area in the Surkhet Valley: a. and b. At the flat land to the north of Kakrebihar, c. and d. At the flat area to the south of Kakrebihar (Ghogreni area)

All the information on bank cutting, river channel shifting pattern, local inundation, and flooding of all the rivers flowing through the Birendranagar Municipality has been integrated to prepare an overall hazard map associated with river activities. The integrated map has been classified into three classes: moderate, high, and very high hazard zones to describe the relative degree of susceptibility.



Map 0-13: Integrated fluvial hazard map showing the potentiality of bank cutting, river channel shifting, and flooding in an integrated form

FLOOD HAZARD AND INUNDATION

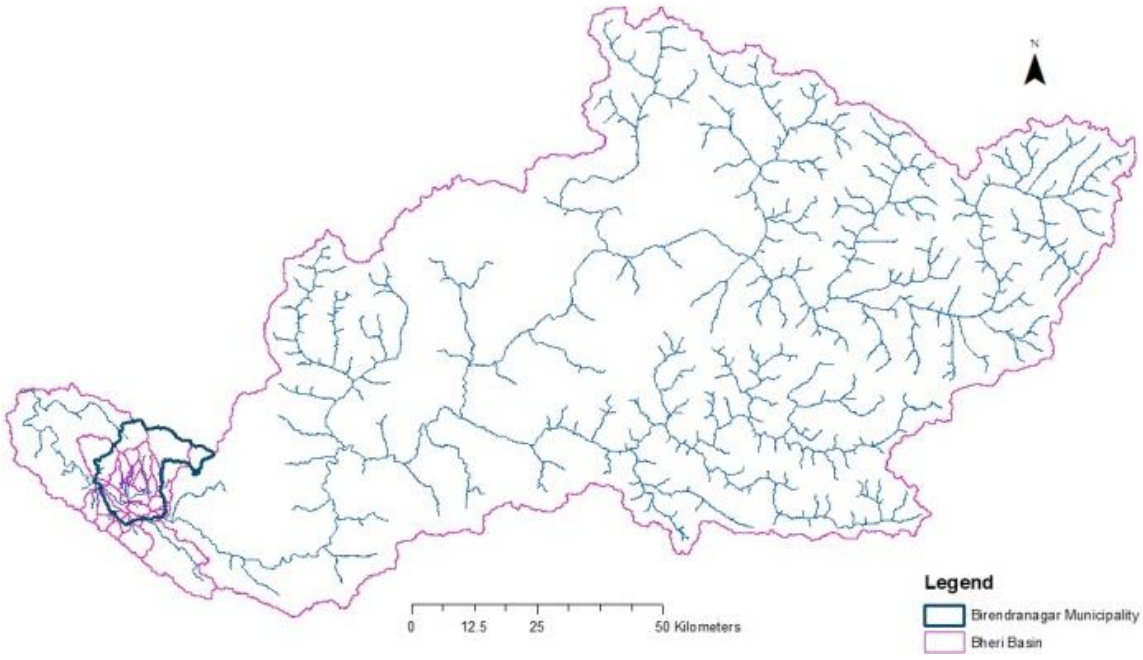
1.70 INTRODUCTION

1.70.1 FLOOD HAZARD APPROACH

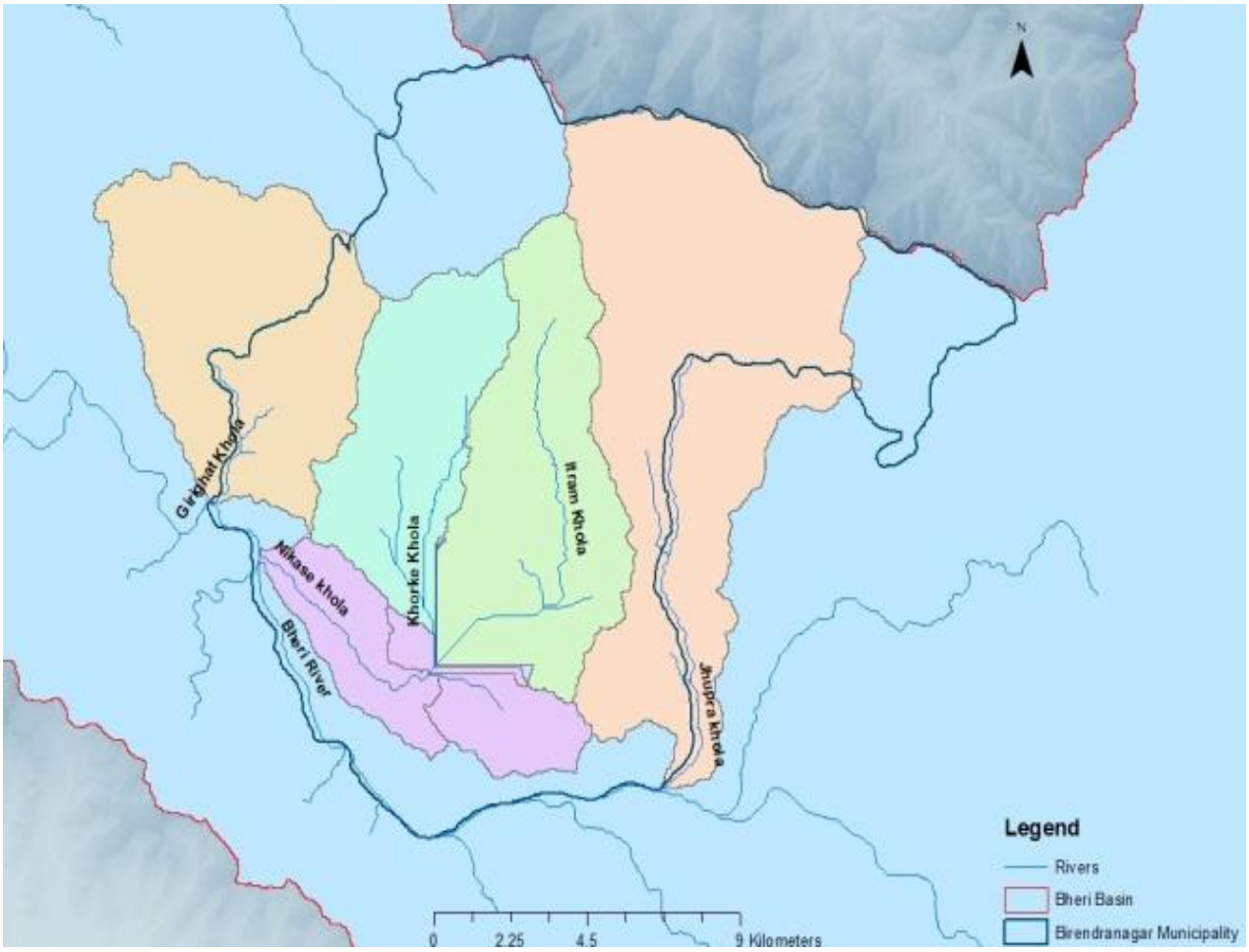
Birendranagar municipality lies in inner Terai region at the elevation ranging from 364 to 2277m (approximately). Flood hazard problem caused by the streams and river in the municipality is assessed with the study of hydrology, hydraulic modeling and mapping approach. There are numerous rivers and streams flowing through and along the boundary of the municipality. The major river flowing in the municipality is Bheri River, draining along the southern boundary of the municipality. There are other numerous small and medium rivers such as Neware, Khorke, Itram, Tuni Khola etc. inside the municipality, flowing only in the monsoon season.

1.70.2 WATERSHEDS AND RIVER SYSTEM

Birendranagar Municipality is situated in Bheri river watershed. The Bheri River originate from the snow peaked mountains in North and flow downstream to confluence with Karnali River. It is a major tributary to Karnali River. The drainage area of Bheri River up to the hydrological station at Samaijighatola is 12200 square km (DHM). The Samijighat hydrological station is near the confluence of Bheri River with Jupra Khola. Bheri RIver flows along the southern boundary of the Municipality. Jhupra khola and Girighat khola flows along eastern and western boundary of the municipality. There are other numerous streams flowing throughout the valley of Birendranagar such as Itram, Khorke, Neware, Tuni and Sot Khola. Most of them are dry in winter season and they flow with monsoonal discharge causing flooding, soil erosion and bank cutting in monsoon season. These rivers are originating from the Siwalik region and the river system of Siwalik is flashy type of flow.



Map 0-1: Catchment area of Bheri River

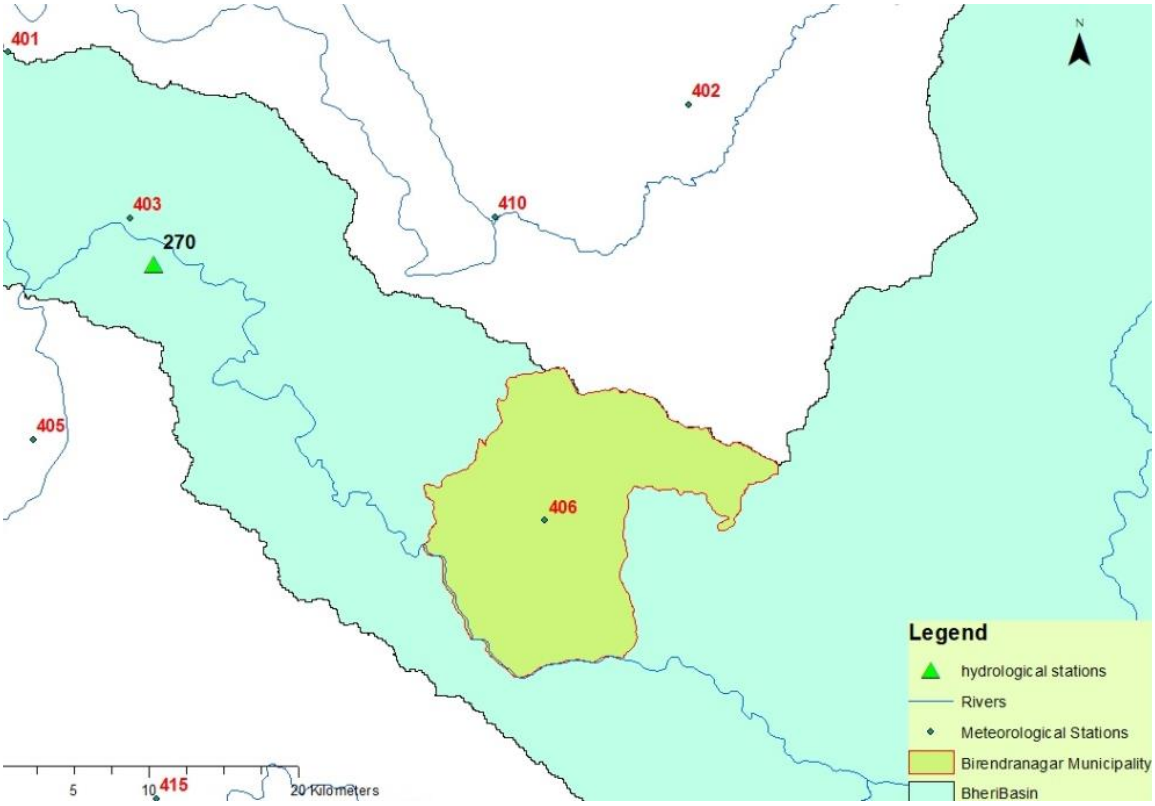


Map 0-2: Bheri watershed and location of Birendranagar Municipality

1.71 DATA AND METHODOLOGY

1.71.1 DATA USED

There is one meteorological station (406) inside the municipality Map 0-3 . The rainfall and temperature data are collected from this station. The average of monthly sum of rainfall Figure 0-1shows that there is a high rainfall in the month of July and minimum in the month of December. The average annual rainfall is around 1500mm.The average of minimum temperature is ranging from 5 to 23 degree Celsius and maximum temperature is ranging from 20 to 34 degree Celsius (Map 0-3) recorded in this station.



Map 0-3: Hydro meteorological stations inside and outside the municipality

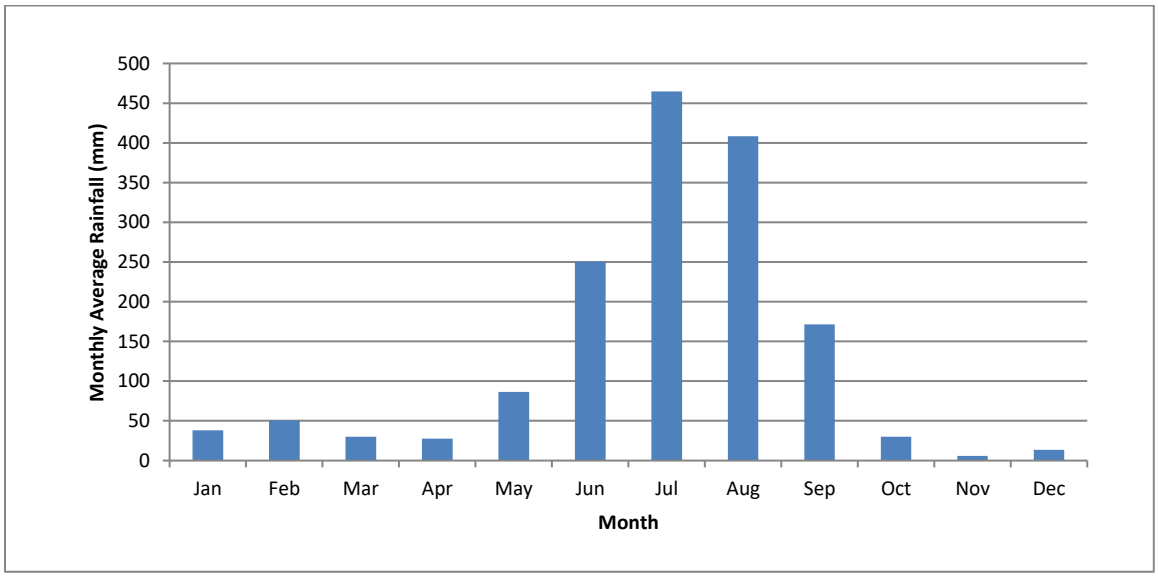


Figure 0-1: The daily monthly rainfall data plot of station 406 in Birendranagar

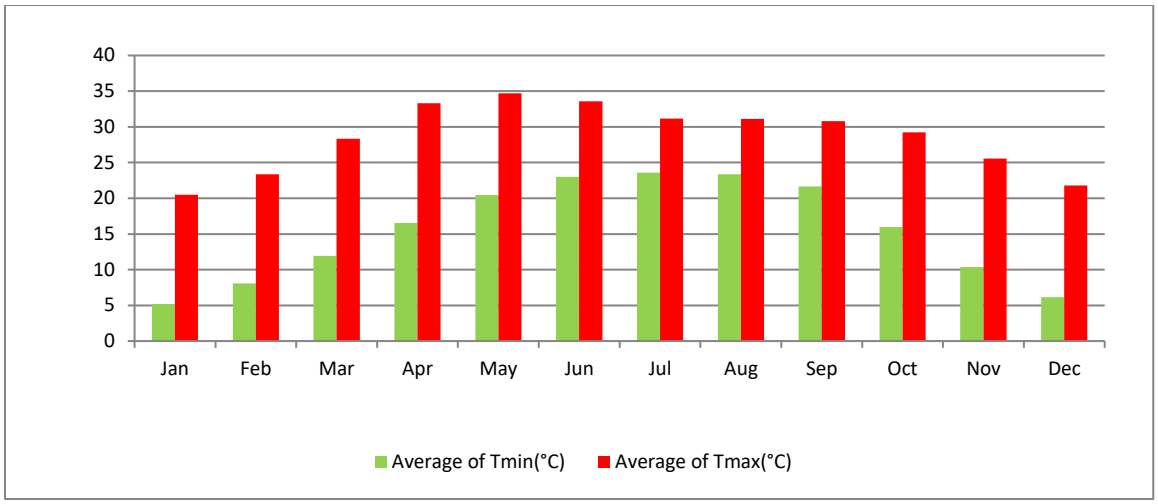
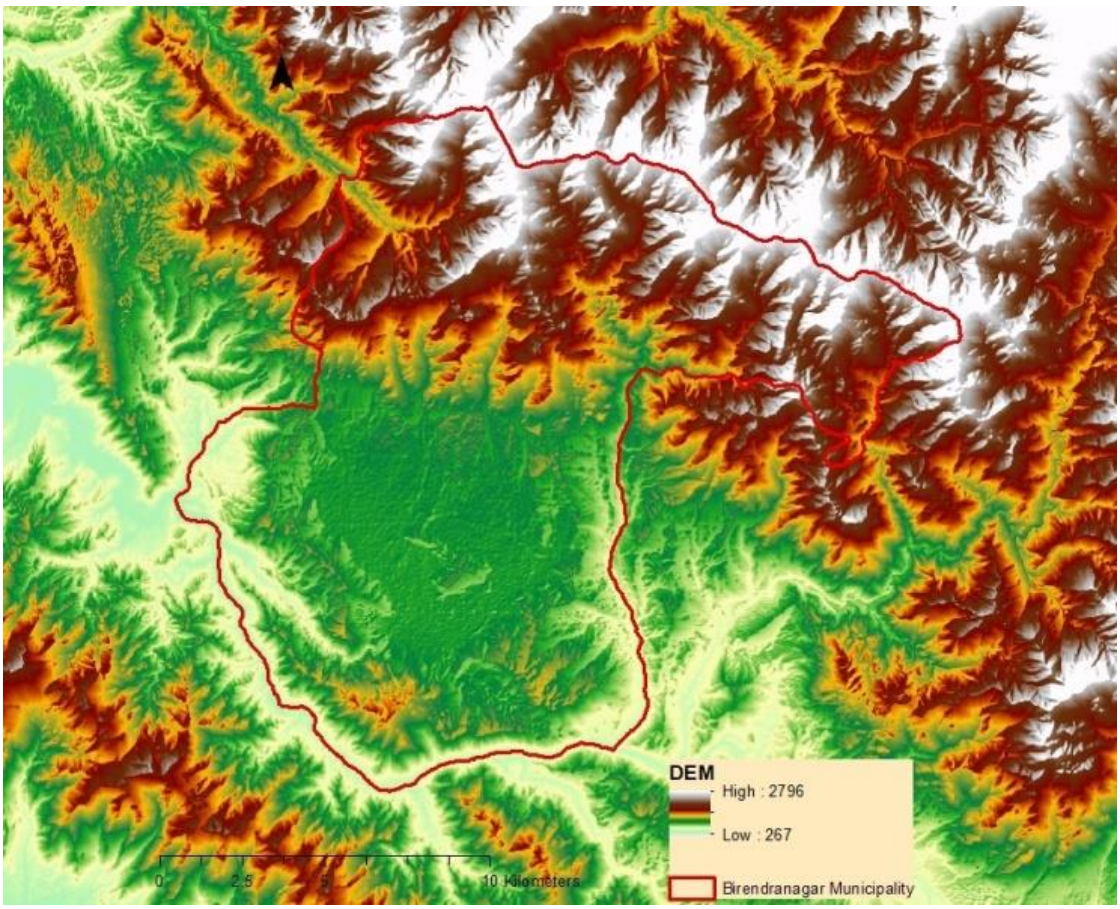


Figure 0-2: Mean of maximum and minimum temperature

The 5meter resolution DEM (Digital elevation model figure) and satellite image provided by TAYAR project are used as base for preprocessing of geometry data and hydraulic modeling and mapping. Field work was carried out for river cross section survey and discharge measurements. The field surveyed cross section data are applied for the model result validation.



Map 0-4: Slope map

Map 0-5: Five meter resolution DEM and Image used for Birendranagar Municipality

1.71.2 METHODOLOGY

The model based flood hazard assessment and mapping for the Bheri River and its tributaries was completed using hydraulic modelling using one dimensional HEC-RAS (Hydrologic Engineering Center-River Analysis System) and HEC GEORAS tool. The preprocessing of necessary geometric data such as river center line, bank lines, flow path lines and cross sections were extracted in HEC Geo-RAS and the different return period flood depth were analyzed in HEC-RAS. For the purpose of risk zonation of the inundation area, steady state conditions are considered for different return period flood. In HEC-RAS water surface profiles are computed from one cross section to the next by solving the energy equation with an iterative procedure (HEC-RAS River Analysis System,Hydraulic reference manual, 2016). The energy equation is given by:

$$Z_2 + Y_2 + \frac{a_2 V_2^2}{2g} = Z_1 + Y_1 + \frac{a_1 V_1^2}{2g} + h_e$$

Where Z_1 Z_2 = elevation of the main channel inverts

$Y_2 Y_1$ = depth of water at cross sections

V_1, V_2 = average velocities

a_1, a_2 = velocities weighting coefficients

g = gravitational acceleration

h_e = energy head loss

Before the hydraulic modeling, the hydrology of the area and flood frequency analysis was performed. The figure below shows detail methodology for flood modeling and hazard analysis.

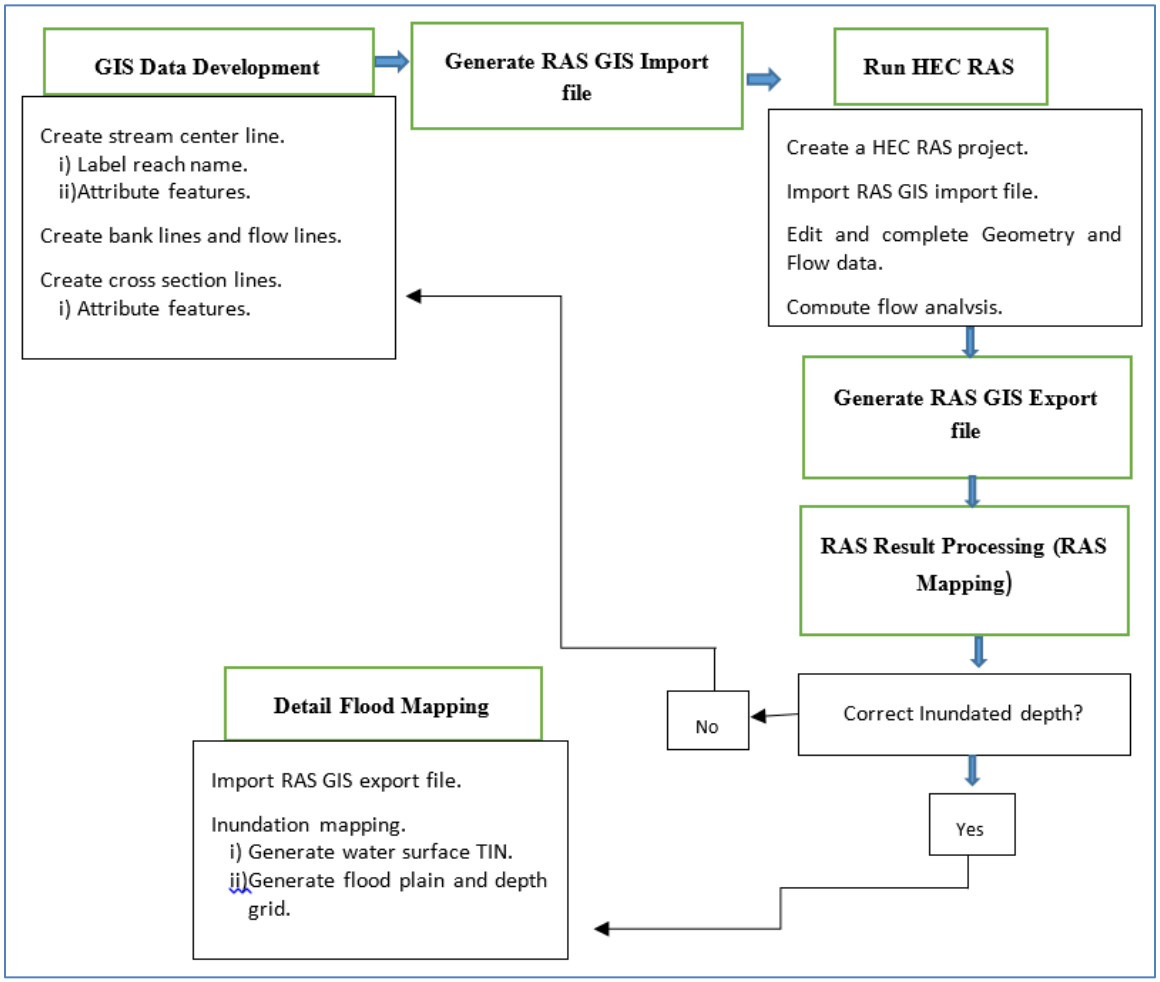


Figure 0-3: Methodology frameworks for flood modeling in HEC RAS

1.71.3 HYDROLOGICAL STUDY AND FLOOD FREQUENCY ANALYSIS

The cross section survey and discharge measurement was conducted for the Bheri River and other streams flowing inside the Municipality. For the Bheri River, the discharge data is available at the gauge station number269 (DHM) at Samaijhighat. The mean monthly flow and annual peak flow is shown in Figure 0-4 and Figure 0-5 below. The flood flow for different return period Table 0-1 of Bheri River is estimated by using the statistical method, Gumbel distribution function which is best for annual extreme discharge data. This method used the historical annual maximum discharges Figure 0-5 of the Bheri River. The equation of Gumbel's distribution for any return period is given by $X_T = X + K\sigma_x$ where σ_x is standard deviation of the sample size; k is frequency factor, X is mean of annual peak discharges and X_T is magnitude of peak discharges for different return period T.

