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TAYAR NEPAL PROGRAM

DEVELOPING RISK SENSITIVE LAND USE PLANNING FOR GODAWARI MUNICIPALITY

Final Report of Risk Sensitive Land Use Plan
April 2022

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EXECUTIVE SUMMARY

The multi-hazard risk assessment of Godawari Municipality is a major component of the Risk Sensitive Land Use Planning (RSLUP), commissioned by the USAID/Nepal's TAYAR Nepal- Improved Disaster Risk Management Project. The project aims at developing RSLUP incorporating both community-based participatory inputs and parameters based on scientific hazard modelling. In this reference, the project requires preparing land-use plans based on systematic procedures for risk assessment and development of proper implementation and monitoring plans. The project aims to contribute to reduce existing, future and residual risks in the project area in close coordination with local government representatives, local communities, and other major stakeholders in order to facilitate the sustainable utilization of land while strengthening the role of local/municipal bodies to reduce disaster risks and hazards.

In order to prepare risk sensitive land use plan, necessary activities were carried out under five phase systems. The detailed plan and methodologies were prepared through detailed literature review together with the establishment of municipal contact through induction meeting and identification of major hazards in the municipality. Windstorm, flooding and inundation, landslide, heatwave/coldwave, earthquake and fire hazards are the major risks of the municipality. Proceeding phase was followed by field data collection for undertaking multi-hazard risk assessment and vision setting workshop for the preparation of risk sensitive land use plan. Intensive field surveys were conducted during the difficult times of COVID-19 adopting covid protocols. During field survey, ward wise detailed consultation meetings were carried out to delineate the present and historical hazard events together with field verification for the formulation of multi-hazard analyses.

The multi-hazard assessment was carried out under joint research between the Rajdevi Engineering Consultants and international experts from Geoinformatics Center of the Asian Institute of Technology (GIC-AIT) and Faculty of Geo-Information Science and Earth Observation of the University of Twente (ITC-UT), the Netherlands, have been implemented to prepare the municipal level multi-hazard risk assessment as the first and major step. The main objective of this assignment is "to develop a methodology for analyzing the major natural hazards prevalent in the municipality, assessing the vulnerability of the communities and infrastructure to the major natural hazards, determining their degree of exposure to future hazardous events, and developing risk profiles as a basis for the land use planning processes." The overall methodologies, analyses and modeling of existing hazards of the municipality are determined. The collected historical events of hazards from the site, in-situ soil infiltration tests, household, institutional and building footprint surveys allow for more realistic scientific modeling of individual hazards. The primary and secondary data have been adopted for multi-hazard risk assessment (MHRA) and combined hazard are present. The hazard assessment is further analyzed the effects on elements-at-risk, loss and damage and multi-sectoral vulnerability assessments of the municipality and produced in required maps. The seven major hazards that are prevalent in Godawari are floods, earthquakes, landslides, windstorms, animal attacks, fire, and heatwaves/coldwaves. Flood hazard maps were produced by modelling in open-source software called OpenLISEM. Earthquake hazard maps were generated from the existing literature data. Landslide susceptibility maps were prepared with GIS using a combined statistical and heuristic method. Wind hazard maps were generated from global satellite datasets with improvements to represent local wind conditions. Animal attack and fire susceptibility maps were produced by Spatial Multi-criteria Evaluation (SMCE) in GIS. Finally, climate extremes were analyzed statistically using globally accepted climate indices. Elements-at-risk data were collected for building footprints, population, agricultural areas, and roads, as key indicators. Image classification, interpretation of high-resolution satellite images, and OpenStreetMap were used for generating a map of agricultural areas and roads. Exposure assessment was done for all relevant combinations of hazard types, elements-at-risk types, and

administrative units, and exposure profiles were generated for each of the wards of the Godawari Municipality. Vulnerability tables for all the elements-at-risk were generated from the literature and expert opinion. Similarly, spatial probability values were estimated for each hazard which indicates the chance that a given location will be impacted by the hazardous event. The study was further focused on multi-sectoral vulnerability and assessed the vulnerability in terms of social, economic, environmental and structural vulnerabilities.

The 38 years of disaster incidents in Godawari Municipality was the consequences of climate change and extreme weather-related phenomena. The probabilistic risk assessment showed the higher risk of windstorm followed by flood and earthquake. Though the disaster incidents are higher in the municipality, the urban expansion in last 15 years increased up to 39.8% followed by the increment of 4.8% rate of change per year in the last 11-year period. On the other hand, the social structures are suffered through lack of nutritious food, health, education and turned into the vulnerable conditions. Proceeding, on the account of migration and increased in haphazard urban development are the key factor to bring the environmental hazard and vulnerability with the degradation in quality of water resources, soil fertilizations, forest encroachment, pathogenic attacks together with decreasing in natural resources and increase of automobiles and dust roads to generate air pollution.

The structural vulnerability shows that the majority of older one storey RCC frame structures have smaller column size as well as inadequate reinforcement therefore in an event of severe earthquake these structures will sustain heavy structural damages due to lack of knowledge and awareness to local people.

Losses were calculated for each hazard type, frequency class, and element-at-risk combination by multiplying the exposure, vulnerability, and spatial probability. The loss results were then used to calculate the Average Annual Loss for all the elements-at-risk and return periods. This report serves as the second content-related deliverable of the RSLUP project and focuses on the risk profiles for the Godawari Municipality.

On the other hand, the existing land data, demographic condition and socio-economic condition are analyzed. Since, the development planning and control depend on the present urban growth and projection, urban scenario analyses have been carried out in order to identify existing urban structure, urban cores and market centers. The existing conditions of the municipal context are analyzed in all possible structures including social services, transportation connectivity of the area together with environment. Among the total length of 566.42 km road, about 127.66 km of roads are black topped, 0.085 km are concrete, 271.69 km are graveled, 0.69 km are stone paved and about 166.28 km of roads are earthen. With reference to social services, 56% of households use tube well for potable use, 12,291 households use firewood and 12,003 household use electricity and 90.92% households use mobile for communication. The literacy rate of the municipality is 83.35% and 38 health centers occupy the municipality with limited DRM related emergency services. The institutional capacity such as security services include 3 APF, 4 Police Stations and 1 Army Camp. With reference to the cultural part, the municipality is surrounded by 86 temples, 11 churches, 2 Gumba (Monastery), 1 Mosque and 7 Dharamsala. The economic condition is reflected by their occupational engagement in which 15.55% of people are engaged in agro-based, 8.99% in foreign employment, 8.93% in job with 8% unemployed with remaining population are reside in student and home maker category. The overall development is influenced by the governing political parties to propose and formulation of the sectoral development projects. The cultivable land of the municipality is 22.93% followed by 64.04% forest, 4.33% built-up, 4.6% water body and sand and 1.3% barren land.

The population growth rate of the municipality from 2011 to 2019 is 2.21% in the existing scenario which is expected to be the same for 2021. The projected population is expected to be 2.63% per annum for the first decade, then 3.13% for the second decade and 4.13% for the third decade. With this assumption, the population growth of the municipality is expected to gradually increase up to 127,783 in the year 2031 to 177,652 in the year 2040 and 273,475 in the year 2050 respectively. With reference to urban growth, the built-up area has been increased by 391.70% in 21 years of the period from 2000-2021.

The analyses of population and urban growth rate in the existing municipal context and the results of MHRA are the background to generate the resource mapping. In this context, the multi-hazard risk projection is overlaid on the existing land use and the discussion is carried out in the land use pattern. Although the National Land Use Policy 2019 act furnishes ten different land use zones, the land use has been classified into five new categories Built-up, cultivation, forest, public use and water body with the reference to urban land use category of DUDBC. The results of MHRA reflects high risk zone area indicated with red zone covers an area of 26.65%, followed by moderate risk denoted by yellow zone with an area of 49.93% and low risk zone denoted by green color in the map with an area of 23.42% in the municipality. In the context to the hierarchy of the settlement, Attariya Bazar is the fastest growing urban center with the presence of the intersection of the East-West Highway and Bhimdutta Highway, followed by Teghari at the second position and Shanti Tole remain in the third position. Besides, the existing transportation network and its impacts are projected for further transportation master plan in this report. On the other hand, the existing natural resources and condition of critical facilities are projected to prepare the development plan.

The resource mapping analysis provides the tools to propose development plans and guiding principles through the SWOC analyses of the entire municipality. The development planning incorporates the proposed urban growth nodes and transportation master plan in the proposed growth nodes for 2030 and 2050 A.D. The development of nodal modality is based on proposed primary, secondary and tertiary nodes after analyzing major constraints and opportunities of the area for the development intervention directed by the policies. These three types of nodes are proposed as per the scale, dimension, settlement pattern, connectivity and available socio-infrastructures in the possible safer zones. For instance, the primary nodes of Attariya for 2030 is confined within 256.77 ha although the urbanized area is greater than existing scenario. Likewise, the primary nodes for 2050 is proposed to 432.26 ha on the basis of projected population growth and density. Hence proposed nodes are further utilized to intervene sectoral development plans based of SWOC analysis, gap analysis and spatial analysis incorporating MHRA. With the thorough analyses, the highest geographical coverage is of Moderate Risk zone with more than 15379.61 ha followed by low risk, whereas 7219.27 ha is in high-risk zone out of that 6108.61 ha is lies in the forest area. Low risk zones are marked as safe for all types of urban developments where moderately risk zones are nominated as Controlled Development Zone and high-risk zones are marked as restricted zones with existing vulnerable settlements.

The results of proposed nodes for the urban structure are further controlled through developing physical development plans and policies such as building by-laws, specific municipal land use policy incorporating risk sensitive land use plan intervening with DRR management and environmental management plans. The intervention further promotes for the identification of humanitarian open spaces and evacuation plan together with vulnerable zones turned into the safer zones in some nodes.

The development control is formulated to describe the controlling factors at various land use zones with reference to planning zone, sub-zone, nodes at existing settlements connecting with the development plan based on the risk sensitive land use for the implementation. This sector is supported by the possible mitigative measures of hazards in the prioritized and identified settlements of DRR

interventions. This will either include single type of intervention or multiple activities to strengthen the municipal capacity by establishing short to long term trainings through specific resources.

Analyses and formulation of development plan and development control at various sectors provide the strategy to implement RSLUP. The implementation strategy provides the institutional capacity building of the municipality/urban centers through various tools for the well-structured future urban growth. The implementation tools include land pooling, incentive/disincentive, specific municipal land use policy and building by-laws for the municipality. These regulatory tools are incorporated together with possible challenges in implementation of RSLUP. The effective and efficient implementation of RSLUP administer the safter and resilient future urban growth.

1. INTRODUCTION

1.1 BACKGROUND

Nepal has experienced several geo-disasters caused by natural hazards resulting in major loss of lives, assets and infrastructure. The rugged geographical terrain, fragile geology, impact of climate change, rapid, haphazard and unplanned urbanization are various factors that cause the entire country subject to various types of disasters and hazards. Further, an increase in population, extensive demands of infrastructure development and services together with poor implementation of disaster planning and management contribute to natural and anthropogenic disaster vulnerability (Luna Thapa & Jib Raj Pokharel, 2014). According to UN DESA (2014), Nepal will lead top 10 fastest urbanizing countries in the world at rate of 1.9% for the period of 2014-2050 resulting the infrastructure to potential risks and hazards.

The federal structure, several newly formed municipalities, the municipal centers have started facing urbanization challenges. The current practices show isolated planning process related to fundamental development and there is an urgent need to integrate resilience component into the planning for a sustainable urban development in order to reduce/minimize risks. In this context, land use planning with consideration of risk factor provides an opportunity for proactive risk reduction through location-based and/or structural approaches in the form of comprehensive plans, zoning and building regulations. Disaster preparedness by incorporating disaster risk reduction (DRR) measures in urban development together with land use planning is fundamental to reduce the disaster vulnerability at community, local and municipal level (World Bank & EMI, 2014).

Recently, most of the urban areas in Nepal are characterized by haphazard and unplanned urbanization practices in the limited land for development on account of lack of sustainable land use management policies resulting into environmental degradation, recurring natural and anthropogenic hazards/risks and socio-economic hazards to people. Considering the risks, the vulnerability and the hazards, there is an urgent need to develop a risk sensitive land use planning (RSLUP) that focuses on reducing the probable disaster risks and build resilient communities. The USAID/Nepal's TAYAR Nepal – Improved Disaster Risk Management Project aims at developing RSLUP incorporating both communities based participatory inputs and parameters based on scientific hazard modelling. A land use planning refers to the rational and judicious approach of allocating available land resources to different land use activities. The land use classification is basically incorporated through physical planning standards, development vision, goals and objective, analysis of actual and potential physical conditions of land. In comparison to this conventional land use planning, the RSLUP reinforces into the conventional land use planning approaches as additional considerations:

- Integration of information on Hazard, Vulnerability, Risk and Capacity.
- Integration into the plans of the government to ensure understanding, acceptance and implementation by enhancing their capacity and fostering the support of all stakeholders.

In this reference, the project has demanded the preparation of the land use plans based on systematic processes of risk assessment and develop a proper implementation and monitoring plans so that it can contribute to reduce existing, future and residual risks in the project area in close coordination with local government representatives, local communities and other major stakeholders in order to facilitate in sustainable utilization of land, be it in settlements or building infrastructures as well as ensures the provision of critical facilities and services while strengthening the role of local/municipal bodies to reduce disaster risks and hazards.

The use of land and its resource has been considered as one of an integral part of development. The production in the agricultural sector depends on land and its use. In the context of the Godawari Municipality, 68.74% of the population depends on the agriculture production for their livelihood. Since, the agriculture land is decreasing in a rapidly urbanizing area, it seems the necessity to intervene through some planning tools. The land use policy is the set of aims and objectives of the government for dealing land issues within the country.

1.2 OBJECTIVES

The main objective of the project is to develop Risk Sensitive Land Use Plans (RSLUPs) for Godawari Municipality incorporating following specific objectives:

- Undertake multi hazard risk assessment and multi-sectoral vulnerability assessment at the municipal level.
- Develop RSLUP by contextualizing the scenario of the municipality and through consultative and multi-stakeholder engagement processes.
- Identify types of multi hazards of the project area and recommend disaster risk reduction measures for major hazards.
- Support municipal governments in identifying 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, and other required communication materials.
- Undertake necessary activities to build local knowledge and capacitate the municipalities to implement, regulate RSLUP related activities and building bylaws.

1.3 METHODOLOGY

The project methodologies are characterized through five phase systems and their corresponding activities. In this project, phase wise methodologies have been incorporated from the beginning as preparatory phase, data collection phase, mapping phase, multi-hazard assessment phase and recommendations and preparation of implementation guidelines of RSLUP phase respectively as illustrated in **Fig. 1.1**.

The **preparatory phase** was accomplished with the establishment of municipal contact, review of relevant literatures, inception report with available information on types of collected data, methods and tools for multi hazard risk assessment and RSLUP and detailed work plan. The discussions with ward chair persons reflected that windstorm, landslide, soil erosion/river bank erosion, inundation (near highway), hailstorm, cold wave, and fire incident are the major hazards in those areas.

The **data collection phase** was based on the primary field data collection, secondary data collection, building, household and institutional survey. Mobile application tool named "Kobo App" was used to collect field level household, institutional, vulnerability surveys in which humanitarian open spaces was also included in the data. Due to nation wide lock down and spreading of COVID-19, methods of online sessions were carried out to provide necessary trainings to Field Coordinators, Field

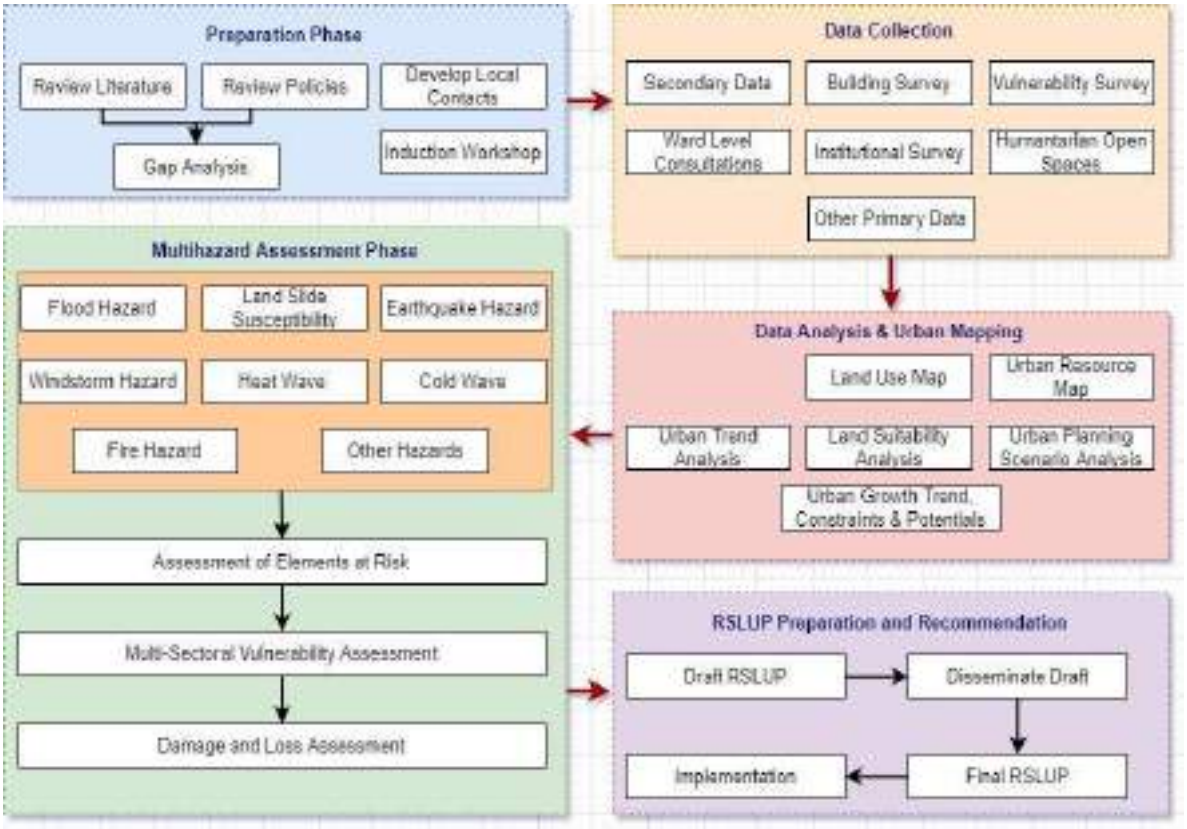


Fig. 1.1 Flow chart of approaching preparation of Risk Sensitive Land Use Plan (RSLUP).

Enumerators and Field Engineers to collect necessary data for analyses. In this phase, ward wise existing land use maps were shared to the Field Coordinators and the Field Enumerators and collected detailed historical hazards and verified at the site together with ward level consultations. Hence collected historical hazard data were digitized for next phase of data analyses. Furthermore, soil field tests were carried out at the required sites in the municipality as the primary data collection. Besides, existing land use data and required other soil parameters were collected from the land use map of the municipality.

The **data analyses phase** was based on the collected primary and secondary data. During this phase, integrated municipal database and existing land use map were analyzed and performed urban trend, urban planning scenario and land suitability analyses together with urban growth trend.

The **multihazard risk assessment (MHRA) phase** was entired based on two parameters, the primary and secondary hazard data and the scientific modeling. The assessment was carried out for individual hazards viz. flood, landslide, earthquake, windstorm, heatwave and coldwave and fire hazard. The individual hazards were further combined, modelded and produced the combined hazard map and assessment were carried out for elements at risk, multi-sectoral vulnerability and risk and loss analyses.

The **RSLUP preparation and recommendation phase** was carried out in two sections. At first, outcomes of MHRA results were disseminated among the municipality, DRR focal persons, engineers, administrative officers, ward chair persons, ward secretaries, ward members and community-based stakeholders during VCA workshop. At the second part, vision setting goal for the preparation of RSLUP was carried out at the same level and prepared Draft of RSLUP. Afterwards, the draft was shared with TAYAR Nepal and adjusted the time with the municipality and related stakeholders for consultation workshop to dissiminate results.

The **submission of Final Report** has been based on the detailed feedbacks received from TAYAR Nepal, the municipality, engineers, DRR focal persons, Chief Administrative Officers, security personals, ward chairpersons, and related stakeholders during the consultation workshop and. The final RSLUP will be shared and stepped up for the implementation and dissemination/sensitization.

1.4 SCOPE OF THE STUDY

The overall project aims to complete the inception phase, assessment, data collection, analysis, planning, sensitization, orientation, reporting and dissemination of learning document to concern stakeholders within 10 months after awarding the contract sign. In this reference, the scope of the study has encompassed the following tasks as the major key activities:

- Development and finalization of methodology, tools for assessment and analyses for multi-hazard assessment and their impacts at local level.
- Collection and analyses of both qualitative and quantitative data.
- Review of existing documents such as municipal profile, periodic plans, sectoral plan documents, and existing policy documents related to Disaster Risk Reduction, land use planning, and urban development and perform a gap analysis to make proper recommendations for RSLUP documents.
- Identification of major hazards in the project area through scientific analyses, community consultations and validations.
- Commence multi-hazard risk assessment for the generation of the probable scenario of different hazards using scientific approaches.
- Conduct multi-sectoral (physical, social, environmental and economic sector) vulnerability assessments.
- Preparation of RSLUP draft for the project municipality together with all necessary supportive and guiding documents, tools, associated manuals, implementation plans, and SOPs.
- Preparation of different kinds of dissemination, communication materials for effective communication of RSLUP vision.
- Organize sensitization and orientation workshops to municipal stakeholders on RSLUP, its process, implementation strategies, mainstreaming in sectoral development plans as per requirement.
- Incorporate GESI components during the entire phases of the project and ensure inclusion of women and other excluded groups.
- Integration of the RSLUP outputs in Nepal Government's disaster information management system-Building Information Platform Against Disaster (BIPAD).
- Provide updates on the progress - a brief report to TAYAR Nepal in English language as per agreed deliverables.

1.5 LIMITATION OF THE PROJECT/STUDY

The contractual documents to prepare the Risk Sensitive Land Use Plan has been limited to nine months from the date of signing the contract. The consultant team has formulated the required team as proposed in the proposal and mobilized developing internal strategy. Though the team had worked on the basis of detailed planned submitted to the TAYAR Nepal in the Inception Report, the global pandemic and rapid spreading of Delta Virus (mutant Covid-19) had impacted the overall field work in the municipality. With the announcement of nationwide lock down, the overall activities had been severely affected. In this reference, the consultant mobilized local field enumerators with the help of the municipality and the field coordinator and, carried out online training sessions. The online training sessions were carried out not only to the field enumerators and field coordinators but also to the field engineers. Afterwards, field staffs had mobilized to collect the data and performed in-situ tests adopting Covid-19 protocols. The consultant had undertaken the full responsibility on own, carried out necessary field data collections and accomplished the task in the two-month nationwide lock down. Fortunately, nobody at the field was infected by Covid-19.

The hard time had finally achieved to complete the multihazard risk assessment and submitted within the internally agreed time of extension period. Although the extension of one month had announced, the rapid emerging of Omicron Virus had impacted thematic experts and the TAYAR Nepal had to further extend the submission of Final Report together with all related deliverable further by one month. Within this extended time, the project has approached the target and accomplished successfully.

1.6 STRUCTURE OF THE REPORT

Fig. 1.2 illustrates the flow chart of the structure of the report for the preparation of Risk Sensitive Land Use Plan (RSLUP). The **Section 1** presents the background of the project, its objectives, methodology, scope, limitation and structure of the report along with the project area.

Section 2 refers to the present scenario of the municipal context. In this section, existing land data, demographic condition and socio-economic condition are analyzed together with the analysis of condition and ownership of GESI. Since, the development planning and control depend on the present urban growth and projection, urban scenario analyses have been carried out in order to identify existing urban structure, urban cores and market centers. The existing conditions of the municipal context are analyzed in all possibe structures including social services, transportation connectivity of the area together with environment.

On the other hand, Section 3 explains the overall methodologies, analyses and modeling of existing hazards of the municipality. The collected historical events of hazards from the site, in-situ soil infiltration tests, household, institutional and building footprint survyes allow for more realistic scientific modeling of individual hazards. The primary and secondary data have been adopted for multihazard risk assessment (MHRA) and combined hazard are present in this section. The hazard assessment was further carried out to identify the effects on elements-at-risk, loss and damage analyses. Furthermore, the multi-sectoral vulnerability assessments of the municipality were also carried out and all the results have been generated in the form of desired maps.

With reference to existing capacity of municipality discussed in Section 2 and results of MHRA, a resource mapping is generated in Section 4 with thorough analyses. In this section, multihazard projection is overlaid in the land use and the land use pattern is discussed. Besides, population projection, growth trend and critical facilities are illustrated. Proceeding, the existing transportation network and its impacts are projected for further transportation master plan in the next section.

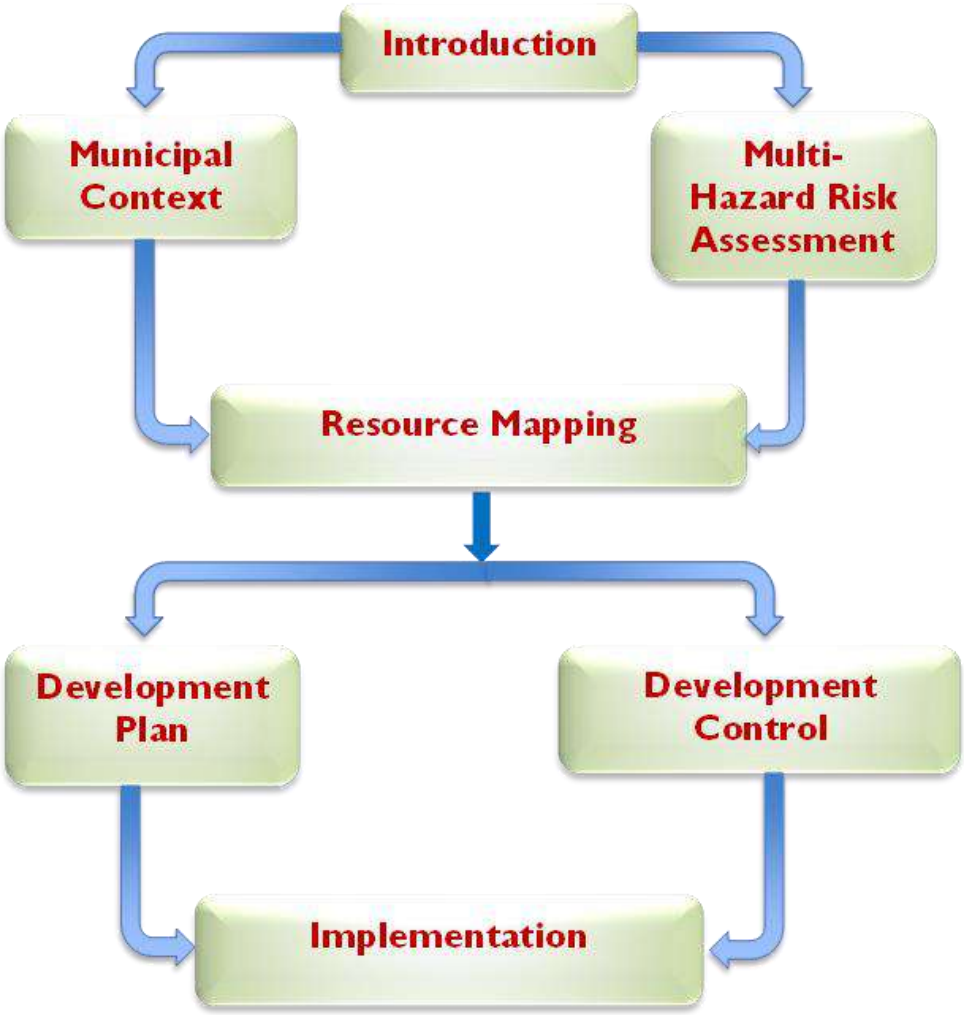


Fig. 1.2 Flow chart representing structure of the report.

Furthermore, the existing natural resources and the condition of critical facilities are projected to prepare the development plan.

The results of Section 4 are the basic steps to formulate the development planning phase for the preparation of RSLUP. Therefore, **Section 5** includes the proposed development plans based on resource mapping analysis. This section feeds the municipal vision goal and SWOC analyses for the formulation of guiding principle for planning. The development planning further incorporates the proposed urban growth nodes and transportation master plan in the proposed growth nodes for 2030 and 2050 A.D. Proceeding, physical, socio-economical, environmental management plans are incorporated in the sectoral development plans. The structure is further intervened with disaster risk reduction and management plan of the municipality together with the identification of humanitarian open spaces and evacuation plan. The policies, legal and regulatory mechanism, municipal preparedness, constraints and issues are discussed in this section.

With reference to Section 4, the development control is formulated in **Section 6**. This section is designed to describe the controlling factors at various landuse zone with reference to planning zone, sub-zone, nodes at existing settlements. This section togther with development plan formulates the risk sensitive land use plan implementation.

Analyses and formulation of development plan and development control at various sectors provide the strategy to implement RSLUP which is discussed in **Section 7**. The implementation strategy provides the institutional capacity building of the municipality/urban centers through various tools for the well-structured future urban growth. The implementation tools include land pooling, incentive/disincentive, specific municipal land use policy and building by-laws for the municipality. These regulatory tools are incorporated together with possible challenges in implementation of RSLUP in this section.

1.7 PROJECT STUDY AREA

Godawari Municipality is one of the emerging urban centers of the Kailali district of the Far-Western Province (Sudur Paschim Pradesh). It lies in the Southern-west part of Nepal covering an area of 307.71 sq. km. within Latitudes of 28° 81' N - 28° 92' N and Longitudes of 80° 55' E - 80° 8' E with an area of 308.63 sq. km. It was formed by including the Malakheti, Shreepur, Geta, Attariya and Godawari of former VDCs. Godawari lies 16 km north from the district headquarter Dhangadhi and 25 km far from Nepal India border, Gaurifanta (**Fig. 1.3**). The major Market center of the Municipality– ttarriya, is the gateway of the mountain district of Sudur Paschim Province. Godawari Municipality is the center of access by road and by air to all over the country in the Far western province of Nepal. It is connected by the East West Highway (H01) and Mahakali Highway (H14) both of which converges at Attariya Chowk. Three Village Development Committee (VDCs) were merged to form the Attariya municipality in 2014 which consisted of 12 wards. Later in 2017, Godawari VDC's 9 wards were merged into Attariya Municipality to form the newly declared Godawari Municipality with current population of 78,018. In 2018, Godawari Municipality was named as the capital of the Far Western Province due to its proximity from the much denser and urbanized city of Dhangadhi which is about 15 km south from the municipality.

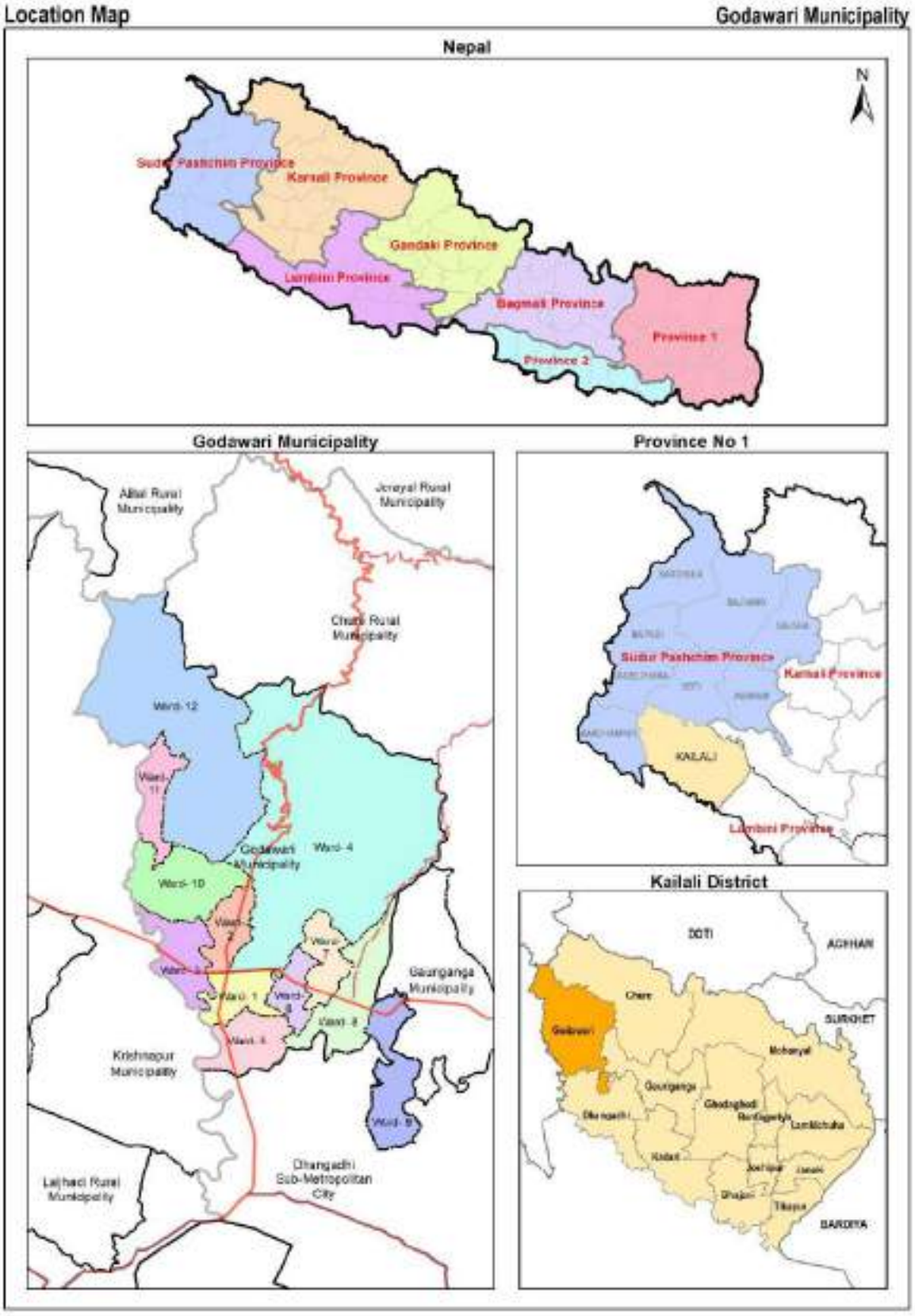


Fig. 1.3 Location map of Godawari Municipality.

2. MUNICIPAL CONTEXT

2.1 DEMOGRAPHIC CONDITIONS

Population distribution is the major component of the municipality which is affected by both geographical as well as socio-economic factors. The wardwise population in this municipality is distributed uneven due to different geographical distributions, physical as well as socio-economic conditions. According to the municipal profile (2019), the total population of this municipality is 78,018 of which male and female populations account for 36,642 and 42,376 respectively. Ward No. 1 has the highest population of 8,531 whereas Ward No. 7 has the lowest population of 4,571. The wardwise total population distribution is shown in **Table 2.1**.

2.2 PHYSICAL URBAN SERVICES

2.2.1 ROAD NETWORKS

Mahendra Highway (H01) along East West and Bhimdutta Highway along North South passes through the municipality connecting to other part of Nepal which intersects at Attariya Chowk. The other major roads include the feeder road connecting Syaule Pahad Sadak of the municipality connecting Doti District to the north. The road networks are well developed providing internal accessibility within the municipality as well as regionally to other districts. **Figs. 2.1-2.3** illustrate the road networks of the Godawari Municipality.

A total length of 566.42 km road network has been developed in the municipality. Based on the surface types, about 127.66 km of roads are black topped, 0.085 km are concrete, 271.69 km are graveled, 0.69 km are stone paved and about 166.28 km roads are earthen. **Table 2.2** summarizes the road network of the Godawari Municipality.

Table 2.1 Population Distribution of Godawari municipality.

POPULATION DISTRIBUTION OF GODAWARI MUNICIPALITY			
WARD NO.	AREA 'SQ. KM.'	POPULATION	DENSITY
1	8.96	12,824	14.31
2	8.58	9,432	11.00
3	11.95	8,869	7.42
4	114.25	10,675	0.93
5	11.85	6,723	5.67
6	6.78	8,746	12.89
7	9.13	5,731	6.27
8	18.25	9,307	5.10
9	16.02	8,298	5.18
10	18.82	8,180	4.35
11	9.20	5,849	6.35
12	73.81	5,864	0.79
Grand Total	**307.62**	**100,498**	**3.27**

Source: Municipal profile, 2021

Fig. 2.1 Dhangadhi Highway Black Topped Road connecting Attariya to Dhangadhi.

Fig. 2.2 Dhangadhi Highway Black Topped Road connecting from Attariya to Dadeldhura.

Fig. 2.3 Internal Road within Municipal Area.

Table 2.2 Road network distribution by surface types.

ROAD NETWORK DISTRIBUTION BY SURFACE TYPES		
SURFACE TYPE	LENGTH (KM)	REMARKS
Black Topped Road	127.67	Including about 14.9 Km section of MahendraHighway and 34 km section of Bhimdutta Highway
Concrete Road	0.086	
Gravel Road	271.69	
Stone Paved Road	0.69	
Earthen Road	166.28	
Total	**566.42**	

Source: Field Survey 2021

2.2.2 TRANSPORTATION FACILITY

There is designated municipal / regional bus park area within municipality at Attariya without proper planning (**Fig. 2.4**). Most of the public vehicles are parked on open spaces and roadside along the highway with the availability of few bus stops along the highway. The public transportation facilities are satisfactory within the municipal area. Buses and auto rickshaws are available for local transportation.

The local transportation such as buses are being parked along the road without any proper planning. The bus stop areas are shown in the map (**Fig. 2.5**).

Fig. 2.4 Existing Attariya Bus Park.

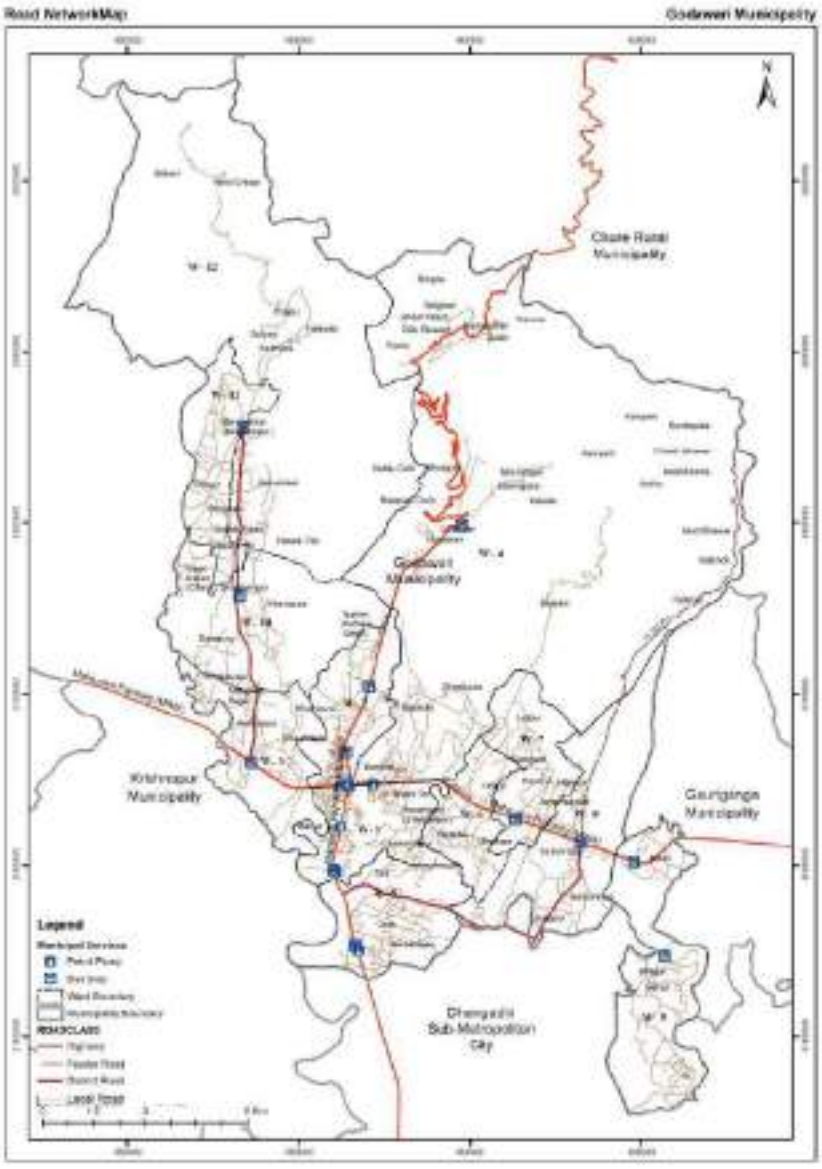


Fig. 2.5 Road Hierarchy and Transportation Network Map.

2.2.3 BRIDGES AND CULVERT

Road conditions of some northern hilly regions of Ward Nos. 4 and 12 are poor and difficult for vehicle movement during rainy season. The municipality has very low coverage of compact older built-up area fed with narrow roads which hinders for emergency services like ambulance and fire brigade. Similarly, scattered settlements in most of the area also pose challenges of providing road access and emergency services. Condition of most of the connecting bridges and culverts along the access road is also good. The condition of major access bridges is shown in **Table 2.3**.

2.2.4 DRINKING WATER

The major source of drinking water in Godawari Municipality is tube well or hand pump. More than 56% of households use tube well as their primary sources of drinking water. The municipality has enough water supply sources and 18 major water distribution sources among which only one is managed by government authority and other 17 are managed by the community water user groups. Similarly, more than 22% household has a personal tap. The source of drinking water of this municipality is given in **Fig. 2.6.**

2.2.5 ENERGY

There are two types of sources of energy in the world. Mainly coal, natural gas, and petroleum are non-renewable source of energy, while solar, wind, biomass, and hydropower, etc. are the renewable sources of energy. Implementation of both types of energy resources have been found in the municipality (**Fig. 2.7**). The primary source of energy for cooking in Godawari Municipality is firewood. According to CBS (2011), 12,991 households reported their source of fuel as firewood while 820 households use LP gas and 802 households use biogas.

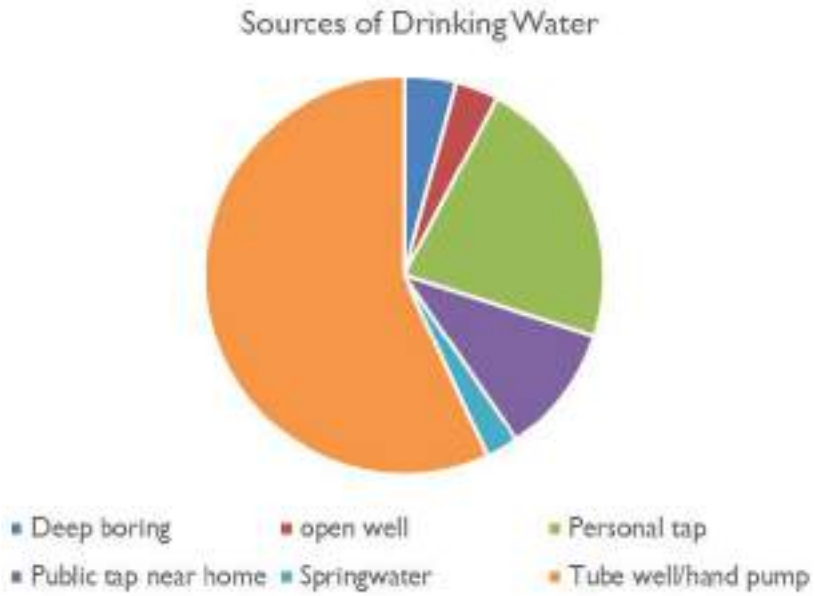


Fig. 2.6 Representation of Sources of Drinking Water in Godawari Municipality (Source: Field Survey, 2021).

Table 2.3 Status of Bridges and Culverts.

STATUS OF BRIDGES AND CULVERTS							
WARD NO.	CONSTRUCTION TYPE			CONDITION			TOTAL
	RCC	SUSPENSION	WOODEN	FAIR	GOOD	POOR	
1	3	0	0	0	3	0	3
2	4	0	0	0	3	1	4
3	4	0	2	3	3	0	6
4	2	0	1	0	2	1	3
5	5	0	0	0	5	0	5
6	1	0	0	0	1	0	1
7	1	0	0	0	1	0	1
8	1	0	0	0	1	0	1
9	0	1	0	0	1	0	1
10	1	0	0	0	1	0	1
11	7	0	0	0	4	3	7
12	29	1	3	3	25	5	33
Total	3	0	0	0	3	0	3

Source: Field Survey 2021 and GIS Database

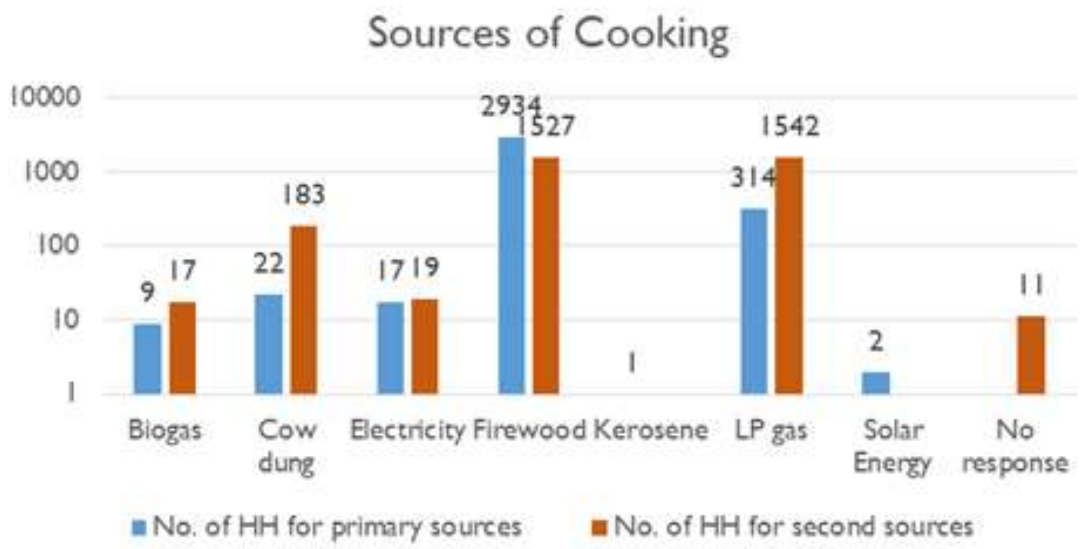


Fig. 2.7 Representation of Source of Cooking in Godawari Municipality (Source: Field Survey, 2021).

2.2.6 ELECTRICITY AND COMMUNICATION

In total, 12,003 households used electricity, and 2,154 households used kerosene as a source of light for their household's lighting. The majority of the households (90.92%) in the municipality use electricity from national grid. However, there were about 0.75% households who use solar energy for lighting purpose.

In this municipality area, only 3.30% of household used the facilities of landline telephone while 62.35% household uses mobile for communication. There are 11 communication units which includes 2 telecommunication units (Nepal Telecom and NCell), 4 FM radio stations, 1 TV station and 4 internet service provider (ISP) companies. The communication network is good in most part of the municipality which is an advantage during the time of emergency response.

2.2.7 IRRIGATION

As a large portion of this Municipality is located in the Terai region, its fertility rate is very high. However, there has been a lot of imbalances in irrigation potential in recent years. Providing reliable irrigation facilities in this area could be a significant step towards increasing the agricultural production of the municipality and making it self-sufficient in food.

The municipality is cultivating 72% of the total land area. So far, 80% of the land is considered suitable for irrigation. In the course of developing the irrigation system, the local people clans developed by the local farmers have also been identified. Due to the efforts of the government, some schemes have been implemented in the municipal area by the District Agriculture Development Office, District committee, Municipal Self and Irrigation Division Office. The Irrigation Division Office in the Municipality has been working with the concerned consumer committees for the development and improvement of medium type irrigation system.

2.3 SOCIO-ECONOMIC CONDITION

2.3.1 EDUCATION

The literacy rate of Godawari Municipality is 83.35%. As education institutions, there are 9 Child Development Centers (CDC), 44 Basic Level School and 27 Secondary Level School. Besides, there are 3 CTEVT institutions, 2 Colleges and 1 Sanskrit education center (Bedh Bidhyashram). **Figs. 2.8** and **2.9** represent examples of schools in Godawari Municipality and **Table 2.4** shows the wardwise educational institutions.

Fig. 2.8 Bageshwari Ni Ma Vi.

Fig. 2.9 J.K Boarding School.

2.3.2 HEALTH

There are 38 health centers in the municipality with the presence of 4 Hospitals, 5 Health Posts, 2 Primary Health Centers, 2 Ayurvedic Clinics, 8 Clinics, 3 Pharmacies and 13 One Stop Health Services. **Figs. 2.10, 2.11** and **2.12** represent health centers in the municipality. Besides, the under constructed Geta Residential Medical College belongs to medical institution equipped with planned 700 bedded hospital facilities. **Table 2.5** represents the health institutes of the municipality. Of the major health service facilities like hospitals and health posts, availability of DRM related emergency services and ambulance service is limited as evident from **Table 2.6**. Of the total health facilities, only 13 has emergency services while ambulance service is available in only 6 health units.

2.3.3 SECURITY

There are 3-Armed Police Force (APF), 4 Police Stations and 1 Army Camp within the boundary of the municipality (**Fig. 2.7**). The wardwise distribution of security infrastructure within the municipal area is shown in **Table 2.7**.

2.3.4 SPORTS

In the municipality, football, cricket, volleyball, basketball and badminton are major sports activities in practice. Municipal level, Ward level, School level sport tournaments are organized in different occasions within the municipality. The municipality has undertaken various steps to promote sports. There are number of open spaces used as playgrounds, some of them under the ownership of schools. However, lack of good infrastructure, plan and strong institution are the general weakness and threats in sports development.

2.3.5 CULTURE

Godawari Municipality is rich in cultural heritage and tourism. There is 86 Temples, 11 Churches, 2 Gumba, 1 Mosque and 7 Dharmashala within the municipal area. The major cultural heritage of municipality is Godawaridham area which is situated on the bank of holy Godawari River and have been developed several Hindu Temples such as Hanuman Mandir, Shiva Mandir etc. around the area. It is believed that in Duaper millennium Lord Krishna, Bhisma along with five Padavas and Dropadi during their Forest exile devotion, they had stayed in this place, had bath in this river and gained knowledge of purity heart and mind. In the memory of these great sages there held a big religious fair on the first day of the month of Magh of every year also known as Godawari Makar Mela. **Fig. 2.14** shows the Godawaridham area. The wardwise distribution of cultural places is enlisted in **Table 2.8**.

Table 2.4 Distribution of Wardwise Educational Institutes.

DISTRIBUTION OF WARDWISE EDUCATIONAL INSTITUTES													
TYPES OF EDUCATION INSTITUTE	WARD NO												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
Child Development Center	0	1	2	0	0	1	0	0	2	2	0	1	9
Basic Level School	2	3	6	5	3	5	1	0	1	8	6	4	44
Secondary Level School	6	7	2	2	3	2	0	1	1	1	1	1	27
CTEVT	1	2	0	0	0	0	0	0	0	0	0	0	3
Campus	0	1	0	0	0	0	0	1	0	0	0	0	2
Bedh Bidhyashram	1	0	0	0	0	0	0	0	0	0	0	0	1
Total	**10**	**14**	**10**	**7**	**6**	**8**	**1**	**2**	**4**	**11**	**7**	**6**	86

Source: Municipal Profile, 2020 (2076BS) and Field Survey 2021

Fig. 2.10 Geta Eye Hospital.

Fig. 2.11 Sudurpaschim Community Hospital.

Fig. 2.12 Geta Residential Medical College Under Construction.

Table 2.5 Distribution of Wardwise Health Institutes.

DISTRIBUTION OF WARDWISE HEALTH INSTITUTES

HEALTH INFRASTRUCTURE	WARD NO.												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
Hospital	2	0	1	0	1	0	0	0	0	0	0	0	5
Health Post	0	1	0	1	1	0	0	0	1	0	1	0	5
Primary Health Center	1	0	0	1	0	0	0	0	0	0	0	0	2
Ayurvedic Clinic	0	0	1	0	0	0	0	0	0	0	0	1	2
Clinic	0	0	2	0	0	0	0	0	0	1	0	5	8
Pharmacy	1	0	1	0	1	0	0	0	0	0	0	0	3
One Stop Service	0	9	0	0	1	0	2	1	0	0	0	0	13
Total	**4**	**10**	**5**	**2**	**5**	**0**	**2**	**1**	**1**	**1**	**1**	**6**	**38**

Source: Field Survey, 2021

Table 2.6 Status of Health Services

STATUS OF HEALTH SERVICES

WARD NO	EMERGENCY SERVICE FOR DISASTER REPONSES		AMBULANCE SERVICE		TOTAL
	NO	YES	NO	YES	
1	0	3	2	1	3
2	7	3	10	0	10
3	2	1	2	1	3
4	2	0	2	0	2
5	1	2	3	0	3
6	3	1	3	1	4
7	2	1	2	1	3
8	1	0	1	0	1
9	1	0	1	0	1

STATUS OF HEALTH SERVICES					
WARD NO	EMERGENCY SERVICE FOR DISASTER REPONSES		AMBULANCE SERVICE		TOTAL
	NO	YES	NO	YES	
10	1	0	1	0	1
11	0	1	0	1	1
12	4	1	4	1	5
Total	24	13	31	6	37

Source: Field Survey, 2021

Fig. 2.13 Security Infrastructures.

Table 2.7 Ward Wise Security Organizations.

WARD WISE SECURITY ORGANIZATIONS													
SECURITY	WARD NO.												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
Armed Police Force (APF)	1	0	0	0	0	0	0	0	0	0	0	2	3
Police Station	1	0	1	0	1	1	0	0	0	0	0	0	4
Army Camp	0	0	0	1	0	0	0	0	0	0	0	0	1
Total	**2**	**0**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**2**	**8**

Source: Municipal Profile, 2020 (2076BS) and Field Survey 2021

2.3.6 ECONOMIC CONDITION OF THE MUNICIPALITY

Economic conditions mean the present state of the economic variables like income, expenditure, occupation, wealth, etc. in a municipality. Economic conditions can be measured by using the present situation of these variables. Economic conditions should be taken into consideration in other social and political variables which are also assessed to understand the social status and economic status of an individual or a community or a municipality. The research found that the total monthly income of the 3299 households of the study area is NRs. 4, 24, 92,346. According to the respondents, their monthly average income is NRs. 12, 880.37, and their maximum monthly income is NRs. 500, 000. The economic conditions of the study area are given in **Table 2.9.**


Fig. 2.14 Godawaridham Area.

Table 2.8 Ward Wise Cultural Sites.

WARD WISE CULTURAL SITES													
CULTURAL SITES	WARD NO												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
Temple	7	8	2	14	10	4	4	10	2	12	3	10	86
Church	1	0	0	1	2	0	0	5	0	0	2	0	11
Gumba	0	1	0	1	0	0	0	0	0	0	0	0	2
Mosque	1	0	0	0	0	0	0	0	0	0	0	0	1
Dharmashala	2	0	3	1	0	0	0	1	0	0	0	0	7

Source: Municipal Profile, 2076

Table 2.9 Monthly Income of the household in Godawari Municipality.

MONTHLY INCOME OF GODAWARI MUNICIPALITY		
S.N.	MONTHLY INCOME OF HOUSEHOLD	INCOME (IN NRS)
1	Total income	42492346
2	Average income	12880.37163
3	Max income	500000
4	Min income	0
5	Standard Deviation income	16654.91142

Source: Field survey, 2021

But the Economic Census (2018) mentioned that there is a total of 2,681 economic sector established in Godawari Municipality that are involved in various economic activities. In those establishments, a total of 8,531 persons are engaged for the economic activities, as a self-employed or an employee, with a total male engagement of 5,583 and female engagement of 2,948 persons. In every business, there was an average of 3.18 people engaged with the average males are 2.08 and females are 1.10 (Nepal archive, 2020).

The **Table 2.9** shows that the monthly income of the study area is on average in comparison to other parts of this area. The major sources of income of study area are based on agriculture, foreign migration, the job at the local level, trade, etc. Based on this economic vulnerability are discussed in the separate sections in detail.

Occupational Engagement: The occupation refers to the economic conditions that should be taken into consideration in other socio-economic as well as the political situation. Occupation is an independent variable that indicates the individual and social class status of that area. The occupation

is the major component for the analysis of the economic situation of the municipality. According to the Municipality Household survey (2019), the occupation of the municipality is given in **Fig. 2.15**.

The data show the largest population of this municipality i.e., 26.74% students and 21.82% are home maker, but these two are not the occupational groups. Occupationally, 15.55% of people engaged in agriculture and animal husbandry, 8.99% are in foreign employment, and 8.93% are engaged in other job or occupational work. More than 8% of people are unemployed and searching the job in Nepal or India.

Land Owner Household: The poverty rates are higher within the rural population in terms of landless and near-landless situation. The agricultural wage laborers have 58% households, 50% has small agricultural lands. Proceeding, the formerly untouchable castes, indegineous nationalities depending on intragroup differentials and Muslim groups have 48%, 20-61% and 43% lands respectively (Nepal and Bohar 2009, cited from USAID, 2018). A similar case can also be observed in the Godawari Municipality in which a large population of more than 37% has less than 0.1 hectares of land as shown by the study of land ownership in **Fig. 2.16**.

Fig. 2.16 shows that more than 28% household has only less than 0.2-hectare land and more than 23% has less than 0.5 ha land. Similarly, 0.12% has 5 to 10 ha land that is the landlord in this municipality. It shows that Godawari Municipality also has an unequal land distribution pattern like Nepal. Similarly, Gender wise land distribution pattern is given in **Fig. 2.17**.

Fig. 2.17 shows more than 52% of land ownership belongs to male and only 16.19% of the landowner belongs to female. Similarly, more than 28% household does not have land ownership. It shows that they have Guthi land or government owned land and they do not have land ownership certificate.

2.4 EXISTING LAND USE

This municipality has a diverse topography comprising of Hills and Terai region. The majority of land cover of the municipality holds higher proportion of forest land. The land use classification shows the large part, 64.04% of municipal area is forest followed by 22.93% cultivation. Built up area accounts only 4.33 % of the municipality, while, 4.60% area is covered by water body and sand and 1.30% barren land. The present land use of municipality is summarized in **Table 2.10**.

Table 2.10 Existing Land use status of Municipality.

EXISTING LAND USE STATUS OF MUNICIPALITY		
LAND USE TYPE	AREA (SQ.KM)	PERCENTAGE (%)
Builtup	13.97	4.54
Cultivation	72.60	23.60
Forest	202.42	65.80
Public Use	4.61	1.50
Water Body	14.02	4.56
Total	307.62	100.00

Source: Field Survey, 2078

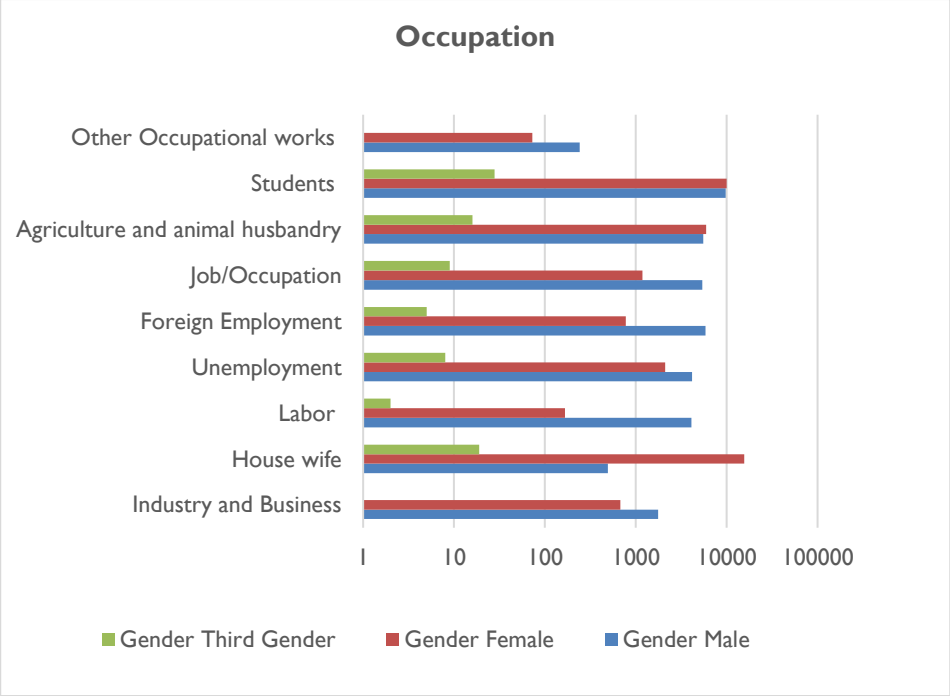


Fig. 2.15 Occupational Engagement in Godawari Municipality (Source: CBS Household Survey, 2019).

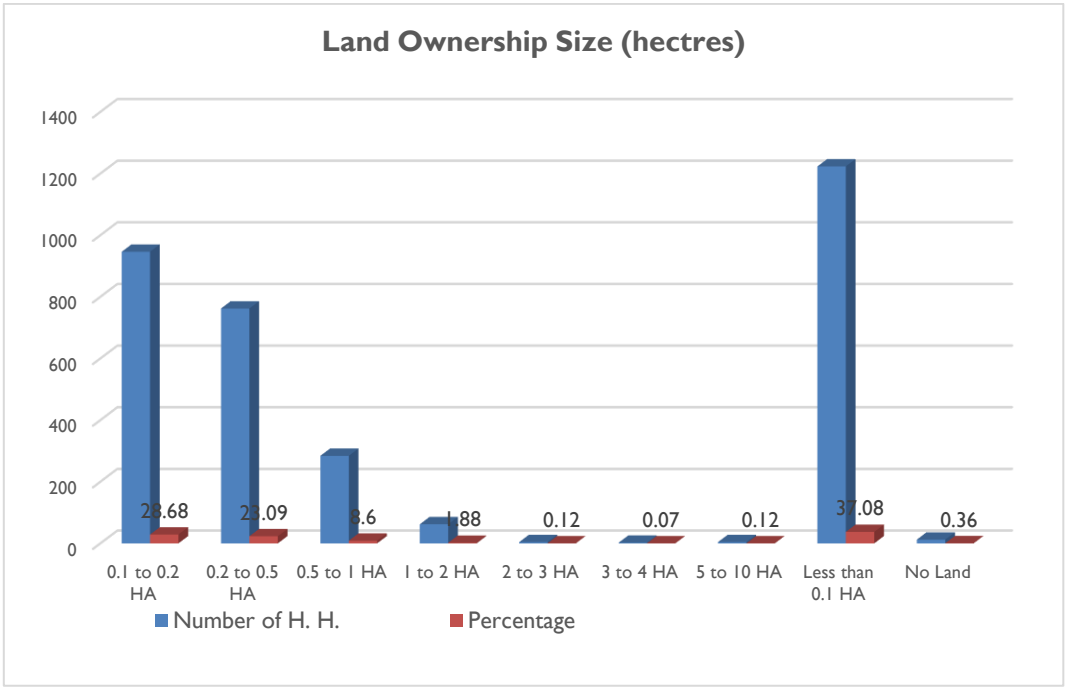


Fig. 2.16 Land Ownership in Godawari Municipality (Source: Field Survey, 2021).

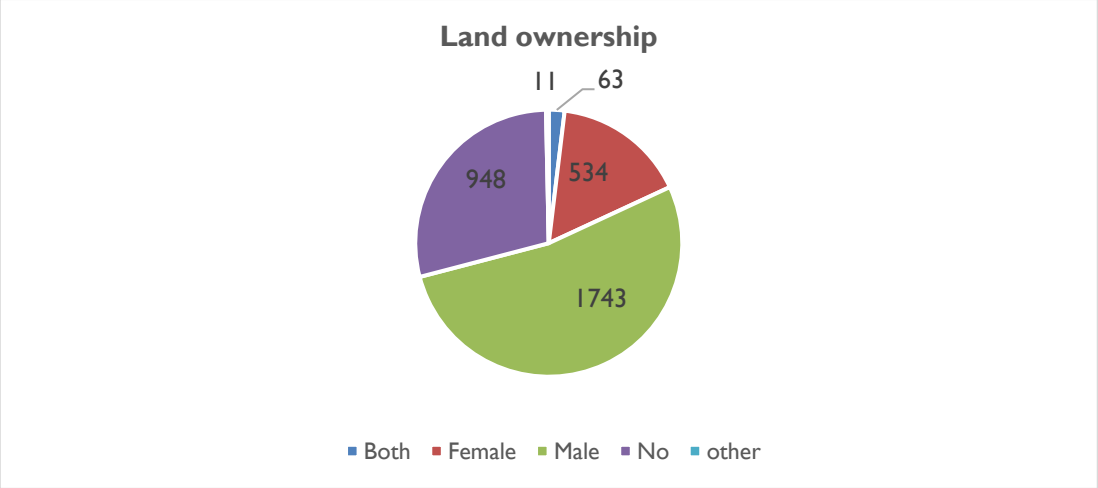


Fig. 2.17 Gender-wise Land Ownership in Godawari Municipality (Source: Field Survey, 2021).

2.5 GENDER EQUALITY AND SOCIAL INCLUSION (GESI) ANALYSIS WITHIN MUNICIPALITY

The concept of Gender Equality and Social Inclusion (GESI) is a very familiar and provocative issue in Nepal since the promulgation of the interim constitution of Nepal. Practically it is implemented from the new constitution 2015. This concept addresses unequal power relations experienced by people on the grounds of gender, wealth, ability, location, caste/ethnicity, language, and agency or a combination of these dimensions. It focuses on the need for action to re-balance these power relations, reduce disparities and ensure equal rights, opportunities, and respect for all individuals regardless of their social identity (MoHP/GoN, 2013). The Government of Nepal has created various institutional mechanisms and structures over the years to address gender equality and social inclusion issues, from the central to local levels. At the rural municipality/municipality level, these mechanisms have, in many cases, gradually become effective structures for channeling the voice of ward-level people into the local development planning process. At the higher levels, the established institutional mechanisms have experienced inadequate resources and weak institutional processes and thus have not been sufficiently effective in protecting and furthering the cause of gender equality and social inclusion. The GESI implementation mechanism in Nepal has three levels: Federal, Provincial and Municipal. At the Municipality level, it emphasizes on social and economic empowerment of women, Dalits, marginalized caste and ethnic groups with the implementation of GESI policies, the standard of living, governance of local resources and institutions as shown in **Table 2.11**.

Table 2.11 GESI Mechanism

GESI MECHANISIM	
LEVEL	LEVEL GESI MECHANISM
Central	Central National Planning Commission; Ministry of Women, Children and Social Welfare (MOWCSW) and its Department of Women Development; Ministry of Federal Affairs and Local Development (MOFALD) and its Dalit and Adibasi/Janajati coordination committees; constitutionally established National Commissions for Women, Dalits, Indigenous Nationalities, Madhesis, Muslims, Tharus and a National Inclusion Commission that is mandated to protect the rights of Khas Aryas, Pichardiaka ("backward") class, persons with disabilities, senior citizens, laborers, peasants, minority and marginalized communities, people of the Karnali, and the indigent class;14 Gender/GESI Focal Points in NPC, MOFALD, MOWCSW and the ministries of Education, Health, Urban Development, Forestry, and Agriculture.
District	District Women and Children Offices (WCOs), Social Committee with a Social Development Officer of District Development Committees (DDCs); Adibasi/Janajati District Coordination Committee and Dalit Class Upliftment District Coordination Committee, the Gender Mainstreaming Coordination Committee (GMCC), and the GESI Implementation Committee

GESI MECHANISIM	
LEVEL	LEVEL GESI MECHANISM
Rural Municipality/ Municipality	Rural Municipality / Municipality Representative Integrated Planning Committees in each Palika; Ward Citizens' Foram and Citizen Awareness Centres

Source: Adapted from UN Women information, GESI Operational Guidelines of MOUD, and the Sectoral Monograph series of ADB, DFID, WB, and the Nepal Constitution (2015)

Godawari Municipality has formulated and implemented gender equality and social inclusion (GESI) policy since 2021. The policy has the following provisions:

1. To achieve the concept of gender equality and social inclusion in the Municipality
2. To maintain the national and international standards of policy, law, and norms
3. Ensuring the meaningful participation of the target group in the planning and program of the municipality
4. To make gender-responsive planning and budget of the municipality
5. To access the financial resources for the target community
6. To increase the capacity of GESI related organizations
7. To ensure the access and control of the target group in the use of public resources, means, and benefits.
8. To empower poor & helpless women, children, senior citizens, and persons with disabilities.
9. To ensure social protection and security.

To adopt a zero-tolerance policy against any form of sexual violence, exploitation, exclusion, discrimination, etc.

Social Inclusion

There is a positive connotation between poverty and caste/ethnic identity, the majority of Dalits and ethnic communities' households are also among the poorest group in Nepal. Dalits are dependent on other caste groups for wage labor and for a loan to meet immediate needs which comes with high interest rates. Other caste and ethnic groups also depend on Dalits for ironwork (for agricultural tools and equipment), for sewing, and wage labor (especially for fishing). The traditional concept of untouchability exists in practice. Even at Kohalpur of Godawari Municipality which is a market area, Dalits cannot use the same water tap that is used by other caste groups and they cannot sit and eat together. In public places and during community groups meetings, Dalits cannot touch Brahmin/Chhetri and other higher caste people.

The caste-based discriminations still prevail in various locations of the municipality such as restriction of Dalit to enter into households of upper castes and temples; food items are not allowed to touch. Similarly, the violence against women has been reported common in most of the Tole/villages of the municipality mainly due to the alcoholism among the male members, particularly in Janajatis and Dalit communities. The USAID (2017) has mentioned that the different wage rates for males and females for the same work is one of the major exploitative forms between men and women in most villages of this municipality. Similarly, gender isolation is stronger in some communities, mostly among Tharu, Madhesi, and Hill Brahmin that restricts girls and women to visit other villages or traveling and night staying outside the village to participate in discussion, training, and meeting. The out-migration of the male population caused a shortage of workforce in the villages that resulted in the increased workload of women; time poverty to participate in public forums (USAID, 2017). So, gender equality and social inclusion are very complex issues in this municipality.

Political Inclusion

Godawari Municipality is inhabited by different castes and ethnic groups. More than 25 caste and ethnic groups are inhabited in the Municipality. Pahadi Chhetri has the highest population in the Municipality and their population is 37.6%. Similarly, the other highest population are Pahadi Brahman 15.15%, Dalit 15.78%, Tharu 13.75%, etc. in the municipality. The political representation of ethnic groups, Dalits, minority groups, and Muslims concerning their population in the council or Municipal body of Godawari Municipality is shown in **Table 2.12**.

The **Table 2.12** shows that Godawari Municipality has more than 43% are ethnic and caste group people who are most vulnerable situation. Among them, the Dalits population is more than 15% who are most vulnerable than other ethnic/caste groups. But politically, they have less representation in the municipality body. Similarly, in the case of gender the population and political representation are given in **Table 2.13**. The **Table 2.13** shows that the total population of women in this municipality is around 49% but their representation is only about 35%. There is no political representation in the municipal body of the third gender but 120 people are living in the municipality.

Gender Inclusion

Gender inclusion is very essential for gender equality. The Constitution of Nepal 2015 has made it obligatory that 33% of women in all levels of the government including the Municipality level. In the case of gender, the population and political representation are given in **Table 2.13**. The **Table 2.13** shows that the total population of women in the Godawari Municipality is 49.19% but their political representation is only 35.48%. There is no political representation of the third gender in the municipal body although 120 people are living in the municipality.

Table 2.12: Caste/ ethnic groups of the Municipality

CASTE/ ETHNIC GROUPS OF THE MUNICIPALITY			
CASTE/ETHNIC GROUPS	POPULATION	PERCENTAGE	POLITICAL REPRESENTATION
High caste people (Brahman, Chhetri & Thakuri)	52891	56.46	34
Major ethnic groups (Gurung, Tamang, Kumal, Tharu &Newar)	13438	14.3	10
Minor & Madhesi ethnic group	12,167	12.99	7
Dalit	14779	15.78	11
Muslim	40	0.04	-
Other	371	0.39	-
Total	93686	100	62

Source: Household Survey, 2019

Table 2.13 Gender wise population of the municipality.

GENDER WISE POPULATION OF THE MUNICIPALITY				
GENDER	POPULATION	PERCENTAGE	POLITICAL REPRESENTATION	PERCENTAGE
Male	47487	50.68	40	64.52
Female	46079	49.19	22	35.48
Third gender	120	0.13	-	-
Total	93686	100	62	100

Source: Household Survey, 2019

Cultural Inclusion

The religious minority group Muslim, Madhesi indigenous people, Dalit, and women are socially, culturally, and economically excluded and more vulnerable than other ethnic and religious groups. These groups have a lack of or limited access to resources such as information, knowledge, and technology; lack of or limited access to political power and representation and are in marginalization and exclusive from society. They have a lack of or limited access to social capital including social networks, social institutions, organizations, and connections as well as inadequate beliefs, customs, and attitudes in response to risk or disasters. They have vulnerable residential settings like weak structure, poor protection, poor maintenance, etc., and live in environmentally risk areas. A local Tharu community member stated that many in his community struggle to raise their issues and concerns because of the language barrier, as most are not fluent in Nepali, the official language. As a result, the community has delegated a recently elected woman representative, who is well-spoken in Nepali, to speak in public on behalf of the Tharu community. Due to the lack of linguistic knowledge, they are unable to express their demands and cannot raise their communal issues. This could also be true of elected representatives from linguistic communities with poor Nepali skills (Samjhauta Nepal, 2018). Hence, GESI is a strong social issue for the development of the municipality.

2.6 DEMOGRAPHIC ANALYSIS

2.6.1 POPULATION GROWTH TREND

The population of Godawari municipality was 78,018 in the year 2011 which was increased by 2.21% annually to 93,686 in the year 2019. The urban growth trend of the municipality shows that the wards through which the East West Highway passes hold the major market centers that are included as the urban core. For the purpose, the linear growth rate is considered for all the wards. On this regard, the population for the year 2021 is expected to reach 101,499 as shown in **Table 2.14**.

2.6.2 POPULATION PROJECTION

Population projections are calculations of future population based on the past and present conditions. They are neither predictions, nor forecasts, nor estimates. Rather they are in between predictions and forecasts. Government policymakers and planners around the world use population projections to gauge future demand for food, water, energy, and services, and to forecast future demographic characteristics. Population projections can alert policymakers to major trends that may affect economic development and help policymakers craft policies that can be adapted for various projection scenarios.

The population of Godawari Municipality is projected taking the year 2019 as the base year. The population projection is made with the formula for growth rate calculation,

$P_t = P_o (1+ r)^t$

Where, P_o = Population at the base year, P_t = Population after t years, r = growth rate

The annual population growth rate as of the year 2019 is 2.21% and the same is expected till 2021. With the increased facilities and employment opportunities due to investments in the municipality the out-migration will be reduced and other people from surrounding rural hinterlands will be attracted on the other hand. In this context the aggregated growth rate of the municipality has been adopted as 2.63% per annum for the first decade, then 3.13% for the second decade and 4.13% for the third decade respectively. After 20 years, the provincial capital will have developed infrastructure, so the

population growth rate has been adopted as the current urban population growth rate. Considering the current urban form, the proposed projects and built-up growth along with past population growth trends the annual population growth rate in each ward have been adopted.

With this assumption, the population of Godawari Municipality is projected to gradually increased to 127,783 in the year 2031 to 177,652 in the year 2040 and 273,475 in the year 2050 respectively as shown in **Table 2.15**.

2.7 URBAN SCENARIO ANALYSIS

2.7.1 EXISTING URBAN STRUCTURE

The notion of urban spatial structure is multifaceted, consisting of the distribution of population, employment, built-up volumes, transportation networks and land uses. The urban structure is the physical framework that binds the settlement area together, and provides the physical context for future developments. It also reflects the arrangement or pattern of points, lines, and surfaces within an urban area. The existing urban structure provides the physical context for future developments, establishing the spatial framework within which the future urban structure will be developed and defined. **Fig. 2.18** illustrates the road density of the municipality.

The settlements in the municipality are sparsely located and are either linear or compact. The majority of the settlements here are linearly developed along the road sections and elongated. Most of them are sparsely developed. Some market centers are agglomerate around the major road junctions as in Attariya settlement. Besides, few settlements like Chaukidanda, Geta, Tegari, Shanti tole, Lalpur and Syaule Bazar are compactly developed around road junctions in the highways and feeder road. Some market centers in the verge of urbanization, are bulk in nature and somewhat compact especially along road junctions. The form is flexible for the extension of the city. Similarly, the road density is also high in these main market areas of Attariya, Tegari, Geta, Syaule bazar etc. **Fig. 2.19** illustrates the road density of the municipality.

Attariya Bazar is one of the trade centers and developing cities of Kailali District and is the major urban center of the municipality. It is the most developed market center of the municipality. The other comparatively developed market centers are Tegari, Geta, Shanti Tole, Lalpur and Syaule Bazar. These markets are well facilitated by institutional, banking, commercial, transportation and other services. In addition to these centers, other emerging market centers which are also providing the basic market facilities are termed here as minor urban center and they are: Chaukidanda, Malakheti. These market centers are well connected with the major road networks and have the potential to develop as urban centers in near future. There is gradual increase in the infrastructures and services that attracts the in-migrants.

The major settlements with higher building density with present urban characteristics and future potentials for urban development are computed for the urban hierarchy. The parameters are categorized into 6 main indicators such as Building Density, Accessibility (Approach Road and Transportation Facilities), Built up changes from 2010 – 2021, Social Services (Education, Health, Security, Government Offices), Market Expansion (Linkage and Connectivity, Financial Institution, Industries) and Building Construction Technology (Material used, Number of Storey, Roof Types).

2.7.2 URBAN GROWTH

Far western region of Nepal or Sudur Paschim Pradhesh has seen substantial growth in population and infrastructure after the completion of the Karnali Bridge which connected the far western region to other parts of Nepal. This connectivity has affected the growth in the area in two ways: one removed dependency on Indian routes to central and eastern part of Nepal and two increased the migration from the hilly areas to flatlands to capitalize on the opportunity of growth. It lies 25 km north from Indian boarder Gaurifanta and just 50 km east from Gaddachauki, one of the major entry points from India in the far west Nepal.

The urban growth is analyzed in terms of the built-up change. The built-up change in turn includes either of the densification of the settlement area and the newly built areas. Built-up area increased by 391.70 % in 21 years the period of 2000-2021. The area changes between 21-year period is detailed in **Table 2.15.**

Table 2.14 Population Growth Trend.

POPULATION GROWTH TREND					
WARD	POPULATION (2011)	POPULATION (2019)	EXISTING RATE	GROWTH	POPULATION (2021)
1	8,531	11,475	3.78%		12,824
2	7,433	8,839	2.19%		9,432
3	7,569	8,494	1.45%		8,869
4	7,585	9,725	3.16%		10,675
5	6,233	6,586	0.69%		6,723
6	5,764	7,806	3.86%		8,746
7	4,571	5,388	2.08%		5,731
8	7,174	8,669	2.39%		9,307
9	6,359	7,717	2.45%		8,298
10	6,377	7,643	2.29%		8,180
11	4,979	5,598	1.48%		5,849
12	5,443	5,746	0.68%		5,864
Total	**78,018**	**93,686**	**2.21%**		**101,499**

Source: CBS 2011; Municipal Household Survey 2075

Table 2.15 Population projection of Godawari Municipality.

POPULATION PROJECTION OF GODAWARI MUNICIPALITY									
WARD	POPULATION (2019)	ADOPTED GROWTH RATE UPTO 2021	POPULATION (2021)	ADOPTED GROWTH RATE UPTO 2030	POPULATION (2030)	ADOPTED GROWTH RATE UPTO 2040	POPULATION (2040)	ADOPTED GROWTH RATE UPTO 2050	POPULATION (2050)
1	11,475	3.78%	12,824	3.78%	18,577	4.28%	28,248	5.28%	47,255
2	8,839	2.19%	9,432	3.50%	11,713	4.00%	17,338	5.00%	28,242
3	8,494	1.45%	8,869	1.75%	10,244	2.25%	12,797	3.25%	17,620
4	9,725	3.16%	10,675	3.50%	14,564	4.00%	21,558	5.00%	35,116
5	6,586	0.69%	6,723	1.75%	7,203	2.25%	8,998	3.25%	12,389
6	7,806	3.86%	8,746	3.00%	12,778	3.50%	18,024	4.50%	27,991
7	5,388	2.08%	5,731	3.50%	7,038	4.00%	10,419	5.00%	16,971
8	8,669	2.39%	9,307	2.70%	11,791	3.20%	16,157	4.20%	24,380
9	7,717	2.45%	8,298	2.70%	10,569	3.20%	14,481	4.20%	21,849
10	7,643	2.29%	8,180	2.54%	10,258	3.04%	13,839	4.04%	20,563
11	5,598	1.48%	5,849	1.73%	6,772	2.23%	8,440	3.23%	11,593
12	5,746	0.68%	5,864	1.10%	6,275	1.60%	7,354	2.60%	9,506
Total	**93,686**	**2.21%**	**100,499**	**2.63%**	**127,783**	**3.13%**	**177,652**	**4.13%**	**273,475**

Source: CBS 2011; Municipal Household Survey 2019

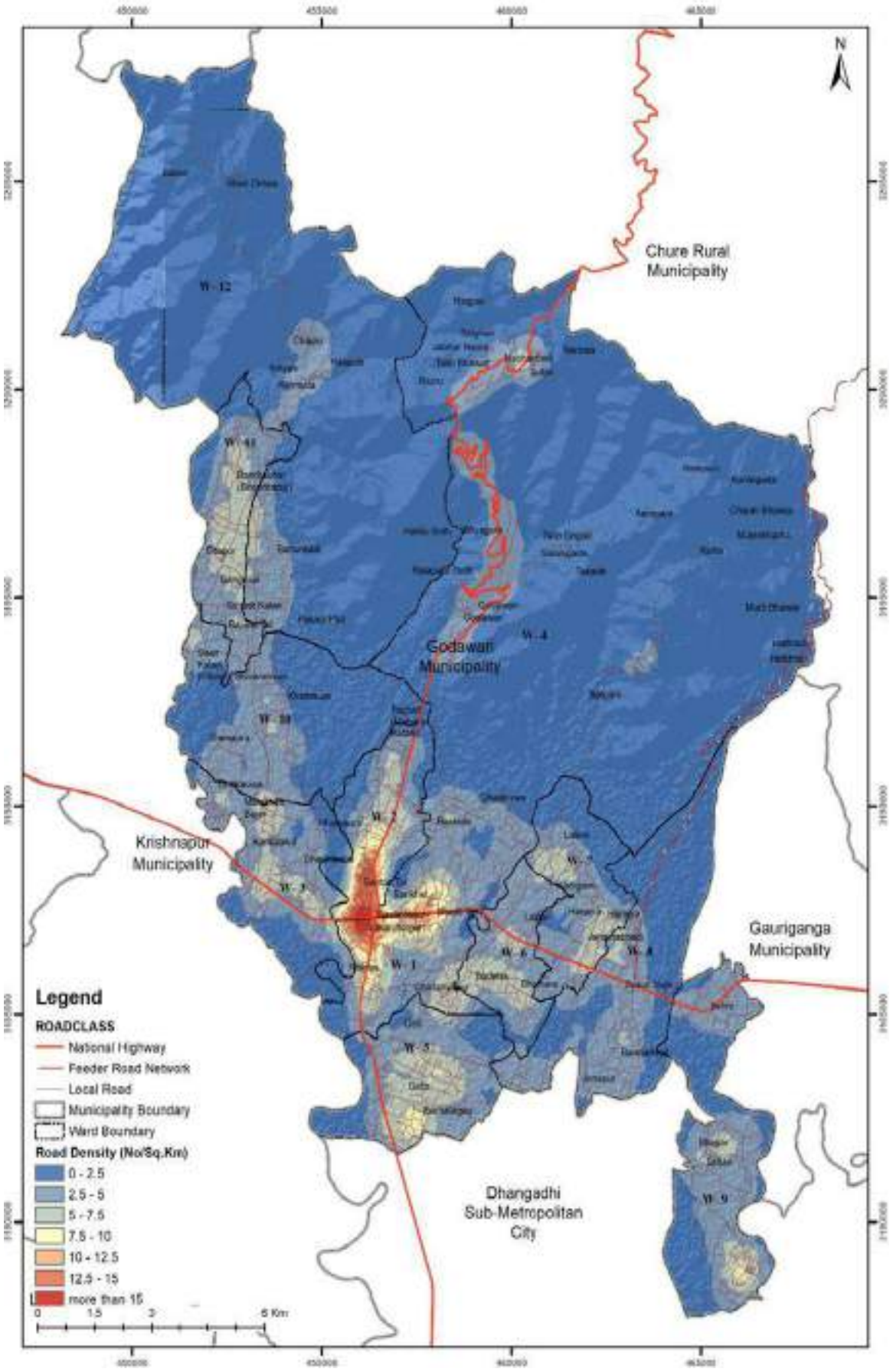


Fig. 2.18 Road Density of Godawari Municipality.

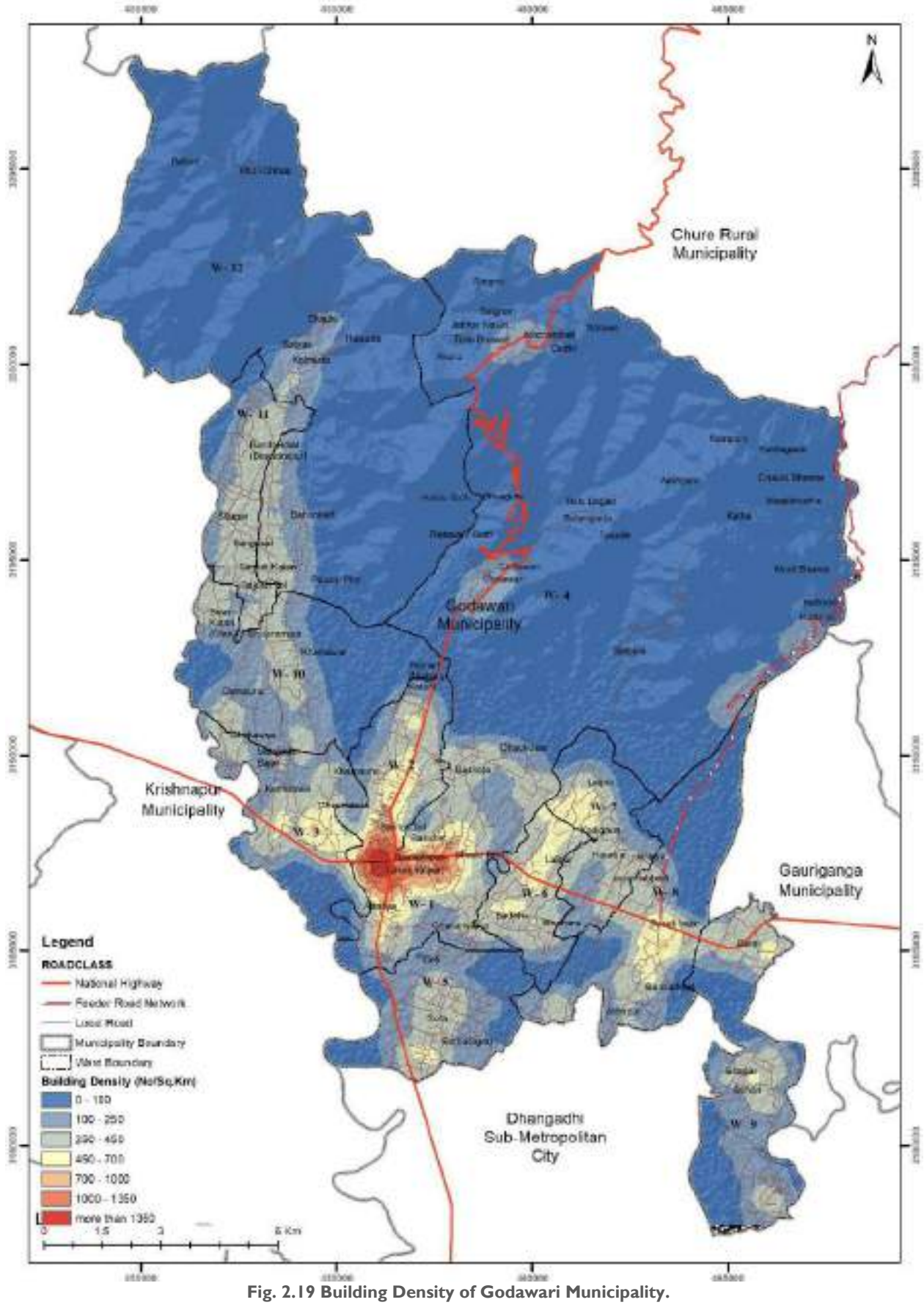


Fig. 2.19 Building Density of Godawari Municipality.

The urban life and vast opportunities in the cities attract many youngsters to migrate from the hilly districts to the municipalities in the South. Godawari municipality is one such prime attraction as it offers quality education with multiple choices of government and private schools, hospitals and jobs at small to medium scale industries. Major industries of manufacturing and production are found in the southern part next to Dhangadhi municipality indicating and employment opportunity for locals besides trade and commerce. Majority of built-up change is observed along the east-west highway corridor around major market centers and new growth is seen around major market centers like Tegari, Geta, Shreepur, Malakhati and Bijaura. Spatial growth during 2000-2015 is presented in **Fig. 2.20.**

2.7.3 URBAN CORES AND MARKET CENTERS

Though Godawari has been declared as municipality, the majority of the settlements are rural in nature. Only few settlements within the East-West Highway and other major road of the municipality, pose urban characters in terms of infrastructures and services they provide. The major urban centers of the municipality are where the most of the administrative, institutional, commercial activities take place. The gradual development of these services in turn have led to the densification of the settlements.

Attariya, is the major urban center of the municipality. It is the most developed market center of the municipality. The other comparatively developed market centers are Chauki Danda, Lalpur (Koli Katan) and Geta. These market centers are well connected with the major road networks and have the potential to develop as urban market centers in near future. There is gradual increase in the infrastructures and services that have attracted the in-migrants. Industrial estate is proposed in Ward No. 7, Hariaya which will direct the urban growth in the surrounding areas. Proposed provincial capital covering Ward Nos. 2 and 4 around Teghari area is another possible urban growth factor of the municipality.

The major settlements with higher building density with present urban characteristics and future potentials for urban development are computed for the urban hierarchy. The parameters are categorized into 6 main indicators such as Building Density, Accessibility (Approach Road and Transportation Facilities), Built up changes from 2010 – 2021, Social Services (Education, Health, Security, Government Offices), Market Expansion (Linkage and Connectivity, Financial Institution, Industries) and Building Construction Technology (Material used, Number of Storey, Roof Types). **Table 2.16** illustrates the major settlement urban characteristics of the municipality.

Table 2.16 Built-up area change.

BUILT UP AREA CHANGE			
S.N.	YEAR	AREA (HA)	PERCENTAGE
1	2000	284.39	8.00
2	2005	372.64	10.49
3	2010	1199.16	33.74
4	2015	1697.69	47.77
	Total	**3553.87**	**100.00**

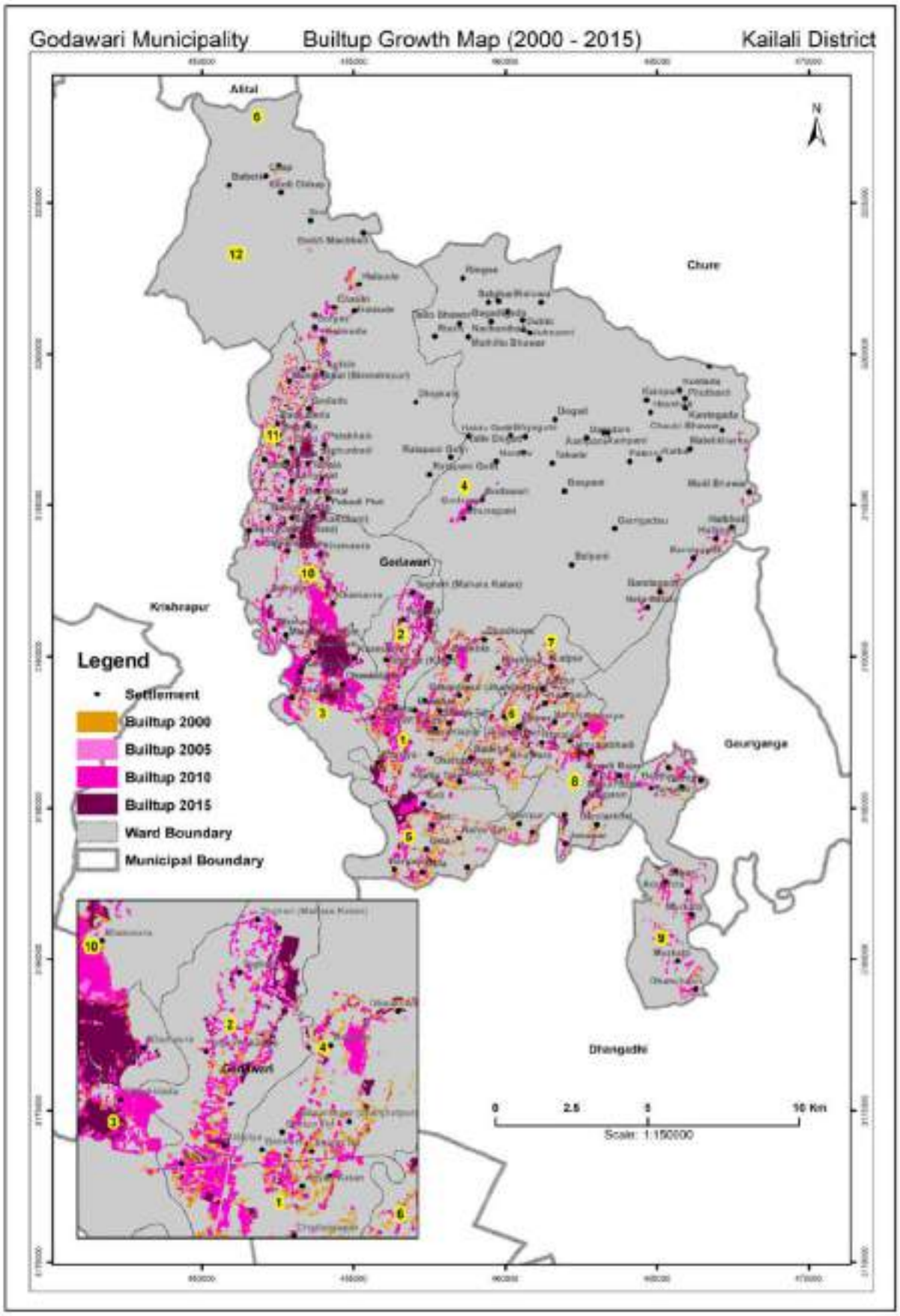


Fig. 2.20 Urban Growth in Godawari Municipality (2000-2015).

2.8 SPATIAL DISTRIBUTION OF SOCIAL SERVICES

Spatial analyses for social infrastructures have been made on the basis of spatial distribution of social infrastructures for educational and health services. The analysis includes the access to these services which in turn were evaluated on the basis of walking distance for basic schools, cycle distance of secondary schools and colleges and vehicular distance and cycle distance for health services from the household. **Tabe 2.17** shows the spatial analysis for educational services in the municipality.

The spatial distribution of basic schools in the municipality shows the majority of the households (57.98%) have access to these schools within the walking distance of less than 15 minutes, while 28.57% households take 15 to 30 minutes, 8.30% household take 30-45 minutes and 5.14% household take more than 45 minutes which is illustrated in **Fig. 2.21**. Similarly, the majority households (57.26%) within the municipality are in access to secondary schools at a cycle distance of less than 15 minutes which can be seen in **Fig. 2.22**.

Likewise, for colleges the proportion of households in access within cycle and vehicular distance of less than 15 min is only 13.80% while 49.83% households take more than 45 minutes to reach a college which is illustrated in **Fig. 2.23**.

Similarly, spatial analysis for the health services were done too, based on the vehicular distance (for households within the reach of transportation routes) or cycle distance to reach these services, mainly health posts and urban health center in **Tabe 2.18**.

The spatial distribution of hospital and health posts in the municipality indicates the higher proportion of households (63.07%) have vehicular access to health posts within less than 15 min time. Similarly, 25.51% and 6.06% households take 15-30- and 30-45-minute time to reach a health facility respectively. Likewise, 5.36% households take more than 45 minutes time in **Fig. 2.24**.

Table 2.17 Major settlement urban characters.

MAJOR SETTLEMENT URBAN CHARACTERS														
S. N.	MAIN INDICATOR	SUB INDICATOR	ATTARIYA	TEGHARI	GETA	CHAUKIDANDA	MALAKHETI	GOLDADA	SHANTI TOLE	LALPUR	SYAULI BAZAR	TAMAULI	SEHARI	BUDHITOLA
1.1	**Transportation**	**Approach Road**	East-West Highway and Dhangadhi Highway	Dhangadhi Highway	Dhangadhi Highway	East-West Highway and Urban Road connecting to Malakheti - Sim	Dhangadhi Highway	Internal Road	East-West Highway	East-West Highway	East-West Highway	East-West Highway	Internal Municipal Road	Dhangadhi Highway
		Transportation Facilities	Regional Bus Park	Bus Stop and service of public transportation	Bus Stop and service of public transportation	Bus Stop and service of public transportation	Bus Stop	Tricycle available	Bus Stop and service of public transportation	Bus Stop and service of public transportation	Bus Stop and service of public transportation	Bus Stop and service of public transportation	Tricycle available	Bus Stop and service of public transportation
		Built up area 2000	13.61	2.88	7.5	2.4	1.21	2.26	14.75	5.75	1.81	1.53	1.79	0.28
		Built up area 2005	21.24	11.8	8.94	5.04	1.57	2.49	15.95	6.81	2.84	2.06	1.84	0.65
		Built up area 2010	80.88	24	35.76	23.24	4.38	7.71	35.81	13.9	13.62	5.41	3.16	1.12
		Built up area 2015	85.8	35.2	40.91	24.94	5.26	8.64	38.49	21.29	20.45	6.91	6.58	1.95
		Built up area 2021	137.39	71.17	45.27	29.11	7.34	10.33	53.45	22.83	26.28	8.23	7.09	2.35
3.1	**Education**	**Private**	8	1	2	1	1		1	3				
		Government	1	1	2		1	1		1	1			
3.2	**Health**	**Private**	13		1		2							
		Government			2						1			
		Community							1					
3.3	**Security**		2	1	1									
3.4	**Government Office**		2	**1**	**1**		**1**	**1**	**1**	**1**			**1**	
4.1	**Number of Financial Institutional**		54	1	10		1		2	1	2		1	
4.2	**Number of market infrastructure**													
4.3	**Number of Industries**	**Private**	16	**1**	14	**2**	**2**	**3**	**4**	**5**	**2**			
		Government	1						1					
5.1	**Household Number**		2490	620	577	779	112	186	1223	277	495	215	209	98
6.3	**Building Typology**	**Number of Floors**												
		1 Storey	1817	567	474	743	108	186	1142	248	461	201	191	98
		2 Storey	469	43	87	33	4		68	28	33	14	18	
		3 Storey	180	10	16	3			13	1	1			
		4 Storey	20											
		5 Storey	4											
		Building Materials Used												
		Cement	2372	573	435	623	90	75	1108	204	286	74	38	25
		GI Sheet	7		10	1			1					1
		Metal	2											
		Mud	77	24	126	150	21	111	96	61	201	110	110	62
		Steel	1			1								
		Wood	31	23	1		1		18	12	8	61	61	10
		Roof types												
		GI Sheet	503	113	144	197	24	69	80	24	122	53	44	24
		Khar Phus	2	2	4	8			2		16	4	5	
		RCC	1918	461	303	447	63	53	10	168	210	53	18	168
		Tile	67	44	126	127	25	64		85	147	147	142	85

Table 2.18 Major settlement urban characters.

SPATIAL ANALYSIS FOR EDUCATION SERVICES			
SOCIAL SERVICE		WALKING/CYCLE DISTANCE (MIN)	PERCENTAGE OF HOUSEHOLD (%)
Walking distance (min)			
Education	Basic Schools	<15	57.98
		15-30	28.57
		30-45	8.30
		>45	5.14
	Cycle distance (min)		
	Secondary Schools	<15	67.26
		15-30	25.42
		30-45	1.29
		>45	6.03
	Cycle and vehicle distance (min)		
	College	<15	13.08
		15-30	19.66
		30-45	16.71
		>45	49.83

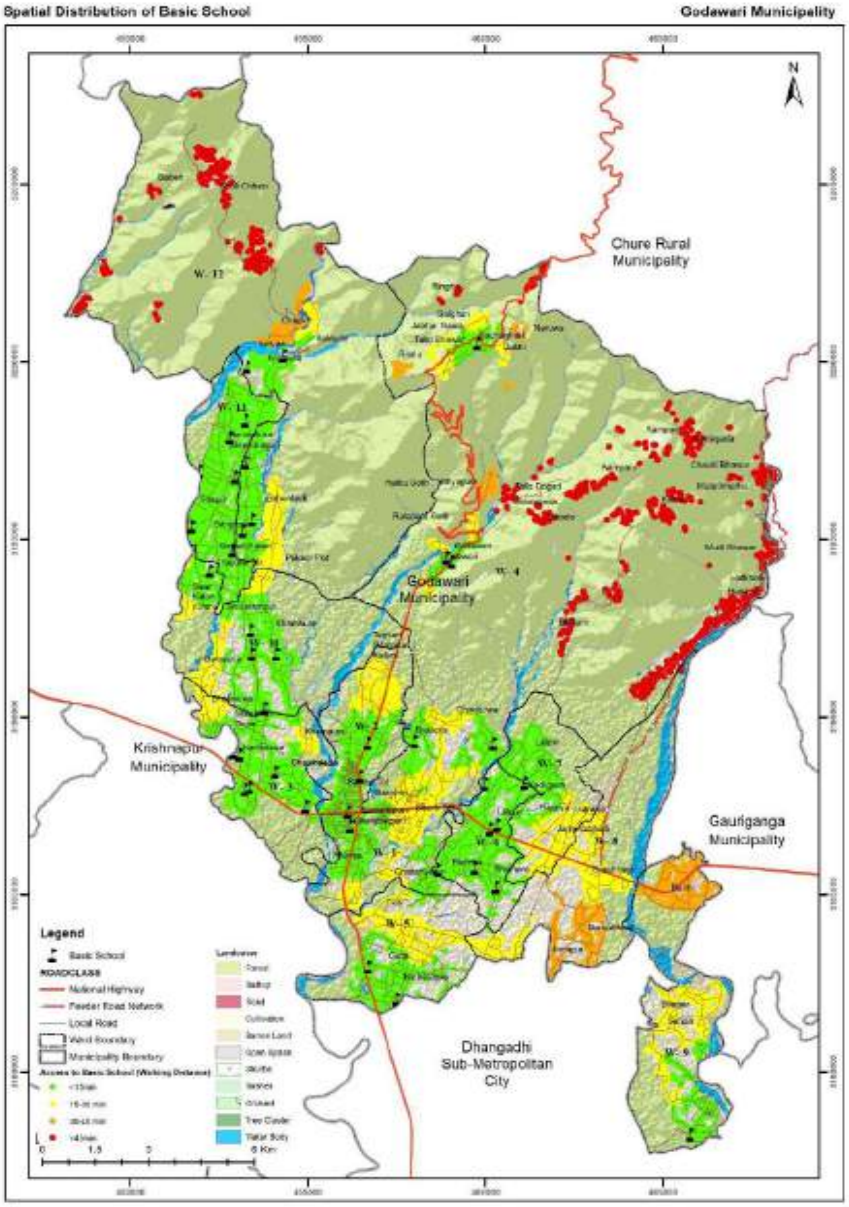


Fig. 2.21 Spatial distribution of basic schools.

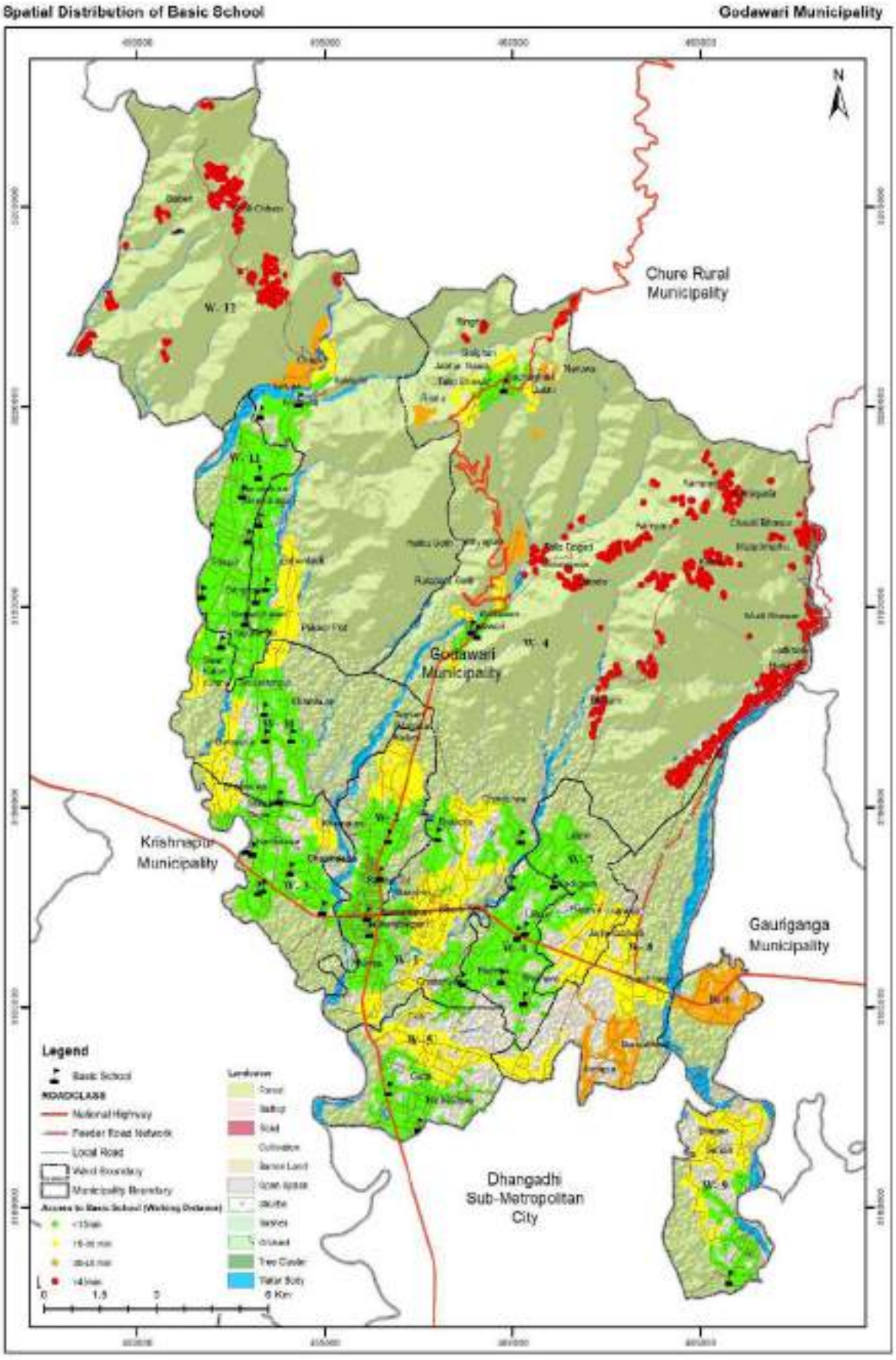


Fig. 2.22 Spatial distribution of secondary schools.

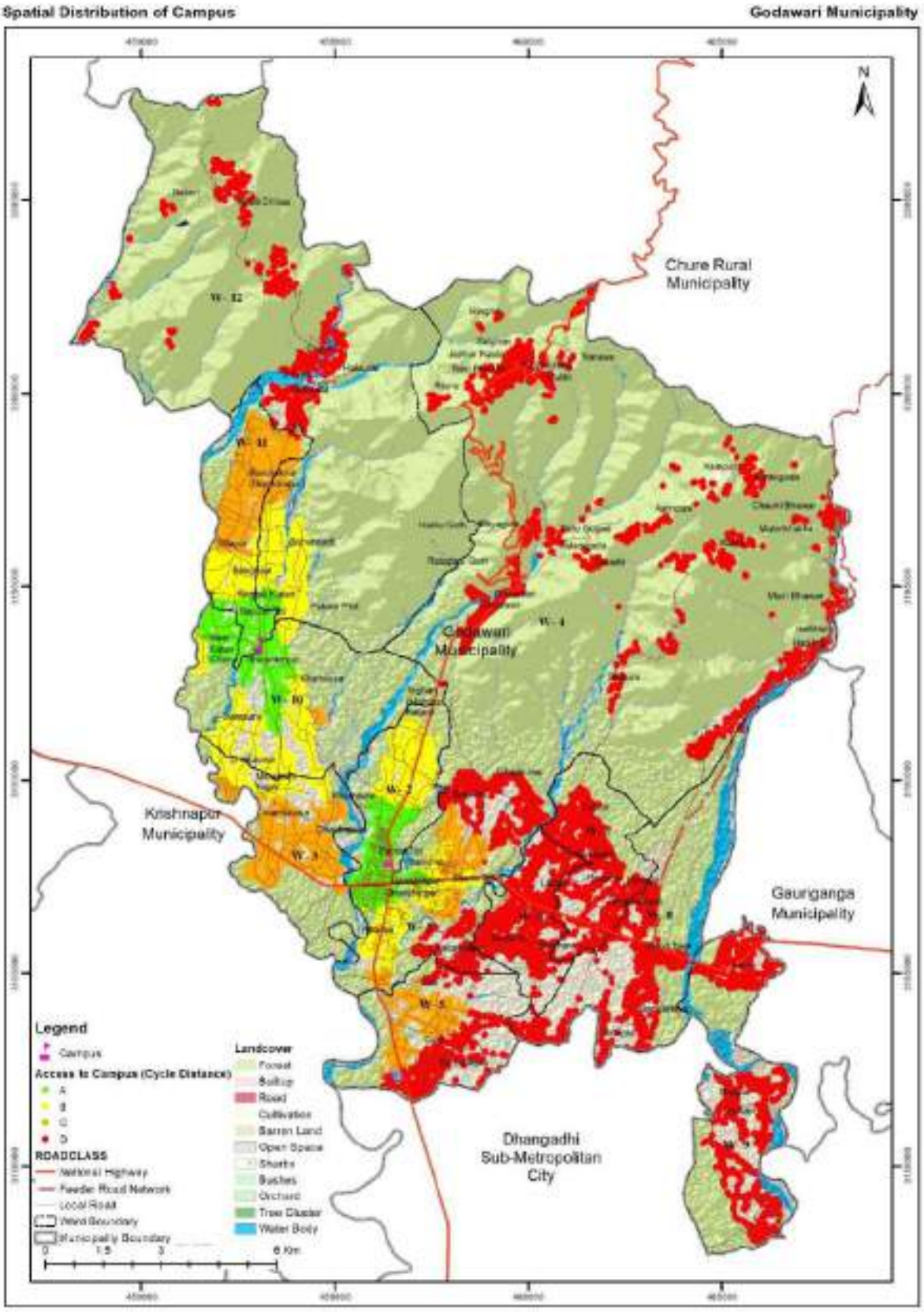


Fig. 2.23 Spatial distribution of colleges.

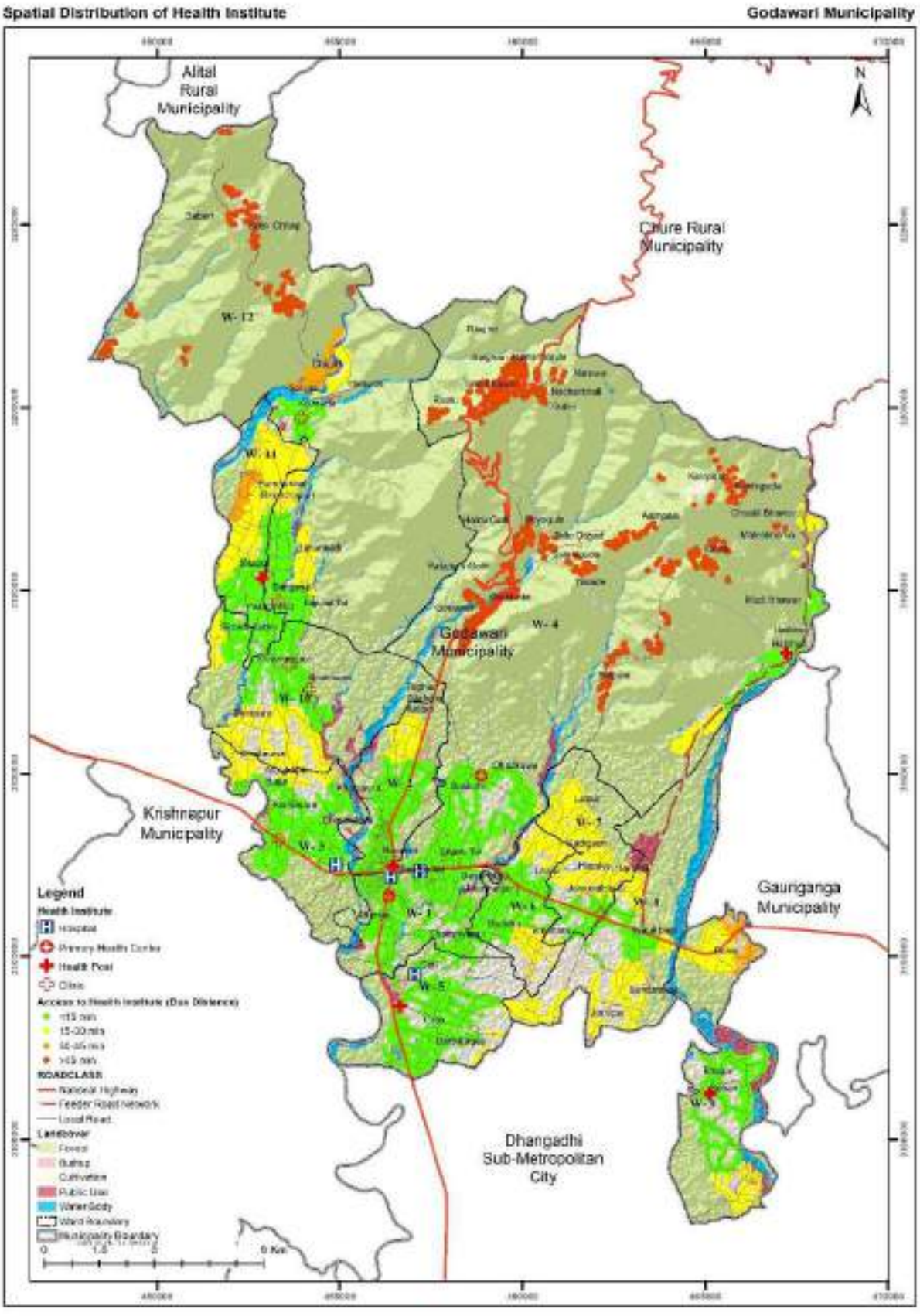


Fig. 2.24 Spatial distribution of health services.

Table 2.19 Spatial analysis for health services.

SPATIAL ANALYSIS FOR HEALTH SERVICES			
SOCIAL SERVICE		VEHICLE/CYCLE DISTANCE (MIN)	PERCENTAGE OF HOUSEHOLD (%)
Health	Hospital, Health Posts	<15 (Bus distance)	63.07
		15-30	25.51
		30-45	6.06
		>45	5.36

2.9 REGIONAL LINKAGE

Godawari Municipality is neighbored by Gauriganga Municipality on East, Chure Rural Municipality and Alital Rural Municipality on North, Krishnapur Municipality on West and Dhangadhi Sub-Metropolitan City on South. This municipality is one of the developed municipalities of Kailali District as well of Sudurpaschim Province. This municipality has also been declared as the capital city of province.

In the context of accessibility, East-West Highway passes through the municipality. The highway connects the municipality with other cities like Kanchanpur, Chitwan, Itahari and more. Dhangadhi Highway also passes through the municipality connecting North-South part of the province. Godawari is also the gateway to the northern 7 districts – Dadeldhura, Doti, Achham, Baitadi, Darchula, Bajhang and Bajura. Besides, local road network is well established providing access to the highway. These means of accessibility have supported well for the inflow and outflow of the goods and services in the municipality. The municipality provides various services to its neighboring local bodies viz. trade, market, transportation etc. **Fig. 2.25** represents the regional connectivity of the municipality.

Godawari Municipality is commercially developed and provides trading link to the major eastern and western cities. The economy of the municipality centers is basically on trade, services and industries. Besides modern shopping, a traditional form of market called Haat Bazaar is regulated either weekly or twice a week in the major market centers. All kinds of traders; farmer and entrepreneurs sell goods and vegetables directly to the retail and wholesale customers in the busy market setup. The market is the major regional hub for the trade of livestock. The livestock from nearby areas along with Dadeldhura, Doti, Achham, Baitadi, Darchula, Bajhang and Bajura District are brought here and exported to major cities of eastern Nepal along with other parts of the country. The goods for local supply such as groceries, clothes and shoes, cosmetics, utensils, seeds and manure, construction materials etc. are imported from India, Dhangadhi, Kanchanpur, Kohalpur, Kathmandu and other parts of Nepal.

Besides the developed economic activities and market hub at Attariya, the municipal also have developed health service facilities. Geta Eye Hospital is one of the famous eye hospitals located within the municipal area which is providing the health service not only in Nepal but also to the Indians. In addition, Geta Medical College with the capacity of 600 bed nearly in completion of construction and ready for the operation which will add up the health service in the municipal area. Till now, for health services others that the optical, the locals depend on Kohalpur, Chitwan and Kathmandu Valley for better health service. In case of education facilities, it is gradually developing but the locals here still depend on the other major cities like Dhangadhi, Nepalgunj, Bharatpur as well as Kathmandu Valley to achieve higher education.

The people of adjoining rural areas of Kailai, Dadeldhura, Doti, Achham, Baitadi, Darchula, Bajhang and Bajura District usually come here for trade and business. Tourism is other perspectives that make the municipality a regional hub. The famous Godawari Dham attracts lots of pilgrims from different places of Nepal as well as India. The Lamital wetland area, Bandevi Temple, Mastadham, Gajari Jharana, View

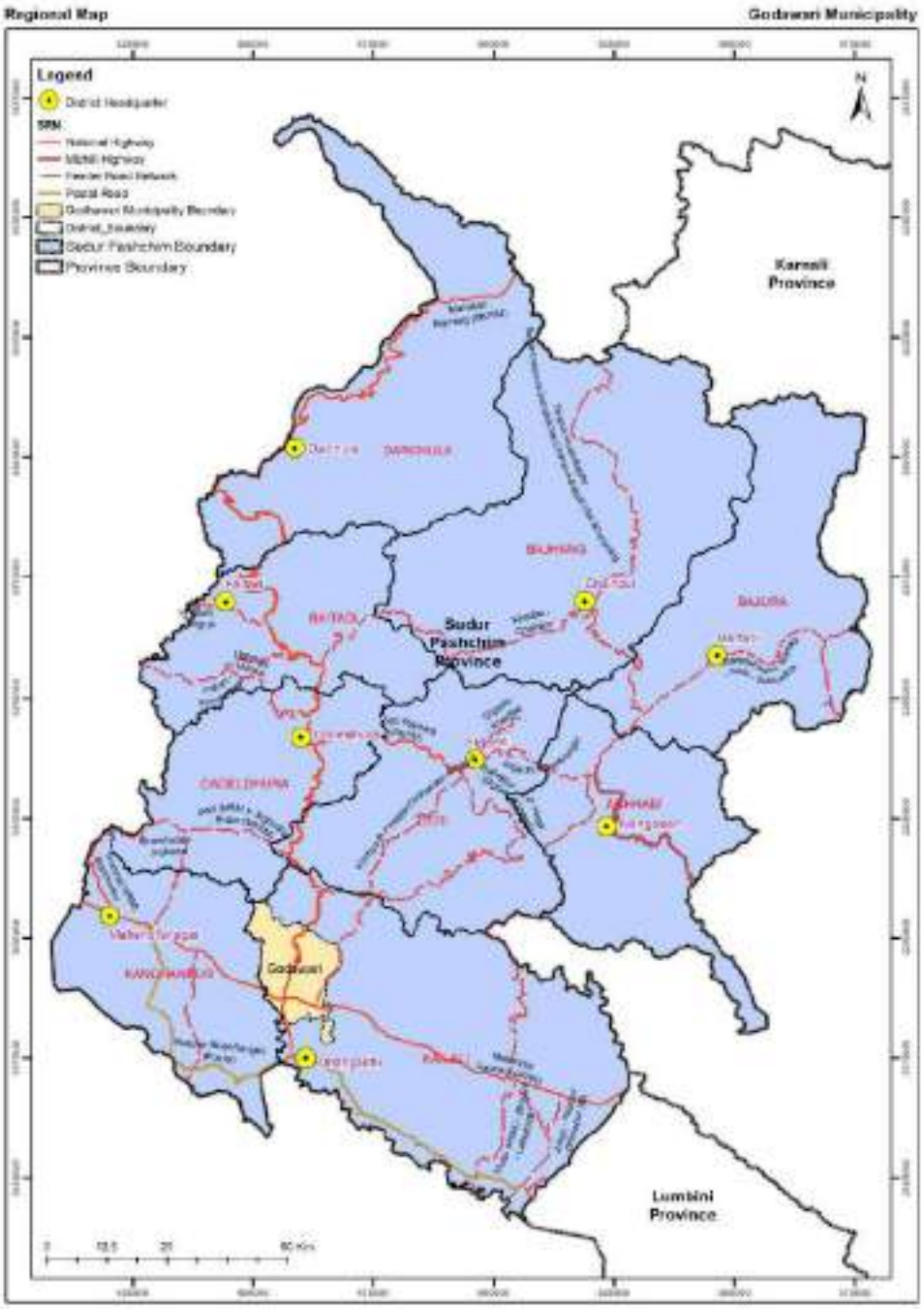


Fig. 2.25 Regional connectivity map of Godawari Municipality.

Tower at Buditola, Sashartradhara, Suspension bridge at Saheri, Chauki etc have been developed as a major regional tourism hub.

Similarly, various banking and financial institutions, money transfer service along with saving and credit cooperatives are established, providing banking and financial services are developed within the primary hub of municipality i.e., Attariya.

2.10 ENVIRONMENTAL

Air Quality Status: Local people reported that the air quality of their surrounding is degrading over time. The main reason that they relate to degrading air quality is due to increasing automobile traffic mainly in urban and also in rural areas. Lot of smokes coming out of those vehicles together with the dust coming out of the paved as well as non-paved roads are polluting the environment. The project team also observed that majority of the local people manage their waste by open burning by themselves. Moreover, they also burn crop residues openly. Such practices will have impact on air quality which in long run will affect human health, plant health and animal health.

With reference to Godawari Municipality, a total 3,315 household survey was carried out and collected the information through key informant using mobile KOBO App. The survey has shown about 58.2% have noticed changes in air quality while 41.78% have reported there is no change in air quality as shown by **Fig. 2.26**. Further survey was carried out to collect the heavy automobile traffic conditions in the municipality. **Fig. 2.27** shows that the 2.23% reported very heavy followed by 4.71% as heavy, 31.55% by not so much, 44.43% by less and 17.07% reported no effects. The survey has confirmed the increased in automobile pollutions are contributing mainly in highway and expanded roads and settlements.

Soil Quality Status: Local people reported various opinion on the quality of soil in their territory. According to household survey, **Fig. 2.28** shows that 29.23% people reported that the soil quality is improving while 32.7% people mentioned the degradation of soil quality. On the other hand, 36.8% household survey revealed that the quality of soil was not changed at their locality. Besieds, soil quality was degraded due to execcive usage of pesticides in crops. A survey revealed that 83.74% households did not use pesticides in the municipality.

Industrial Hazard Status: The entire municipality have ten industries such as five brick industries, two gas refilling stations, two stone crushers and a mined sand collection center. The survey showed that more than 80% air pollutions are responsible to brick factories and stone crushers by emitting smokes and dusts. Besides, chemical wastes and waste waters have been discharged directly into the river/stream which have caused industrial hazard in the municipality.

Water Quality Status: The household survey in the municipality confirmed that the major source of water for daily life including drinking, cooking, washing utensils and clothes are based on tube well and/or hand pumps. Both the availability and quality of water are declining gradually. Due to decrease in the groundwater table, the need of water could not be fulfilled. On the other hand, usage of higher amount of chemical fertilizers for agricultural purpose seeped directly into groundwater and dumping of domestic and/industrial waste directly into the surface water (river/stream) caused the both surface and groundwater polluted.

Municipal Solid Waste Management Status: The entire municipality have been using different resources to collect household/domestic waste collection. A poor management of municipality and ward have not undertaken the serious concern to collect household/domestic waste. A total 3,314 household survey was carried out and collected the information through key informant using mobile KOBO App. With reference to household survey, **Fig. 2. 30** shows that 0.57% waste was collected by the municipality and 0.30% people reported that waste was collected by ward; which are almost negligible. In other words, municipality and ward offices are not taking responsibility to manage wastes. On the contrary, 5.88% wastes have been collected by the private sector. As a consequence, most of people has to manage self to dispose waste. The survey revealed that 93.51% households have managed waste disposal by themselves as shown in **Fig. 2.30**

Since the waste management by the local governing body and private sectors are very poor, the people need to degrade wastes either by burning or disposing directly into the nearby river/stream. With reference to the crop, the household survey showed that 85.43% household used to burn their crop residue while 14.15% did not burn their crop residue **(Fig. 2. 31).**

Forest Hazard: Increased Incidences of Forest Fire: Forest fire frequency is increasing globally with the significant incidents occurring in Asia (Giglio et al., 2006). Forest fires are one of the major ecological threats that affect different regions of these landscapes annually, mainly in the pre-monsoon season (WWF Nepal, 2007). Factors such as high surface temperature, low rainfall, and the amount of accumulated fuels in the forest contributes to the forest fire.

In many cases, forest fire occurred due to negligence of smokers and of passerby. Grazers ad the fuelwood collectors, sometimes unintentionally throw the burning buds of cigarette inside the forests which easily catch fire on the dried leaves and twigs. It has also been reported that children set fire for roasting prey such as birds and do not put it out which can outbreak. Security problems and burning for fun also contributed to the forest fire. Least income and unemployment, which is high in Terai (Shrestha et al., 2003), compel people to resort logging, fuelwood collection, hunting and most importantly the collection of non-timber forest products. All these activities increase the number of deliberate and accidental forest fire.

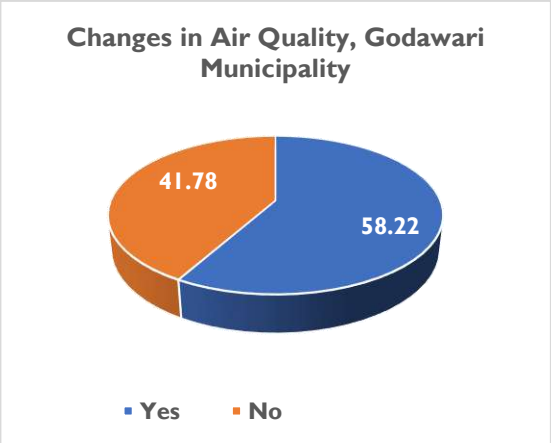


Fig. 2.26 Changes in air quality in Godawari Municipality (Source: Household Survey, 2021).

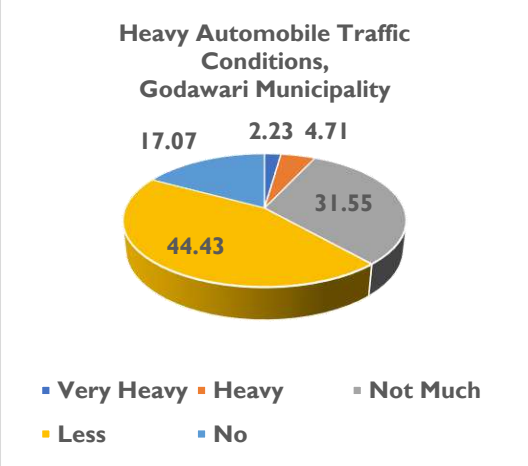


Fig. 2.27 Changes in air quality in Godawari Municipality (Source: Household Survey, 2021).

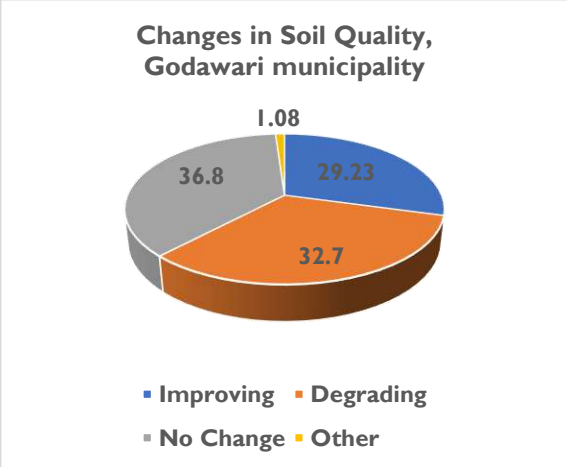


Fig. 2.28 Changes in soil quality in Godawari Municipality (Source: Household Survey, 2021).

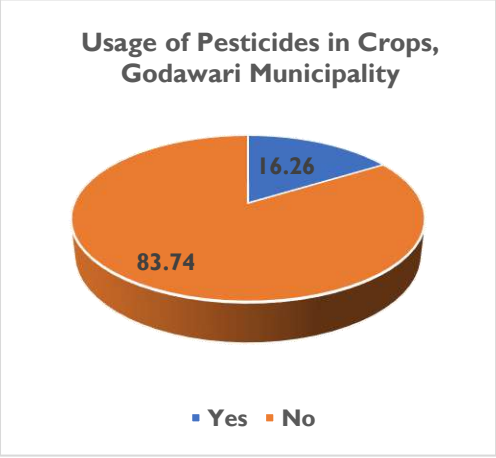


Fig. 2.29 Usage of pesticides in Godawari Municipality (Source: Household Survey, 2021).

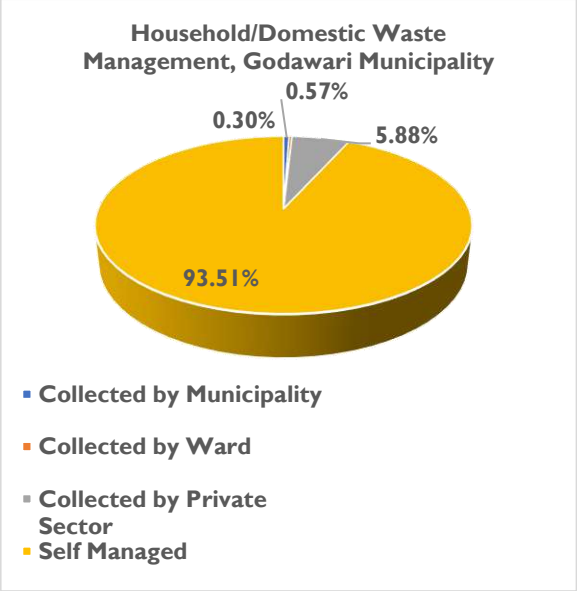


Fig. 2.30 Changes in soil quality in Godawari Municipality (Source: Household Survey, 2021).

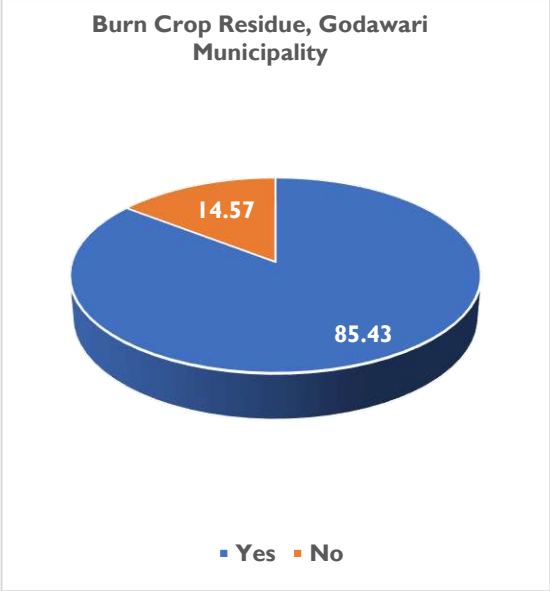


Fig. 2.31 Usage of pesticides in Godawari Municipality (Source: Household Survey, 2021).

Forest fires in Nepal are a serious risk to forest degradation with the increase in observed climate variability including droughts, long-warm days, and heatwaves. Tremendous forest fires during the dry season for which efficient forest fire risk assessment, warning, and monitoring system need to be improved (Matin et al., 2017). An increasing trend of forest fire incidences are reported in the high-value lowland forests of Tarai and Siwaliks and the year 2016 was the year with the highest number of incidences (about 10,658) recorded across Nepal (Bhujel et al., 2020).

The incidences of forest fire occurred almost every year in the municipality. The fire lasted for a day to a week. A significant forest fire occurred in the 2075. Whenever fire occurred, most of the time it will be forest user groups who immediately make an attempt to control it. Local forest guards of firefighters are often the first to respond to forest fires Later the local community also informs forest division office. It has been reported that local people set fires for hunting and masking illegal logging. Timber smugglers are also important to set fire in forest.

Infestation of Insect Pests & Pathogen: There have been incidences of pathogen attack in the forest. The recent pathogen attack recorded in the municipality was in 2077 B.S. In many cases, seriously affected by the infestation of insect pests and pathogens. Seedlings in forest nurseries were also found in feeble condition due to various fungal diseases. Diseased seedlings act as the vectors and are likely to carry pathogens from one place to another and may cause outbreak of diseases in plantation sites in future. Nepal has already witnessed a huge economic loss, though not precisely estimated, due to pathogenic attacks in commercial timber-yielding species like controlling insect pests and pathogens in the forests is a critical task of forest managers. It is more difficult in natural forests compared to plantation forests. Use of chemicals to control forest insect pests and pathogens is in practice; however, it is limited to forest nurseries or in small forest patches. It is extremely difficult to control them once they spread over a larger area. Therefore, producing insect and pathogen-free robust planting materials is important to keep a forest plantation healthy. The proper consideration on selecting healthy and robust genetic materials may limit the future infestation of insect pests and pathogens on forest crops; ultimately increasing the profits from plantations. Through the general key informants, grasshopper, patero and gobara (in Nepali) had affected the crops of Godawari Municipality

in high ratio however, the team could not get the exact data during the survey. These insects are the main cause of the destructions in the agricultural area.

Impacts of Flood & Storm on Forest: It has been reported that impact of storm and flood on forest occur almost every year in the study area. We have monsoonal rain with heavy precipitation during the wet monsoon that frequently cause severe floods destroying crops, vegetations and displacing millions of people. One of the aftermaths of floods, especially flash flood is loss of wild animals and vegetation in the forest. It also decreases the productivity of the forest soil. Likewise, local people also mentioned that the frequent storm that occurred every year damages the forest by falling off the trees and vegetation.

Forest Encroachment: It was also reported by local communities and the stakeholders that forest encroachment is another forest hazard in the municipality, although not in all wards. For example, in Ward Nos. 1, 2 and 3 have forest encroachment while Ward Nos. 8, 9 and 10 rarely have forest encroachment. Among the drivers of forest degradation, human encroachment has high level of significance in forest degradation especially degrading crown cover, habitat, biomass and understory. Forest encroachment is a serious problem in the Terai plains. An estimate shows that 100,000 ha of forest is under encroachment in the Terai and many more coming under threat of encroachment by illegal squatters (MoEST, 2008).

2.11 POLITICAL ECONOMY

The political economy of Godawari Municipality is influenced by various local dynamics and regional systemic and political challenges. Most of the national political parties like the Communist Party (UML & Moist), Nepali Congress, Rashtriya Prajatantra Party, etc. have a strong influence in this municipality. In the 2017 election, Nepal Communist Party (Unified Marxist-Leninist) owned the election of Mayor, Deputy Mayor, and most of the ward members, and Nepali Congress was in the second position. **Table 2.20** represents the political composition of the municipality.

Out of these, more than 8 candidates secured 15.44% votes in the election. It indicates that, in Godawari Municipality, there are more than ten political parties that have actively conducted their political activities. Among them Nepali Congress has 31, NCP (UML) has 30 and NCP (Maoist) has only one seat in the Municipality body.

Economic Conditions of the Municipality

The people in Godawari Municipality share a similar economic and political system with the mainstream society of Nepal. The local people living in the Municipality in terms of livelihood patterns, access to economic resources, political, health, and educational opportunities are not different from other communities of that region. According to National Economic Census (2018), there is a total of 2,681 establishments in Godawari Municipality that are involved in various economic activities. An establishment is an economic unit (business or industrial area) at a single geographic location, where business is conducted, service is delivered or industrial operations are performed.

In those establishments, a total of 8,531 persons are engaged for the economic activities, as a self-employed or an employee, with a total male engagement of 5,583 and female engagement of 2,948 persons. In every business, an average of 3.18 people gets engaged with an average of 2.08 males and 1.10 female (**Fig. 2.26**). Most of the people of this municipality are engaged in agriculture followed by business, self-employed activities, foreign migration, etc.

The Policy of the Municipality

The Constitution of Nepal, 2015 identifies the municipalities as the third tier of government and having executive and legislative power, and limited judicial authority. The authorities of the local government based on the constitution have mentioned in the Local Government Operation Act, 2017 which has clear instructions to ensure the maximum participation of local citizens, marginalized communities, and other stakeholders in the planning and implementation of development plans and programs (International Alert, 2020). It details and specifies the power, functions, duties, roles, and rights of local government and its elected officials and chief administrative officer, who is appointed by the federal government.

Local governments must follow the rules and regulations implemented by the federal and provincial governments and can make new laws, acts, rules, and regulations based on their needs. Most acts, laws, and policies related to land like National Land Use Policy, 2015 and National Land Use Act, 2019 have already been formulated and implemented by the federal government. There are other several sectoral policies, acts and regulations, formulated and implemented during the 1990s that implicitly incorporate DRR components like the Soil and Watershed Conservation Act 2039 (1982), Water Resource Act (1992), Forest Act 2049 (1993), Environmental Protection Act 2053 (1997), National Urban Development Strategy 2017 and the regulations under them are some of the important legal provisions. The Godawari Municipality has also formulated various acts and provisions since 2018. Some of them are mentioned in **Table 2.21**.

The **Table 2.21** shows that Godawari Municipality has formulated various acts, rules, and procedures. The municipality has ratified various acts, rules/regulations, Procedures, Directives, and other papers. Godawari Municipality operates the legislative, executive, and judiciary powers over the Municipality geographical areas distinguished for administrative and political purposes to equalize the national interest (Acharya, 2018). It has the full authority to make bylaws, raise revenue, carry out spending, recruit staff and adjudicate local disputes on a limited scale (Kharel, 2018). These all functions have completed Godawari Municipality as an independent government body.

Political Intervention in the Policy-Making Process

Political intervention at the Municipality level is mainly dominated by the NCP (UML) and NC in almost equal proportion which have a majority in the Municipal body as well as in the supporter's level. Most of the policies, acts, laws and regulations passed in municipal body unanimously, but there are some debates in the sectoral allocation of the budget and local level development activities. Out of these, there is no outer political intervention in the policy-making process in Godawari Municipality.

Table 2.20 Political Composition in Municipality.

POLITICAL COMPOSITION IN MUNICIPALITY			
S.N.	POSITIONS	POLITICAL PARTIES	NUMBER
1	Mayor	NCP (UML)	1
2	Deputy Mayor	NCP (UML)	1
3	Ward chairperson	• Nepali Congress	5
		• NCP (UML)	5
		• NCP (Maoist)	1
4	Ward Member	• NCP (UML)	23
		• Nepali Congress	26
		• NCP (NS)	-

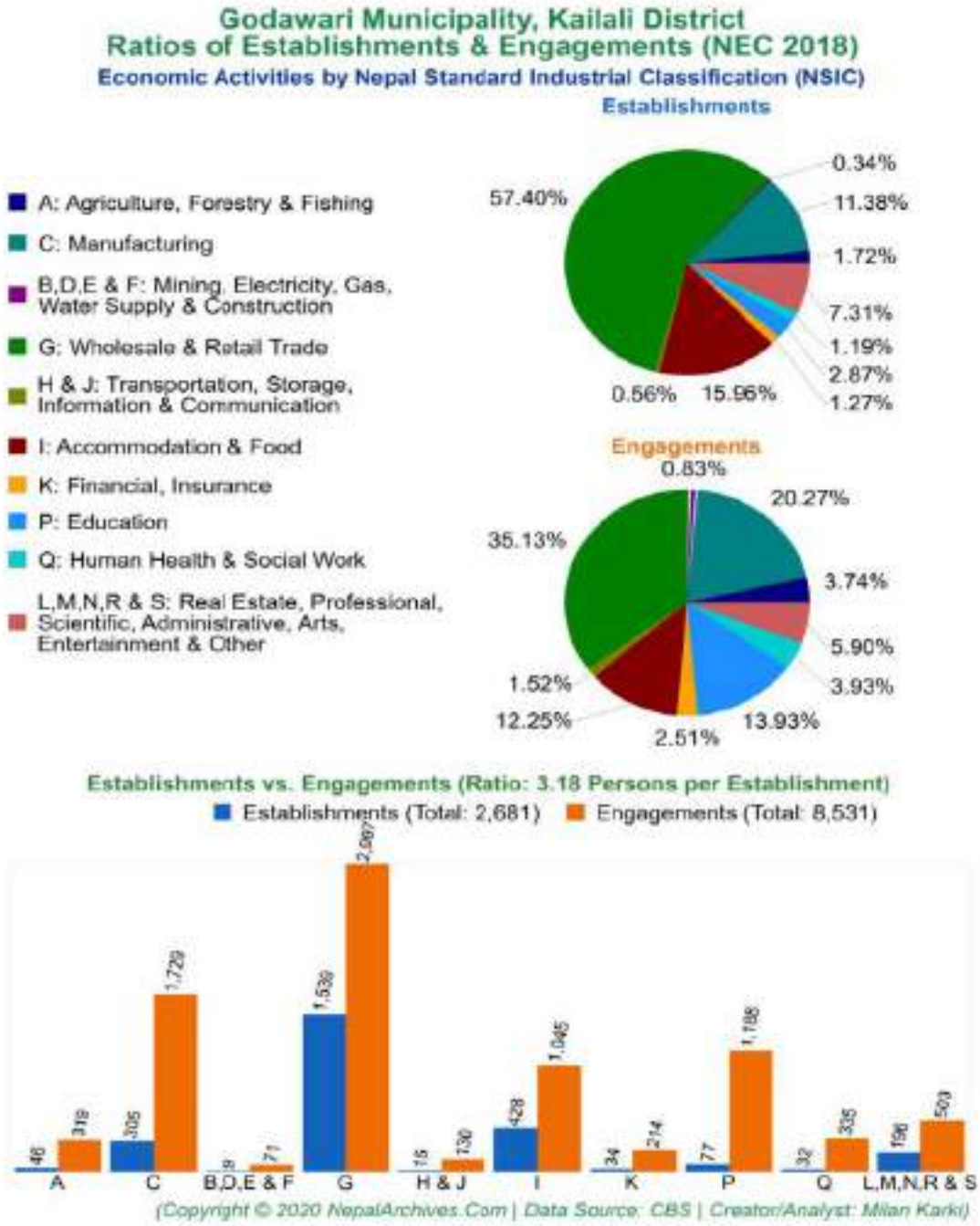


Fig. 2.32 Economic condition of the municipality (Source: NepalArchives.Com; data source: CBS, after Milan Karki).

Table 2.21 Acts, Rules, and Procedures of Lamkichuha Municipality

ACTS, RULES, AND PROCEDURES OF LAMKICHUHA MUNICIPALITY			
S.N.	**Acts /Rules/Procedures/Directory**		**Acts /Rules/Procedures/Directory**
1	Economic Procedure, 2021	9	Tole development procedure,
2	Education Act, 2018	10	Extremely Poor Families Affected by Kovid-19 Epidemic cash transfer procedure, 2021
3	Education Procedure, 2017	11	Municipality Meeting Procedure, 2017
4	Interest Subsidy Program for Concessional Loans Procedure 2021		-

ACTS, RULES, AND PROCEDURES OF LAMKICHUHA MUNICIPALITY		
S.N.	**Acts /Rules/Procedures/Directory**	**Acts /Rules/Procedures/Directory**
5	COVID-19 crisis management procedure, 2018	-
6	Public expenditure, Economic Activities Regulation, and Systematization Act, 2018	-
7	Municipality Appropriation Act, 2018	-
8	Appropriation Bill 2019	-

Source: https://godawarikailali.gov.np/en/act-law-directives

3. MULTI HAZARD RISK ASSESSMENT

3.1 HAZARD ASSESSMENT

This section presents the introduction of hazard and susceptibility maps followed by methodologies and procedures adopted for each hazard in the municipality.

Multi-hazard is referred to as 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. Multi-hazards are caused by different triggering factors, and there are often complex relations between the individual hazards. Multi hazard Risk Assessment, MHRA, is relatively new approach and increasing practice as a tool for DRM. It is an integrated approach to urban risk assessment, and an emergent area. MHRA has different explanation and, generally accepted definition of multi-hazard still does not exist, in practice (Schmidt, et. al., 2011). The term is often used to indicate all relevant hazards assessment that are present in a specific area.

The MHRA approach is developed to overcome the limitations of single-hazard appraisal, which builds on single-hazard risk assessment, and integrates considering hazard interaction and interdependencies among number of hazards, if these exist (Liu et. al., 2016). In comparison to single hazard risk assessment, multi-hazard risk analysis poses challenges. Some of the challenges related to multi-hazard risk analyses are, fewer available studies on multiple hazards lack of single standard approach to MHRA (Kappes et al., 2012). The complex and variable interrelationship between multi-hazards and their potential effect to elements differ from one environment to another. Multi-hazard risk assessment determines the total risk from several hazard taking into account possible hazards and vulnerability interactions (European Commission, 2010). Multiple-hazard interactions can occur at the same time, may follow one after another or occur independently but affect the same element at risk. Depending upon the timing and occurrences those hazard interactions are termed in different ways like follow-on events, domino effects or cascading events. The creation of a set of scenarios correlating adverse events from different hazard sources is a unique aspect of multi-hazard risk assessment (Marzocchi et. al., 2009). As the multi-hazard and risk concept is a relatively novel area of natural risk governance, only few multi-risk models are available and are practiced. Nevertheless, the MHRA directly feeds into the development of disaster management plans at the local level, which use this information to identify and prioritize activities to mitigate risks and prepare for disasters.

MHRA requires historical data and information on hazard events, frequency of events, causes of the event and interactions between those. The greater the availability of historical data and process information, the higher the validity of the assessment. This successively leads to realistic plans for better response to disasters by reducing risk and the severity of adverse effect. MHRA at local and regional scales remains a major challenge because of lack of (historical) data. Data available from simple scenarios to full probabilistic analysis, can lead to better decision-making in DRM context. Quantitative, semi-quantitative, qualitative and increasingly mixed-methods approaches are applied to MHRA. The best suitable approach depends on the scope/purpose of the assessment (e.g. identification hotspot or risk reduction measures), temporal and spatial scale of the area being assessed. A simple approach to risk management is systematic incorporation of risk information: risk identification, risk assessment, risk evaluation and risk treatment measures (ISO, 2009). A systematic approach is fundamental to carry out MHRA combining quantitative and qualitative methods with expert-based knowledge, decision and local experience and knowledge at community level. Basic to consider for multi hazard risk assessment is multiple hazards and multiple vulnerabilities though the frameworks employed and the indicators selected for analysis vary widely. However, both largely depends on the geographical area, spatial scale and local context. The systematic process of addressing multiple hazard in Nepal

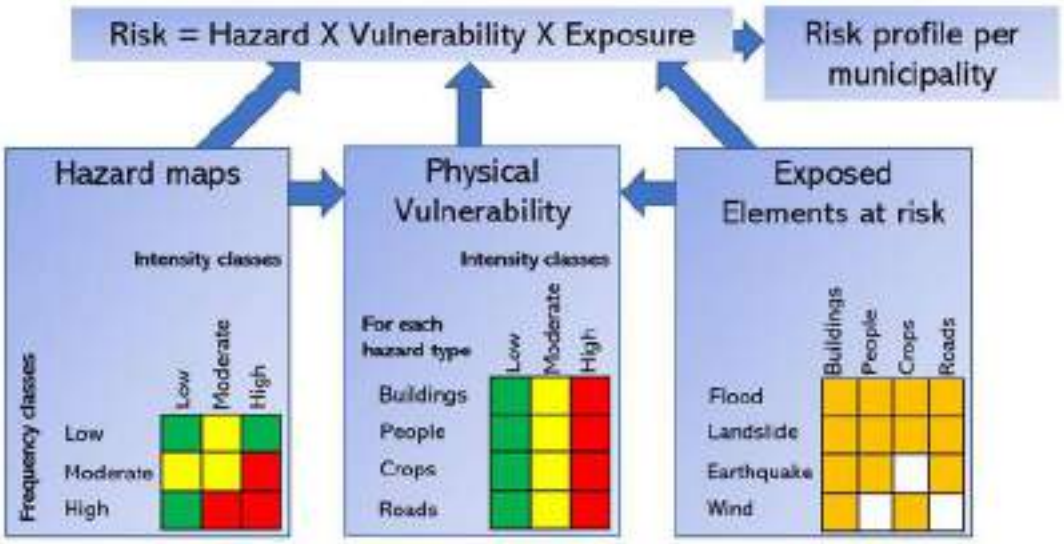


Fig. 3.1 Method for analyzing multi-hazard risks.

was started with Nepal Hazard Risk Assessment carried out jointly by Asian Disaster Preparedness Center (ADPC) Norwegian Geotechnical Institute (NGI) and Centre for International Studies and Cooperation (CECI) with the financial assistance from the World Bank-Global Facilities for Disaster Reduction and Recovery, GFDRR.

The aim is to generate risk information for the sub divisions within the municipality, for a combination of hazard types (in the figure indicated as earthquakes (EQ), floods (FL), windstorms (WS), landslides (LS)) and four types of elements-at-risk (buildings, people, agriculture and roads). Other hazards include animal attacks, fire and climate extremes. **Fig. 3.1** shows the method adopted for analyzing the multi-hazard risk analysis.

The hazard intensities such as water depth (flooding), acceleration (earthquake), speed (wind) were modelled using separate modelling approaches. The frequencies of these hazards were estimated from historical records of precipitation, wind speed and earthquakes. The return periods for which intensity information was available differed for the various hazard maps. For instance, earthquake hazard maps were generated for return periods (475 and 2475 years) that are much larger than for other hazards such as flooding. For some hazard types (e.g., landslides), it was not being possible to create intensity/frequency maps due to lack of historical landslide data. For these only susceptibility maps were made using a hybrid model (statistical modelling and heuristic) that show zones with a relative likelihood of occurrence of hazardous phenomena, without a clear indication of the frequency and intensity. For these hazard types, the spatial probability that a particular area would be impacted was estimated based on the ratio of the expected area of future events (based on limited historical records and expert estimation) and the area of the susceptibility classes. Due to the absence of spatially referenced historical inventories, and the overall incompleteness of the historical records, the spatial and temporal probability was uncertain. All hazard maps were classified into three or four classes of frequency and intensity (or susceptibility and spatial probability). This classification was done taking into account the damaging effects of the hazard, where the high-class boundaries were chosen such that they represent different danger levels with respect to buildings and people.

The hazard types, and their expected impacts were considered within the municipalities, and considered (whenever possible) the hazard interactions that could take place. These might lead to cascading hazards (e.g., earthquake-triggered landslides, floods and landslides providing sediments in

the rivers through flash-flood and debris flows), or the occurrence of one type of hazard might lead in time to another (e.g., wildfires in the sloping areas might lead to mudflows in due course of time).