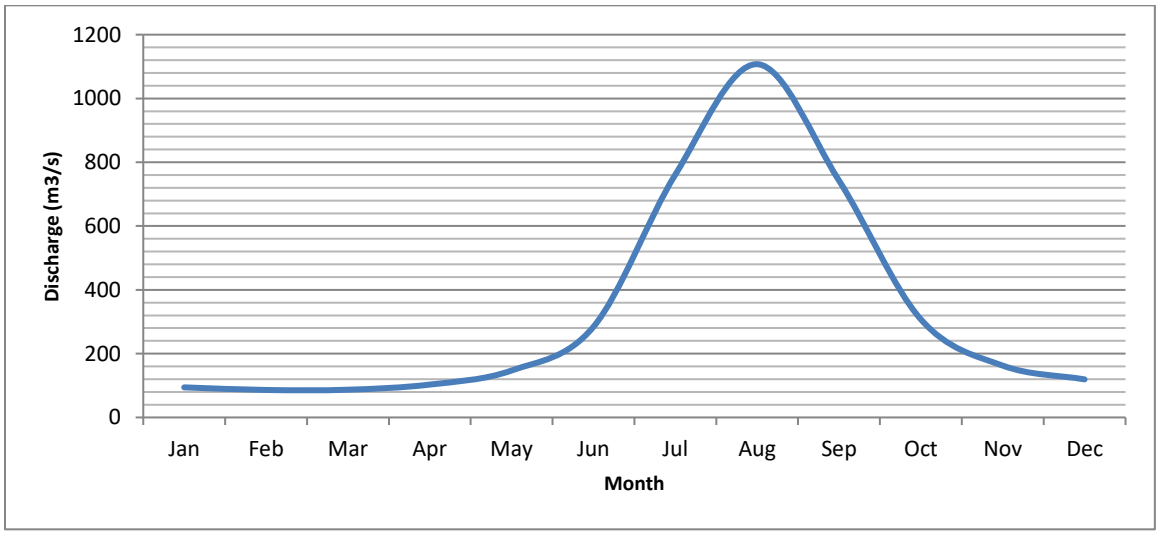


Figure 0-4: Monthly flow at the station at Samaijighat

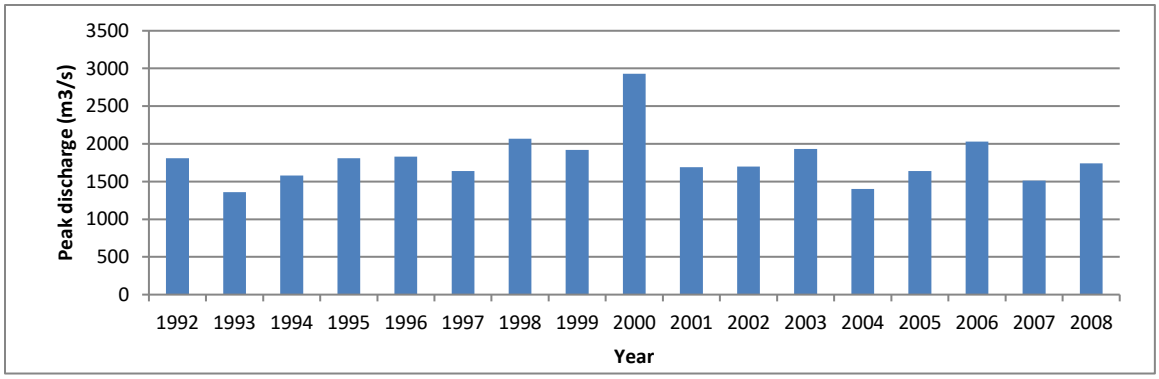


Figure 0-5: Annual maximum discharges at the station 269, Samijighat

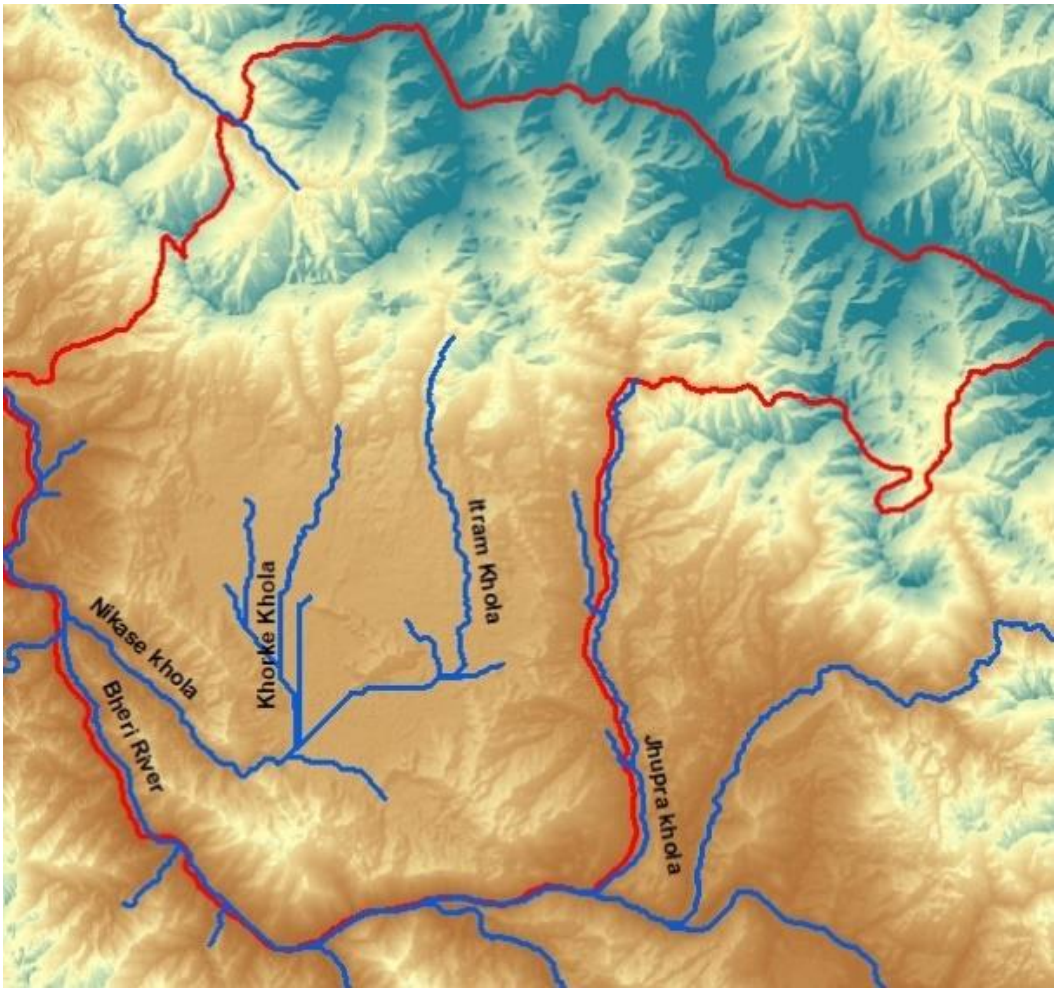
Table 0-1: Flood flow for different return period

RETURN PERIOD	FLOW (M3/S)	RETURN PERIOD	FLOW (M3/S)
2	1798.62	100	3550.58
5	2267.66	200	3838.46
10	2578.20	500	4218.27
50	3261.65	1000	4505.31

Most of the streams Map 0-6 inside the municipality are originating from the Siwaliks and they are non-runoff type of river. The major streams and their watershed area of these streams delineated in GIS is given below in table. They are mostly dry during our field work and it gets flows only during monsoon period. The Municipality may be affected by seasonal flood from these streams as there is increase of settlement, urbanization, and deforestation which contribute to the increase of runoff and sedimentation. Since the flow data are not available for the rivers inside the Municipality, the flow data required for flood modeling are estimated with different empirical methods used for Nepal watersheds by WECS. The empirical methods used for flow calculation are described below.

Table 0-2: Major tributaries with water shed area

MAJOR TRIBUTARIES	WATERSHED AREA (SQ.KM)
Khorke Khola	40.3
Itram Khola	46.2
Jhupra Khola	89.8
Girighat Khola	51.4
Tuni Khola	7.3
Neware Khola	13.5



Map 0-6: Tributaries to inside Birendranagar Municipality

1.71.4 RATIONAL METHOD

The different return period peak runoff rates for the small catchments and their river are estimated with the rational method which is based on empirical formula. The empirical formula developed by Water and Energy Commission Secretariat (WECS) generally used for the catchment area less than 12km^2 and catchment area lies in urban and rural area (WECS, 2019). WECS has formulated rational method as given below.

$Q = 0.278 C_T \ I_{T_t}$ A

Where,

Q= Discharge (m^3/s)

A= Area of the catchment (Km^2)

C_T = runoff coefficient

I_{T_t} = rainfall Intensity (mm/hr)

Rainfall intensity in cm/hr for given return period T (years) and time of concentration t (min)

The time of concentration in minute is determined by the kirpich equation given by t= $57\ (\frac{L^3}{H})^{0.385}$

Where, L is the length of watershed (km) and H is the difference in elevation (m). The runoff coefficients are taken from the Chow, Maidment and Mays (1998). The runoff coefficient values are depending on catchment surface and return period.

1.71.5 WECS/DHM METHOD

The Water and Energy Commission Secretariat (WECS) has developed an approach to estimate the flood flows in any ungauged catchment area below 3000 m elevation. The 2 year (Q_2) and 100 year (Q_{100}) return period floods are given by:

- Q_2 =2.29 x (A<3k) $^{0.86}$
- Q_{100} = 20.7x (A< 3k) $^{0.72}$
-

- Where Q is the flood discharge in m3/s and A is the basin area insq.km. The subscripts 2 and 100 indicate 2-year and 100-year flood respectively. Similarly, subscript <3k indicates area below 3000m.
- Based on the algebraic evaluation of the equations used for lognormal distribution, the following relationships (WECS/DHM, 1990) can be used to estimate flood at other return periods.
- The flood for any return period of years is given by:
- $Q_f = e^{(\ln Q_2 + s\sigma)}$
- Where, s = standardized normal variable for a particular return period,
  - $\sigma = \ln\left(\frac{Q_{100}}{Q_2}\right)/2.326$

Table 0-3: Values of S for different return periods

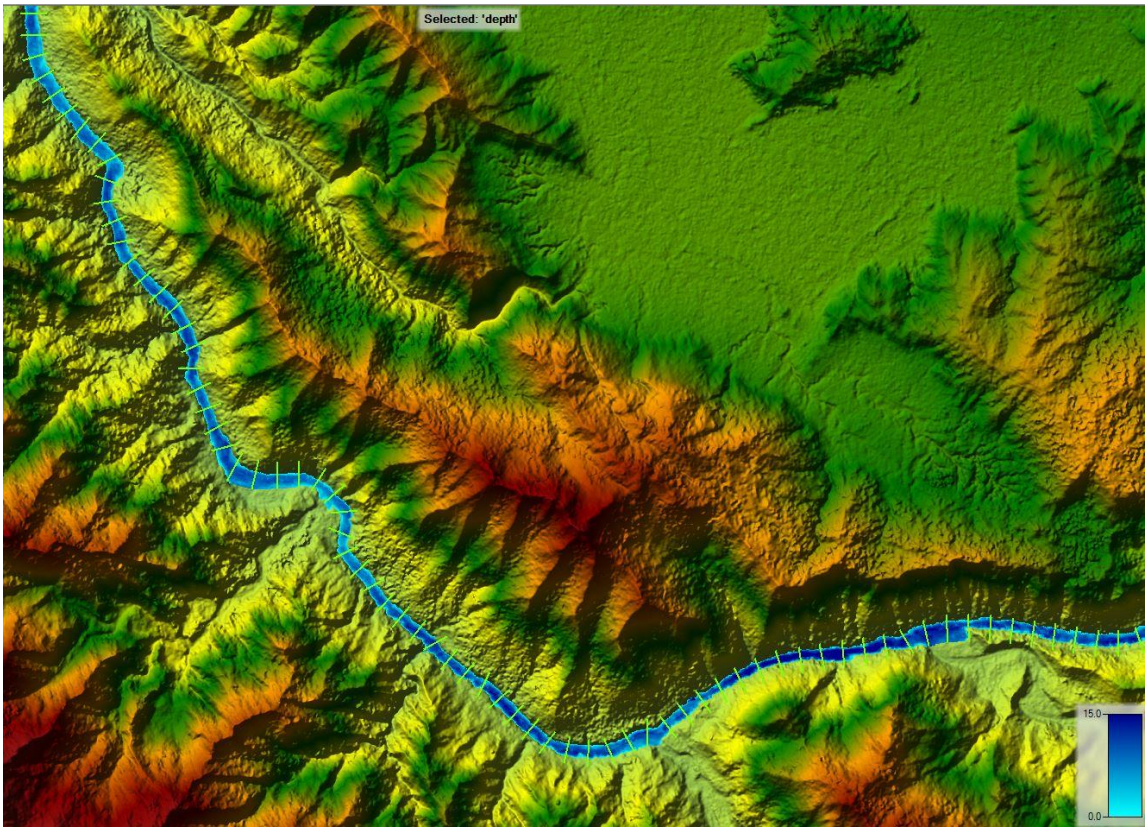
RETURN PERIOD	2 YRS	5 YRS	10 YRS	20 YRS	50 YRS	100 YRS	200 YRS	500 YRS	1000 YRS
S	0	0.842	1.282	1.645	2.054	2.326	2.576	2.878	3.090

1.72 HYDRAULIC MODELING AND FLOOD MAPPING

The geometry data such as river centerline, bank lines, flow paths and cross sections lines are prepared for the rivers in Birendranagar Municipality Map 17-7. These geometry databases are required for the flood model and they are prepared in HEC-GEORAS. The 5m resolution DEM provided was used to extract the different properties for stream and cross section as GEORAS import file. The manning's value n for different land use and channel are refereed by Chow (1959) to use in HEC RAS model.

HEC-RAS model perform 1D water surface profile calculation for steady flow 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, gravitational acceleration etc. and the resulting depth were produced based on given terrain or DEM (grid) to analyze for the assessment of different risk level such as high, medium or low risk level based on the depth of flood water.

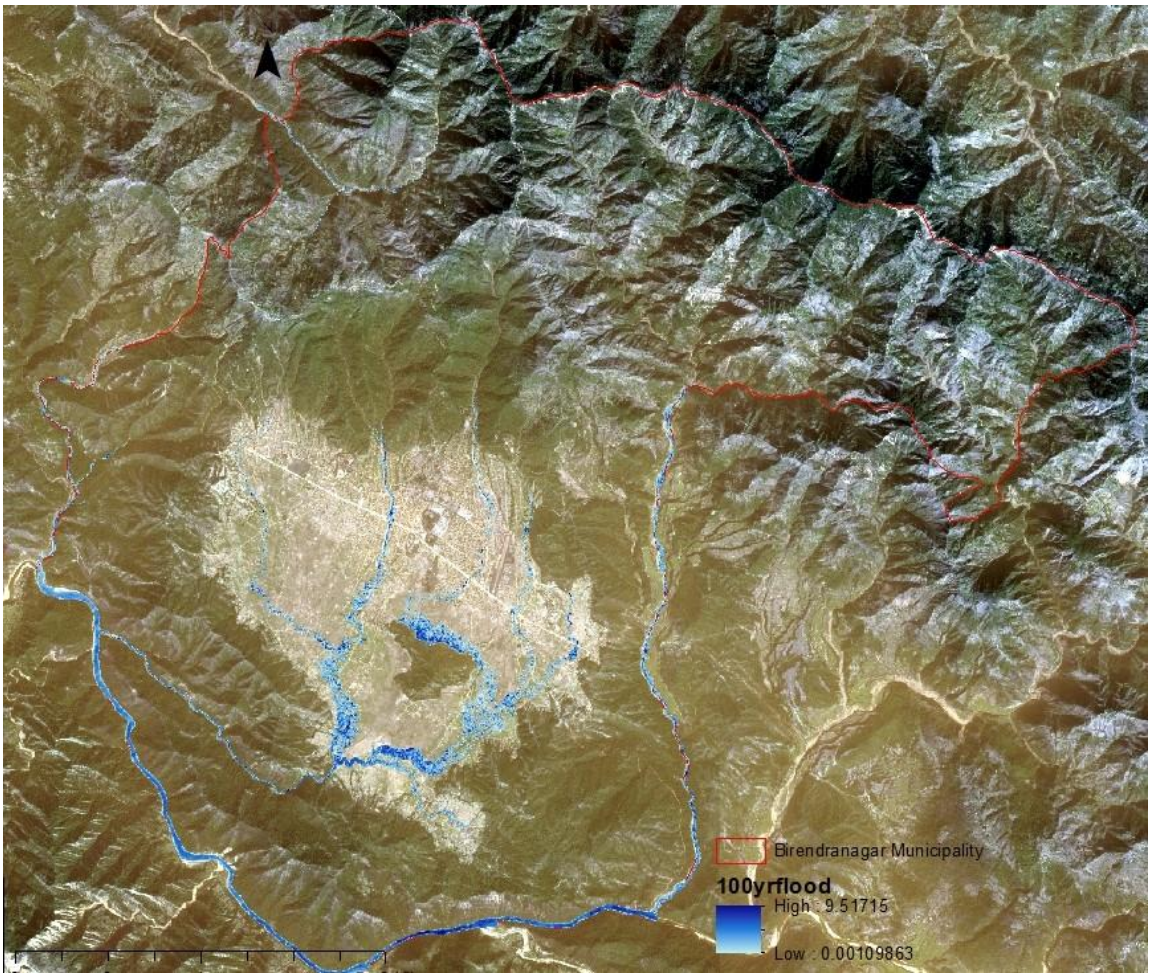
Map 0-7: Geometry data prepared in HEC GEO RAS for Bheri River



Map 0-8: Flood water depth of Bheri River as a output from HEC RAS Model

1.72.1 RESULTS AND DISCUSSIONS

With the output result of HEC RAS modeling the inundation scenarios for the different return period flood flows are generated. The output result is calibrated with the help of data from cross section field survey by comparing the simulated flood water depth with high flood level data from the field. The spatial inundation of water depth of different return periods was prepared with the HECGO-RAS in GIS. Map 0-9 below is the flood inundation scenario of 100 year return period flood given by flood model. According to the flood depth classification simulated by the model, the low, medium and high risk area can be identified.



Map 0-9: 100 year return period flood depth for the rivers in Birendranagar Municipality

The settlements built near to the Khorke, Itram khola, Neware Khola are at risk of flooding. There are risks of flooding in downstream area by these streams and there is a high possibility of inundation of large area of land at the confluence of those all small rivers downstream at inlet to the Nikashe Khola due to improper drainage provisions and urban settlements and urbanization at upstream area.

Table 0-4 Wardwise Distribution of Flood

Ward	Ward (ha)	Low (ha)	Low %	Medium (ha)	Medium %	High (ha)	High %
1	1423.55	3.83	0.27	3.69	0.26	11.24	0.79
2	2909.42	19.84	0.68	17.85	0.61	66.85	2.30
3	660.28	12.14	1.84	9.13	1.38	12.13	1.84
4	703.99	2.21	0.31	2.14	0.30	3.94	0.56
5	576.14	0.33	0.06	0.25	0.04	0.34	0.06
6	58.99	0.55	0.94	0.46	0.77	0.93	1.58
7	523.46	2.11	0.40	1.73	0.33	2.16	0.41
8	140.79	0.94	0.67	0.71	0.50	0.97	0.69

9	2876.51	19.88	0.69	21.63	0.75	143.31	4.98
10	1697.18	37.38	2.20	40.76	2.40	94.74	5.58
11	2664.87	14.48	0.54	14.80	0.56	46.98	1.76
12	880.32	5.93	0.67	4.12	0.47	3.15	0.36
13	2585.00	4.70	0.18	5.28	0.20	15.89	0.61
14	2969.04	4.20	0.14	4.39	0.15	7.77	0.26
15	2456.86	0.04	0.00	0.04	0.00	0.19	0.01

FIRE HAZARD

1.73 FOREST FIRE

1.73.1 INTRODUCTION

Forest fire can be described as any uncontrolled and non-prescribed or burning of plants in a natural setting such as forest, grassland, bush which consumers the natural fuels and spreads based on environmental conditions (e.g. wind, topography). It can be the result of human actions or nature caused by lightning (UNSpider, 2017). Hot, windy weather further exacerbates the fire.

Remote sensing can be used to detect forest fire. Moderate Resolution Imaging Spectroradiometer (MODIS) is used to detect forest fire. Whenever the product detects a "hot spot," it flags the signal's location in the data set. When the data get turned into an image, the fire-detection locations from the product are added as an overlay on the image, which marks the fires in bright red (NASA, 2021). This study also has used MODIS data for studying the trend and hotspot of forest fire in Nepal.

1.73.2 METHOD

Forest Fire Trend

Historical fire incident data (2010- till date) recorded by moderate resolution imaging spectroradiometer (MODIS) was obtained from NASA (https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms/active-fire-data). The fire detection strategy is based on absolute detection of a fire (when the fire strength is sufficient to detect), and on detection relative to its background (to account for variability of the surface temperature and reflection by sunlight (NASA, 2021).

1.73.3 HOTSPOT ANALYSIS

Hotspot analysis was done to identify the areas where forest fire is concentrated using Getis-Ord. It compares the values of each feature with neighboring features within a user specified distance. An area can be a hotspot, when a higher than average occurrence of the event being analyzed is found in a cluster. The higher above the average with similar surrounding areas the 'hotter' the hotspot (Kumari & Pandey, 2020).

1.73.4 RESULT

Forest Fire Trend

From 2010 to 2021, a total of 175 forest fire incidents were recorded by MODIS. Highest forest fire was recorded in 2016 and 2021. Figure below shows the trend of forest fire incidents in the municipality,

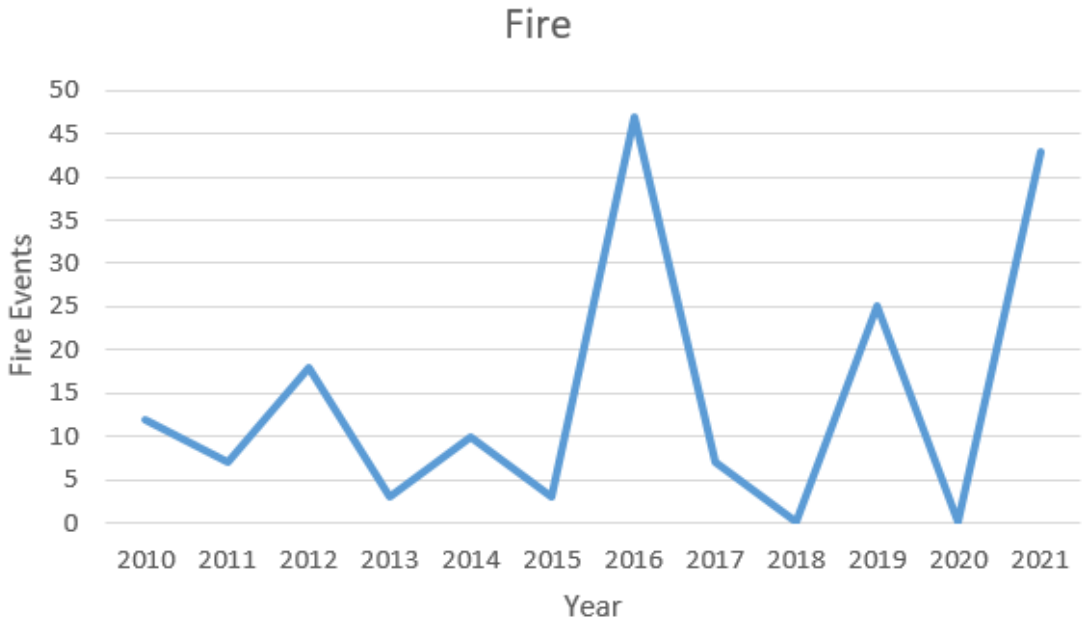
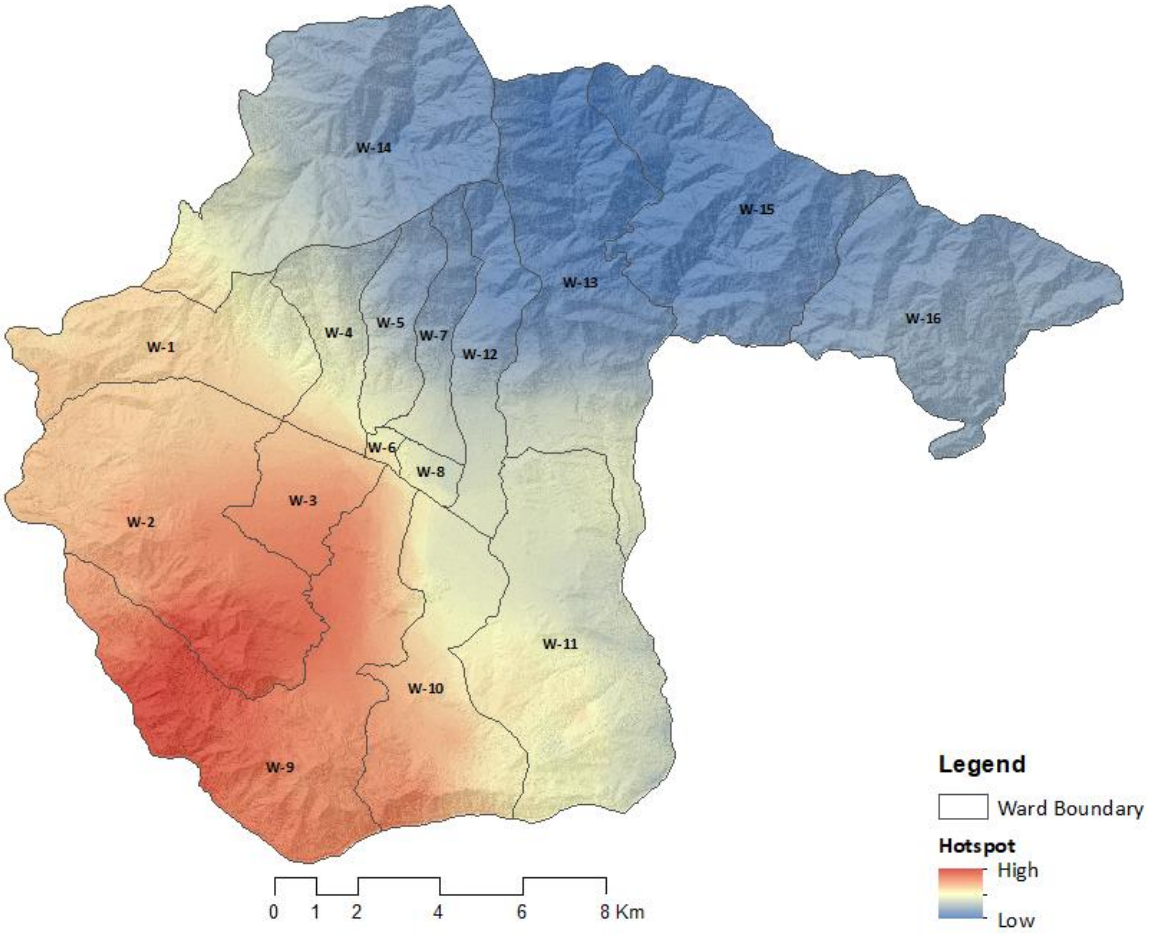


Figure 0-1: Forest Fire Trend (2010-2021)

Hotspot analysis

Hotspot analysis showed that the forest fire hotspots were present in the South Western parts of the municipality and are presented in following figure.



Map 0-1: Forest Fire (Hotspot)

1.74 URBAN FIRE SUSCEPTIBILITY

1.74.1 INTRODUCTION

Urbanization is increasing at an alarming rate in Nepal. Urbanization leads to house densification in both planned and unplanned settlements. The densification, coupled with insufficient number of fire brigades, trained fire fighters, absence of wide road, water facilities, lack of fire protection policies and safety codes for the use of electricity, gas and other inflammable fuel increases the likelihood of fire risk occurrence and spread (Dhakal & Sharman, 2021; Mtani & Mbuya, 2018). Fire in highly dense areas have potential to rapidly spread to adjacent structures causing huge damage to life and property (Eugene, 2021). In order to subdue problems caused by fire, a systematic study related with fire such as mapping of area affected by fire, mapping of fire potential zone have to be undertaken (Chhetri & Kayastha, 2015).

1.74.2 METHOD

Urban fire susceptibility assessment was done using multi-criteria evaluation (MCE). It involves identifying factors, assigning weights and combining factors using weighted linear combination to meet specific objective (Omar & Raheem, 2016).

Seven different factors (Table 0-1) were identified based on available data, literatures and in consultation with relevant experts. Analytical Hierarchy Process (AHP) method, introduced by (Saaty, 1987), was used to determine the weights of each factor and check the consistency of the weight. AHP is a "theory of measurement through pairwise comparisons and relies on the judgment of experts to derive priority scales". In AHP, comparisons are made using a scale of absolute judgment that represents how much one element dominates another with respect to a given attribute. There are possibilities for the judgment to be inconsistent. AHP helps to check such inconsistency and improve judgment (Saaty 2008).

To check the consistency of the judgment or comparison made, consistency ratio (CR) was calculated. If CR is greater than 10% i.e. > 0.10, then the weighted result indicates the presence of inconsistencies in the pairwise comparison matrix. Here, consistency ratio obtained was 0.03, which shows comparison is acceptable, and the eigenvector obtained for each factors can be used to assign weight to it.

Table 0-1: Factors and Weight Assigned to Each Factor

SN	FACTORS	WEIGHT
1	Building typology	0.4016
2	Building density	0.2312
3	Distance from petrol pumps	0.1527
4	Distance from fire station	0.0944
5	Distance from forest	0.0581
6	Distance from road	0.037
7	Land use land cover	0.025

Weighted linear combination (WLC) was used to identify the susceptible areas. In WLC, susceptibility (S) is identified by applying weight to each factor followed by summation of the result i.e. standardized factor map is multiplied by its factor weight, and the result is then summed. If constraint is applied, the suitability obtained from the factors is multiplied by the constraint to get the suitability map (Eastman, 1999).

$S = (\sum W_i * X_i) \times C_j$

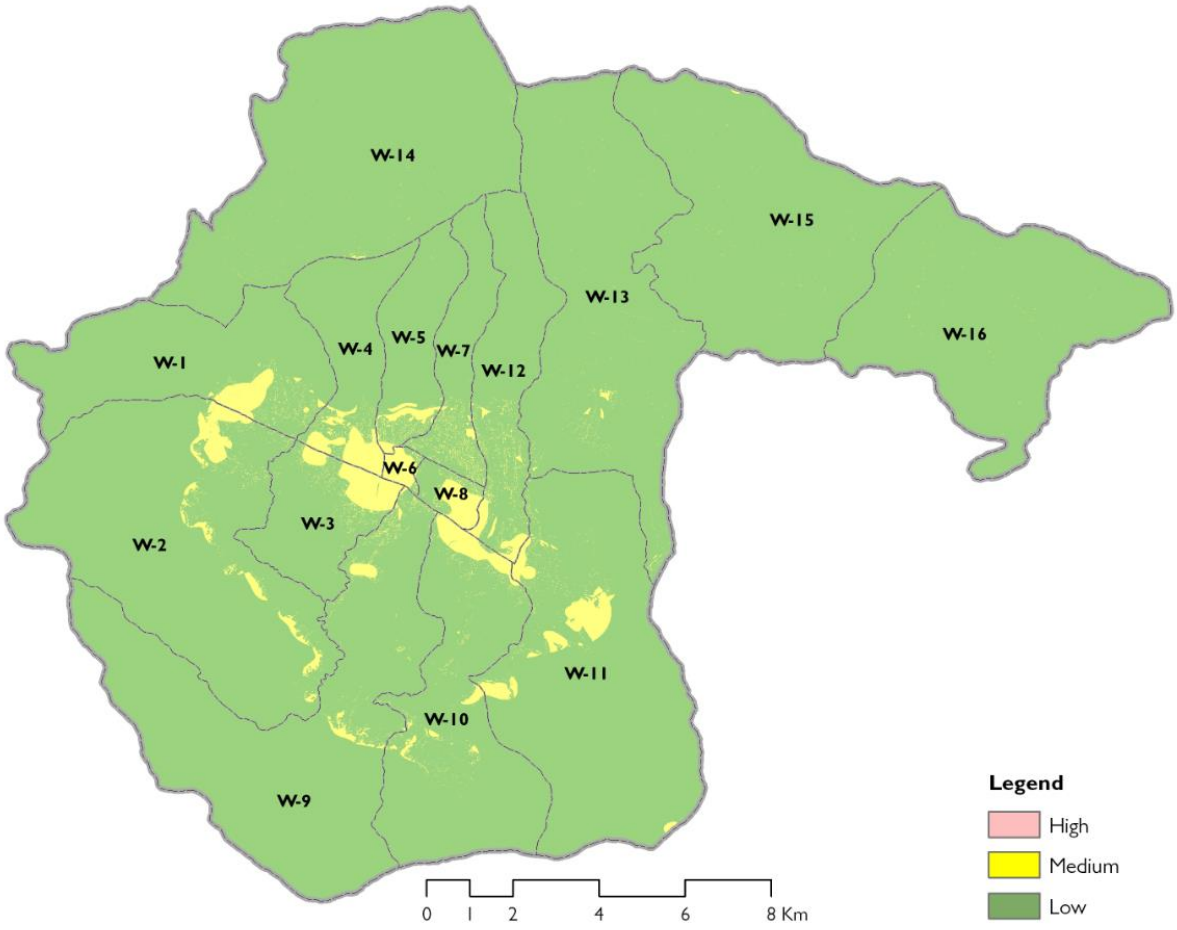
Where, W_i = Weight of factor i; X_i = Criterion score of factor i; C_j = Criterion score of constraint j

1.74.3 RESULT

Based on MCE, around 4.69 ha of the municipality was highly susceptible to urban fire, while 1034.15 ha was moderately susceptible to urban fire.

Table 0-2: Urban Fire Susceptibility

Ward	Total Area (ha)	Low (ha)	Low (%)	Medium (ha)	Medium (%)	High (ha)	High (%)
1	1423.55	1341.1452	94.21	82.032	5.76	0.38	0.03
2	2909.42	2770.5548	95.23	138.1236	4.75	0.7288	0.03
3	660.28	543.836	82.36	116.4408	17.64	0.0064	0.00
4	703.99	603.258	85.69	100.6776	14.30	0.0488	0.01
5	576.14	533.5888	92.61	42.554	7.39	0	0.00
6	58.99	11.4836	19.47	47.4632	80.47	0.0384	0.07
7	523.46	497.9276	95.12	25.5208	4.88	0.0024	0.00
8	140.79	72.0544	51.18	68.6516	48.76	0.0768	0.05
9	2876.51	2822.1092	98.11	54.304	1.89	0.1228	0.00
10	1697.18	1586.086	93.45	110.9076	6.53	0.1768	0.01
11	2664.87	2507.8092	94.11	156.5764	5.88	0.4808	0.02
12	880.32	816.164	92.71	64.0588	7.28	0.1104	0.01
13	2585.00	2569.0876	99.38	15.724	0.61	0.2056	0.01
14	2969.04	2963.768	99.82	4.4012	0.15	0.8244	0.03
15	2456.86	2452.45	99.82	3.6664	0.15	0.7212	0.03
16	2219.45	2215.6024	99.83	3.048	0.14	0.7708	0.03
Total	25345.84	24306.9248	95.90	1034.15	4.08	4.6944	0.02



Map 0-2: Urban Fire Susceptibility

1.75 VAPOR CLOUD EXPLOSION

In Birendranagar Municipality, there are petrol pumps that can cause explosion and fire in case of accidental release and ignition. Such event can be categorized as Vapor Cloud Explosion (VCE). VCE is a process where combustion of premixed gas results in a rapid increase in pressure. When a large amount of flammable vaporizing liquid of gas is rapidly released from different sources like storage tank, process, transport vessel or pipelines, a vapor cloud forms and disperses with surrounding air. If the cloud gets ignited before the cloud is diluted below its lower flammability limit, the cloud will burn very fast and would result in the formation of a blast wave with considerable overpressure. This can cause huge loss of life and property (Renjith & Madhu, 2010).

1.75.1 METHOD

In Birendranagar Municipality, there are 8 petrol pumps with different capacities. The different capacities of petrol and diesel in each petrol pump are presented in following table. Other parameters for VCE modeling were obtained from different literatures.

Table 0-3: Petrol pump with capacity

SN	Petrol Pump	Diesel (ltr)	Petrol (ltr)
1	Dipmala Oil store	60,000.00	12,000.00
2	Bhubaneshwori Oil store	4,400.00	22,000.00
3	Bulbule Oil Store	54,000.00	22,000.00
4	Uma Petrol pump	66,000.00	16,000.00
5	Narayan Petrol Pump	35,000.00	20,000.00
6	Ganga Maya OilStore	80,000.00	40,000.00
7	Shankar Oil Store	62,000.00	36,000.00
8	Surkhet Oil Store	20,000.00	16,000.00

Source: Field Survey data 2021

Multi-Energy Model was used for VCE modeling. It treats vapor cloud explosion as a number of sub-explosions and recognizes that the explosive potential of a vapor cloud is primarily determined by the blast generative properties of the environment in which the vapor is released and disperses (CCPS, 2010). The general methodological framework for VCE modeling is presented in figure below.

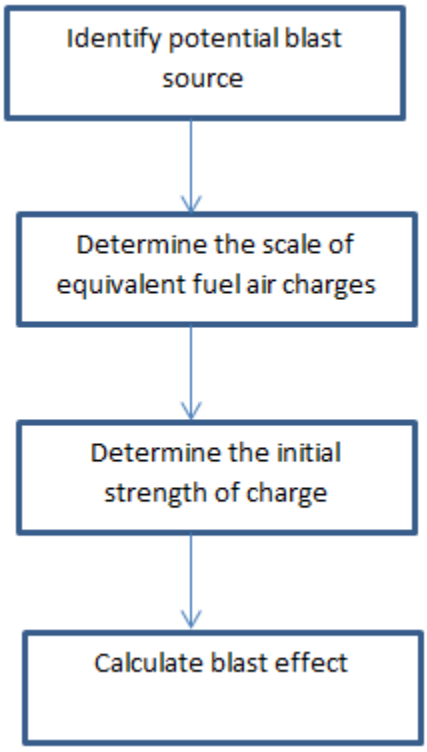


Figure 0-2: Methodological framework for VCE

First, the potential blast sources are identified, and then the scale (size) of equivalent fuel air charge is determined using volume and heat of combustion. Once size of equivalent fuel air charge is determined, the strength of charge is determined. The fuel air charge expressing the explosion severity of the source of strong blast is assumed to be of strength number 10, while the fuel air charge expressing the explosion severity within the rest of the vapour cloud is assumed to be of strength number 2. Once the equivalent charges expressing the vapor cloud's potential explosion severity are known, corresponding blast effects can then be determined. The blast effect is determined using the side on peak over pressure, which can be calculated using following equations.

$$\overline{R} = \frac{R}{(E/P_0)^{1/3}}$$

$$\Delta Ps = \Delta \bar{P}s \, Po$$

Where,

$\overline{R}$ = non dimensionalized distance from charge

R= distance from charge

E= charge Combustion energy

Po = ambient pressure

ΔPs = side on peak over pressure

$\Delta \bar{P}s$ = non dimensionalized side on peak overpressure

1.75.2 RESULT

Analysis showed that side on peak over pressure had inverse relation with distance. As the distance increased, the overpressure decreased. The overpressure was significantly high within 5-15m of the source of petrol pumps, depending on the quantity of fuel, which then sharply declined till 100 m. From 100 m onward, overpressure declined slowly with increasing distance.

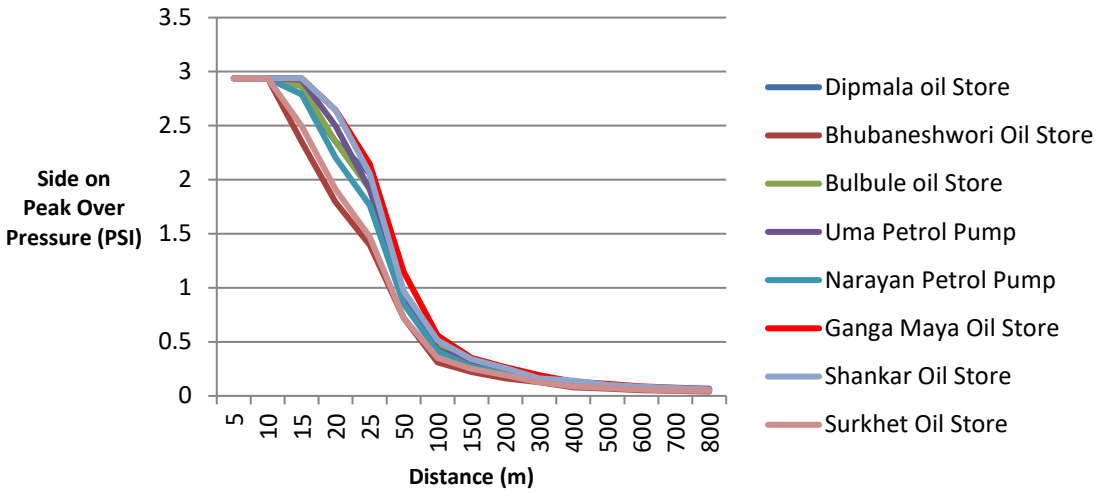


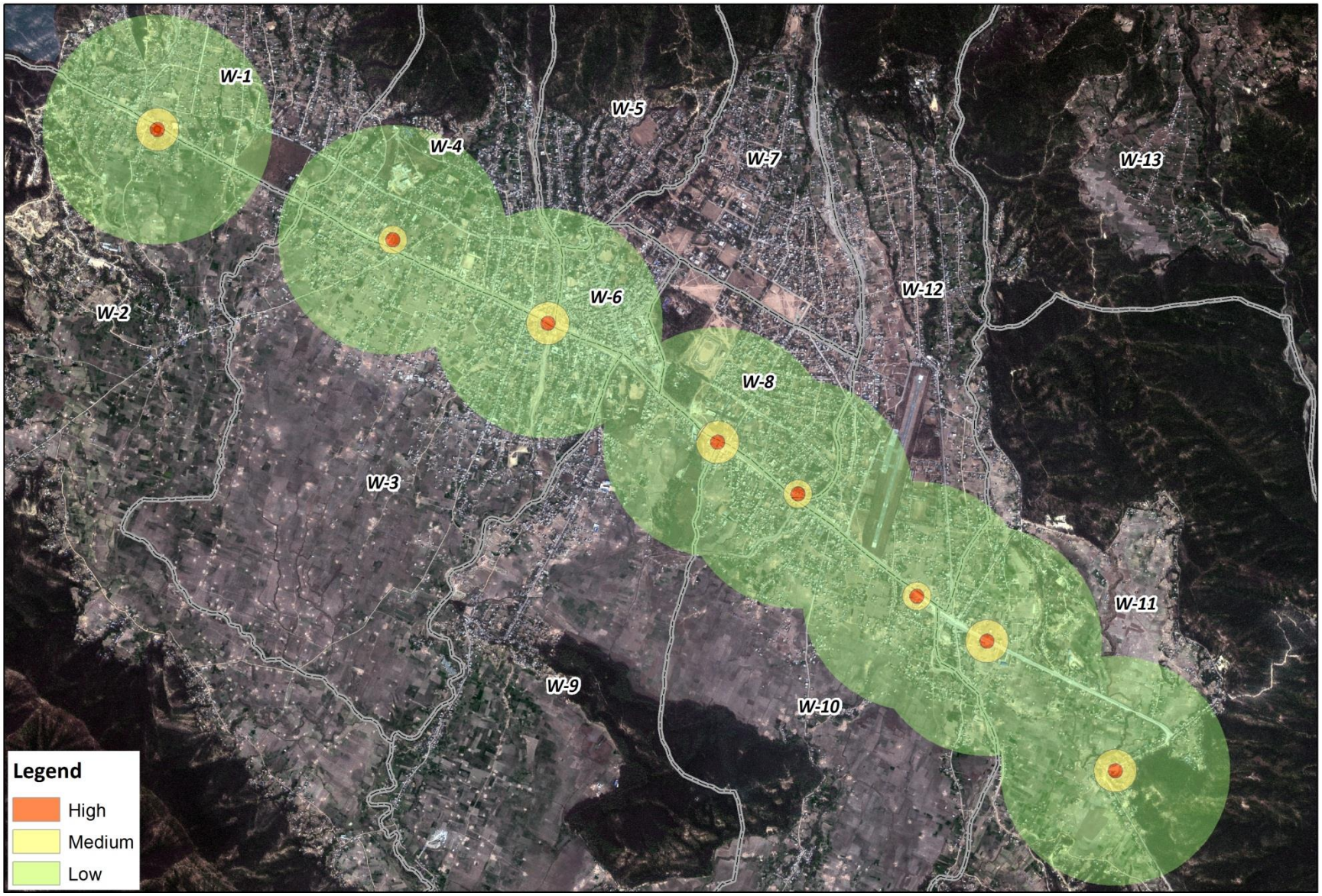
Figure 0-3: Side on peak overpressure of different VCE sources

The levels of hazard- low, medium and high- was categorized based on side on peak over pressure value and the distance it covered. The distance at which the side on peak over pressure was less than 0.3 PSI was considered as low hazard zone, while distance at which the side on peak overpressure was 0.3-0.7 PSI and above 0.7 PSI was considered as medium and high hazard zone respectively.

The total area of high, medium and low hazard zone was 6.27 ha, 38.46 ha and 1259.63.14 ha respectively.

Table 0-4: Vapour Cloud Explosion

Ward	Total Area (ha)	Low (ha)	Low (%)	Medium (ha)	Medium (%)	High (ha)	High (%)
1	1423.55	102.73	7.22	2.75	0.19	0.17	0.01
2	2909.42	102.06	3.51	3.53	0.12	0.61	0.02
3	660.28	163.43	24.75	3.51	0.53	0.33	0.05
4	703.99	124.02	17.62	3.73	0.53	1.23	0.18
5	576.14	7.41	1.29	0.00	0.00	0.00	0.00
6	58.99	49.99	84.76	1.40	2.37	0.00	0.00
7	523.46	0.01	0.00	0.00	0.00	0.00	0.00
8	140.79	94.87	67.38	4.09	2.90	0.87	0.62
9	2876.51	66.41	2.31	1.84	0.06	0.32	0.01
10	1697.18	169.06	9.96	3.93	0.23	0.93	0.05
11	2664.87	292.94	10.99	12.56	0.47	1.57	0.06
12	880.32	86.72	9.85	1.13	0.13	0.24	0.03
13	2585.00	0.00	0.00	0.00	0.00	0.00	0.00
14	2969.04	0.00	0.00	0.00	0.00	0.00	0.00
15	2456.86	0.00	0.00	0.00	0.00	0.00	0.00
16	2219.45	0.00	0.00	0.00	0.00	0.00	0.00
Total	25345.84	1259.63	4.97	38.46	0.15	6.27	0.02



Map 0-3: VCE hazard map of Birendranagar Muncipality

1.75.3 DISCUSSION

The categorization of different levels of hazard- low, medium and high- depends on side on peak overpressure value and the distance it covers. Low hazard zone is considered as a safe distance zone as probability of serious damage is less than 95 percent. In low hazard zone, there can be annoying noise and occasional breaking of glass. In medium hazard zone, there is minor structure damage like damage to window frame, while in high hazard zone, there is major structural damage.

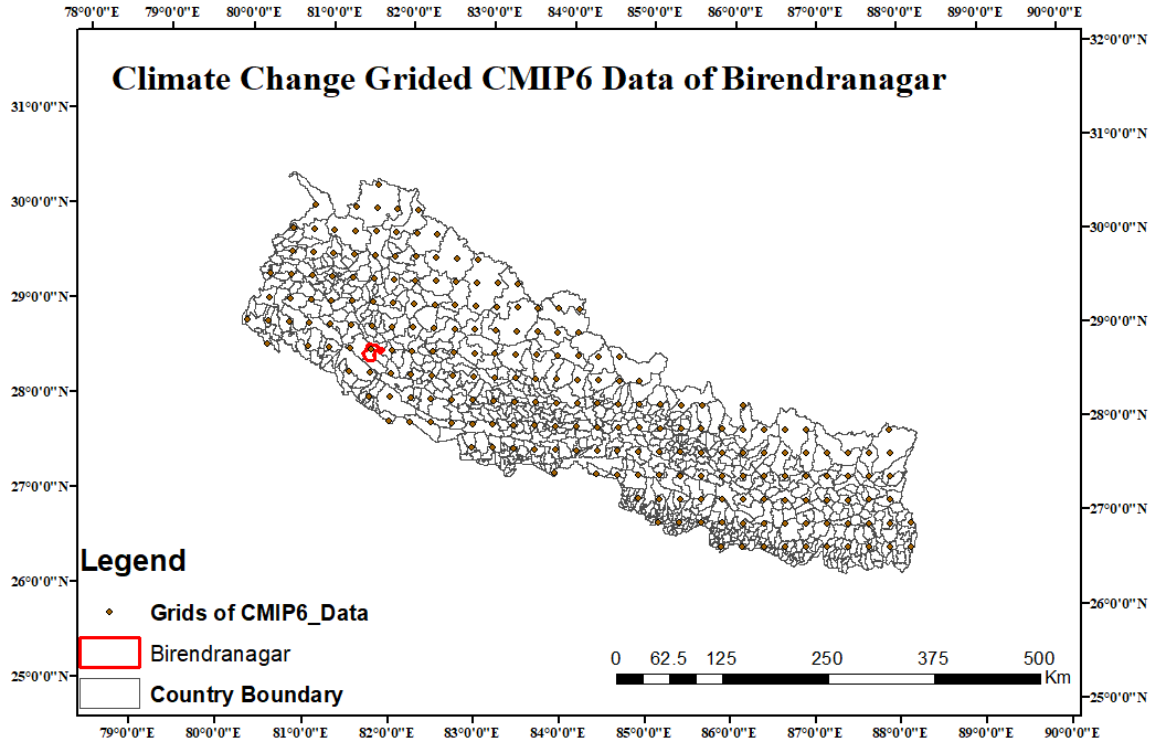
CLIMATE HAZARD

1.76 METHOD AND ANALYSIS

Methodology of data collection and climate change analysis

The observed daily precipitation and temperature data of Birendranagar stations from 1990 to 2020 were obtained from the Department of Hydrology and Meteorology, Government of Nepal. The missing rainfall data were replaced by normal ratio method and missing temperature in small gaps were filled by simple linear interpolation and large number of missing values estimated by lapse rate methods. The climate change three scenarios of gridded (about 27.75 km) CMIP6 daily precipitation, maximum temperature and minimum temperature data were collected from Australian Community Climate and Earth System Simulator Coupled Model (ACCESS-CM2), Australian Community Climate and Earth System Simulator (ACCESS-ESM1-5) and the Canadian Earth System Model version 5 (CanESM5) from existing longitude **81.13**^{0} and latitude **28.63**^{0} nearest grid point in a red boundary of Map 0-1. The total no. 215 gird available in Nepal, the nearest rainfall and temperature observed station grid data were selected for the heatwave coldwave and drought analysis, the download link: https://climexp.knmi.nl/selectfield_cmip6.cgi?id=someone@somewhere). These data were downscaled with the basis of observed station data in R environment of CliamPact2 Model. The CliamPact2 Model were used to calculation the heatwave (ehf), coldwave (ecf), maximum temperature (Tx90) and minimum temperature (TN90) Map 0-1 and Figure 0-1. The climate change of heat and cold wave projected in the basis of near future (2025-2049), mid future (2050-2074), and far future (2075-2100) trend are presented in the Appendix I and Appendix II.