In this study, elements-at-risk include buildings, population, agricultural areas and roads. Roads were obtained by the digitization from high resolution satellite images and Open Street map. Agricultural areas were obtained through digital image processing, combined with collaborative mapping. Built-up areas and buildings were obtained using OpenStreetMap and field mapping. Census data were used in combination with the buildings and building types (including occupancy type, number of floors and total floor space) to estimate the number of people.

Exposure was calculated by spatially overlaying the hazard maps with the elements-at-risk maps, and with the administrative boundaries of wards, to obtain the area of built-up zones, the number of buildings and people, the area of agricultural land, and the length of roads within each ward exposed to a certain level of hazard intensity (or susceptibility). Not all combinations of hazards and elements-at-risk were considered relevant to evaluate (e.g., the effect of drought on roads, or earthquakes on agriculture land). The exposure analysis resulted in a database with data per ward.

Vulnerability curves from literature (Papathoma- Köhle, 2016; Ciurean et al., 2017; Fuchs et al. 2019; CAPRA, 2020) were consulted and converted into vulnerability matrices, that displayed the damage ratio (percentage of exposed elements-at-risk that would be destroyed) for each hazard type and each intensity class. For those hazard types (landslides) for which no hazard intensity information was available, exposed elements were assigned a vulnerability value of 1 (which means that the element-at-risk is completed damaged when impacted). The vulnerability matrices were used in combination with the exposure data to convert the intensity into vulnerability, which was multiplied by the spatial probability. This resulted in the loss database where losses are stored for each combination of hazard type/frequency class and elements-at-risk type.

Average annual losses were calculated for each hazard type and element-at-risk combination using the three available frequency and loss values, and applying a simplified method to assess the area under the risk curve. This procedure is illustrated in **Fig. 3.2.**

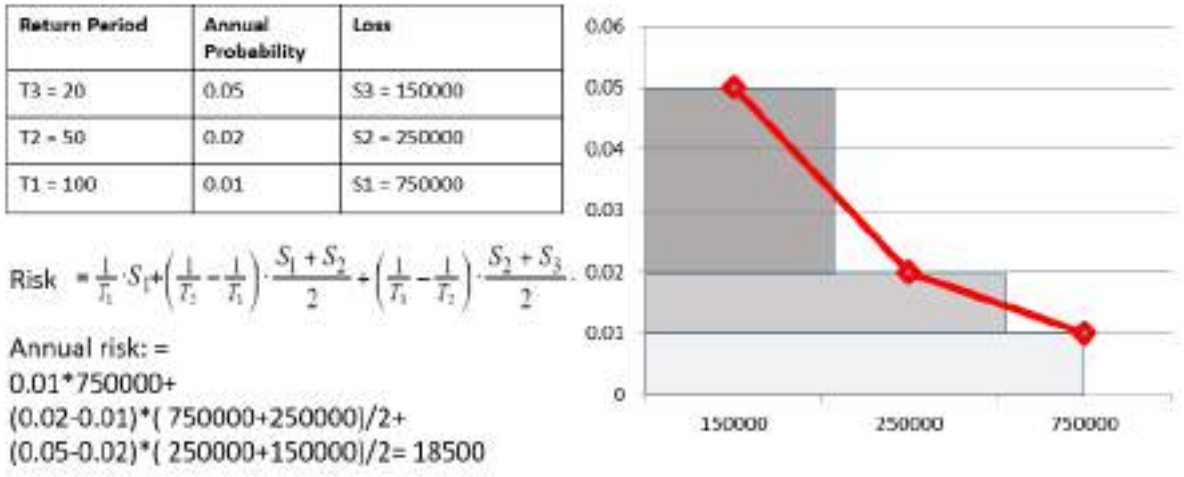


Fig. 3.2 Simplified method used to calculate annual risk from a limited set of damage data with different return periods.

Hazard assessment was conducted in Godawari Municipality for seven hazards (flood, landslide, earthquake, windstorm, animal attacks, heatwave/coldwave and fire) using hazard-specific models. All hazard maps were classified into a number of classes of frequency and intensity (or susceptibility and spatial probability). This classification was done considering the damaging effects of a hazard, where the high-class boundaries were chosen such that they represent a clear danger level with respect to buildings and populations. For the heatwave and coldwave, statistical trend analysis of the temperature extremes was presented based on globally accepted climate indices.

Table 3.1 gives a summary of the hazard maps with frequency classes (which are different for the various hazard types) and intensity classes (also different for the various types of hazards). The frequency classes were differed because the return periods were much larger for some hazard types (e.g., earthquakes) than others (e.g., flooding). The intensities were modelled based on hazard modelling and describe the potentially damaging effects of the hazard (e.g., water depth for flooding, acceleration for earthquakes, and wind speed for windstorms). Given the small scale of the study and the size of the study area, the intensities are classified into general classes, where some hazard intensities needed to be rescaled locally (e.g., windstorm effects). The intensities classes were linked later with the vulnerability.

Probabilistic risk assessments are characterized by the inclusion of inherent uncertainties, related to the randomness of hazards and partly because of the incomplete understanding and measurement of the hazards, exposure and vulnerability under consideration. Probabilistic risk assessment simulates those future disasters based on scientific evidences which are likely to occur. In the context of disaster risk, probability refers to the frequency of occurrence or the **return period** of losses associated with hazardous events.

Not all hazard risk can be assessed through probabilistic approach. Hazards like flood, earthquake and windstorms have certain frequency-intensity relationship whereas hazards like landslide, animal attacks, fire etc. do not have such relationship. There is no clear distinction of frequency and intensity for the latter hazards. In this project, the probabilistic risk assessment was considered for the hazards that have frequency-intensity relation or those having certain return period (flood, earthquake and windstorm). For landslides, the expert-based assumptions were made to assign its frequency-magnitude relation to fit the multi-hazard risk assessment methodology. This part is detailly explained in spatial probability part at sub-section 3.1.8. Based on the return periods, the exposure and losses are calculated and summed to give Average Annual Loss (AAL) or the risk curve as shown in **Fig. 3.2**.

Comprehensive multi-hazard probabilistic risk assessment requires number of factors to account for since disaster risk is a dynamic topic. Various factors like land use change, climate change etc. influence the disaster risk. In addition, the hazard modelling requires many simulations for number of parameters sets which are computationally time consuming.

Table 3.1 Summary of the hazards (with its frequency and intensity classes) and susceptibility map.

SUMMARY OF THE HAZARDS (WITH ITS FREQUENCY AND INTENSITY CLASSES) AND SUSCEPTIBILITY MAP					
HAZARD TYPE	FREQUENCY CLASSES	INTENSITY CLASSES	INTENSITY TYPE	TYPE OF MAP	TYPE OF MODELLING
Earthquake	475, 2475 years	4 classes	Acceleration	Hazard	Probabilistic
Flood	20, 50, 100 years	3 classes	Water height	Hazard	Probabilistic
Windstorm	10, 25, 50 years	4 classes	Wind speed	Hazard	Probabilistic
Landslide	3 susceptible classes		Relative class	Susceptibility	Statistical-Heuristic-Expert
Animal attack	4 susceptibility classes		Relative class	Susceptibility	Heuristic-Expert
Fire	4 susceptibility classes		Relative class	Susceptibility	Heuristic-Expert

SUMMARY OF THE HAZARDS (WITH ITS FREQUENCY AND INTENSITY CLASSES) AND SUSCEPTIBILITY MAP					
HAZARD TYPE	FREQUENCY CLASSES	INTENSITY CLASSES	INTENSITY TYPE	TYPE OF MAP	TYPE OF MODELLING
Heatwave/coldwave		only statistical analysis; no spatial representation			Statistical

3.1.1 FLOOD HAZARD ASSESSMENT

Floods are an important hazard type in Godawari municipality. It is ranked 3rd as the major hazard in the municipal disaster report. Most of the streams in Godawari are ephemeral in nature. They get flooded only in the monsoon season and have none to very low discharge in the rest of the year. Because of the flat terrain of the settlement areas, the flood water spreads over a very large area, once leaving the hills. Every year, flood inundates the settlement areas, damages the houses and crops as well as it cuts off the riverbank. There are also historical records of human and livestock casualties in the municipal report.

A physical approach was utilized to produce municipal-scale flood hazard maps. The basis for the physical methods is rainfall which is obtained through statistical analysis. Based on the resulting probability distribution of rainfall events, regional or local scale hydrology, runoff, and flow can be modelled. For the flood simulations, an open-source multi-hazard tool called "OpenLISEM" was used, which is capable of simulating hydrology, channel and surface flow, (flash) floods, and additionally includes sediment related processes such as erosion, transport and deposition (van den Bout et al., 2018).

Input Data for Flood Modeling

A mixture of global and local datasets was used for modelling the flood hazard maps. The data required for the flood hazard maps and their process of preparation are described are as follows:

1.Digital Elevation Model (DEM) and its derivatives. A DEM with a spatial resolution of 5 m was obtained from TAYAR NEPAL. The watershed of the rivers flowing in the Godawari extend far above the municipality so, DEM outside of the study area had to be extracted and used it in our model. It was done so that it doesn't underestimate the hydrological processes while modeling the flood. After the final simulation, the extra extent were clipped to present Godawari Municipality only. The exact source of the DEM is not known, and it contained several pits and artefacts which had to be pre-processed rigorously. Local drainage direction (LDD), accumulation flux, channel properties, and watershed delineation were the derivatives of the DEM that were used in the model. The channel depth and channel heights were generated with the help of the empirical relation from Frasson et al. (2017)

$$Width\ (meters) = 9.68 * CatchmentArea(km^2)^{0.32}$$

$$Depth\ (meters) = 11.3 * CatchmentArea(km^2)^{0.083}$$

2.Landcover. A landcover map was developed for this project by the partner organization Rajdevi. The map was further improved using OpenStreetMap and satellite images.

3. Soil-water characteristics. Soilgrids is a globally available digital soil database which is generated with state of the art machine learning methods (Hengl et al., 2017). The soil grids data provides a global prediction for the standard numeric soil properties (bulk density, soil texture fractions, organic content etc.) for seven standard depth layers. The spatial resolution of the data is 250m. Based on this data, a pedotransfer function (empirical relation) was applied to generate the soil-water characteristics

needed for the OpenLISEM hazard input. The pedotransfer function is based on (Saxton & Rawls, 2006), which uses a predictive set of equations based on regression of soil texture (Saxton et al., 1986). The regression equation was used as a PCRaster script (Dynamic GIS tool developed by the University of Utrecht) to develop the necessary parameters such as the saturated hydraulic conductivity (ksat), porosity (theta), initial moisture content of the soil (theta1) etc.

4.Soil depth. The soil depth model is based on von Ruette et al. (2013). The soil depth in this case was derived by a colluvium diffusion equation. The equation was further simplified by the assumption that the landscape topography is at steady state. The final soil depth is given in reference to the soil production and soil transport. There are several parameters to calibrate to get a realistic set of results. Parameters such as the 1) soil production rate, 2) diffusion coefficient of soil flux, 3) weight of erosion though surface runoff could be varied within the study area to generate accurate results. The soil depth model was programmed as a PCRaster script to develop the soil depth model.

5. Leaf Area Index (LAI). With the calculated value of Normalized Difference Vegetation Index (NDVI), the leaf area index (LAI) and the vegetation cover for the spatial extent are derived based on empirical relations given as

$$vegcover = e^{\frac{-2.0*NDVI}{1-NDVI}}$$

$$LAI = \ln(1 - vegcov)/(-0.4)$$

6. Manning N and random roughness. Manning N and random roughness values were applied as per the landcover maps for each study area. The landcover maps are rasterized along with the DEM with the help of align raster tool available in the QGIS tool.

7. Design storm (rainfall) as a trigger. For the preparation of the rainfall data, two sources were used. The choice was motivated as the measured rainfall from each municipality only had a daily record. Although this daily record was available for a significantly long time (~50 years), this was not sufficient for the physically-based modelling as the modelling requires (half)hourly rainfall records. This

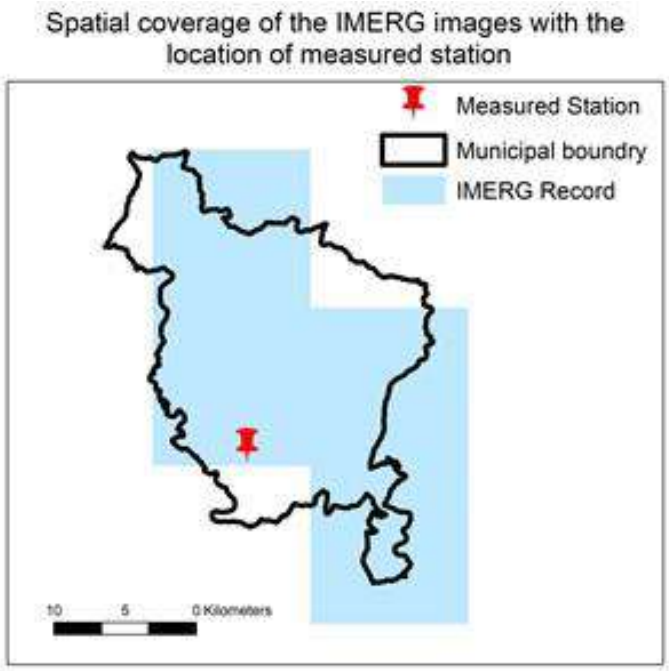


Fig. 3.3 Spatial coverage of IMERG datasets.

requirement was met by incorporating the remotely sensed data from the NASA repository called Integrated Multi-satellite Retrievals for GPM (IMERG). The repository gives access to the half an hour rainfall record in a grid of 10X10 m. The spatial coverage of the data is shown in **Fig. 3.3**. Both of these datasets were then combined so that the daily total rainfall could fit into the half-hourly record giving the synthetic rainfall. This synthetic rainfall was used input to the physically-based model.

The daily rainfall record was processed using the Gumbel distribution, also known as extreme value distribution. The Gumbel distribution generated the maximum (or minimum) value within a sample of distribution. The estimation of the minimum/maximum value was based on the maximum likelihood of a sample distribution. The two major parameters in this distribution are the scale and location parameters.

In Godawari Municipality, 65 years of daily measurements from 1956-2020 was available from the single station inside the study area. The station Dhangadhi (Attariya) with the code GSID-39 is located geographically at lat/long: 28.8127, 80.5599. Using the Gumbel method, the maximum daily rainfall was calculated for 20, 50- and 100-year return periods. The values of the daily total rainfall for the specific return periods are as shown in **Fig. 3.4**.

The next step was to process the half-hourly IMERG record. From the daily measurement, the event with the maximum rainfall was chosen. It generated a worst-case scenario flooding for the municipality. There were significant differences in the measured and the IMERG datasets.

Then, the date was selected which produced the highest rainfall in the municipality from the past record as indicated by the star in **Fig. 3.5**. For Godawari, the maximum daily measure of rain during the whole period was 290.9 mm, which happened on 2013/07/19. In this case, the images downloaded were from 2013/07/18 2013/07/19. Half hourly records for two days were downloaded from the repository of IMERG as shown in **Fig. 3.6**. 96 rasters were then obtained each divided into two multi band images representing a day and 48 bands to it. Furthermore, we did not presume extensive variability in the occurrence of rainfall in the study area, so the pixel having the maximum rainfall was selected for each study site. The choice was motivated by the fact that there was only one station measurement and therefore needed to be co-relatable to the IMERG data.

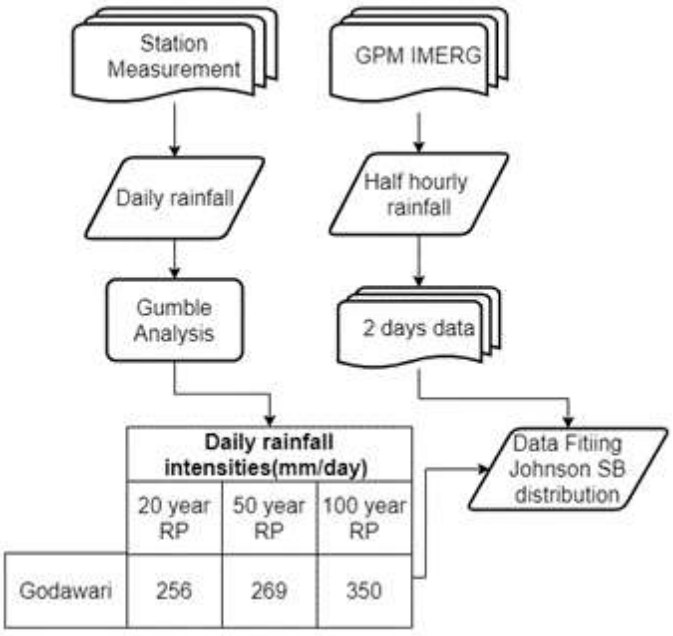


Fig. 3.4 Merging of two datasets using Johnson SB distribution.

The purpose of creating a synthetic design storm is to use the intensity values for the half an hour record and fit the data according to the return period values calculated by the Gumbel analysis. For the fitting of the half-hour data in according to the total daily values from the measured data, the Johnsons SB distribution was used. The probability density function (PDF) generated from the Johnsons SB distribution was used to generate separately fitted curves for the daily total rainfall calculated for 20-year, 50-year and 100-year return period via Gumbel analysis.

The measured IMERG record was fitted with the Johnsons SB distribution into a PDF with the formula as shown in **Fig. 3.7**. The cumulative density function was calculated with the relative change of data within the distribution. The relative change of data was calculated as per the measured record. To perform the best fit data, the solver function in excel was optimized in a way where the best fit values for the four parameters within the framework progressed into achieving the minimum value for the difference in the relative change within the cumulative function.

The modelling was done for every 10min timesteps. Although, the IMERG record is a 30 min record, the 10 min record for the rainfall intensity was achieved by extracting the data from the distribution

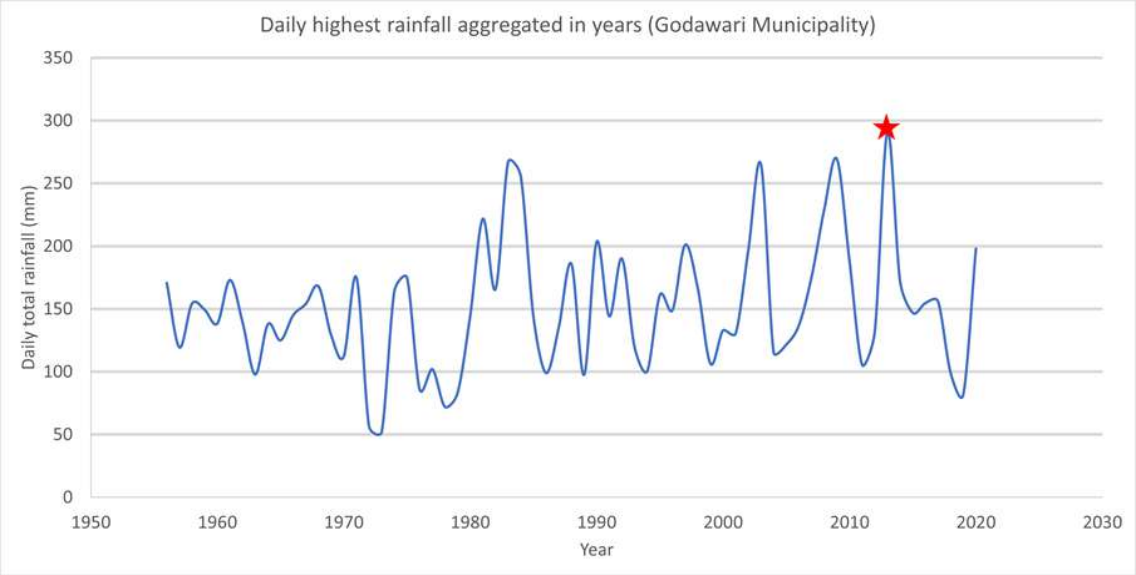


Fig. 3.5 Selection of the highest daily record.

Fig. 3.6 49 hours record of the IMERG datasets.

curve as shown in **Fig. 3.8.** The extraction was done fitting a polynomial into higher-order derivatives and extracting the 10 min interval data thereby.

Fig. 3.9 shows the various processes that are calculated for every timestep of the model simulation. The calculation of the equations related to each individual processes are shown in colored boxes. Hydrology is the fundamental basis of model simulation which is combined with various solid processes. In other words, depending on the simulated fluid and water content the flow properties are first calculated and combined with the advection properties generated by the solids. This process iterates with every timestep. However, because of the limited time and lack of proper datasets on sediments and solids, the simulation was limited to water processes only.

Johnson SB Distribution

Parameters

γ - continuous shape parameter
δ - continuous shape parameter ($\delta > 0$)
λ - continuous scale parameter ($\lambda > 0$)
ξ - continuous location parameter

Domain

$$\xi \leq x \leq \xi + \lambda$$

Probability Density Function

$$f(x) = \frac{\delta}{\lambda \sqrt{2\pi}\, z (1-z)} \exp\left(-\frac{1}{2}\left(\gamma + \delta \ln\left(\frac{z}{1-z}\right)\right)^2\right)$$

Cumulative Distribution Function

$$F(x) = \Phi\left(\gamma + \delta \ln\left(\frac{z}{1-z}\right)\right)$$

where $z \equiv \frac{x-\xi}{\lambda}$, and Φ is the Laplace Integral.

Fig. 3.7 Theoretical framework of the Johnsons SB distribution.

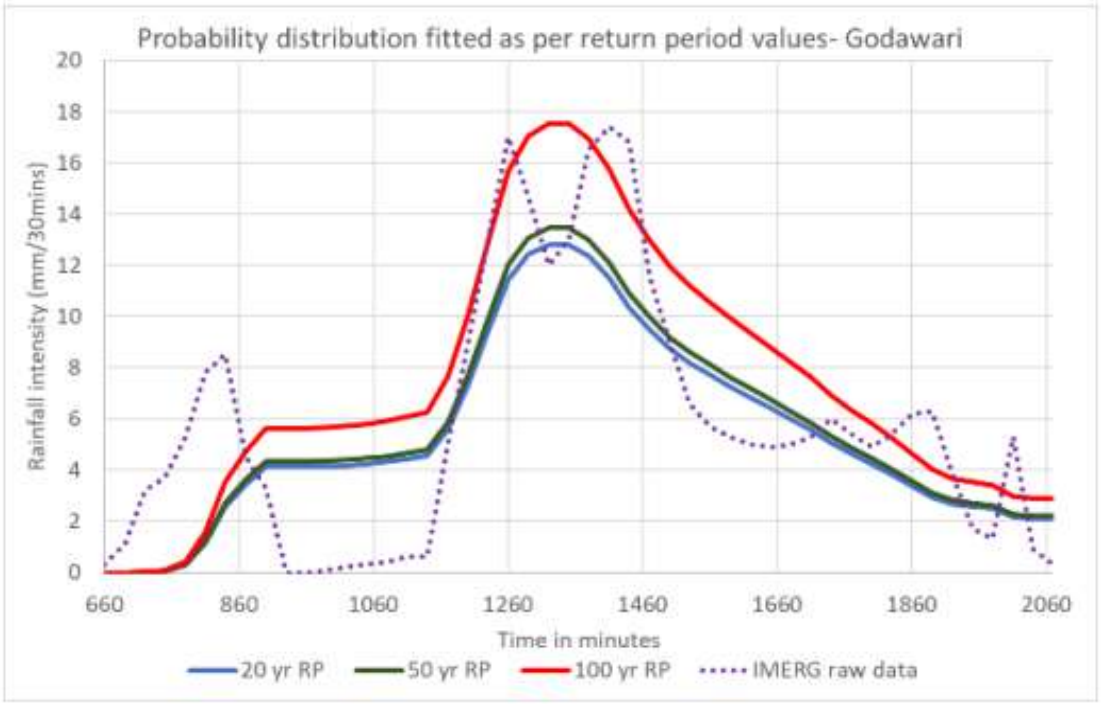


Fig. 3.8 Designed rainfall intensities as per return period.

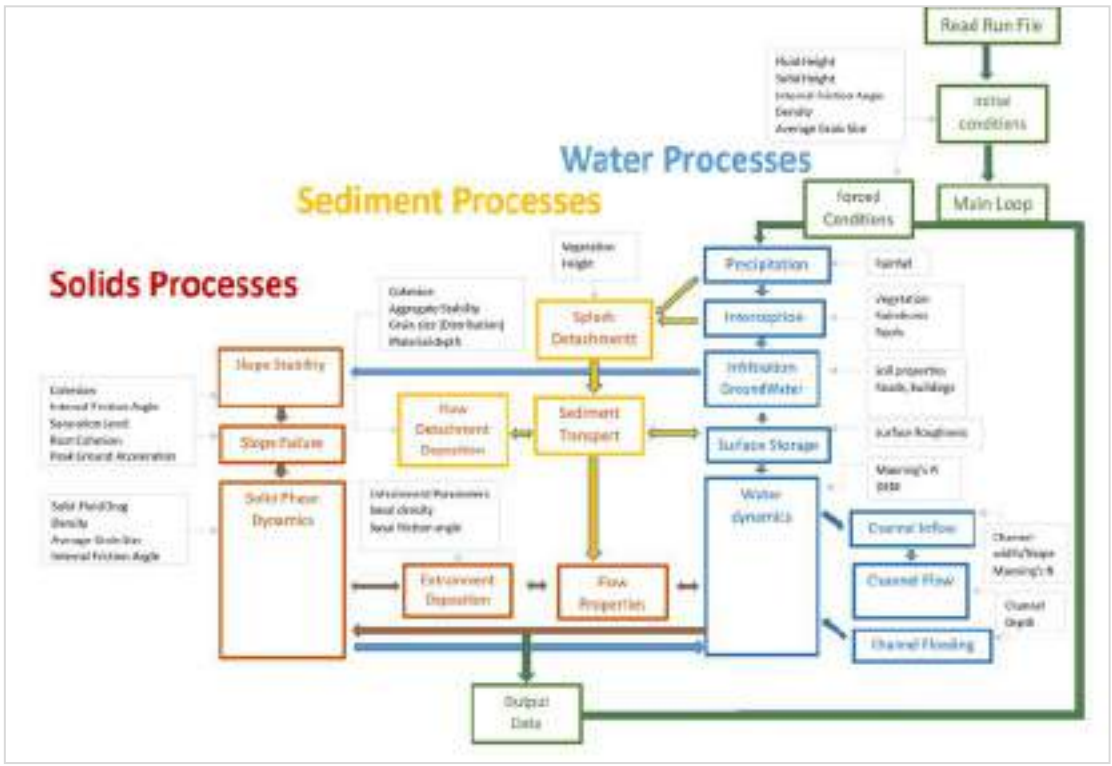


Fig. 3.9 Schematic diagram showing the flow of processes calculated by OpenLISEM hazard.

The field water content was determined and unit weight at that particular natural moisture content and angle of internal friction was determined using the graph at the site. Besides, saturated hydraulic conductivity (k_{sat}) was determined at these locations using Double Ring Infiltrometer method. On the

other hand, the textural soil classification, USCS classification and consistency limits were determined by laboratory test method **(Annex II & III). Table 3.2** shows the input parameters for flood hazard.

Table 3.2 Summary of the input parameters of OPENLISEM for flood hazard modelling.

SUMMARY OF THE INPUT PARAMETERS OF OPENLISEM FOR FLOOD HAZARD MODELLING	
INPUT PARAMETER	SOURCE
Elevation	• DEM from TAYAR NEPAL. 5 m resolution.
Channel Network	• Drainage network created from DEM
Channel Properties	• Channel width and depth measured in the field for a number of streams at upstream point and outlet. Linear relationship obtained between drainage area and channel dimensions.
Land Surface	• Land use map from existing maps or classified satellite images. • Land cover classes, Digital image classification • Vegetation Density, Normalized Differential Vegetation Index from satellite imagery. • Vegetation Cover, obtained through empirical relations • Root Cohesion (c_r), Field sampling, numbers of samples decided by the field expert. • Manning's N (n), to be derived based on landcover • OpenStreetMap's vector data for roads, buildings and bridge locations
Soil Material	• Conductivity (k)/permeability, measured at the field (Infiltration Test), number of tests decided by the field expert. • Cohesion (c), angle of internal friction (ϕ) measured at the field from the selected site defined by the expert. • Porosity (θ_s) and suction (ψ) derived from literature values. • Density (ρ) measured from field, number of samples to be decided by the field expert. • Initial soil water content (θ_i), few months'/three months' ground water simulation, using hourly rainfall. Initial ground water levels and effective moisture content during the monsoon. • Soil Depth (h_s), Multi-variable linear regression through soil depths measured at landslide scarps, combined with steady-state soil depth simulations as proposed by Ruette et al. (2013). Also measured at the site using field identification methods.
Precipitation	• Design rain storm used by the combination of station data fitted with the IMERG data for different return periods
Landslide Inventory	• Obtained from high-resolution imagery used to map visible traces of mass movements and flash floods.

The first step of flood modelling was to design the storm graphs of different return periods. Frequency analysis was performed using the daily rainfall data from the meteorological station and the satellite data (IMERG). The final rainfall intensity graphs were produced for the 20-year, 50-year and 100-year return periods. Other input data for the hydrological model included topographic information, land use data, soil characteristics, channel properties along with mass movement information. The intermediate output was flood depth maps of different return periods. Historical flood height levels were obtained from hazard zonation maps. The water level along with crucial hydrological parameters were used to calibrate the intermediate flood depth maps. Finally, the calibrated flood depth maps were classified into Low, Moderate and High classes for the return periods of 20-year, 50-year and 100-year. **Fig. 3.10** represents the simplified flow diagram of flood hazard assessment.

The output flood hazard maps were prepared for 20-, 50- and 100-years return periods. The maps were classified into three classes according to water height: **None (< 0.25 m),** Low **(0.25 – 1.0m), Moderate (1.0 – 2.0 m), and High (>2.0 m).** Insignificant hazard class was also added where the water height is less than 0.25 m. Among the twelve wards, Ward 4 was highly affected by the floods followed by Ward 12 and Ward 10 as represented by **Figs. 3.11**. **3.12, 3.13. Figs. 3.14, 3.15** and **3.16** represent the flood hazard maps of Godawari Municipality for three different return periods.

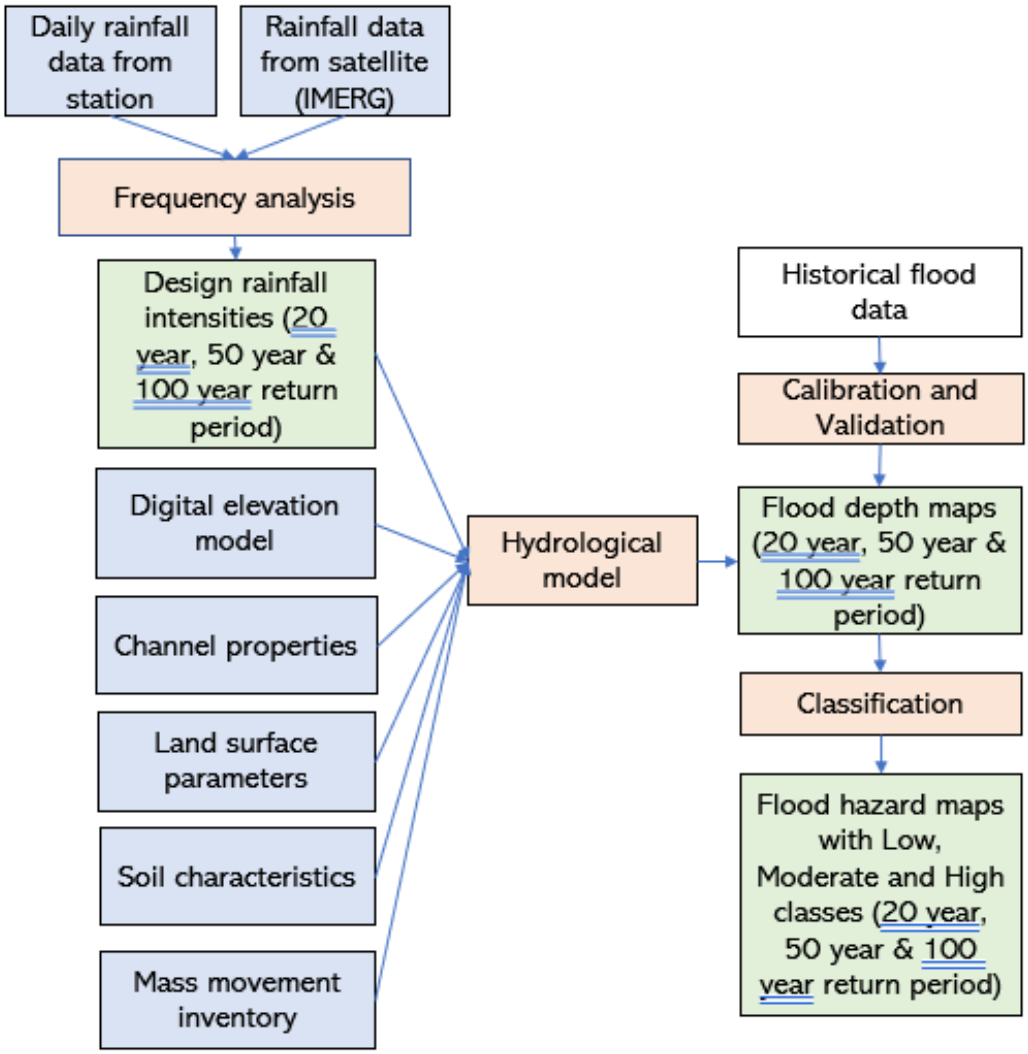


Fig. 3.10 Simplified workflow diagram of flood hazard assessment.

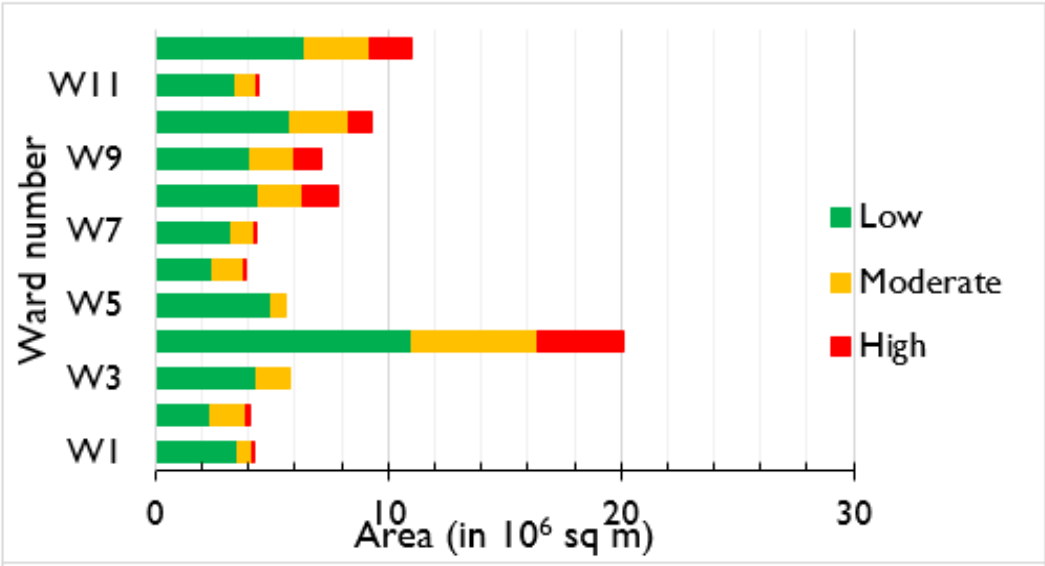


Fig. 3.11 Ward wise area with flooding as low, moderate or high for 20 years of Return Period.

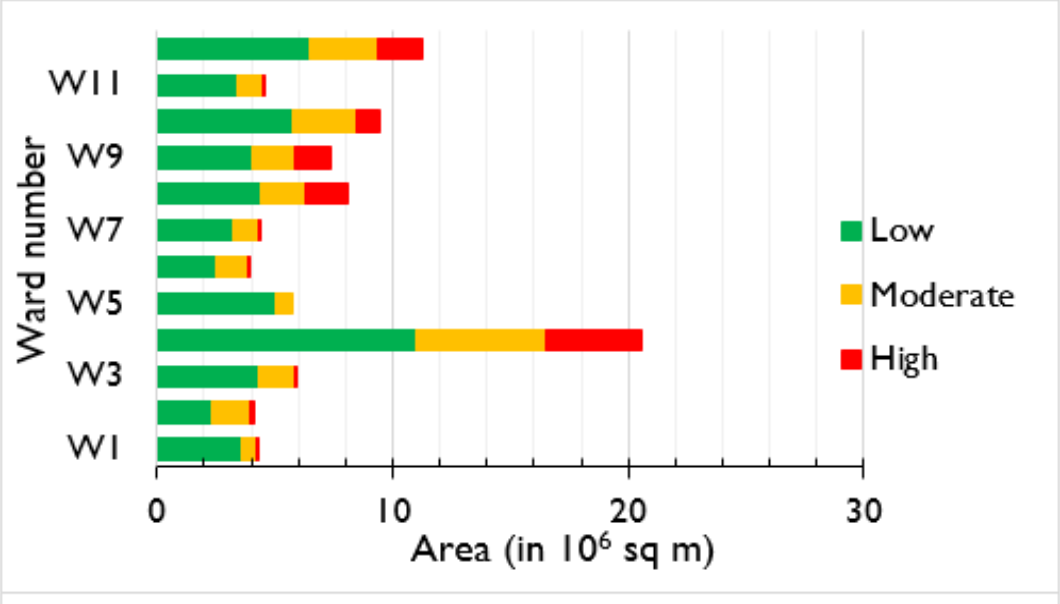


Fig. 3.12 Ward wise area with flooding as low, moderate or high for 50 years Return Period.

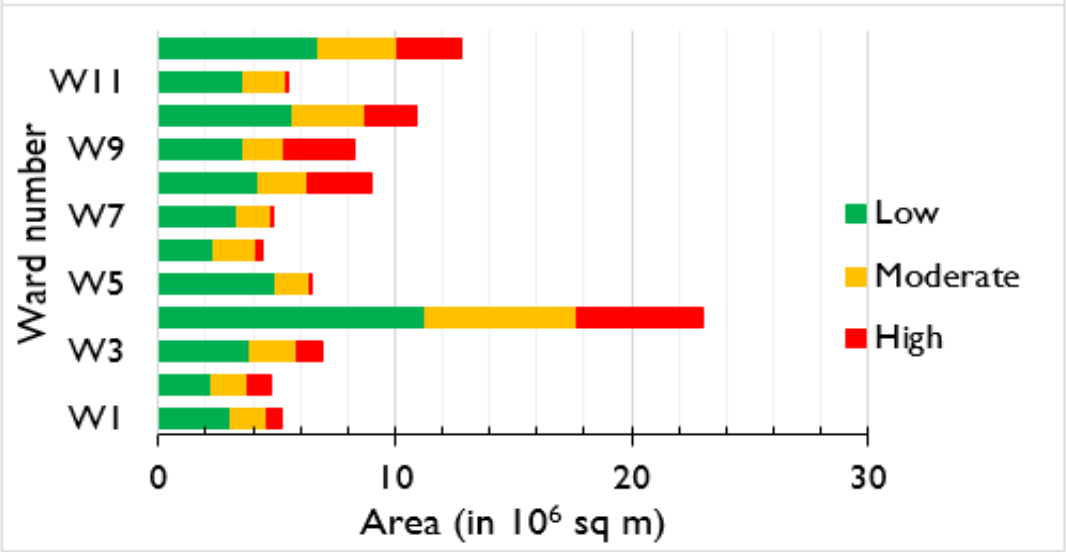


Fig. 3.13 Ward wise area with flooding as low, moderate or high for 100 (below) years Return Period.

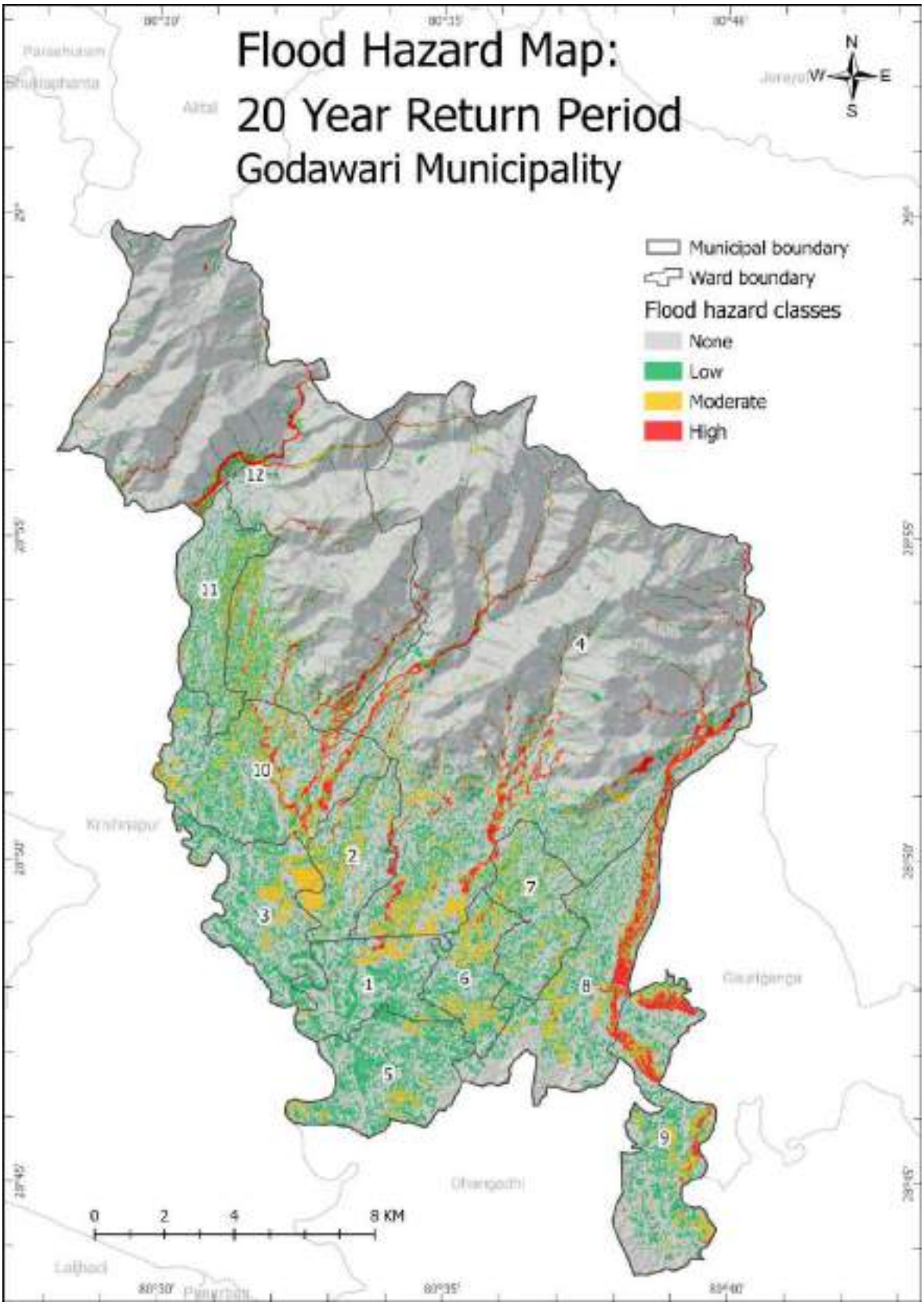


Fig. 3.14 Flood hazard map of Godawari Municipality for 20 years of Return Period.

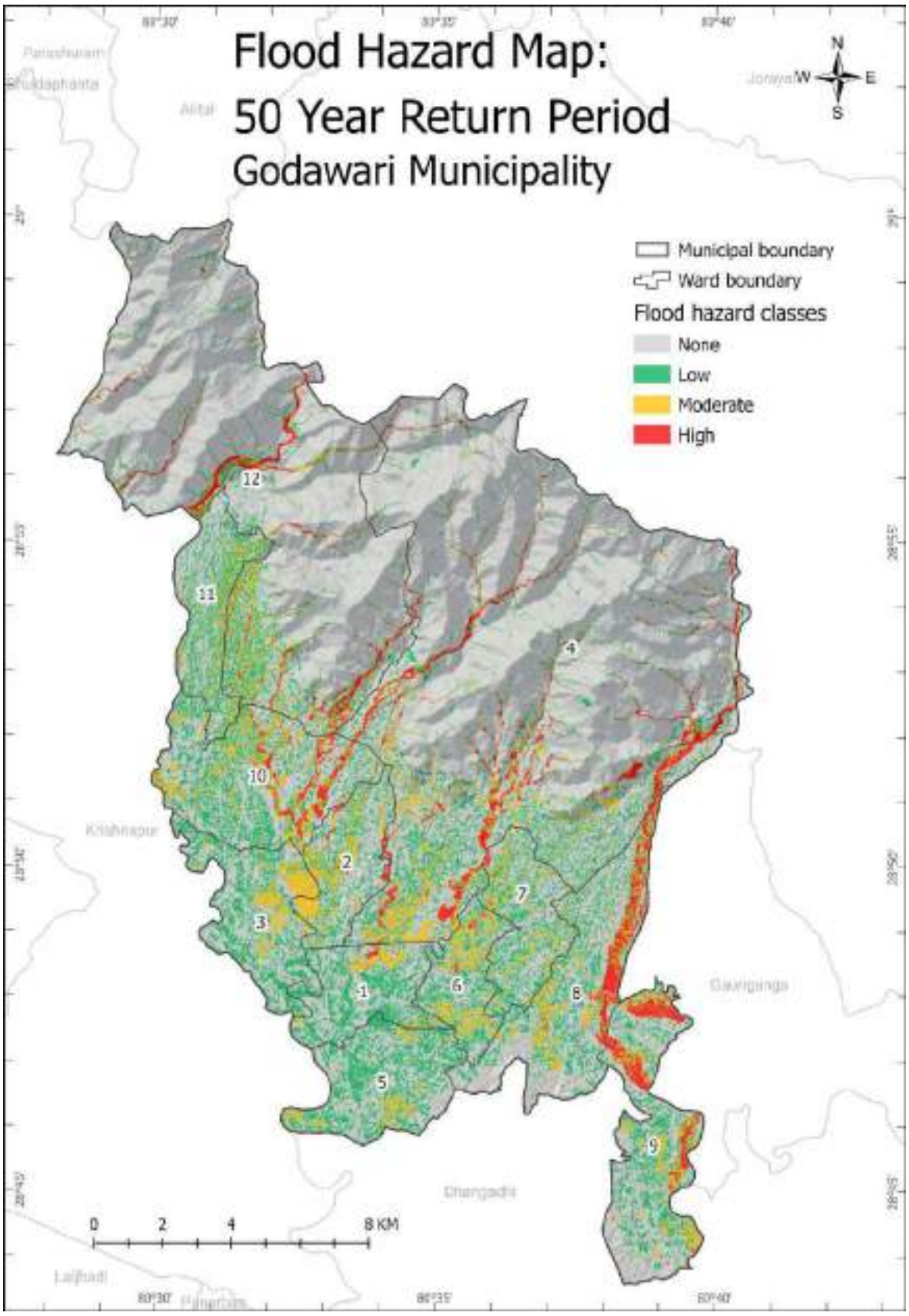


Fig. 3.15 Flood hazard map of Godawari Municipality for 50 years Return Period.

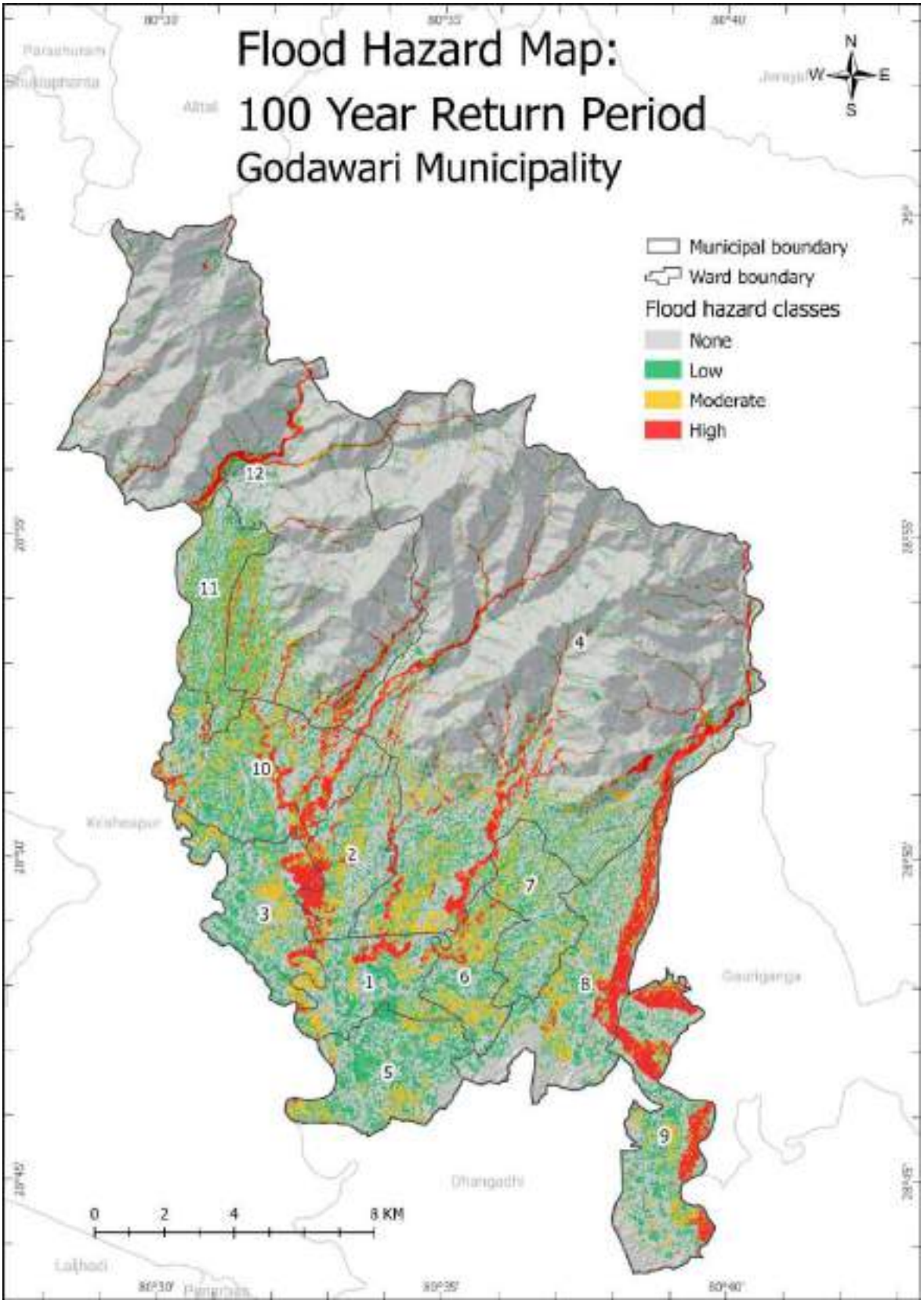


Fig. 3.16 Flood hazard map of Godawari Municipality for 100 years Return Period.

3.1.2 LANDSLIDE HAZARD ASSESSMENT

Landslides in the Godawari Municipality are limited within the Siwalik region with an elevation above 400 meters. Beneath the foothills of Siwalik is the plain Terai zone, where landslides can only occur in the side slopes of channel incisions. The elevation ranges from 172 - 1733 m in the Godawari Municipality.

The landslides were delineated by the visual interpretation from three dimensional Google Earth images. The landslide inventory was made using different images spanning a period for the past 20 years, to check their conditions whether they expanded or recovered within the given period. The number of landslides in the Godawari Municipality for different periods are shown in **Table 3.3**

Table 3.3 Landslide inventory for different time periods.

LANDSLIDE INVENTORY FOR DIFFERENT TIME PERIODS.			
LANDSLIDES UP TO 2003	NEW LANDSLIDES 2003-2016	NEW LANDSLIDES 2017-2021	TOTAL
105	98	19	222

The spatial distribution of new landslides showed that they occur within the proximity of existing landslides.

Landslide predisposing factors or indicator maps

Landslide predisposing factors may contribute to the susceptibility for landslide occurrence. Generally, these factor maps include topography, geology, and land use. Triggering factors include rainfall and earthquakes. The list of factor maps is shown in **Table 3.4.**

Table 3.4 Landslide conditioning factors and their descriptions.

LANDSLIDE CONDITIONING FACTORS AND THEIR DESCRIPTIONS			
GROUP	LANDSLIDE CONDITIONING FACTOR	DESCRIPTION	UNITS
Topographical	Slope	major conditioning factor; divided into six classes: flat, undulating, slightly sloping, sloping, steep, very steep	degrees
	Aspect	orientation of slope influences the landslide formation attributed to exposure from sunlight, rain, wind etc	degrees
Lithological	Geology	an important factor that provides information on soils, drainage patterns and pedogenesis	n/a
Seismic	Peak Ground Acceleration (PGA)	expressed in terms of acceleration due to gravity (g)	m/s^2
	Fault distance	distance from active faults.	km
Meteorological	Average annual rainfall	rainfall combined with geology conditions the landslides	mm
Landuse	Landuse	landslides influenced by anthropogenic activities; only considered above 350 m	n/a
	Road distance	undercutting during road construction influences landslides; only considered roads in elevation above 350 m	m
Proximity	Distance to existing landslides	an important factor in our case. Landslide may be reactivated and grow in size	m
Spatial constraints	Flat areas	flat areas do not have landslides. This can be used to mask out areas.	n/a

The detailed description of input landslide causing factors is as follows:

- The Digital Elevation Model (DEM) from USAID TAYAR-Nepal (5 m) was used for slope and aspect maps.
- The geological map (1:100,000) from 1994 was digitized and was clipped for the study areas. The map was very general and contains only three classes Quaternary, Upper Siwalik and Lower Siwalik.
- For the Peak Ground Acceleration maps, the data from Stevens *et al.* (2018) was used for 10% probability of exceedance for 50-year return period which corresponds to 475 years return period.
- The Main Frontal Thrust (MFT) is the main fault that passes through the study areas. The fault polyline from Styron *et al.* (2010) was used to calculate fault distances.
- Global average monthly rainfall data (spatial resolution= 0.01°, approx. 1 $km^{2)}$ from the year 1990-2000 was downloaded from the WorldClim-Global Climate Data. The rainfall data was resampled and divided by 12 months to produce an average annual rainfall map.
- A land use map containing several features was obtained from Rajdevi Engineering Consultant (P) Ltd. The roads were masked for the elevation greater than 350 m for preparing multiple buffers that had potential of influencing the landslides, as road cuts are often leading to landslides.
- Most of the landslides in the project area occurred in the vicinity of the existing landslides so a landslide proximity map was used.
- Spatial constraints are the maps or attributes where the landslides do not occur at all such as flat lands, which as used to mask out the areas.

Methodology

Landslide predisposing factors influence the landslide origin and characteristics. Such factors were used to generate the maps having different classes. These classified factors maps were assigned in the Spatial Multi-Criteria Evaluation in a GIS software. The factor maps were standardized because different factor maps have different physical units so they must be aligned in a dimensionless quantity. Then, the factor maps were assigned weights or ranked based on their influence over landslide generation. All factor maps were integrated to produce a susceptibility map having values from 0 to 1 indicating low to high susceptibility. Using the landslide inventory, such susceptibility map was validated. The validated susceptibility map was then classified into Low, Moderate and High classes based on threshold value obtained during validation process. **Fig. 3.17** represents the simplified flow diagram of landslide susceptibility assessment.

The landslide susceptibility maps were made using the Spatial Multi-Criteria Evaluation (SMCE) tool in ILWIS GIS software. The spatial indicator maps that influence the landslides in the region can be assessed by the team of experts in SMCE as per their preferences and assign the weights according to specified decision rules. The final output will be an aggregation of multi-dimensional information into a single decision or composite index map. The first step of SMCE is the construction of criteria tree classifying indicator maps into different groups for easy understanding and simplification. The second step is the standardization where the physical units of indicators are transformed to scores of equal, dimensionless scale (0 to 1) followed by the assignment of the weights or prioritizing the factor over another. The assignment of weights depends upon the consensus of experts' opinions and judgements. Final step is the aggregation which gives a composite index map as an output. A schematic representation of SMCE is shown in **Fig. 3.18**. The criteria tree for preparation of the landslide susceptibility map in Godawari Municipality is shown in **Fig. 3.19**.

In the **Fig. 3.19** the line with Flat areas indicated a spatial constraint where the landslide susceptibility will be absent. Below this a number of groups are indicted with a value that indicates the weight of that group. For example, the topographical factor group contains two indicators: slope and aspect, which

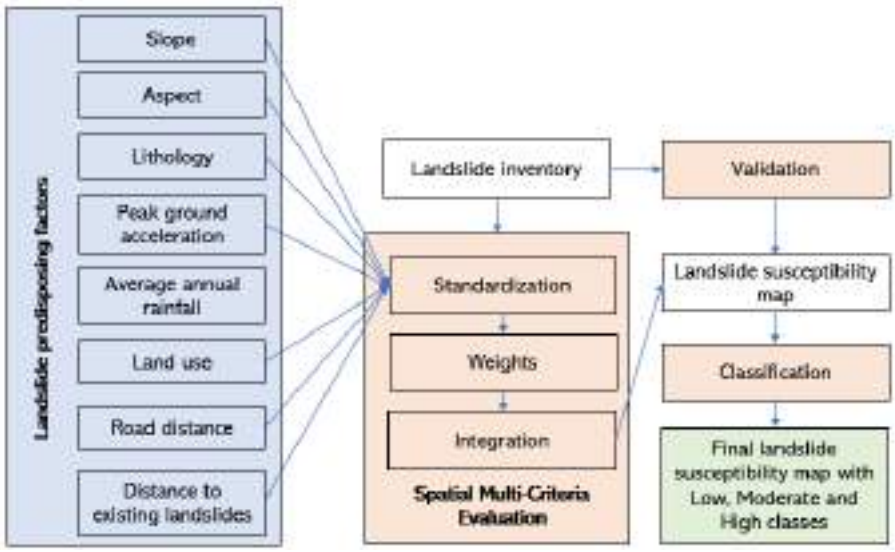


Fig. 3.17 Simplified workflow diagram of landslide susceptibility assessment.

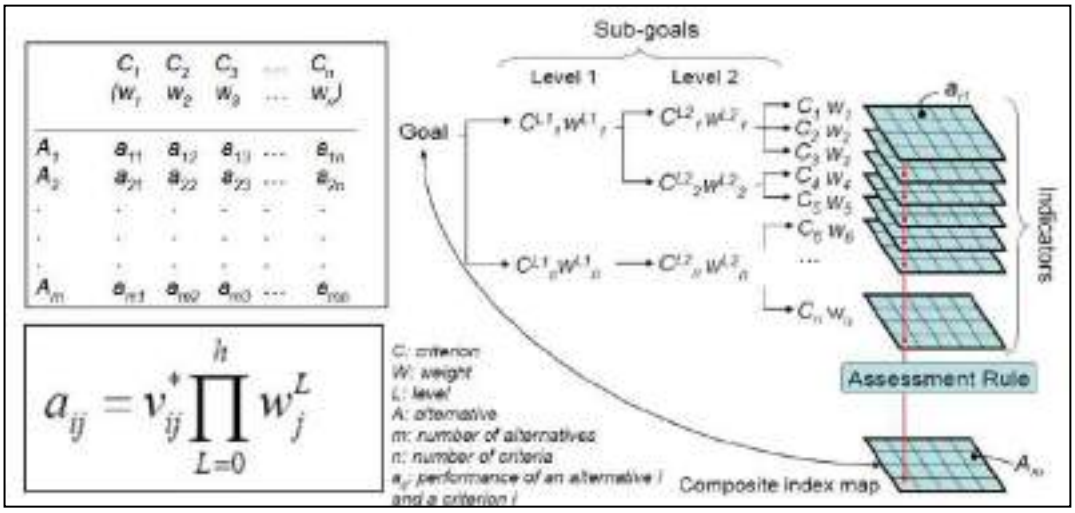


Fig. 3.18 Schematic procedure of SMCE showing different levels of criteria with the weight assignments and final output (Castellanos et al., 2008).

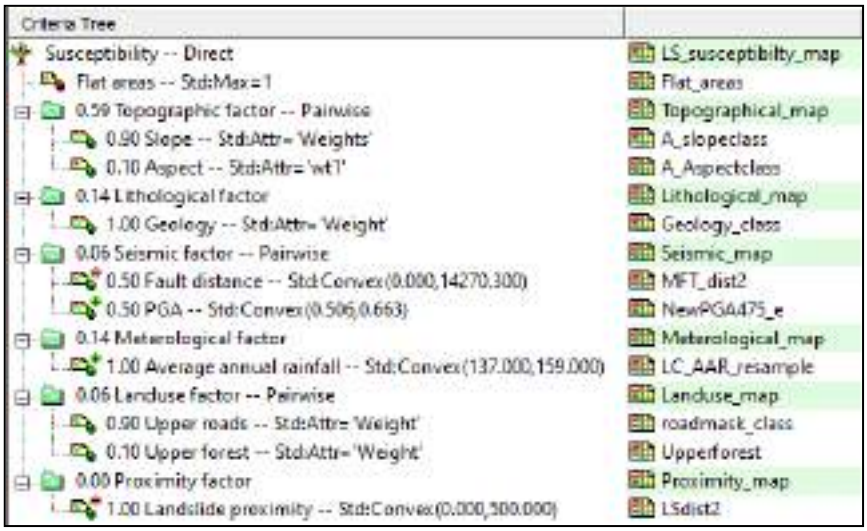


Fig. 3.19 Criteria tree displaying standardization and prioritization of the landslide conditioning factors in Godawari Municipality.

also have a relative weight each. The relative importance of the groups and indicators was obtained using expert opinion, supported by statistical analysis (Weight of Evidence). In the right side of the figure the corresponding maps are indicated. The final landslide inventory was used to check and validate the weight map using so-called success rate curves and finally classified the map into the scale of 0-1, where 1 shows the highest susceptibility to landslides. Bivariate and multivariate statistical analysis are helpful in the situation where there are many units, and a sufficiently large landslide dataset to be considered for the weight assignment. The geology map had only three classes so it was easy to assign weights. The Upper and Lower Siwalik were assigned the highest weights and Quaternary with the lowest or no weights since it represented flat Terai. For seismic factors, the PGA and distance from the active fault were given equal weights. The higher the values of PGA, the higher the susceptibility of co-seismic landslides. The fault distances were limited within the boundary of the municipality. The meteorological factor was standardized using a convex curve with maximum rainfall of 153 mm. The higher the rainfall, the higher the chance of triggering landslides. Land use factors such as distance to the road were standardized using a convex curve with a maximum range of around 300 meters. As the distance from the road increases, the susceptibility of the landslide decreases, as landslides are often related to road cuts and to drainage from the road. In our cases, only the roads present at elevation higher than 350 m were considered. From the visual interpretation of landslide positions, only the forest class and bare land classes were affected so these classes above 350 m elevation were masked for our analysis.

The highest weight was assigned to the topographical factor since it was the dominating factor in our project area, followed by equal weightings of lithological and meteorological factors. Seismic and land use factors were given equal weights but comparatively lower since the effects of earthquake and land use were limited. Landslide proximity maps were important but their rankings had to be changed iteratively and checked because of its dominance while producing the final maps.

Finally, a composite index map was produced from SMCE which was then subjected to the success rate script to check the predictive power of the map. The success rate indicates the percentage of landslide occurrences in the areas with the highest susceptibility values. The application of the success rate has two purposes: one is to classify the map into susceptibility zones and the other is to predict the landslide pattern from the weighted combination maps. The map was generated in an iterative process by changing the weights of the parameters, and each time validated with the existing landslide inventories using the success rate. Finally, the maps were classified into three susceptibility classes:

Low, Moderate and High. The landslides inventory from past 20 years was used to produce the susceptibility maps and the changes in landslide area, density and volume were also analyzed.

From **Fig. 3.20**, the landslides percentage were classified into 70%, 20% and 10% for high, moderate and low susceptibility classes respectively. From the success rate graph plotted with the final combined landslide inventory, it was found that around 70% of the landslides occurred within around 12% of area of the map which was classified as high susceptibility zone. Whereas 20% of landslides and 10% of landslides might occur in 18% and 70% of the area of the map respectively. The cutoff values and area cover of different susceptibility classes obtained from the success rate using different time period inventories of Godawari Municipality. In Godawari Municipality, there was a steady increase in the landslide density indicating the instability of the slopes. The landslides density increased from 1.31% to 1.73% from 2003 to 2021. The area of the high susceptibility zones increased from 71 km^2 to 84 km^2 from 2003 to 2021. The low susceptibility area represents the flat Terai area and river valleys where the eroded sediments have potential to get transported and deposited.

The landslide volume estimation was done based on the empirical relation proposed by Guzetti *et al.* (2009): $V = 0.074\ A^{1.45}$, where V is the volume in m^3 and A is the area in m^2. 677 landslides were used from the global database to derive the area-volume relationship in form of a power law using the empirical equation. The landslide volume estimation gives a general idea about the volume of sediments that have the potential to be transported during rainfall events in the lower catchment or in the stream channels. For the accurate volume estimation, this method is not recommended as it may underestimate the volume, because the erosion in the channel itself is not considered **Table 3.5** shows the statistics of the landslides in Godawari Municipality. The average size of the landslides was found to be approximately 8,000 m^2 and average volume was about 54,000 m^3. Total landslides volume was about 12 million m^3 (0.012 km^3).

Ward-wise comparison of the landslide susceptibility area showed that the Ward Nos. 4 and 12 were highly susceptible to landslides as shown in **Fig. 3.21.** The area covered by high susceptibility class in Ward Nos. 4 and 12 were 50,242,000 m^2 and 34,128,200 m^2 respectively. Whereas the rest of the wards were located in lower elevations so they had lower susceptibility to landslide. **Fig. 3.22** shows landslide susceptibility map of Godawari Municipality along with historical data.

Table 3.5 Criteria for dividing susceptibility maps into high, moderate and low class along with the statistics on landslide density and area coverage for Godawari Municipality.

CRITERIA FOR DIVIDING SUSCEPTIBILITY MAPS INTO HIGH, MODERATE AND LOW CLASS ALONG WITH THE STATISTICS ON LANDSLIDE DENSITY AND AREA COVERAGE FOR GODAWARI MUNICIPALITY				
LANDSLIDE SUSCEPTIBILITY		LANDSLIDES COMBINED (2021)	LANDSLIDES UP TO 2016	LANDSLIDES UP TO 2003
High susceptibility	Cut-off value	0.65	0.65	0.71
	Percentage of the map	11.76%	11.75%	8.88%
	Percentage landslides	70.00%	70.00%	70.00%
	Landslide density	1.73%	1.66%	1.31%
	Area in square kilometers	84.38	84.38	71.24
	Percentage of total area	27.73%	27.73%	23.41%
Moderate susceptibility	Cut-off value	0.47	0.47	0.53
	Percentage of the map	17.94%	17.95%	16.06%
	Percentage landslides	20.00%	20.00%	20.00%
	Landslide density	0.26%	0.24%	0.12%
	Area in square kilometres	45.84	45.84	58.99
	Percentage of total area	15.06%	15.06%	19.38%
Low susceptibility	Cut-off value	0.04	0.04	0.04
	Percentage of the map	70.30%	70.30%	75.06%

	Percentage landslides	10.00%	10.00%	10.00%
	Landslide density	0.11%	0.10%	0.04%
	Area in square kilometres	174.07	174.07	174.07
	Percentage of total area	57.20%	57.20%	57.20%

Table 3.6 Landslide statistics of Godawari Municipality.

LANDSLIDE STATISTICS OF GODAWARI MUNICIPALITY				
NUMBER OF LANDSLIDES	AVERAGE SIZE (m^2)	AVERAGE VOLUME (m^3)	VOLUME STANDARD DEVIATION (m^3)	TOTAL VOLUME (m^3)
222	8,089	54,202	223,225	12,032,883

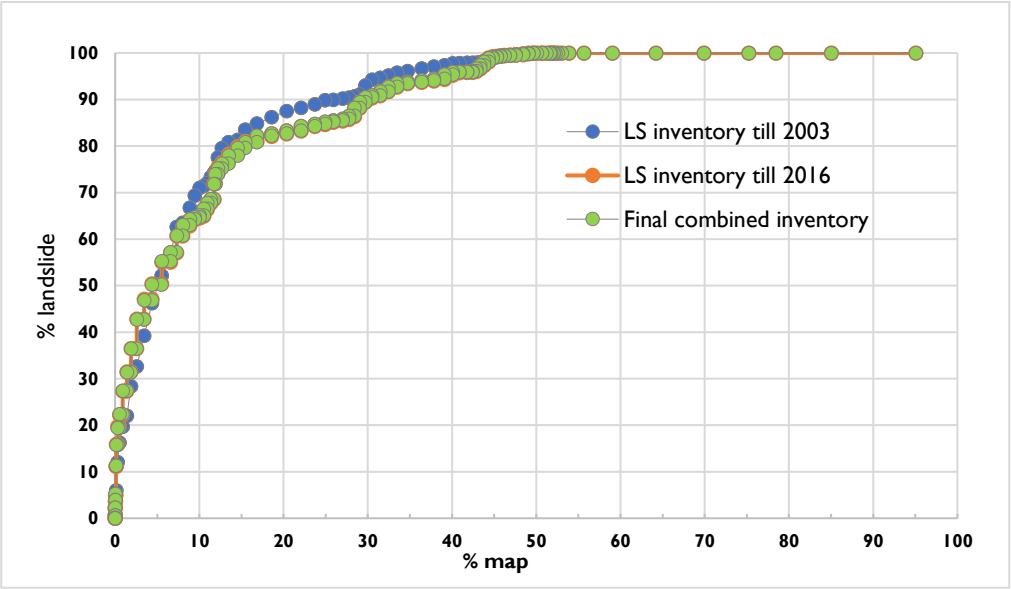


Fig. 3.20 Success rate curve showing the percentage of landslides occurring in the output susceptibility map of Godawari Municipality.

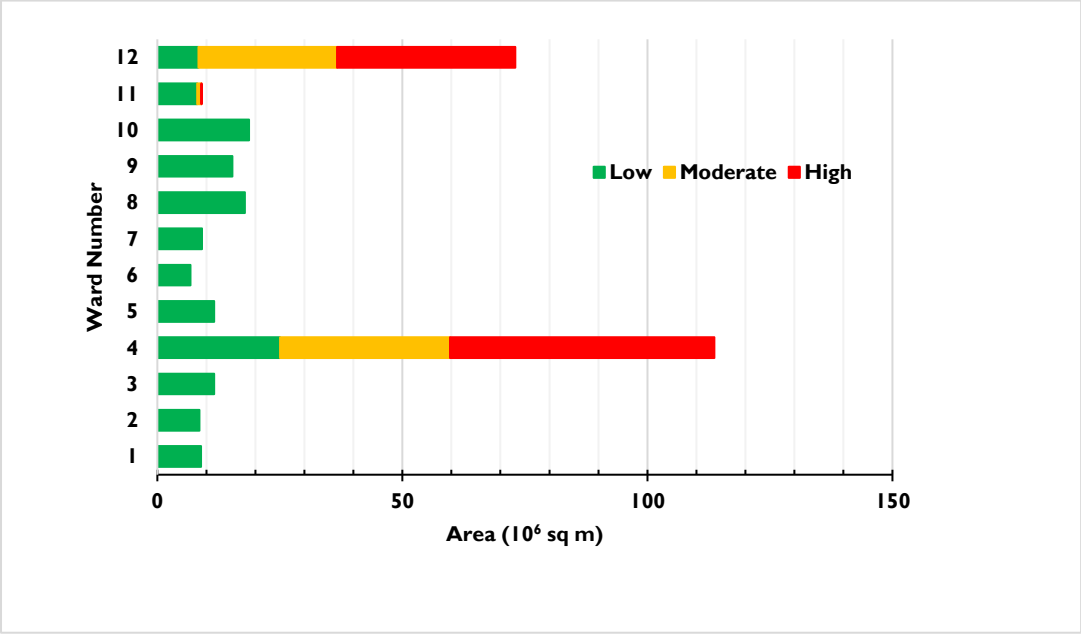


Fig. 3.21 Seasonal River located in the Godawari Municipality.

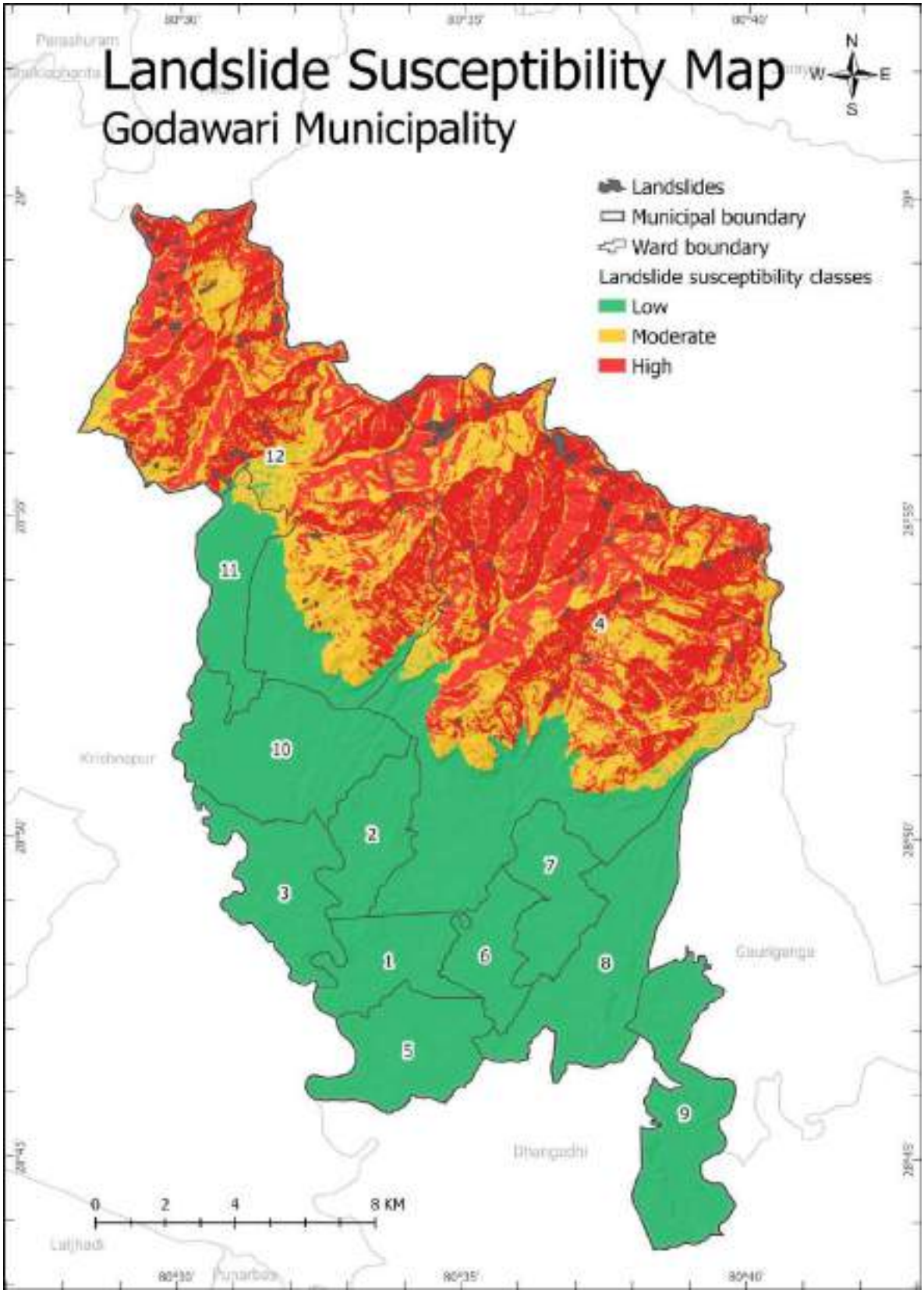


Fig. 3.22 Landslide susceptibility map of Godawari Municipality along with historical data.