Similarly, the drought in this Birendranagar area were analyzed using 30 years observed data by two techniques SPEI and SPI. The number of drought frequency of both values are different the maximum magnitude of SPI (2.411) and SPEI (1.96) and the minimum magnitude of SPI -2.85 and SPEI -2.07 found from 1990 to 2021. The SPI drought value slightly decreasing trend and SPEI drought value are slightly increasing trend as shown in Figure 0-4.



Map 0-1: vGrids of CMIP6 data only red indicate the study area of Birendranagar

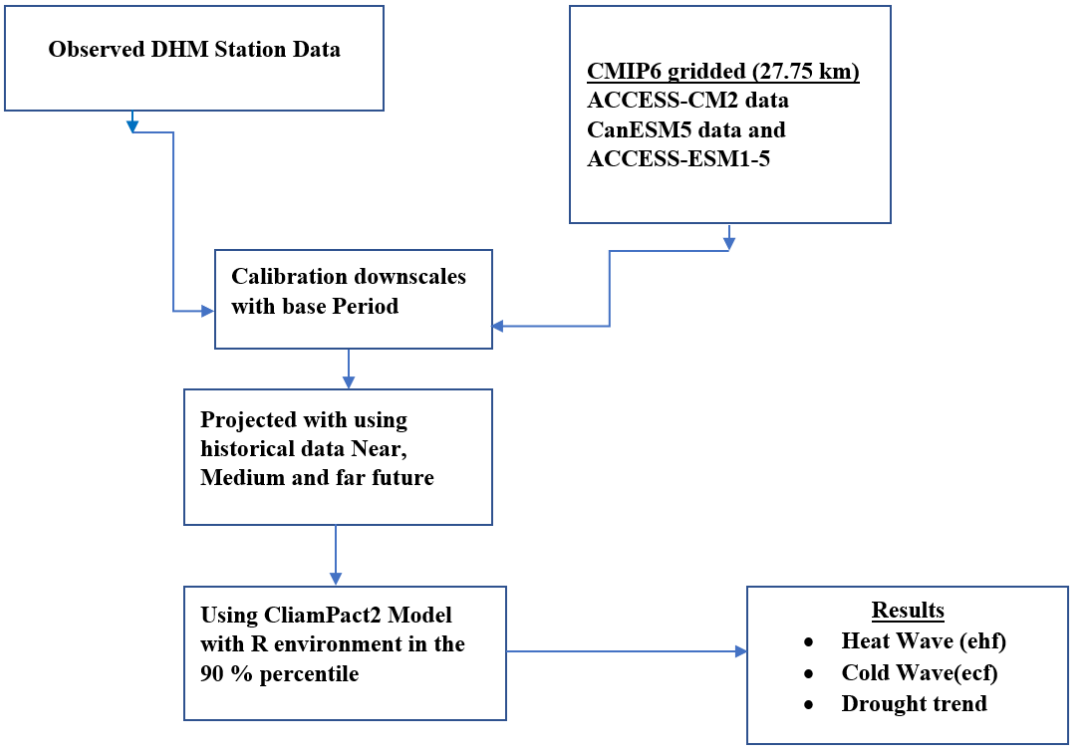


Figure 0-1: Data and Methodology of climate change modeling

1.77 RESULT

Birendranagar Observed Rainfall and Temperature analysis:

The average monthly maximum 464.7 mm and minimum 5.9 mm rainfall is found in the month of July and November during 30-years (990 to 2020) from observed data. Similarly, the 3-days maximum temperature of 34.6 ^{0}C and minimum of 7.3 ^{0}C is found in the month of May and December, which is depicted in Table 0-1.

Table 0-1: Monthly Average rainfall and temperature of Birendranagar

MONTH	RAINFALL (MM)	MAX TEMP (C)	MIN TEMP(C)	AVERAGE (C)
Jan	38.0	20.6	8.0	14.3
Feb	50.5	23.3	11.5	17.4
Mar	30.2	28.2	14.8	21.5
Apr	26.3	33.3	19.0	26.1
May	86.5	34.6	21.8	28.2
Jun	247.4	33.6	23.3	28.4
Jul	464.7	31.1	22.8	27.0
Aug	140.0	31.1	21.6	26.3
Sep	171.3	30.8	19.2	325.0
Oct	30.1	29.1	14.0	21.6
Nov	5.9	25.5	9.8	17.7
Dec	13.6	21.8	7.3	14.6

1.77.1 HEATWAVE RESULTS FROM OBSERVED DATA

A heatwave is defined as 3 or more days where either the EHF is positive, TX > 90th percentile of TX or where TN > 90th percentile of TN. In heatwave the ehf five indices warm spells of Average temperature across all individual heatwaves (HWM), Hottest day of the hottest heatwave (HWA), Average temperature across all individual heatwaves (HWN), Length of the longest heatwave (HWD) and total number of days that contribute to individual heatwave (HWF) were calculated. In the Birendranagar the 95 % percentile of total 535 days and in the 90 % percentile the total 1088 days of heatwave has been found from observed data (1990 to 2020) of 10950- days (30-years). Whereas the 0.56 per days and the total contributed of HWF 0.22 per days are increasing from 1990 to 2020. Similarly, the heatwave of HWM is found to be decreasing trend of -0.08°C per year, the heatwave of HWA is found to be decreasing trend of -0.14°C per, year, the heatwave of HWN is found to be increasing trend of 0.113°C per year, the heatwave of HWD is found to be increasing trend of 0.01 per day and the heatwave of HWD is found to be increasing trend of 0.60 per day as shown in Figure 0-2.

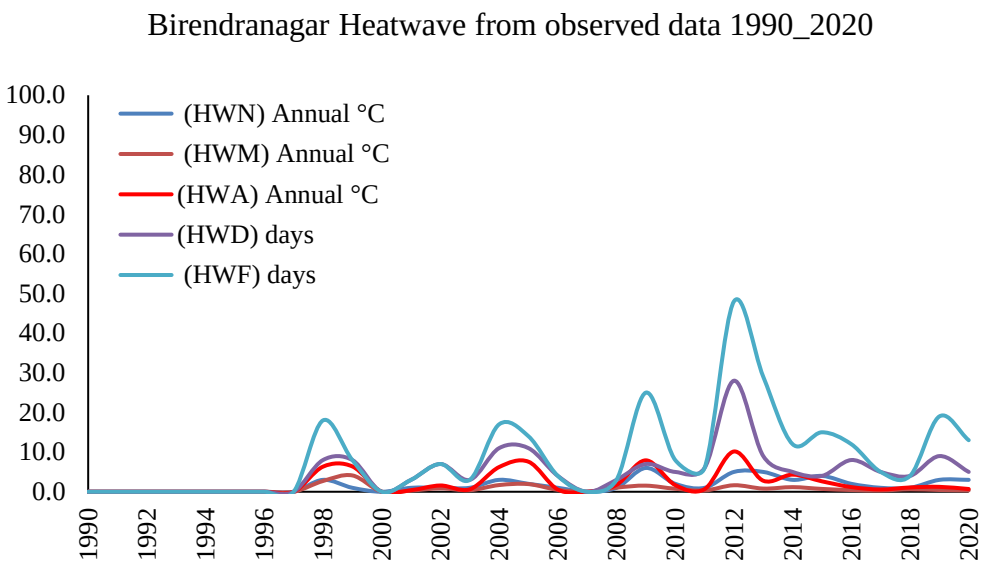


Figure 0-2: The status of heatwave of observed data in Birendranagar project area from 1990_2020

1.77.2 COLD WAVE RESULTS FROM OBSERVED DATA:

The **ecf** mean temperature of all 'coldwaves' identified the ECF_HWN (CWN), the minimum daily values coldest 'cold wave' (defined as the cold wave with lowest ECF_HWM) (CWA), the number of individuals 'cold waves' that occur each year (CWN), the length of the longest 'cold wave' identified by ECF_HWN (CWD), and the number of days that contribute to 'cold waves' as identified by ECF_HWN (CWF) from observed 30-years data. The results are found to be the number of contribute cold waves (CWF) are 0.19 per year increasing, the number of individuals cold waves (CWN) trend are increasing 0.002 each year and the length of the longest cold wave (CWD) is also increasing 0.19 per year and the number of contribute cold waves (CWF) are 0.28 increasing per year shown in Figure 0-3.

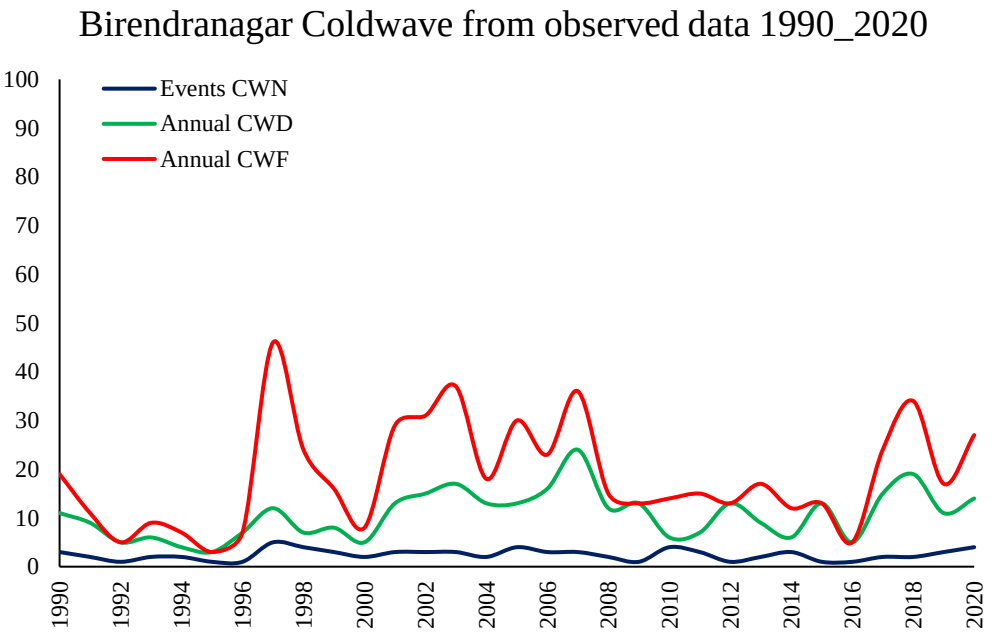


Figure 0-3: The status of Coldwave of observed data in Birendranagar project area from 1990_2020

1.77.3 DROUGHT RESULTS FROM OBSERVED DATA

In the Birendranagar area the drought is analyses using 30 years observed data by two techniques SPEI and SPI technique. The number of drought frequency of both values are same but the magnitude of SPI (-1.83) values is high as compared to SPEI (1.58) and both are found to be in increasing trend as seen in Figure 0-4.

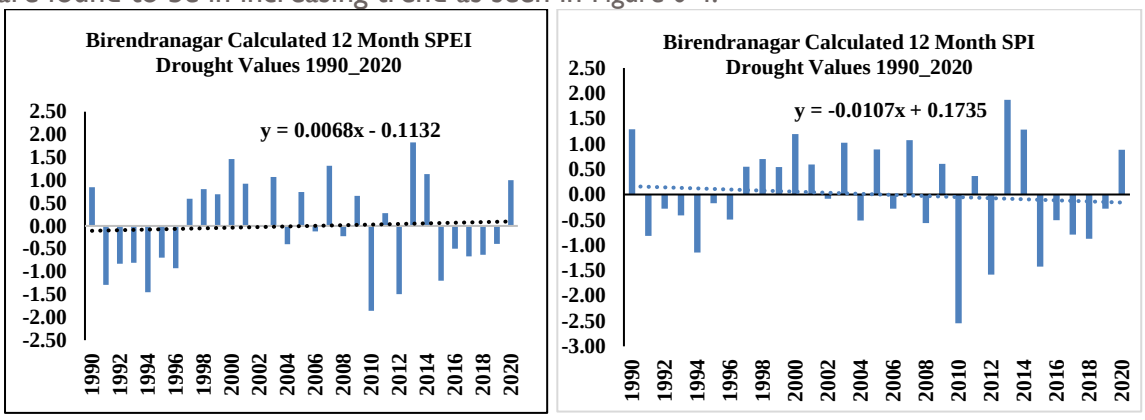


Figure 0-4: a (SPEI) and b (SPI) 12-month drought values from 30-years observed data (1990_2020)

1.78 SUMMARY

Heatwave is global temperature phenomena and occurs when the ocean temperature rises normally high and moves toward the atmosphere in the land area. T temperature acts to lead and traps a hot air usually rising coming from the sea and continues for few weeks and is called heat wave. These rising temperature of dry wind parameters characteristics are different in different countries. Mostly when the dry wind rises temperature in several country. They have a self-right to make decisions about the heat wave conditions in their respective country. Mostly any day appeared this rising temperature of 40^0C above they announce as heat wave, if five days continuously rising more than above given temperature, they called intense heat wave. But in our country from Government of Nepal such criteria are still not fixed. In the Birendranagar the 95 % percentile of total 535 days (36.6^0C) and in the 90 % percentile the total 1088 days (34.9^0C) of heatwave has been found from observed data (1990 to 2020) of 10950- days (30-years). Whereas the HWD trend of 0.110 per days and the total contributed of HWF 0.601 per days are increasing from 1990 to 2020. Similarly, HWN 0.11°C per annual and average temperature across all HWM -0.08°C per annual are increasing. Similarly, the hottest day of the HWA -0.14°C per annual is also increasing. Overall trends of this heatwave are increasing but the extreme peak of individual heatwave is found in (1998, 2005, 2012, 2016) years from the observed data.

Coldwave is a cold snap of weather phenomenon, distinguish by cooling of the air and rapid temperature going to minimum falls within 24 hours. It is decadent with geographic region and time of year. A cold wave is also declared differently for different values and according to Indian Meteorological Department (IMD) the minimum temperature is 10^0C or below and is 4.5 notches less than normal. A "severe" cold wave is when the minimum temperature dips to 2^0C or the departure from normal is more than 6.4^0C. But Government of Nepal has not fixed the above types of criteria. The study of coldwave in Birendranagar results are found, the trend of annual event contribute cold waves (CWF) are 0.20 per year increasing, the number of individuals cold waves (CWN) trend are increasing 0.00 annual /day and length of the longest cold wave (CWD) is also increasing 0.20 annual/ day 1990 to 2020.

Similarly, the projected CMIP6 data heatwave (HWF) is more procurance in the mid future from three scenario (ACCESS-CM2, ACCESS-ESM1-5 and CanESM5) and the individual peak (HWF) found be too hot from mid future to far future up to the 2100 century. The number of days contribute to 'cold waves' of ECF_HWN (CWF) are found to be decreasing trend after the mid future 2055. It is very essential to make decisions from our government about the heatwave and coldwave.

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Heatwave

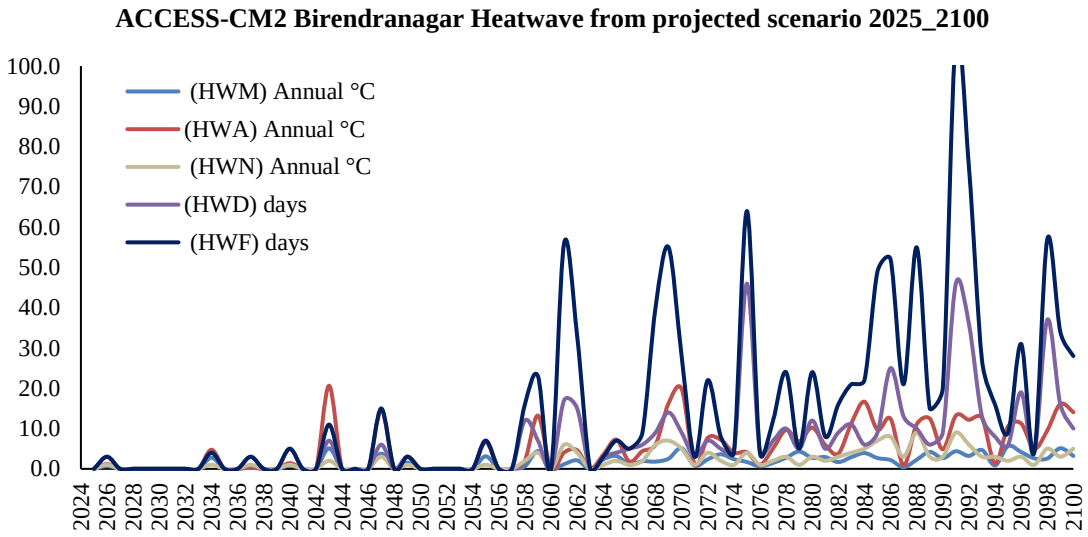


Figure 0-5: ACCESS-CM2 Birendranagar Heatwave from projected scenario 2025_2100

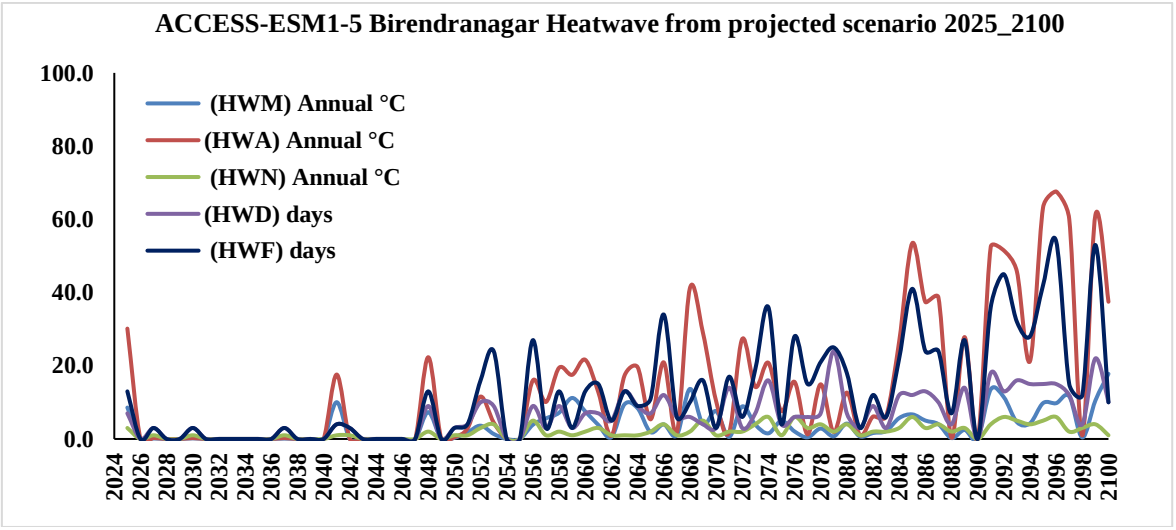


Figure 0-6: ACCESS-ESM1-5 Birendranagar Heatwave from projected scenario 2025_ 2100

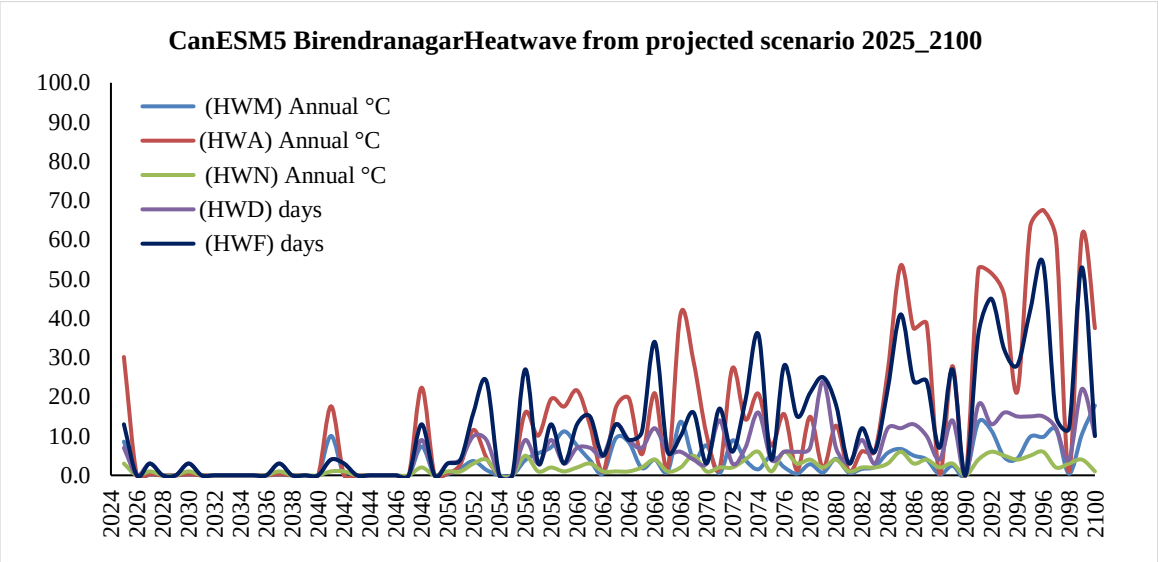


Figure 0-7: CanESM5 Birendranagar Heatwave from projected scenario 2025_ 2100

Coldwave

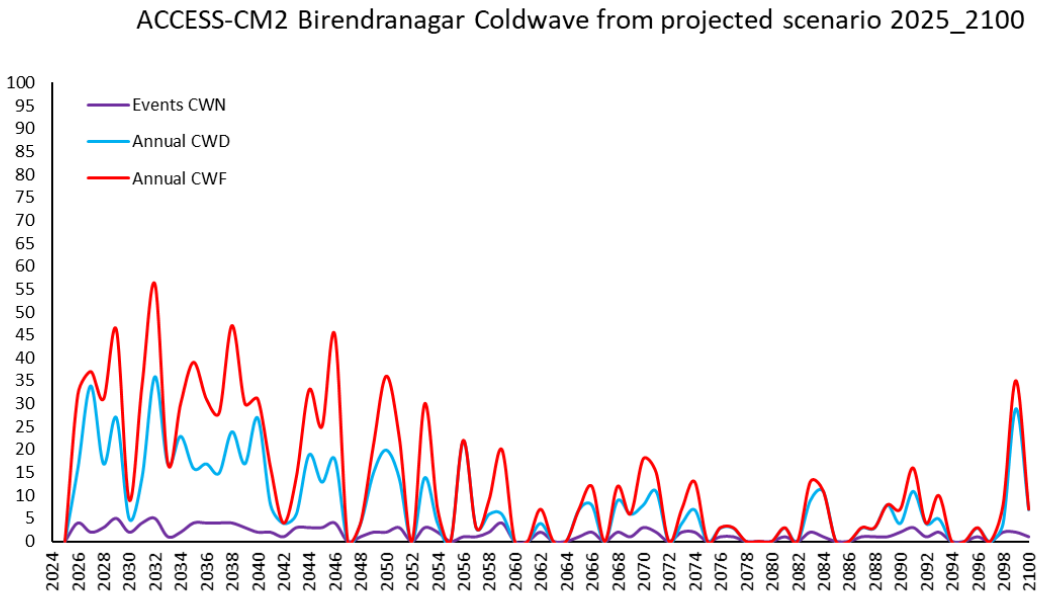


Figure 0-8: ACCESS-CM2 Birendranagar Coldwave from projected scenario 2025_2100

Coldwave

ACCESS-ESM1-5 Birendranagar Coldwave from projected scenario 2025_2100

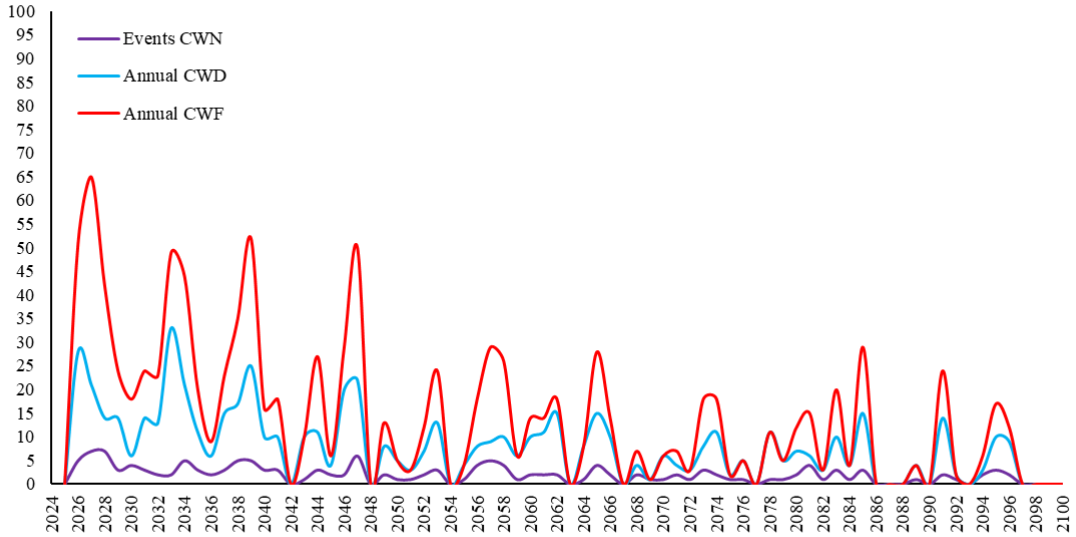


Figure 0-9: ACCESS-ESM1-5 Birendranagar Coldwave from projected scenario 2025 2100

CanESM5 Birendranagar Coldwave from projected scenario 2025_2100

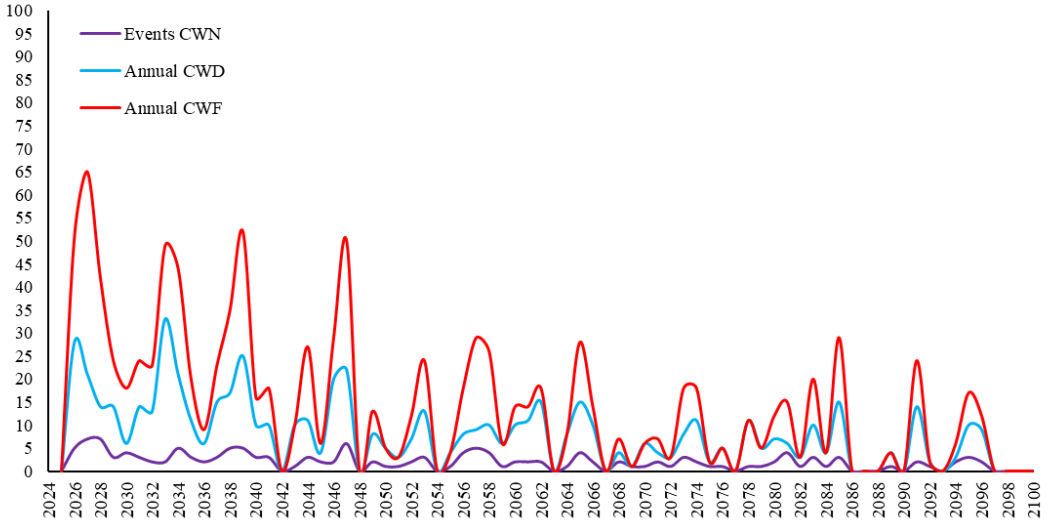


Figure 0-10: CamESM5 Birendranagar Coldwave from projected scenario 2025_2100

Birendranagar climate change projection Trends

Projections	(HWM) Annual °C	(HWA) Annual °C	(HWN) Annual °C	(HWD) days	(HWF) days
Heatwave Discription (ehf)					
Near future (2025-2049)	0.10	0.46	0.03	0.09	0.17
Mid future (2050-2074)	0.02	0.12	0.15	-0.28	0.84
Far future (2075-2100)	0.08	0.24	0.05	0.19	0.57
Heatwave Discription (Tx90)					
Near future (2025-2049)	0.23	0.25	0.05	0.03	0.19
Mid future (2050-2074)	-0.03	-0.05	0.13	0.04	0.73
Far future (2075-2100)	0.00	0.07	0.04	-0.02	0.38
Heatwave Discription (Tn90)					
Near future (2025-2049)	-0.57	-0.63	0.05	0.70	0.26
Mid future (2050-2074)	-0.10	-0.03	0.15	0.15	0.80
Far future (2075-2100)	-0.01	0.04	0.10	0.22	0.81
Coldwave Discription (ecf)					
Near future (2025-2049)	0.12	1.04	-0.07	-0.43	-0.70
Mid future (2050-2074)	-0.06	-0.06	-0.02	-0.21	-0.26
Far future (2075-2100)	0.06	-0.08	0.02	0.32	0.30
Heatwave Discription (ehf)					
Near future (2025-2049)	0.11	0.09	-0.02	0.08	-0.03
Mid future (2050-2074)	0.09	0.55	0.07	0.12	0.42
Far future (2075-2100)	0.38	1.93	0.03	0.31	0.75
Heatwave Discription (Tx90)					
Near future (2025-2049)	0.14	0.02	-0.05	-0.04	-0.20
Mid future (2050-2074)	0.33	0.26	0.01	-0.16	-0.13
Far future (2075-2100)	0.05	0.24	0.07	0.31	0.77
Heatwave Discription (Tn90)					
Near future (2025-2049)	0.18	0.17	0.01	-0.06	0.02
Mid future (2050-2074)	0.16	0.12	0.14	0.12	0.78
Far future (2075-2100)	-0.07	0.04	0.16	0.20	1.03
Coldwave Discription (ecf)					
Near future (2025-2049)	-0.19	1.05	-0.14	-0.37	-1.28
Mid future (2050-2074)	-0.07	0.80	-0.03	-0.12	-0.24
Far future (2075-2100)	0.02	-1.10	-0.04	0.04	-0.26
Heatwave Discription (ehf)					
Near future (2025-2049)	0.11	0.09	-0.02	0.08	-0.03
Mid future (2050-2074)	0.09	0.55	0.07	0.12	0.42
Far future (2075-2100)	0.38	1.93	0.03	0.31	0.75
Heatwave Discription (Tx90)					
Near future (2025-2049)	0.14	0.02	-0.05	-0.04	-0.20
Mid future (2050-2074)	0.33	0.26	0.01	-0.16	-0.13
Far future (2075-2100)	0.05	0.24	0.07	0.31	0.77
Heatwave Discription (Tn90)					
Near future (2025-2049)	0.18	0.17	0.01	-0.06	0.02
Mid future (2050-2074)	0.16	0.12	0.14	0.12	0.78
Far future (2075-2100)	-0.07	0.04	0.16	0.20	1.03
Coldwave Discription (ecf)					
Near future (2025-2049)	-0.19	1.05	-0.14	-0.37	-1.28
Mid future (2050-2074)	-0.07	0.80	-0.03	-0.12	-0.24
Far future (2075-2100)	0.02	-1.10	-0.04	0.04	-0.26

OTHER HAZARDS

1.79 HUMAN WILDLIFE CONFLICT

1.79.1 INTRODUCTION

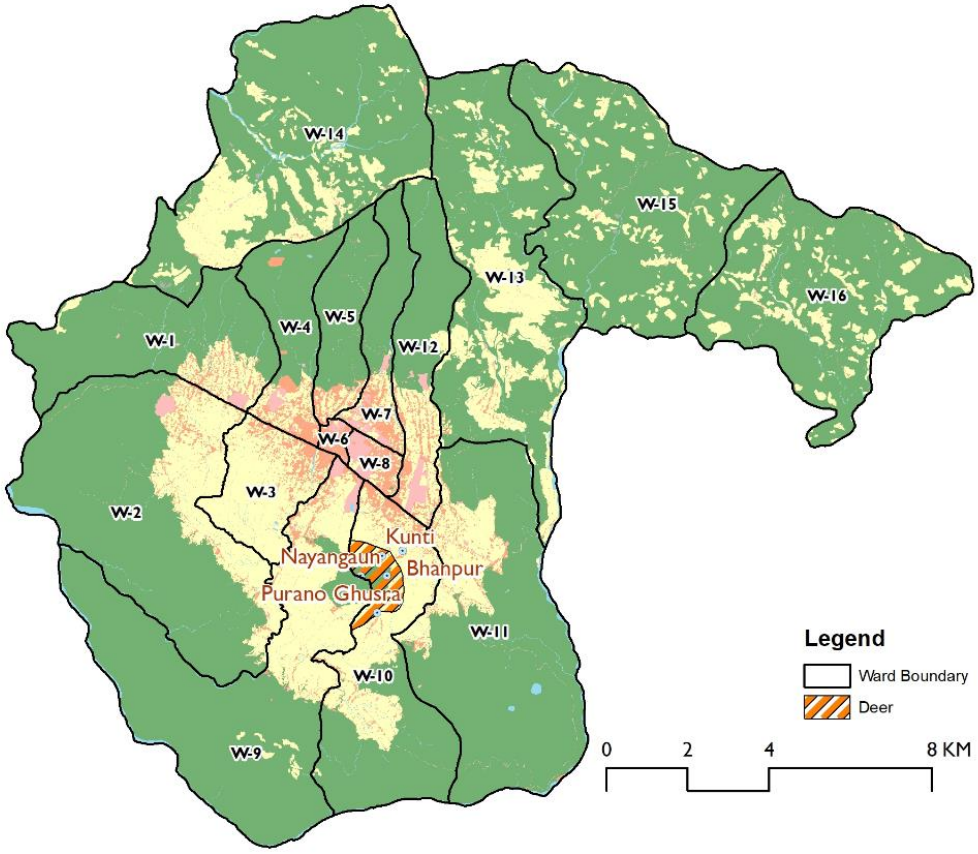
Human-wildlife conflict (HWC) occurs when animals pose a direct and recurring threat to the livelihood or safety of people, leading to the persecution of that species(IUCN, 2021). It arises mainly because of the loss, degradation and fragmentation of habitats through human activities such as, logging, animal husbandry, agricultural expansion, and developmental projects (WWF, 2007). Every year, incidents of conflicts between people and wildlife, especially deer, have been occurring in Birendranagar municipality resulting in loss of crops. These animal's influx from the forests of Kakrebihar.

1.79.2 METHOD

Focus group discussion was used to gather data of human wildlife conflict.

1.79.3 RESULT

Kurit, Kakre Bihar, Nayangaun and Purano Ghusra are some of the settlements affected by wildlife.



Map 0-1: Human wildlife conflict

1.1 LIGHTNING

1.1.1 INTRODUCTION

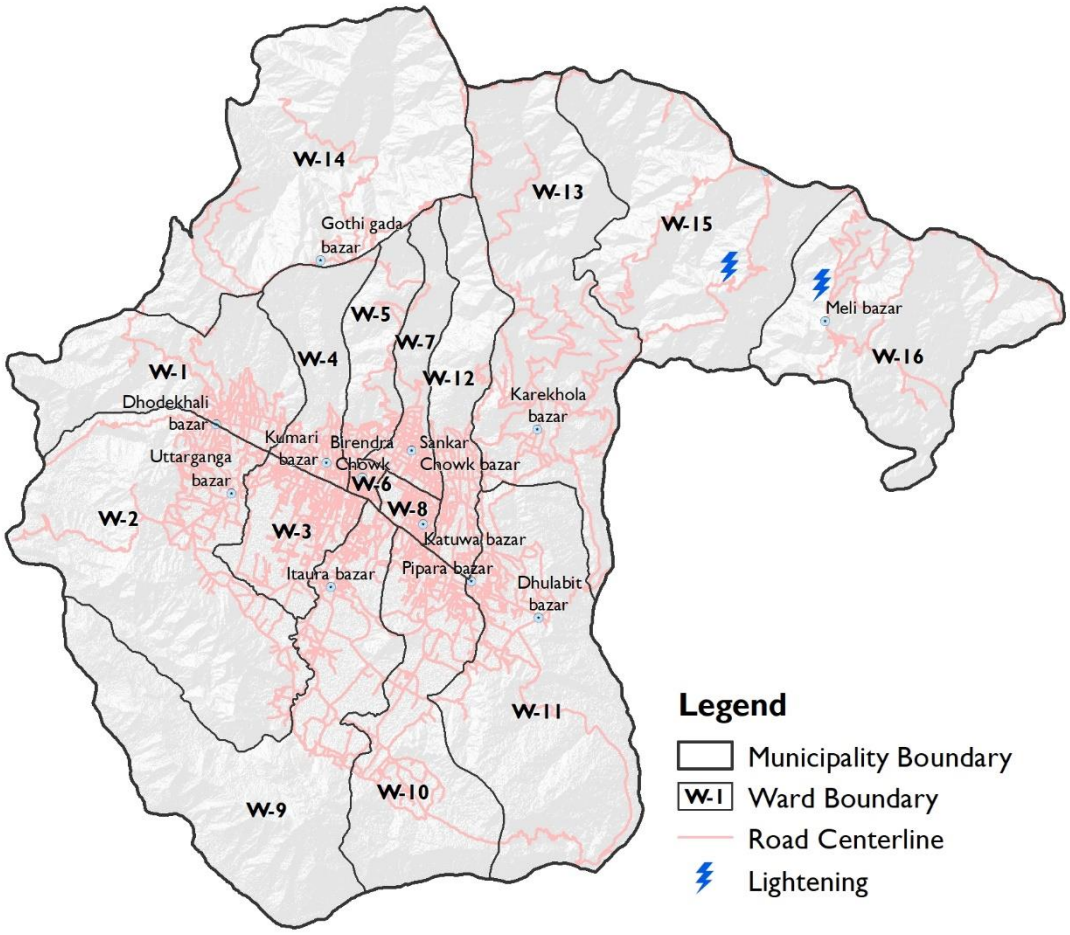
Lightning is a giant spark of electricity in the atmosphere between clouds, the air, or the ground. Tall objects such as trees and skyscrapers are more likely than the surrounding ground to produce one of the connecting sparks and so are more likely to be struck by lightning. Mountains also make good targets. Lightning can strike the ground in an open field even if the tree line is close by (NSSL, 2021).

1.1.2 METHOD

Focus group discussion was used to map the lightening incidents.

1.1.3 RESULT

Few incidents of lightening have occurred in Birendranagar Municipality. Focus group discussion showed that past two incidents occurred in wards- 15 (Ratu settlement area had frequent lightening and in 2019 ward 16 (Meheli settlement area lightening caused death of cow and buffalo). While DRR portal showed that 3 incidents occurred in wards 14, 15 and 16 in 2019 (1 event each in 2011, 2013 and 2015).



Map 0-2: Lightening, Birendranagar Municipality

MULTI HAZARD ASSESSMENT

A multi-hazard map furnishes composite illustration of the natural hazards of varying magnitude, frequency, and spatial distribution. Thus, multi-hazard risk assessment is performed to depict the holistic natural hazards scenario of any particular region (Khatakho et al., 2021). Multi hazard map was prepared using Analytical Hierarchy Process (AHP) as proposed by (Aksha, Resler, Juran, & Carstensen Jr, 2020; Khatakho et al., 2021).

1.2 METHOD

Six different hazards were used for multi-hazard assessment and weights were assigned to each hazard in consultation with experts.

The multi-hazard assessment was done using following equation (summation of the weight multiplied by corresponding hazards)

$$MH = \sum_{i=1}^{n} Hi\, Wi$$

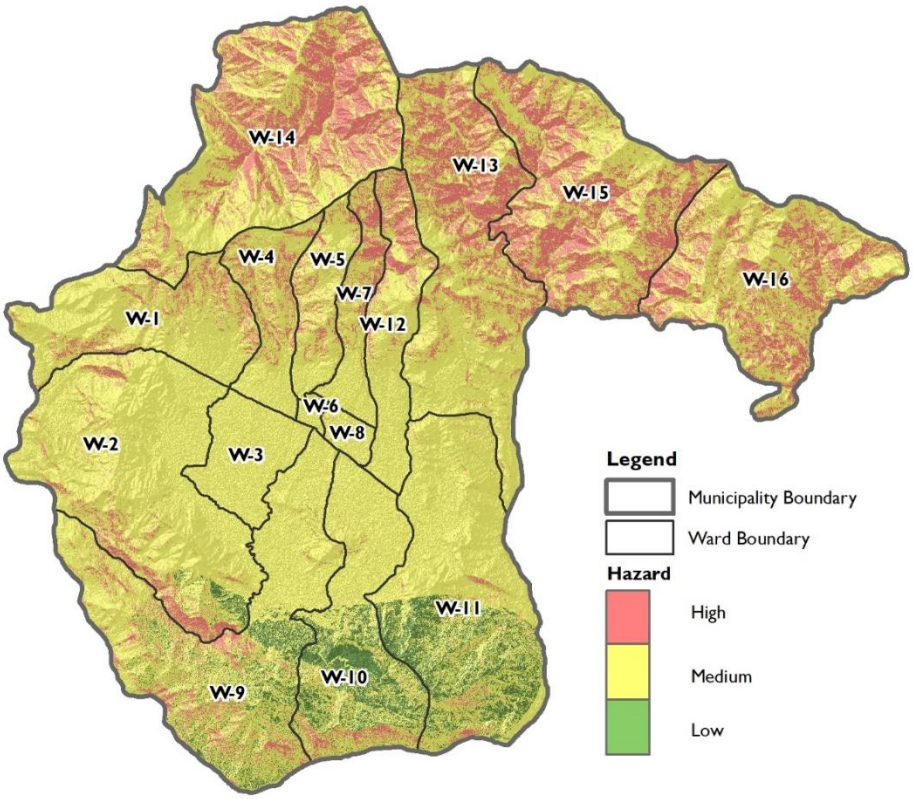
Where, MH is a multi-hazard, n is the total number of hazards, Hi is the hazard i, and Wi is the weight of the hazard i.

Table 0-1 Hazard and Weight Assigned to Each Hazards

SN	Hazard	Weight
1	Rainfall induced landslide	0.372456
2	Earthquake induced landslide	0.249547
3	Liquefaction	0.159695
4	Rockfall	0.10071
5	Flood	0.076543
6	Seismicity	0.041049

1.3 RESULT

Based on multi-hazard assessment, around 4.90% (1241.77 ha) of total area was categorized as low hazard zone, while 75.38% (7063.74 ha) and 19.67% (1034.15 ha) of total area were categorized as moderate and high hazard zone respectively. Multi hazard scenario in each ward is presented in following table.



Map 0-1: Multihazard, Birendranagar Municipality

Table 0-2 Ward wise Multi hazard

WARD	LOW (HA)	LOW (%)	MEDIUM (HA)	MEDIUM (%)	HIGH (HA)	HIGH (%)
1	0.00	0.00	1255.83	88.22	167.13	11.74
2	49.57	1.70	2636.00	90.60	223.38	7.68
3	0.00	0.00	660.02	99.96	0.26	0.04
4	0.00	0.00	586.79	83.35	117.19	16.65
5	0.00	0.00	492.93	85.56	83.21	14.44
6	0.00	0.00	58.97	99.97	0.01	0.01
7	0.00	0.00	408.36	78.01	115.15	22.00
8	0.00	0.00	140.09	99.50	0.72	0.51
9	294.30	10.23	2327.84	80.93	253.10	8.80
10	406.90	23.97	1213.97	71.53	75.98	4.48
11	491.01	18.43	2107.21	79.07	66.24	2.49
12	0.00	0.00	705.17	80.10	175.11	19.89
13	0.00	0.00	1824.14	70.57	760.22	29.41
14	0.00	0.00	1799.44	60.61	1167.46	39.32
15	0.00	0.00	1411.83	57.46	1043.40	42.47
16	0.00	0.00	1477.65	66.58	737.83	33.24

Settlement and Multihazard

Table below shows different settlements in different levels of multihazard in different wards of Birendrangar Municipality

Table 0-3 Settlements in Different Levels of Multihazard

Ward	Multi hazard		
	Low	Medium	High
1		Amdali Chanabari Dharapani Dhodekhali Solighoptegaun Tinkune	
2	Labasta	Bhureli Daulatpur Guptipur Jayapur Kholigaun	

Ward	Multi hazard		
	Low	Medium	High
		Koldanda	
		Krisnaganj	
		Thauri	
		Uttarganga	
3		Gandaki Tol	
		Itaura	
		Masurikhet	
		Mulpani	
		Pateni	
		Tatapani	
		Tilpur	
4		Dunigaira	
		Hilekhali	
		Kalagaun	
		Kharke	
		Khokre	
5		Bhute Pokhari	
		Chisapani	
		Ganesh Chok	
6		Birendra Chok	
7		Itram	
		Kalun Chok	
		Kapase	
8		Khajura	
		Naulapur	
9	Alayechaur	Badhthari	
	Bulbule	Chandan Chauki	
	Mathillo Parseni	Latikoili	
		Mangalgadhi	
		Nanpur (Ghogreni)	
		Park Area	
		Patalganga	
		Purano Ghusra	
		Saktekanda	
		Tallo Parseni	
		Thulthari	
10	Banghusra	Bamekholagaun	
	Raharpur	Banghusra	
	Sano Surkhet	Belghari	
		Bhanpur	
		Budbudi	

Ward	Multi hazard	
Low	Medium	High
	Kakre Bihar	
	Kunti	
	Mananikapur	
	Naulapur	
	Nayangaun	
	Padampur	
	Pipira	
	Purano Ghusra	
11	Achhamidanda	
	Barakuna	
	Barrakuna	
	Bastipur	
	Bhusaldanda	
	Charkune	
	Chauke Dhunga	
	Dhol Dhunga	
	Dhulabit	
	Gagretal	
	Pipira	
	Subbakuna	
12	Bastipur	
	Bhabar	
	Chanaute	
	Khoriyan	
	Neware	
	Padampur	
13	Baudel Tol	Banjhokhet
	Dahaldanda	Jamindanda
	Dobilla	Lamidanda
	Guptipur	
	Indrapur	
	Jarbuta	
	Karekholagaun	
	Khapkhera	
	Maumare	
	Nayangaun	
	Pipaldanda	
	Ratedanda	
	Salami Tol	
	Sitapur	
	Sunaritar	

Hazard Summary

The ward wise summary of all hazards are presented in following table

Table 0-4 Hazard Summary

Type of Hazard	Ward No./ Rank	1		2		3		4	
		Area at Risk (ha)	%	Area at Risk (ha)	%	Area at Risk (ha)	%	Area at Risk (ha)	%
Rain Triggered Landslide	High	162.07	11.39	218.62	7.51	0.01	0.00	97.83	13.90
	Medium	646.20	45.39	1167.39	40.12	209.55	31.74	300.15	42.64
	Low	614.92	43.20	1523.11	52.35	450.71	68.26	305.99	43.47
Earthquake Triggered Landslide	High	84.62	5.94	169.20	5.82	0.00	0.00	53.93	7.66
	Medium	658.03	46.22	1223.21	42.04	20.47	3.10	334.09	47.46
	Low	680.47	47.80	1516.68	52.13	639.81	96.90	316.05	44.89
Flood	High	11.24	0.79	66.85	2.30	12.13	1.84	3.94	0.56
	Medium	3.69	0.26	17.85	0.61	9.13	1.38	2.14	0.30
	Low	3.83	0.27	19.84	0.68	12.14	1.84	2.21	0.31
Urban Fire	High	0.38	0.03	0.73	0.03	0.01	0.00	0.05	0.01
	Medium	82.03	5.76	138.12	4.75	116.44	17.64	100.68	14.30
	Low	1341.15	94.21	2770.55	95.23	543.84	82.36	603.26	85.69
RockfallHazard	High	20.80	1.46	35.38	1.22	0.00	0.00	13.11	1.86
	Medium	343.86	24.15	455.80	15.67	0.00	0.00	233.36	33.15
	Low	1058.21	74.34	2417.93	83.11	660.28	100.00	457.51	64.99
liquefaction	High	97.98	6.88	165.56	5.69	443.52	67.17	252.85	35.92
	Medium	332.30	23.34	804.32	27.65	216.76	32.83	258.02	36.65
	Low	993.31	69.78	1939.57	66.67	0.00	0.00	193.11	27.43
VCE	High	0.17	0.01	0.61	0.02	0.33	0.05	1.23	0.18

	Medium	2.75	0.19	3.53	0.12	3.51	0.53	3.73	0.53
	Low	102.73	7.22	102.06	3.51	163.43	24.75	124.02	17.62
Multihazard	High	167.13	11.74	223.38	7.68	0.26	0.04	117.19	16.65
	Medium	1255.83	88.22	2636.00	90.60	660.02	99.96	586.79	83.35
	Low	0.00	0.00	49.57	1.70	0.00	0.00	0.00	0.00
Total Ward area(ha)		**1423.55**		**2909.42**		**660.28**		**703.99**	

Type of Hazard	Ward No./ Rank	5		6		7		8	
		Area at Risk (ha)	%	Area at Risk (ha)	%	Area at Risk (ha)	%	Area at Risk (ha)	%
Rain Triggered Landslide	High	60.84	10.56	0.00	0.00	110.65	21.14	0.09	0.06
	Medium	254.73	44.21	2.60	4.41	184.61	35.27	10.43	7.41
	Low	260.57	45.23	56.37	95.57	228.26	43.61	130.29	92.54
Earthquake Triggered Landslide	High	36.03	6.25	0.01	0.02	30.71	5.87	0.57	0.40
	Medium	293.49	50.94	5.32	9.02	229.97	43.93	8.39	5.96
	Low	246.58	42.80	53.64	90.94	262.76	50.20	131.84	93.65
Flood	High	0.34	0.06	0.93	1.58	2.16	0.41	0.97	0.69
	Medium	0.25	0.04	0.46	0.77	1.73	0.33	0.71	0.50
	Low	0.33	0.06	0.55	0.94	2.11	0.40	0.94	0.67
Urban Fire	High	0.00	0.00	0.04	0.07	0.00	0.00	0.08	0.05
	Medium	42.55	7.39	47.46	80.47	25.52	4.88	68.65	48.76
	Low	533.59	92.61	11.48	19.47	497.93	95.12	72.05	51.18
RockfallHazard	High	9.31	1.62	0.00	0.00	19.93	3.81	0.00	0.00
	Medium	176.81	30.69	0.01	0.01	174.31	33.30	0.56	0.40