3.1.3 EARTHQUAKE HAZARD ASSESSMENT

The seismic hazard assessment was done in two steps: finding out the seismicity of the entire country and preparation of ground shaking or peak ground acceleration maps from the available literature. Earthquake catalogue from the period 1994-2020 was used to obtain the earthquake frequency and magnitude relationship for the entire country. The Gutenberg-Richter formula was used for it. For seismic hazard modelling, the existing literature were used. Intensity measure points or peak ground acceleration values were available from the past study by Stevens et al. (2018). These points were spatially interpolated to obtain the distribution of PGA values within the municipality boundary. Other existing PGA maps from past studies were used to cross check its validity. The PGA maps were then classified into Low, Moderate, High and Very High classes for the return period of 475 year and 2475 year. **Fig. 3.23** represents the simplified flow diagram of seismic hazard assessment.

There were altogether 1013 earthquakes (with a Magnitude above 4.0) that occurred in that period as shown in **Fig. 3.24**. There were very few epicenters recorded in and around Kailali District whose local magnitudes were around 4 Richter scale. Both the earthquakes in Kailali occurred in 2002 according to NEMRC.

Then the Gutenberg-Richter (GR) law was used to plot the frequency-magnitude relationship between the earthquakes in any given region and time period. The law states that the earthquakes are distributed exponentially as

$Log_{10}N(m) = a\text{-}bm$,

Where N(m) is the number of earthquakes with magnitudes larger than or equal to m, b is a scaling parameter and a is a constant. The parameter b value is typically in the range of 0.8 to 1.1. From the GR relation, it is found that the number of earthquakes of magnitude 5.0 or larger events will be 10 times as many as magnitude 4.0 or larger earthquakes and 100 times as many as magnitude 3.0 or larger and so on. The earthquakes of various magnitudes were divided into different classes and applied the GR relation as shown in **Table 3.7**. **Fig. 3.25** shows the frequency and magnitude relation of the earthquakes that occurred between 1994 to 2020 in Nepal.

For the probabilistic seismic hazard analysis, we did not model ourselves but used the data from a national scale seismic hazard study done by Stevens et al. in 2018. The paper was titled *"Probabilistic Seismic Hazard Assessment of Nepal"*.

In this study, the Probabilistic Seismic Hazard Analysis (PSHA) method was used which is the standard way of analyzing earthquakes all around the world. Various seismic sources in Nepal such as Main Himalayan Thrust (MHT), Karakoram fault, Northerly Grabens, Western Nepal strike slip and normal, Eastern Nepal strike slip, and the Main Frontal Thrust (MFT) were considered for calculating the GR a, b values and maximum magnitude M_{max} values. Also, global Ground Motion Prediction Equations (GMPEs) and average shear-wave velocities V_{S30} were used to compensate the site effects due to an earthquake. OpenQuake software, which is a logic-tree-based seismic hazard software was used for quantitative analysis. The inputs were as follows:

- Seismic source models
- Geometry of the seismic sources
- Magnitude-frequency statistics
- Site locations with site parameters (V_{S30})
- GMPEs

The outputs were the Peak Ground Acceleration (PGA) maps for 10% probability of exceedance in 50 years and 2% probability of exceedance in 50 years as shown in Figure 4.23 (star symbol indicating the location of the municipality). From the results, it was expected that the most part of Nepal would experience 0.4g – 0.6g of shaking for 10% probability of exceedance and 1.0g – 1.3g shaking for 2% probability of exceedance in any 50-year period.

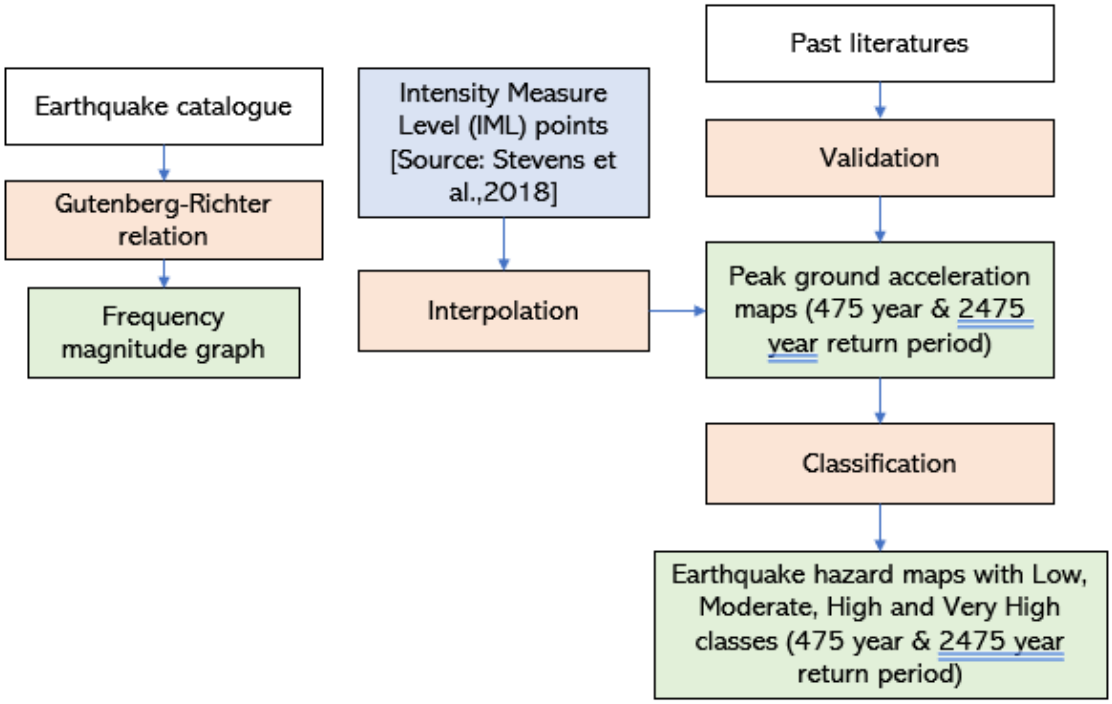


Fig. 3.23 Simplified workflow diagram of seismic hazard assessment.

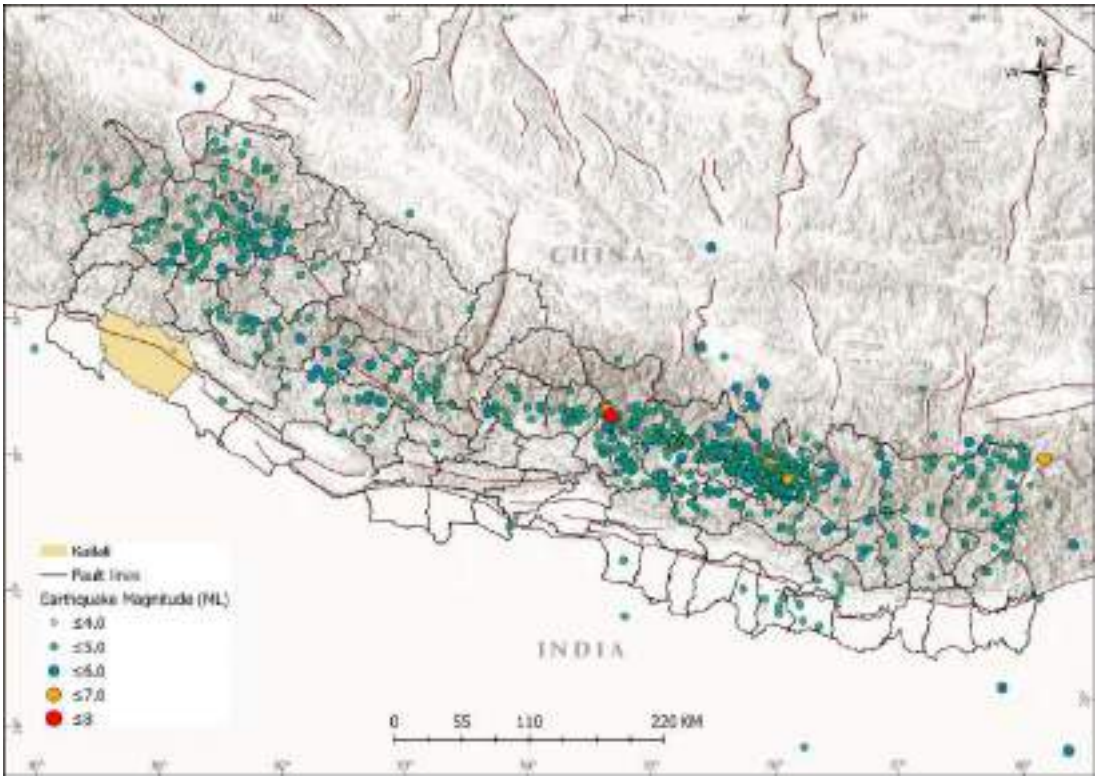


Fig. 3.24 Epicenters and spatial earthquake distribution in Nepal.

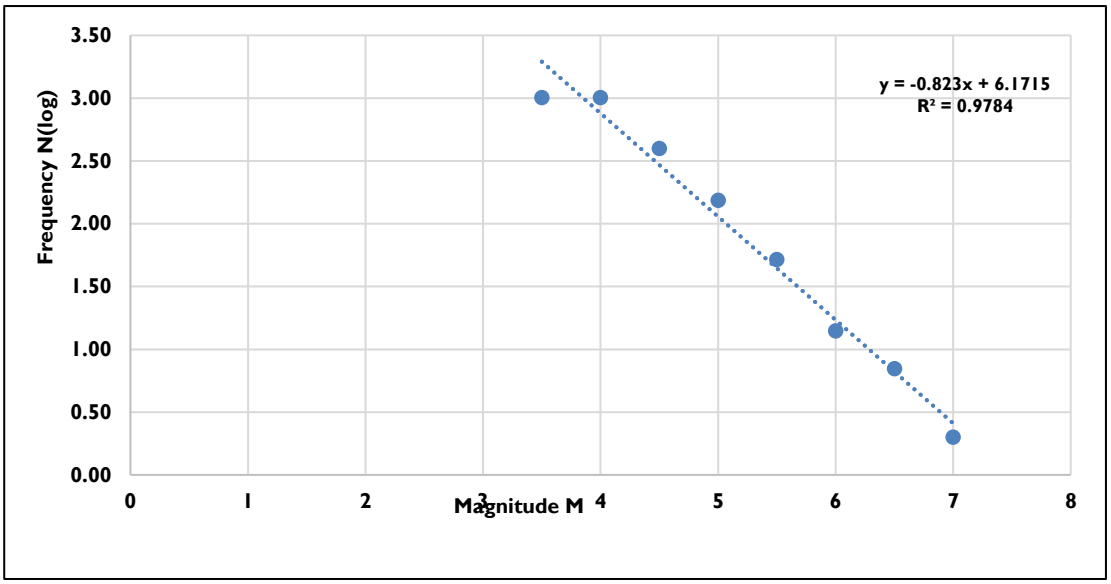


Fig. 3.25 GR plot of earthquakes from period 1994-2020 in Nepal.

Table 3.7 Frequency and magnitude of earthquakes obtained using Gutenberg-Richter relation.

FREQUENCY AND MAGNITUDE OF EARTHQUAKES OBTAINED USING GUTENBERG-RICHTER RELATION				
MAGNITUDE RANGE	LOWER M	COUNT PER M RANGE	CUMULATIVE TOTAL ABOVE LOWER M IN RANGE	LOG CUMULATIVE
3.5-3.9	3.5	1	1013	3.01
4.0-4.4	4	614	1012	3.01
4.5-4.9	4.5	244	398	2.60
5.0-5.4	5	102	154	2.19
5.5-5.9	5.5	38	52	1.72
6.0-6.4	6	7	14	1.15
6.5-6.9	6.5	5	7	0.85
7.0-8.0	7	2	2	0.30
		1013		

The results of this paper can be accessed through following link: https://vickystevens.shinyapps.io/Nepal_seismichazard/ . The results of this paper were used because the files of the intensity values with their spatial location could be downloaded.

The CSV files containing coordinates and the intensity measure level (IML) values were downloaded for Kailali district. The coordinates were used to plot the point data containing IML values i.e., PGA in ArcMap. Then, the points were interpolated to obtain a PGA map of the Kailali district for 10% and 2% probability of exceedance for 50 years. It was found that the PGA values ranged from 0.36g – 0.7g and 0.86g – 1.29g for 10% and 2% probability of exceedance for 50 years respectively for the Kailali district as shown in **Fig. 3.26**. The Main Frontal Thrust (MFT) is one of the active seismic sources that pass through the Kailali District and the project municipalities. Therefore, these areas are prone to earthquakes, though their frequency is very low, the losses can be massive.

The ground shaking for Godawari Municipality ranged from 0.50g – 0.70g and 1.06g – 1.29g for 10% and 2% probability of exceedance for 50 years respectively as shown in **Fig. 3.26**. The 10% probability of exceedance for 50 years is equivalent to the return period of 475 year. The 2% probability of exceedance for 50 years is equivalent to the return period of 2475 year. The conversion of probability of exceedance to return periods were done according to calculation provided in US Geological Society website accessed through the link: https://www.usgs.gov/natural-hazards/earthquake-hazards/science/earthquake-hazards-201-technical-qa?qt-science_center_objects=0#qt-science_center_objects.

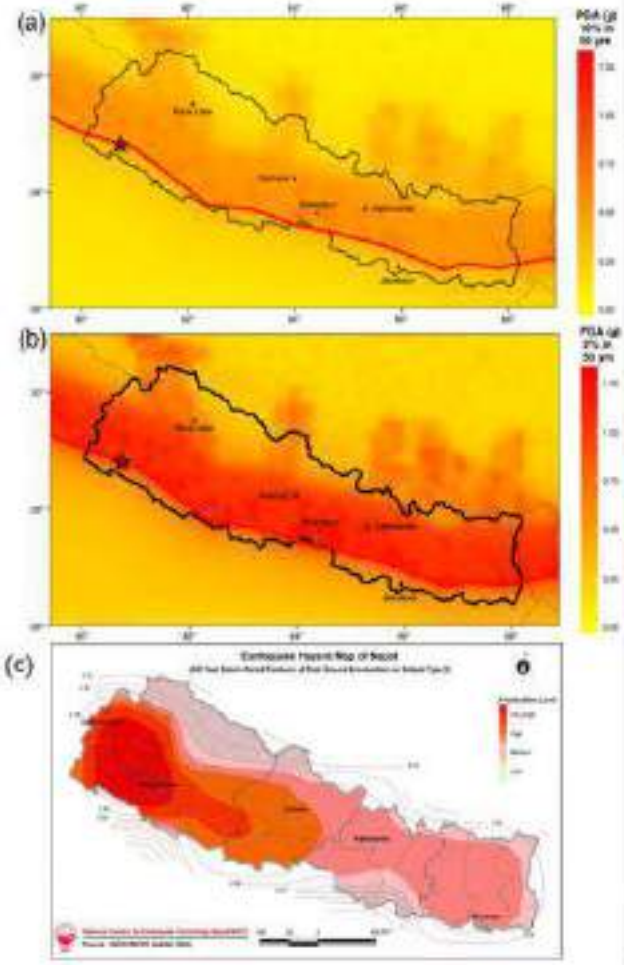


Fig. 3.26 Peak ground acceleration values for entire Nepal (a) 475 year Return Period (b) 2475 year RP (Source: Stevens et al., 2018) (c) 500- year RP map by UNDP and NSET (Dixit et al., 2017).

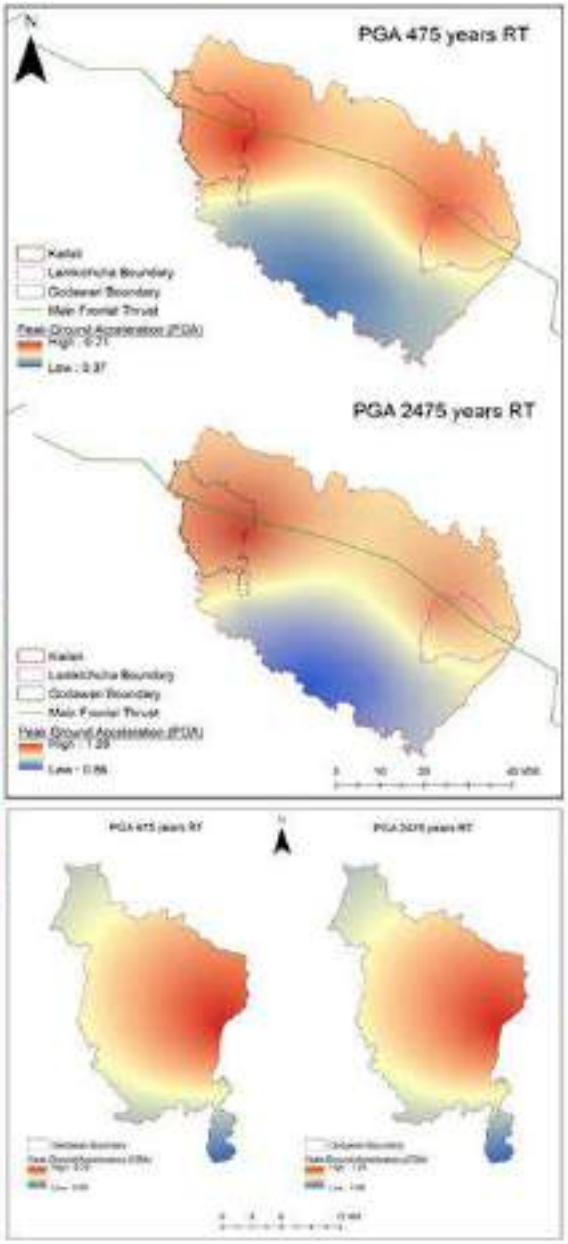


Fig. 3.27 Peak ground acceleration values of Kailali District and Godawari Municipality for 475 year and 2475 year return periods.

From the earthquake hazard map published in Dixit et al. (2017), we can see the study area (indicated by star symbol) is located in the very high hazard zone as shown in **Fig. 3.26 (c)**. According to their map, Kailali district had Modified Mercalli Intensity scale above 7, which was equivalent to PGA above 0.3 g (Wood & Ratliff, 2011; Panjamani et al., 2016) and had 98% High hazard zone and 2% Very High hazard zone as indicated by **Fig. 3.27**. We compared our maps with the earthquake hazard map of return period 500 year developed by the Asian Disaster Preparedness Center (ADPC), Norwegian Geotechnical Institute (NGI) and Centre for International Studies and Cooperation (CECI) in 2010 **Fig. 3.28**. In our case, the peak ground accelerations for Godawari were found to be very large for both return

periods (475 and 2475 years). Our estimated PGA was comparatively higher attributed to the lack of data to consider soil amplification and topographic amplification, which would have represented the local effect of the sediment areas with respect to ground shaking. The detailed seismic hazard assessment requires ample data and time which was out of the scope of this project. The peak ground accelerations for Godawari were found to be very large, however, its probability of occurrence is very low. The maps were classified into four classes based on the PGA: Low (PGA < 0.18 g), Moderate (PGA 0.18 g – 0.35 g), High (PGA 0.35 g – 0.5 g), and Very High (PGA > 0.5 g). Our maps only had PGA greater than 0.5 g so, we assigned the class 'Very High' for both return periods for entire municipality. Ward wise comparison of the area affected by the earthquake is shown in **Fig. 3.29.**

3.1.4 WIND HAZARD ASSESSMENT

Daily maximum wind speed data were collected from satellite called MERRA2. The daily wind speed from period 1981-2020 were fitted to the Gumbel extreme value evaluation to get the maximum speed at different return periods. This method gave the value of maximum wind speed but not the maps. Therefore, Global wind atlas data at 10 m altitude was used to locally rescale and produce wind hazard maps. For rescaling, the historical wind damage data was used to understand the intensity of wind that had cause damages in the municipality. The final outputs are the wind hazard maps for the return period of 10 year, 25 year and 50 year. **Fig. 3.30** shows the simplified flow diagram of wind hazard assessment.

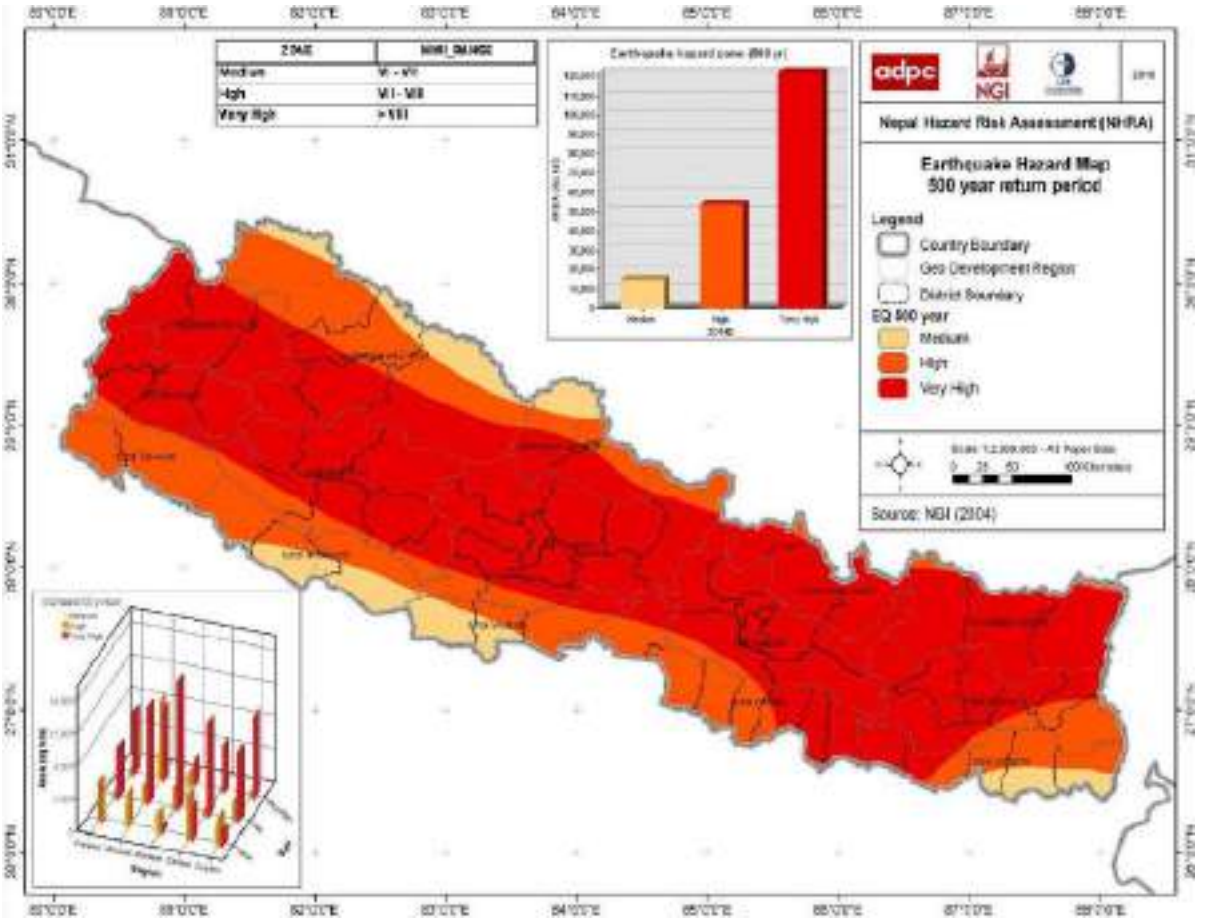


Fig. 3.28 Earthquake hazard map of Nepal (ADPC et al., 2010).

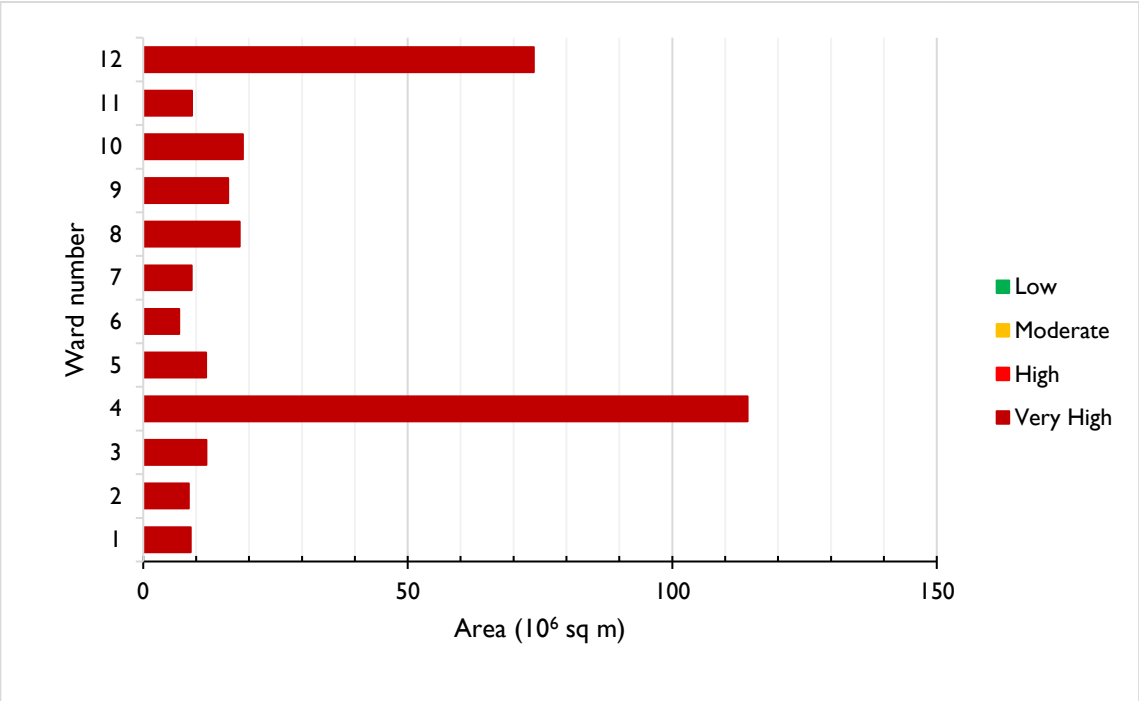


Fig. 3.29 Ward wise area comparison of earthquake hazard for return periods of 475 year and 2475 year.

Wind related hazard is ranked 1st as the major disasters in Godawari Municipality. But it is not sure whether the windstorms occur independently like tornadoes or occur as a part of local convective thunderstorms. There were challenges in analyzing the wind hazard in the municipality attributing to data gaps from the only available station. So, for the analysis of wind hazard, two additional datasets were used: the satellite data obtained from NASA Global Modelling and Assimilation Office (GMAO) termed as Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA2) accessed from https://power.larc.nasa.gov/data-access-viewer/ and another data from Global Wind Atlas (GWA) accessed from www.globalwindatlas.info. From the MERRA2 data, the daily maximum wind speed (m/s) at 10 m altitude was used for the period 1981 to 2020. Mean daily wind speed (m/s) at 10 m altitude was used from GWA for our area of interest. The spatial resolution of MERRA2 data was about 55 km whereas the output data from GWA was about 250 m. They were available in .csv format and .tiff format respectively.

First, using the MERRA2 data, the maximum wind speed was aggregated per year from the daily maximum wind speed for the period 1981-2020 (40 years) as shown in **Fig. 3.31**. Gumbel extreme value fitting analysis was performed for the maximum wind speed for different return periods (10-year, 25 year and 50 year) as shown in **Table 4.8**.

The wind speeds obtained for the different return periods were not enough to cause significant damages according to the Beaufort wind force scale which is widely used for wind damage assessment. Beaufort scale was developed by Sir Francis Beaufort in 1805, which is an empirical measure that relates wind speed to observed conditions at sea or on land. The scale is shown in **Fig. 3.32.**

According to this scale, our calculated wind speed was equivalent to a fresh breeze or strong breeze which was not enough to damage houses as mentioned in the historical events occurred in these municipalities. Several reasons could be devised for these discrepancies between the observed damages and wind speed assessment which were as follows:

I. Satellites and station data could not measure the extreme wind speed during local convective thunderstorms therfore, could not represent the actual wind speed. The location of the meteorological station could also be an issue.
II. The meteorological station data was not complete during these events, as we have many missing data.

In order to represent a logical wind hazard map, we used the GWA maps at 10 m altitude for as shown in **Fig. 3.33**. These were locally rescaled them to match the findings in the hazard zonation maps and finally classified them in four classes according to Beaufort wind speed damaged scales (Very Low (<17.2 m/s), Low (< 20.7 m/s), Moderate (<24.5 m/s), and High (>25 m/s). The final classified wind hazard maps for return periods of 10-year, 25 year and 50 year are shown in **Fig. 3.34**. **Fig. 3.35** represent wind hazard map for return periods of 10, 25 and 50 years respectively.

Table 3.8 Gumbel extreme value fitting for wind speed.

GUMBEL EXTREME VALUE FITTING ANALYSIS	
RETURN PERIOD (YEAR)	WINDSPEED (m/s)
	Godawari
10	9.57
25	10.32
50	10.88

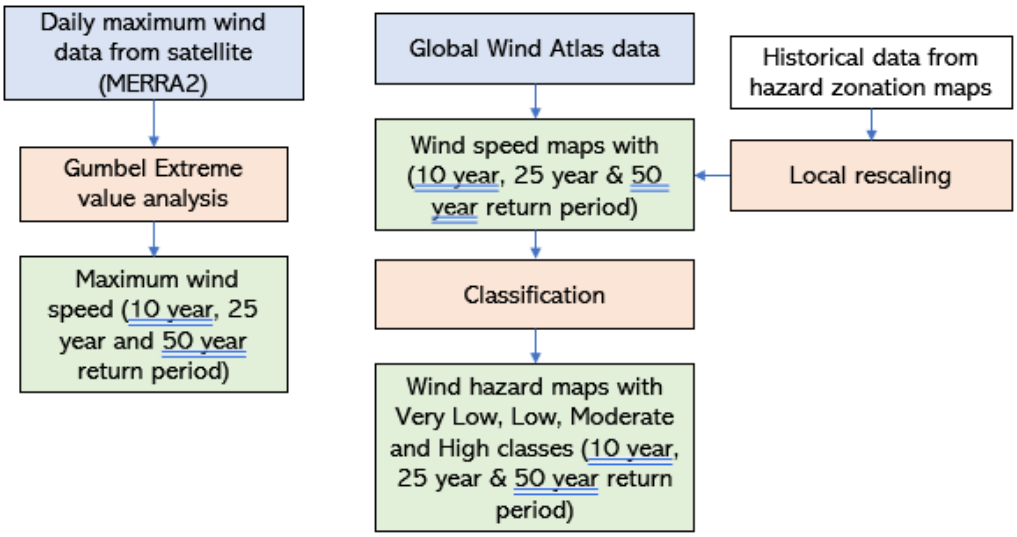


Fig. 3.30 Simplified workflow diagram of wind hazard assessment.

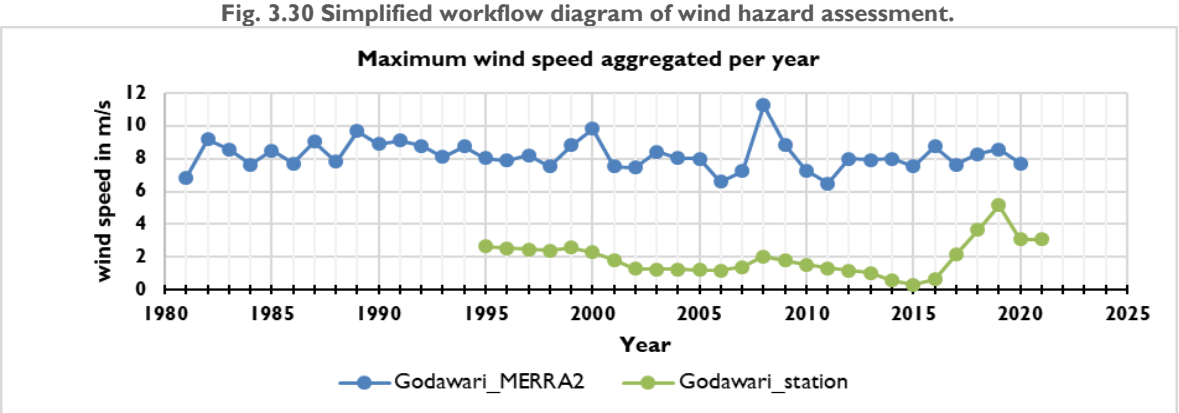


Fig. 3.31 Maximum wind speed data from MERRA2 for Godawari Municipality.

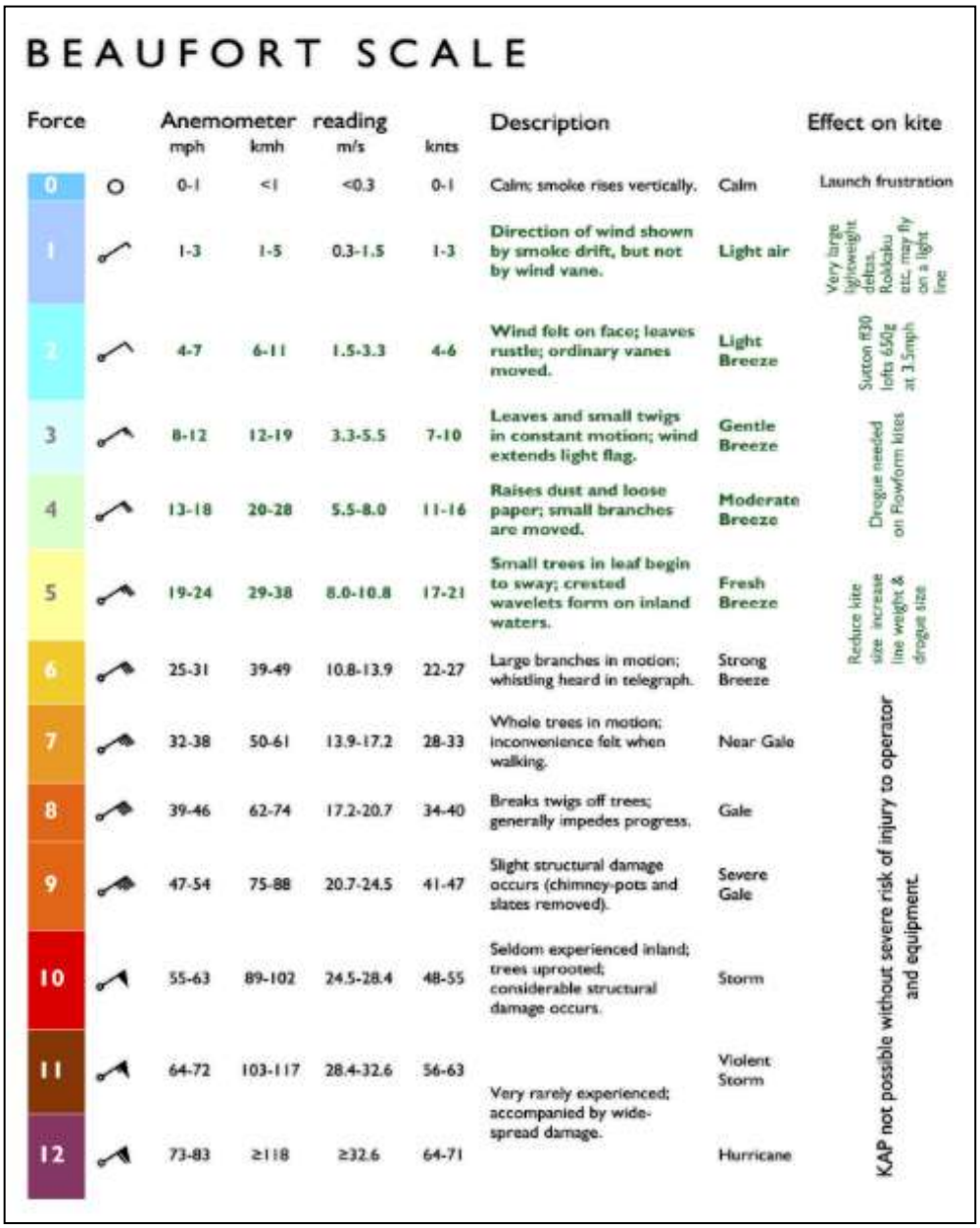


Fig. 3.32 Beaufort scale and its description (Source: [https://billboyheritagesurvey.wordpress.com/2012/01/13/beaufort-scale/]).

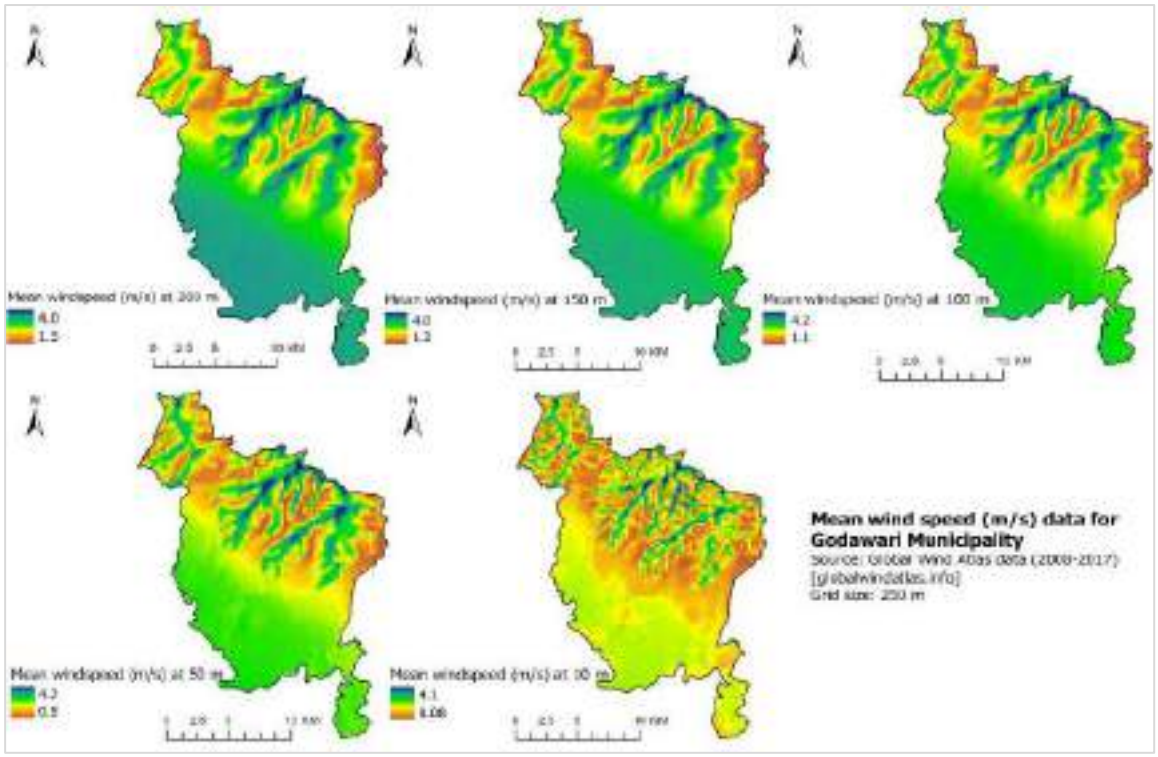
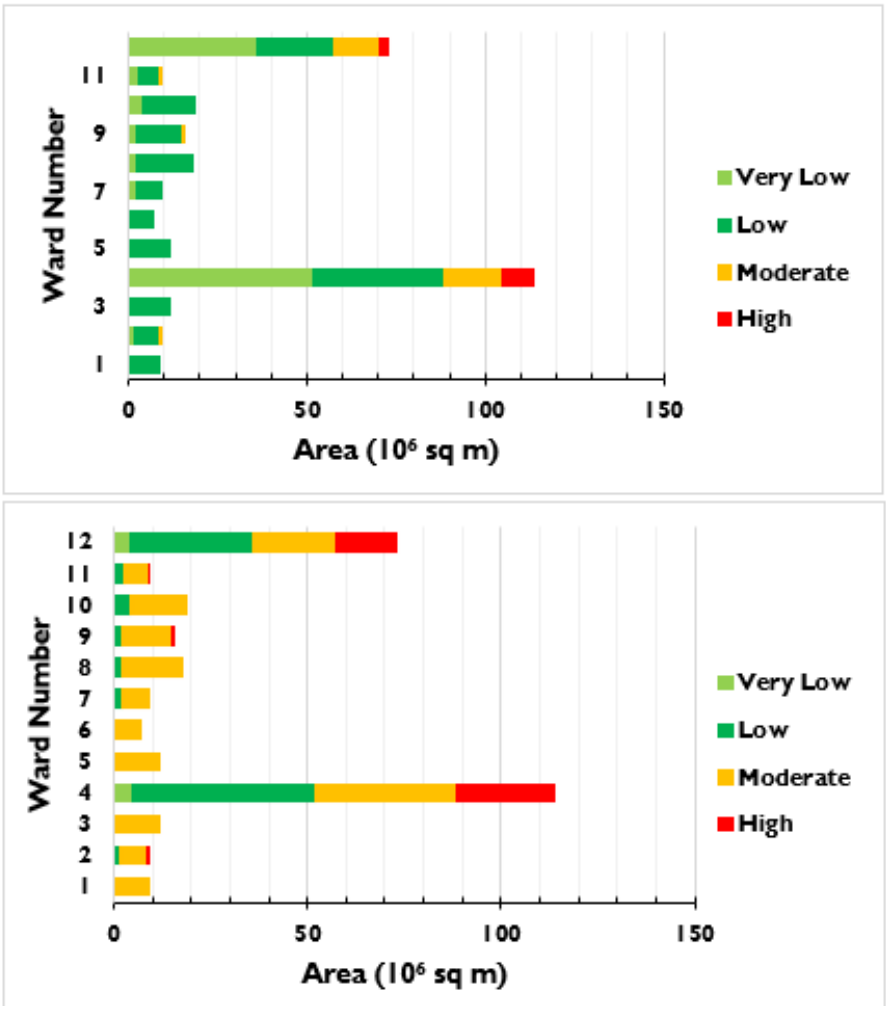


Fig. 3.33 Beaufort scale and its description (Source: [https://billboyheritagesurvey.wordpress.com/2012/01/13/beaufort-scale/]).



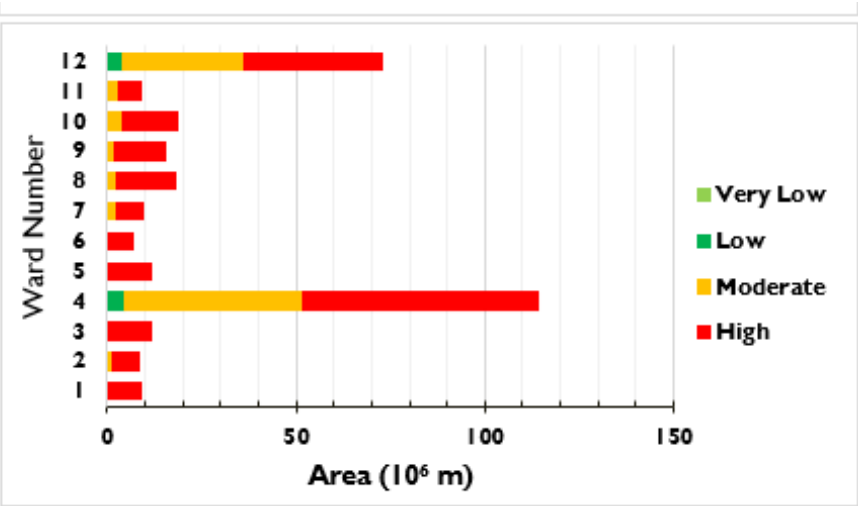


Fig. 3.34 Wardwise area with windstorm as low, moderate or high for 10 (above), 25 (middle) and 50 (below) years return period.

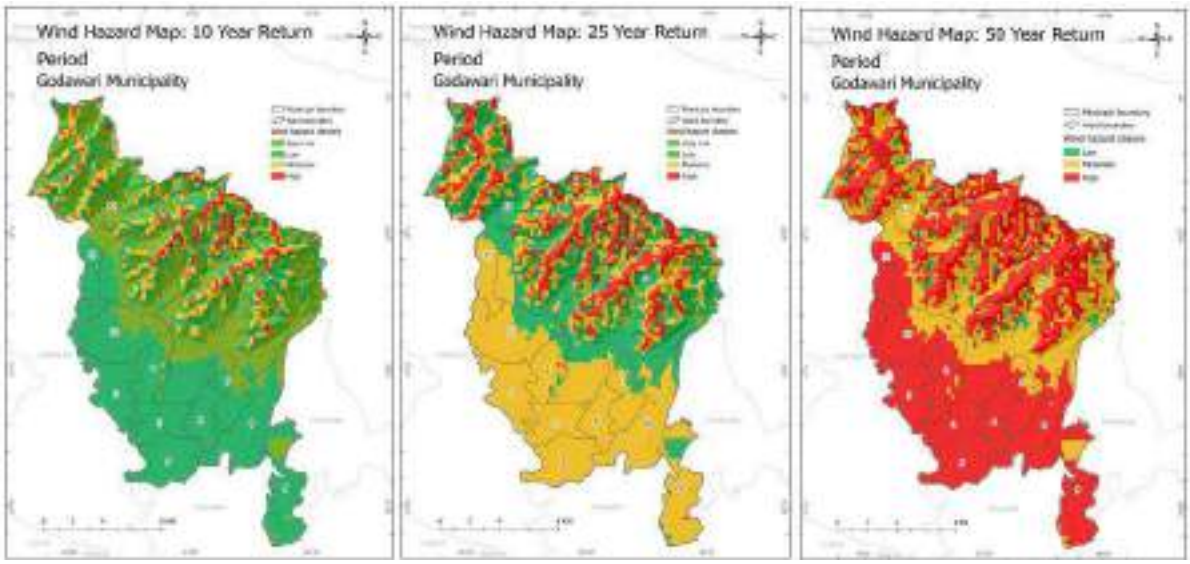


Fig. 3.35 Wind hazard map of Godawari Municipality for 10-year, 25-year and 50-year return periods.

3.1.5 ANIMAL ATTACK HAZARD AND RISK ASSESSMENT

Impacts by animals are common in some parts of Godawari Municipality. Animal attacks are of different types such as pests, untamed livestock, attacks of livestock by jackals, wild dogs etc. In this analysis, small animal attacks by wild dogs, foxes were only considered. Historical data from the field survey showed the main zones of animal impacts on agriculture, livestock and people in Godawari Municipality. For this map it doesn't make much sense to separate the hazard from the risk map, and therefore the whole procedure was presented here. The qualitative risk index map can be used to show the consequences of animal attacks/terror on different elements-at-risk. For this, Spatial Multi-Criteria Analysis (SMCE) was used in GIS (ILWIS) to produce an animal attack susceptibility map for small animal attacks. The factors considered important for the animal attack susceptibility were: the distance from the forests and tree clusters and the distance from historical occurrences. Wild animals attack in or close to the forest areas. The forest zones were obtained from the landcover maps as shown in **Fig. 3.36**. Likewise, the distance from the historical events were also considered assuming

attacks due to ample presence of preys or food grains nearby previously attacked locations. The factors maps were standardized and given weights as per expert opinions and literature. The output maps were the composite susceptibility index map with value ranging from 0 to 1 for the small animal attacks/terror. **Fig. 3.37** shows the simplified flow diagram for animal attack susceptibility assessment.

Another step is to prepare vulnerability maps considering several factors such as land use and buildings near the forest and tree clusters as shown in **Fig. 3.38** (bottom). Vulnerability maps for the cultivation area and the built-up area were prepared separately. Built up area was used as proxy to represent the chances of livestock or human casualties. The vulnerability factor maps were weights assigned in the criteria tree, standardized and combined. The output maps were the composite vulnerability index map with values ranging from 0 to 1 for agriculture and built-up. The susceptibility and vulnerability maps were classified into different classes (Low, Moderate, High and Very High) based on pixel values for easy interpretation. In last step, the susceptibility maps and vulnerability maps were crossed to obtain the classified qualitative animal attack risk index map. **Table 3.9** shows the risk matrix with vulnerability domain in x-axis and susceptibility domain in y-axis from which the risk map was classified and the combination of class was based on expert opinions.

Fig. 3.38 shows the wardwise comparison of animal attack susceptibility in Godawari Municipality. Ward wise comparison of animal attack susceptibility showed Ward 4 as the highly susceptible to animal attack followed by Ward 12, attributed to the presence of forest areas. The following pages show the maps of animal attack susceptibility, vulnerability and risk index maps (**Figs. 3.39-3.43**).

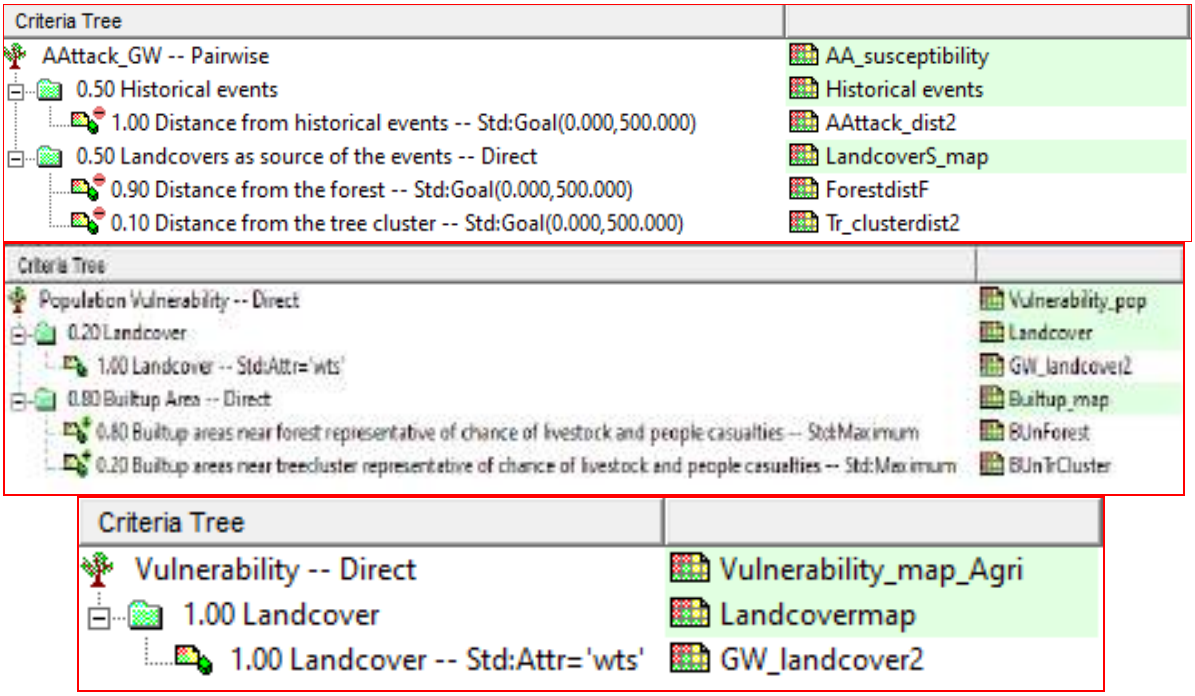


Fig. 3.36 Criteria trees for Spatial Multi-criteria analysis for animal attack susceptibility map (top), built-up vulnerability (middle) and agriculture vulnerability maps (bottom).

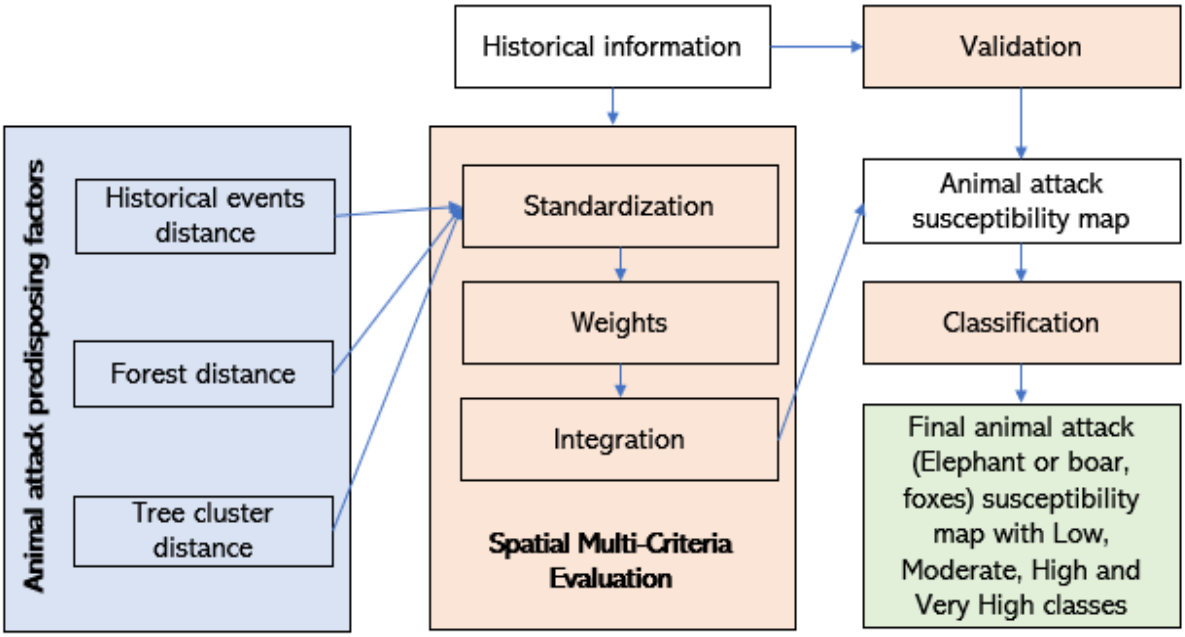


Fig. 3.37 Simplified workflow diagram for animal attack susceptibility assessment.

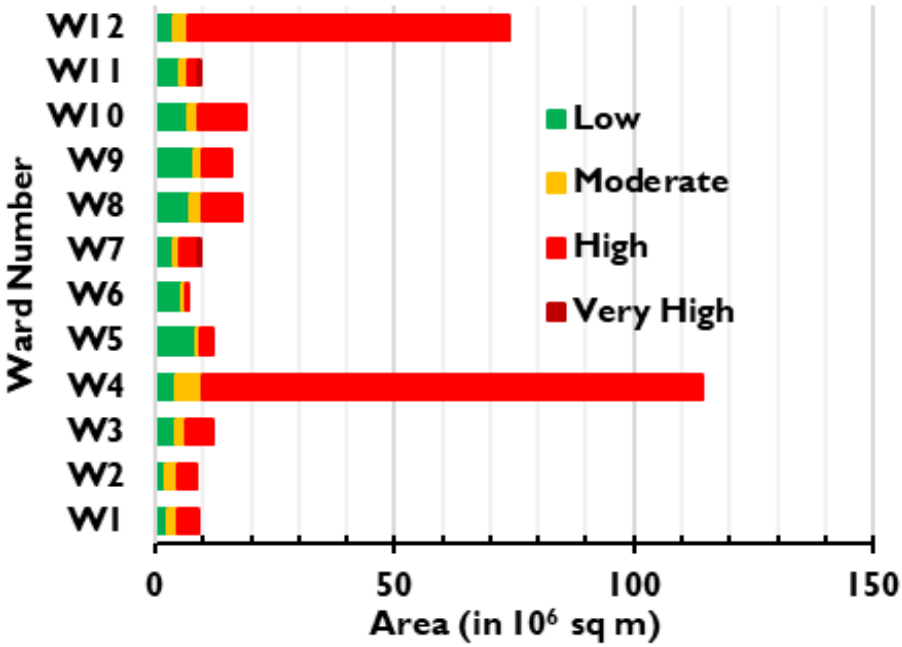


Fig. 3.38 Ward-wise area comparison for animal attack susceptibility in Godawari Municipality.

Table 3.9 Risk matrix table obtained from combination of vulnerability and susceptibility domain.

RISK MATRIX TABLE OBTAINED FROM COMBINATION OF VULNERABILITY AND SUSCEPTIBILITY DOMAIN					
SUSCEPTIBILITY	VULNERABILITY				
		Low	Moderate	High	Very High
	Low	Low	Low	Low	Low
	Moderate	Low	Moderate	Moderate	High
	High	Low	Moderate	High	Very High
	Very High	Low	High	Very High	Very High

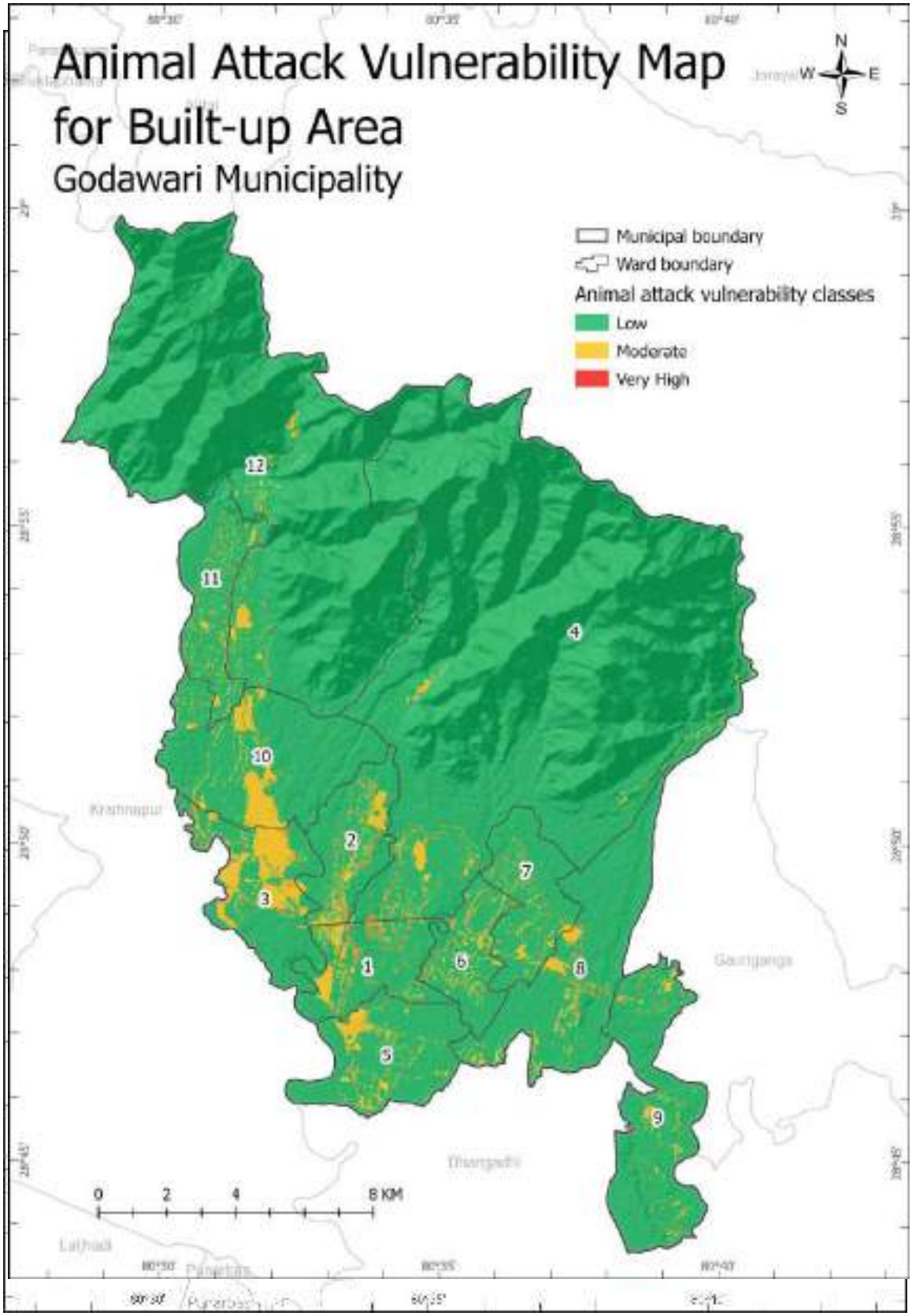


Fig. 3.39 Animal attack susceptibility map along with historical animal attack events.
Fig. 3.40 Animal attack vulnerability map for built-up area. Built-up area acts as proxy for livestock and human casualties.

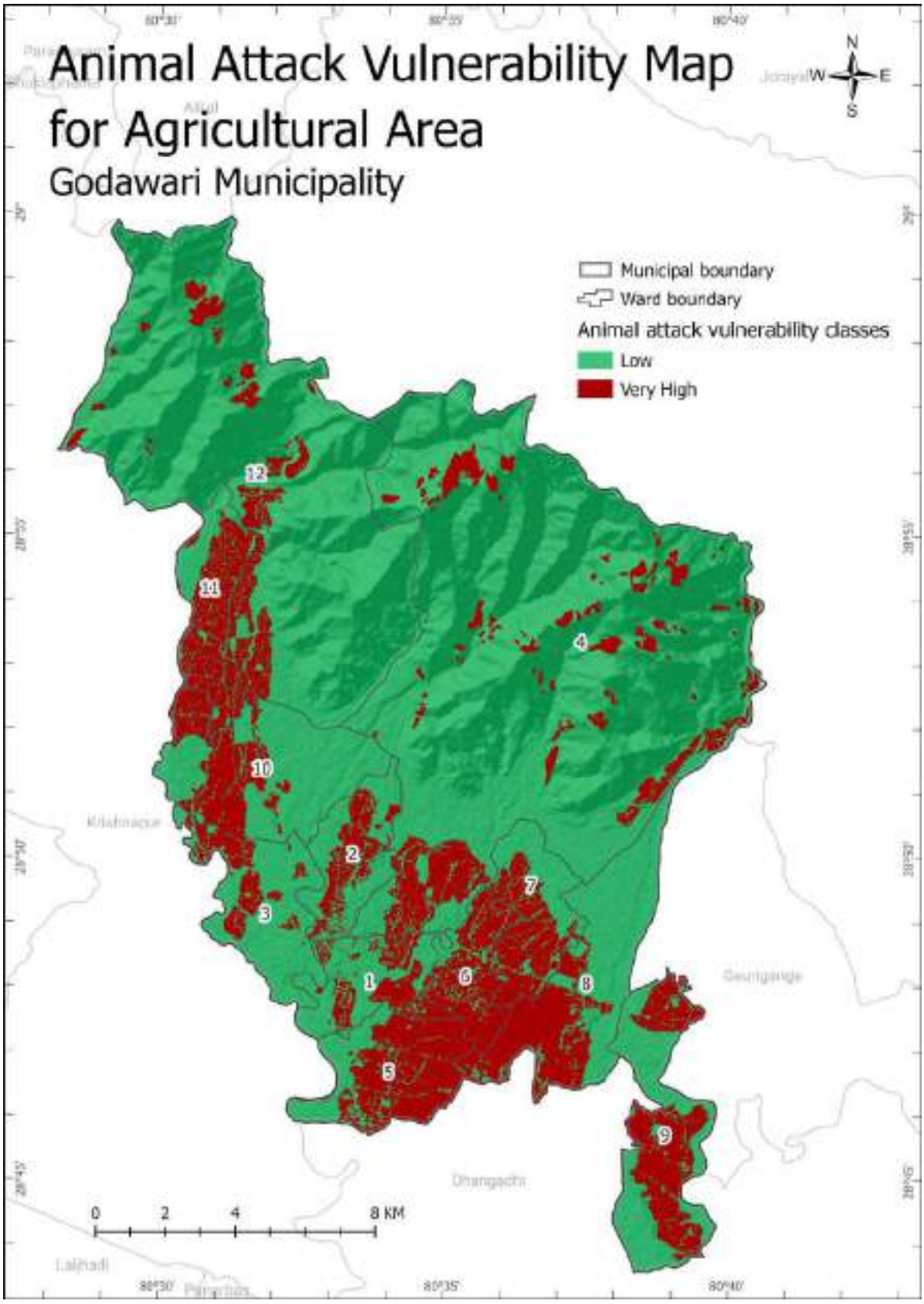


Fig. 3.41 Animal attack vulnerability map for agricultural area.

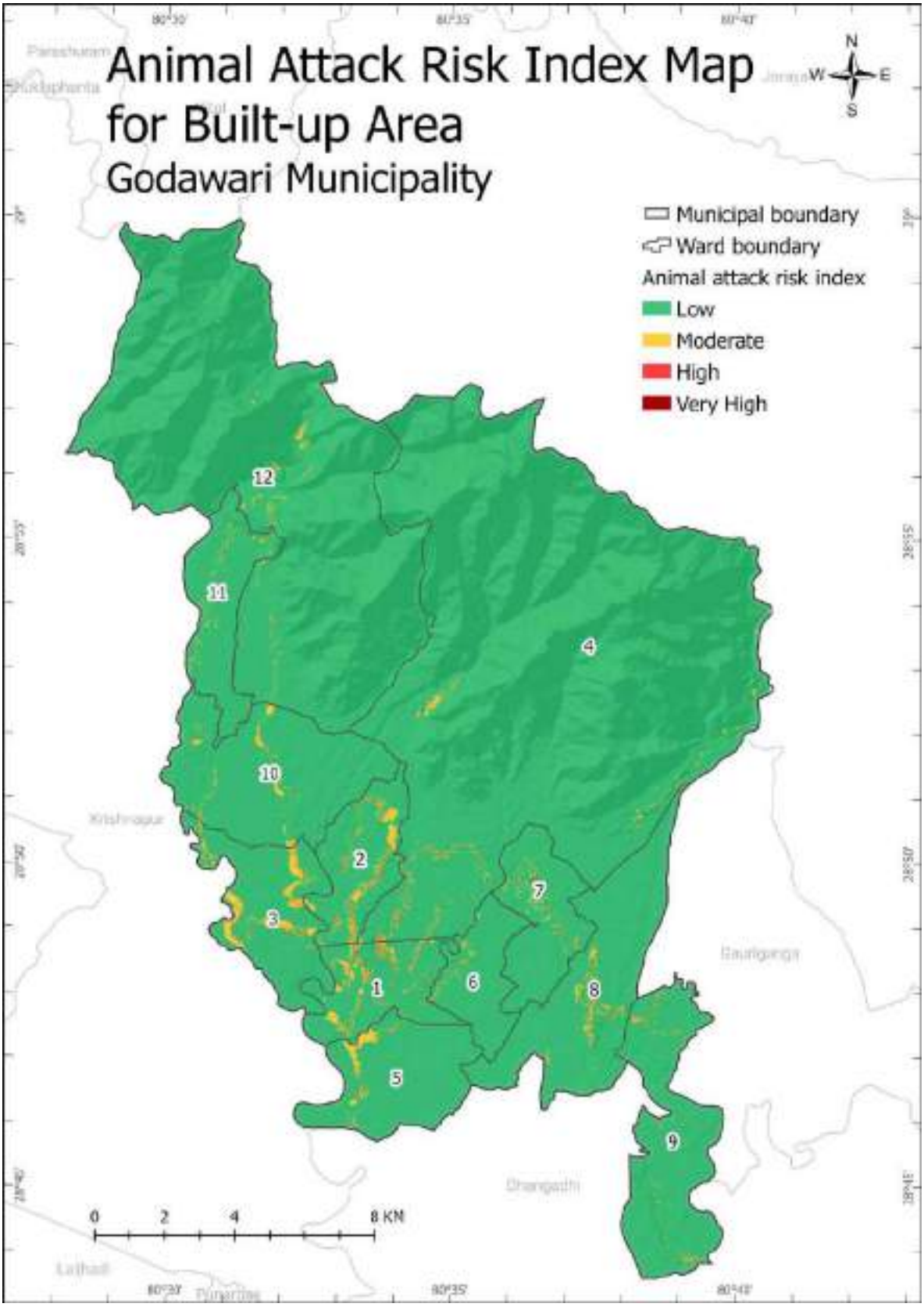


Fig. 3.42 Animal attack risk index map for built-up area. Built-up area acts as proxy for livestock and human casualties.

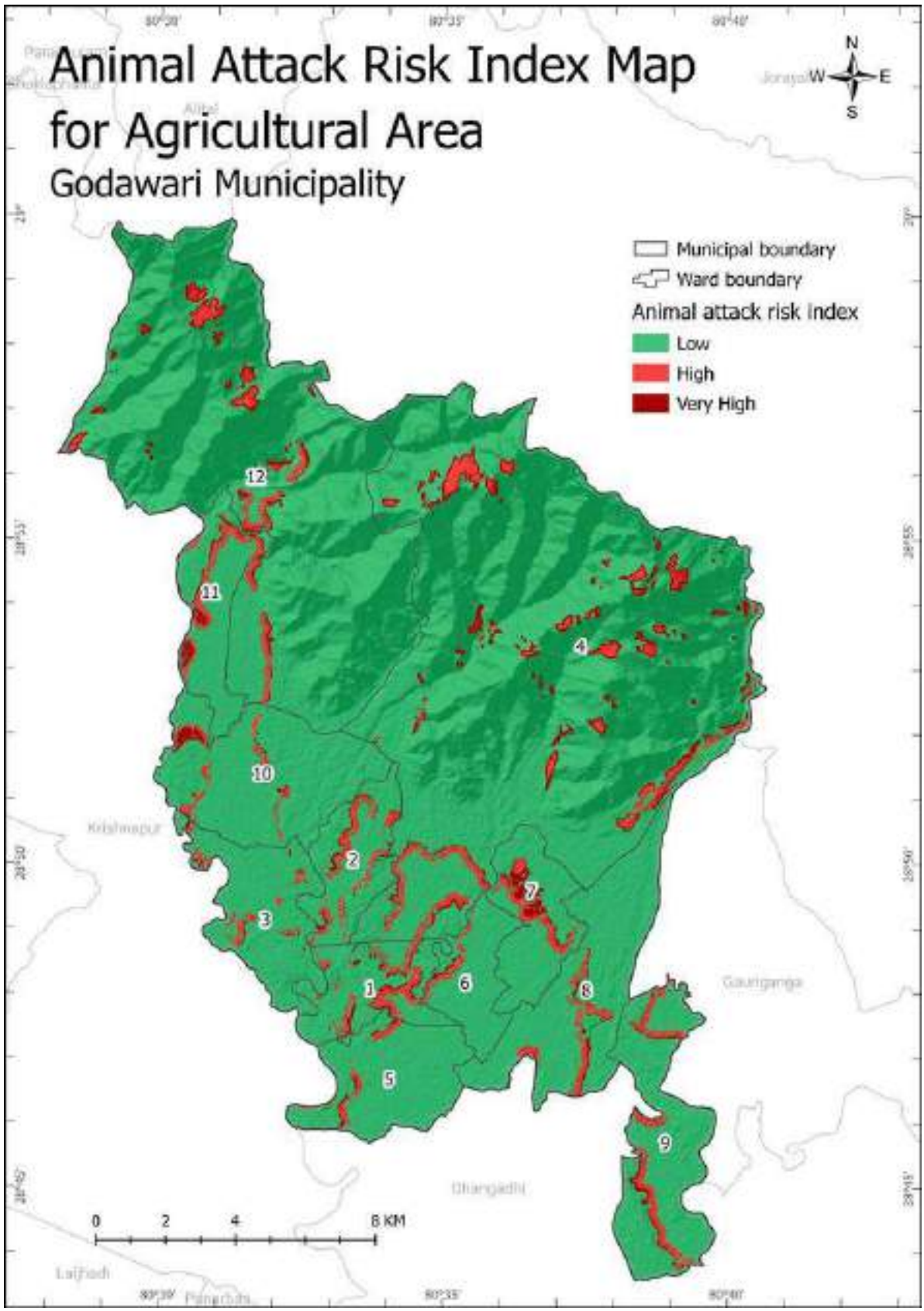


Fig. 3.43 Animal attack risk index map for agricultural area.

3.1.6 FIRE HAZARD AND RISK ASSESSMENT

Fire can be caused naturally (e.g., forest fire, lightning strike) or man-made (e.g., electrical short circuit, gas cylinder blast, road accidents, carelessness, cigarettes etc.). Historical records showed that the fire incidents mainly due to man-made causes in this municipality. The qualitative fire risk assessment was done using GIS software. It utilized the fire causal factors in the Spatial Multi-Criteria Evaluation (SMCE) tool in order to make a fire susceptibility map. Several factor maps were used based on fire sources such as distance from buildings themselves, distance from petrol pumps, gas stores, natural fires and road accidents as shown in **Fig. 3.44** (left). The factors maps were assigned in a criteria tree and the maps were standardized based on distance and given weights based on literature and expert judgements. The output map was the composite susceptibility index map with value ranging from 0 to 1. **Fig. 3.45** simplified flow diagram of susceptibility assessment.

Another step was to prepare a fire vulnerability map considering several factors such as land use and building construction types. Building characteristics were considered such as construction types, roof types etc. as shown in **Fig. 3.44** (right). The factor maps were assigned to the criteria tree, standardized and weighted. The output was the composite vulnerability index map with values ranging from 0 to 1. Then the composite index maps were classified into different susceptibility classes like Very High, High, Moderate and Low based on pixel values for easy interpretation.

In last step, the susceptibility maps and vulnerability maps were crossed to obtain the classified qualitative fire risk index map. **Table 3.9** shows the risk matrix with vulnerability domain in x-axis and susceptibility domain in y-axis from which the risk map was classified and the combination of classes were based on expert opinions.

Ward wise area comparison (**Fig. 3.46**) showed that most of the wards were in moderate risk from fire. High susceptibility in ward 4 could be attributed to presence of forest areas and associated forest fire risk. **Figs. 3.47, 3.48** and **3.49** show the fire susceptibility, vulnerability and risk index maps of Godawari Municipality respectively.

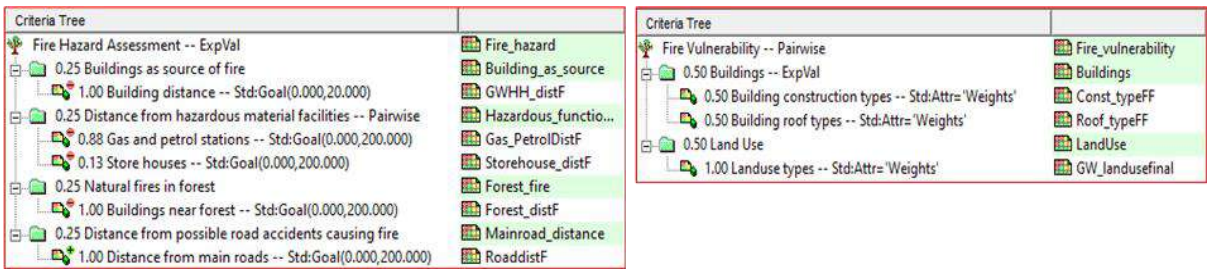


Fig. 3.44 Animal attack risk index map for agricultural area. Criteria trees for Spatial multi-criteria evaluation for susceptibility map (left) and vulnerability map (right).

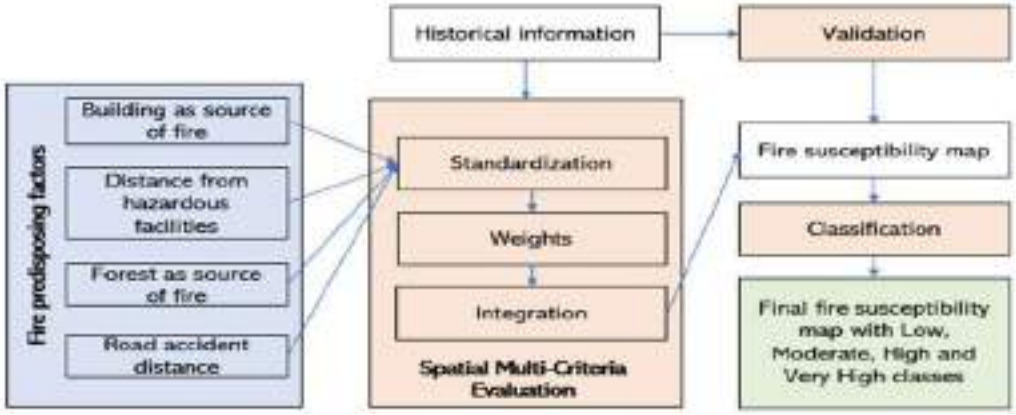


Fig. 3.45 Simplified workflow diagram of fire susceptibility assessment.

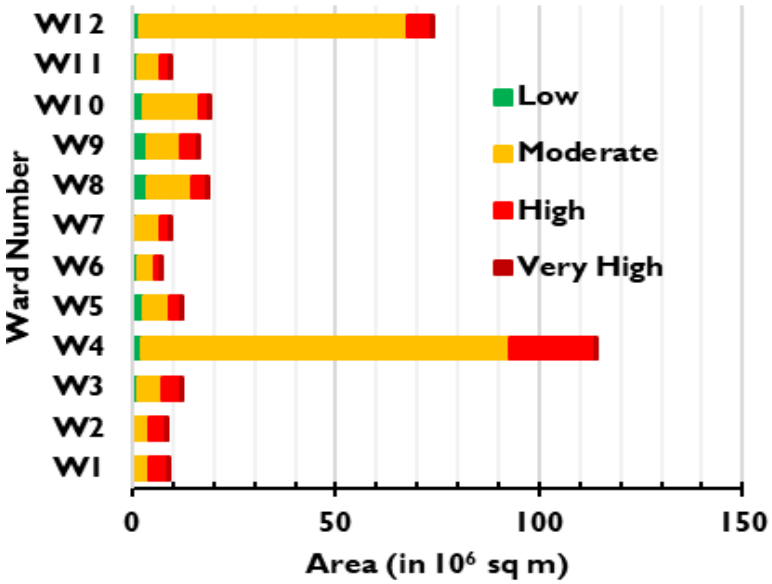


Fig. 3.46 Ward wise area comparison for fire susceptibility in Godawari Municipality.

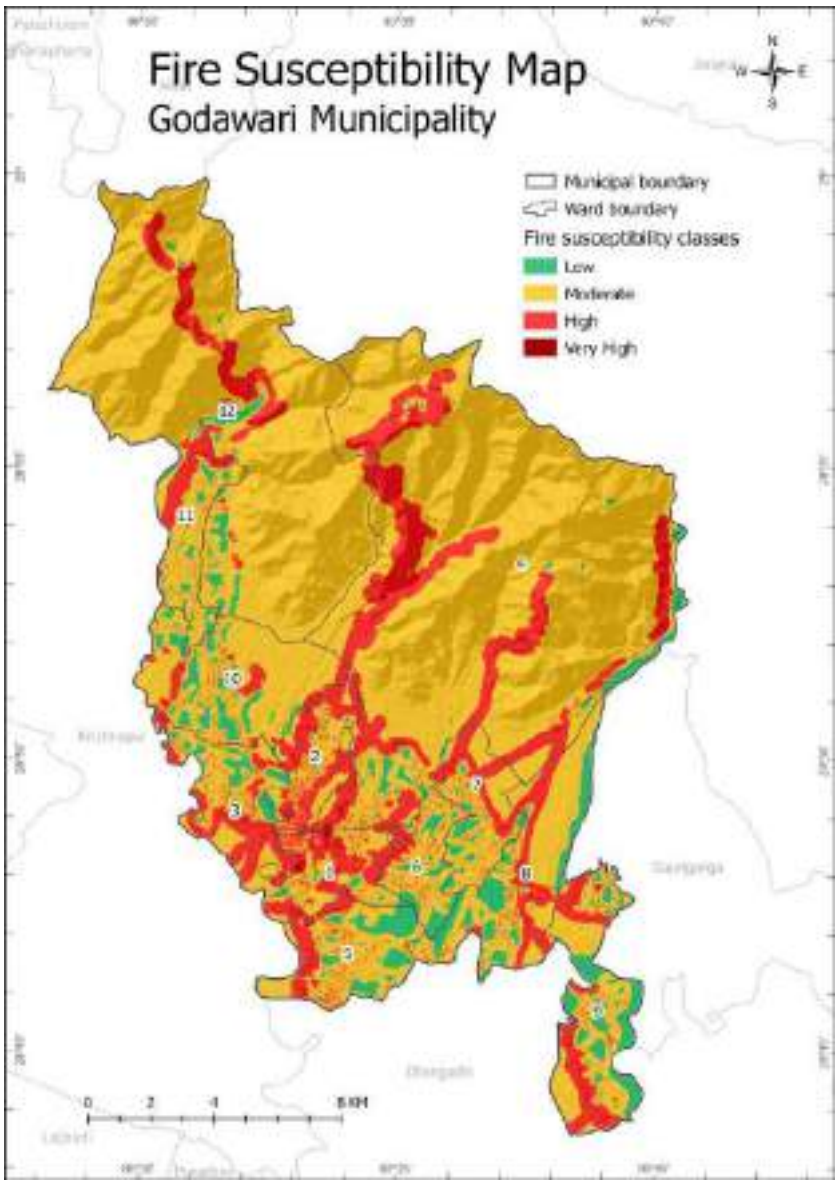


Fig. 3.47 Fire susceptibility map of Godawari Municipality.

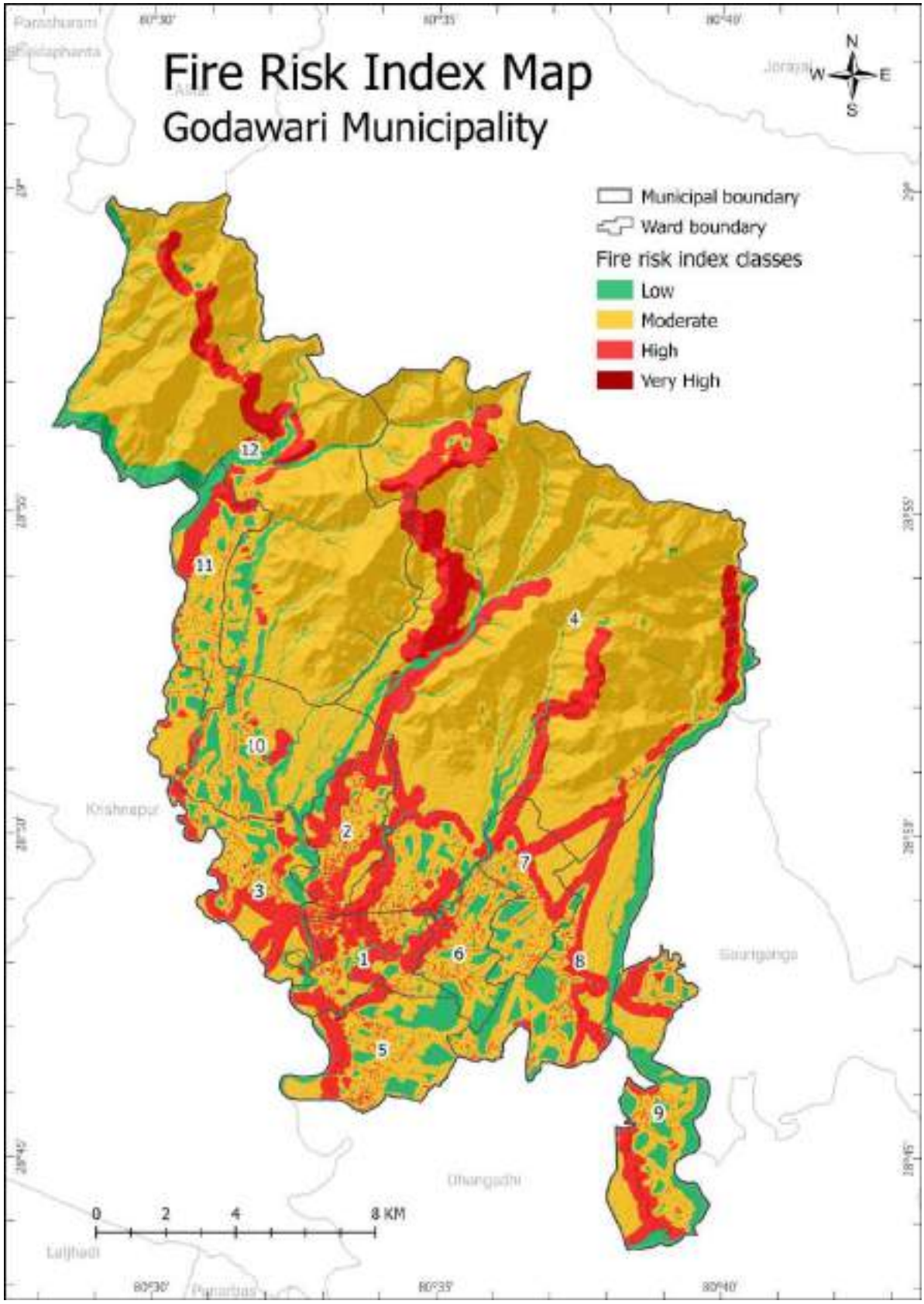


Fig. 3.48 Fire risk index map of Godawari Municipality.

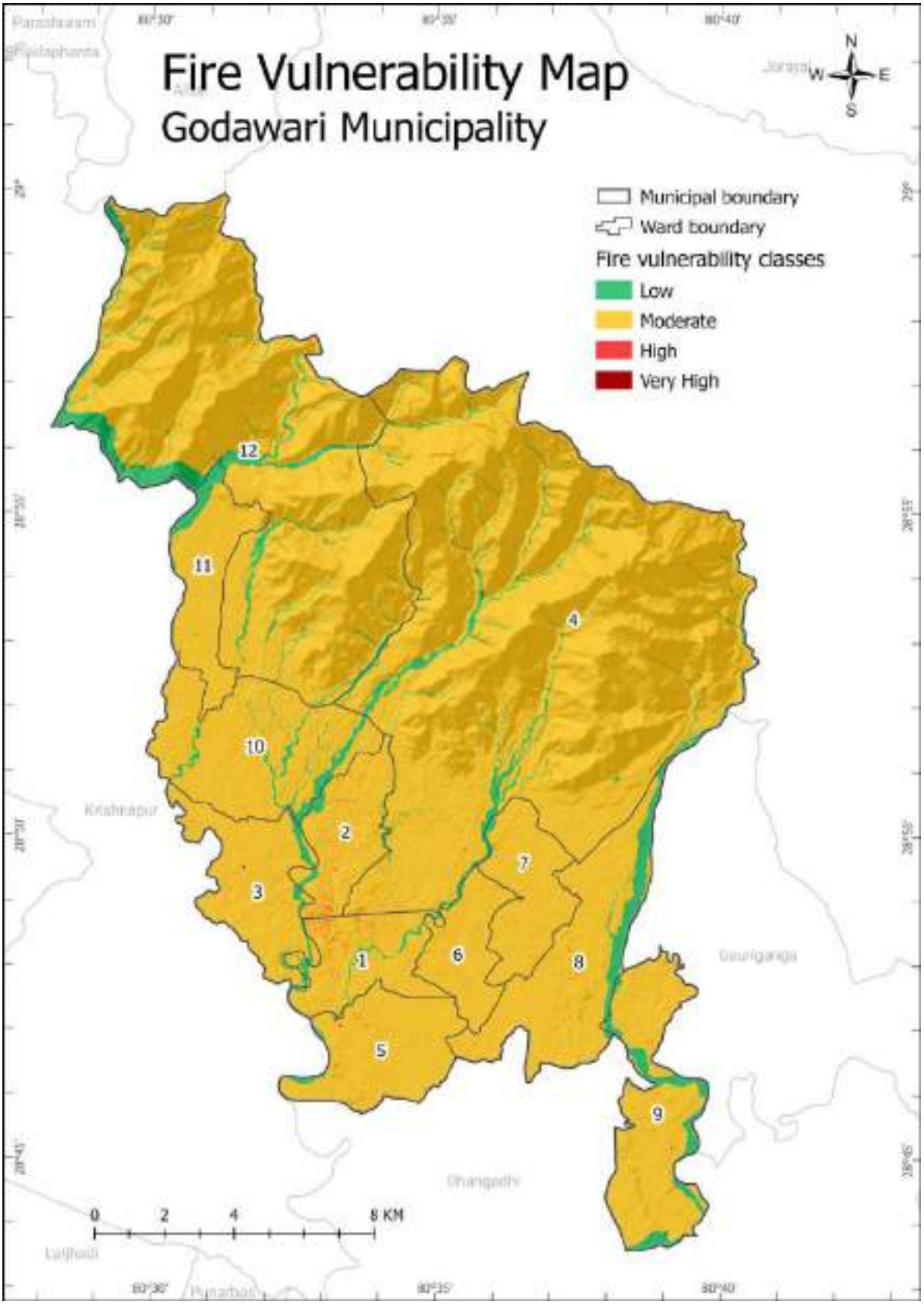


Fig. 3.49 Fire vulnerability map of Godawari Municipality.

3.1.7 HEATWAVE AND COLDWAVE HAZARD ASSESSMENT

Climate extremes such as heatwaves and coldwaves have profound effects on both human society and the natural environment. With the ongoing change in climate, there is general agreement that significant changes in intensity or/and frequency of extreme weather will occur, although the degree of change will be different around the globe (IPCC, 2021). Climate extremes can be placed into two broad groups: i) those based on statistical analysis of daily minimum and maximum temperature and rainfall that occur every year; and ii) more complex event-driven extremes such as droughts and floods, which do not necessarily occur every year at a given location.

For this analysis, statistical analysis of daily temperature was conducted from the period of 1981 to 2020. The daily maximum and minimum temperatures were used from NASA Global Modelling and Assimilation Office (GMAO) termed as Modern-Era Retrospective Analysis for Research and Applications; Version 2 (MERRA2) accessed from https://power.larc.nasa.gov/data-access-viewer/. There were no data gaps for the study period unlike the stations data near the municipality.

The Climdex indices were used which are the standardized set of climate extreme indices recommended by Commission on Climatology (CCl), World Climate Research Program (WCRP) /JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI), accessed from https://www.climdex.org/. The Climdex indices help us understand patterns in temperature and precipitations extremes. There are 27 Climdex indices of which we are only using those indices related to heatwaves and coldwaves. The Climdex indices use percentile-based or fixed threshold indices which provides the user flexibility and attempts to represent the local climatic variations as well. Some improvisation was done for the coldwaves as the Climdex's R based software did not have the script for coldwave calculation. But the theory was applied in Python script and the indices were calculated accordingly. **Fig. 3.50** illustrates thesimplified flow diagram of heatwave and coldwave assessment. **Table 3.10** gives the descriptions of the indices used in this analysis.

Table 3.11 shows the overview of average, lowest and highest temperatures in Godawari Municipality obtained from the MERRA2 data. The maximum and minimum daily temperatures from peak summer months (April-June) for heatwaves and peak winter months (December-February) for coldwaves were used for the analysis. The following section presents the results of heatwave and coldwave analysis for the period 1981 to 2020 for the Godawari Municipality (**Figs. 3.51-3.56**).

There is at least one heatwave every year in the period 1981 to 2020 except for 1986 and 1989 in Godawari Municipality. However, from the local disaster reports in the municipality, no casualties related to heatwaves have been reported. Godawari municipality is located in the Terai region of Nepal where temperatures reach above 40°C in the peak summer months of April-June. It is also important to consider the adaptation behavior of the local communities toward the heat in these regions since they could already have developed the physiological capacity to cope with such heat in the peak summer months. And this might be the reason why no heatwave casualties are recorded. From **Fig. 3.56**, a slightly increasing trend could be observed in the intensity of the heatwaves denoting more severe heatwaves than the past records.

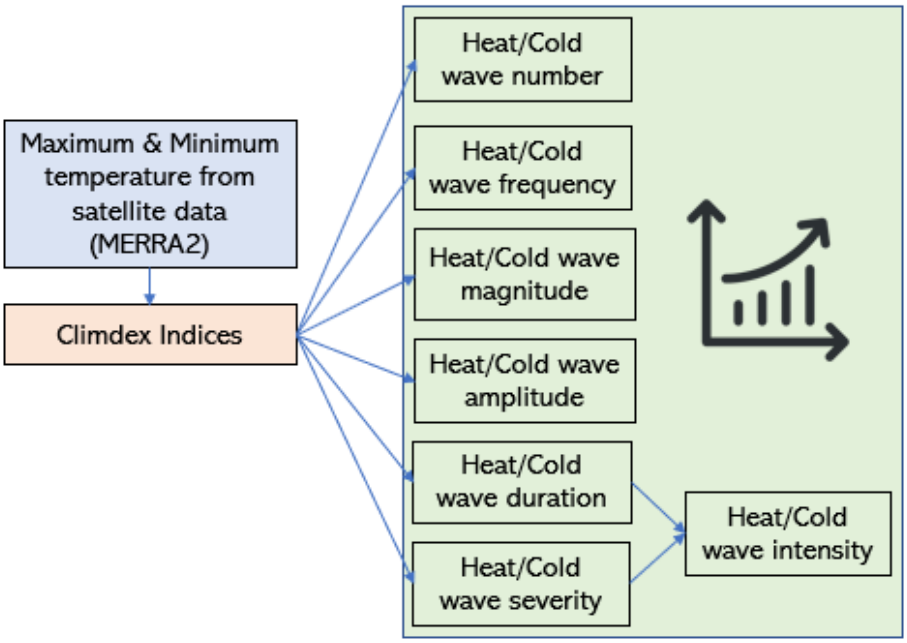


Fig. 3.50 Simplified workflow diagram of heatwave and coldwave assessment.

Table 3.10 Description of the extreme climate indices used for the analysis.

DESCRIPTION OF THE EXTREME CLIMATE INDICES USED FOR THE ANALYSIS				
NAME	ABBREVIATION	DEFINITION	PLAIN LANGUAGE DESCRIPTIONS	UNITS
Heatwave Number	HWN(Tx90)	The number of individual heatwaves that occur each summer (Nov – Mar in the southern hemisphere and May – Sep in northern hemisphere). The months can be adjusted as per study location. 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. Where percentiles are calculated from base period specified by user, TX and TN are maximum and minimum daily temperatures. EHF is excess heat factor. See Perkins and Alexander (2013) for more details.	Number of individual heatwaves	events
Heatwave Frequency	HWF(Tx90)	The number of days that contribute to heatwaves as identified by HWN.	Total number of days that contribute to individual heatwaves	days
Heatwave Duration	HWD(Tx90)	The length of the longest heatwave identified by HWN.	Length of the longest heatwave	days
Heatwave Magnitude	HWM(Tx90)	The mean temperature of all heatwaves identified by HWN.	Average temperature across all individual heatwaves	°C
Heatwave Amplitude	HWA(Tx90)	The peak daily value in the hottest heatwave (defined as the heatwave with highest HWM).	Hottest day of the hottest heatwave	°C
Heatwave Severity	HWS(Tx90)	The sum (in absolute values) of the differences between the temperature values and the percentile threshold. See Spinoni et al (2015)	Severity of the heatwave	°C
Heatwave Intensity	HWI(Tx90)	The ratio of severity to duration	Intensity of the heatwave	no units
Coldwave Number	CWN(Tn10)	The number of individual coldwaves that occur each winter. The months can be adjusted as per study location. A coldwave is defined as 3 or more days where TN < 10th percentile of TN. Where percentiles are calculated from base period specified by user, TN is the minimum daily temperature.	Number of individual coldwaves	events

DESCRIPTION OF THE EXTREME CLIMATE INDICES USED FOR THE ANALYSIS				
NAME	ABBREVIATION	DEFINITION	PLAIN LANGUAGE DESCRIPTIONS	UNITS
Coldwave Frequency	CWF(Tn10)	The number of days that contribute to 'coldwaves'.	Total number of days that contribute to individual coldwaves	days
Coldwave Duration	CWD(Tn10)	The length of the longest 'coldwaves' identified by CWN.	Length of the longest coldwave	days
Coldwave Magnitude	CWM(Tn10)	The mean temperature of all 'coldwaves' identified by CWN	Average temperature across all individual coldwaves	°C
Coldwave Amplitude	CWA(Tn10)	The minimum daily value in the coldest 'coldwave' (defined as the coldwave with lowest CWN).	Coldest day of the coldest coldwave	°C
Coldwave Severity	CWS(Tn10)	The sum (in absolute values) of the differences between the temperature values and the percentile threshold. See Spinoni et al (2015)	Severity of the coldwave	°C
Coldwave Intensity	CWI(Tn10)	The ratio of severity to duration	Intensity of the coldwave	no units

Table 3.11 Overview of daily minimum, maximum and average temperature from MERRA2 data.

OVERVIEW OF DAILY MINIMUM, MAXIMUM AND AVERAGE TEMPERATURE FROM MERRA2 DATA			
TEMPERATURE (IN °C)			
Average maximum	29.97	Average minimum	17.88
Lowest maximum	11.82	Lowest minimum	2.28
Highest maximum	44.92	Highest minimum	29.78

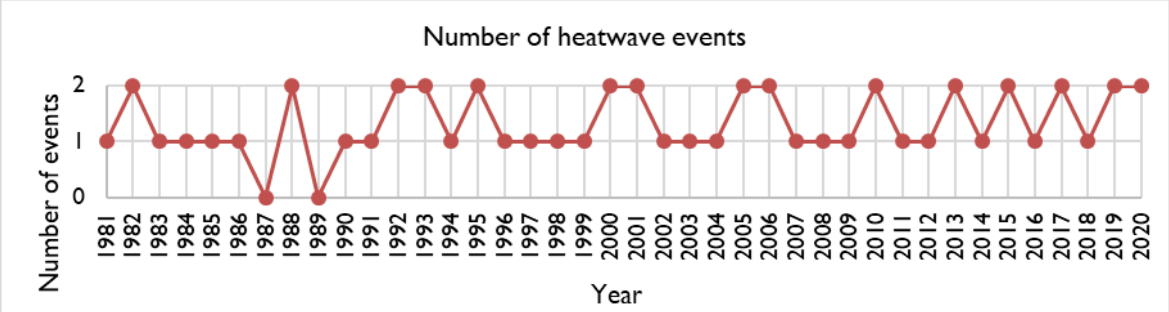


Fig. 3.51 Number of heatwave events (HWN). 1987 and 1989 did not have any heatwave as defined by the climate index.

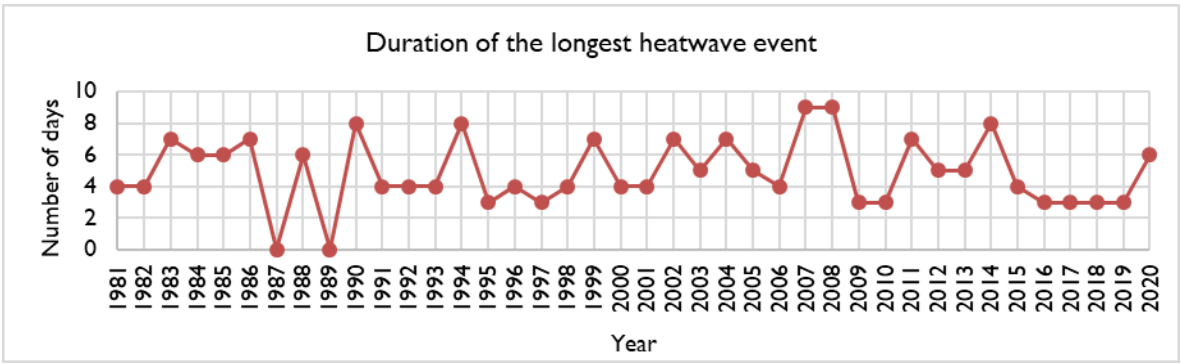


Fig. 3.52 Duration of the longest heatwaves (HWD).

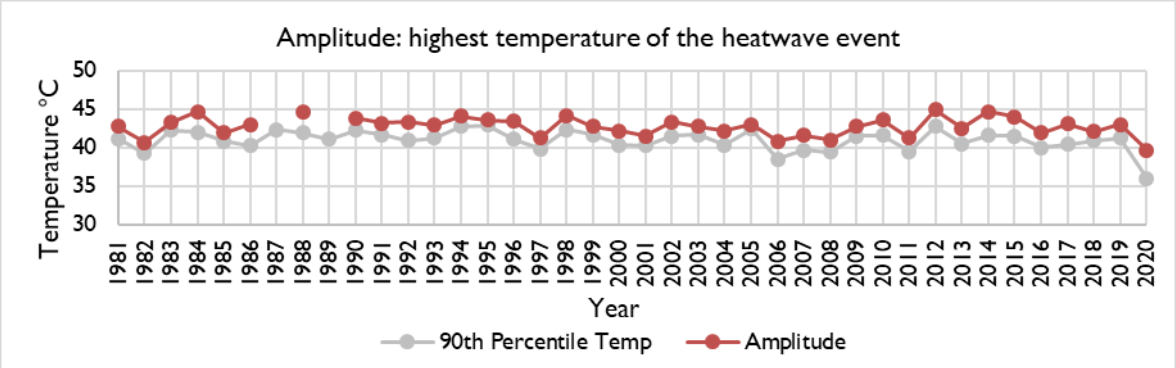


Fig. 3.53 Amplitude of the heatwaves (HWA) along with 90th percentile maximum temperature for the comparison.

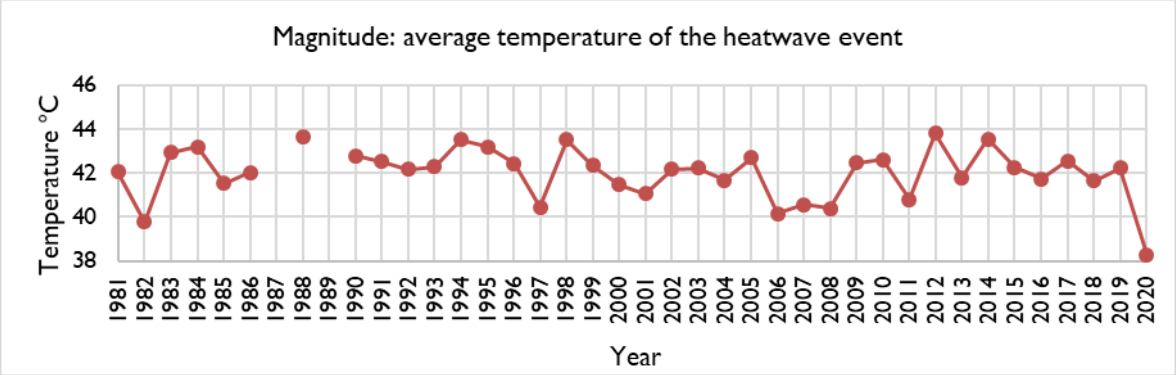


Fig. 3.54 Magnitude of the heatwaves (HWM).

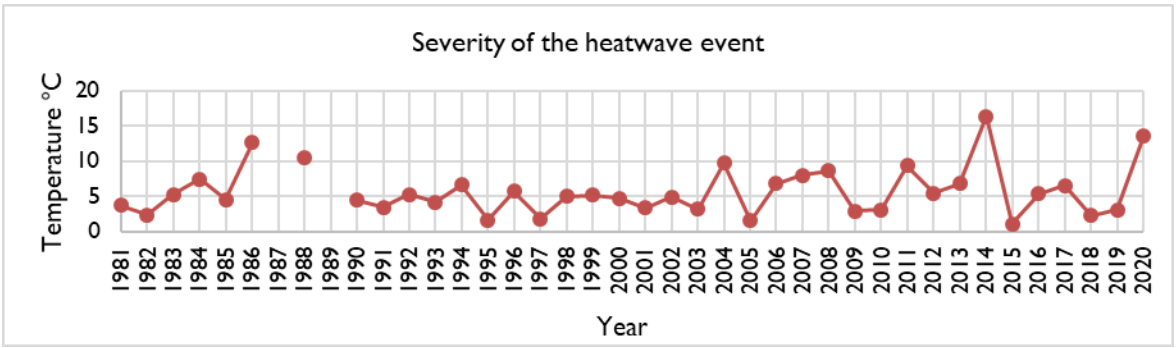


Fig. 3.55 Severity of the heatwaves (HWS).

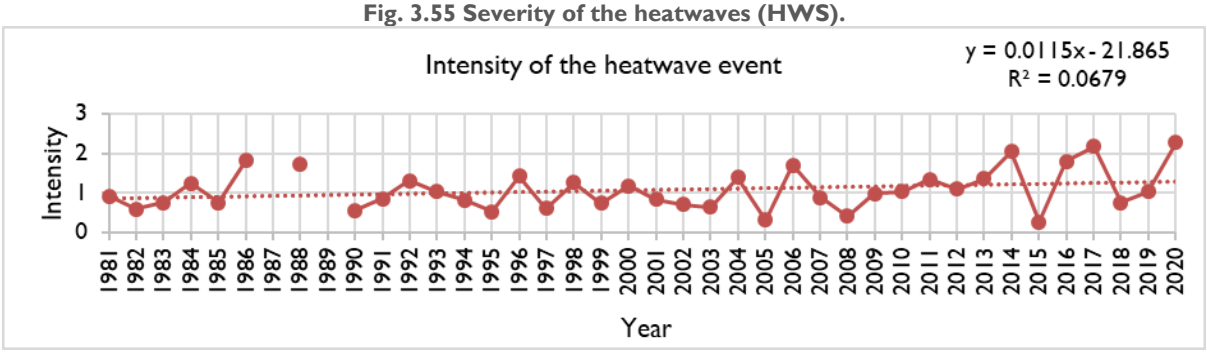


Fig. 3.56 Intensity of the heatwaves (HWI).

Coldwaves pose a more severe threat than heatwaves in the Terai region of the Nepal. There were several human and livestock casualties reported in the local disaster reports. Several reasons could be attributed to this, such as the poor economic condition of the people where they cannot afford warm clothes and blankets. The buildings in the Terai region are well-equipped for the summer but not for the winter temperature. People often burn charcoals and dried cow dungs to heat their rooms with no proper ventilations during nighttime and there are several accidents related to asphyxiation due to such heating habits. Lack of awareness and education also play vital role in such accidents. Most of the deaths due to coldwaves are related to the social vulnerability status rather than the coldwave itself. Coldwaves also occur almost annually in the Godawari municipality except for 1984,1986,1994,1996 and 2020 from the period 1981 to 2020. **Fig. 3.57** shows the increasing trend of coldwaves intensity denoting more severe coldwaves than the past records. **Figs. 3.58-3.62** show the longest coldwave, lowest temperature, magnitude, severity and intensity of coldwaves respectively.

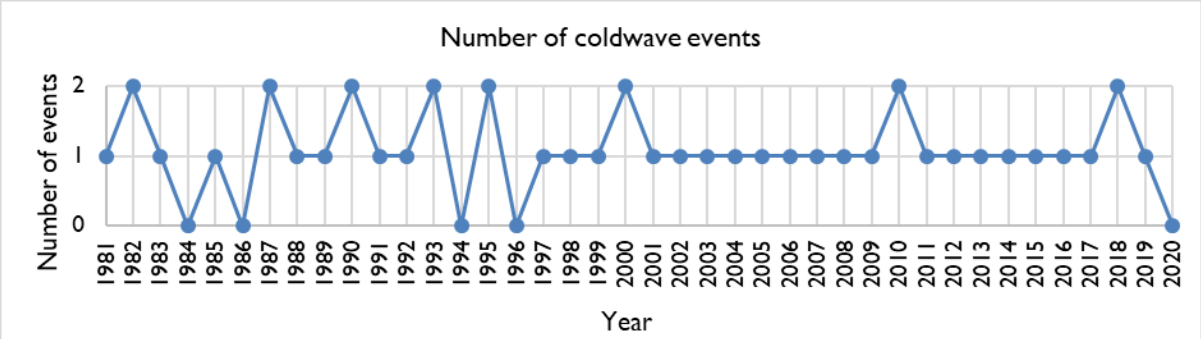


Fig. 3.57 Number of coldwave events (CWN). 1984,1986, 1994,1996 and 2020 did not have coldwaves as defined by the climate index.

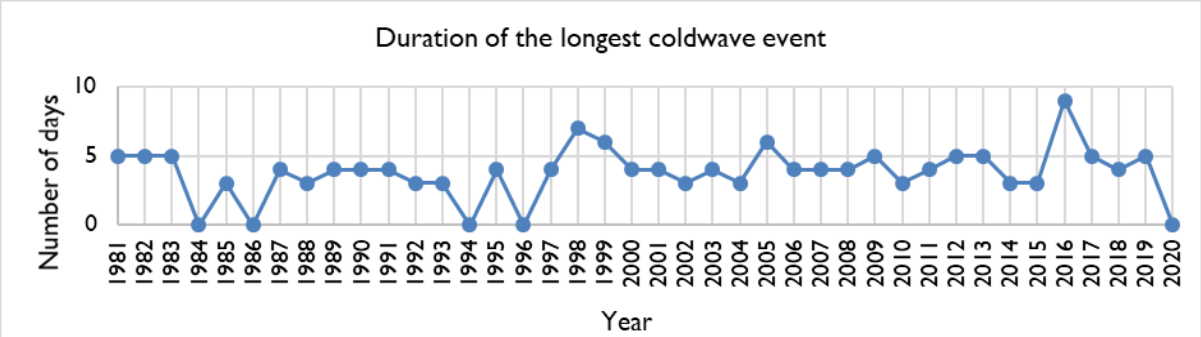


Fig. 3.58 Duration of the longest coldwaves (CWD).

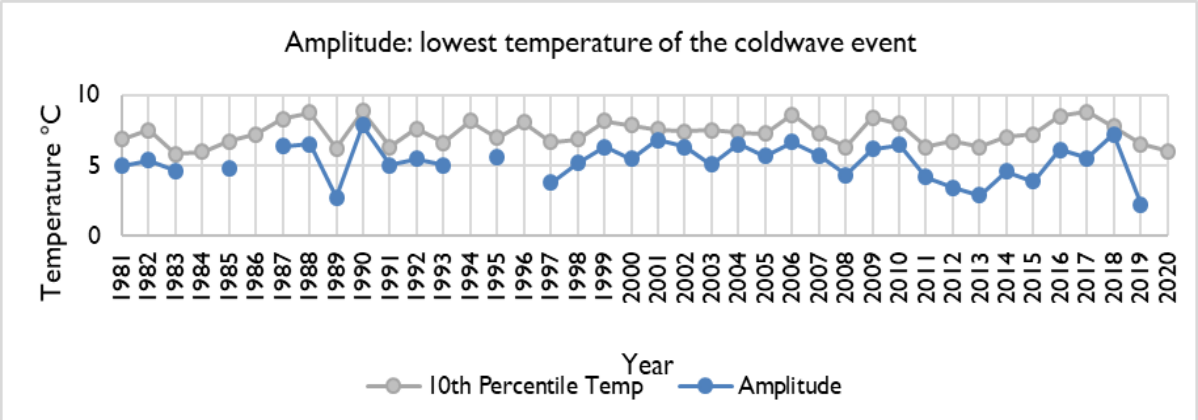


Fig. 3.59 Amplitude of the coldwaves (CWA) along with 10th percentile temperature.

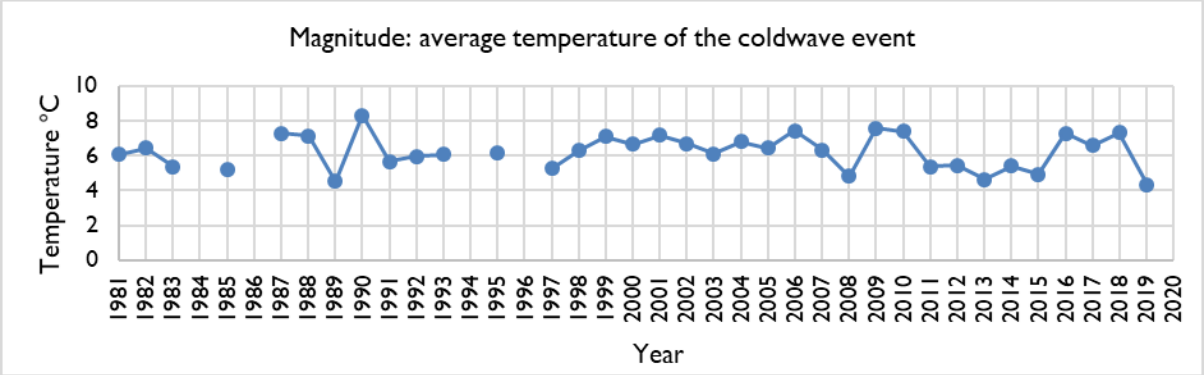


Fig. 3.60 Magnitude of the coldwaves (CWM).

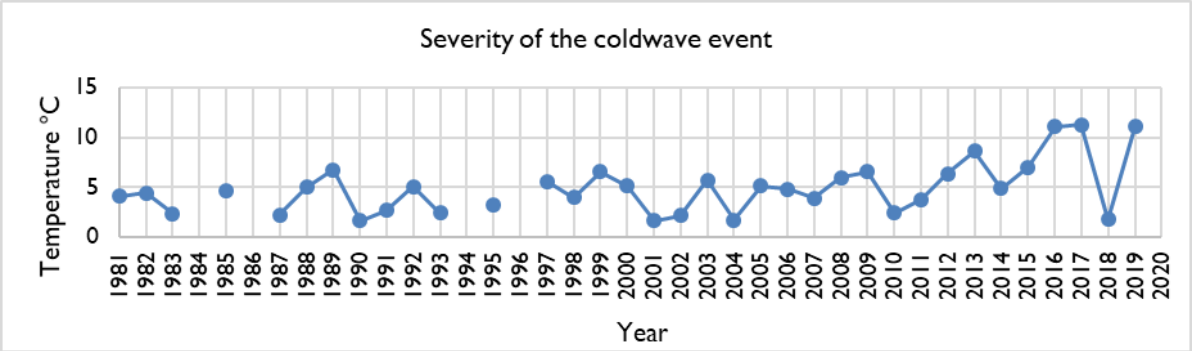


Fig. 3.61 Severity of the coldwaves (CWS).

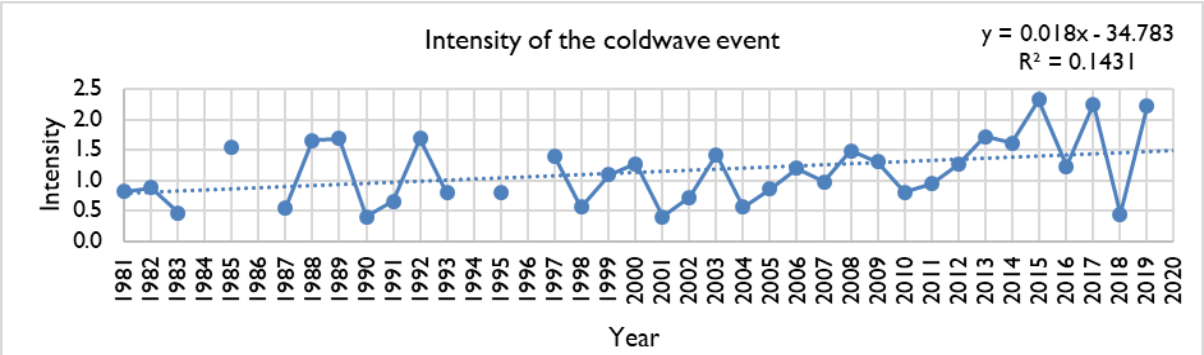


Fig. 3.62 Intensity of the coldwaves (CWI).

3.1.8 SPATIAL PROBABILITY

Spatial probability indicates the chance that a particular location, within one of the three susceptibility classes (high, moderate or low) might be impacted by a hazardous phenomenon (e.g., landslide) within a particular time period (e.g., 10 or 50 years). This is basically the density of hazardous phenomena within a given time period and susceptibility zone. For that the expected area of the phenomena, and the area of the susceptibility class need to be known. The area of the expected phenomena is based on the number of hazardous events from historical records within a particular period (e.g., the last 50 years). Since the historical information is always incomplete, an assumption of higher density values has to be made than the value coming from the historical record. Therefore, we apply a multiplication factor for unknown records. An estimate of the average area for an event also needs to be done.

For landslide, we carried out the calculation per municipality. The following assumptions were made based on expert opinion:

- No events will happen within the low susceptibility zones. Spatial probability is zero in low susceptibility classes.
- The number of the events that happen in the high class is higher than in the moderate class. The percentage of the events that happen in the high class is 75% and in the low class 25%.
- The number of events that happen in a higher return period is more than for an event with a lower return period.
- We consider the typical area of a single event (e.g., a landslide) and then estimate how many would occur in one square kilometer.
- For landslide hazard, we do not have intensity/frequency data, but only susceptibility data, we estimated the spatial probability for three return periods: 20, 50, and 100 years.
- A multiplication factor that will account for the missing information, and also the possible increase in the future.
- The factor was used for scaling the number of events recorded over the whole record, to another time period (e.g., if the data is available for 50 years, and you want to make the calculation for 20 years: 20/50).

Spatial probability must be estimated for other hazard types including floods, earthquakes and windstorm. For example, an earthquake is likely to affect large areas, and the spatial probability that the entire municipality is affected by a given earthquake event with a certain return period can be considered as 1. For floods on the other hand, it is much less likely that the entire modelled flood area would be hit by a single event within a given return period. Optimally, there would be historical evidence of events in the form of maps showing areas affected by extreme events. In the absence of that certain assumptions are made, which are summarized in the **Table 3.12.**

For landslides, a different approach was used. Since for these maps, the intensity could not be modelled for different return periods, the susceptibility classes for these maps were used and estimated how many events, and with what area, would occur in minor, moderate and major triggering events, assuming return periods of 20, 50 and 100 years. The density of the phenomena in the susceptibility classes was taken as the spatial probability values used in the loss calculation. For example, in the case of landslides, we assume that in a major event with a 100-year return period, there would be 5 landslides (with an average area of 8,000 m^2 from landslide inventory) in each 1 km^2 of the zones with high susceptibility and 1 every 2 km^2 in the moderate susceptibility zones (**Table 3.12**).

Table 3.12 Spatial probability values for different hazards with different return periods.

SPATIAL PROBABILITY VALUES FOR DIFFERENT HAZARDS WITH DIFFERENT RETURN PERIODS			
HAZARD TYPE	RETURN PERIOD	SPATIAL PROBABILITY	JUSTIFICATION
Flood	20	0.25	It is estimated that about 25% of the modelled area will experience flooding with every 20-year return period flooding. A flood with a larger return period will also affect a larger area. We estimate that a 40% of the modelled area will be affected by moderate event of 50 years. For an extreme event, that occurs once every hundred years, we estimate that half of the modelled area will be affected.
	50	0.4	
	100	0.5	
Earthquake	All	1	Earthquakes affect relatively large areas. The entire municipality would be affected by an earthquake.
Heatwave Coldwave	All	1	Heatwave/Coldwave will affect larger areas, and the entire district is likely to be affected by a severe temperature extreme event.
Windstorms	All	1	Windstorms are generally events that may affect large areas. Unless the event is a tornado, which affects only a small area but with a larger devastation.

Table 3.13 Spatial probability values for landslides with different return periods.

SPATIAL PROBABILITY VALUES FOR LANDSLIDES WITH DIFFERENT RETURN PERIODS						
HAZARD TYPE	RETURN PERIOD	SUSCEPTIBILITY CLASS	SIZE OF SINGLE EVENT	NUMBER OF EVENTS	PER NUMBER OF KM^2	SPATIAL PROBABILITY
Landslides	20	Low	8000 m^2	0	1	0.00
		Moderate	8000 m^2	1	10	0.0008
		High	8000 m^2	1	2	0.004
	50	Low	8000 m^2	0	1	0.00
		Moderate	8000 m^2	1	5	0.0016
		High	8000 m^2	1	1	0.008
	100	Low	8000 m^2	0	1	0.00
		Moderate	8000 m^2	1	2	0.004
		High	8000 m^2	5	1	0.04

3.1.9 COMBINED HAZARD MAP

A combined hazard map was generated in which the various hazard types are combined in order to show the areas which have the highest levels of combined hazard. The Spatial Multi-Criteria approach was used in which we developed a criteria tree with all hazard maps. The weights were assigned to the hazard classes (high hazard = 1, moderate hazard = 0.5, low hazard and no hazard = 0). The maps of the different return periods were also weighted, with events with higher return periods having higher values than lower return periods. The individual hazards were also weighted with respect to their severity, with earthquakes and flood having the highest weights. Animal attacks and fire were given lowest weights because of their limited impacts in the municipality. **Table 3.14** represents the summary of hazard assessment together with its necessary input and out put parameters. The summary table also explains the softwares used to model each hazards accordingly.

The SMCE criteria tree is shown in **Fig. 3.63**. The composite index map with High, Moderate and Low classes is shown in the **Fig. 3.64**. It is clear from this figure that the northern part of the municipality where there are Siwalik hills and along the river channels are highly hazardous zones. Therefore, proper land use planning needs to adopted especially in these areas.

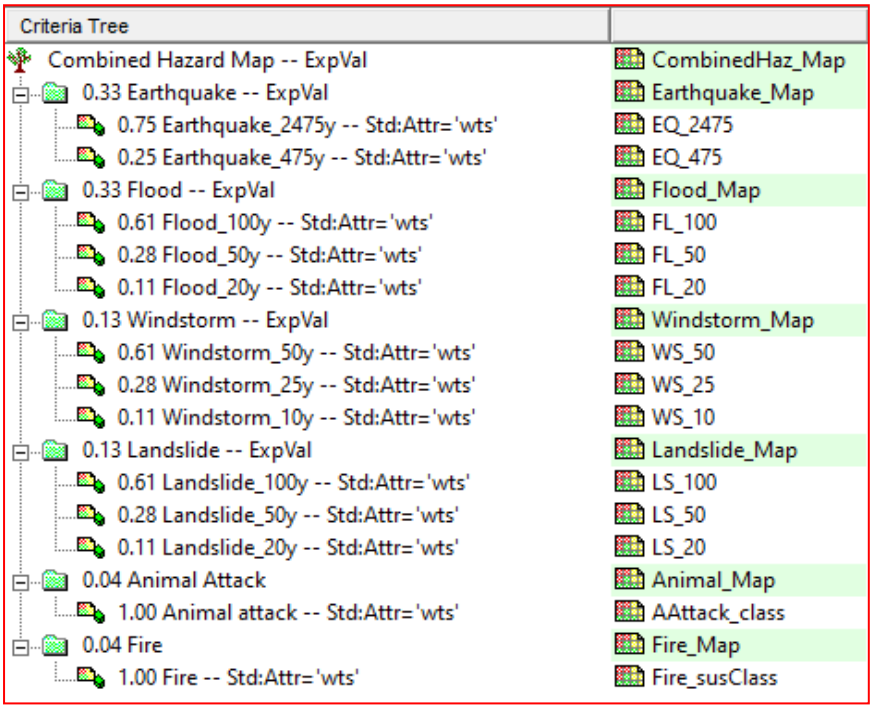


Fig. 3.63 Criteria trees for Spatial Multi-criteria analysis for combined hazard map.

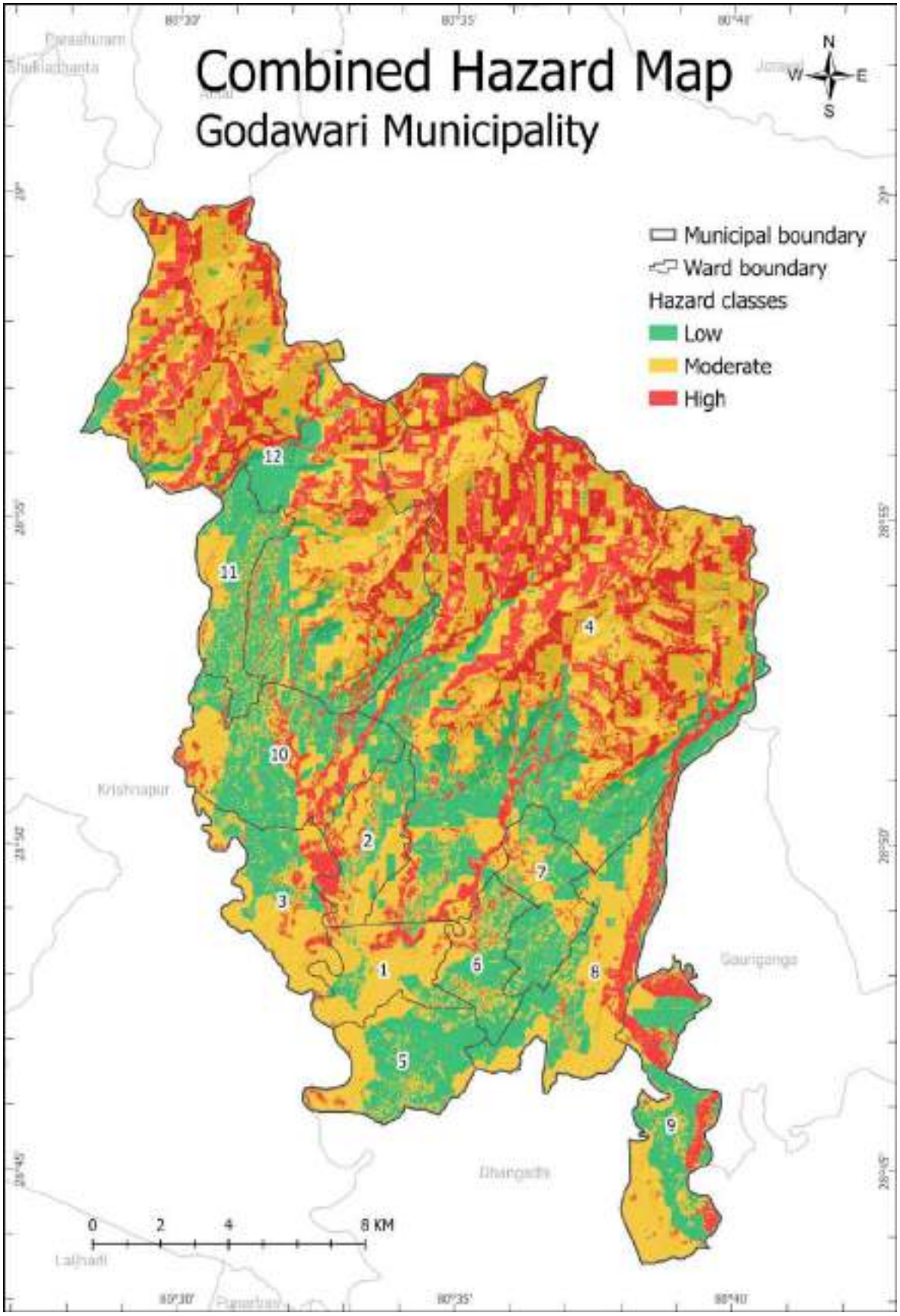


Fig. 3.64 Combined hazard map of Godawari municipality.

Table 3.14 Summary of hazard assessment with input and output data.

SUMMARY OF HAZARD ASSESSMENT WITH INPUT AND OUTPUT DATA				
S.N.	HAZARDS	INPUT DATASETS		SOFTWARES/METHODS
		PRIMARY DATA	SECONDARY DATA	
1	**Earthquake**	• We did not collect primary data as such but we collected information from community based focal group discussions regarding past earthquake incidents, its impacts	• Earthquake catalogue of the region • Fault maps • Earthquake hazard maps with Peak ground acceleration for different return periods.	• Gutenberg-Richter relation • Use some existing Hazard maps as earthquake are not local phenomenon • Use existing peak ground acceleration maps from other projects and not do micro zonation. • ArcPro (for visualization)
2	**Flood**	• Satellite images • River cross section measurements. • Building footprints data digitized from satellite images • Soil types, Soil depth in the area • Soil characteristics measured in field • Points in terrain with height and date of flooding	• Digital Elevation Model • Landover/Land use map • Intensity-Duration-Frequency (IDF) curves • Soil physical parameters such as porosity, texture, infiltration rate, moisture content • Soil depth • Geotechnical properties: cohesion, internal friction angle (to include sediment interaction with flood water) • River discharge data	• OpenLISEM Hazard (physically based modelling) • ArcPro (for visualization)
3	**Landslide**	• Field based survey to prepare Landslide inventory (active, dormant) and identify Landslide susceptible area and sites (EQ triggered; precipitation triggered) • Collect data on Soil erosion and Gully formation areas • Geotechnical Investigation to identify to potential landslide	• Digital Elevation Model • High-resolution satellite image • Location of occurrence of landslides –Historical information through participatory discussions and existing local disaster reports • Geological data • Seismic data such as Fault maps, PGA map • Average Annual Rainfall data • Land use/land cover • Road, water bodies data	• ILWIS (Spatial Multi Criteria Evaluation, statistical and heuristic modelling) • ArcPro (for visualization)
4	**Fire**	• Field based survey to collect location data of gas stations, fuel pumps and other sources of potential hazard (industries, toxic, inflammable and chemical storage, petroleum storage, liquid petroleum gas storage/depot) etc. • Historical data on which buildings and areas have been affected by fire. • Building level use of different materials e.g.: LPG gap, electricity types etc. • Characteristics of building frames e.g.: roof types etc. (This information comes from a building survey such as construction type, roof type, no. of floors, what kind of cooking options do they use and define which area are more hazardous)	• Incident reports from local authorities	• ILWIS (GIS operations, buffering and Spatial Multi-Criteria Evaluation) • ArcPro (for visualization)

SUMMARY OF HAZARD ASSESSMENT WITH INPUT AND OUTPUT DATA				
S.N.	HAZARDS	INPUT DATASETS		SOFTWARES/METHODS
		PRIMARY DATA	SECONDARY DATA	
5	**Windstorm**	• Identify historical times of major and minor windstorm through community consultations and participatory meetings	• Global models	• Excel (Frequency analysis) • Use of wind data from Global Wind Atlas (GWA) • ArcPro (for visualization)
6	**Animal Attacks\Terror**	• Field-based data collection, Community consultation, VCA workshop • Identification of the potential animal attack sources such as forests patches, tree cluster areas, water bodies etc.	• Incident reports from local authorities	• ILWIS (GIS operations, buffering and Spatial Multi-Criteria Evaluation) • ArcPro (for visualization)
7	**Climate extremes (Heatwave\Coldwave)**	• Satellite data for the temperature (maximum and minimum) • Meteorological station data	• Incident reports from the local disaster reports and literature	• Climpact and Python (Climdex indices) • Excel (Extreme value analysis)
8	**Liquefaction** (Not used for risk assessment)	• Field survey for geotechnical parameters, granulometry, plasticity of the soil, age of sediments, density, depth of water table	• Geological data • Soil classification data • Strength of ground motion during earthquake from literature	• Expert based analysis

3.2 ELEMENTS AT RISK ASSESSMENT

Elements-at-risk or *assets* are generic terms that include all objects and activities that might be exposed to hazards, either directly or indirectly. Buildings, facilities, transportation, people, livestock, economic activities, public services, and environment are some examples of elements-at-risk that are critical when they are exposed to a particular type of hazard. All elements-at-risk have a "value", which can be expressed in terms of monetary value, number of persons affected, number of areas affected or in less quantifiable units such as cultural importance or environmental quality. This chapter describes the elements-at-risk including buildings, population linked to the building footprints, agriculture, and roads.

3.2.1 BUILDING FOOTPRINTS

Buildings and built-up areas are important components in multi-hazard risk assessment. Building footprints were digitized in the GIS software and the information regarding each building such as spatial location, functional uses, construction types, construction materials, roof types, number of floors, population, owner descriptions were collected in the field survey. The building footprints were classified based on the construction types and functional uses for further simplification and to link them with their vulnerability values as shown in **Table 3.15**.

Fig. 3.65 shows the types of buildings in the Godawari Municipality based on the construction types along with its codes. The construction types were classified based on the dominance of the buildings in the municipality. **Annex II** and **Annex III** show the number of buildings of different typologies collected during building footprint survey and their reclassification respectively. **Annex IV** shows the building footprint questionnaire. However, several questions in the questionnaire were not addressed because of various reasons. Because the survey was carried out during COVID-19 situation, there was

minimal contact with the household owners, so the surveyors had to estimate the details by visual interpretation. Other problems were that the digitized building footprint were not automatically connected to the attributes collected in the field. The information was not spatially aligned with the building polygons in the field and it took manual effort to align the information which took quite a long time during the project period. There were several errors found during the spatial alignment of the information to building footprint. For example, we found five buildings in an area of 100 m^2, which was questionable so the total number of buildings might vary while analyzing per ward. **Annex V** shows the number of building types combined with floors per ward in Godawari Municipality. The following pages show the maps of elements-at-risk of Godawari Municipality. (**Figs. 3.65-3.70**).

Table 3.15 Classification of building footprints based on the occupancy type & construction types with floors.

CLASSIFICATION OF BUILDING FOOTPRINTS BASED ON THE OCCUPANCY TYPE & CONSTRUCTION TYPES WITH FLOORS				
OCCUPANCY/ PRIMARY FUNCTION TYPE	CONSTRUCTION TYPES	CODE	FLOORS	CODE
Residential	Bamboo wood with mud/wood	BMW	1 (Single-storied)	SS
Institutional	Frame structure with cement	RCC	>1 (Multi-storied)	MS
Educational	Loadbearing with cement	LBC		
Governance	Loadbearing with mud	LBM		
Religious/Culture	Others	OTH		
Health				
Industrial				
Commercial				
Public amenities: Toilet, Park, Bus stands				

Fig. 3.65 Types of buildings based on the construction type (1: BMW, 2: LBC, 3: RCC, 4: LBM, 5: OTH).

3.2.2 POPULATION

Population is the most important component of the elements-at-risk. Population data was collected in the field survey which were linked to the building footprints. Gender information was available in the

building footprint survey. Age distribution information was only available through household survey, however the data was obtained very late. The building footprint survey had enough information to carry out the risk assessment. Also, there was no clear differentiation whether the population data was collected for daytime or nighttime. It depends on the hazard type to consider the number of people at which time period. For earthquakes a clear daytime and nighttime scenario should have been used. For other hazards that are not instantaneous, that information might not be needed. Therefore, the population was assumed to be a nighttime population for our analysis.

3.2.3 AGRICULTURAL AREA

Agricultural area is another major component of elements-at-risk since it is associated with the livelihood of the people in the municipalities. The cultivated land was extracted from the recent landcover map developed within this project. Since, there were no data available on the further classification of the crops in the agriculture landcover type, simple agriculture landcover was used for the risk assessment. Besides no data were available on livestock distribution. Exposure, loss and risk of agricultural area was calculated in hectares.

3.2.4 ROADS

Roads are also important elements-at-risk as it affects the transportation and daily livelihood routine. Road data was digitized from the satellite images. It was classified as per surface type: Black top road, Cement Road, Earthen Road, Gravel Road and Stone paved.

Table 3.16 shows the summary of ward wise number of buildings, population, agricultural area and roads in Godawari Municipality.

Table 3.16 Summary of elements-at-risk in Godawari Municipality.

SUMMARY OF ELEMENTS-AT-RISK IN GODAWARI MUNICIPALITY				
WARD	NUMBER OF BUILDINGS	NUMBER OF PEOPLE	AGRICULTURAL AREA (HECTARES)	ROAD(KM)
W1	3552	14049	298.39	50.6
W2	3055	14577	281.99	52.8
W3	2748	12861	244.61	41.67
W4	2810	12325	1035.77	98.39
W5	2101	9283	756.47	51.07
W6	1737	9869	492.23	29.4
W7	1142	6838	458.48	29.25
W8	2174	9816	682.85	37.34
W9	2253	9525	702.9	48.25
W10	2318	10507	554.52	33.92
W11	1264	6405	564.88	40.02
W12	1422	7267	598.1	37.01
Total	**26576**	**123322**	**6671.19**	**549.72**

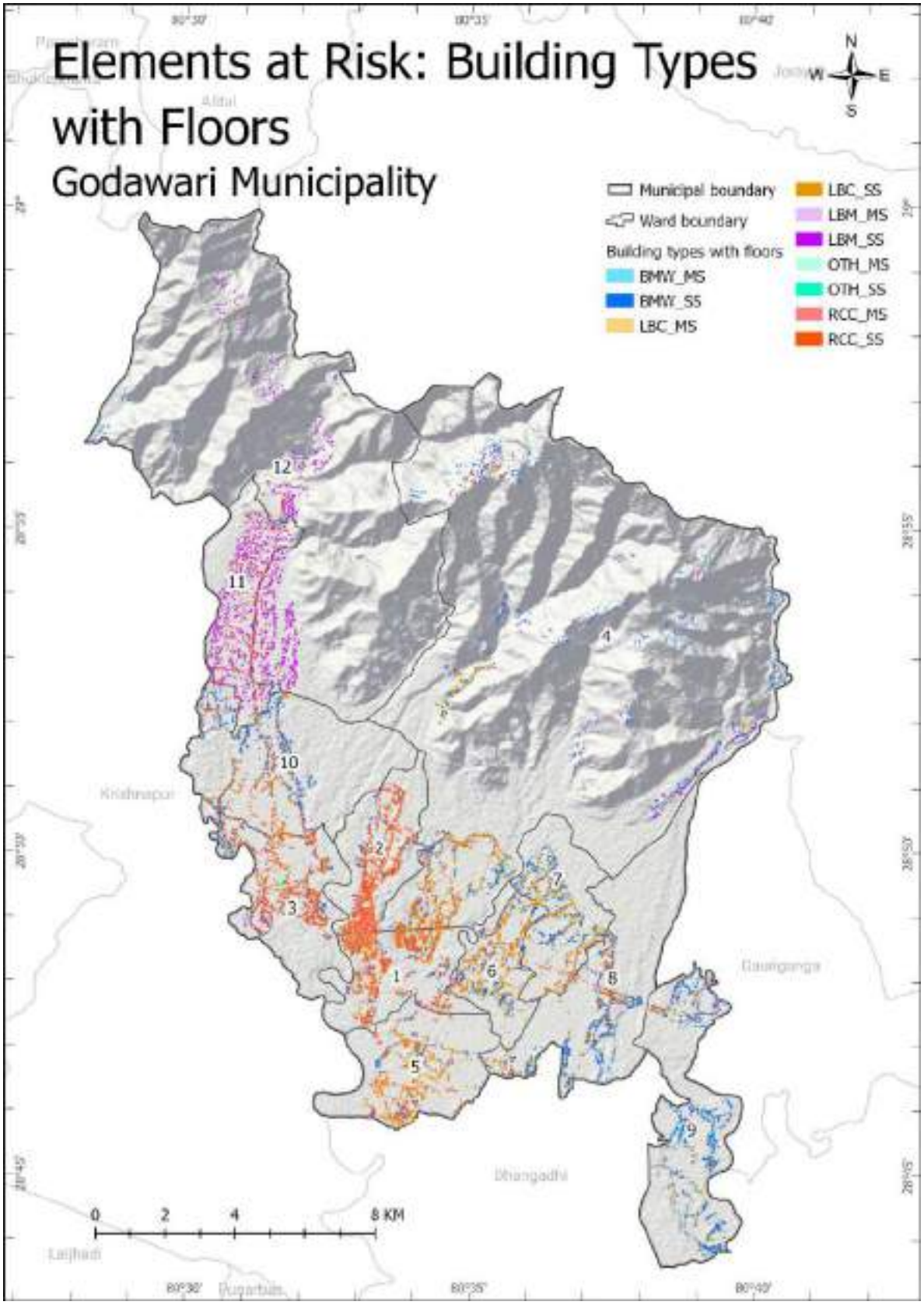


Fig. 3.66 Building footprints map based on construction type with floors.

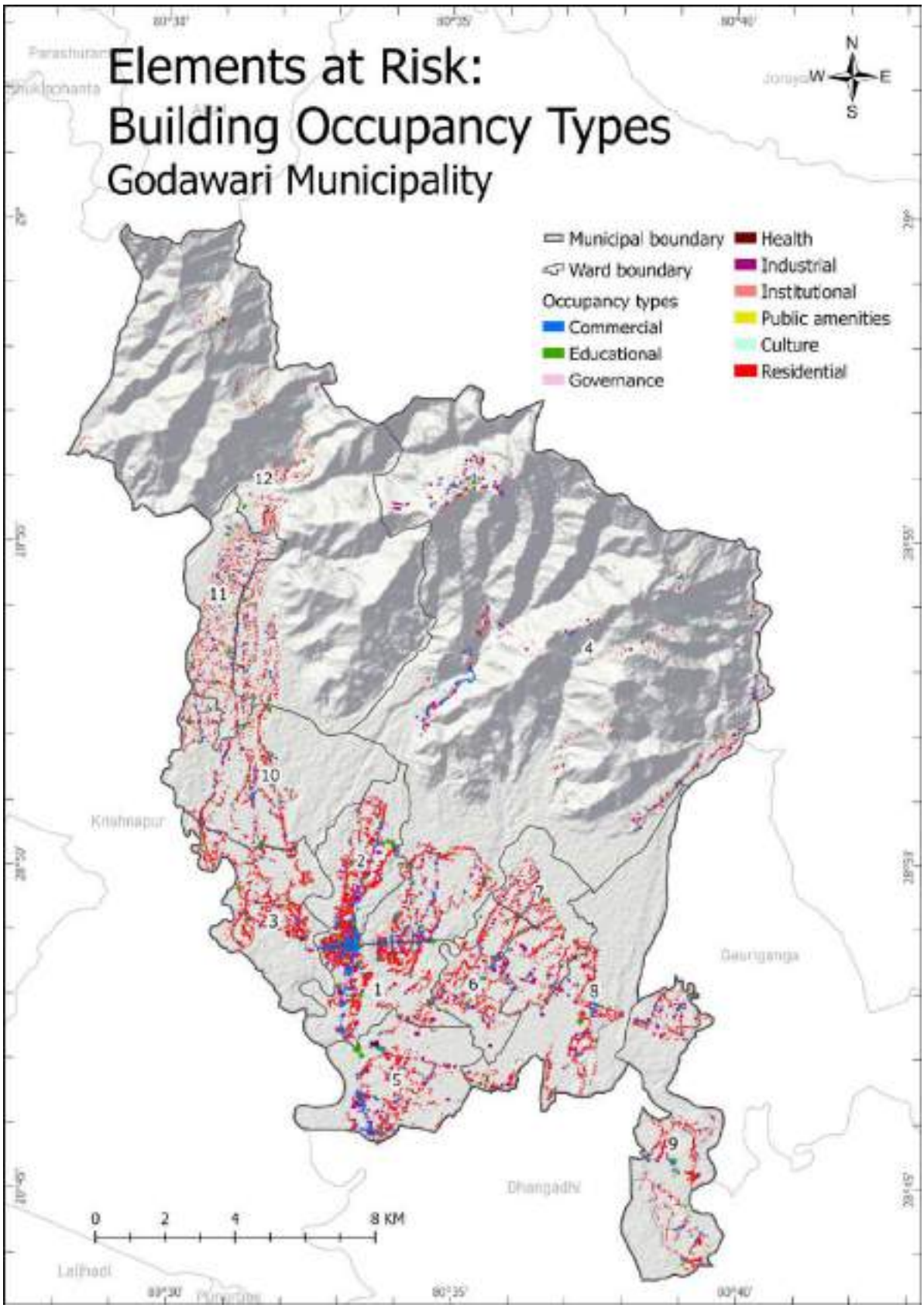


Fig. 3.67 Building footprints map based on occupancy types.

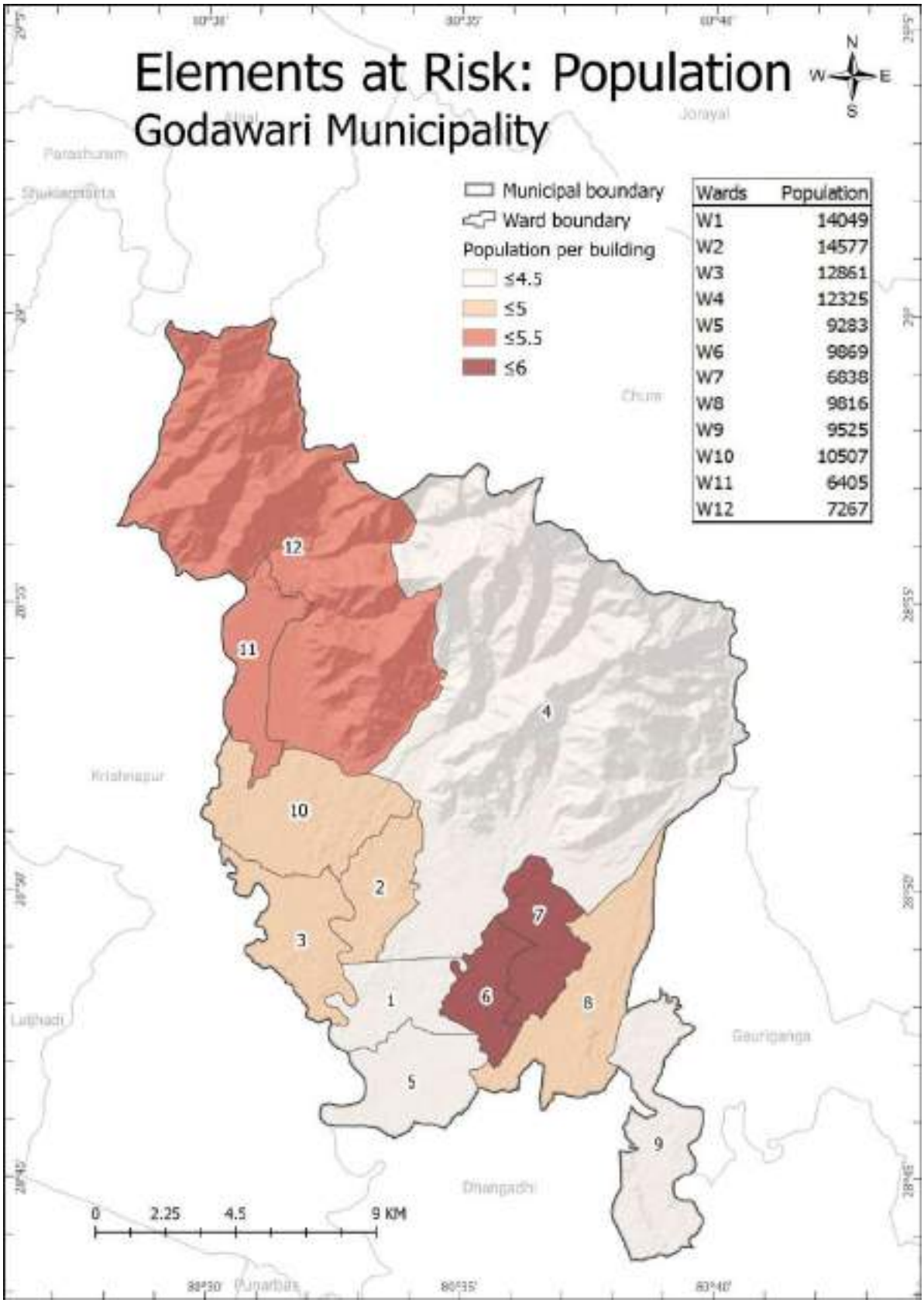


Fig. 3.68 Population map of Godawari Municipality.

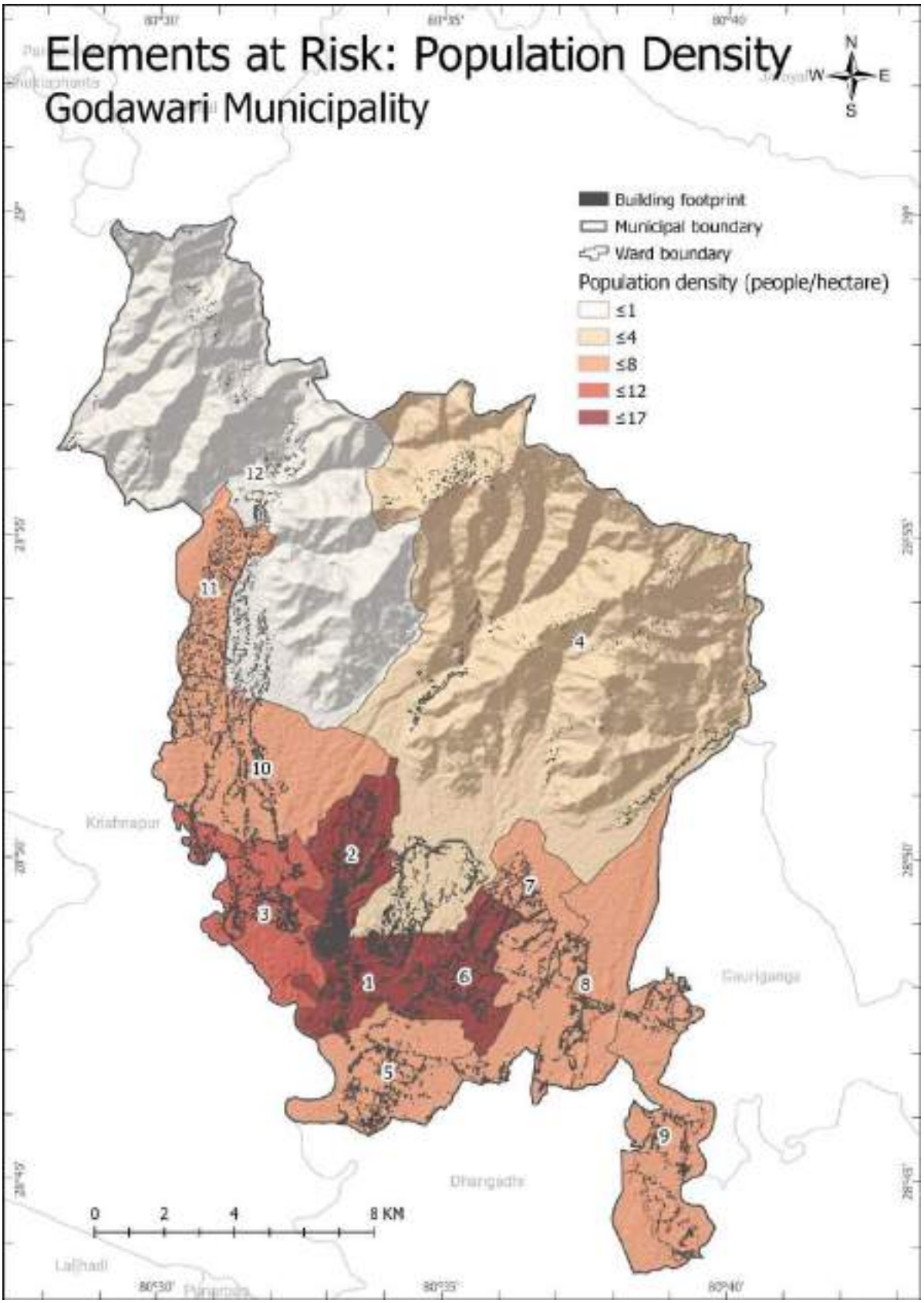


Fig. 3.69 Population density map of Godawari Municipality

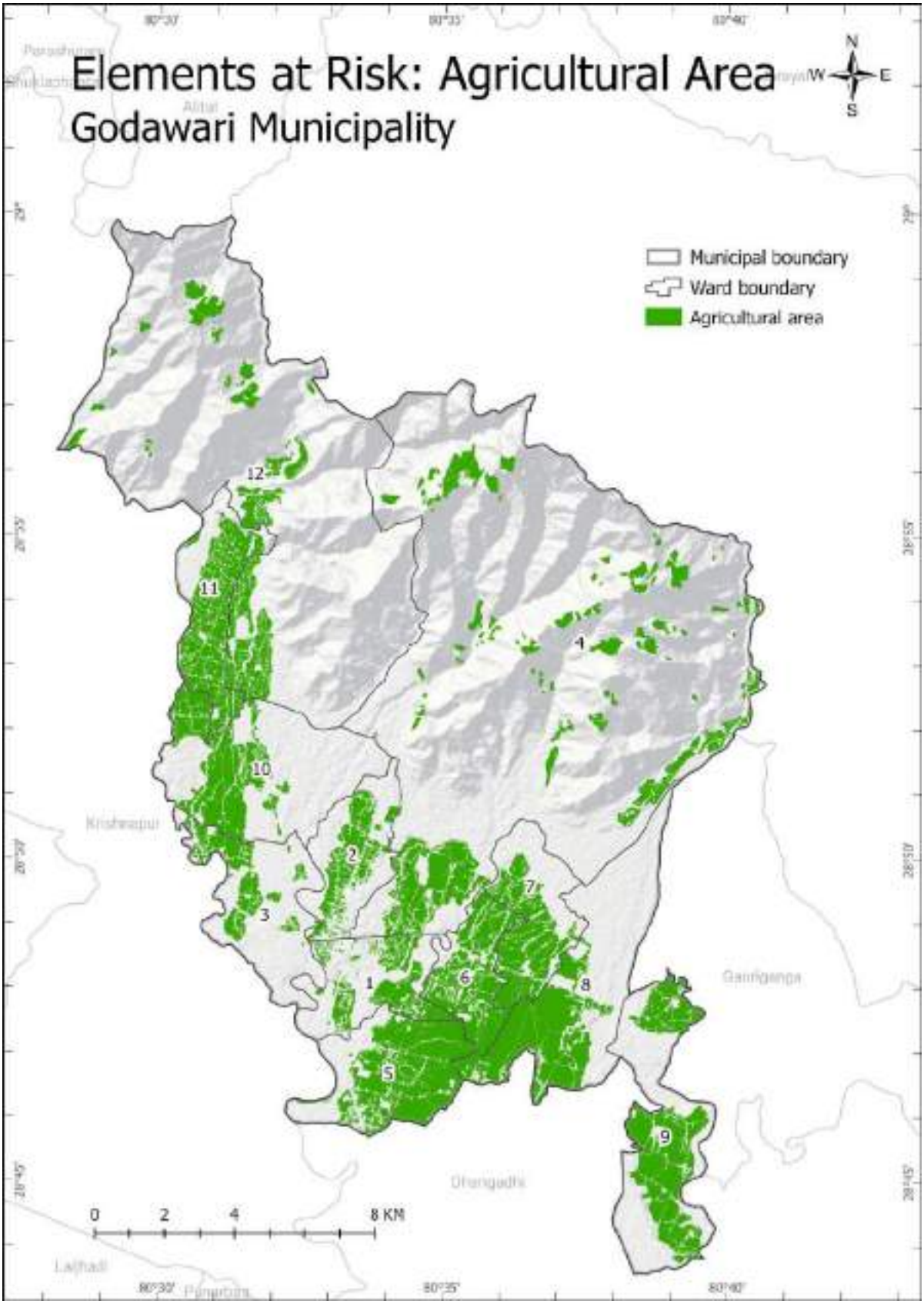


Fig. 3.70 Agricultural map of Godawari Municipality.