	Low	390.03	67.70	58.97	99.98	329.22	62.89	140.25	99.62
liquefaction	High	193.21	33.53	58.97	99.98	193.63	36.99	124.97	88.77
	Medium	265.29	46.05	0.00	0.00	212.68	40.63	15.83	11.25
	Low	117.64	20.42	0.00	0.00	117.20	22.39	0.00	0.00
VCE	High	0.00	0.00	0.00	0.00	0.00	0.00	0.87	0.62
	Medium	0.00	0.00	1.40	2.37	0.00	0.00	4.09	2.90
	Low	7.41	1.29	49.99	84.76	0.01	0.00	94.87	67.38
Multihazard	High	83.21	14.44	0.01	0.01	115.15	22.00	0.72	0.51
	Medium	492.93	85.56	58.97	99.97	408.36	78.01	140.09	99.50
	Low	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Ward area(ha)		**576.14**		**58.99**		**523.46**		**140.79**	

Type of Hazard	Ward No./ Rank	9		10		11		12	
		Area at Risk (ha)	%	Area at Risk (ha)	%	Area at Risk (ha)	%	Area at Risk (ha)	%
Rain Triggered Landslide	High	251.61	8.75	75.77	4.46	69.58	2.61	173.31	19.69
	Medium	1327.53	46.15	634.63	37.39	842.18	31.60	303.84	34.51
	Low	1296.62	45.08	986.49	58.13	1752.81	65.77	403.13	45.79
Earthquake Triggered Landslide	High	360.87	12.55	93.58	5.51	90.65	3.40	60.04	6.82
	Medium	1273.83	44.28	457.15	26.94	972.44	36.49	359.78	40.87
	Low	1241.09	43.15	1146.07	67.53	1601.39	60.09	460.52	52.31
Flood	High	143.31	4.98	94.74	5.58	46.98	1.76	3.15	0.36
	Medium	21.63	0.75	40.76	2.40	14.80	0.56	4.12	0.47
	Low	19.88	0.69	37.38	2.20	14.48	0.54	5.93	0.67
Urban Fire	High	0.12	0.00	0.18	0.01	0.48	0.02	0.11	0.01

	Medium	54.30	1.89	110.91	6.53	156.58	5.88	64.06	7.28
	Low	2822.11	98.11	1586.09	93.45	2507.81	94.11	816.16	92.71
RockfallHazard	High	63.03	2.19	39.03	2.30	5.71	0.21	65.28	7.42
	Medium	851.67	29.61	193.90	11.42	240.15	9.01	256.46	29.13
	Low	1961.55	68.19	1464.22	86.27	2418.96	90.77	558.52	63.45
liquefaction	High	136.02	4.73	30.03	1.77	0.00	0.00	27.39	3.11
	Medium	276.26	9.60	439.28	25.88	34.49	1.29	589.06	66.91
	Low	2464.19	85.67	1227.92	72.35	2630.38	98.71	263.83	29.97
VCE	High	0.32	0.01	0.93	0.05	1.57	0.06	0.24	0.03
	Medium	1.84	0.06	3.93	0.23	12.56	0.47	1.13	0.13
	Low	66.41	2.31	169.06	9.96	292.94	10.99	86.72	9.85
Multihazard	High	253.10	8.80	75.98	4.48	66.24	2.49	175.11	19.89
	Medium	2327.84	80.93	1213.97	71.53	2107.21	79.07	705.17	80.10
	Low	294.30	10.23	406.90	23.97	491.01	18.43	0.00	0.00
Total Ward area(ha)		**2876.51**		**1697.18**		**2664.87**		**880.32**	

Type of Hazard	Ward No./ Rank	13		14		15		16	
		Area at Risk (ha)	%	Area at Risk (ha)	%	Area at Risk (ha)	%	Area at Risk (ha)	%
Rain Triggered Landslide	High	783.96	30.33	1205.32	40.60	1076.76	43.83	752.32	33.90
	Medium	1109.19	42.91	1279.96	43.11	1078.42	43.89	1120.34	50.48
	Low	691.57	26.75	482.91	16.26	301.08	12.25	345.34	15.56
Earthquake Triggered Landslide	High	211.43	8.18	420.79	14.17	364.74	14.85	333.91	15.04
	Medium	1482.10	57.33	1906.03	64.20	1636.38	66.60	1526.44	68.78

	Low	891.18	34.47	641.14	21.59	454.94	18.52	357.51	16.11
Flood	High	15.89	0.61	7.77	0.26	0.19	0.01	0.00	0.00
	Medium	5.28	0.20	4.39	0.15	0.04	0.00	0.00	0.00
	Low	4.70	0.18	4.20	0.14	0.04	0.00	0.00	0.00
Urban Fire	High	0.21	0.01	0.82	0.03	0.72	0.03	0.77	0.03
	Medium	15.72	0.61	4.40	0.15	3.67	0.15	3.05	0.14
	Low	2569.09	99.38	2963.77	99.82	2452.45	99.82	2215.60	99.83
RockfallHazard	High	263.84	10.21	512.63	17.27	471.12	19.18	318.15	14.33
	Medium	1121.15	43.37	1478.35	49.79	1367.50	55.66	1253.31	56.47
	Low	1199.72	46.41	976.66	32.89	617.35	25.13	646.91	29.15
liquefaction	High	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Medium	179.66	6.95	0.00	0.00	0.00	0.00	0.00	0.00
	Low	2405.37	93.05	2969.13	100.00	2456.90	100.00	2219.42	100.00
VCE	High	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Medium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Low	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Multihazard	High	760.22	29.41	1167.46	39.32	1043.40	42.47	737.83	33.24
	Medium	1824.14	70.57	1799.44	60.61	1411.83	57.46	1477.65	66.58
	Low	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Ward area(ha)		**2585.00**		**2969.04**		**2456.86**		**2219.45**	

COMMUNITY VULNERABILITY AND CAPACITY

1.4 THE NEW URBAN AGENDA

Although the concept of VCA is not directly referred, however, the issue of vulnerability and risk reduction is explicitly mentioned and discussed in the Vision of the NUA. The discussion is more precisely articulated as- adopt and implement disaster risk reduction and management (DRRM), reduce vulnerability, build resilience and responsiveness to natural and human-made hazards and foster mitigation of and adaptation to climate change. Besides, the principles and commitments also discuss the concern of environmental sustainability by promoting clean energy, sustainable use of land and resources, protecting ecosystems and biodiversity and by building urban resilience, reducing disaster risks and by mitigating and adapting to climate change. In the process of securing environmentally sustainable and resilient urban development, the NUA commit to facilitate the sustainable management of natural resources in cities and human settlements in a manner that protects and improves the urban ecosystem and environmental services, reduces greenhouse gas emissions and promotes DRRM, by supporting the development of DRR strategies and periodical assessments of disaster risk caused by natural and human-made hazards, while fostering sustainable economic development and protecting the well-being and quality of life of all persons through environmentally sound urban and territorial planning, infrastructure and basic services.

The NUA further commit to strengthening the resilience of cities and human settlements, including through the development of quality infrastructure and spatial planning, by adopting and implementing integrated, age- and gender-responsive policies and plans and ecosystem-based approaches in line with the Sendai Framework for DRR and by mainstreaming DRRM at all levels to reduce vulnerabilities and risk, especially in risk-prone areas of formal and informal settlements, including slums, and to enable households, communities, institutions and services to prepare for, respond to, adapt to and rapidly recover from the effects of hazards, including shocks or latent stresses. We will promote the development of infrastructure that is resilient and resource efficient and will reduce the risks and impact of disasters, including the rehabilitation and upgrading of slums and informal settlements. The New Urban Agenda recognizes the linkages between sustainable urbanization and, inter alia, sustainable development, disaster risk reduction and climate change.

1.5 DEFINING URBAN COMMUNITIES

There are always certain communities or groups in urban municipalities that are at more risk from hazards because they are less able to avoid them, and have less capacity to cope with them. Such communities/groups are called vulnerable communities. Vulnerability of these communities are mostly linked with external socio-economic and cultural context which increases their risk – for instance poor quality dwelling units in the urban areas are more exposed to earthquake and fire hazards. Similarly, susceptibility due to the endogenous factors such as nutritional status, disability, age etc. also increases the risk to hazards. Therefore, it is critical to identify the vulnerability of these communities through a multisector vulnerability analysis measuring their vulnerability as well as adaptive capacity. The indicators for community level vulnerability can be divided into four major categories:

Table 0-1: Indicators for community level vulnerability

CATEGORIES	INDICATORS
Demography, Housing and Human Settlements	Density, Age of Settlement, Built Form, Access to Documents (citizenship), Ethnicity, FHH, Insurance, Pregnant Women, HHs below poverty line, Plot Size, Household Assets etc.
Education, Economy and Development	Literacy Rate, Dropout Rate of Children, Major Occupation base, Remittance Economy, Unemployment and HHs below poverty, Agriculture Production etc.
Access to Basic Infrastructure and Services	Access to infrastructure (water, transport, health, sanitation), Access to financial institutions
Knowledge and Awareness	Awareness and preparedness on threats, evacuation process, Social Protection systems, open space identification, first aid training, drill & simulation exercise.

1.6 VULNERABLE COMMUNITIES IN THE MUNICIPALITY

1.6.1 SENIOR CITIZEN IN MUNICIPALITY

The status of senior citizens, in every ward throughout VCA, there are about (2.9 %) to almost (12.4%) households were population above 55 years are living. Among the 16 ward of municipality Ward no 12 has highest percent of senior citizen household (12.4%), followed by ward no. 10 and 3 (11.9%) and (11.6%) respectively. ward no 15 has the lowest senior citizen household i.e., (2.9 %).

Table 0-2: Household of senior citizen in percentage

WARD	ABOVE 55 YEARS HOUSEHOLD%	WARD	ABOVE 55 YEARS HOUSEHOLD%
1	9.6	9	10.4
2	9.9	10	11.9
3	11.6	11	10.1
4	8.4	12	12.4
5	6.4	13	7
6	6.9	14	4.9
7	5.9	15	2.9
8	6.4	16	4.2

Source: VCA 2021/Municipal profile

1.6.2 INDIGENOUS GROUPS IN MUNICIPALITY CITY

Birendranagar Municipality has diversity in ethnicity. According to VCA, it is reported that all the ethnic groups are distributed and living in harmony. Among 16 wards, ward no 9 and 15 has the highest number of janjati (50%). Dalit household are also found in every ward. Ward no 6 has the highest number of Dalit household (40%). Similarly, Brahman and chhetri are also found in equal proportions. Details of household based on caste and ethnicity are shown below:

Table 0-3: Households based on caste system

WARD	JANAJAT HOUSEHOLD%	DALIT HOUSEHOLD%	BRAHMAN HOUSEHOLD%	CHETTRI HOUSEHOLD%
1	40	28	11	21
2	26	34	5	35
3	15	22	32	31
4	0	20	19	61
5	40	20	11	29
6	0	40	25	35
7	26	12	30	32
8	20	10	32	38
9	50	25	4	21
10	40	13	17	30
11	44	13	30	13
12	20	20	30	30
13	30	20	25	25
14	45	20	15	20
15	50	11	9	30
16	15	30	15	40

Source: VCA 2021/Municipal profile

1.6.3 FEMALE HEADED HOUSEHOLDS AND THEIR SOURCE OF INCOME

Due to patriarchal society we find male as a house headed in most of the parts of Nepal. It is rare to find female headed household, where female handles the house socially and economically. Similarly, in Birendranagar Municipality there are only few household, where female is house headed. According to VCA ward no 2 and 3 has (20%) and ward no 1 has (18%) female headed household. Where most of the other ward consist minimum 5 percent to 12 percent household with female headed. It is difficult to find female headed household in case of single women. There are minimum 2 percent to 12 percent single female headed households. Ward no 8 has highest (12 %) followed by ward no 11 (19%) single female headed household. Where others ward like ward no 2,3,4,5 has 2 percent to about 8 percent.

Table 0-4: Number of female headed and single women headed household

WARD	FEMALE HEADED HOUSEHOLD%	SINGLE FEMALE HEADED HOUSEHOLD%	TOTAL%
1	18	4	22
2	20	2	22
3	20	8	28
4	5	3	8
5	7	5	7
6	5	2	7
7	12	3	15
8	12	12	24
9	10	3	13
10	3	2	5
11	8	10	18
12	7	2	9
13	9	4	13
14	10	6	16
15	10	7	17
16	7	4	11

Source: VCA 2021/Municipal profile

1.6.4 INCOME SOURCE OF FEMALE HEADED HOUSEHOLD

According to the VCA, most of female headed household of Birendranagar Municipality engage in traditional agriculture. Household of ward no 3 has highest involvement in agriculture (50%). In the same ward (5%) are engaged in animal husbandry. About (14.2%) of the household of ward no 8 are engaged in daily labor and wages. About (17 %) household of the ward no 8 are engage in entrepreneurship. Females of Birendranagar municipality are growing their business. From (0.3%) to (35%) female headed household are doing business. In overall major earning of female headed household are from daily labor, agriculture and animal husbandry. Few are doing business where, very few are in practice of entrepreneurship.

WARD	AGRICULTURE%	JOB/SERVICE%	ANIMAL HUSBANDRY%	DAILY WAGES/LABOR%	ENTREPRENEUR%	BUSINESS%	OTHERS%
1	10	20	0	8.7	0	6.7	0
2	0	0.7	0	1	2	0.7	0
3	50	5	0	0.4	3	1.4	0
4	0.5	2.5	0	2	4	0.5	0
5	0	1.8	0	6.3	3	0.3	0
6	0	0.5	0	4.5	5	1	0
7	0	3.1	0	3.8	1	0.6	0
8	0	8.5	8	14.2	17	35	0
9	1.3	2.6	0	0.2	1	4.3	0
10	0.6	0.5	0	1.1	2	0	0
11	0.9	0.2	0	2.2	1	0.8	0
12	1	26.7	0.33	5	0	1.3	0
13	0	2.7	0.66	1.3	0	0	0
14	2.1	1	0.14	1.4	1	2.1	0
15	7.9	1.3	0	5.3	0	0	0
16	0.6	0	0	0	0	0	0

Source: VCA 2021/Municipal profile

1.6.5 POPULATION WITH DISABILITY

According to VCA, disabled population accounting for about minimum (1%) to maximum (18%) Among the 16 ward Birendranagar Municipality ward 11 has highest physically disabled household (18%). In the same ward (1%) household are deaf and they are facing problem in hearing. Similarly, ward no 7 has (10%) household suffering blindness and low vision. About (12%) percent household of ward no 7 are facing mental disability. Details about household with differently disabled population is shown below in table.

Table 0-5: Household with disdable population

WARD	PHYSICAL DISABLE HOUSEHOLD%	BLINDNESS/LOW VISION HOUSEHOLD%	DEAF/HARD TO HEARING HOUSEHOLD%	INTELLECTUAL DISABLE HOUSEHOLD%	SPEECH PROBLEM HOUSEHOLD%	MENTAL DISABLE HOUSEHOLD%	DEAF/BLIND HOUSEHOLD%
1	4	9	3	1	8	6	3
2	3	15	10	1	8	6	3
3	1	15	5	2	22	10	5
4	2	5	0	0	1	1	0
5	2	1	0	0	1	0	5
6	2	0	0	1	5	5	0
7	2	10	8	1	6	12	3
8	1	6	3	0	9	8	0
9	3	1	1	0	0	0	9
10	3	1	0	0	0	0	0
11	18	5	1	1	5	9	3
12	3	1	1	0	1	0	0
13	1	1	1	0	0	1	0
14	2	1	0	0	2	2	0
15	5	1	2	0	1	2	0
16	2	0	0	5	3	5	0

Source: VCA 2021/Municipal profile

1.7 MULTI-SECTORAL VULNERABILITY AND CAPACITY ASSESSMENT

1.7.1 INTRODUCTION

The Vulnerability and Capacity Assessment (VCA) of Birendranagar Municipality focused on assessing the underlying conditions influencing susceptibility of communities & households, and their adaptive capacities to overcome shocks and stresses caused by climatic and non-climatic hazards in the area. The framework for the VCA was based on the UNDRR's concept of Vulnerability – the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, community, assets or systems to the impacts of hazards. UNDRR considers vulnerability as a function of Hazard, Vulnerability, Exposure and Adaptive Capacity. The proposed framework for VCA for this exercise unpacks the elements, influencing susceptibility at community level and measures the strengths, attributes and capitals within a community to manage and reduce disaster risk and strengthen resilience. Hence, the following function was adopted specifically for measuring vulnerability of communities:

$$\text{Vulnerability} = \frac{\text{Susceptibility}}{\text{Adaptive Capacity}}$$

The VCA tool was developed to collect, combine and analyze information obtained through Focused Group Discussion that was organized at ward/community level in the municipality. The questionnaire for the FGD were divided into 5 main sections with a total of 34 main questions (and additional sub-questions) designed for collecting holistic information from participating community members. A total of 16 FGD was conducted in 16 wards of the Municipality with a total participation of 277 individuals (Male: 177 and Female:100). The answers obtained from the FGD were plotted across indicators to examine susceptibility and adaptive capacity. These indicators were identified after analysis of FGD data, and based on indicators designed for NAP formulation in Nepal. A total of 10 indicators focusing on socio-economic characteristics of the communities were developed for measuring susceptibility and 48 indicators for measuring adaptive capacities. Since, all these indicators were equally important and had direct impact on susceptibility and capacity of communities, equal weights were provided to each indicator. A proportion based ranking method was adopted to rank the effective vulnerability of the wards/communities based on the average scores obtained for each indicator. A score of 0 means the ward/community is less vulnerable to climate and non-climatic hazards and score above 1 depicts higher vulnerability of the communities. It is assumed that this method would help in understanding specific elements that need to be prioritized at the community and ward level for building resilience of vulnerable communities. The following table provides an overview of the information and data collected through the questionnaires.

Sections	*Information and Data Collected*
Section 1	Household Level Information – Population, Density, Literacy, Ethnicity, Disability, Access to Social Security, Occupation Base
Section 2	Hazard and Exposure – Households Affected by Disasters, Vulnerable Households, Historic Timeline of Disasters, Response and Recovery Efforts
Section 3	Economic Vulnerability and Capacity – Land Holdings, Vocational Training, Information of Community Based Organizations, Savings and Credit
Section 4	Preparedness and Capacity – DRM Plans, Training, Simulation and Drill, Access to Response Services, HHs Knowledge and Capacity and Rescue and Response
Section 5	Urban Development and Services – Access to physical and social infrastructure, Building Typologies, Slums & Squatters, Culture and Heritage Zones

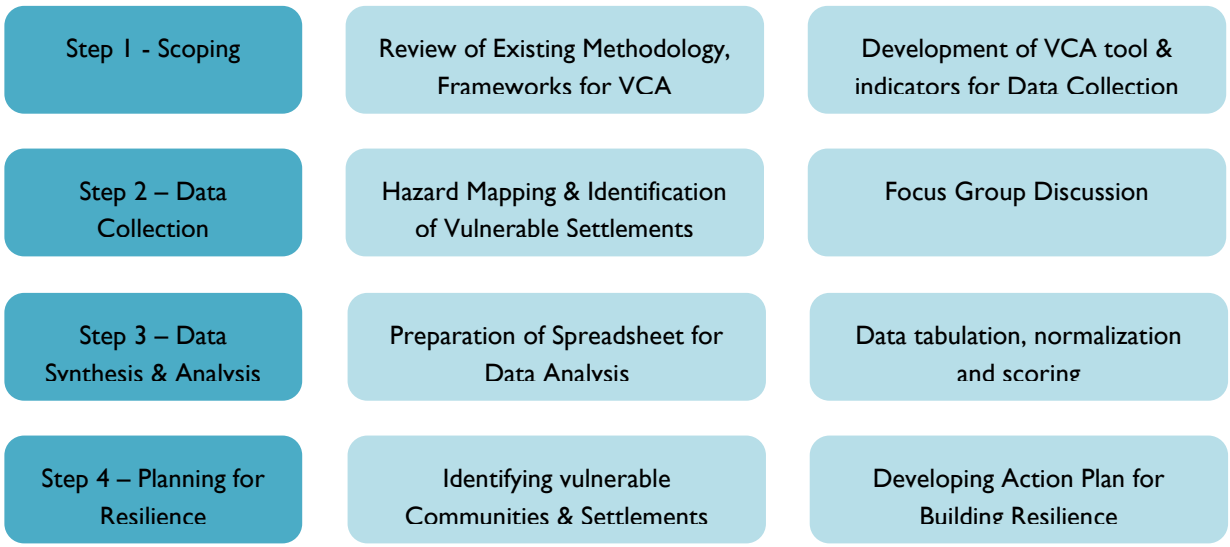


Figure 0-1: Methodological Steps for VCA Assessment in Birendranagar

1.7.2 SUSCEPTIBILITY

The indicators used to understand the susceptibility of Birendranagar Municipality mainly focuses on the demographic and economic indicators which can undermine the resilience at household level as well as community level. The indicators included are like; literacy rate, irregular occupation, old and child only households, women headed and single women households, disability, poverty, marginalized population etc.

Based on the data received from the FGD, it was observed that the ward 9 was more susceptible to climatic and non-climatic hazards based on their demographic and economic characteristics. This ward was followed by ward 15, 11, 3 and 2 in the susceptibility ranking. The main attributes for higher susceptibility is because of higher percentage of poor households and irregular sources of income with most of the households depending on daily wage labour for sustenance. It was found that around 65% HHs in ward 9 and 80% HHs in ward 15 are poor, and around 73% HHs in ward 9 and 60% HHs in ward 15 are engaged in daily labour jobs. These characteristics definitely decreases the coping capacity of individuals during disasters. The highest percentage of HHs in daily labour was observed in ward 2 (80%), and % of household with disables population was highest in ward 11 (18%), and both these wards have substantial population size. From exposure calculation it is observed that, the population at risk to flood is higher in ward 9 and rainfall induced landslide is higher in ward 15. Based on exposure calculation it is observed that, 3.5% of the population are at risk in case of water level rise above 2 meters, and 43% of the population are in high-risk zone of rainfall induced landslide in Ward 15.

The climate change also had a negative impact on the livelihood and health of the families which has increased their susceptibility to hazards. Most of the farmer groups and fish farmers reported decrease in agricultural production, increase in diseases in the crop and difficulty in rearing animals especially due to cold wave in winters and drought or extreme rainfall in the rainy season.

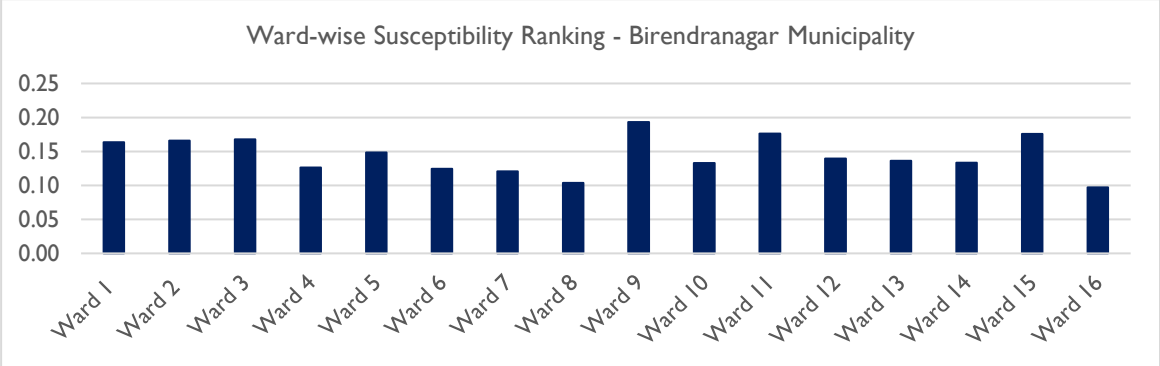


Figure 0-2: Susceptibility Scoring of Birendranagar Municipality based on FGD at ward level

Table 0-6 Susceptibility Scoring

Indicators for Susceptibility (scores in proportion)											
Wards	Illiterate HHs	HHs with Children below 5 years	Dalit HHs	Female Headed HHs	Single Women (Widow) HHs	Poor HHs	Physically Disabled HHs	HHs in daily labour	HHs income through foreign employment	HHs with only children (adults in foreign employment)	Average of Scores
Ward 1	0.07	0.08	0.28	0.18	0.04	0.35	0.04	0.61	0.00	0.00	**0.16**
Ward 2	0.10	0.08	0.34	0.20	0.02	0.25	0.03	0.53	0.10	0.00	**0.17**
Ward 3	0.04	0.12	0.22	0.20	0.08	0.20	0.01	0.80	0.00	0.00	**0.17**
Ward 4	0.06	0.06	0.20	0.05	0.03	0.15	0.02	0.55	0.15	0.00	**0.13**
Ward 5	0.20	0.04	0.20	0.07	0.05	0.19	0.02	0.56	0.12	0.04	**0.15**
Ward 6	0.00	0.05	0.40	0.05	0.02	0.10	0.02	0.60	0.00	0.00	**0.12**
Ward 7	0.20	0.05	0.12	0.12	0.03	0.20	0.02	0.38	0.09	0.00	**0.12**
Ward 8	0.09	0.04	0.10	0.12	0.12	0.11	0.01	0.45	0.00	0.00	**0.10**
Ward 9	0.01	0.07	0.25	0.10	0.03	0.65	0.03	0.74	0.05	0.00	**0.19**
Ward 10	0.00	0.11	0.13	0.03	0.02	0.46	0.03	0.55	0.00	0.00	**0.13**
Ward 11	0.02	0.09	0.13	0.08	0.10	0.35	0.18	0.79	0.00	0.01	**0.18**
Ward 12	0.10	0.10	0.20	0.07	0.02	0.20	0.03	0.40	0.00	0.27	**0.14**
Ward 13	0.00	0.05	0.20	0.09	0.04	0.50	0.01	0.47	0.01	0.00	**0.14**
Ward 14	0.00	0.02	0.20	0.10	0.06	0.50	0.02	0.43	0.00	0.00	**0.13**
Ward 15	0.00	0.01	0.11	0.10	0.07	0.80	0.05	0.60	0.02	0.00	**0.18**
Ward 16	0.05	0.02	0.30	0.07	0.04	0.17	0.02	0.29	0.01	0.00	**0.10**

1.7.3 ADAPTIVE CAPACITY

The adaptive capacity of the community was measured using assets identified in the sustainable livelihood framework. The VCA tool takes into consideration the households with strengthened capital will be better prepositioned to cope with climatic and non-climatic hazards. The assets were classified into 5 categories – Social, Financial, Human (Training and Preparedness), Financial and Physical. Overall assessment shows that ward 1 has the highest adaptive capacity and ward 4 had the lowest adaptive capacity.