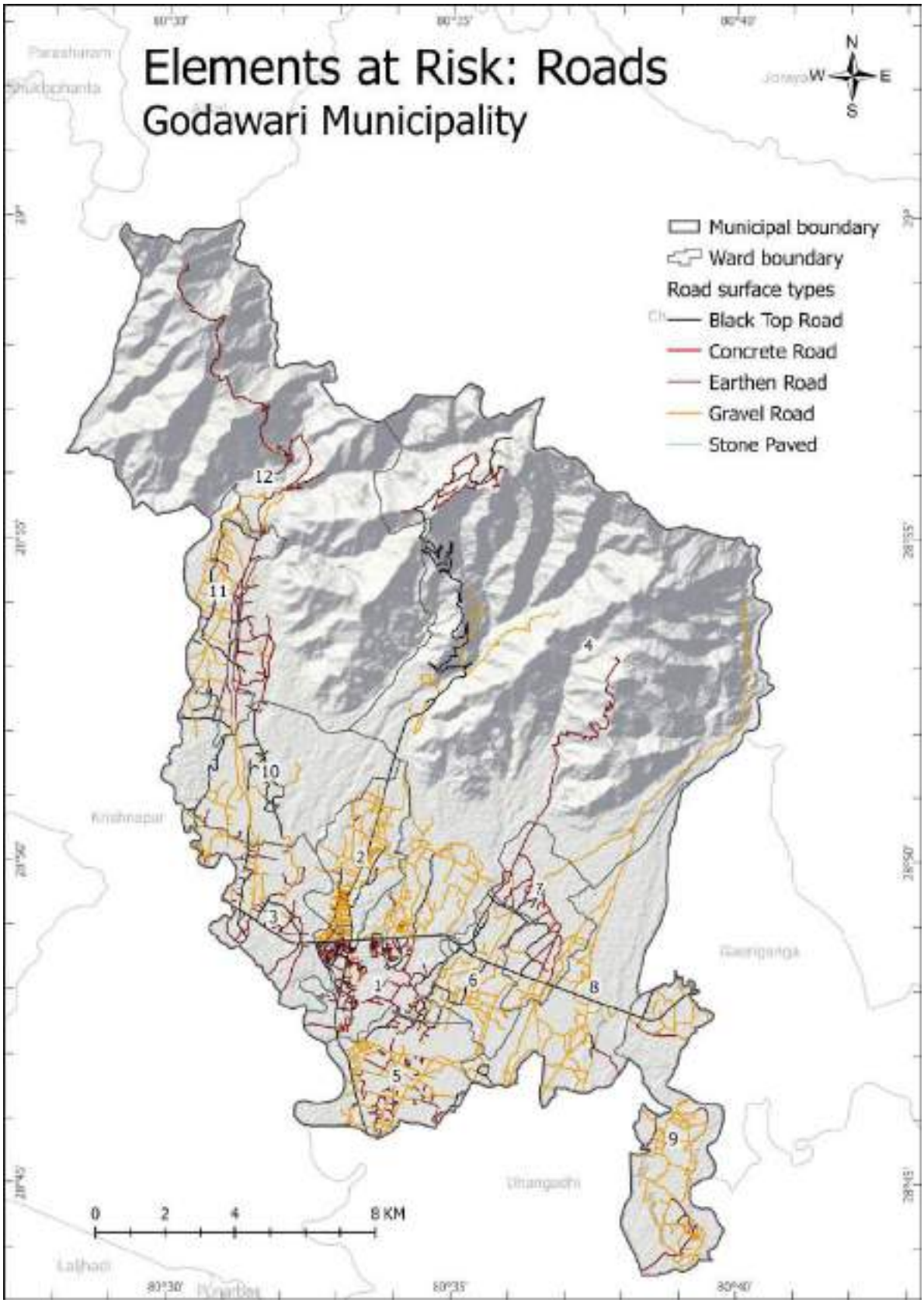


Fig. 3.71 Road map of Godawari Municipality.

3.3 EXPOSURE ASSESSMENT

Exposure is one of the most important components of the multi-hazard risk assessment. It indicates the degree to which the elements at risk are exposed to a particular hazard type and class. The degree of exposure is measured based on the spatial interaction between the element-at-risk and the hazard classes.

Exposure is highly dynamic, varying across temporal and spatial scales. It evolves over time as a result of changes of elements-at-risk often due to land use changes, unplanned urbanization, demographic changes, modifications in building practice and other socio-economic, institutional and environmental factors (World Bank, GFDRR, 2014). It can be characterized at different spatial scales, depending on the basic spatial unit at which the analysis is carried out, for example based on the administrative level. It also covers several dimensions such as physical (e.g., building and infrastructure), social (e.g., humans and communities) and economic (JRC, 2017). In this project, exposure analysis was carried out for the four types of hazards, for which classified hazard maps have been prepared, including flood, earthquake, landslide and windstorm. Depending on the hazard type, the hazard analysis was conducted for different hazard frequencies (return periods). The element-at-risk considered here, subject to the relevant hazard type, were building footprints (number of different types of buildings), population (number of people ion buildings), roads (length of roads in kilometers) and agriculture areas (total areas of agriculture in hectares). Not all the combinations of elements-at-risk and hazards were considered relevant and thus, not presented in this section. For example, the exposure of agriculture area to earthquake is irrelevant as ground shaking does not affect the crops directly. The analysis was conducted at the ward level for the final output. The exposure was calculated using a script in ILWIS GIS software with the following procedure:

- rasterize the elements-at-risk maps using proper georeferencing that matches with the hazard layers;
- overlay the raster maps with hazard intensity maps classified into classes such as Very Low (VL), Low (L), Moderate (M), High (H) and Very High (VH) and having certain return periods. This gives the joint frequency table (also called cross table) containing all the possible combinations of the exposure maps;
- joining the combined exposure map values with the administrative units (ward) to calculate the physical units (number, area, length) of exposed elements-at-risks per ward.

The exposure summary of different elements-at-risk to the major hazards (earthquake, flood, landslide, windstorm) in Godawari municipality are shown in the following section. The hazards of the highest return period or the worst case was used for the exposure summary. Only relevant hazards-elements at risk combination were used. **Figs. 3.72-3.75** represent the hazards to elements such as building, population, agriculture and road respectively.

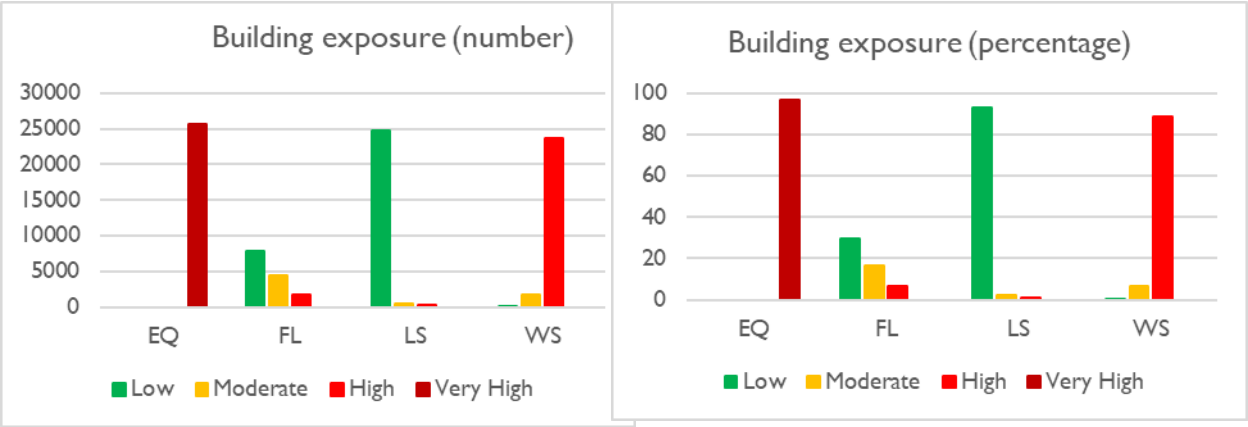


Fig. 3.72 Summary of buildings exposed to different hazards in number (top) and percentage (bottom)

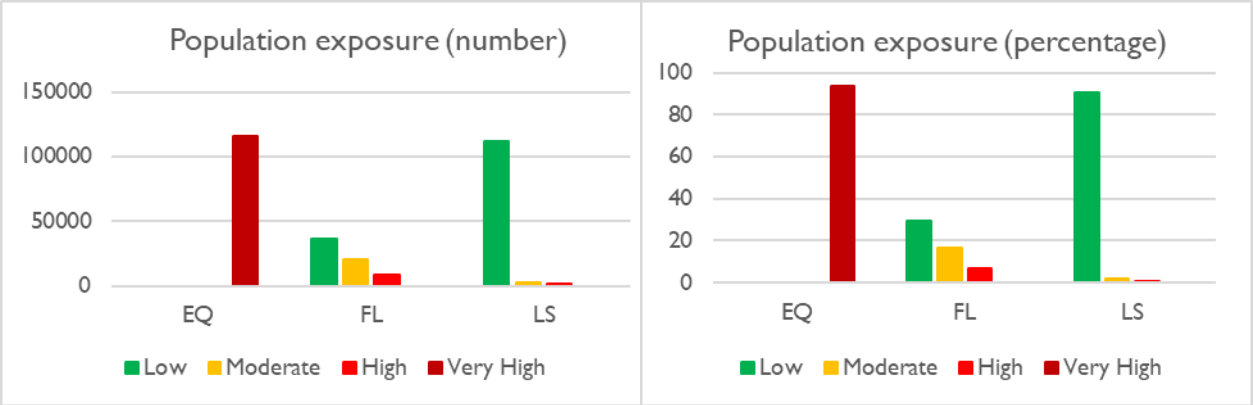


Fig. 3.73 Summary of population exposed to different hazards in number and percentage.

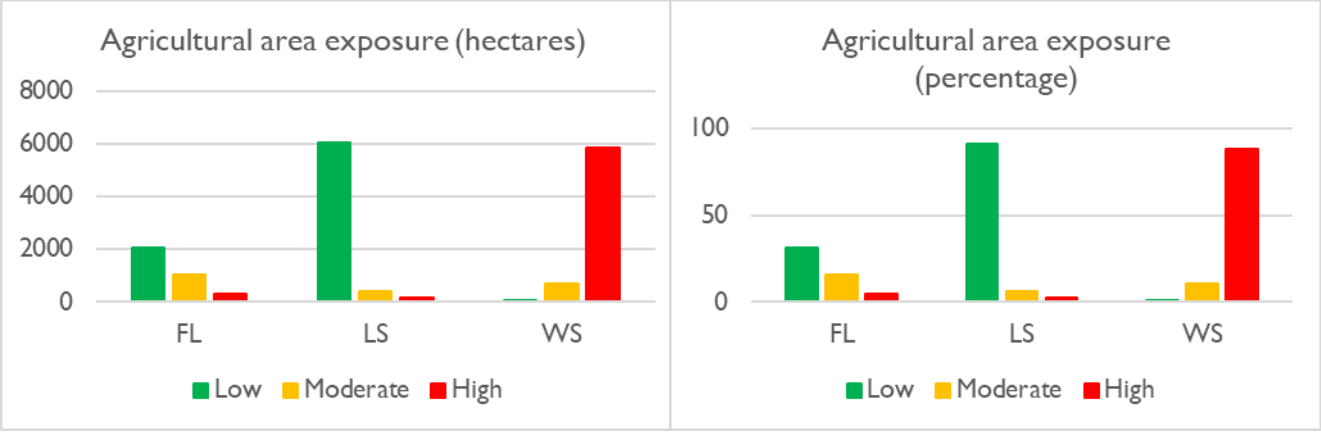


Fig. 3.74 Summary of agricultural land exposed to different hazards in hectares and percentage.

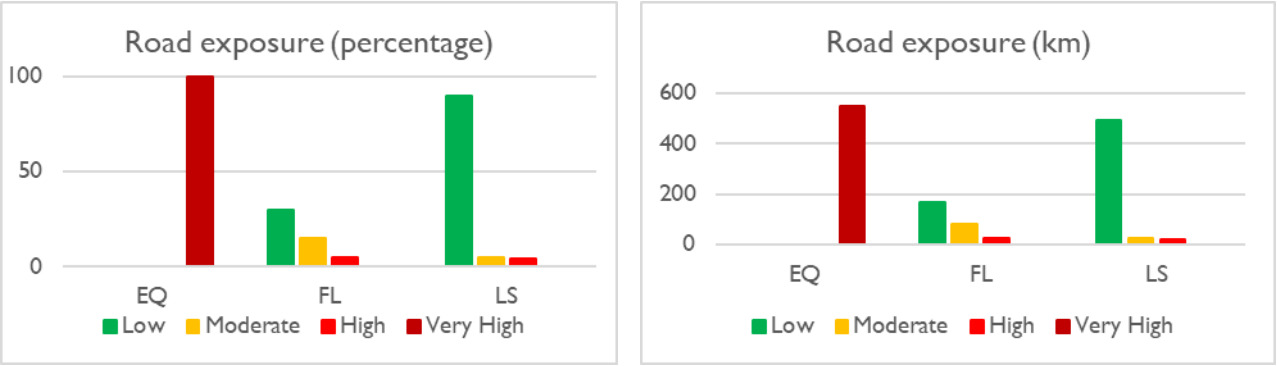


Fig. 3.75 Summary of roads exposed to different hazards in kilometers and percentage.

It is difficult to compare the exposure of elements-at risk to different hazards because the intensity classes vary among the hazard types, and also the exposure varies among the different frequency classes. Nevertheless, some conclusions can be drawn with respect to the exposure: Earthquake exposure is very high in Godawari Municipality. The earthquake hazard maps of 475 and 2475 years return period are expected to result in very high levels of earthquake acceleration in the area, and all buildings irrespective of their construction types would be affected. Wooden and load bearing mud houses will be completely collapsed. A large number of people will be affected. There will be considerable damage in the roads as well due to cracks. However, the frequency of occurrence of a large earthquake is very low. Nevertheless, it is important to consider this in the planning mainly by adhering to the available building codes for earthquake resistant building, and the maintenance of a building permit system by the municipality.

Flooding will have varying water depth in the municipality. The wards at the higher elevation will be less exposed compared to wards in the flood plains of the streams that come out of the Siwaliks. Wards consisting of streams and rivers will be highly exposed by the flood. Flood are probably the major threat to the Godawari municipality as most of the areas are located in flat terrain affecting large area of cultivation and houses without flood protections. However, the current flood hazard maps are probably over aggerating the flood prone areas. Further and more detailed flood modeling would be required.

Landslides are only a threat to the roads and some buildings in the wards in the northern part of Godawari, especially ward 4 and ward 12, since these are located in the Siwalik hills.

Windstorm is another major hazard for agriculture and buildings in the municipality. As we do not have information on the type of agriculture, it is not clear to which extent strong winds may cause crop damage. Also, this requires further analysis. Wind affects the houses especially the roofs since most of the houses in the municipality have roofs made of locally available plants, straws, and GI sheets without strong attachments.

For animal attack and fire, no exposure analysis was carried out, instead qualitative risk assessment was done (See **Section 3.5**). Spatially, the animal attacks would affect the population and agriculture near the forest areas, since the probable attack/terror would initiate from the forests nearby. The exposure analysis of heatwave/coldwave was also not carried out as there will be no spatial variation within the municipality. The spatial distribution of climatic extremes would be in regional scale rather than in municipal scale. Furthermore, the effects of heatwave/coldwave on population depend upon the social vulnerability status of the people. Their age, income and education level play more vital roles than the intensities of the heatwaves/coldwaves.

Annexes V-VIII contains the exposure summary tables of elements-at-risk to different hazards of different return periods per ward in Godawari municipality. **Fig. 3.76** shows an example of ward exposure summary table and the description of its contents.

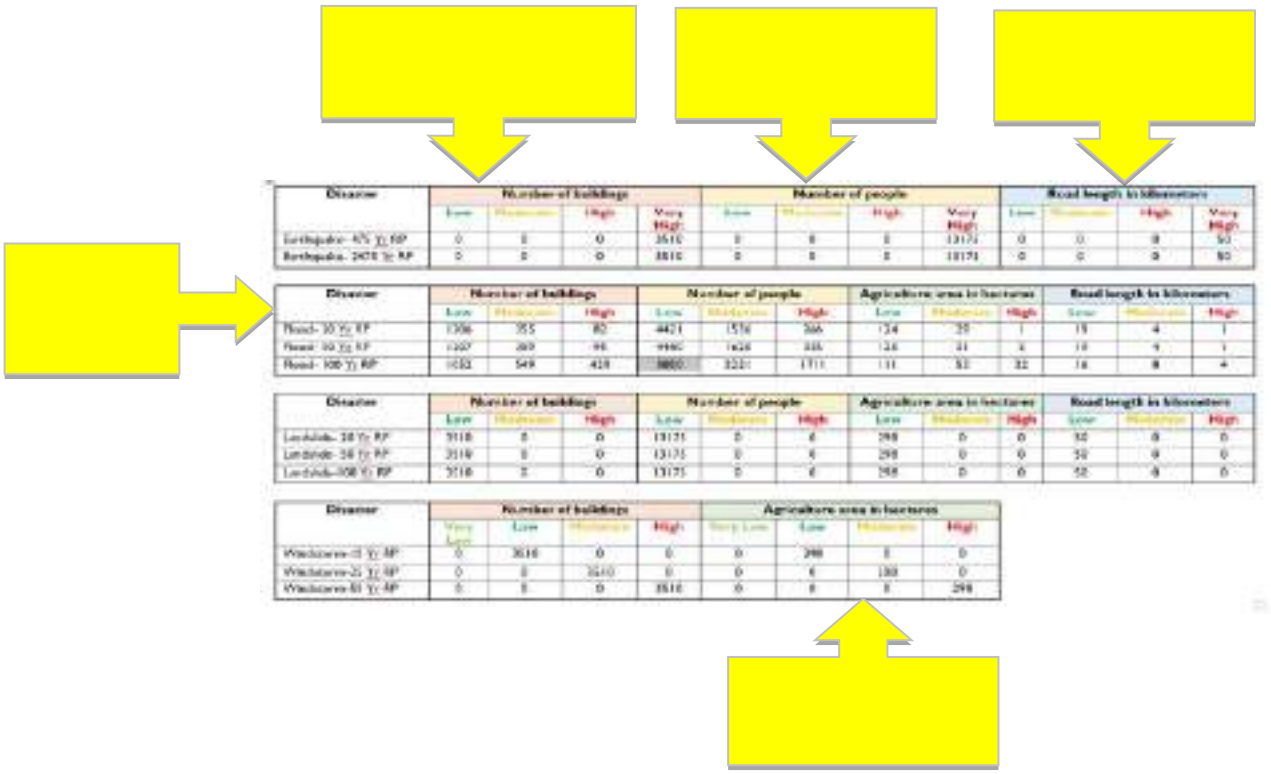


Fig. 3.76 Example of a ward exposure summary table with description of contents.

3.4 MULTISECTORAL VULNERABILITY ASSESSMENT

UN-ISDR (2009) defines vulnerability as *"The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards".*

Vulnerability assessment is one of the most complicated components of multi-hazard risk assessment, since it has wide range of interpretations. Multiple definitions and different conceptual frameworks of vulnerability exist depending upon different academic domains. However, there are some common aspects among all definitions which is:

- *Multi-dimensional:* physical, social, economic, environmental, institutional and human factors define the vulnerability
- *Dynamic:* vulnerability changes over time
- *Scale-dependent:* vulnerability ranges from human to household to community to country resolution
- *Site-specific*: each location might need a separate and unique approach

3.4.1 SOCIAL VULNERABLITY

Vulnerability is a complex approach that has multiple dimensions. The assessments of vulnerability are very essential to examine the underlying socio-economic, institutional, and, to a lesser extent, political and cultural factors, that determine how people cope with the natural environment, climate change, and natural hazards. Socio-economic information is operationalized in impact and vulnerability assessments mainly through the construction of indicators. These indicators aim to describe the socio-economic conditions of the people in case of impacts assessments and to highlight drivers and

determinants of vulnerability and adaptive capacity (UNFCC, 2006). It indicates the social and economic status of the people and their livelihood strategies towards their environment.

Theoretical Approach: There are various theoretical approaches to explain socio-economic vulnerability. One of them is the socioeconomic vulnerability indicator framework (SVIF). This report has applied this SVIF framework which highlighted vulnerability as a complex, multifaceted concept, and has suggested that vulnerability is underpinned and can be defined by three essential components, namely exposure, susceptibility, and resilience. Furthermore, under each of these dimensions, a range of economic, demographic, and social as well as resource capacity and infrastructure aspects were included to capture the broad overall assessment (Jhang et al., 2020) of the Municipality.

Methodology: The vulnerability has different facets and there is no one single method for assessing vulnerability. Ideally, any assessment should adopt a holistic approach to measuring vulnerability. In reality, methods are usually divided into those that consider physical or environmental vulnerability and those that consider socio-economic vulnerability. But, most of the methodological approaches place particular emphasis on the elaboration of risks, risk response strategies, and the livelihood characteristics of households, individuals, and communities. World Bank (2001) experts are gradually converging towards a schema that considers vulnerability to be the result of the aggregation of three distinct components: risk factor, risk management, and risk hazard (Heitzmann, Sudharshan, Canagarajah & Siegel, 2001). It has the following relations:

Risk Factor + Risk Management = Risk Hazard

(External probability) (Ex-ante and ex-post tools) (Negative outcome)

The World Bank (2001) developed a schema based on the basic understanding of dynamics between risk, vulnerability, and Poverty which is shown in flow chart (**Fig. 3.77**).

It is widely agreed that risks are derived from a variety of sources - natural, political, social, economic, etc. Some methodologies like the World Bank also distinguish between the characteristics of the risk, such as frequency, magnitude, intensity, and correlation (FAO, 2003). To find out the vulnerable at the basic level, this research has applied the Household Economy Analysis Approach (HEA) which is designed to illustrate the big picture on vulnerability. For small-scale information, this research has applied the Individual Household Model (IHM) which offers more granular information on vulnerability at the household level (Holzmann et al., 2008). As a tool of data collection, HEA conducts group interviews with representatives of households belonging to different wealth groups and IHM utilizes semi-structured interviews with individual households selected using either random sampling or "whole village" samples. This generates more detail on household-level vulnerability as well as data needed for targeting (Petty & Seaman, 2004 and Moret, 2017). Hence, this research utilizes the individual household to a group of household and community to Municipality level data to study the vulnerable situation of the Municipality.

The social dimension is multi-faceted and cross-cutting. It focuses primarily on aspects of societal organization and collective aspects rather than individuals. However, some assessments also use the 'individual' descriptor to clarify issues of scale and units of analysis (Adger and Kelly, 1999; K. O'Brien et al., 2008). The social dimension includes demography, migration, and displacement, social groups,

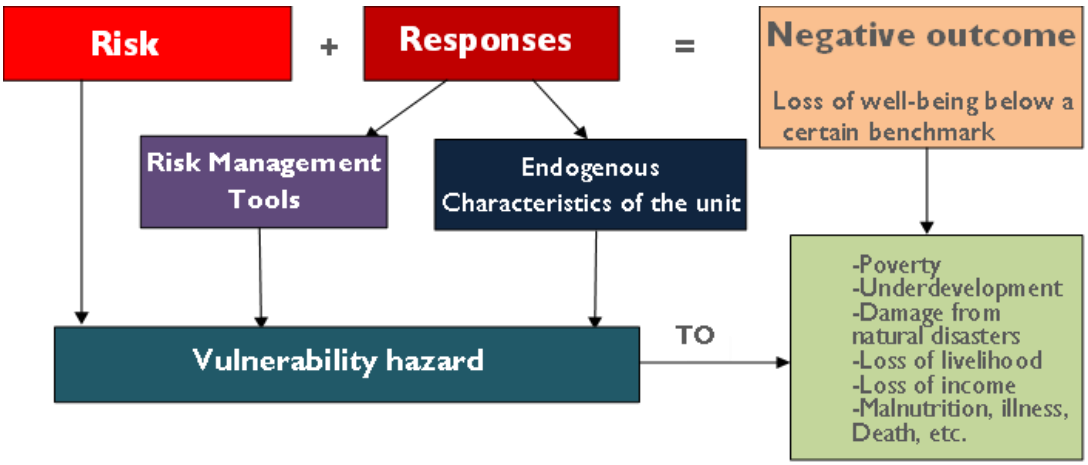


Fig. 3.77 Vulnerability Assessment Tools (Source: FAO, 2003).

education, health and well-being, culture, institutions, and governance aspects (Cardona, et al., 2012). But this research includes only age group, the population outside the home (absentee), differently-abled people, sources of energy, sources of light, drinking water; income, occupation, land ownership, and gender-wise land ownership.

Age Group: In Godawari Municipality, children come first to mind but, from public health and other wellbeing perspectives, one should be quick to add the elderly, the pregnant women, the disabled, and the chronically ill at least. There is more than 9% of children who are directly or indirectly vulnerable situation mainly from the lack of nutritious food, accesses to health and education facilities, traditional cultural practices, etc. Similarly, more than 8% population are 65+ age group who are considered a high-risk group to the impacts of extreme temperatures. They are most vulnerable due to the lack of health facilities, proper care of the family, and lack of other old age-related facilities. Direct and indirect effects of heatwaves and cold waves are associated with an increase in respiratory and cardiovascular diseases and impact the mortality and morbidity of the older age population. The vulnerability of the Municipality is shown in **Fig. 3.78**. It shows that about 13.18% population are high, 17.80% are in moderate and 68.95% population are low vulnerable situation. In the case of age group, the total population of 0-5 is 14,648; among them 2149 highly, 2766 moderately and 9733 populations are low vulnerable condition. From a gender perspective, males are more vulnerable than females in this age group. Similarly, the total population of the 5-15 age group is 27,636; among them 3993 highly, 5431 moderately, and 18,212 low vulnerable. Females are more vulnerable than males in this age group. Likewise, the highest population is in the 15-60 age group. The total population of this age group is 90, 185; among them 11,564 highly, 15,306 moderately, and 63, 315 low vulnerable conditions. In this age group, males are more vulnerable than females. Similarly, the total population of the 65+ age group is 12, 475; among them 1397 highly, 2402 moderately and 8676 are low vulnerable condition. Female is more vulnerable than males in this age group. Similarly, the vulnerability of Ward No. 10 is shown in **Fig. 3.79**. It shows that only 7.06% are high, 35.87% are moderate and 57.07% population are low vulnerable situation in Ward No. 10 of this municipality. GIS data shows that the total population of the age group 0-5 is 878; among them 69 highly, 336 moderately, and 473 low vulnerable situations. Similarly, 1846 is the total population of the 5-15 age group; among them 123 highly, 671 moderately and 1052 are low vulnerable. In the 15-60 age group, the total population is 5545; among them 404 highly, 1946 moderately, and 3195 low vulnerable situations. Likewise, 695 is the total population of 60+ age group; among them 37 highly, 262 moderately and 396 are low vulnerable condition.

Population Outside Home (Absentee): Similarly, there are 2002 people out of 3299 who are staying outside the home which is around 60% who are also in a vulnerable situation due to the lack of job guarantee, regular income, discrimination from the job provider, etc.

Differently Abled People & Their Types: From the study area, there is 348 differently-abled population. Among them, 59% are physically disabled and about 12% are blind and mentally disabled. These all types of differently abled people are most vulnerable situation because of the lack of proper policy of the local and federal government; lack of health facility, problems in travel, discrimination, and attitude of other people. But in the municipality, there are 2739 people are disable which are shown in **Fig. 3.80**. It shows that 11.13% high, 21.44% moderate, and 67.43% are in low vulnerable in the total municipality. In the case of Ward No. 10, there are 124 differently abled populations shown in **Fig. 3.81**. It shows that only 8.87% of differently abled people are highly vulnerable in Ward No. 10. Similarly, 39.52% are moderate and 51.61% are low vulnerable in Ward No. 10.

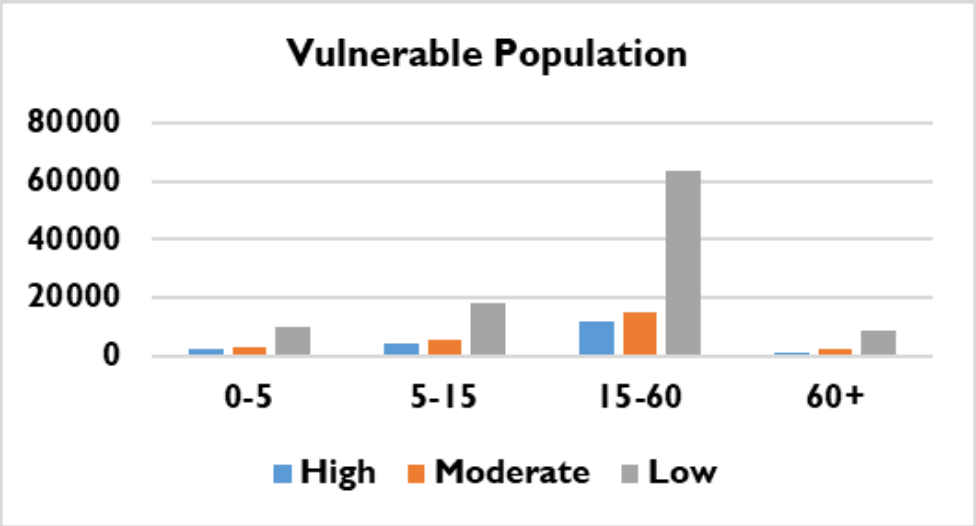


Fig. 3.78 Vulnerable Age Group in Godawari Municipality (Source: Field Survey, 2021).

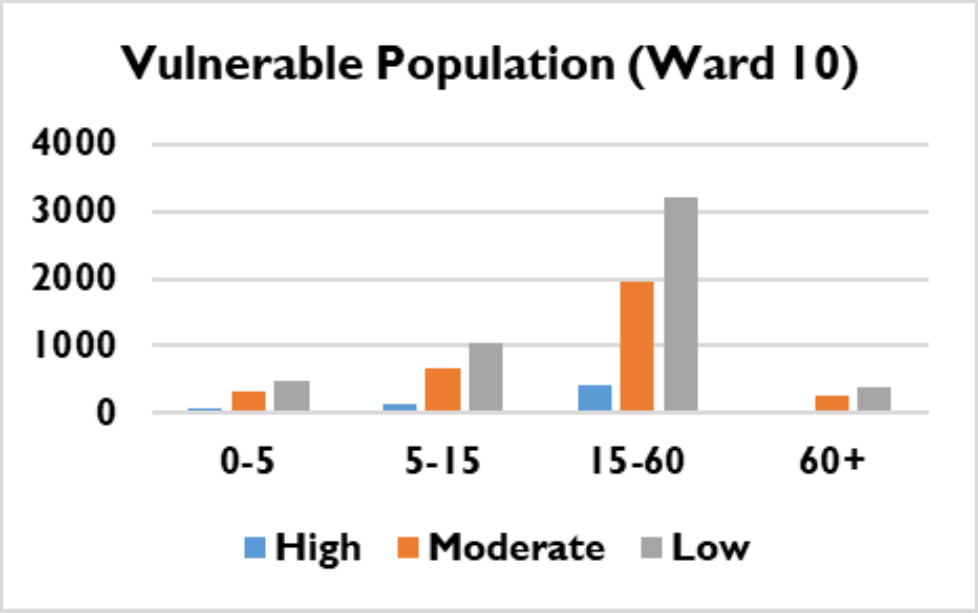


Fig. 3.79 Vulnerable Age Group in Ward No. 10 in Godawari Municipality (Source: Field Survey, 2021).

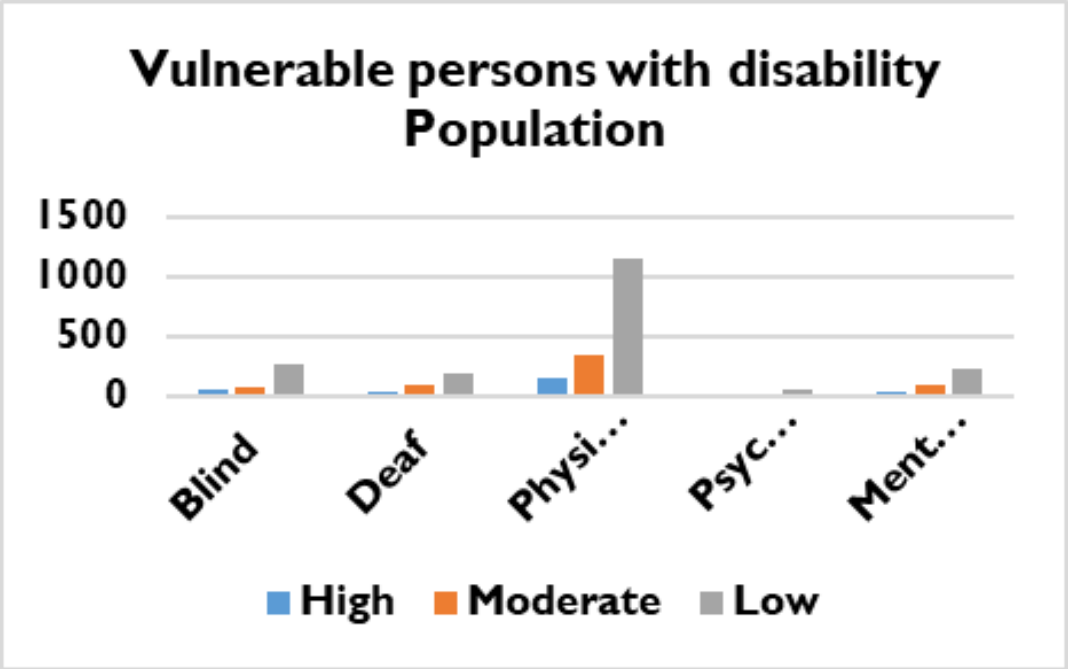


Fig. 3.80 Representation of Vulnerability of Persons with disability in Godawari Municipality (Source: Field Survey, 2021).

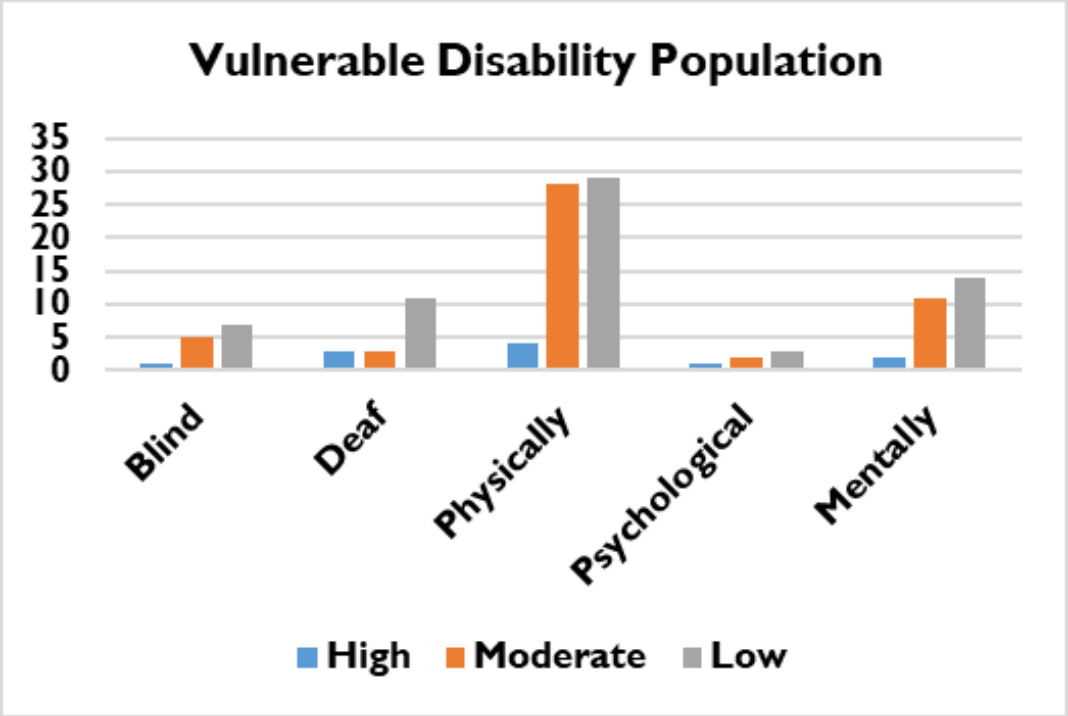


Fig. 3.81 Representation of Vulnerability of Persons with disability Ward No. 10 in Godawari Municipality (Source: Field Survey, 2021).

Ethnic/Caste Groups: Godawari Municipality is a multi-ethnic, caste and multi-lingual area which has various types of caste and ethnic groups. Caste and ethnic composition are very important factor of society which determines the social vulnerability, cohesion, conflict and the organizational structure. A major caste and ethnic group play a dominant role in organizing and decision making in the community. This is a general statement, although it may not always be true. Godawari Municipality is inhabited by different castes and ethnic groups. More than 25 caste and ethnic groups are inhabited in

the Municipality. Pahadi Chhetri has the highest population of the Municipality and their population is 37.60%. Similarly, other highest population are Pahadi Brahman 15.15%, Dalit 15.78%, Tharu 13.75%, etc. in the Municipality. The population composition of the municipality is given in the **Table 3.17**.

According to CBS (2011), the Far-western region of poverty rate (head count method) is 45.61 and Rural Terai mainly of Mid & Far-Western region is 31.09%. Although the poverty rate of the country reduced from 39.13% to 28.62 in the period of 2011 to 2014. But the percentage of poverty in Sudurpaschhim province has not more declined that is still in 33.56% (MPI, 2018). In comparison to the ethnic and caste group, 38.2% Terai Dalits, 25.9% Terai Janajati and 20.2% Muslim community are below the poverty line. The above table shows that, Godawari Municipality has more than 43% are ethnic and caste group people who are mostly vulnerable situation. Among them, Dalits population is more than 15% who are most vulnerable than other ethnic/caste groups (**Fig. 3.81**).

The religious minority group Muslim and Madhesi indigenous people are socially, culturally and economically vulnerable than other ethnic and religious groups. These groups have lack of or limited access to resources such as information, knowledge and technology; lack of or limited access to political power and representation and are in marginalization and exclusive from the society. They have lack of or limited accesses to social capital including social networks, social institutions, organizations and connections as well as inadequate beliefs, customs and attitude in response to risk or disasters. They have vulnerable residential settings like weak structure, poor protection, poor maintenance, etc. and live in environmentally risk areas.

Sources of Use of Energy: The use of energy is another variable to determine vulnerability. In Godawari Municipality, more than 88% population depends on firewood as their main source of cooking energy. Less than 1% use electricity and about 9% use LP gas for cooking purposes. It shows that most of the population of this municipality are in vulnerable conditions due to the dependency on firewood and lack of electricity.

Sources of Drinking Water: Most of the population of this municipality has direct access the drinking water. Generally, consequences of a threat carried out on a water supply can affect the quantity and/or quality of water supply, as well as general sanitation and safety issues in a community. The underground water is sufficient in Godawari Municipality. Around 60% population directly depends on underground water. In the case of safe drinking water, only 32% of people use public and private taps. In means that more than 68% population are in a vulnerable situation due to the lack of safe drinking water and inadequate supply of safe water.

Table 3.17 Caste/ ethnic groups of the Municipality.

CASTE/ ETHNIC GROUPS OF THE MUNICIPALITY		
CASTE/ETHNIC GROUPS	POPULATION	PERCENTAGE, %
Pahadi Thakuri	3480	3.71
Pahadi Chhetri	35223	37.60
Pahadi Brahman	14188	15.15
Gurung	242	0.26
Minor ethnic group	9217	9.84
Tamang	162	0.17
Dalit	14779	15.78
Kumal	65	0.03
Tharu	12883	13.75
Madeshi Indigenous people	2950	3.15
Newar	86	0.09
Muslim	40	0.04
Other	363	0.39
Total	93678	100

Source: Municipal Profile, 2019

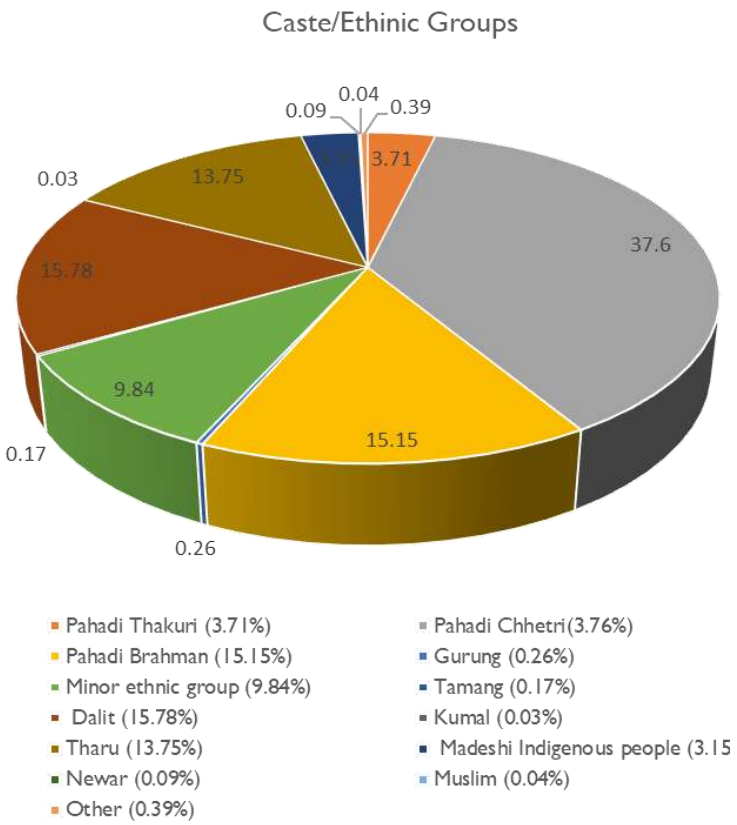


Fig. 3.82 Representation of Caste/Ethnic Groups Vulnerability of Persons in Godawari Municipality.

3.4.2 ECONOMIC VULNERABLITY

The economic vulnerability was assessed on the basis of their economic status. The cost of living in Nepal can be calculated by various techniques and sources. According to Numbeo (2021), the family of four-member estimated monthly costs is NRs.139, 972.57 without rent, and a single person estimated monthly costs is NRs 39,614 without rent which is very low in Godawari Municipality. According to the survey, the average monthly income of a family is only NRs 12,880 which varies less than a single person's monthly costs in comparison to Numbeo global data. This shows that most of the people of this municipality are below the poverty line as well as vulnerable conditions.

Similarly, more than 88% of people of this municipality have less than 1 ha of land. Survey shows that about 37% has less than 0.1 ha, more than 28% has in between 0.1 to 0.2 ha and 23% has 0.2 to 0.5 ha of land. It means most of the population of this municipality are in vulnerable conditions due to the limited ownership of the productive land. Among them, only 16.19% female has the ownership over the land and are more vulnerable than male.

Economic Estimates of Natural Disaster Impacts: Impact assessments make use of socio-economic information also in the form of economic estimates of the impacts of natural disasters. Monetization of the impacts of natural disasters is crucial and very complex but it enables comparison of impacts across the sectors, thereby facilitating decision-making to allocating funds for appropriate responses. Money is indeed the most commonly used quantitative metric for the impacts of natural disaster, usually expressed in welfare changes, income or revenue losses (Nordhaus and Boyer, 2000), and estimates of people's willingness to pay to avoid certain impacts of natural disaster (Li et al., 2004) (UNFCC, 2006). But some of the costs cannot be estimated in monetary value like killed or injure of people, psychological impacts, loss of human relation, etc. Flood, earthquakes, and wind are the major natural disaster in Godawari Municipality. The impacts of flood, earthquake, and wind are given in

Table 3.18. The table shows that Godawari Municipality is more vulnerable due to natural disaster and a large number of buildings and cropland has damaged due to the flood, earthquake, and wind. The average cost of these properties is given in **Table 3.19**. The table shows that 253 buildings are damaged by natural disasters in Godawari Municipality and its economic value is NRs 455, 400, 000. Similarly, 141-hectare cropland has been damaged due to different types of disasters whose economic value is around NRs 19,281,750. According to the cost value of district administration, the economic value of the damaged road is NRs 9,000,000. Hence, total NRs 483, 681, 750 were lost due to the flood, earthquake, and wind. So, Godawari Municipality is vulnerable zones in terms of the economic cost of buildings, cropland, and road.

Institutional Vulnerability: Institutional vulnerability is a very important concept to identify the roles of formal rules of the government, informal institutions, and government organizations. According to Papathoma-Köhle, Thaler & Fuchs (2021), it is strongly connected to all other vulnerability dimensions and specific socio-economic and physical indicators. Moreover, different types of crises such as economic, political, or health crises strongly affect the institutional capacity of communities to deal with the consequences of natural hazards. It is calculated through the drivers of institutional vulnerability and the indicators of other vulnerability dimensions like physical, social, economic, cultural, and environmental. But in this study, institutional vulnerability is measured as the accumulation of educational, health, and industrial planning, management, preventive actions, and emergency management.

Table 3.20 shows that there are multiple responses towards topics of vulnerable related issues. The table shows the responses of three institutions i.e., educational, health, and industry/factory. The educational and health institutions have a more positive response to the gender-friendly toilet but industries have negative responses. All the institutions have more responses to the safe assembly points for emergency and negative responses to the expert for the disaster management system. Hence, most of the institutions are in vulnerable conditions towards the management, safety measures, plans, and facilities.

Table 3.18 Impacts of Natural Disaster.

IMPACTS OF NATURAL DISASTER								
HAZARD	FLOOD			EARTHQUAKE			WIND	
Ward Number	Number of buildings damaged	Number of people killed/injured	Crops damaged (hectares)	Number of buildings damaged	Number of people killed/injured	Roads damaged (km)	Number of buildings damaged	Crops damaged (hectares)
1	8	0	2	6	2	0.03	10	5
2	5	0	2	5	2	0.03	6	4
3	8	1	2	5	3	0.02	10	4
4	12	1	5	6	4	0.05	17	16
5	3	0	4	3	2	0.03	6	12
6	7	1	4	3	3	0.01	9	8
7	5	1	3	3	3	0.02	8	7
8	6	1	3	3	3	0.02	12	11
9	13	1	5	4	3	0.03	15	11
10	8	1	4	4	3	0.02	12	9
11	6	1	4	3	3	0.02	7	7
12	6	1	3	3	3	0.02	7	6
Total	**87**	**9**	**41**	**47**	**33**	**0.3**	**119**	**100**

Source: Field Study, 2021

Table 3.19 Economic Cost of Natural Disaster.

ECONOMIC COST OF NATURAL DISASTER							
S.N.	DISASTER TYPE	NUMBER OF BUILDINGS+++	THE AVERAGE COST OF BUILDING	CROPS LAND DAMAGED (IN HECTARE) +	COST OF CROPS (PADDY)++	LENGTH OF THE ROAD (IN KM)	COST OF ROAD
1	Flood	87	156,600,000	41 (2050 Q.)	5,606,750	-	-
2	Earthquake	47	84,600,000	-	-	0.3	9,000,000
3	Wind	119	214,200,000	100	13,675,000	-	-
	Total	**253**	**455,400,000**	**141**	**19,281,750**	**0.3**	**9,000,000**

Source: Field Study, 2021

+1 Hectare = 50 quintal production of paddy

++1 Quintal paddy = NRs 2,735 (Government price)

+++Brick wall with mud mortar with CGI sheet roof cost = NRs 1,800/sqft and 1 and ½ size building size = 1000 sqft (average)

Table 3.20 Institutional Vulnerability.

INSTITUTIONAL VULNERABILITY			
	I Educational Institution	**Number of multiple Responses (81)**	
S.N.	Topics	Yes	No
1	Disaster response facilities	6	75
2	Gender friendly toilets	60	20
3	Availability of fire extinguisher	11	70
4	Proper evacuation plan during disaster	43	38
5	Earthquake alarm	4	77
6	Emergency plan	14	66
7	Exit routes displayed in school premises	41	39
8	Safe assembly places for emergency	48	33
9	Expert for disaster management	3	78
10	Disaster contingency plan	8	72
	II Health Institution	**Number of multiple responses (37)**	
11	Disabled friendly infrastructure	8	29
12	Gender friendly toilets	20	17
13	Availability of fire extinguisher	8	29
14	Proper evacuation plan	11	26
15	Earthquake alarm	1	36
16	Emergency plan	2	35
17	Exit routes displayed in hospital	9	28
18	Safe assembly points for emergency	14	23
19	Expert for disaster management	1	36
20	Disaster contingency plan	1	36
	III Industries /factories	**Multiple Responses (54)**	
21	Disaster response facility	8	46
22	Gender friendly toilets	8	46
23	Availability of fire extinguisher	14	40
24	Proper evacuation plan	15	39
25	Earthquake alarm	2	52
26	Emergency plan	7	47
27	Exit routes displayed in hospital	23	31
28	Safe assembly points for emergency	24	30
29	Expert for disaster management	4	50
30	Disaster contingency plan	11	43

Source: Field Study, 2021

3.4.3 ENVIRONMENTAL VULNERABLITY

Nepal is highly vulnerable to the impacts of climate change and is ranked fourth, eleventh, and thirtieth in terms of vulnerability to climate change, earthquake, and flood risks respectively. Nepal has been experiencing a multitude of disasters, resulting in the fatality of lives and devastating financial losses, time and again. The fragile geophysical structure, high peaks, high angle of slopes, complex geology, active tectonic processes, rapid urbanization, unplanned settlements, increasing population, weak economic conditions are some of the causes of nation's exposure to the disaster (Tuladhar, 2012), which is further aggravated by environmental degradation and climate change. The impacts of the climate-induced disaster are reported to be in all sectors such as water, energy, agriculture, tourism, energy, infrastructure, and biodiversity resulting in reverse gains in poverty reduction and hinder development. In 2017/18, due to flood, landslide, and heavy rainfall only, the Ministry of Home Affairs

(MoHA, 2019) has estimated 17817 families infected, death of 374 people, and destruction of about 15,632 houses and economic loss of three million worth annually (MoHA, 2019). The unprecedented sudden outbreak of the pandemic COVID-19 has increased the vulnerability of Nepalese people. Enforcement of nationwide lockdown by the Government of Nepal has consequently disrupted all the social and economic activities of the country impacting all the income generation sectors including tourism, agriculture, industrial and informal sectors.

As decentralized structure of seven provinces and 753 local units covering urban and rural areas, local units now have the authority and responsibility to design and execute plans including issues on disaster risk reduction/management and climate change. However, local government should strengthen the capacity of technical, financial, and necessities to mobilize their funds and resources for disaster risk reduction (DRR) and climate change adaptation (CCA) as both are critical for development.

Vulnerability to climate change is not evenly distributed across Nepal and varies amongst different sectors including water, land and forest. Its magnitude is related to the socio-economy, institutions, conservation practices and structural development. However, marginal groups, women and children are more affected from the adverse impacts of climate change.

Methods of Environmental Vulnerability assessment

The team used mainly Participatory Rural Appraisal (PRA) tools to estimate exposure and sensitivity of environmental components to disaster caused combinedly by rapid urbanization and climate change. It is a useful tool to make decisions for the appropriate action to reduce disaster risk and assists in the design and development of programs that are mutually supportive and receptive to the needs of the communities. During this process, the team used both primary and secondary method to collect data and information needed for vulnerability assessment. For secondary source of information, respective municipality profile wherever possible and other information from respective ward and municipality was used. For primary source of information, the following methods were used;

- Discussion and interviews with local people from risk communities
- Key Informant Interviews with stakeholders at municipality level
- Resource availability and accessibility
- Communities ranking

Although the team has focused on using mainly PRA tools, partly the VRA tool was also used (MoPE, 2017).

Step 1: Scoping vulnerability and risk in different environmental components such as: water body, land resources, flora, fauna and energy sector in the proposed Municipality.

Step 2: Identifying key indicators for hazard, exposure, and vulnerability (sensitivity and adaptive capacity)

Step 3: Exploring data sources, nature, and character

Step 4: Data collection, tabulation, filtering, and normalization

Step 5: Analysis of data

Step 6: Identifying urbanization impact and risk

Step 7: Interpretation of final outcomes.

Result of Environmental vulnerability

Environmental Hazards: The environmental hazards are the substances, state or event which has the potential to threaten the environment and could adversely affect people's health. The hazards that were identified in the municipality were as follows:

- Degrading quality of drinking water
- River pollution
- Natural hazards: flood, soil erosion, cold waves and diseases
- Community fire
- Chemical fertilizers
- Invasion of alien species

Industrial Hazards: There are altogether 131 industries existed in the municipality. These industries include rice mill, chemical industry, mineral water, paint industry, concrete industry, poultry industry, milk, paint industry, feed industry, agro-industry, brick industry and furniture industry. Rice mills are found in maximum number followed by furniture industry. However, the chemical, paint and ago-industries although in less numbers, produce chemicals such as xylene, toluene, formaldehyde, methylene chloride, solvents, insecticides, herbicides, fungicides etc. These chemicals are very harmful to human health as well as to environment. Majority of (128 industries) are owned privately and three are owned by the government, for e.g., milk supply scheme. There is no wastewater treatment system in most of the industries especially chemical, paint and agro-industry do not have any wastewater treatment system. They directly discharge wastewater to the nearby river or land. There is no proper waste management system. The industries mostly burn the waste in an open area, while many dumps it in nearby water body, while few sell wastes to scavengers as well.

The industrial hazards were identified in the municipality which are as follows:

- Harmful chemicals
- Wastewater discharge
- Waste disposal
- Air quality

Drinking Water Sources & Water Availability: Communities use water for drinking purposes from various sources such as tube well, spring water, tap water, deep boring and open well (**Table 3.21)**. The major source of drinking water in Godawari municipality is tube well or hand pumps. In the municipality, 57% of the survey households are dependent on tube well. During workshop at municipality level, we also carried out an exercise to find out whether there is any change in water availability in each ward of the municipality. Water availability was found to be decreasing in most of the wards of the municipality (**Table 3.22**).

Rapid urbanization occurring in the Godawari Municipality will increase the paved ground surfaces and reduce the infiltration capacity of ground and thus the recharge of ground water will also decrease. Thus, urbanization combined with changes in rainfall pattern will definitely make the availability of water as well as communities more vulnerable as communities are dependent mostly on groundwater. It has been reported that the quality of drinking water is declining in Godawari Municipality.

Table 3.21 Response related to drinking water source.

RESPONSE RELATED TO DRINKING WATER SOURCE	
SOURCES OF DRINKING WATER	% OF RESPONDENTS IN GODAWARI MUNICIPALITY
Deep boring	4
Open well	3
Personal tap	22
Public tap near home	11
Spring water	3
Tube well/hand pump	57

Table 3.22 Perception on change in water availability.

PERCEPTION ON CHANGE IN WATER AVAILABILITY												
WARD	1	2	3	4	5	6	7	8	9	10	11	12
Godawari Municipality												
Decreasing		√			√	√	√		√		√	
Increasing	√									√		√
No change			√	√				√				

Source: Based on discussion held at municipality.

Status of Water Bodies: There are many rivers that flows across the municipality, such as Godawari, Khairana, Mohana, Dude Pani Khola, Chakle Khola, Gardhbya nadi, Gharepani Khola, Kabdani Khola, Ghanteswar Khola and Tudela khola that flows across Godawari Municipality. Local communities mentioned that the rivers are getting polluted. When asked during survey about whether the rivers in their premises are polluted or not, majority of the locals clearly mentioned that the rivers are getting polluted since 5 to 10 years (**Table 3.23**). They used to use the water from rivers for domestic as well as irrigation purposes, whereas nowadays they rarely use for domestic purposes. They relate the river pollution to haphazard throwing of wastes along the riverside by local communities as well as the travelers. This can be attributed to the increasing concentration of people in the municipality and malmanagement of waste produced by the communities. Most of the rivers have some cultural and aesthetic values for the people living nearby. If not management by the concerned authority on time, the rivers will lose its identity in future.

Impacts on Biodiversity: Rapid increase of built-up areas are the major causes of loss of vegetation. The vegetation is degrading in both municipalities as reported by the local people (**Tables 3.24** & **3.25**). During discussion, local people also mentioned that there has been invasion of several alien flora and fauna in the area. The invasion of alien flora and fauna could degrade habitats. The habitat alternation could further jeopardize many other plants and animals. Similarly, the effects of wetland degradation will be critical to both migratory and resident waterbird communities in lowland wetlands in Nepal that use wetlands as feeding, resting, and breeding habitats (Adhikari et al., 2018). Likewise, the wild animals are also at threat but mainly due to disasters such as flood, community fire, diseases and cold waves.

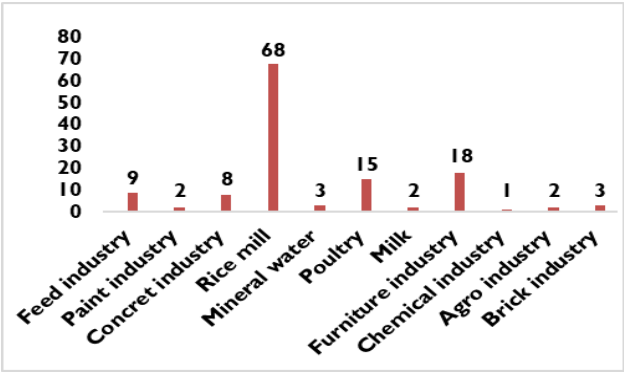


Fig. 3.83 Types of industries existed in the Godawari Municipality.

Table 3.23 Response related to river pollution.

RESPONSE RELATED TO RIVER POLLUTION	
	% OF RESPONDENTS IN GODAWARI MUNICIPALITY
Less than 5 years	11
5 to 10 years	73
More than 10 years	16

Table 3.24 Response related to floral diversity.

RESPONSE RELATED TO FLORAL POLLUTION	
	% OF RESPONDENTS IN GODAWARI MUNICIPALITY
Degrading	85
Improving	4
No change	11

Table 3.25 Ward wise perception of local people on changes in vegetation pattern in the last 10 years.

WARD WISE PERCEPTION OF LOCAL PEOPLE ON CHANGES IN VEGETATION PATTERN IN THE LAST 10 YEARS												
WARD	1	2	3	4	5	6	7	8	9	10	11	12
Godawari Municipality												
Decreasing	√	√	√	√	√		√	√	√	√	√	
Increasing												
No change						√						√

Watershed Degradation: Several forms of land and watershed degradation arising from natural events such as floods, landslides, soil erosion, and debris flow etc. is already there in Nepal (MoFE, 2021). The rapid urbanization in most of the cities of Nepal is further contributing to degradation of watershed. The case is similar to Godawari Municipality. Climate-related stressors such as heavy rainfall events have further triggered these natural as well as anthropogenic events along with increasing soil erosion and mass movements and decreasing water holding capacity in recent years. This has a considerable effect on the degradation of watersheds and watershed resources (Chalise et al., 2019). Insufficient water availability mainly during winter may again impair the hydrological cycle and nutrient supply. This in turn will accelerate soil loss and wind erosion, which ultimately degrade watersheds (Chalise et al., 2019). Besides, the irregularity of the water flow exacerbates overall watershed quality, thereby reducing productivity and degrading watershed resources (UN-habitat, 2015).

Soil & Agricultural Land Degradation: Majority of the farmers grow cereal crops, while they also tend to adopt cash crops, especially vegetables for commercial production. Local people are using both chemical and organic fertilizers in their farmland, but mainly they are applying chemical fertilizers. Majority of farmers apply urea and diammonium phosphate, while only few farmers use potash. According to local people, application of organic fertilizer has significantly reduced due to readily availability of chemical fertilizers. At the same time, they are also reporting that the quality of soil is degrading than before. However, majority of the farmers do not use pesticides in their farmlands although they are commercially cultivating crops. During the discussion, local people also mentioned that the productive agricultural lands are being converted into settlement and this is happening because of lack of proper planning of land. Our analysis shows that both municipalities lack necessary trained personnel provide advice to local people regarding soil quality of agricultural land. Even the human resource that are associated with this municipality seem to lack necessary training and better training of those personnel is must. **Table 3.26** Shows land condition of soil and agricultural land degradation.

Natural Resource Analysis: In Godawari Municipality, natural resource had trend of decreasing. Also, gave "+ve" sign to indicate that accessibility to resource for target group is increasing and "-ve" sign to indicate that accessibility to resource for target group is decreasing. **Table 3.27** represents status and quality of resources for livelihood.

Table 3.26 Soil & Agricultural Land Degradation.

SOIL & AGRICULTURAL LAND DEGRADATION		
DESCRIPTION	CAPACITY	CONDITION
Agricultural land	Food crops and cash crops grown	Affected by land cutting, inundation and disease infestation
Means and resource for irrigation	canals, deep boring	In good condition
Main agricultural resource	**Fertilizers used**	**Seed availability**
Paddy	Chemical Fertilizers and compost manure	Local and from nearby agro-vet centre
Maize	Chemical Fertilizers and compost manure	Local and from nearby agro-vet centre
Wheat	Chemical Fertilizers and compost manure	Local and from nearby agro-vet centre
Lentils, Mustard	Chemical Fertilizers and compost manure	Local and from nearby agro-vet centre

Source: Based on information obtained from discussion with local people and stakeholders.

Table 3.27 Status & Quality of Resources for Livelihood.

STATUS & QUALITY OF RESOURCES FOR LIVELIHOOD				
RESOURCES FOR LIVELIHOOD	PRESENT STATUS AND QUALITY	FUTURE CONDITION	STATUS OF QUALITY (+ FOR BETTERMENT, - FOR WORSENING)	ACCESSIBILITY TO TARGET GROUP (+ FOR INCREASING, - FOR DECREASING)
Natural resource	Community forest number: 1 Tree and shrubs species: Saal, Sissoo, jamuna, Simal, Khayar Wild animals: Elephant, Monkey, Chittal, Indian hare, Porcupine, wild boar, blue bull, wild ass Birds: Parrot, Adjutant, dove, crow, sparrows, egrets	Decreasing	-	+

Source: Based on information obtained from discussion with ward office, community people and stakeholders.

Air Quality Status: Local people reported that the air quality of their surrounding is degrading over time. The main reason that they relate to degrading air quality is due to increasing automobile traffic mainly in urban and also in rural areas. Lot of smokes coming out of those vehicles together with the dust coming out of the paved as well as non-paved roads are polluting the environment. The project team also observed that majority of the local people manage their waste by open burning by themselves. Moreover, they also burn crop residues openly. Such practices will have impact on air quality which in long run will affect human health, plant health and animal health.

Forest Hazard: Increased Incidences of Forest Fire: Forest fire frequency is increasing globally with the significant incidents occurring in Asia (Giglio et al., 2006). Forest fires are one of the major ecological threats that affect different regions of these landscapes annually, mainly in the pre-monsoon season (WWF Nepal, 2007). Factors such as high surface temperature, low rainfall, and the amount of accumulated fuels in the forest contributes to the forest fire.

The incidences of forest fire occurred almost every year in the municipality. The fire lasted for a day to a week. A significant forest fire occurred in the 2075. Whenever fire occurred, most of the time it will be forest user groups who immediately make an attempt to control it. Local forest guards of firefighters are often the first to respond to forest fires Later the local community also informs forest division office. It has been reported that local people set fires for hunting and masking illegal logging. Timber smugglers are also important to set fire in forest.

In many cases, forest fire occurred due to negligence of smokers and of passerby. Grazers ad the fuelwood collectors, sometimes unintentionally throw the burning buds of cigarette inside the forests

which easily catch fire on the dried leaves and twigs. It has also been reported that children set fire for roasting prey such as birds and do not put it out which can outbreak. Security problems and burning for fun also contributed to the forest fire. Least income and unemployment, which is high in Terai (Shrestha et al., 2003), compel people to resort logging, fuelwood collection, hunting and most importantly the collection of non-timber forest products. All these activities increase the number of deliberate and accidental forest fire.

Forest fires in Nepal are a serious risk to forest degradation with the increase in observed climate variability including droughts, long-warm days, and heatwaves. Tremendous forest fires during the dry season for which efficient forest fire risk assessment, warning, and monitoring system need to be improved (Matin et al., 2017). An increasing trend of forest fire incidences are reported in the high-value lowland forests of Tarai and Siwaliks and the year 2016 was the year with the highest number of incidences (about 10,658) recorded across Nepal (Bhujel et al., 2020).

Infestation of Insect Pests & Pathogen: There have been incidences of pathogen attack in the forest. The recent pathogen attack recorded in the municipality was in 2077 B.S. In many cases, seriously affected by the infestation of insect pests and pathogens. Seedlings in forest nurseries were also found in feeble condition due to various fungal diseases. Diseased seedlings act as the vectors and are likely to carry pathogens from one place to another and may cause outbreak of diseases in plantation sites in future. Nepal has already witnessed a huge economic loss, though not precisely estimated, due to pathogenic attacks in commercial timber-yielding species like controlling insect pests and pathogens in the forests is a critical task of forest managers. It is more difficult in natural forests compared to plantation forests. Use of chemicals to control forest insect pests and pathogens is in practice; however, it is limited to forest nurseries or in small forest patches. It is extremely difficult to control them once they spread over a larger area. Therefore, producing insect and pathogen-free robust planting materials is important to keep a forest plantation healthy. The proper consideration on selecting healthy and robust genetic materials may limit the future infestation of insect pests and pathogens on forest crops; ultimately increasing the profits from plantations.

Impacts of Flood & Storm on Forest: It has been reported that impact of storm and flood on forest occur almost every year in the study area. We have monsoonal rain with heavy precipitation during the wet monsoon that frequently cause severe floods destroying crops, vegetations and displacing millions of people. One of the aftermaths of floods, especially flash flood is loss of wild animals and vegetation in the forest. It also decreases the productivity of the forest soil. Likewise, local people also mentioned that the frequent storm that occurred every year damages the forest by falling off the trees and vegetation.

Forest Encroachment: It was also reported by local communities and the stakeholders that forest encroachment is another forest hazard in the municipality, although not in all wards. For example, in Ward Nos. 1, 2 and 3 have forest encroachment while Ward Nos. 8, 9 and 10 rarely have forest encroachment. Among the drivers of forest degradation, human encroachment has high level of significance in forest degradation especially degrading crown cover, habitat, biomass and understory. Forest encroachment is a serious problem in the Terai plains. An estimate shows that 100,000 ha of forest is under encroachment in the Terai and many more coming under threat of encroachment by illegal squatters (MoEST, 2008).

3.4.4 PHYSICAL VULNERABILITY

In this project, the physical vulnerability was considered which is analyzed per group of constructions (i.e., structural types) having similar damage performance. It is an intrinsic quality of a structure and it does not depend upon location.

Physical vulnerability is the degree of loss of a particular type of element-at-risk when exposed to a particular level of intensity of hazard. It is different for each hazard type and each element-at-risk combination. It can be expressed as vulnerability functions, that relate the intensity (e.g., flood depth, earthquake acceleration, wind speed) to the degree of damage. In our case, *damage ratios* were used, which indicate the fraction of the elements at risk that are exposed to the intensity which will receive serious damage. Also, *fragility curves* were used which is defined as the probability of reaching or exceeding a specific damage state when exposed to hazards of certain intensity. As we have classified the intensity in a number of classes, we have simplified the vulnerability values in tables, with an average value for the intensity class for each element-at-risk type. In this chapter, the vulnerability curves and tables for the various hazard types are presented.

3.4.5 STRUCTURAL VULNERABLITY

Data Collection: In order to obtain an overview of the building character of the built-up structures, all the wards were visited in Godawari Municipality and carried out the necessary structural assessments. Meetings were conducted with the engineering department of concerned municipality, where building bylaws, setback, ground coverage, Floor Area Ratio (FAR) and other relevant topics regarding the registration of the building permits were discussed.

As per the survey in the municipality along the East-West Mahendra Highway, most of the land was used for commercial purpose. Most of the erected buildings belong to 3 to 5 storey high and are belonged to reinforced concrete frame (RCC) structures. In these area majority of the structures have been built recently hence using good construction techniques and building materials. These buildings have been analyzed for seismic loadings and supervised by engineers while constructing. **Fig. 3.84** shows the RCC frame structure building in the municipality along East-West Highway.

In the municipality the two most prevalent building structural systems exists in every ward visited and are namely RCC framed structure and masonry load bearing structure. These buildings are predominantly used for residential purpose. These buildings are mostly one storey but few were two to three storied. The RCC framed buildings represents the new construction. The completion period of these building ranged from 5 to 7 years, and some were built recently. Most of the RCC structures have good maintenance. The masonry load bearing structures represent relatively old construction as compared to that of RCC structures and were built more than 5 to 7 years back. **Fig. 3.84** Represents the typical masonry load bearing residential buildings in the municipality. Similarly, **Figs. 3.85** & **3.86** represent typical RCC and load bearing residential buildings with CGI & tiled roof structures.

Fig. 3.84 RCC Frame Structure Buildings along the East-West Highway, Godawari Municipality.

Fig. 3.85 Typical Masonry Load Bearing Residential Buildings, Godawari Municipality.

Fig. 3.86 Typical RCC Residential Buildings, Godawari Municipality.

Fig. 3.87 Typical Load Bearing Residential Buildings with CGI & Tiled Roof, Godawari Municipality.

Modeling & Analysis: Modeling of one storey (RS1) and two and half storey (RS2) building is considered. In order to critically evaluate the RC framed buildings, collected data of building

samples are modeled using STAAD Connect structural analysis software. Apart from the dead and live loads, building is evaluated to the design basis earthquake (DBE) loads, the earthquake which can reasonably be expected to occur at least once during the lifetime of the structures. Model analysis based on response spectrum method has been adopted to dynamically analyze the building. The building components under evaluation should be able to resist the effect of the seismic forces prescribed in **IS 1893-2016**. The seismic base shear (V_B) calculated as per codal provisions is the basic seismic demand placed on the structure for seismic ground motion. The analysis directly computes member end forces and then each member is designed for worst load combination. The design module of analysis engine gives the longitudinal and transverse reinforcement for each member. This calculated reinforcement from analysis in a particular member would correspond to capacity. The calculated reinforcement of structural members has been compared with provided reinforcement in the building. **Table 3.28** represents designed data of RCC frame structure.

First the Earthquake loads as per **IS1893-2016, Part-1** are applied for structure located in zone V. And dynamic analyses i.e., Response spectrum method is carried out for 5% damping as per IS code in both X and Y directions, assuming that material property is linear static.

Results & Discussions: Most of the new RCC Frame buildings were found to be using good construction technology and had adopted earthquake resistance measures. Reinforced masonry is a construction system where steel reinforcement in the form of reinforcing bars is filled with concrete. This reinforced concrete enhances the resistance to seismic loads which in turn increases the energy dissipation capacity. **Figs. 3.84-3.86** show the constructed buildings in the ward. The picture shows earthquake resistance elements in the building thus providing good example of construction techniques in the buildings. The RCC framed structure building comprises of RCC column and RCC beam as a structural element. The masonry infill walls that are placed in between the frames are of burnt bricks laid in cement mortar. The roofs and floors are supported on interior beams and columns of RCC frame. These roof and floor acts as a diaphragm and transfer the lateral load to vertical structural elements and to the foundation.

Load Bearing is the structure in which the loads of the roofs as well as lateral loads such as earthquake, wind etc. are borne by walls, and through walls they are transferred to lower floor and eventually to foundations. For load-bearing construction it has restriction in height as the thickness of wall increases with increase in height. The load bearing system construction can be observed in **Figs. 3.85** & **3.87** in the municipality. In most of older construction the buildings do not have sill and lintel band. Since most of the building have RCC roof they have roof beam placed below the roof along the walls. For the CGI roof and tiled roof load bearing building type they also do not have sill and lintel band. The gable wall does not have gable band going on top of the wall. Load-bearing masonry does not perform well in earthquake loads. In particular, non-reinforced units cannot withdraw the high tensile and shear stresses and experience a brittle failure that can prove to be catastrophic.

Table 3.28 Design Data of RCC Frame Structure.

DESIGN DATA OF RCC FRAME STRUCTURE		
S. N.	PARTICULARS	DIMENSION/SIZE/VALUE
1	Model	Single Storey RCC Building
2	Seismic Zone	V
3	Floor Height	3.0 m
4	Plan Size	8.2 x 6.4 m
5	Size of Columns	0.25 x 0.25 m
6	Size of Beam	0.23 x 0.325 m
7	Walls	i) External Walls – 0.25 m ii) Internal Walls – 0.10 m
8	Thickness of Slab	100 mm
9	Type Of Soil	Type – II, Medium As per IS – 1893: 2016

DESIGN DATA OF RCC FRAME STRUCTURE		
S. N.	PARTICULARS	DIMENSION/SIZE/VALUE
10	Material Used	Concrete M15, Reinforcement Fe – 415 and Brickwork in 1:6 CM
11	Dynamic Analysis	Response Spectrum Method
12	Earthquake Loads	As per IS 1893:2016
13	Specific Weight of Concrete	25 KN/m^2
14	Specific Weight of Brick Walls	20 KN/m^2

The above mentioned two types RCC frame structures are analyzed dynamically and the results of Beam end forces, Column end forces, Nodal Displacement and Storey Drift at different nodes and beams are tabulated below (**Tables 3.29-3.41** & **Figs. 3.88-3.91**).

Table 3.29 Results of Single Storey Sample RCC Building, Beam End Forces.

RESULTS OF SINGLE STOREY SAMPLE RCC BUILDING, BEAM END FORCES					
BEAM	L/C	NODE	FX (KN)	FY (KN)	MZ (KN-M)
1	Seismic Loads	13	0.461	4.082	7.223
		14	-0.461	-4.082	-6.45
	Dead + Live	13	-3.831	23.256	12.549
		14	3.831	23.208	-12.468
	Static + Seismic	13	-4.012	17.12	1.671
		14	4.012	29.343	-2.794
2	Seismic Loads	14	0.082	24.482	14.657
		15	-0.082	-24.482	-14.721
	Dead + Live	14	-2.136	8.21	2.956
		15	2.136	8.433	-3.09
	Static + Seismic	14	-2.037	-28.553	-19.009
		15	2.037	45.197	18.923
8	Seismic Loads	22	0.082	25.694	15.383
		23	-0.082	-25.694	-15.45
	Dead + Live	22	-2.137	8.217	2.959
		23	2.137	8.427	-3.085
	Static + Seismic	22	-2.037	-30.366	-20.094
		23	2.037	47.009	20.019
9	Seismic Loads	23	0.578	3.647	6.283
		24	-0.578	-3.647	-7.027
	Dead + Live	23	-4.55	25.362	14.982
		24	4.55	25.262	-14.8
	Static + Seismic	23	-4.797	19.903	5.554
		24	4.797	30.721	-4.216
33	Seismic Loads	28	0.501	0.317	0.531
		32	-0.501	-0.317	-0.435
	Dead + Live	28	4.895	22.553	7.79
		32	-4.895	28.867	-17.419
	Static + Seismic	28	5.202	33.412	27.785
		32	-5.202	15.391	-32.28
34	Seismic Loads	32	0.524	0.265	0.395
		36	-0.524	-0.265	-0.493
	Dead + Live	32	6.128	31.659	19.428
		36	-6.128	26.043	-10.022
	Static + Seismic	32	6.761	40.146	33.192
		36	-6.761	14.401	-28.87

Table 3.30 Results of Single Storey Sample RCC Building, Beam End Forces.