Social Capital – The information from FGD shows that the participation of HHs in community-based organization, women's group and youth organization are relatively low in urbanizing wards in the city, and higher in the rural wards like ward 15, 16 and 14. Similarly, the participation in agriculture groups and community forest is also high in these wards. This shows the rural wards have higher degree of participation and sharing, and support in their networks.

Financial Capital – The access to banking services is higher in wards like 1, 3, 4, 5 and 6 and comparatively less in ward like 14, 15, and 16. This shows a higher degree of financial services available in city area and less outreach to the wards with rural characteristics. However, a lot of HHs have accounts in cooperatives and *laghu bittiya sansthan* (micro finance) in wards 14, 15 and 16.

Human Capital (Training) – A lot of HHs have received vocational training for diversifying income in field of tailoring, carpentry, plumbing etc. However, the outreach of the training program for diversification of income remains low and it is unknown what percentage of people are engaged in employment post training.

Human Capital (Preparedness) – The preparedness to hazards like flood, earthquake and fire seems to be better as most of the HHs during FGD acknowledged their participation in these drills and training. However, landslide preparedness is low in most of the wards.

Natural Capital – Most of the HHs had agricultural land in ward 9, 10, 11, 14, 15 and 16 and they practice agriculture to sustain livelihood. These wards have access to community forest and other natural resources for supporting their livelihood means.

Physical Capital – Almost 70% of the HHs have their own land and house in the municipality and almost all wards reported a good access to drinking water and sanitation except ward 13, and 12 where sanitation facilities are still challenging.

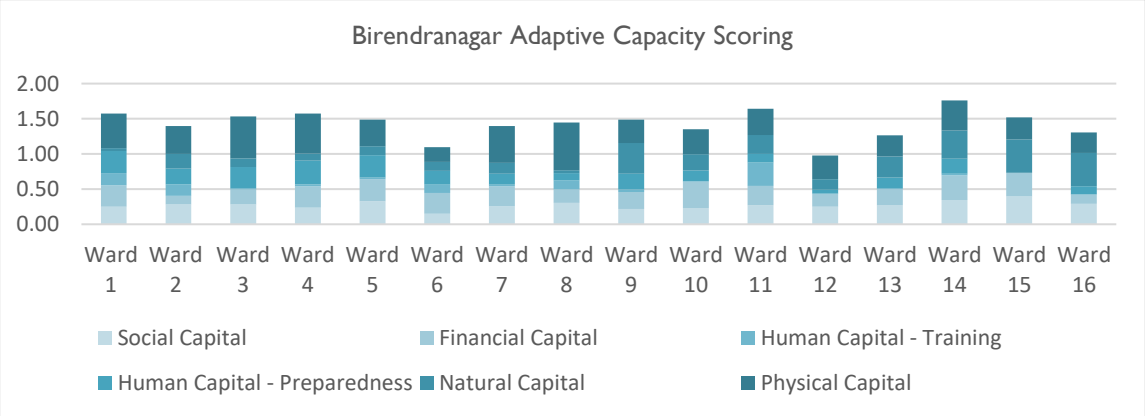


Figure 0-3: Adaptive Capacity Scoring of Birendranagar Municipality based on FGD at Ward Level

Table 0-7 Adaptive Capacity Scoring

Components for Assessing Adaptive Capacity (Scores in Proportion)							
Wards	Social Capital	Financial Capital	Human Capital - Training	Human Capital - Preparedness	Natural Capital	Physical Capital	Average of Scores
Ward 1	0.25	0.31	0.17	0.31	0.04	0.49	**0.26**
Ward 2	0.28	0.12	0.16	0.23	0.21	0.40	**0.23**
Ward 3	0.28	0.21	0.02	0.30	0.13	0.60	**0.26**
Ward 4	0.23	0.31	0.03	0.34	0.10	0.57	**0.26**
Ward 5	0.32	0.32	0.02	0.32	0.13	0.38	**0.25**
Ward 6	0.15	0.30	0.11	0.20	0.13	0.21	**0.18**
Ward 7	0.25	0.29	0.02	0.16	0.16	0.52	**0.23**
Ward 8	0.30	0.19	0.13	0.11	0.04	0.68	**0.24**
Ward 9	0.22	0.24	0.03	0.23	0.43	0.33	**0.25**
Ward 10	0.23	0.37	0.01	0.15	0.23	0.35	**0.23**
Ward 11	0.27	0.27	0.33	0.13	0.26	0.38	**0.27**
Ward 12	0.25	0.18	0.01	0.05	0.15	0.34	**0.16**
Ward 13	0.27	0.23	0.02	0.15	0.30	0.30	**0.21**
Ward 14	0.34	0.35	0.02	0.21	0.40	0.43	**0.29**
Ward 15	0.40	0.33	0.00	0.00	0.48	0.31	**0.25**
Ward 16	0.29	0.13	0.00	0.11	0.48	0.29	**0.22**

1.7.4 FINDINGS OF THE VCA

The findings from VCA shows the wards in Birendranagar Municipality fall into mid to high level of vulnerability status. Though most of the wards have relatively higher adaptive capacity, their ranking shows 8 out of 16 wards in relatively higher vulnerability zone with a score in-between 0.6 to 0.9. Ward 9 & 12, has been identified as the most vulnerable ward in the indexing, while wards 14 and 16 have scored the least in the vulnerability. It is also evident that ward 9 is highly exposed to flood hazards, and with high susceptibility of the HHs, their resilience to shocks is low. Although, wards 14 and 16 have scored low in the vulnerability indexing but are equally exposed to hazards like rainfall induced landslide with almost 37%, 43% and 33% HHs exposed to landslide hazard respectively. With the given scenario, the RSLUP for Birendranagar should focus on identifying specific policies and programs to mitigate the disaster risk ward-wise and enabling better preparedness at local level.

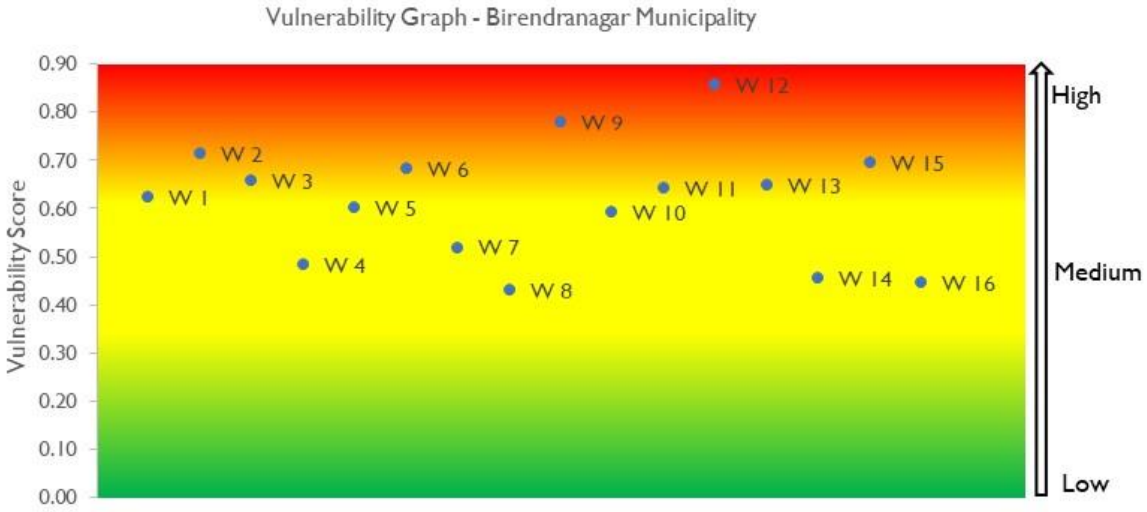


Figure 0-4: Vulnerability Graph of Birendranagar Municipality based on VCA finding

Table 0-8 Vulnerability Score

Wards	Susceptibility	Adaptive Capacity	Effective Vulnerability Score
Ward 1	0.16	0.26	**0.62**
Ward 2	0.17	0.23	**0.71**
Ward 3	0.17	0.26	**0.66**
Ward 4	0.13	0.26	**0.48**
Ward 5	0.15	0.25	**0.60**
Ward 6	0.12	0.18	**0.68**
Ward 7	0.12	0.23	**0.52**
Ward 8	0.10	0.24	**0.43**
Ward 9	0.19	0.25	**0.78**
Ward 10	0.13	0.23	**0.59**
Ward 11	0.18	0.27	**0.64**

Ward 12	0.14	0.16	**0.86**
Ward 13	0.14	0.21	**0.65**
Ward 14	0.13	0.29	**0.46**
Ward 15	0.18	0.25	**0.69**
Ward 16	0.10	0.22	**0.45**

PHYSICAL VULNERABILITY OF BUILDINGS

Physical vulnerability of buildings were analyzed based on the fragility curve provided by JICA in Report "The study on Earthquake Disaster Mitigation in The Kathmandu Valley." Damage rate and collapse rate for each building were calculated in-reference to the PGA values. Analysis showed that damage ratio for collapse rate and damage rate was higher for building with mud mortar, while it was the least for RCC building with height below 3 storeys.

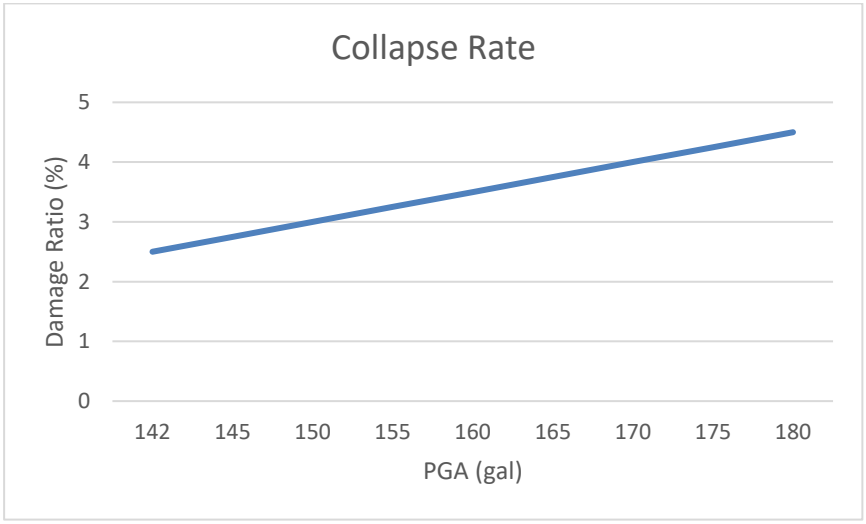


Figure 0-1 Cement Masonary Buildings Collapse Rate and Fragility Curve

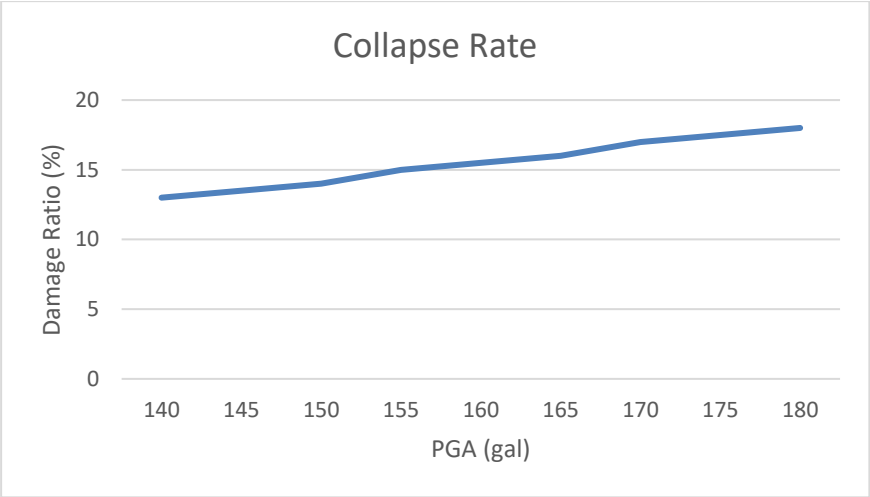


Figure 0-2 Mudmortar Buildings Collapse Rate and Fragility Curve

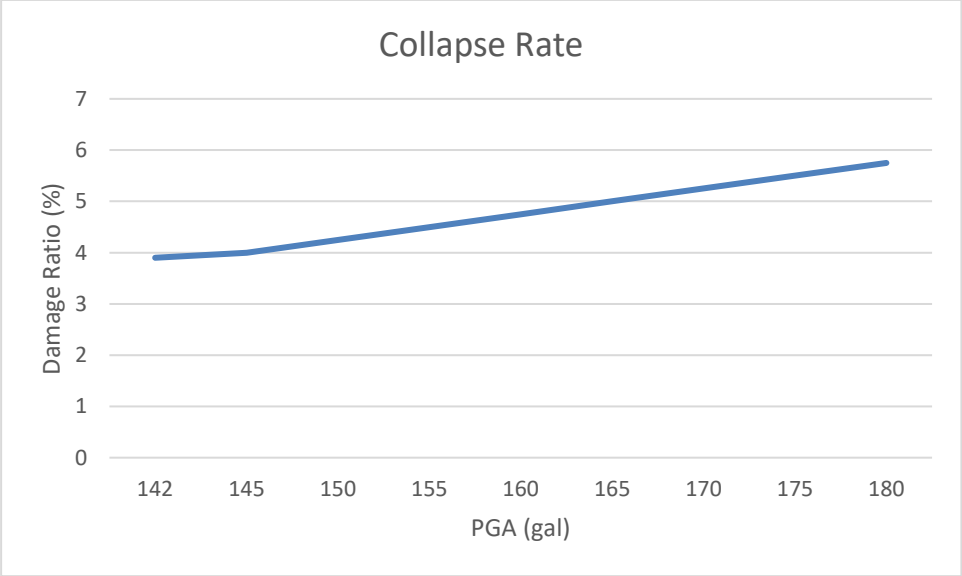


Figure 0-3 RCC3 Buildings Collapse Rate and Fragility Curve

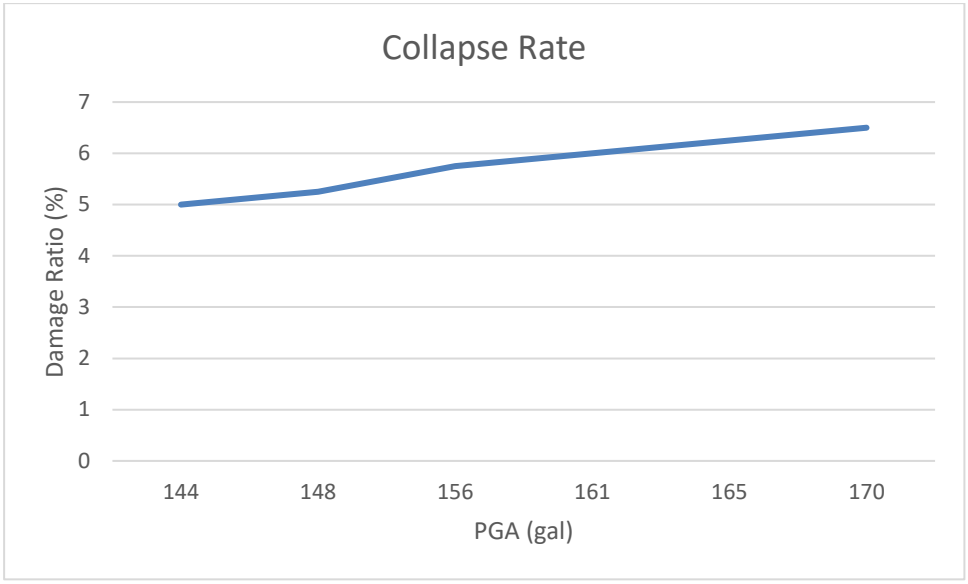


Figure 0-4 RCC5 Buildings Collapse Rate and Fragility Curve

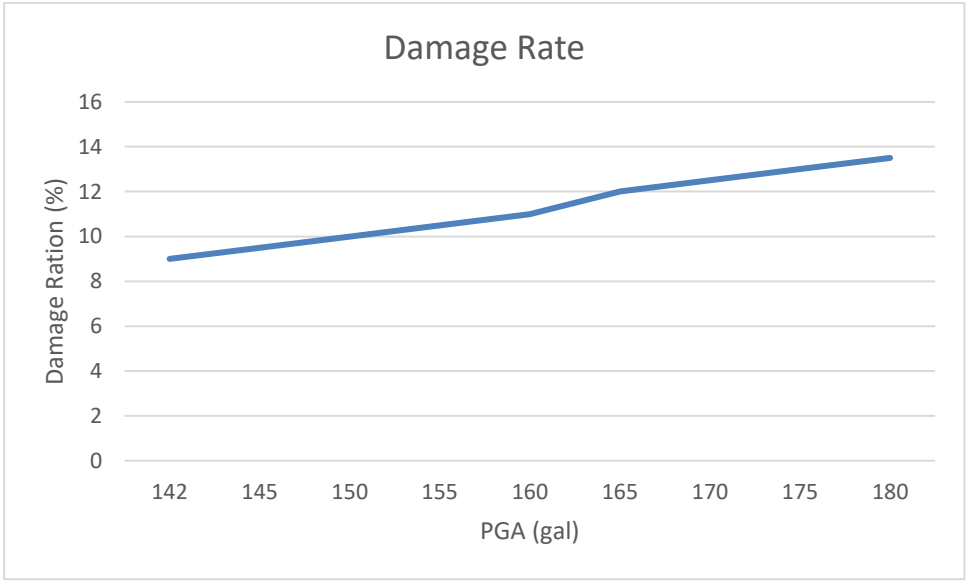


Figure 0-5 Cement Masonary Buildings Collapse Rate and Fragility Curve

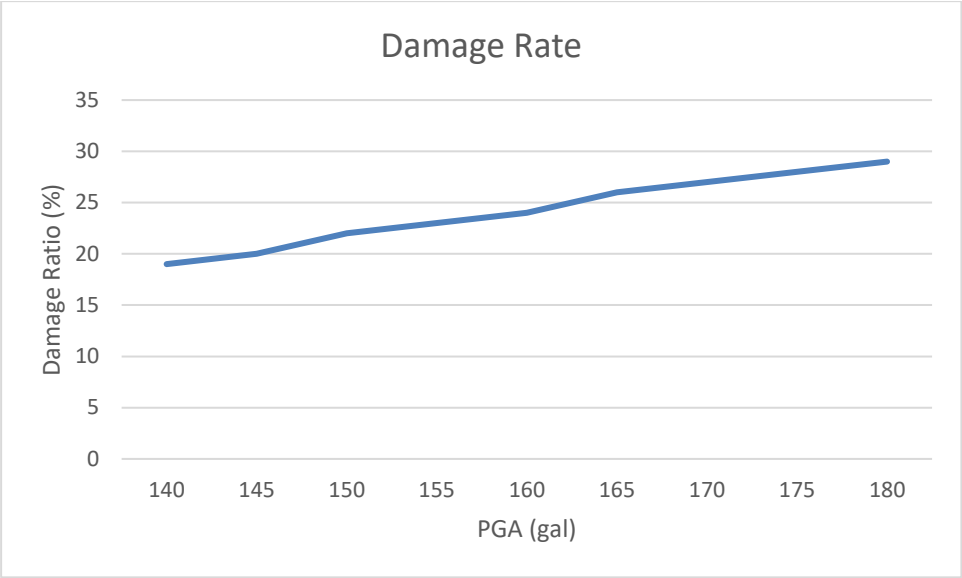


Figure 0-6 Mud Mortar Buildings Damage Rate and Fragility Curve

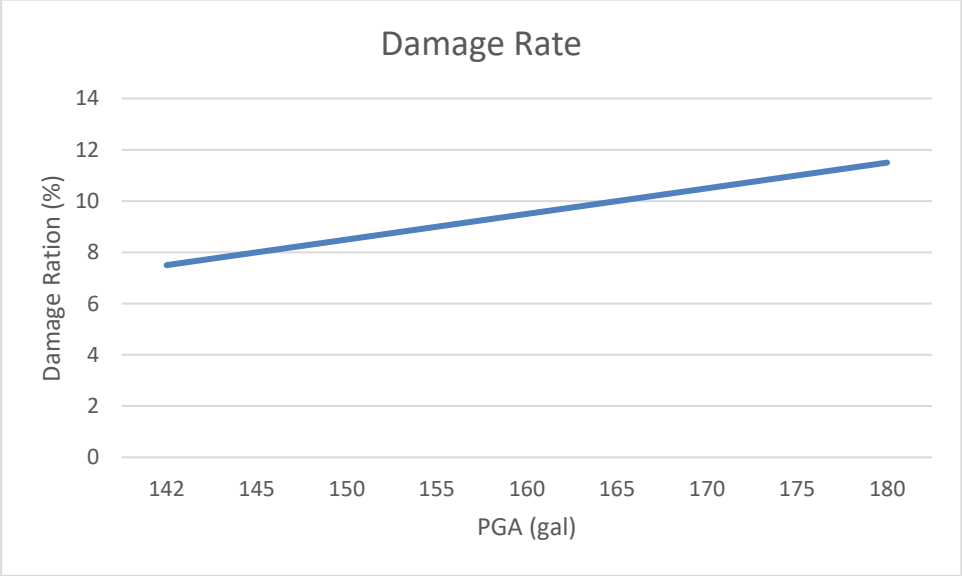


Figure 0-7 RCC3 Buildings Damage Rate and Fragility Curve

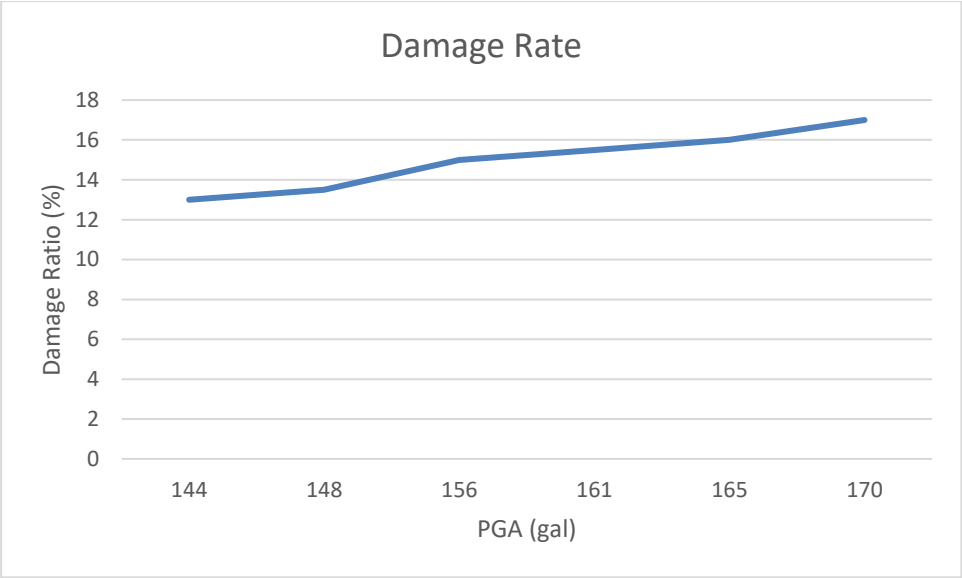


Figure 0-8 RCC5 Buildings Damage Rate and Fragility Curve

SECTION 5 MAINSTREAMING HVRA IN DRRM AND RSLUP PROCESSES

MAINSTREAMING HVRA IN DRRM AND RSLUP PROCESS

Over more than two decades, there has been increasing recognition of the need to 'mainstream' disaster risk reduction into development – that is, to consider and address risks emanating from natural hazards in national and local level strategic frameworks, institutional structures and sectoral strategies and policies and in the design of individual projects in hazard-prone countries. Mainstreaming requires analysis both of how potential hazard events could affect the performance of policies, program, and projects and of the impact of those policies, program, and projects, in turn, on vulnerability to natural hazards.

Mainstreaming of DRR is also a governance process enabling the systematic integration of DRR concerns into all relevant development spheres. In other words, responsive, accountable, transparent, and efficient governance structures underwrite the environment where DRR can be institutionalized as an underlying principle of sustainable development. Mainstreaming disaster risk and climate change adaptation involves systematically assessing and incorporating information and measures related to climate risks and vulnerabilities into development policies, plans, institutions, programs and projects.