RESULTS OF SINGLE STOREY SAMPLE RCC BUILDING, COLUMN END FORCES					
COLUMNS	L/C	NODE	FX (KN)	FY (KN)	MZ (KN-M)
35	Seismic Loads	1	9.774	7.994	14.328
		13	-9.774	-7.994	-2.46
	Dead + Live	1	105.013	-3.078	-2.209
		13	-100.374	3.078	-4.254
	Static + Seismic	1	123.069	-2.204	-0.766
		13	-118.43	2.204	-5.106
36	Seismic Loads	13	5.557	5.303	5.914
		25	-5.557	-5.303	-9.465
	Dead + Live	13	56.369	-6.908	-8.239
		25	-49.963	6.908	-11.794

RESULTS OF SINGLE STOREY SAMPLE RCC BUILDING, COLUMN END FORCES					
COLUMNS	L/C	NODE	FX (KN)	FY (KN)	MZ (KN-M)
	Static + Seismic	13	65.448	-5.918	-7.164
		25	-59.042	5.918	-12.071
	Seismic Loads	3	33.171	12.649	17.545
		15	-33.171	-12.649	-9.017
	Dead + Live	3	135.515	-3.294	-2.328
39		15	-130.877	3.294	-4.59
	Static + Seismic	3	153.939	-2.014	-0.611
		15	-149.3	2.014	-5.881
	Seismic Loads	15	12.537	10.45	13.106
		27	-12.537	-10.45	-17.199
	Dead + Live	15	76.294	-5.689	-7.26
40		27	-69.888	5.689	-9.238
	Static + Seismic	15	84.835	-4.411	-5.727
		27	-78.429	4.411	-10.231
	Seismic Loads	8	9.276	11.634	19.186
		20	-9.276	-11.634	-5.245
	Dead + Live	8	179.934	3.296	2.272
49		20	-175.296	-3.296	4.65
	Static + Seismic	8	176.381	3.754	2.725
		20	-171.743	-3.754	4.909
	Seismic Loads	20	5.49	7.362	8.903
		32	-5.49	-7.362	-12.446
	Dead + Live	20	104.839	9.245	10.377
50		32	-98.434	-9.245	16.433
	Static + Seismic	20	99.697	8.687	10.052
		32	-93.291	-8.687	14.76

Table 3.31 Results of Single Storey Sample RCC Building, Nodal Displacement.

RESULTS OF SINGLE STOREY SAMPLE RCC BUILDING, NODAL DISPLACEMENT					
NODE	L/C	HORIZONTAL X (MM)	VERTICAL Y (MM)	HORIZONTAL Z (MM)	RESULTANT (MM)
	Seismic Loads	0	0	0	0
1	Dead + Live	0	0	0	0
	Static + Seismic	0	0	0	0
	Seismic Loads	3.925	0.015	0.25	3.933
13	Dead + Live	-0.037	-0.159	-0.038	0.168
	Static + Seismic	5.852	-0.132	0.338	5.863
	Seismic Loads	11.307	0.027	0.683	11.328
25	Dead + Live	-0.146	-0.272	-0.186	0.361
	Static + Seismic	16.825	-0.223	0.851	16.848
	Seismic Loads	0	0	0	0
12	Dead + Live	0	0	0	0
	Static + Seismic	0	0	0	0
	Seismic Loads	4.121	0.013	0.224	4.127
24	Dead + Live	-0.009	-0.175	-0.024	0.177
	Static + Seismic	6.17	-0.151	0.312	6.18
	Seismic Loads	11.902	0.022	0.629	11.918
36	Dead + Live	-0.181	-0.302	-0.207	0.408
	Static + Seismic	17.684	-0.257	0.75	17.701

Table 3.32 Results of Single Storey Sample RCC Building, Storey Drift.

RESULTS OF SINGLE STOREY SAMPLE RCC BUILDING, STOREY DRIFT			
NODE	L/C	DISPLACEMENT RESULTANTS (mm)	DRIFT (mm)
1	Static + Seismic	0	
13	Static + Seismic	5.863	5.863
25	Static + Seismic	16.848	10.985
12	Static + Seismic	0	
24	Static + Seismic	6.18	6.18

36	Static + Seismic		17.701	11.521

Table 3.33 Reinforcement Needed and Provided for Beams of Single Storey Sample RCC Building.

REINFORCEMENT NEEDED AND PROVIDED FOR BEAMS OF SINGLE STOREY SAMPLE RCC BUILDING

S.N.	BEAM NO	SIZE	SITE CONDITION		AS PER ANALYSIS	
			AREA OF REBAR PROVIDED (SQUARE mm)		AREA OF REBAR NEEDED (SQUARE mm)	
			TOP	BOTTOM	TOP	BOTTOM
1	Beams					
	1	230 x 230	226	339	319	251
	2	230 x 230	226	339	453	264
	8	230 x 230	226	339	467	275
	9	230 x 230	226	339	429	237
	33	230 x325	226	339	358	297
	34	230 x 325	226	339	377	288

Table 3.34 Reinforcement Needed and Provided for Columns of Single Storey Sample RCC Building.

REINFORCEMENT NEEDED AND PROVIDED FOR COLUMNS OF SINGLE STOREY SAMPLE RCC BUILDING

S.N.	COLUMN NO.	SIZE	SITE CONDITION	AS PER ANALYSIS
			AREA OF REBAR PROVIDED (SQUARE mm)	AREA OF REBAR NEEDED (SQUARE mm)
1	Columns			
	35	250 x 250	452	950
	36	250 x 250	452	1110
	39	250 x 250	452	1068
	40	250 x 250	452	1178
	49	250 x 250	452	951
	50	250 x 250	452	1224

Table 3.35 Design Data of RCC Frame Structure of Single Storey Sample

DESIGN DATA OF RCC FRAME STRUCTURE OF SINGLE STOREY SAMPLE

S.N.	PARTICULARS	DIMENSION/SIZE/VALUE
1	Model	Two and Half Storey RCC Building
2	Seismic Zone	V
3	Floor Height	3.0 m
4	Plan Size	9.35 x 6.75 m
5	Size of Columns	0.30 x 0.30 m
6	Size of Beam	0.23 x 0.325 m
7	Walls	i) External Walls – 0.25 m ii) Internal Walls – 0.10 Mts
8	Thickness of Slab	125 mm
9	Type Of Soil	Type – II, Medium As per IS – 1893: 2016
10	Material Used	Concrete M15, Reinforcement Fe – 415 and Brickwork in 1:6 CM
11	Dynamic Analysis	Response Spectrum Method
12	Earthquake Loads	As per IS 1893:2016
13	Specific Weight of Concrete	25 KN/m^2
14	Specific Weight of Brick Walls	20 KN/m^2

Table 3.36 Results of Two and Half Storey Sample RCC Building, Beam End Forces

RESULTS OF TWO AND HALF STOREY SAMPLE RCC BUILDING, BEAM END FORCES

BEAM	L/C	NODE	FX (KN)	FY (KN)	MZ (KN-M)
10	Seismic Loads	12	2.725	7.881	13.842
		13	-2.725	-7.881	-13.74
	Dead + Live	12	-1.875	21.578	12.439
		13	1.875	21.716	-12.681
	Static + Seismic	12	3.044	33.379	33.163
		13	-3.044	9.915	-33.321
11	Seismic Loads	13	2.689	6.983	12.939
		14	-2.689	-6.983	-13.039
	Dead + Live	13	-2.565	23.092	14.341
		14	2.565	22.923	-14.026
	Static + Seismic	13	2.487	33.579	33.763
		14	-2.487	12.436	-33.555
34	Seismic Loads	48	4.186	21.973	39.46
		49	-4.186	-21.973	-37.447
	Dead + Live	48	-2.795	32.893	19.637

RESULTS OF TWO AND HALF STOREY SAMPLE RCC BUILDING, BEAM END FORCES					
BEAM	L/C	NODE	FX (KN)	FY (KN)	MZ (KN-M)
35	Static + Seismic	49	2.795	34.013	-21.598
		48	3.924	61.531	75.935
		49	-3.924	-3.602	-74.295
	Seismic Loads	49	3.615	19.351	35.092
		50	-3.615	-19.351	-36.895
	Dead + Live	49	-1.507	36.412	24.103
		50	1.507	35.634	-22.655
	Static + Seismic	49	4.191	60.347	72.834
		50	-4.191	1.742	-74.515
69	Seismic Loads	61	9.621	16.532	29.214
		62	-9.621	-16.532	-28.65
	Dead + Live	61	8.354	22.259	12.647
		62	-8.354	23.286	-14.445
	Static + Seismic	61	21.745	45.355	55.271
		62	-21.745	-3.176	-56.292
70	Seismic Loads	62	7.95	15.235	27.648
		63	-7.95	-15.235	-29.024
	Dead + Live	62	-0.406	33.285	21.999
		63	0.406	32.539	-20.612
	Static + Seismic	62	11.147	54.273	62.026
		63	-11.147	7.816	-62.688

Table 3.37 Results of Two and Half Storey Sample RCC Building, Column End Forces.

RESULTS OF TWO AND HALF STOREY SAMPLE RCC BUILDING, COLUMN END FORCES					
COLUMN	L/C	NODE	FX (KN)	FY (KN)	MZ (KN-M)
125	Seismic Loads	2	72.452	13.598	32.259
		13	-72.452	-13.598	-4.267
	Dead + Live	2	338.066	-0.42	-0.342
		13	-328.974	0.42	-0.539
	Static + Seismic	2	421.449	19.935	48.029
		13	-412.357	-19.935	-7.013
126	Seismic Loads	13	63.499	14.139	16.464
		49	-63.499	-14.139	-23.221
	Dead + Live	13	265.861	-1.115	-1.116
		49	-253.738	1.115	-2.007
	Static + Seismic	13	335.826	20.236	23.668
		49	-323.704	-20.236	-36.526
128	Seismic Loads	49	37.349	11.195	12.573
		62	-37.349	-11.195	-18.775
	Dead + Live	49	153.466	0.187	-0.42
		62	-141.344	-0.187	0.945
	Static + Seismic	49	200.335	16.958	18.571
		62	-188.213	-16.958	-27.413
130	Seismic Loads	62	18.624	4.663	4.946
		110	-18.624	-4.663	-8.14
	Dead + Live	62	54.948	-8.419	-8.532
		110	-42.826	8.419	-15.041
	Static + Seismic	62	79.77	-0.787	-0.594
		110	-67.647	0.787	-25.986

Table 3.38 Results of Two and Half Storey Sample RCC Building, Nodal Displacement.

RESULTS OF TWO AND HALF STOREY SAMPLE RCC BUILDING, NODAL DISPLACEMENT					
NODE	L/C	HORIZONTAL X (mm)	VERTICAL Y (mm)	HORIZONTAL Z (mm)	RESULTANT (mm)
2	Seismic Loads	0	0	0	0
	Dead + Live	0	0	0	0
	Static + Seismic	0	0	0	0
13	Seismic Loads	6.08	0.019	2.142	6.447
	Dead + Live	-0.006	-0.263	-0.01	0.264
	Static + Seismic	9.115	-0.214	3.207	9.666
49	Seismic Loads	20.012	0.04	7.093	21.232
	Dead + Live	0.005	-0.537	-0.048	0.539
	Static + Seismic	30.024	-0.43	10.6	31.844
62	Seismic Loads	29.161	0.049	10.496	30.992
	Dead + Live	0.098	-0.692	-0.144	0.713
	Static + Seismic	43.834	-0.563	15.618	46.536

RESULTS OF TWO AND HALF STOREY SAMPLE RCC BUILDING, NODAL DISPLACEMENT					
NODE	L/C	HORIZONTAL X (mm)	VERTICAL Y (mm)	HORIZONTAL Z (mm)	RESULTANT (mm)
	Seismic Loads	36.981	0.048	12.549	39.053
110	Dead + Live	-0.133	-0.743	0.264	0.8
	Static + Seismic	55.35	-0.611	19.062	58.544

Table 3.39 Results of Two and Half Storey Sample RCC Building, Storey Drift.

RESULTS OF TWO AND HALF STOREY SAMPLE RCC BUILDING, STOREY DRIFT			
NODE	L/C	DISPLACEMENT RESULTANTS (mm)	DRIFT (mm)
2	Static + Seismic	0	
13	Static + Seismic	9.666	9.666
49	Static + Seismic	31.844	22.178
62	Static + Seismic	46.536	14.692
110	Static + Seismic	58.544	12.008

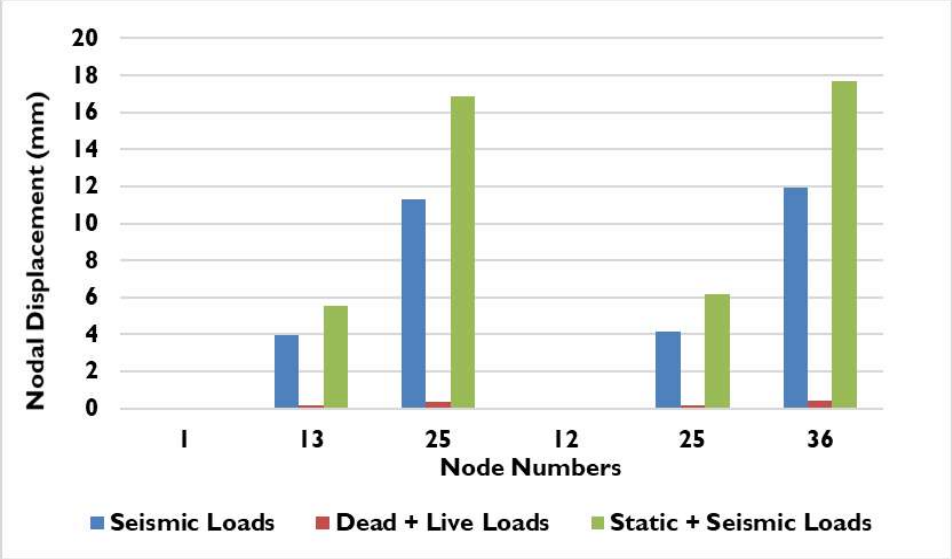


Fig. 3.88 Nodal Displacement Results of Single Storey Sample RCC Building.

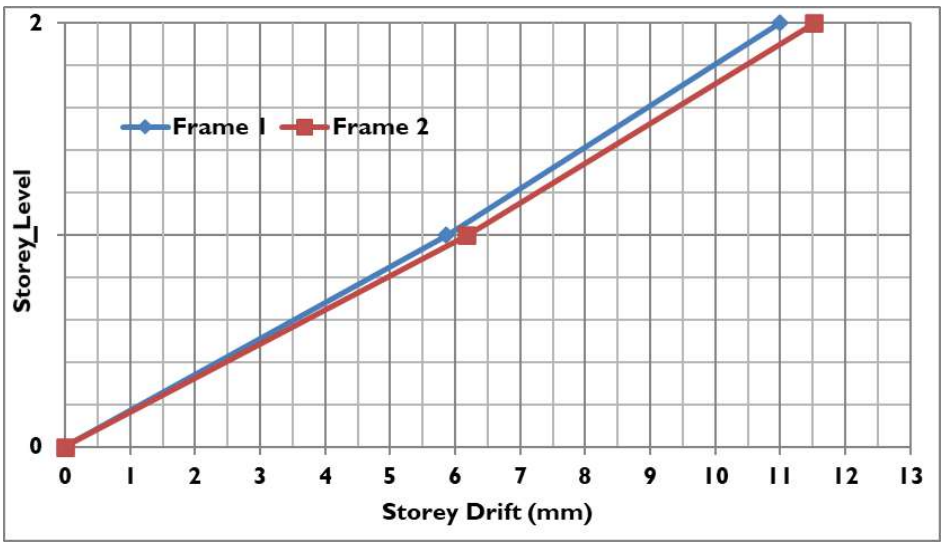


Fig. 3.89 Drift of Frames of Single Storey Sample RCC Building.

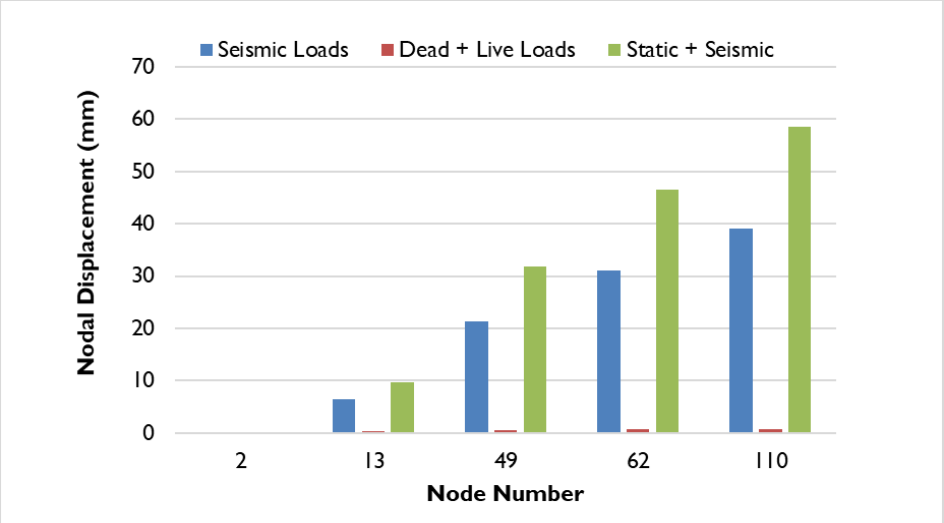


Fig. 3.90 Nodal Displacement of Two and Half Storey Sample RCC Building.

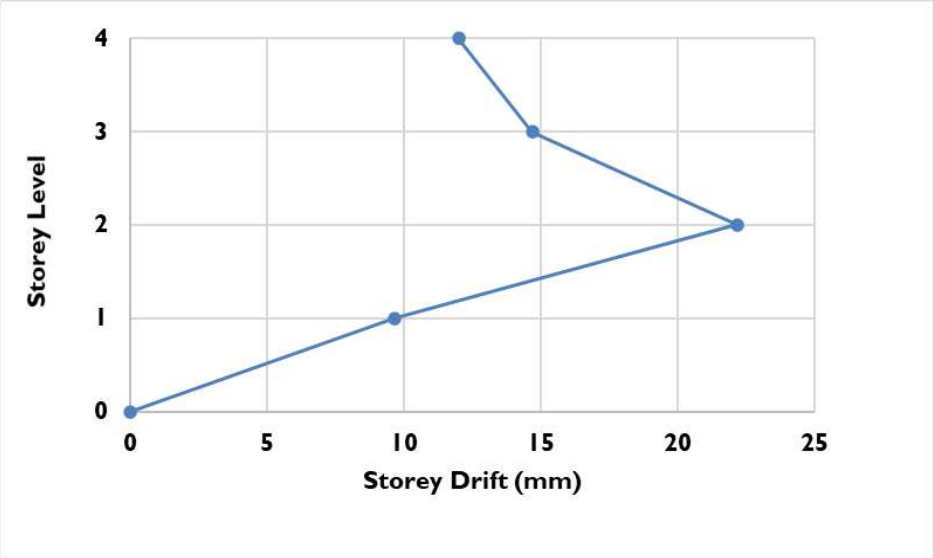


Fig. 3.91 Storey Drift of Two and Half Storey Sample RCC Building.

Table 3.40 Results of Reinforcement Needed and Provided for Beams of Two and Half Storey Sample RCC Building.

RESULTS OF REINFORCEMENT NEEDED AND PROVIDED FOR BEAMS OF TWO AND HALF STOREY SAMPLE RCC BUILDING						
S.N.	BEAM NO	SIZE	SITE CONDITION		AS PER ANALYSIS	
			AREA OF REBAR PROVIDED (SQUARE mm)		AREA OF REBAR NEEDED (SQUARE mm)	
			TOP	BOTTOM	TOP	BOTTOM
1	Beams					
	10	230 x 230	339	339	397	292
	11	230 x 230	339	339	413	210
	34	230 x 350	339	339	691	401
	35	230 x 350	339	339	687	397
	69	230 x 350	339	339	505	317
	70	230 x 350	339	339	577	372

Table 3.41 Results of Reinforcement Needed and Provided for Columns of Two and Half Storey Sample RCC Building.

RESULTS OF REINFORCEMENT NEEDED AND PROVIDED FOR COLUMNS OF TWO AND HALF STOREY SAMPLE RCC BUILDING				
			SITE CONDITION	AS PER ANALYSIS
S.N.	COLUMN NO.	SIZE	AREA OF REBAR PROVIDED (SQUARE mm)	AREA OF REBAR NEEDED (SQUARE mm)
1	Columns			
	125	250 x 250	904	1787
	126	250 x 250	904	1387
	127	250 x 250	904	1289
	128	250 x 250	904	1069

Discussion of Analyzed Results: Bending moments increased in columns and beams due to seismic excitation. It is observed that the bending moments decreased in the upper floors as compared to the tie beam level in both the building. Rotation of the beams and due to rigid connection at their junction with the column causes rotation of the column. Hence beam transfers bending moments to the column in addition to axial load. Also, it is observed that the axial forces decreased for upper floors as compared to the lower storey. The axial forces were observed greater for the static and Seismic as compared to that of Dead and live loads. These values indicated that horizontal motion has a greater effect on the axial compression loads of the exterior columns compared to the interior columns because of the overturning moment effect.

The result of the analysis shows that the frame suffered a maximum horizontal displacement at the top level of the structure. For a single storey structure, the drift was observed maximum for Static + seismic load combination which was also seen for the two and half storey building. For the single storey structure, this value observed less than that of prescribed by the code which is 0.004 times the inter storey height. The maximum value was 11.52 mm. In case of two and half storey building the inter storey drift for ground floor was more than that prescribed by the code, it exceeded by 84% of the prescribed value. This deficiency can be overcome by increasing the lateral stiffness of the relevant story in the direction of drift. This may be done by increasing column dimension in that particular direction, increase beam depths or the slab thickness.

In the case of analyzed single storey building the actual size of the tie beam and slab beams provided were 230 x 230 mm and 230 x 325 mm respectively. The strength of concrete was 15 N/mm^2. Upon analyzing the existing structure for Zone V earthquake loadings, the area of rebar required for the loading were in the range of 319 - 467 mm^2 and 251 - 297 mm^2 for top and bottom reinforcement for beams. The provided reinforcement areas were 339 mm^2 for bottom and 226 mm^2 for top of the beams. It is clearly seen that the bottom reinforcement area is adequate but there is deficiency in the area of steel at the top. This also clearly shows that these building were primarily designed for static loadings only. The columns in most of the older house had size of 250 x 250 mm and they had 452 mm^2 of reinforcement area provided to them. As per the analysis the area provided are minimal as the calculated area were in the range between 950 - 1224 mm^2.

Same things as stated above applies for the analyzed two and half storey building as well as there is inadequate reinforcement for both the beams and columns. The provided reinforcements for the beams are 339 mm^2 for top and bottom whereas the calculated area comes in the range between 339 - 691 mm^2 for top and 210 - 397 mm^2 for bottom reinforcement. For columns the provided area of reinforcement is 904 mm^2 but the required is in the range of 1069 - 1787 mm^2. The higher area is for the bottom column and the lower one for the top columns. The column is

the main element that carries the vertical loads to the foundation. Failure of a column could lead to the failure of the whole structure. Therefore, the failure of columns shall be avoided than any other element. Further, the failure of the column could lead to the progressive collapse of the structure. Therefore, it is very important to identify the critical column and pay attention to them during design and construction.

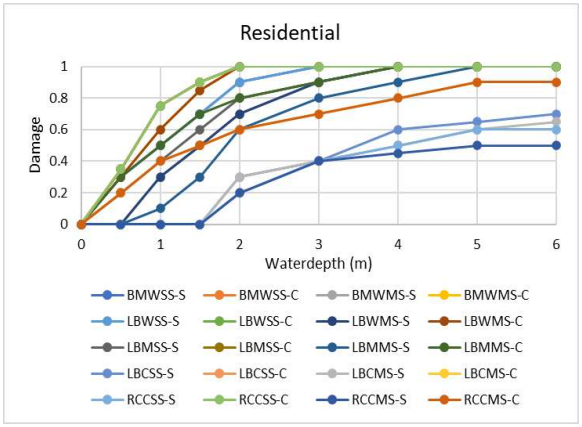
3.4.6 PHYSICAL VULNERABILITY TO FLOOD

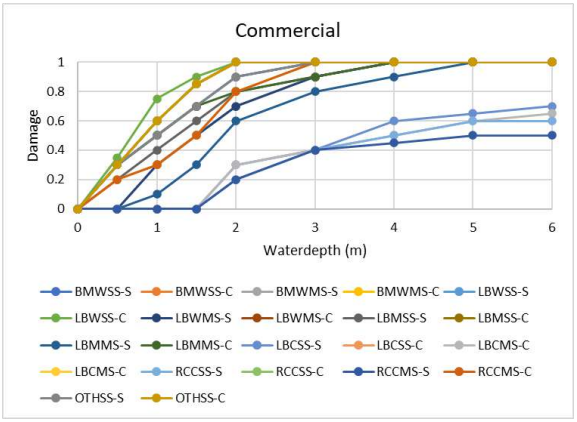
For the flood vulnerability analysis of buildings in Godawari Municipality the building typologies were classified based on construction type, number of floors and occupancy type/functional use type which result in following classes as shown in the **Table 3.42**. The curves are prepared from expert judgements and literatures (Huizinga et al., 2017). Two damage curves were produced; one for the structure of the buildings and another for the contents inside it, as different occupancy types have different contents inside their properties. The curves were produced for each occupancy type. Not all occupancy types have a combination with all construction types. The water height/depth was used as intensity for flood. In the case of flashflood also flow velocity could be important. However, we lack sufficient information to take this into account. **Table 3.43** shows the flood vulnerability damages.

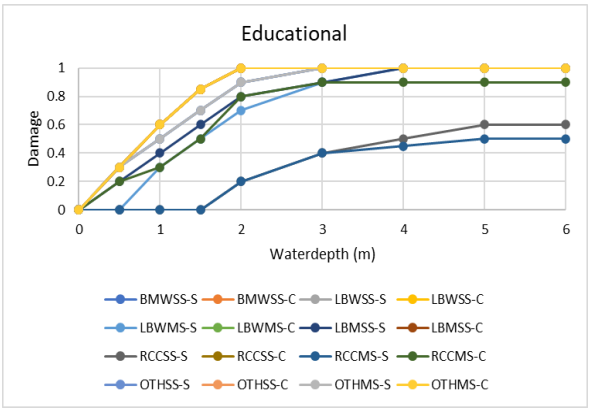
Fig. 3.92 shows the flood vulnerability curves (for building structure and building contents) for all the functional uses of buildings in Godawari Municipality. Some building types can have similar vulnerability functions for structure and contents. The flood intensity maps were classified into four classes (None, Low, Moderate and High). From the above flood vulnerability curves, the damage values of buildings and other elements-at-risk (building, roads and population) were derived according to flood hazard maps with classes. For the roads damage by flood, the water velocity plays vital role but we lack such information and road damage further depend upon types as well. Gravel roads are more susceptible to get damaged or will be inaccessible than the black topped road during flood.

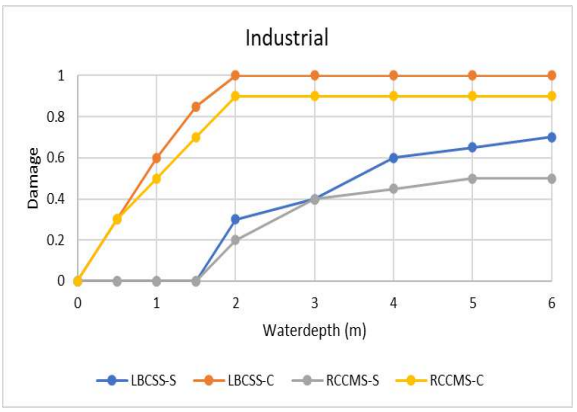
Table 3.42 Classification of the buildings based on occupancy type, construction type, number of floors, structure and contents for flood vulnerability curves.

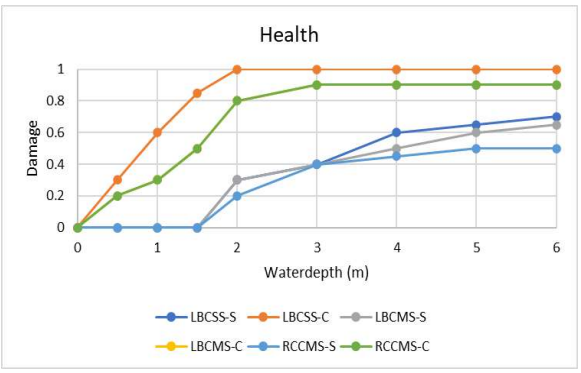
Classification of the buildings						
OCCUPANCY/ PRIMARY FUNCTION TYPE	CONSTRUCTION TYPES	CODE	FLOORS	CODE	CURVE TYPE	CODE
Residential	Bamboo wood with mud/wood	BMW	1 (Single-storied)	SS	Structure	S
Institutional	Frame structure with cement	RCC	>1 (Multi-storied)	MS	Content	C
Educational	Loadbearing with cement	LBC				
Governance	Loadbearing with mud	LBM				
Religious/Culture	Others	OTH				
Health						
Industrial						
Commercial						
Public						

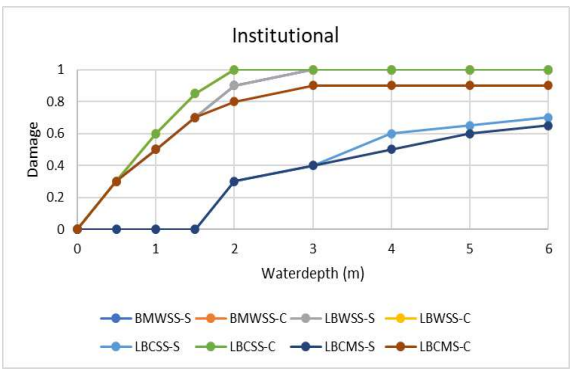


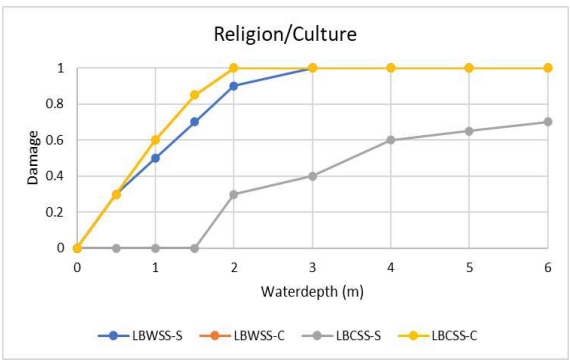












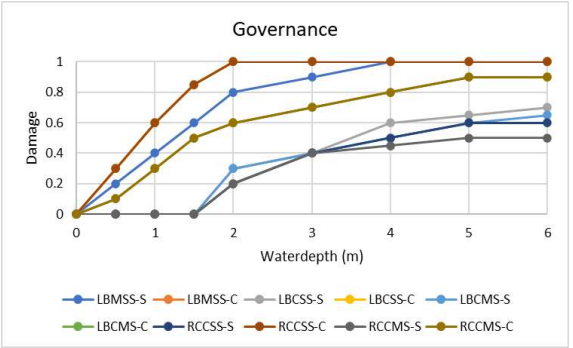


Fig. 3.92 Flood vulnerability curves of different building construction types classified based on their functional use.

3.4.7 PHYSICAL VULNERABILITY TO LANDSLIDES

For the landslides, the intensity information was not available so the damage was related to the susceptibility zones. It was assumed that landslides in the high susceptible zone are generally larger than in the moderate susceptible zone causing higher damages to the elements-at-risk (buildings, roads, agriculture and population). These values were derived from the expert opinions and literature. **Table 3.44** shows the landslide vulnerability damages.

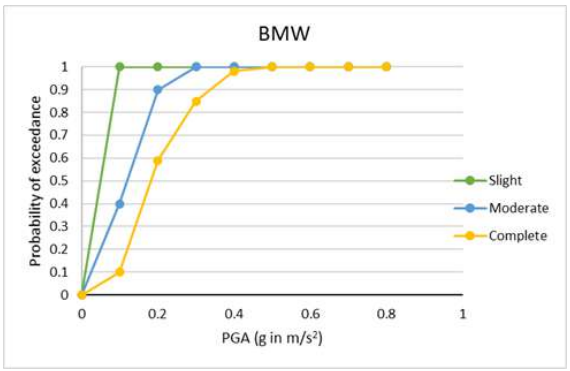
3.4.8 PHYSICAL VULNERABILITY TO EARTHQUAKE

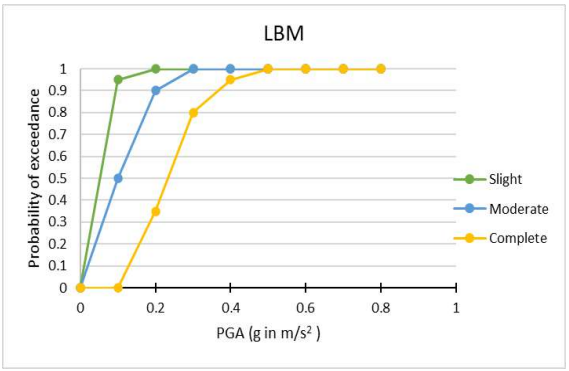
Earthquake vulnerability depends on the building construction types, construction materials and the number of floors in relation to peak ground acceleration. The fragility curves were developed from the past literature (Guragain et al., 2012, Guragain et al., 2020) based on building types which are shown in **Fig. 3.93**. Fragility curves indicates the probability of exceeding or reaching the specific damage state of the buildings linked to the earthquake intensities.

In our case, the earthquake hazard maps corresponding to 475 years and 2475 years return period have only one class (Very High) because it has peak ground acceleration greater than our threshold value of 0.5g. If such earthquake occurs, then it is likely that most of the buildings irrespective to its construction types will have high damages and high fatalities. The effects of earthquake on agriculture were not considered because it was not very relevant. **Table 3.45** shows the flood vulnerability damages.

3.4.9 PHYSICAL VULNERABILITY TO WINDSTORM

Windstorm vulnerability was considered only for the buildings and the agriculture area. Buildings have different construction types and roof types which have different levels of vulnerability to wind. The effects of wind hazard on population and roads were not considered as they were not considered relevant. The hazard to people were mostly from the conditions of the buildings or the falling of trees and electric poles. **Fig. 3.94** shows the vulnerability of different types of buildings and their damage probability with respect to wind intensities obtained from past studies (Cardona et al., 2013). **Table 3.43** shows the windstorm vulnerability damages. The following pages show the vulnerability tables containing the damage values for different elements-at-risk with respect to different hazards.





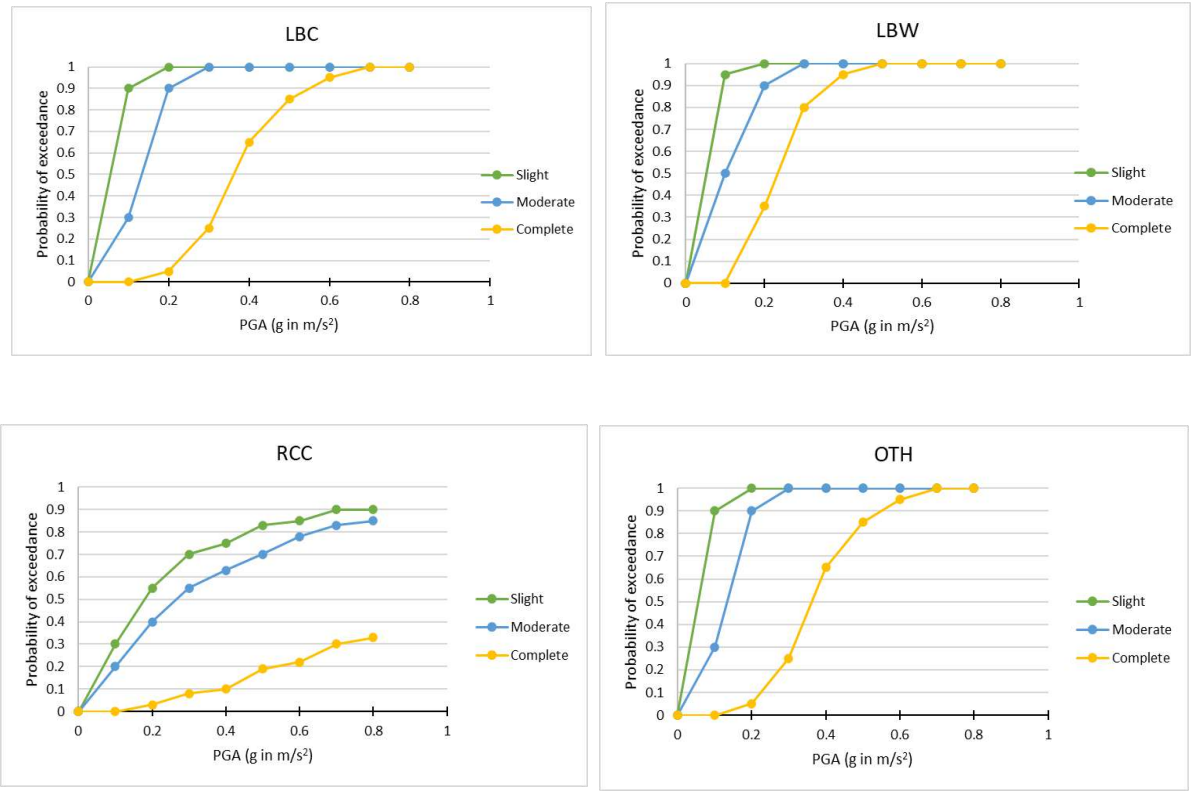


Fig. 3.93 Earthquake vulnerability curves of different building construction types.

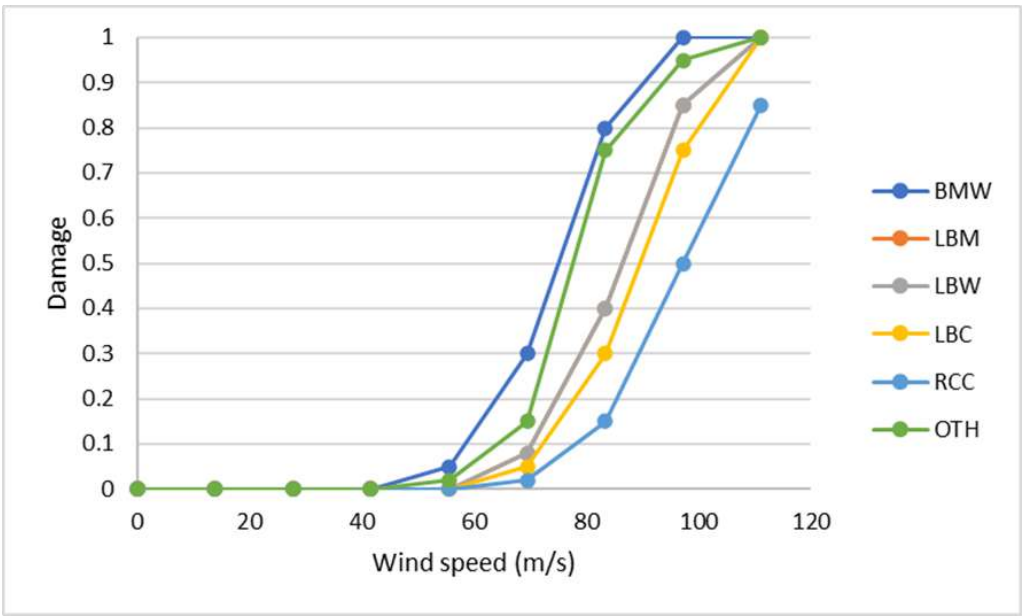


Fig. 3.94 Wind vulnerability curves of different building construction types.

Table 3.43 Flood vulnerability damage values of different elements-at-risk extracted from the flood vulnerability curves.

FLOOD VULNERABILITY DAMAGE VALUES OF DIFFERENT ELEMENTS-AT-RISK EXTRACTED FROM THE FLOOD VULNERABILITY CURVES													
FLOOD INTENSITY	WATER HEIGHT (M)	EFFECT ON BUILDING STRUCTURE TYPE (1ST ROW) AND POPULATION (2ND ROW)											
		BMW_MS	BMW_SS	LBC_MS	LBC_SS	LBM_MS	LBM_SS	LBW_MS	LBW_SS	RCC_MS	RCC_SS	OTH_MS	OTH_SS
None	<0.25	0	0	0	0	0	0	0	0	0	0	0	0
Low	0.25-1	0.3	0.5	0	0	0.1	0.4	0.3	0.5	0	0	0.3	0.3
		0	0.015	0	0	0	0.015	0	0.015	0	0	0	0.015
Moderate	1-2	0.7	0.9	0.3	0.3	0.6	0.8	0.7	0.9	0.2	0.25	0.9	0.9
		0	0.025	0	0	0	0.025	0	0.025	0	0	0	0.025
High	>2	1	1	0.65	0.7	1	1	1	1	0.5	0.6	1	1
		0	0.05	0	0.001	0	0.05	0	0.05	0	0.001	0	0.05
Flood intensity	**Water height (m)**	**Effect on agriculture**						**Effect on roads**					
None	<0.25	0						0					
Low	0.25-1	0.5						0.1					
Moderate	1-2	0.75						0.5					
High	>2	1						1					

Table 3.44 Landslide vulnerability damage values of different elements-at-risk obtained from literature and expert opinions.

LANDSLIDE VULNERABILITY DAMAGE VALUES OF DIFFERENT ELEMENTS-AT-RISK OBTAINED FROM LITERATURE AND EXPERT OPINIONS												
LANDSLIDE SUSCEPTIBILITY	EFFECT ON BUILDING STRUCTURE TYPE (1ST ROW) AND POPULATION (2ND ROW)											
	BMW_MS	BMW_SS	LBC_MS	LBC_SS	LBM_MS	LBM_SS	LBW_MS	LBW_SS	RCC_MS	RCC_SS	OTH_MS	OTH_SS
Low	0.25	0.25	0.1	0.15	0.15	0.25	0.15	0.25	0.05	0.1	0.15	0.25
	0.0125	0.0125	0.005	0.0105	0.0125	0.0125	0.0125	0.0125	0.005	0.0105	0.0125	0.0125
Moderate	0.75	0.75	0.5	0.5	0.75	0.75	0.75	0.75	0.5	0.5	0.75	0.75
	0.0375	0.0375	0.025	0.035	0.0375	0.0375	0.0375	0.0375	0.025	0.035	0.0375	0.0375
High	1	1	0.75	1	1	1	1	1	0.75	0.75	1	1
	0.05	0.05	0.045	0.05	0.05	0.05	0.05	0.05	0.045	0.0525	0.05	0.05
Landslide susceptibility	**Effect on agriculture**						**Effect on roads**					
Low	0.25						0.5					
Moderate	0.5						0.75					
High	1						1					

Table 3.45 Earthquake vulnerability damage values of different elements-at-risk extracted from the earthquake fragility curves and expert opinion.

EARTHQUAKE VULNERABILITY DAMAGE VALUES OF DIFFERENT ELEMENTS-AT-RISK EXTRACTED FROM THE EARTHQUAKE FRAGILITY CURVES AND EXPERT OPINION													
EARTHQUAKE INTENSITY	PGA (G IN M/S^2)	EFFECT ON BUILDING STRUCTURE TYPE (1ST ROW) AND POPULATION (2ND ROW)											
		BMW_MS	BMW_SS	LBC_MS	LBC_SS	LBM_MS	LBM_SS	LBW_MS	LBW_SS	RCC_MS	RCC_SS	OTH_MS	OTH_SS
Very High	>0.5	1	1	0.8	0.8	1	1	1	1	0.8	0.8	1	1
		0.25	0.25	0.1	0.1	0.25	0.25	0.25	0.25	0.05	0.05	0.25	0.25
Earthquake intensity	**PGA (g in m/s^2)**	**Effect on agriculture**						**Effect on roads**					
Very High	>0.5	not relevant						0.25					

Table 3.46 Wind vulnerability damage values of different elements-at-risk extracted from the wind vulnerability curves and expert opinion.

WIND VULNERABILITY DAMAGE VALUES OF DIFFERENT ELEMENTS-AT-RISK EXTRACTED FROM THE WIND VULNERABILITY CURVES AND EXPERT OPINION												
WIND INTENSITY	EFFECT ON BUILDING STRUCTURE TYPE/ROOFS (1ST ROW) AND POPULATION (2ND ROW)											
	BMW_MS	BMW_SS	LBC_MS	LBC_SS	LBM_MS	LBM_SS	LBW_MS	LBW_SS	RCC_MS	RCC_SS	OTH_MS	OTH_SS
Very Low	0	0	0	0	0	0	0	0	0	0	0	0
	Population vulnerability to wind is considered not relevant. People are considered to be within buildings.											
Low	0	0	0	0	0	0	0	0	0	0	0	0
	Population vulnerability to wind is considered not relevant											
Moderate	0.05	0.05	0.005	0.005	0.05	0.05	0.05	0.05	0.005	0.005	0.05	0.05
	Population vulnerability to wind is considered not relevant											
High	0.3	0.3	0.05	0.05	0.25	0.25	0.25	0.25	0.05	0.05	0.3	0.3
	Population vulnerability to wind is considered not relevant											
Wind intensity	**Effect on agriculture**						**Effect on roads**					
Very Low	0						Not relevant					
Low	0.01											
Moderate	0.10											
High	0.40											

3.5 LOSS AND RISK ANALYSIS

Loss Analysis

Losses were calculated for each hazard type, frequency class, and element-at-risk combination. The losses were calculated by multiplying three components: Exposure, Physical Vulnerability, and Spatial Probability. The loss analysis is done for each combination of a hazard map (for a given return period) and an elements-at-risk map. Each loss estimation requires a number of steps, which makes that doing this type of analysis manually is very time consuming. Therefore, an automated script was used, which combines a number of calculations and operations, and uses parameters. It does the following steps:

- Rasterize the element-at-risk map (EAR) (e.g., AGRI = agricultural areas, BUIL= buildings, PEOP = people, ROAD = road)
- Overlay the element at risk map with the hazard intensity map. This is done with the Cross operation. For example, the element-at-risk map AGRI is crossed with the hazard intensity map, e.g., FL_100
- The resulting cross table (joint frequency table) contains all combinations of the EAR and the intensity values (e.g., water depths). Classify the results, according to the classification of the hazard intensity (e.g., domain class group FL), so that the result is in the form of classes, which can be used to join with the vulnerability tables.
- As EAR are sometimes large and only part of them might be actually exposed to hazard intensity the script calculates the losses first for the parts of the EAR with the same intensity.
- In order to know which fraction of each EAR has a certain intensity, the script reads in in the area of the whole EAR from the attribute table of the EAR maps.
- Then the script calculates the fraction of the EAR (Area of the unit in the joint frequency table / the area of the entire EAR).
- Then the script joins with the attribute table of the EAR and reads in the amount column which can either be the value or the people, depending on the input provided by the user.
- The script uses this then to calculate the amount for each combination of EAR and intensity class.
- The script joins with the attribute table of the EAR and reads in the different EAR types.
- The script joins with the vulnerability table (of the hazard type indicated) and reads in the vulnerability values for all EAR types.
- The vulnerability for each record is calculated by taking the vulnerability value of the column that has the same code as in the record.
- The script calculates a column that has an indication whether we are dealing with a spatial probability map. This is done by creating a column SPCheck and then checking if the entered value is SP (Spatial Probability) or not.
- If this is the case, we use the spatial probability, otherwise a value of 1.
- The script then calculates the loss by multiplying the amount * vulnerability * spatial probability and aggregates the loss for the administrative units storing in a separate table.
- The script aggregates the losses for the whole area and stores the results in the separate Table.
- The script then deletes all the intermediate files.
- The results of the loss analysis of Godawari municipality are presented in the following pages.

Risk Analysis

After the loss estimation, risk analysis was done for the available return periods of the hazard type(s) that were selected, and for the different EAR maps, and the risk type (physical or population). Average

Annual Loss (AAL) for the various combination of hazards and elements-at-risk was computed by calculating the area under the risk curve. AAL is the loss of the elements-at-risks that can be expected on an annual basis due to hazardous events of certain intensity and return periods. For the risk analysis, the losses had already been aggregated for a given administrative unit. We therefore use the values of the wards. **Table 3.47** represents an example of AAL calculation.

The risk values are disparate for the various hazard & elements-at-risk combinations and cannot be added together. For instance, expected losses of agriculture to windstorms in hectares, cannot be added to expected kilometers of road flooded. Therefore, we used them as individual factors that were calculated for each ward and could then be compared with similar values of other ward in order to prioritize the wards based on multi-hazard risk. All combinations of hazards and elements-at-risk were not considered as some combinations were meaningless (e.g., road exposed to wind).

The annualized risk was calculated using following equation:

$$\frac{1}{T1}.S1+\left(\frac{1}{T2}-\frac{1}{T1}\right).\frac{S1+S2}{2}+\left(\frac{1}{T3}-\frac{1}{T2}\right).\frac{S2+S3}{2}+\left(\frac{1}{T4}-\frac{1}{T3}\right).\frac{S3+S4}{2}$$

Where T1, T2 etc are the return periods used, and S1 , S2 etc are the losses. For example:

Table 3.47 Example of Average Annual Loss (AAL) calculation.

EXAMPLE OF AVERAGE ANNUAL LOSS (AAL) CALCULATION		
LOSS	RETURN PERIOD	ANNUAL PROBABILITY
1,493,819	20	0.05
2,528,022	50	0.02
6,676,012	100	0.01

Annual risk: =0.01*6676012+(0.02-0.01) *(6676012+2528022)/2+(0.05-0.02) *(2528022+1493819)/2= 173,108

When analyzing the risks, we need to decide if the hazard types are dependent or not. This means if they are related to the same triggering event. This is important for the estimation of the risk, where we take the maximum loss per administrative unit of the various hazards, and do not add them up. We would therefore not add the losses for different hazards, but would take the maximum losses for each of the hazards. The risk analysis was also done using a script. It can only be executed after the estimation of the losses. It requires the individual losses for different hazards for the available return periods. The risk analysis script does the following:

- For each EAR it will calculate the maximum loss for the same return period resulting from various hazards; also checks if these events are caused by the same trigger;
- Then the resulting losses are aggregated by the administrative units;
- Then the annual risk is calculated using the equation indicated above;

The results of the average annual loss of Godawari municipality are presented in the following section.

3.5.1 AUTOMATED PROCEDURE OF RISK ASSESSMENT USING GIS

In order to calculate the risk, an automated procedure was developed based on a series of calculations. These calculations are done in an Open Source and free GIS system (ILWIS), making use of a series of scripts, which are lists of statements to perform the individual steps of the procedure. We developed the following scripts for the subcomponents:

Exposure analysis: This script calculates for each combination of administrative unit (ward), the number of elements-at-risk exposed to a certain hazard type with a certain return period. The user can select the administrative unit level, the hazard type and the return period.

The elements-at-risk maps are raster maps of agricultural area, roads and built-up area, of which the latter one contains information in a table on the number of buildings and people per building class. The hazard map and return period are also selected. For those hazard types for which no return period is available, the user selects the file with "no" instead. When the script is executed, it will carry out the steps shown in **Fig. 3.95** related to the exposure calculation. Results are stored in exposure tables, containing the combination of administrative unit, element-at-risk and hazard. This forms the basis for the second analysis.

Loss analysis: The second script uses the results of the exposure analysis, and combines these with the vulnerability data from the vulnerability tables for each combination of hazard and element-at-risk. It is then also combined with the spatial probability values that are derived from historical data (and expert opinion), and loss is calculated for each element-at-risk/hazard/return period combination as shown in **Fig. 3.96**. These data are aggregated to the administrative unit level and stored in a loss table that is linked to the administrative unit map and which can be displayed in GIS.

*Risk analysis***:** The last calculation (which can also be carried out in Excel) combines the losses for the different return periods and calculates the average annual losses per administrative unit, following the procedure outlines in **Fig. 3.96**.

3.5.2 AUTOMATED PROCEDURE OF RISK ASSESSMENT USING THE RISKCHANGES SDSS

An alternative to ILWIS-GIS, a newly developed tool called RiskChanges SDSS could also be used to assess the multi-hazard risk in the local level. It aims to analyses multi-hazard risk in risk prone area, the tool have Python based version for scientist https://pypi.org/project/RiskChanges/ and Graphical User Interface for non-technical users http://riskchanges.org/ shown in **Fig. 3.97**. It is easy to use and fast but it is still in development and testing phase. The tool includes several major features: multi-hazard, multiple assets, vulnerability database, multi-user, compare risk and spatial analysis. In general, the tool has three main components to conduct the multi-hazard risk assessment: data management, analysis, and visualization component.

Data management: The data management focuses on the input data preparation of elements-at-risk, hazard maps, vulnerability curves, administrative units, risk reduction alternatives and future scenarios. The data management performs different functions on the input data mainly matching projections, classify hazard maps, project vector and raster maps, checks projections, checks unique types, and links vulnerability to hazard.

Building footprints, land parcels, linear feature (road, railway, powerline) and point data are the elements-at-risk that can be included in the tool. The hazard data required to identify the model can be of either a susceptibility map with classes or an intensity map, with given units of intensity. The vulnerability curve is linked with the modelled hazard intensity the curves include intensity (from> to) and for susceptibility hazard it will be linked to susceptibility classes (e.g., from very low to low). The vulnerability database includes different information to be defined and used by the users which are the type of the elements-at-risk (e.g., building footprint), elements-at-risk class, hazard type, intensity type, source of vulnerability, and region for which the curve is valid.

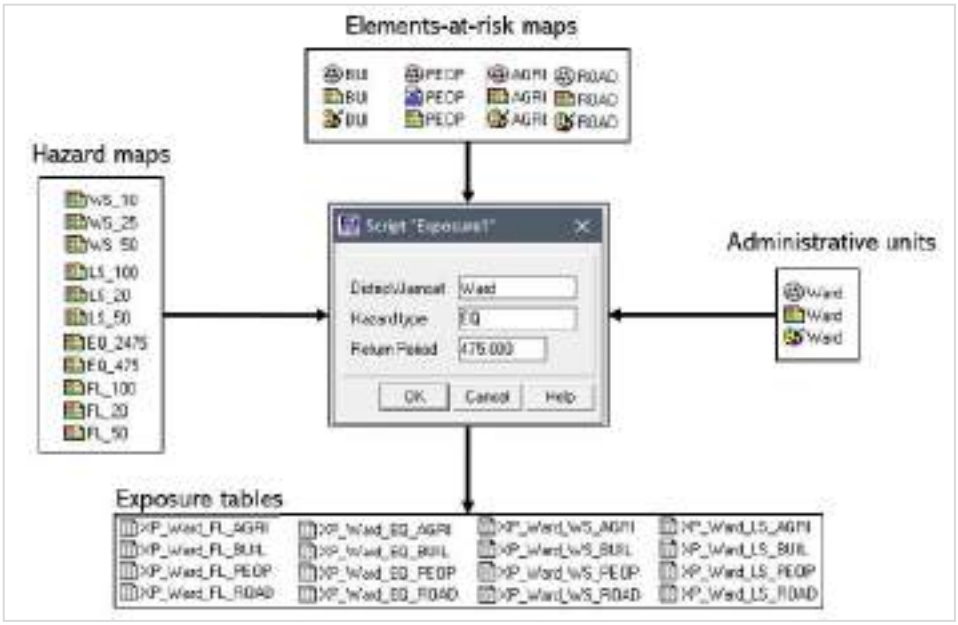


Fig. 3.95 Procedure for exposure analysis with GIS using a script file in ILWIS.

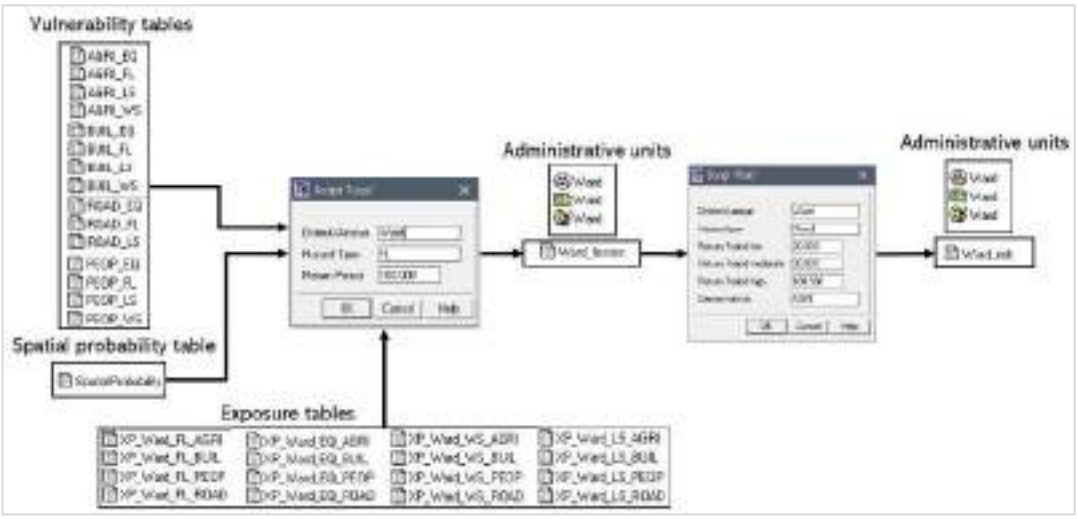


Fig. 3.96 Procedure for loss and risk analysis with GIS using a script in ILWIS.

Fig. 3.97 Preview of Risk Changes website homepage (http://riskchanges.org/).

Similarly, risk reduction alternatives (such as engineering, ecological and relocations) and the corresponding changes in the hazards, elements-at-risks and vulnerability can be added and loss can be compared with the status quo of the location, which could help in planning and decision making. Finally, different future scenarios can also be added to analyze how the risk changes over time.

Analysis: The analysis component is used to compute the analysis of the exposure, loss, risk, and cost benefit analysis. The Exposure function calculate the exposure with and without aggregation per administrative unit. The calculation is done in the system by using the elements at risk (EAR) shapefile, classified hazard, and unique identification key in EAR. RiskChanges perform the exposure for different combination of elements-at-risk, hazard, future scenarios, and year, return period and alternatives.

The Loss function computes the loss using the calculated exposure data, EAR unique ID, cost column, linked vulnerability column, and spatial probability of the hazard. The loss can be aggregated to the administration unit and different combination of hazard and elements-at-risk is possible in the system. The loss report will be for single asset or in the administrative level.

The RiskChanges calculate the single and multi-hazard risk. The risk calculation takes over after calculating the losses. An advantage over the ILWIS-GIS is that it efficiently incorporates the interaction between the hazards such as described below in **Table 3.48**.

The Risk Changes is able to compare the risk reduction alternatives by analyzing the cost benefit ratio. The analysis required the cost of alternatives, investment period, benefits, lifetime of the investment and discount rate. The system calculates the Net Present Value, Benefit Cost Ratio and Internal Rate of Return. The analysis can be done for current and future risk.

*Visualization***:** As discussed earlier, the Risk Changes has a Python based and a Graphical User Interface (GUI), the visualization of the GUI includes maps, graphs, and tables for all combination (exposure, loss, risk, risk reduction alternatives, future scenarios) but the Python based method do not have any visualization method only the user run the procedures and get the result in shapefile, raster, and csv format.

Table 3.48 Method used to calculate hazard interactions in Risk Changes (Source: Van Westen, 2020).

METHOD USED TO CALCULATE HAZARD INTERACTIONS IN RISK CHANGES	
HAZARD INTERACTION	EXPLANATION
Independent events	Losses can be added up if the events are truly independent
Compounding events	The loss of B should be calculated when A has occurred. If calculated before this equation is an approximation
Coupled events	The hazard should be calculated together ideally and therefore also the loss. If this is not possible, this is an approximation
Dominos events	If the elements-at-risk are not located in the same area
Conditional events	The hazard B can only be calculated after A has occurred. Otherwise, possible scenarios are used beforehand

3.5.3 FLOOD LOSSES

Flood losses were calculated for three return periods (20, 50 and 100 years) and for the elements-at-risk shown in **Table 3.49**. The exposure data shown in **Annex VIII** were multiplied with the vulnerability values given in **Table 3.43** for the appropriate flood intensity classes and elements-at-risk types. The losses were calculated and then multiplied with the spatial probability values as indicated in **Table 3.12**. Then the losses were aggregated per ward, and finally per municipality, and the loss percentage was calculated dividing the losses by the total number of elements-at-risk. The resulting loss results are shown in **Table 8.1**. Flood losses for buildings and agricultural area are substantial in Godawari. The flood maps could be one of the reasons for the overestimation since the input parameters for the model were obtained from global and local datasets, resulting in excess flooded areas. So, better input maps followed by sufficient post processing time is required to produce more detailed flood maps. **Fig. 3.98** shows the loss maps of different elements-at-risk for 50 year return period flood.

Table 3.49 Flood loss summary of Godawari Municipality.

FLOOD LOSS SUMMARY OF GODAWARI MUNICIPALITY												
Ward Number	**Number of buildings damaged**			**Number of people injured/killed**			**Crops damaged (hectares)**			**Roads damaged (km)**		
Return period	**20**	**50**	**100**	**20**	**50**	**100**	**20**	**50**	**100**	**20**	**50**	**100**
W1	69	149	297	3	6	10	21	44	59	2	3	5
W2	39	87	169	2	5	5	23	48	58	1	4	6
W3	80	161	230	6	12	17	16	33	43	2	2	4
W4	123	257	304	12	25	30	55	115	131	3	7	7
W5	29	56	72	3	5	5	47	95	110	2	2	2
W6	76	162	207	8	17	22	41	86	100	1	2	3
W7	52	109	125	6	15	17	31	64	72	1	2	3
W8	57	120	156	6	15	19	33	68	80	1	1	2
W9	137	299	363	14	31	40	53	111	133	2	5	5
W10	81	166	217	8	18	25	39	81	99	2	2	2
W11	61	129	165	9	19	25	42	86	108	1	3	3
W12	65	134	165	11	23	29	34	70	81	1	3	3
Total	**869**	**1829**	**2470**	**88**	**191**	**244**	**435**	**901**	**1074**	**19**	**36**	**45**
Percentage	**3.27**	**6.88**	**9.29**	**0.07**	**0.15**	**0.20**	**6.52**	**13.51**	**16.10**	**3.45**	**6.55**	**8.18**

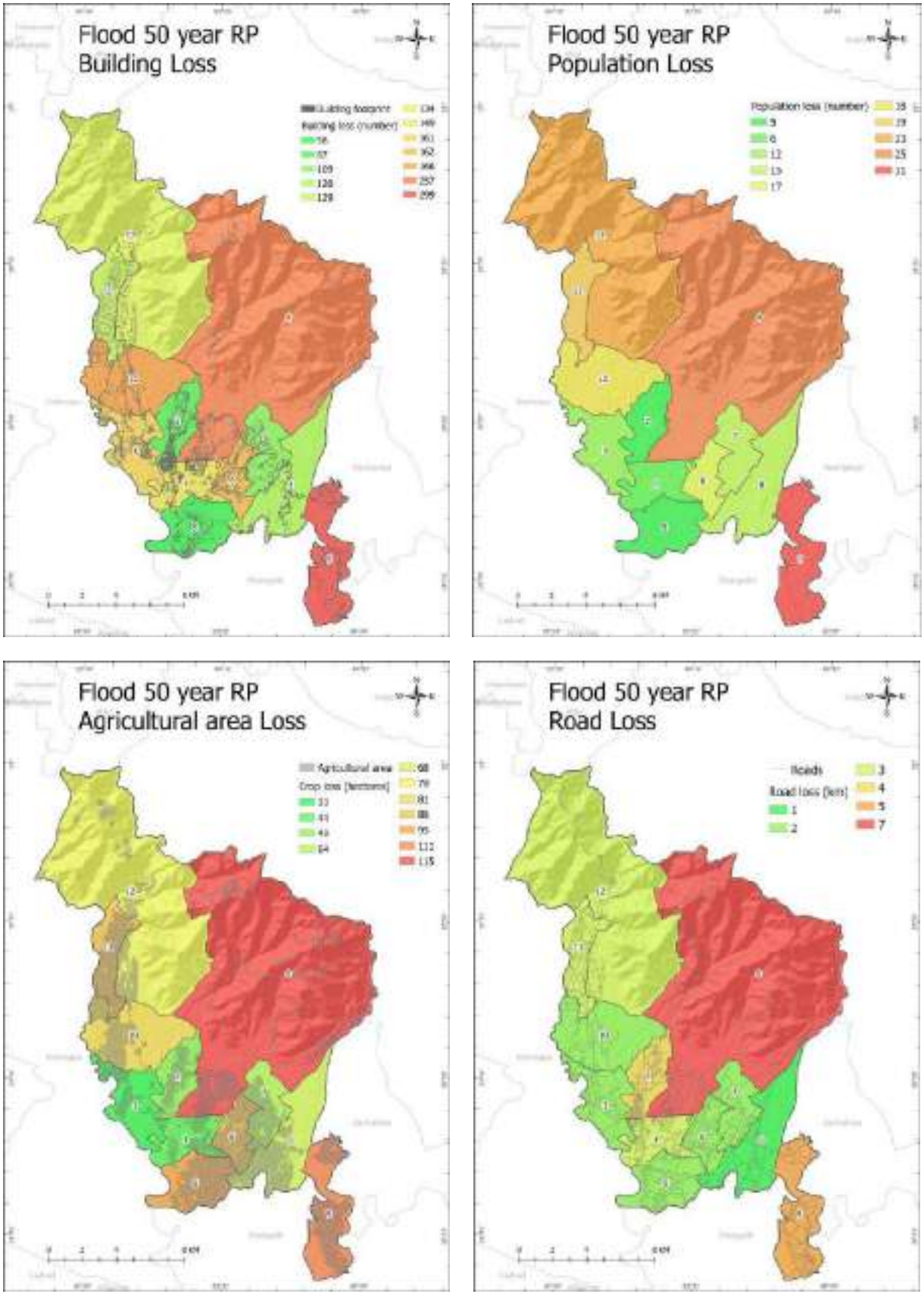


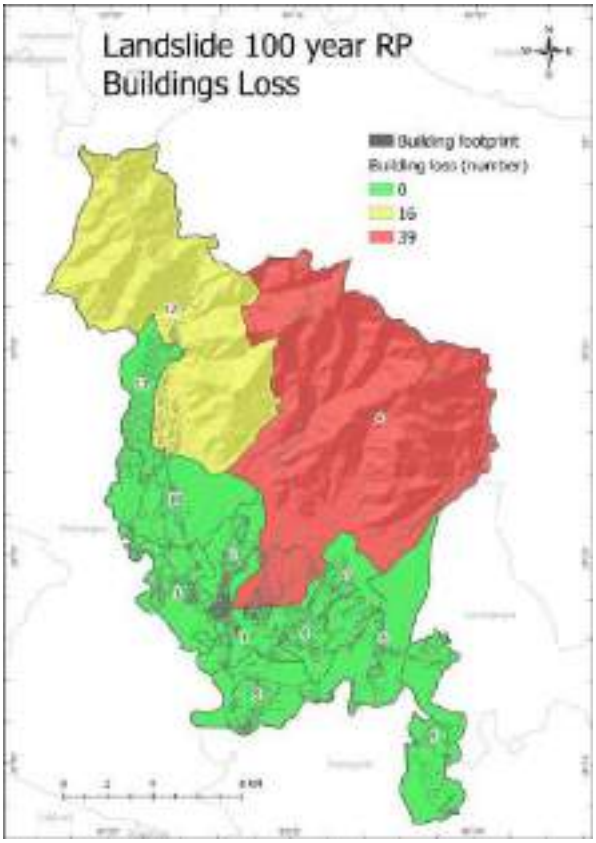
Fig. 3.98 Flood loss maps of different elements-at-risk for 50 year return period.

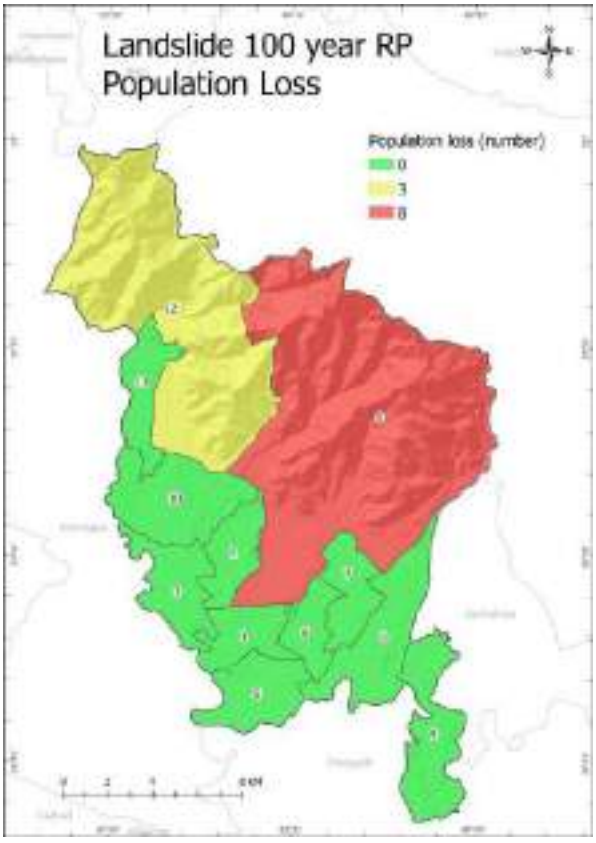
3.5.4 LANDSLIDE LOSSES

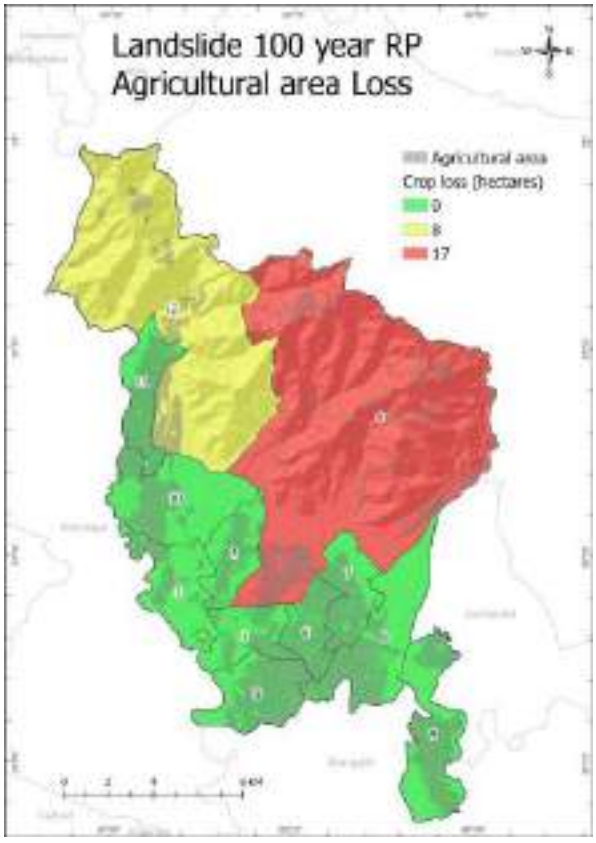
Landslide losses were expected to be low, as the susceptibility was low, the spatial probability was low due to the lack of historical events in the catalogue, and therefore also the exposure to moderate and high susceptibility classes was low (**Annex VIII**), except for wards 4 and 12. The resulting landslide loss values shown in **Table 3.50** indicates that landslides are not a significant hazard type in the Godawari municipality. **Fig. 3.99** shows the loss maps of different elements-at-risk for 100-year return period landslide, which was considered the worst-case scenario. So, even for the worst-case landslide, the loss was comparatively negligible to other hazards.

Table 3.50 Landslide loss summary of Godawari Municipality.

LANDSLIDE LOSS SUMMARY OF GODAWARI MUNICIPALITY												
WARD NUMBER	NUMBER OF BUILDINGS DAMAGED			NUMBER OF PEOPLE INJURED/KILLED			CROPS DAMAGED (HECTARES)			ROADS DAMAGED (KM)		
Return period	**20**	**50**	**100**	**20**	**50**	**100**	**20**	**50**	**100**	**20**	**50**	**100**
W1	0	0	0	0	0	0	0	0	0	0	0	1
W2	0	0	0	0	0	0	0	0	0	0	0	1
W3	0	0	0	0	0	0	0	0	0	0	0	0
W4	0	1	39	0	0	8	0	1	17	0	0	3
W5	0	0	0	0	0	0	0	0	0	0	0	1
W6	0	0	0	0	0	0	0	0	0	0	0	0
W7	0	0	0	0	0	0	0	0	0	0	0	0
W8	0	0	0	0	0	0	0	0	0	0	0	1
W9	0	0	0	0	0	0	0	0	0	0	0	1
W10	0	0	0	0	0	0	0	0	0	0	0	0
W11	0	0	0	0	0	0	0	0	0	0	0	0
W12	0	1	16	0	0	3	0	0	8	0	0	1
Total	**0**	**2**	**55**	**0**	**0**	**11**	**0**	**1**	**25**	**0**	**0**	**9**
Percentage	**0**	**0.0075**	**0.20**	**0**	**0**	**0.009**	**0**	**0.01**	**0.37**	**0**	**0**	**1.64**







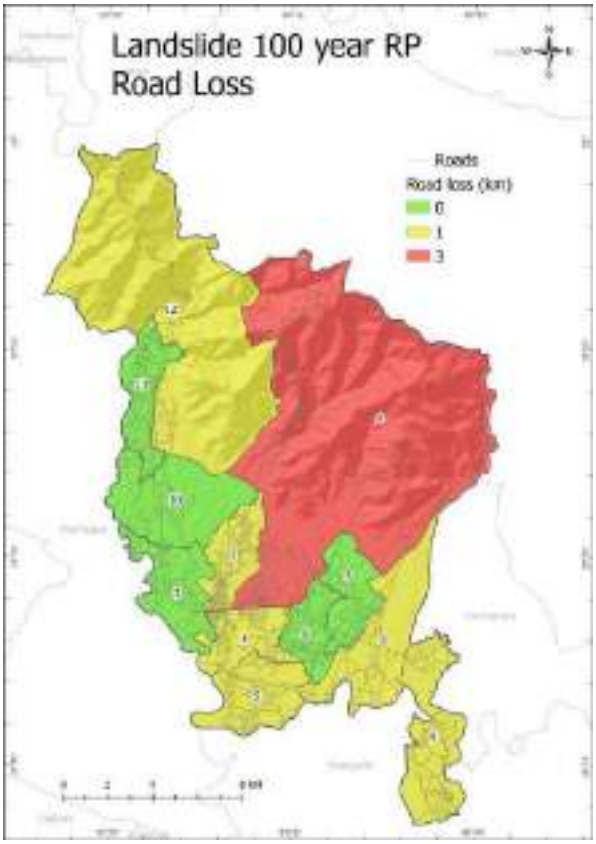


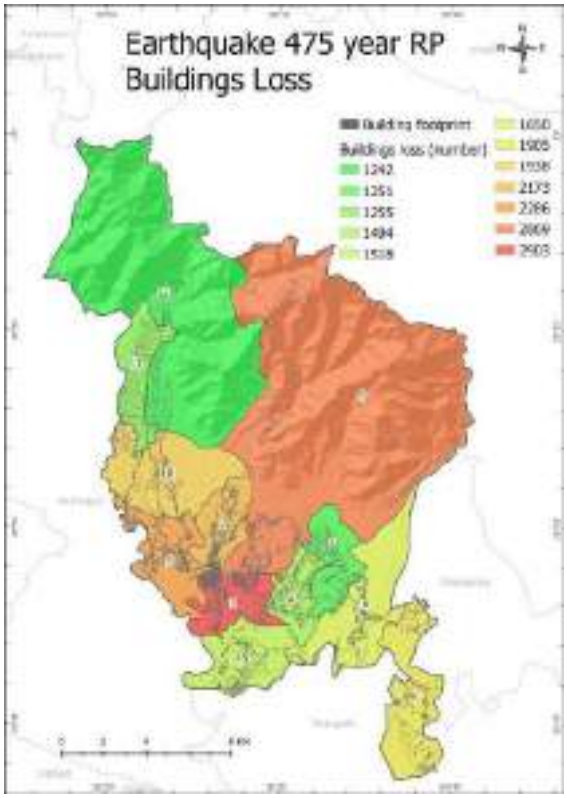
Fig. 3.99 Landslide loss maps of different elements-at-risk for 100 year return period.