Recently, the local governments in Nepal are significantly empowered. Many new responsibilities (like-power to resolve local disputes, authority to enact and implement new acts, policies, and strategies; full cycle of DRRM; local economic development and others) are first time transferred to the local governments. On top of that, majority of sectoral responsibilities (education, health, agriculture, tourism, irrigation, and others) are now under the portfolio of local governments. A comprehensive and robust local development is a multi-sectoral and multi-dimensional agenda, which needs to be championed by adopting a truly integrated and resilient approach. Besides, local governments having power and authority to manage full cycles of DRRM is another major plus, which supports mainstreaming of DRRM at the local level in Nepal.

Land is central to all kinds of local developments. Risk Sensitive Land Use Plan (RSLUP) guides the wholesome development of the municipality and ensures that the local development process is risk sensitive and disaster friendly. The RSLUP will not only guide the future growth, but it will also direct sectoral developments in order to guarantee that the overall development of the municipality is overarching, and risk informed as well as integrated and resilient. Both the land use policy and building by-laws developed to facilitate the implementation of RSLUP will also support operationalization of mainstreaming agenda. For this purpose, the municipality must acknowledge the merit and importance of promoting risk sensitive development and therefore commit to inform and implement all the recommendations prescribed by the RSLUP. The process of mainstreaming should start with the categorical mention of this concept, in the vision and strategic documents of the municipality, which later should be formally endorsed on consensus by the municipal council. The pledge and commitment of the municipal council will help and motivate office bearers to operationalize and apply this concept in practice with utmost interest and priority. This is only possible when both the issues of climate change and disaster risk are fully mainstreamed through sectoral departments in the overall planning, budgeting, and monitoring system of the municipality.

In the present context, integrating both disaster and climate change risk into the existing operational system of the municipality is comparatively easier and doable. The municipalities are privileged to have the full control and authority to lead and manage all cycles of disaster risk management, as the process demands simultaneous interventions in all cycles, to achieve an all-inclusive mainstreaming of risk concerns into all forms of physical, social, and economic development of the society and municipality at large. Similarly, having sectoral responsibility under the municipality portfolio is another significant advantage, which directly enables mainstreaming at the local level. In this situation, if the municipal council and their leaders prioritize disaster and climate risk through a principal decision, the concept will automatically trickle down to the sectoral departments including a department of planning, budgeting, and monitoring of the municipal government. However, trickle down alone will not guarantee the successful operationalization of the concept at the level of development planning, formulation of projects and their implementation in the field. Just like the process of IEA and EIA, Initial Risk Assessment (IRA) and Risk Impact Assessment (RIA) mechanism should be developed to make risk impact assessment as compulsory before deciding on investing in any major development projects. It is advisable, if Ministry of Federal Affairs and General Administration (MOFAGA) helps to develop, endorse, and share the standard IRA and RIA model, which will be later adopted by the local municipality as per their ground realities.

Many municipalities are now having DRRM department or section including focal point, which may be considered as a steppingstone to promote mainstreaming agenda, in a more holistic and wholesome manner. The 'Whole of a society approach' and 'leave no one behind' should be the fundamental principle to stimulate mainstreaming process at the local level. Besides, establishment of 'Disaster Fund' by many municipalities is another landmark progress, which will further support the agenda of mainstreaming, leading to risk informed development of the municipality. The municipalities must champion the model of participatory development and should collaborate with all relevant partners and stakeholders (DPs, I/NGOs, security forces, donors, civil society, volunteers, universities, professionals, and others) on a frequent basis. At the same time, local municipalities must also invest in knowledge building, skill and capacity development and information management at the local level.

1.8 LIST OF RELEVANT ACTS AND POLICIES

S. No	Policy	Key attributes
International level		
1	Hyogo Framework for action (2005 - 2015)	The Hyogo Framework was the global blueprint for disaster risk reduction efforts between 2005 and 2015. Its goal was to substantially reduce disaster losses by 2015 - in lives, and in the social, economic, and environmental assets of communities and countries.
2	Sendai Framework 2015-2030	Implementation of Disaster Risk Reduction and Management Act, 2017. Set out the following four priority areas: Understanding disaster risk; Strengthening disaster risk governance to manage disaster risk; Investing in disaster risk reduction for resilience; Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction.
3	Sustainable Development Goals, 2015-30	SDG 11 aspires to make cities and human settlements inclusive, safe, resilient, and sustainable SDG 13 calls for urgent action to combat CC and its impacts
4	New Urban Agenda, UN Habitat III, 2016	It has envisaged adopting and implementing the DRRM, lessening crisis, building resilience and response capacity on natural and human induced disaster, and cities promoting the climate change reduction and adaptation.
5	Paris Agreement 2015	The central aim of this agreement is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Additionally, the agreement aims to increase the ability of countries to deal with the impacts of CC, and

S. No	Policy	Key attributes
		at making finance flows consistent with a low GHG emissions and climate-resilient.
National Level		
1	Nepal's Constitution, 2015	The Constitution of Nepal has clearly stipulated that DRM is a shared responsibility at all levels of government. The Constitution further states that the responsibility of disaster management falls under the jurisdiction of all tiers of government.
2	National DRRM Policy, 2074	Aid and assistance to women, children, Senior citizen, physically handicapped, economically backward etc. Community level awareness programs for pre and post disaster preparedness as well as reconstruction
3	National DRRM Act, 2074	The Act is the primary instrument to lead disaster response, risk reduction, preparedness and management interventions in an event of a disaster in the country. It is a paradigm shift from the relief centric approach to a broader disaster risk management and risk reduction aligning with the SFDRR, also replacing the Natural Calamity Relief Act of 1982.
4	Local Government Operation Act, 2074	The act outlines the roles and responsibilities of Urban and Rural Municipalities, District Councils/District Coordination Committees, and Provincial Coordination Councils. This Act entrusts the local level units with the responsibilities of formulating their own laws, by-laws, regulations; levying taxes; and raising funds, in addition to the judiciary responsibilities.
5	National DRR Strategic Action Plan 2018-2030	Inclusion of Marginalized communities and households in the DRM programs and process; Insurance and financial aid to economically weaker section for reconstruction; Institutionalization of DMCs, fund distribution, identification of beneficiaries etc.
6	Reconstruction and Rehabilitation Policy 2016	
7	Guidance Note on Disaster Preparedness and Response Planning 2011	
8	National Disaster Response Framework 2019	
9	National Urban Development Strategy, 2017	Considered resilience among one of the five guiding principles for a balanced and prosperous urban future by integrating resilience in urban system and community plan formulation
10	National Climate Change Policy 2020	
11	National Land use Act 2019	
12	National Land Policy 2019	
13	LISA 2020	
14	Nepal Road Safety Action Plan (2013-2020)	Made with a vision to reduce loss of life and property through the provision of safe road infrastructure and services backed with effective post-crash responses.
Province Level		
1	DRRM Act	
2	DRRM Policy	
3	DRRM Strategic Action Plan (2020-2030)	
Local Level		
1	DRRM Act	
2	DRRM Policy	
3	DRRM Strategic Action Plan (2020-2030)	
4	DRR Fund Operational Guideline	
5	LDRMP	

1.9 IDENTIFIED DRRM ACTIVITIES

The most prevalent and recurring hazards in the municipal region are localized landslides (primarily debris flow/slide and rock slid) followed by localized river bank cutting and flooding. Liquefaction susceptibility is medium to high in the entire Surkhet Valley area for scenario earthquakes due to seismicity of the region and local soil conditions. New settlements and encroachment in the flood plains of Itram Khola and other local streams are developing and frequently impacted by flash floods and seasonal monsoonal flooding. Since, municipal region is located in the seismically active MHT and MBT regions, prevalence of earthquake related hazards are high.

Several location specific activities are recommended here, primarily related to adaptation and mitigation of landslides, bank cutting, flood and local inundation. However, these recommendations should not be considered definitive, as there could be other options or choices depending on the resources available and technical capacity of the concerned agency/municipality.

Wards	Location	Type	Recommended Activities
1	Bangesimal	Bank Cutting	• Construction of series of spurs with embankments along both banks • Channelization of stream through spurs and embankments • Green belts choosing bamboos and appropriate plant species • Installation of flood early warning system (EWS)
	Bangesimal	Flood, bank cutting	
	Aapkhori	Flooding	
2	Bhate Kuna	Inundation	• Management of the surface water drainage system • Promotion of flood resilient housing structures • Construction of temporary deep basins/water retention ponds to hold the flood water
	Phalate	Inundation	
	Bhureli	Inundation	
	Bhureli	Inundation	
	Bhureli	Inundation	
	Thauri	Inundation	
	Thauri	Bank Cutting	• Construction of series of spurs with embankments along both banks • Channelization of stream through spurs and embankments • Green belts choosing bamboos and appropriate plant species • Installation of flood early warning system (EWS)
	Daulatpur	Cutting and flash flooding	
	Company Khola Dobhan	Flood and Inundation	
	Nikas Area	Flood	
3	Yari Chowk	Flooding	• Construction of series of spurs with embankments along both banks • Channelization of stream through spurs and embankments • Green belts choosing bamboos and appropriate plant species • Installation of flood early warning system (EWS)
	Downstream from Yari Chowk bridge	Flooding	
	Sukumbashi tol	Flooding, bank cutting	
4	Sahid Park	Flooding	

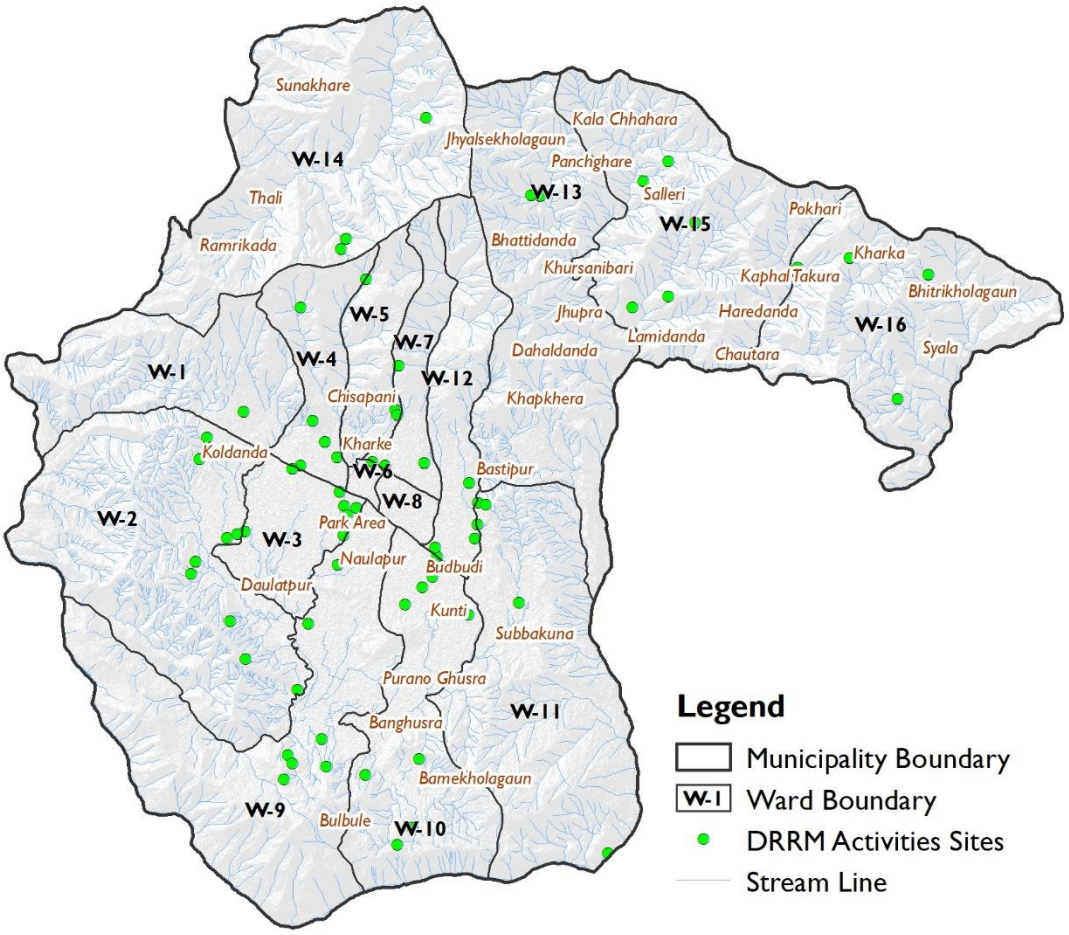
	Upstream from Sahid Park	Flooding	• Construction of series of spurs with embankments along both banks • Channelization of stream through spurs and embankments • Green belts choosing bamboos and appropriate plant species • Installation of flood early warning system (EWS)
	Zero Dam	Flooding and Landslide	
	Gunapani	Flooding	
	Kalagaun tol	Bank Cutting	
	Upstream from Yeri Chowk bridge	Bank Cutting	
	Upstream from Yeri Chowk bridge	Flooding	
5	Bhute Pokhari	Landslide	• Surface water management through cutoff drains and retaining wall below the village • Groundwater management through surface drains and weep holes • Landscape/watershed level NbS and local scale Bioengineering measures
	Shrinagar	Flooding	• Channelization of stream through spurs and embankments • Green belts choosing bamboos and appropriate plant species • Installation of flood early warning system (EWS)
6	Birendrachowk	Flooding	• Channelization of stream through spurs and embankments • Green belts choosing bamboos and appropriate plant species • Installation of flood early warning system (EWS)
	Yari Chowk	Flooding	
	Upstream from Yari Chowk bridge	Flooding	
7	Dailekh Road	Landslide	• Surface water management through cutoff drains and retaining wall on uphill side of road • Trimming the hanging mass and regrading • Groundwater management through weep holes and surface drains • Landscape/watershed level NbS and local scale Bioengineering measures
	Dailekh Road	Complex Landslide	
	Dailekh Road	Landslide	
	Sagarmatha tol	Flooding	• Channelization of stream through spurs and embankments • Green belts choosing bamboos and appropriate plant species • Installation of flood early warning system (EWS)
8	Birendranagar Industrial Area	Flooding	• Channelization of stream through spurs and embankments • Green belts choosing bamboos and appropriate plant species • Installation of flood early warning system (EWS)
	Pangeni chowk	Bank cutting	
	Airport	Flooding, bank cutting	
	Airport	Flooding, bank cutting	
9	Itaura	Flood and Bank cutting	• Channelization of stream through spurs and embankments • Green belts choosing bamboos and appropriate plant species
	Itaura	Bank Cutting	

	Ghogreni	Inundation and Bank cutting	• Installation of flood early warning system (EWS)
	Khorke Khola and Parseni Khola confluence	Flood and Bank cutting	
	Mathilo Parseni	Flood and Bank cutting	
10	Bame Kholagaun	Bank Cutting	• Channelization of stream through spurs and embankments • Green belts choosing bamboos and appropriate plant species • Installation of flood early warning system (EWS)
	Bame Kholagaun	Flood	
	Budbudi	Flood	
	Raharpur	Bank Cutting and Inundation	
	Manikapur	Inundation	
11	Jhupra Khola	Flood and Bank cutting	• Channelization of stream through spurs and embankments • Green belts choosing bamboos and appropriate plant species • Installation of flood early warning system (EWS)
	Gagre Tal (Barrakuna), Taulidaha	Bank cutting, Bank scouring and landslide	
	Bastipur	Flood	
12	Basghari (Culvert)	Flood	• Channelization of stream through spurs and embankments • Green belts choosing bamboos and appropriate plant species • Installation of flood early warning system (EWS)
	Jhykri Tole, Sukumbasi Basti	Bank cutting	
13	Guptipur, Subedi Tole	Flood	• Channelization of stream through spurs and embankments • Green belts choosing bamboos and appropriate plant species • Installation of flood early warning system (EWS)
	Guptipur, Subedi Tole	Flood, Bank cutting	
	Guptipur	Bank cutting	
	Nikas Khola, Pragatishil Tol	Rock slide	• Surface water management through cutoff drains and retaining wall on uphill side of road • Groundwater management & afforestation • Landscape/watershed level NbS and local scale Bioengineering measures
	Jumlakot	Soil Slide	
14	Gothikada	Debris slide	• Surface water management through cutoff drains and surface drains • Retaining wall on uphill side of road • Groundwater management and gully plugging through check dams and brush layering • Landscape/watershed level NbS and local scale Bioengineering measures
	Darnakot	Debris slide	
	Sal Danda	Landslide	
	Chedda	Complex Landslide	
	Sano Chandane	Landslide	
15	Kapase	Landslide	• Surface water management through cutoff drain and surface drains • Construction of retaining walls on uphill side of road and below the village base • Groundwater management • Gully plugging and brush layering on the landslide wall
	Damai Tol	Landslide	
	Laure Dada	Landslide	
	Bhir	Landslide	
	Kamere	Landslide	

	Pagali Dada	Landslide	• Landscape/watershed level NbS and local scale Bioengineering measures
	Bhalu Khola Gau	Landslide	
	Chuli	Landslide	
16	Gothikada	Complex Landslide	• Surface water management through cutoff drain and surface drains • Construction of retaining walls on uphill side of road and below the village base • Groundwater management • Gully plugging and brush layering on the landslide wall • Landscape/watershed level NbS and local scale Bioengineering measures
	Darnakot	Debris flow	
	Sal Danda	Landslide	
	Chedda	Landslide	
	Sano Chandane	Landslide	
	Pokhaaribata	Landslide	
	Jugepani	Landslide	

Any one of the recommended activities may not be effective considering the conditions of the flooding at any given time. Combination of the approaches along with short term engineering solutions enhanced by longer term ecosystem based approaches (such as bio-dykes and artificial wetland/retention pond) could provide additional co-benefits to the communities. Early warning system installation will provide lead time to the communities in case of impending event. Upstream/downstream communication and coordination for flood early warning needs to be implemented.

For the settlements in very high risk area (encroached areas in the flood plains of Itram Khola and other local streams), possible alternative could be "voluntary resettlement". Though the Local Government Operation Act 2074 mandates the municipality to "resettle" hazard prone settlements, the municipality do not have full legal authority for the acquisition of land required for such resettlement. The municipality need to coordinate with the federal authority for allocating the land for resettlement. Resettlement process should follow the provisions in the guideline जोखिमयुक्त वस्ती" स्थानान्तरण तथा एकीकृत वस्ती विकास सम्बन्धी कार्यविधि २०७५" by the GoN/Ministry of Urban Development.



Map 0-1: DRRM Activities Sites, Birendranagar Municipality

REFERENCE

Adhikari J., 2008. Land Reform in Nepal: Problem and Prospects. A Report published by ActionAid Nepal, 2008.

Bilham, Roger. 1995. "Location and magnitude of the 1833 Nepal earthquake and its relation to the rupture zones of contiguous great Himalayan earthquakes." *Current Science* 69 (2): 101-128.

CCPS, C. 2010. "Guidelines for Vapor Cloud Explosion, Pressure Vessel Burst, BLEVE and Flash Fire Hazards."

Chitrakar, GR, and MR Pandey. 1986. "Historical earthquakes of Nepal." *Bull. Geol. Soc. Nepal* 4: 7-8.

Eastman, J Ronald. 1999. "Multi-criteria evaluation and GIS." *Geographical information systems* 1 (1): 493-502.

Eckstein, David, Vera Künzel, and Laura Schäfer. 2021. *GLOBAL CLIMATE RISK INDEX 2021*.

Engineer, US Army Corps of. 2016. *HEC-RAS River Analysis System,Hydraulic reference manual.*

ESA. "Speckle Filtering." https://earth.esa.int/documents/653194/656796/Speckle_Filtering.pdf.

---. 2021a. "LEVEL-1 Radiometric Calibration." https://sentinel.esa.int/web/sentinel/radiometric-calibration-of-level-1-products.

---. 2021b. "Senitnel 1." https://sentinel.esa.int/web/sentinel/missions/sentinel-1.

MoUD. 2017. *National Urban Development Strategy.* (Kathmandu). https://www.moud.gov.np/storage/listies/July2019/NUDS_PART_B.pdf.

Omar, Najat Qader, and Aram Mohammed Raheem. 2016. "Determining the suitability trends for settlement based on multi criteria in Kirkuk, Iraq." *Open Geospatial Data, Software and Standards* 1 (1): 1-9.

Pandey, MR, GR Chitrakar, B Kafle, SN Sapkota, S Rajaure, and UP Gautam. 2002. Seismic hazard map of Nepal. Department of Mines and Geology, Kathmandu, Nepal.

Pandey, MR, and Peter Molnar. 1988. "The distribution of intensity of the Bihar-Nepal earthquake of 15 January 1934 and bounds on the extent of the rupture zone." *J. Geol. Soc. Nepal* 5: 22-44.

Pandey, MR, RP Tandukar, JP Avouac, J Lave, and JP Massot. 1995. "Interseismic strain accumulation on the Himalayan crustal ramp (Nepal)." *Geophysical Research Letters* 22 (7): 751-754.

Renjith, VR, and G Madhu. 2010. "Consequence modelling, vulnerability assessment and fuzzy fault tree analysis of hazardous storages in an industrial area." Cochin University of Science & Technology.

Saaty, R. W. 1987. "The analytic hierarchy process—what it is and how it is used." *Mathematical modelling* 9 (3-5): 161-176.

Tavus, BESTE, SULTAN Kocaman, C Gokceoglu, and HA Nefeslioglu. 2018. "CONSIDERATIONS ON THE USE OF SENTINEL-1 DATA IN FLOOD MAPPING IN URBAN AREAS: ANKARA (TURKEY) 2018 FLOODS." *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences*.

USAID. 2019. *Stat tus challeneges and opportunities for improved watershed management.*

World Bank, and Asian Development Bank. 2021. *Climate Risk Country Profile: Nepal.* The World Bank Group and the Asian Development Bank. https://www.adb.org/sites/default/files/publication/677231/climate-risk-country-profile-nepal.pdf.

Zhang, Meimei, Fang Chen, Dong Liang, Bangsen Tian, and Aqiang Yang. 2020. "Use of Sentinel-1 GRD SAR images to delineate flood extent in Pakistan." *Sustainability* 12 (14): 5784.

CCPS, C. (2010). Guidelines for Vapor Cloud Explosion, Pressure Vessel Burst, BLEVE and Flash Fire Hazards.

Renjith, V., & Madhu, G. (2010). *Consequence modelling, vulnerability assessment and fuzzy fault tree analysis of hazardous storages in an industrial area.* Cochin University of Science & Technology.

IUCN. (2021). Human wildlife Conflict. Retrieved from https://www.hwctf.org/about

WWF. (2007). *A Case Study on Human-Wildlife Conflict in Nepal* Retrieved from kathmandu: https://awsassets.panda.org/downloads/wwf_hwc_nepal_2008.pdf

NSSL. (2021). SEVERE WEATHER 101, Lightning Basics.

Chhetri, S. K., & Kayastha, P. (2015). Manifestation of an analytic hierarchy process (AHP) model on fire potential zonation mapping in Kathmandu Metropolitan City, Nepal. *ISPRS International Journal of Geo-Information, 4*(1), 400-417.

Dhakal, R., & Sharman, K. (2021). Fire safety planning: Give it due consideration. Retrieved from https://thehimalayantimes.com/opinion/fire-safety-planning-give-it-due-consideration

Eastman, J. R. (1999). Multi-criteria evaluation and GIS. *Geographical information systems, 1*(1), 493-502.

Eugene. (2021). Urban Fire. Retrieved from https://www.eugene-or.gov/1175/Urban-Fire

Mtani, I. W., & Mbuya, E. C. (2018). Urban fire risk control: House design, upgrading and replanning. *Jàmbá: Journal of Disaster Risk Studies, 10*(1), 1-8.

Omar, N. Q., & Raheem, A. M. (2016). Determining the suitability trends for settlement based on multi criteria in Kirkuk, Iraq. *Open Geospatial Data, Software and Standards, 1*(1), 1-9.

Saaty, R. W. (1987). The analytic hierarchy process—what it is and how it is used. *Mathematical modelling, 9*(3-5), 161-176.

Dhobi, S. H. (2020). Comparative study of air quality of West Terai, Nepal. *International Journal of Multidisciplinary Sciences and Adavanced Technology*, 1-9.

DoEnv. (2017). *Air Quality Management Action Plan for Kathmandu Valley.* Kathmandu: Department of Environment (DoEnv).

Engineer, U. A. (2016). *HEC-RAS River Analysis System,Hydraulic reference manual.*

Jha, A. K., & Bajracharya, T. (2014). Wastewater Treatment Technologies in Nepal. *Proceedings of IOE Graduate Conference* (pp. 76-81). Kathmandu: Institute of Engineering (IOE), Tribhuwan University.

Lamichhane, G. P., Poudel, R., & Shankar, P. P. (2019). Particulate matter pollution in Nepal: Analysis of air quality monitoring stations (AQMS) data from the year 2017. *Journal of Environmental Science*, 63-69.

WaterAid. (2008). *Decentralised wastewater management using constructed wetlands in Nepal.* Kathmandu: WateerAid.

WECS. (2019). *Flood control and managment manual.* Government of Nepal.

WHO. (2017). *Health and sustainable development*. Retrieved from World Health Organization (WHO): http://www.who.int/sustainable-development/transport/health-risks/air-pollution/en/

ANNEXS

ANNEX I GEOLOGICAL AND GECTECHNICAL FIELD STUDY

ANNEX 2 RIVER CROSS SECTION AND FLOW MEASUREMENTS

ANNEX 3 COMMUNUITY VULNERABILTIY ASSESSMENT CHECKLIST

ANNEX 4 CRITICAL INFRASTRUCTURE RAPID VULNERABILITY ASSESSMENT

ANNEX 5 MULTI-HAZARD MAPS

ANNEX 6 HISTORICAL HAZARDS

ANNEX 7 EXPSOURE ASSESSMENT