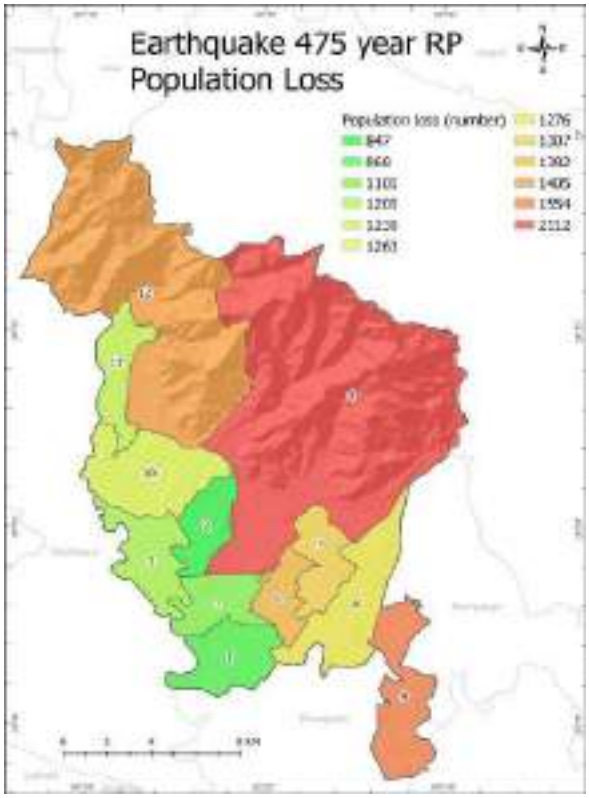
3.5.5 EARTHQUAKE LOSSES

The earthquake losses were calculated for two return periods (475 and 2475 years). Earthquakes are extreme events which can cause a substantial damage and loss of lives, but which occur with a relatively lower frequency than the other hazard types with a meteorological/hydrological trigger. The losses were calculated using the exposure data from **Annex VIII**, and multiplying these with the respective vulnerability values shown in **Table 3.45**. As can be seen in **Table 3.12**, a spatial probability value of 1was applied, which means that the actual area affected will be covering the entirely modelled area in the district. The loss results are shown in **Table 3.51**. It is clear from this table that earthquake losses are expected to be very large, with more than 80% of all buildings destroyed and several thousands of casualties. **Fig. 3.100** shows the loss maps of buildings, population and roads for the 475 return period earthquake.

Table 3.51 Earthquake loss summary of Godawari Municipality.

EARTHQUAKE LOSS SUMMARY OF GODAWARI MUNICIPALITY						
WARD NUMBER	NUMBER OF BUILDINGS DAMAGED		NUMBER OF PEOPLE INJURED/KILLED		ROADS DAMAGED (KM)	
Return period	**475**	**2475**	**475**	**2475**	**475**	**2475**
W1	2903	2903	1105	1105	13	13
W2	2173	2173	847	847	14	14
W3	2286	2286	1205	1205	11	11
W4	2869	2869	2112	2112	25	25
W5	1518	1518	868	868	14	14
W6	1494	1494	1382	1382	7	7
W7	1251	1251	1307	1307	8	8
W8	1650	1650	1276	1276	9	9
W9	1905	1905	1554	1554	13	13
W10	1938	1938	1263	1263	8	8
W11	1255	1255	1238	1238	11	11
W12	1242	1242	1405	1405	11	11
Total	**22484**	**22484**	**15562**	**15562**	**144**	**144**
Percentage	**84.60**	**84.60**	**12.62**	**12.62**	**26.18**	**26.18**





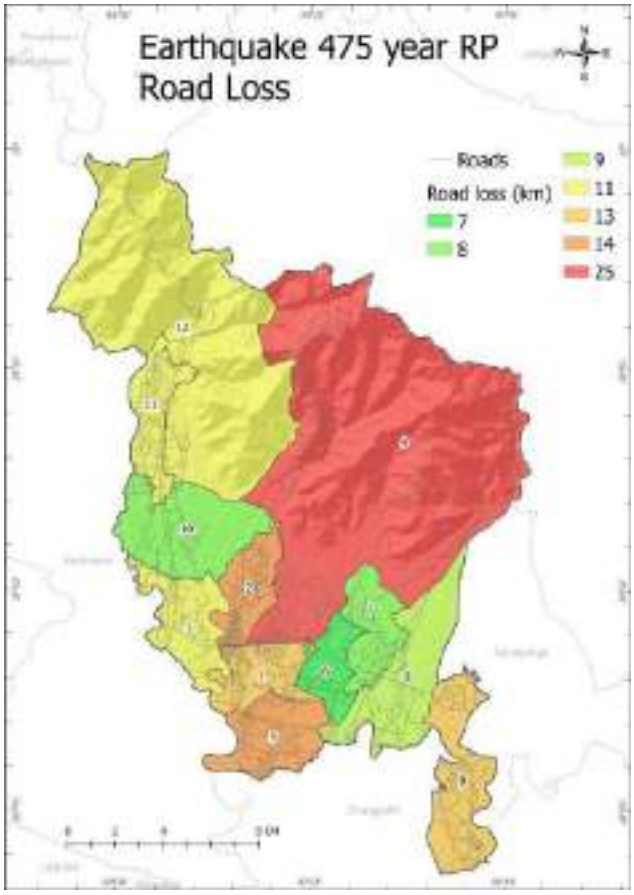


Fig. 3.100 Earthquake loss maps of different elements-at-risk for 475 year return period.

3.5.6 WINDSTORM LOSSES

Windstorm losses were calculated for three return period (10, 25 and 50 years). The exposure values indicated in **Annex VIII** and the vulnerability values from **Table 3.46** were used. The spatial probability values from **Table 3.12** were used. The results in **Table 3.52** show that windstorms can cause substantial losses to buildings (especially the rural buildings, with weaker roofs), amounting to high values almost 40% of the buildings with some roof damage in extreme (and rare) events. Also, losses to crops could be significant. Historical information was inconsistent to corroborate these findings, it is important that future studies look more into this phenomenon, especially the effects on different types of crops. **Fig. 3.101** shows the loss maps of buildings and agricultural area for windstorm of 25-year return period.

Table 3.52 Windstorm loss summary of Godawari Municipality.

WINDSTORM LOSS SUMMARY OF GODAWARI MUNICIPALITY						
WARD NUMBER	NUMBER OF BUILDINGS DAMAGED			CROPS DAMAGED (HECTARES)		
Return period	**10**	**25**	**50**	**10**	**25**	**50**
W1	0	29	287	3	30	119
W2	0	14	183	4	28	108
W3	0	37	289	2	24	97
W4	37	110	382	49	131	323
W5	0	24	181	7	74	298
W6	0	36	240	5	49	197
W7	0	32	213	5	45	181
W8	0	50	324	7	67	267
W9	0	67	419	7	66	261
W10	0	48	337	6	55	220
W11	0	31	185	4	43	182
W12	2	38	174	6	42	154
Total	**39**	**516**	**3214**	**105**	**654**	**2407**
Percentage	**0.15**	**1.94**	**12.09**	**1.57**	**9.80**	**36.08**

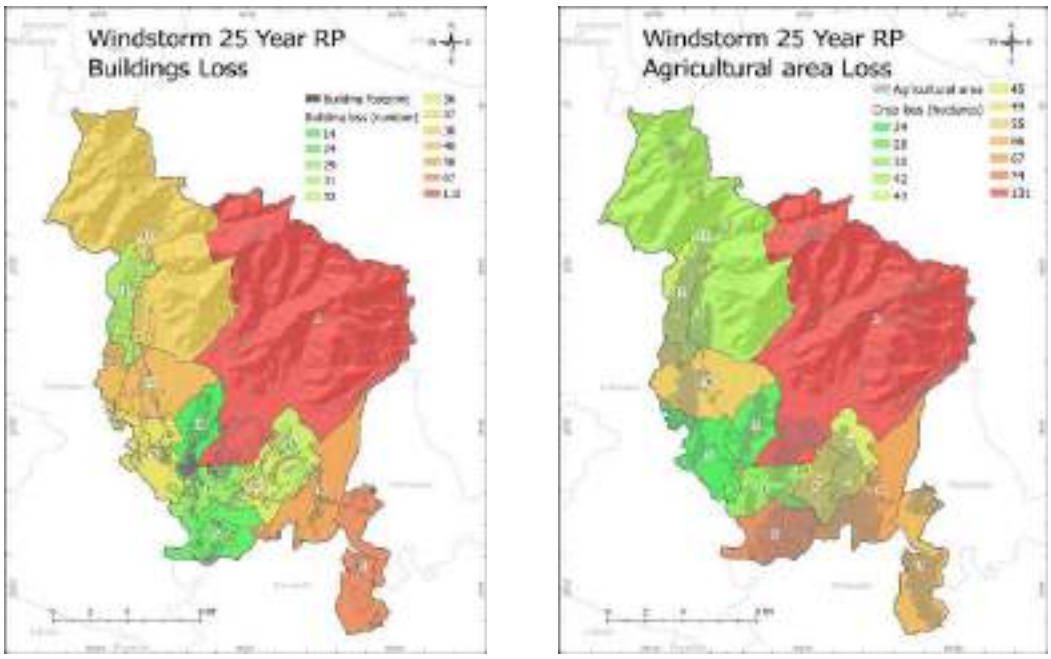


Fig. 3.101 Windstorm loss maps of different elements-at-risk for 25 year return period.

In this project, the loss of elements-at-risk in physical quantities were considered such as numbers of buildings and people, hectares of agricultural land, kilometers of roads. For the economic values estimation, information on construction costs of buildings, repair costs of roads and buildings, gross production of crops etc. need to be collected, which was beyond the scope of this study.

The losses or damages due to animal attacks, fire and climate extremes were not calculated using automated ILWIS-GIS script because of lack of information such as their intensity, physical vulnerability values, spatial probability. This information prevents us from producing the quantitative loss values. However, from the field consultations, historical information on the damages due to animal attacks, fire and heatwaves/coldwaves were collected for different wards in the municipality. The location and the damage details are shown in individual hazard zonation maps in **Annex I**.

On comparing the AAL values among the hazard types, it becomes clear that flooding has higher average annual losses than earthquakes in this area. Although loss values for individual earthquakes can be very large (**Table 3.51**) the frequency of flood events is much higher, which has an important effect on the AAL. The values in **Table 3.53** for building losses indicate the average number of buildings that might be severely impacted in a given year. The high value of windstorm damage to buildings is attributed to the roof damage rather than complete collapse. Further adjustment of vulnerability values of buildings to wind might be required. In terms of population the AAL values show the number of persons that might be seriously injured or killed on an average per year due to the occurrence of a hazardous phenomenon. The values are high for flooding and for earthquake in the Godawari municipality. Average annual crops damage by flood and windstorm is also substantial in this municipality. For the animal attacks and fire, a qualitative risk index maps were produced shown in **Sections 3.1.5** and **3.1.6** respectively.

Table 3.53 Average Annual Losses for the various hazards and elements-at-risk combinations for wards in Godawari municipality.

AVERAGE ANNUAL LOSSES FOR THE VARIOUS HAZARDS AND ELEMENTS-AT-RISK COMBINATIONS FOR WARDS IN GODAWARI MUNICIPALITY													
HAZARD	FLOOD				LANDSLIDE				EARTHQUAKE			WIND	
Ward	**Number of buildings damaged**	**Number of people killed/injure**	**Crops damaged (hectares)**	**Roads damaged (km)**	**Number of buildings damaged**	**Number of people killed/injure**	**Crops damaged (hectares)**	**Roads damaged (km)**	**Number of buildings damaged**	**Number of people killed/injure**	**Roads damaged (km)**	**Number of buildings damaged**	**Crops damaged (hectares)**
W1	8	0	2	0	0	0	0	0	6	2	0.03	10	5
W2	5	0	2	0	0	0	0	0	5	2	0.03	6	4
W3	8	1	2	0	0	0	0	0	5	3	0.02	10	4
W4	12	1	5	0	1	0	0	0	6	4	0.05	17	16
W5	3	0	4	0	0	0	0	0	3	2	0.03	6	12
W6	7	1	4	0	0	0	0	0	3	3	0.01	9	8
W7	5	1	3	0	0	0	0	0	3	3	0.02	8	7
W8	6	1	3	0	0	0	0	0	3	3	0.02	12	11
W9	13	1	5	0	0	0	0	0	4	3	0.03	15	11
W10	8	1	4	0	0	0	0	0	4	3	0.02	12	9
W11	6	1	4	0	0	0	0	0	3	3	0.02	7	7
W12	6	1	3	0	0	0	0	0	3	3	0.02	7	6
Total	**87**	**9**	**41**	**0**	**1**	**0**	**0**	**0**	**47**	**33**	**0.30**	**119**	**100**

3.6 LIQUEFACTION ASSESSMENT & LIQUEFACTION DISTRIBUTION MAP

Liquefaction subject to the sudden loss of strength due to earthquake and any infrastructure imposed on soil supporting layer fails/collapse and/or tilt on account of occurrence of large deformation leading to large settlements. To generate the liquefaction, the sub-surface soil should be unconsolidated fine sands and the plasticity of soils tend to be plastic to highly plastic. Furthermore, groundwater table/level should meet the soils such that pore pressure suddenly increase and the effective stress decrease and form the state of zero bearing capacity condition below the footing in a sand layer. As a result, heavy structures subside and lighter structures push back to the surface. The Godawari Municipality is distributed under the watershed of Siwaliks. The rocks of Siwaliks are distributed along the northern part of the municipality from the foothill towards the top. Stratigraphically, the Lower Siwaliks (Ls) rocks are distributed from the foothill of the area and Middle Siwalik (Ms) rocks are distributed at the top of the watershed as shown in **Fig. 3.102.** The Lower Siwaliks rocks are represented by fine grained, hard, grey sandstones interbedded with purple and chocolate coloured shales. Since the area is at the active Main Frontal Thrust (MFT), the distributions of rock sequences are highly fragile and disturbed with the formation of landslides in the vicinity. The Middle Siiwalik (Ms) is represented by fine to coarse grained sandstone with interbeds of siltstone and mudstone. The foothill of the area is entirely covered with Quaternary deposits with the presence of boulder, gravel, sand, silt and clay together with the sediments distributed by landslides, debris flows and flooding of adjacent streams and/or gulley. Structurally, the Quaternary deposits and Siwaliks are separated by the active Main Frontal Thrust (MFT) also named as Himalayan Frontal Thrust (HFT).

The provenance of Quaternary deposits is quite near to the Siwaliks (Chure Range) in the Godawari Municipality. The near source Quaternary sediments are encompassed with boulders, cobbles, gravels together with sands, silts and clays. During the field survey for the development of land use map, surface soil samplings were carried out from different locations of the entire municipality in order to identify the nature of soil through field identification method and laboratory tests. Altogether 56 soil samples were taken into consideration using the pit sampling methods. The surface soil generally encompasses with fine grained soils such as clays and silts followed by sands. The properties of soils were determined by two ways: First, field identification method and second, laboratory analysis. The field measurement techniques were applied to determine relative density of soil using rod penetration method. **Annex I** shows the detail soil properties and liquefaction potential with reference to soil plasticity in Godawari Municipality.

The liquefaction is primarily depended on geotechnical properties of soils and its age of sediment/soil deposited at the region, density, depth of water table and strength of ground motion during earthquake and the topography. In order to access the liquefaction in detail, the following parameters needs to be evaluated from the site and laboratory analyses.

a. Granulometry of the soil including USCS classification of soil and plasticity of soil determined by laboratory testing methods.
b. Standard Penetration Test (SPT) N-value obtained through geotechnical exploratory drilling at the particular site.

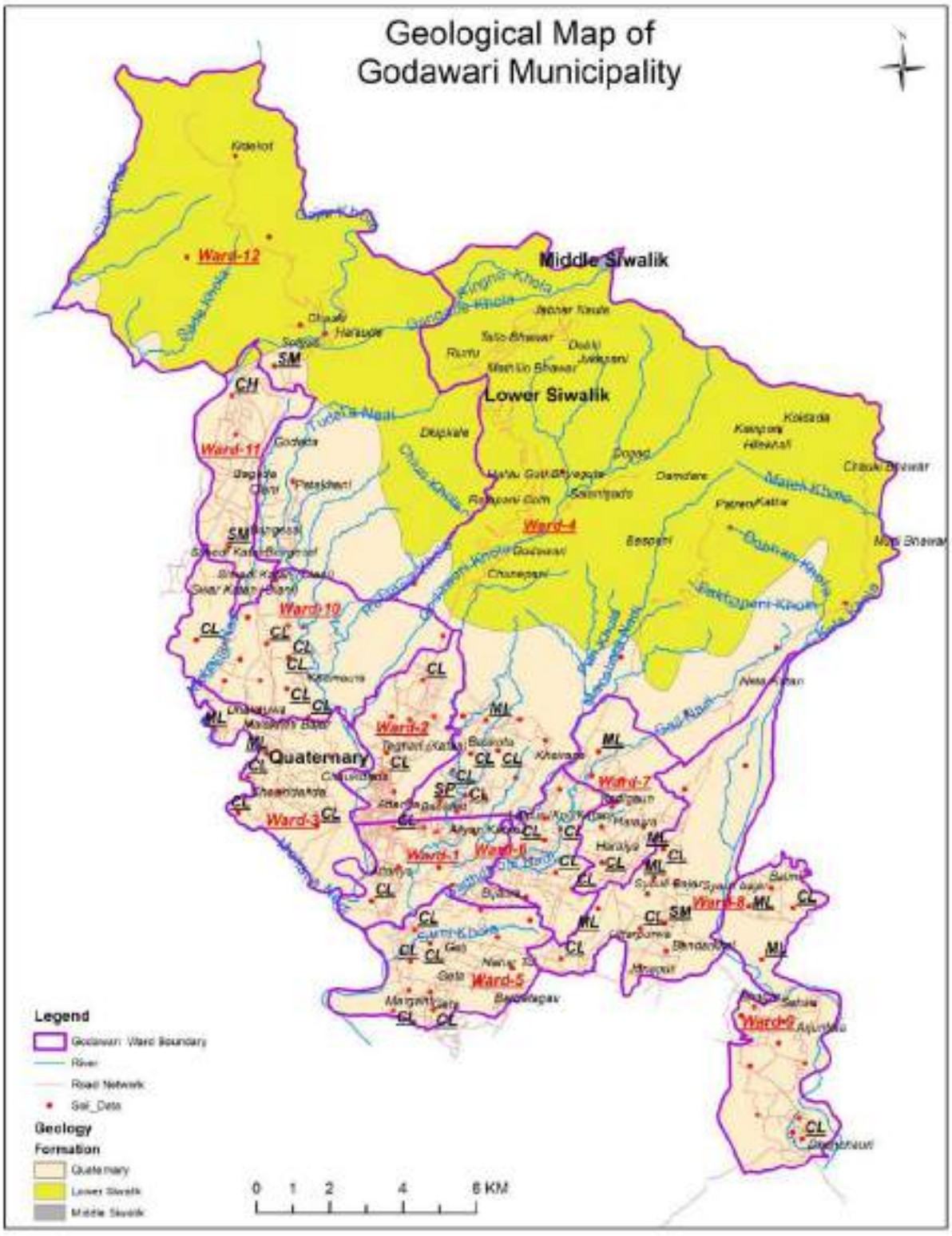


Fig. 3.102 Geological Map of Godawari Municipality.

The shear strength of the soil suddenly reduces due to pore pressure build up in the soil skeleton. The shear strength of cohesionless soil (sands), τ, depends mainly on angle of internal friction and the effective stress acting on the soil skeleton which can be expressed as follows:

$\tau = \sigma' \tan \phi$

$\sigma' = \sigma - u$

Where,

τ = shear strength

σ' = effective normal stress

σ = normal stress

u = pore pressure

ϕ = angle of internal friction

During earthquake, the shear wave propagates through bed rock to soil and they tend to settle and densify. The duration of draining of water immediate after the wave propagation is quite shore and soil volume contraction could not occur immediately. Consequently, pore water pressure becomes equals to the total stress by reducing the effective stress to zero. This will cause the sands temporarily will lose their stiffness and shear strength completely which is known as "initial liquefaction". Hence affected liquefied loose sands will undergo unlimited deformations or flow without mobilizing significant resistant to deformation. As a consequence, infrastructures lying above and/or within the liquified deposit undergo significant settlement and/or tilting; water moves upward to the ground surface generating sand boils. This will cause buoyant effect on buried pipelines and tanks to float on the ground and heavy structures sinks below the ground. For the analyses purpose, the threshold value of liquefaction proposed by Jennings (1980) are considered as represented by **Table 3.54**.

Table 3.54 Threshold values to liquefaction potential of soils

THRESHOLD TO LIQUEFACTION POTENTIAL OF SOILS	
PARAMETERS	THRESHOLD TO LIQUEFACTION
Mean grain size (mm)	0.02 < D50 < 1.0
Clay particle (%)	< 10
Uniformity coefficient	< 10
Relative density	< 75
Void ratio	> 0.8
Plasticity Index, PI (%)	**< 10**
Depth of water table (m)	**< 5**
Depth of sand layer (m)	< 20

In this study, plasticity indices and depth water table during monsoon and dry periods were considered into consideration in order to understand the liquefaction potentials on the ground surface. **Fig 3.103** represents the depth of water table during monsoon and dry period, surface soil and geology of the Godawari Municipality. **Fig. 3.104** shows the water table distribution map of the Godawari Municipality. Similarly, **Fig. 3.105** shows the distribution of soil classification based on USCS of the Godawari Municipality.

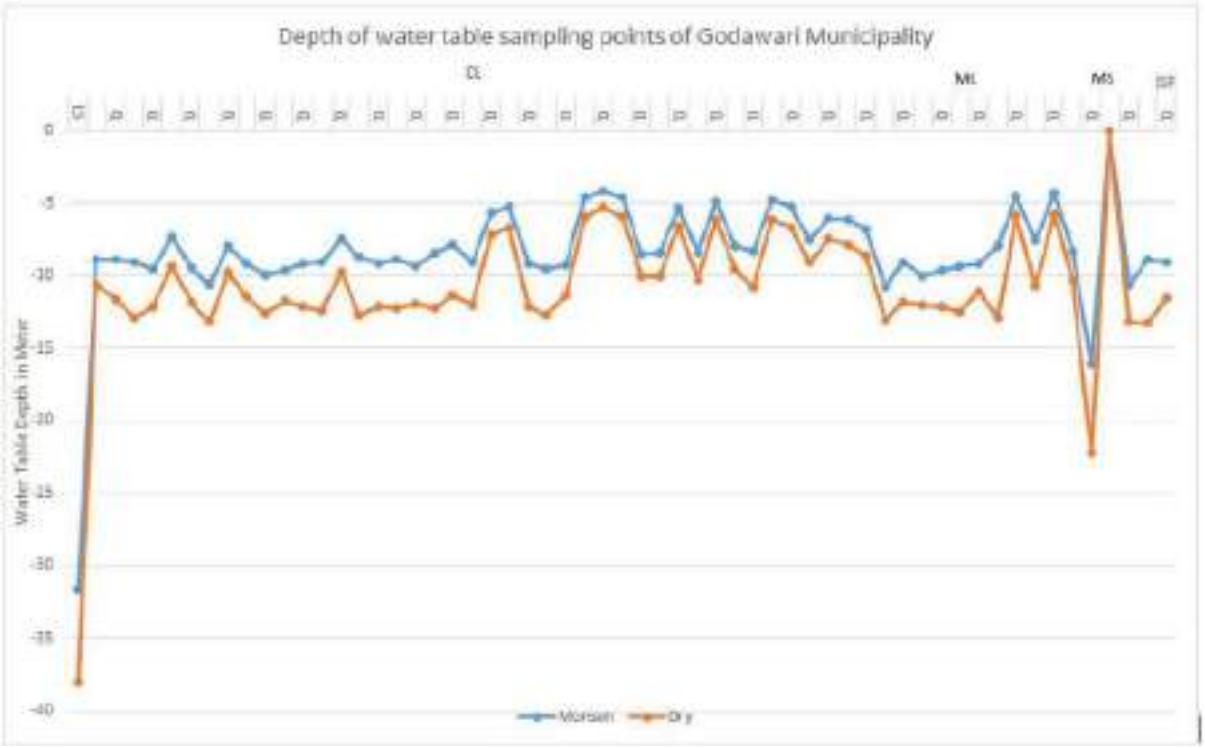


Fig. 3.103 Depth of water table sampling points of the Godawari Municipality.

Rajdevi Engineering Consult carried out detailed soil survey during land use map preparation in order to determine surface layer soil properties for the taxonomy and granulometry determination. These data were used for this project and further accessed the results to understand the possibilities of liquefaction although this surficial depth up to 110 cm soil pit at places does not reflect any detailing. In order to project liquefaction with reference to water table depth, possible data were accumulated with the help of boring experts in local level. With reference to Jennings (1989), water table depth should be less than 5 m for the potential liquefaction for soils which have less than 10% clays as shown in **Table 3-10. Fig 3.106** represents the liquefaction distribution map of the Godawari Municipality. In the figure, liquefaction potentials are accessed in two ways: Where water table depth is known, liquefaction potential have been shown considering water table depth; where water table depth is not known, liquefaction potentiality have been represented based on soil type and soil plasticity. Proceeding, liquefaction distribution is overlain on geology, depth of water table points during monsoon and dry season and soil classification map and obtain combined map to generalize the existing situation as shown in **Fig. 3.107**.

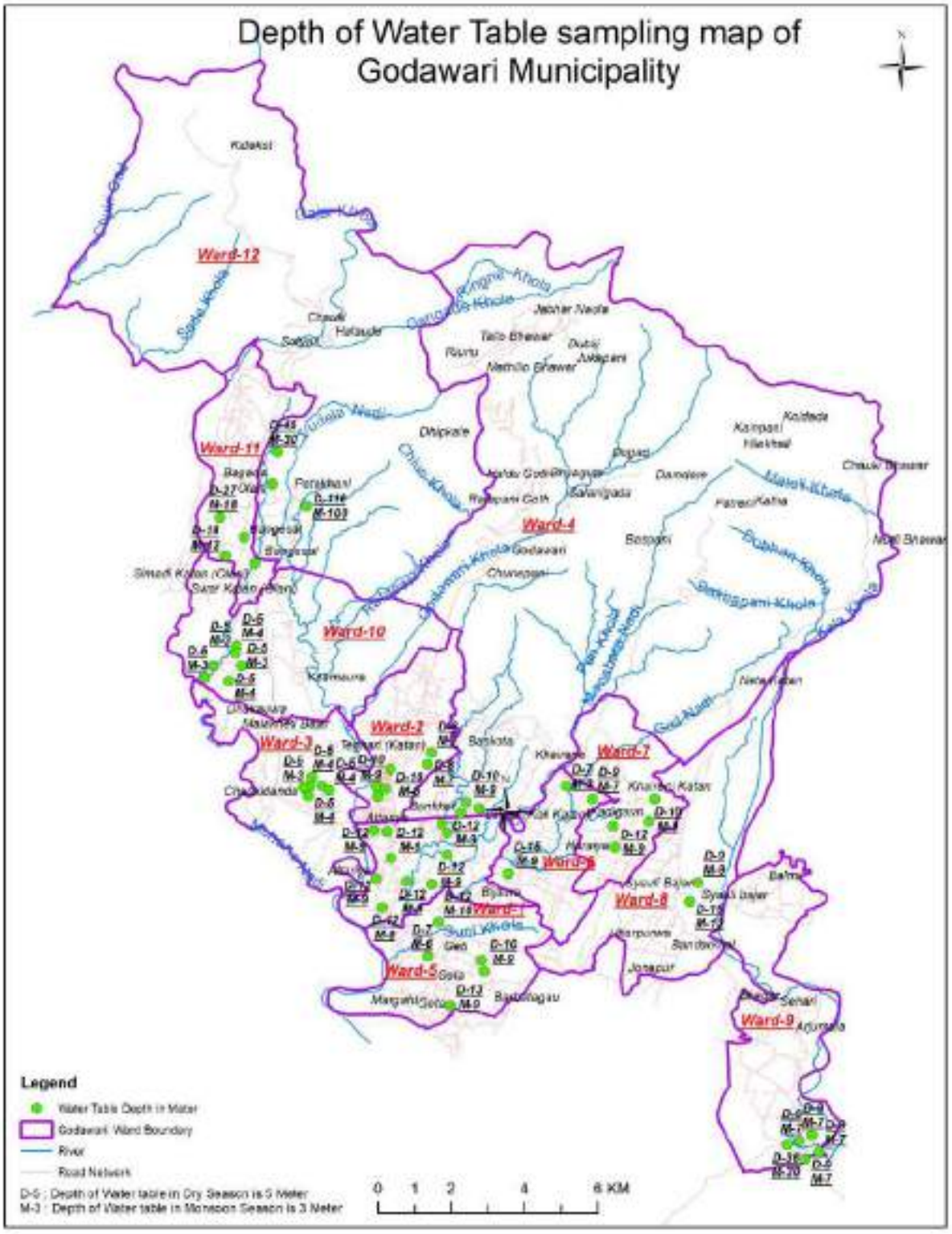


Fig. 3.104 Depth of water table sampling map of the Godawari Municipality.

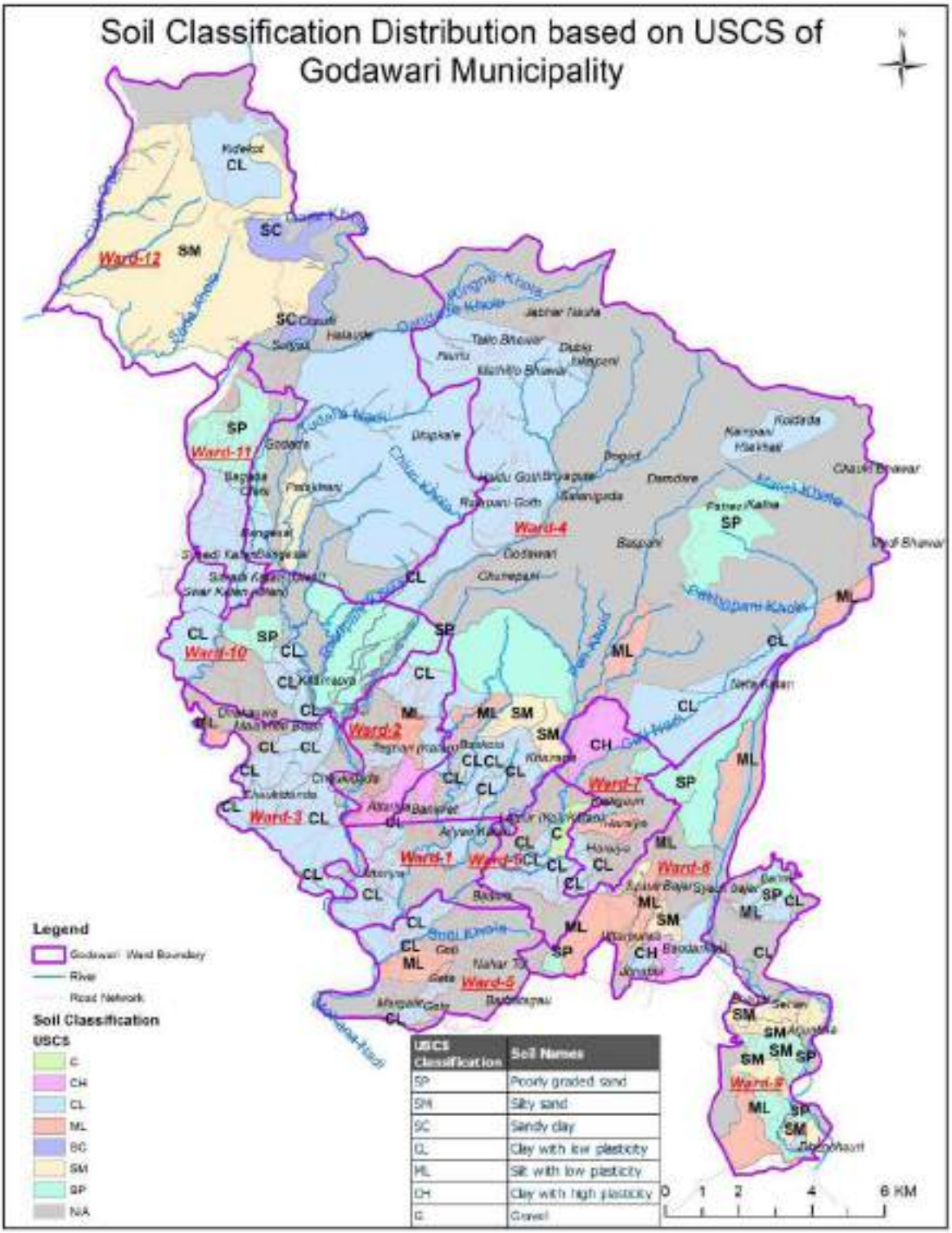


Fig. 3.105 Representation of soil classification distribution based on USCS of the Godawari Municipality.

Liquefaction Potential: From the map in **Fig.3.107**, very high liquefaction potentialities can be expected in Ward No. 11 at Bagada Olani. However, the depth of water tables during monsoon and dry seasons are 30 m and 45 m. In order to meet the liquefaction criteria, these water tables meet the upper layer of poorly graded sand (SP). Similarly, at Attariya Bazaar in Ward No. 1, very high liquefaction can be occurred if the water table rises from 12 m in dry season/9 m in monsoon period up to the surface to saturate clay of low plasticity. On the other hand, Bandarkhal in Ward No. 8

represents very high liquefaction potential with silty sand at the surface if the depth of water table 12 m in monsoon/15 m in dry season meets and saturates the surface. Remaining parts reflect high, medium and low liquefaction potential in the Godawari Municipality. In order to meet the criteria for liquefaction, distribution of soil up to the depth of 10 m or more should be homogenous and water table should meet the layer during earthquake. Besides, the density of the soil formation controls the liquefaction. Therefore, geotechnical exploratory drilling needs to carry out in those locations and identify low SPT-N values and analyze with liquefaction equations. In this reason, although liquefaction distribution map is prepared, it gives surficial information only and strongly suggest to carry out detailed investigation.

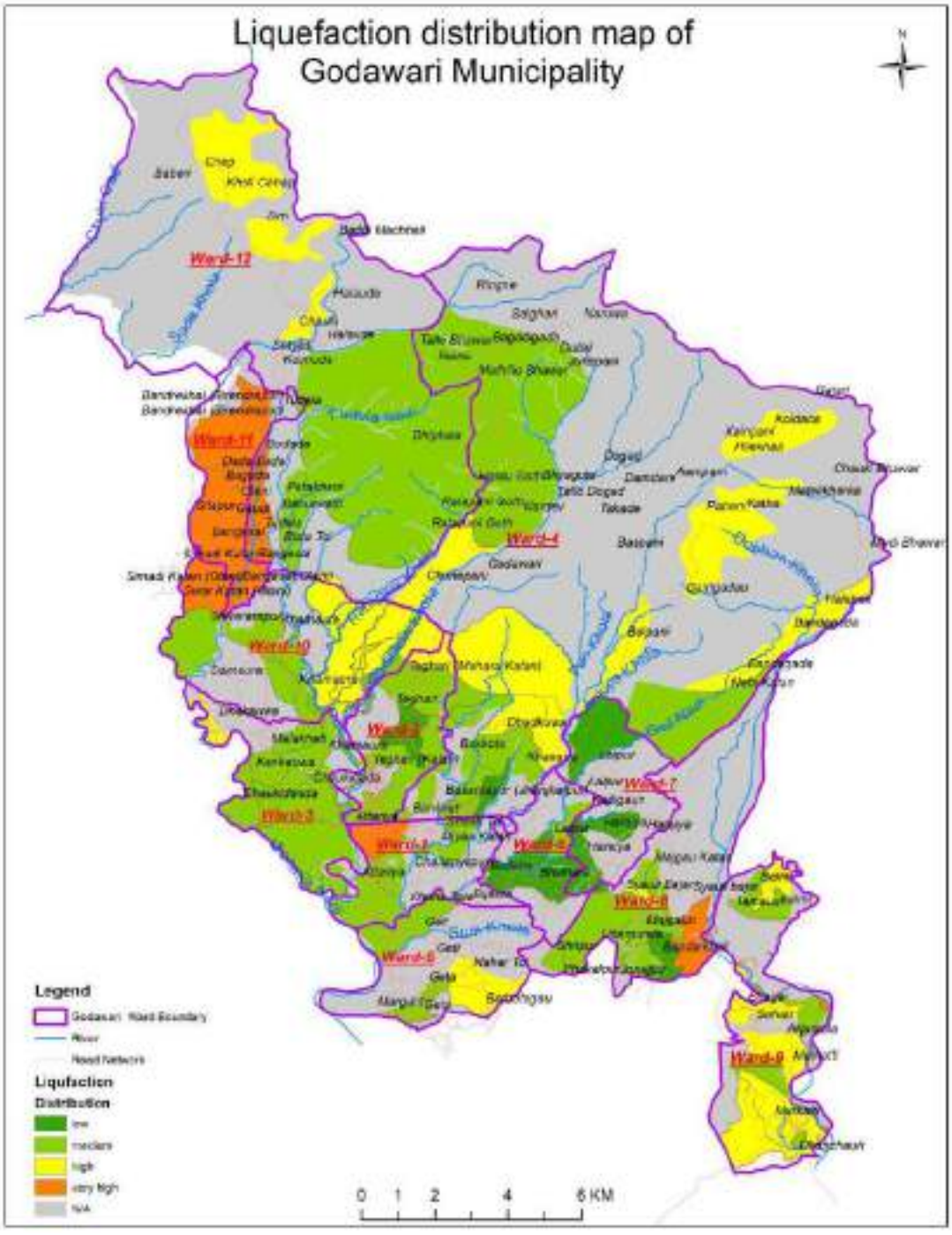


Fig. 3.106 Liquefaction distribution map of the Godawari Municipality.

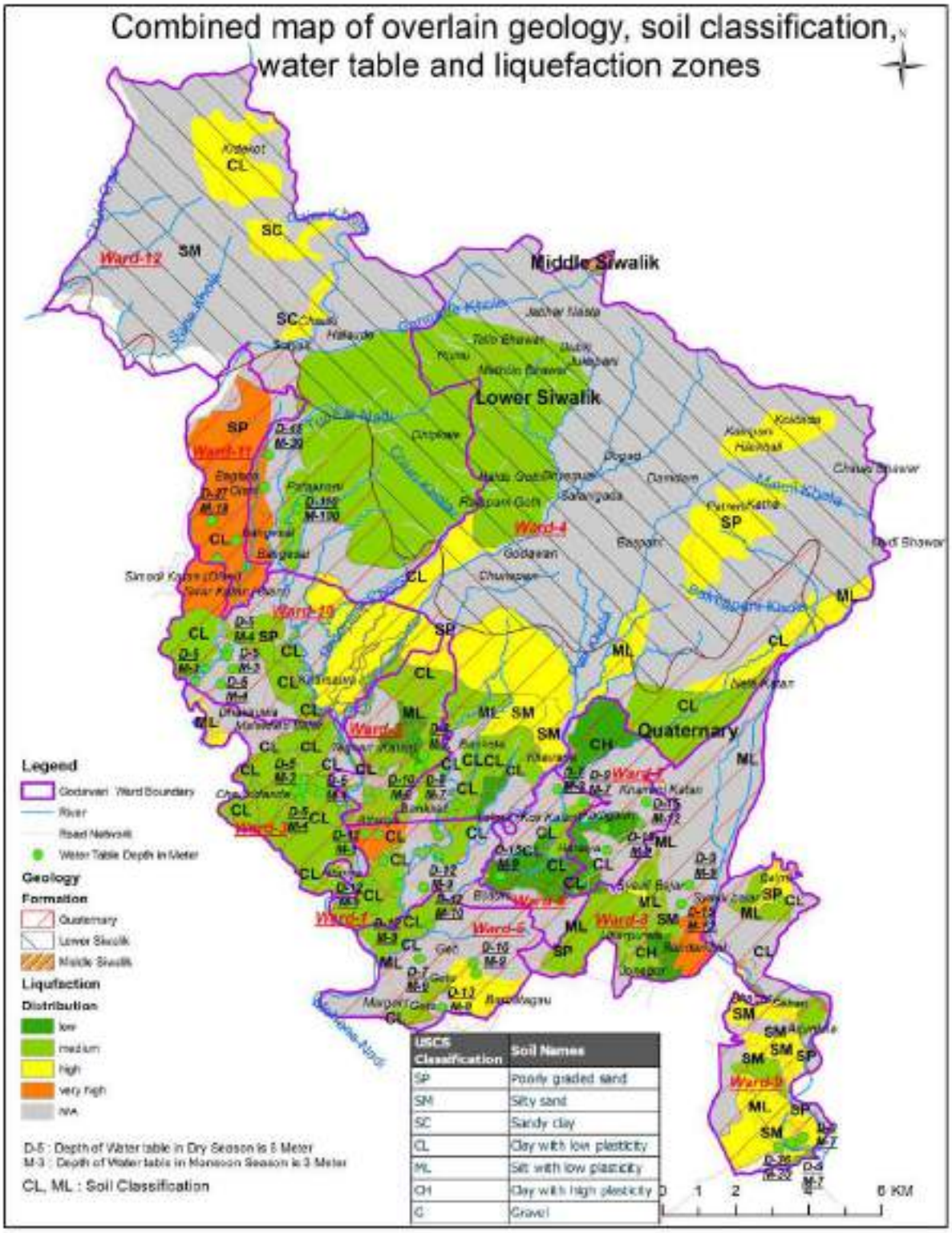


Fig. 3.107 Combined map of overlain geology, soil classification, water table and liquefaction zones.

3.6.1 LIQUEFACTION SCENARIO OF NAVAJEEVAN CO-OPERATIVE LTD., ATTARIYA

The Navajeevan Cooperative Ltd. (**Fig. 3.108**) located at 28.812876, 80.549291 in Attariya carried out detailed geotechnical exploratory drilling for its commercial building in 2076/11/24. They carried out 3 drilling of 15 m depth each using percussion boring technique. The main objective of the study

was to determine geotechnical soil properties of sub-surface, bearing capacity for design criteria and liquefaction assessment (Agni Boring & Soil Test Pvt. Ltd., 2020).

In order to achieve the scope of work, they carried out Standard Penetration Test (SPT) by driving 63.5 kg hammer freely falling through a height of 750 mm and number of blows were determined in terms of 30 cm soil/ground penetration. All three boreholes constituted brown to gray colored clayey silt mixed with silty sand and sand with pebbles up to the depth of 15 m. **Table 3.55** represents summarized soil condition of the strata.

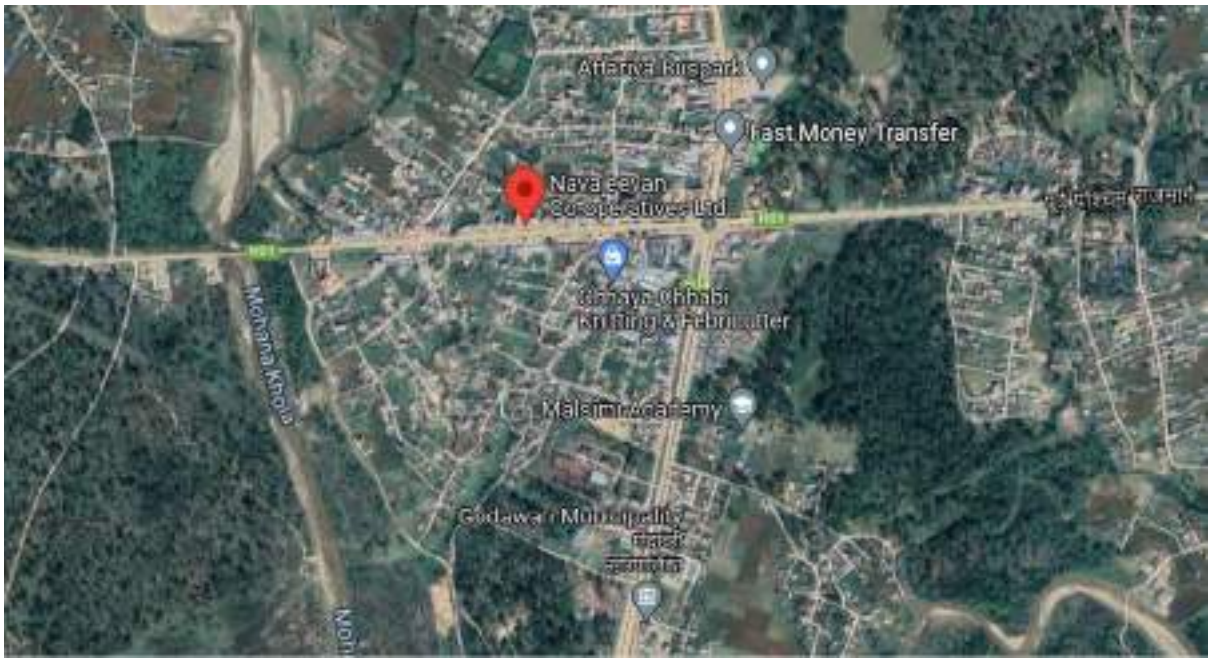


Fig. 3.108 Location map of Navjeevan Co-operatives Ltd., Attariya, Kailali, Nepal.

Table 3.55 Properties of soils obtained from borehole & laboratory, Attariya.

PROPERTIES OF SOILS OBTAINED FROM BOREHOLE & LABORATORY, ATTARIYA				
BOREHOLE NO.	DEPTH OF SOIL (m)	DESCRIPTION OF SOIL	SPT-N VALUE	*C_u, C, PI
BH 1	0-3.0	Pebble mixed clayey silt	5 6	5.0, 0.5%
	3-4.5	Fine to coarse grained sand	9 8	2.31, 1.1%
	4.5-11.5	Clayey silt mixed with sand	36 16 25 22	
	11.5-15.0	Pebble mixed fine to coarse grained sand	20 31	
BH 2	0-3.0	Clayey silt	7 11	4.5, 2.5%
	3.0-4.5	Fine sand	10	
	4.5-6.0	Pebble mixed fine grained sand	14 16	PI = 28.61 1.5, 0.8%
	6.0-12.0	Clayey silt	26 28 29	
	12.0-15.0	Fine to coarse grained sand	30 32	
BH 3	0-1.5	Fine grained sand	4	

PROPERTIES OF SOILS OBTAINED FROM BOREHOLE & LABORATORY, ATTARIYA				
BOREHOLE NO.	DEPTH OF SOIL (m)	DESCRIPTION OF SOIL	SPT-N VALUE	*C_u, C, PI
	1.5-3.0	Clayey silt	9	
	3.0-6.0	Fine grained sand	15 16 15	2.31, 3%
	6.0-10.0	Clayey silt	21 22 24	
	10.0-15.0	Sand mixed clayey silt	28 30	

*** C_u: Uniformity Coefficient, C: Clay in percentage, PI: Plasticity Index**

The description of soil shows that fine grained soils are mixed up with coarse grained soil together with pebbles in all three borehole locations. The SPT-N values shows less than 15 values at the upper part of soil from ground surface up to 4.5 m in BH 1, 4.5-6.0 m in BH 2 and 3.0 m in BH 3 respectively. Correlating with Jennings et al. (1989), the uniformity coefficient (Cu) should be less than 5 and clay should be less than 10%. Besides, the ground water level in BH 1 and BH 2 are encountered at 3.0 m and 4.0 m in BH 3 which is also less than 5 m. The PI at 6.0 m in BH 2 represents moderately higher plasticity indicating towards moderately liquefiable soil. Therefore, this layer up to 4.5 m shows chances of moderate liquefaction in this shallow level. But when checked the SPT-N values below this depth, values are greater than 15 and the soil is mixed in nature, i.e., clayey silt is mixed with sand of fine grained to coarse grained together with the presence of pebbles. The overall drill depth shows of mixed nature. In order to trigger liquefaction, sands more than 10 m should be checked and needs to be satisfied SPT-N values, uniformity coefficient, fine content, soil plasticity and depth of water table. In this location, although shallow level medium liquefaction may occur but the higher SPT-N values together with mixed soil composition prevent from liquefaction in depth below 4.5 m. This case study proves that geotechnical exploratory drilling needs to carry out in all soil sampling locations to determine the liquefaction potentiality. Not only the liquefaction the study will also provide safe bearing capacity evaluations of those sites and can generate general knowledge in developing any types of infrastructures for urban design and urban planning as well as for developing RSLUP.

4. RESOURCE MAPPING

4.1 LAND USE PATTERN

The spatial location of functions and activities is called land use. There are various forms of the functionality of land. The major development activities which take place on land are residing, working, recreating, and moving. There are many factors such as physical, economic and social, which determine how land are being used. These factors combine in unique and often competing ways, and result in certain activities and functions taking place in certain locations (ADPC, 2013).

Land use pattern changes as the population growth it creates the pressure on the land and natural resources and resulting the undesirable outcomes. Land use in the municipal area were as per the availability of natural resources and its connectivity with the market centers. The characteristics of the change in land use as the demand on housing lots created due the opportunities to attract the migrant from the rural areas. As per the National Land Use Policy 2019, the classification of land is as shown in **Table 4.1** and **Fig. 4.1** represents the existing land use map of Godawari Municipality. Basically, the entire lands in the municipality are categorized into the Land Use Patterns as their use as represented in **Tables 4.2** and **Fig. 4.2**.

Table 4.1 Classification of Land Use as per National Land Use Policy 2019.

CLASSIFICATION OF LAND USE AS PER NATIONAL LAND USE POLICY 2019	
S.N.	LAND USE ZONE
a.	Agriculture Zone
b.	Residential Zone
c.	Commercial Zone
d.	Industrial Zone
e.	Forest Zone
f.	Public Use Zone
g.	Mines and Mineral Zone
h.	Cultural and Archaelogical Zone
i.	Riverine, Lake and Marsha Zone
j.	Other Zones as specified as per neccesity

Table 4.2 Land Use category of Godawari Municipality.

LAND USE CATAGORY OF GODAWARI MUNICIPALITY		
LAND USE CATAGORY	AREA (SQ. KM)	PERCENTAGE (%)
Builtup	13.93	4.53
Cultivation	72.70	23.63
Forest	202.19	65.73
Public Use	4.62	1.50
Water Body	14.18	4.61
Total	307.62	100.00

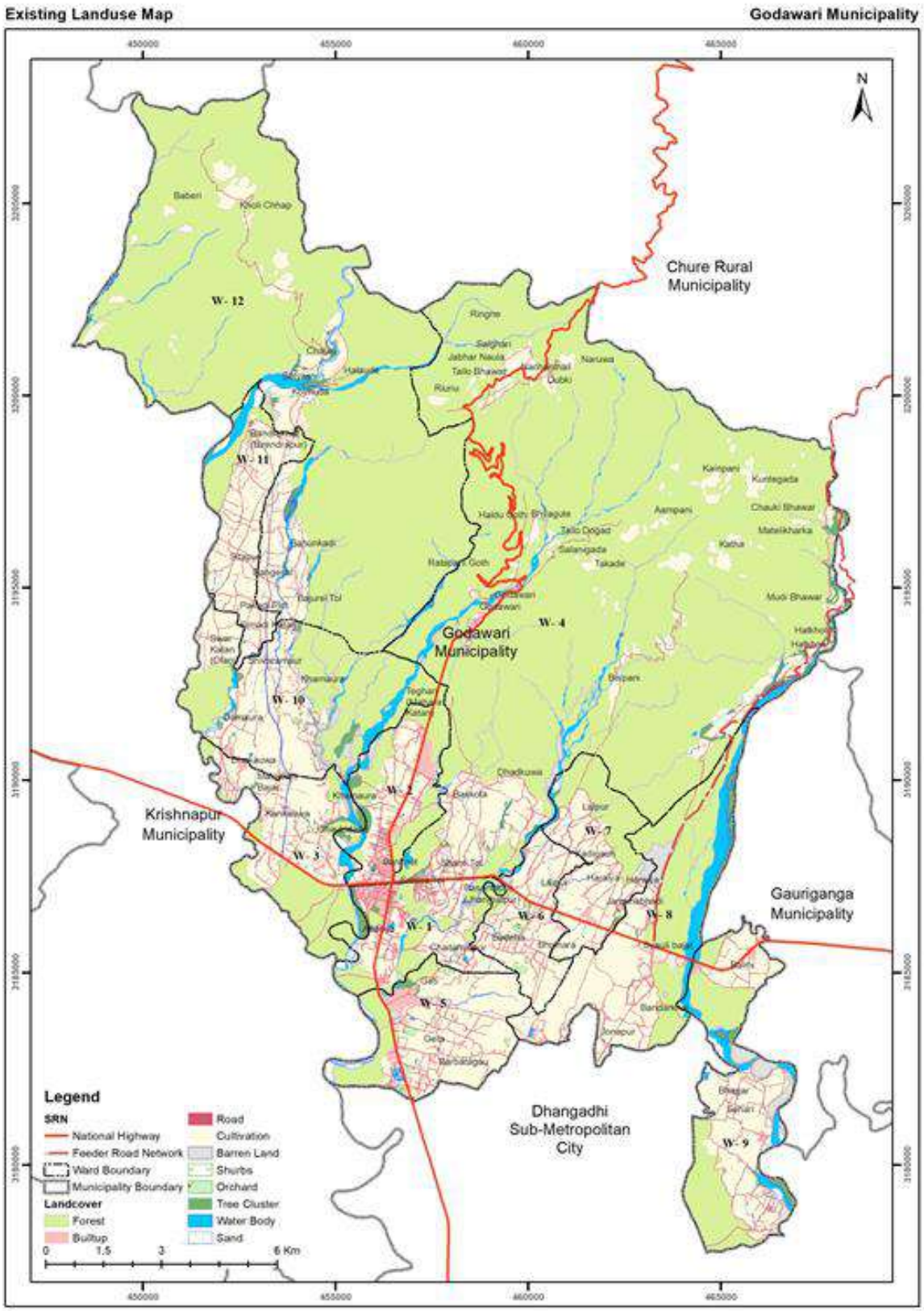


Fig. 4.1 Existing land use map of Godawari Municipality.

Fig. 4.2 Present land use map of Godawari Municipality for comparison.

4.1.1 BUILT UP

Built up area is defined as a combination of commercial, residential, cultural and archaeological industrial and institution areas. In the Godawary Municipality built up area is drastically changing from the last 20 (2000-2021) years due to the population growth. Most of the municipalities are growing its own way and have a rural character and some areas are developing as market centers to service the neighboring settlements. In 2000 the municipal built up area was only 284.08 ha, but in 2005 it was increased by 32%. Within the 10 years of the span of time it was expanded more than three folds. Likewise, it was just 22.31% in the year 2010. At present it was increased by 17.81% and total built up area is 1397.82 ha by 2021. **Table 4.3** represents built up scenario of the municipality.

Table 4.3 Built up scenario of Godawari Municipality

BUILT UP SCENARIO OF GODAWARI MUNICIPALITY			
S.N.	YEAR	BUILT-UP AREA (HA)	INCREASED PERCENTAGE (%) FROM PRECEDING YEAR
1	2000	284.08	
2	2005	372.64	31.17
3	2010	969.42	160.15
4	2015	1185.67	22.31
5	2021(Present)	1396.82	17.81

4.1.2 CULTIVATION

People are engaged in cultivable area for different agricultural activities. With the increase in the number of built-up areas, pressures on agricultural land also increase. Area of the agricultural land is always in the descending order due the sub-division, change in use for areas in the agricultural land. Priority towards agricultural is decreasing due to the irrigation facilities and lack of accessibility to the production market and agriculture inputs. In the Godawary Municipality built up area is drastically changing from the last 20 years (2000-2021 AD). In 2000 AD, the cultivation area was 47.72%, where as in 2005 it was downsized by 45.8%. At present total cultivation area is confined in 23.63 % only. Conservation of agriculture land is national priority as per the present land use policy interventions. Nearly 85.53% of population within the municipality are involved in the agriculture and livestock. Whereas only 2.74% population are involved in the commercial-agriculture activities.

4.1.3 FOREST

Within the municipality area nearly 65.73% of land is covered by forest. In this category combination of forest, community forest, agro forest and public barren land within and nearby of forest are included. The livelihood of the people is attached with the forest resources. The dependency of the economy of the rural people is also connected with it. Pressure on the natural resource is directly related with population growth and demand created by the different activities concerned with the forest product.

4.1.4 PUBLIC USE

Within the municipality area nearly 1.5% of land is covered by public utility space mostly road, bus park and other publicly owned area. Transportation networks are the life of the city without the proper road networks the efficiency of the human resources also have a adverse impact and the its effect on the productivity as well. At present road density within the municipality is varying from 5nos to more 15nos

in major urban area. Specially availability of the road and public facilities are the major urban character and urban centers where the mobility play the important role in economic activities.

4.1.5 WATER BODY

Water bodies are is define as a combination of rivers, wetlands, ponds and other water related areas. It covers 4.61% of land within the municipal area. These natural resources are life line for the agricultural and daily use of people in the rural as well as the urban dwellers. In the past decade the cover area was large but at present it was reduced due to the encroachment. Squatters of the urban area use to squad the marginal land left by river. It was due to the change in the river alignment every year cutting the river banks.

4.2 MULTI HAZARD SCENARIO IN LAND USE

Combined hazard map has been produced for the preparation of Risk Sensitive Land Use Plan (RSLUP) for the Godawary Municipality. The MHRA was done from the historical datasets available, primary and secondary data collected from the field, and the different sources were analyzed using the computer based the OpenLISEM, Spatial Multi-Criteria Evaluation in a GIS and many other software which were more reliable and relevant for this multi hazards analysis propose. According to the multi hazards risk assessment, MHRA the whole area of the municipality was divided in three zones RED, YELLOW and GREEN with its magnitude and direction of the risk (**Fig. 4.3**). High risk zone area is defined as a Red Zone with an area of 26.65%, where the past events happened frequently and risk prone zone with occurrences of the multiple chances in the near future as well. Moderate type risk is denoted by yellow zone, it covers the 49.93% area of the municipality. Likewise, Low risk area are the rest of the area within the boundary and denoted by green color in the map. Which cover 23.42% of area. **Table 4.4** represents the areal distribution of hazards in the municipality.

4.2.1 FLOOD HAZARD

Risk of the flood on the exposure elements are most vulnerable which may loss the life and property of the peoples. About 11.80% of the household are lies in the high-risk zone. In Ward Nos. 4 & 1, 775 & 608 respectively, the highest number of houses affect by the flood as per the 100 years return period of time. Due to the climate change scenario globally, it can't be predicted when these types of disaster occurred. But in the Medium risk zone more than 50% of the households are affected. From the scientific analysis It shows that 62.61% of the household from the different settlements of the municipality are on High and Medium Risk. Only 37.39% of the households lies in the low-risk zone as shown by **Table 4.5** and **Fig. 4.4**.

Table 4.4 Areal distribution of hazards in the Godawari Municipality.

AREAL DISTRIBUTION OF HAZARDS IN THE GODAWARI MUNICIPALITY		
MULTI HAZARD RISK	AREAS IN HA	PERCENTAGE
Low	8197.37	26.65
Moderate	15360.33	49.93
High	7203.97	23.42
Grand Total	30761.66	

*All area is in hectares

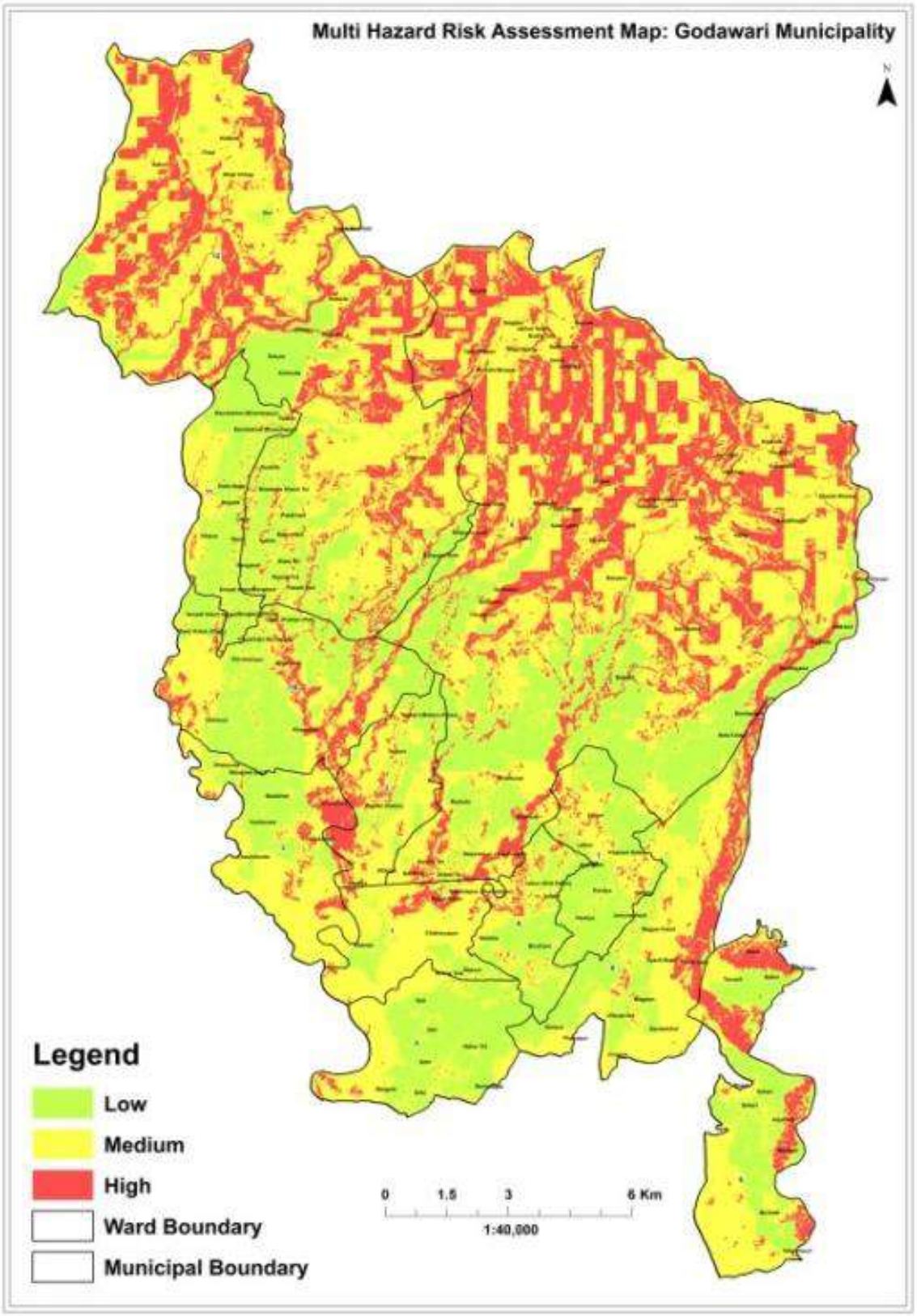
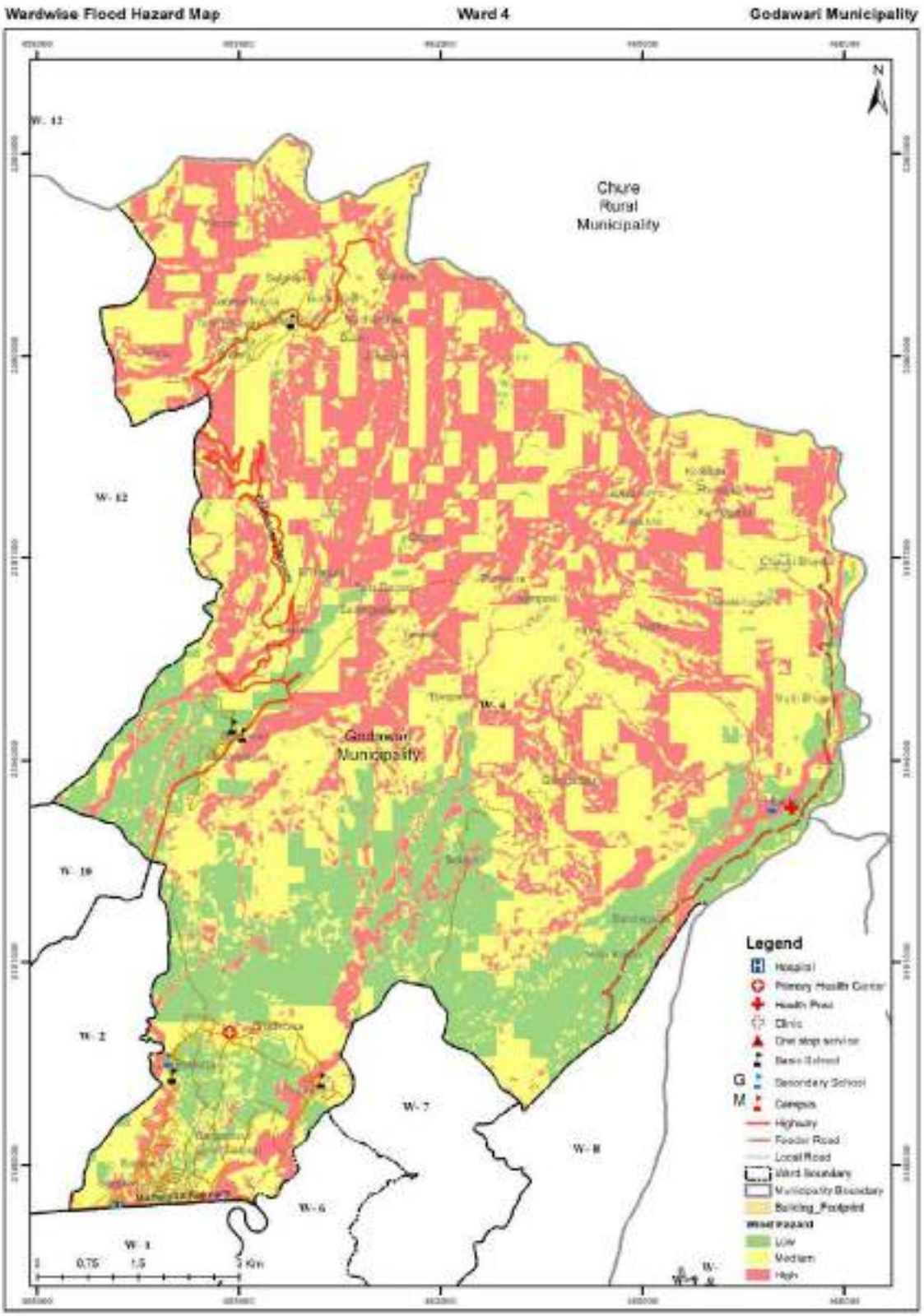


Fig. 4.3 Multi-hazard risk assessment map of Godawari Municipality.


Wardwise Flood Hazard Map
Ward 4
Godawari Municipality
N
Chure
Rural
Municipality
W- 12
W- 11
W- 4
Godawari
Municipality
W- 10
W- 2
W- 7
W- 8
W- 6
W- 1
0 0.75 1.5 3 Km
Legend
Hospital
Primary Health Center
Health Post
Clinic
One stop service
Basic School
Secondary School
Campus
Highway
Feeder Road
Local Road
Ward Boundary
Municipality Boundary
Building_Footprint
Flood Hazard
Low
Medium
High

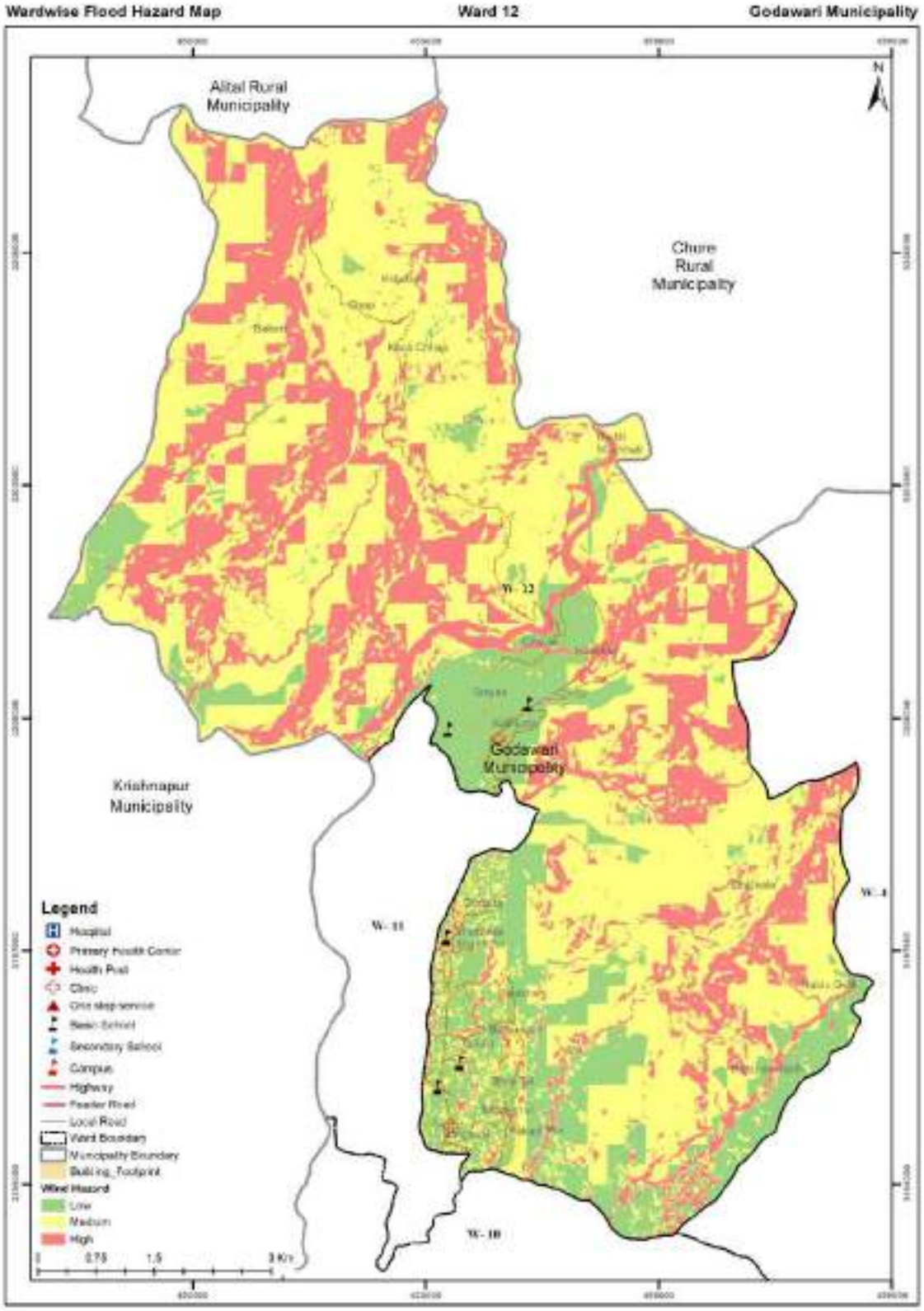


Fig. 4.4 Flood hazard map of Ward Nos. 4 and 12 of Godawari Municipality.

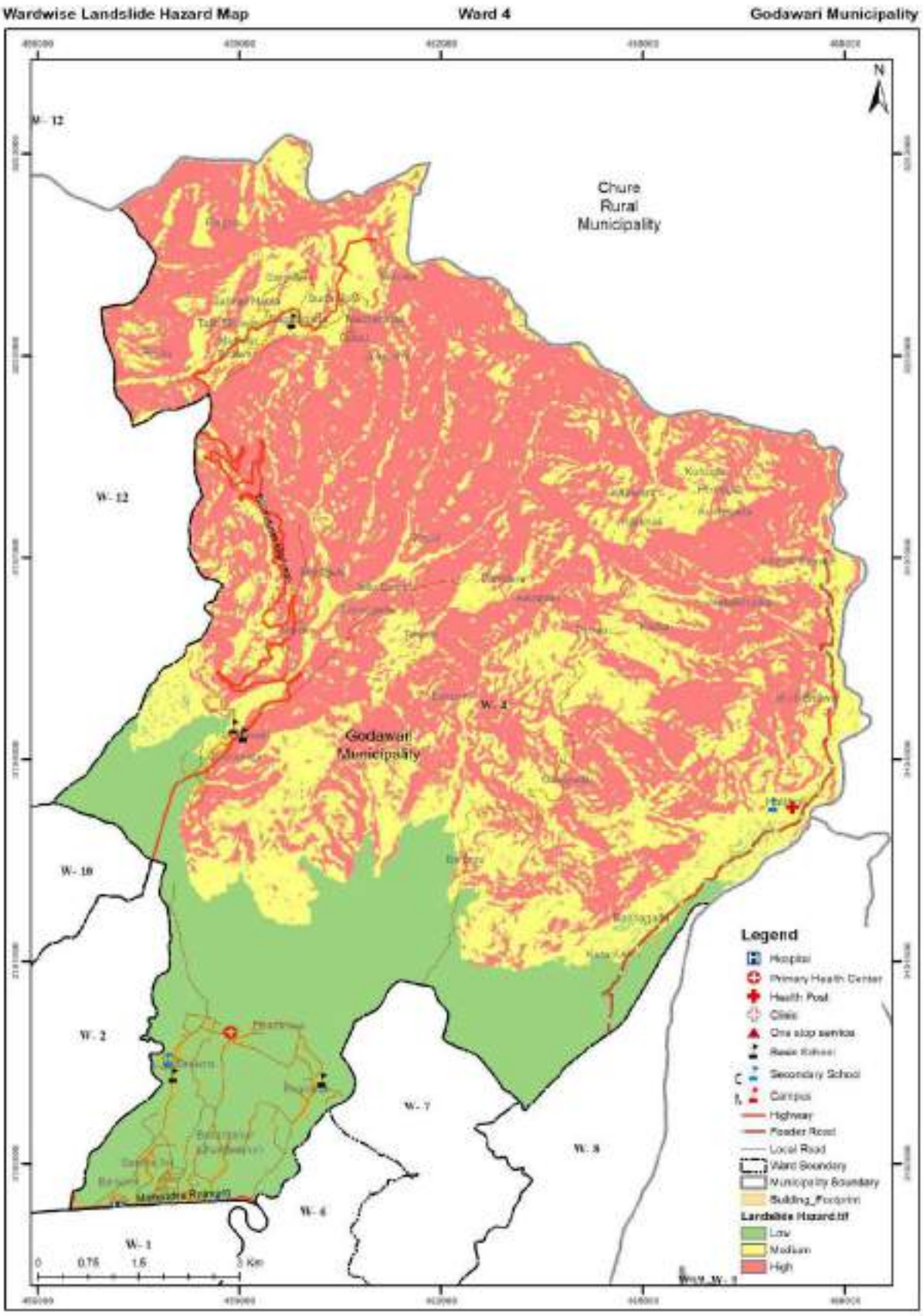
Table 4.5 Summary of Flood Hazard.

SUMMARY OF FLOOD HAZARD			
S.N.	FLOOD HAZARD	NO. OF BUILDINGs	PERCENTAGE, %
1	LOW	11,217	37.39
2	MODERATE	15,246	50.81
3	HIGH	3,541	11.80
	Grand Total	**30,004**	

4.2.2 LANDSLIDE HAZARD

About 60% of area lies in the hilly region of lower siwalik in this municipality. These hilly terrains have the steep slope and fragile geography with the risk landslides. Most of the settlements are situated on old landslides and unstable slopes, which are more vulnerable due the heavy rainfall and became a cause the loss of life, property and the natural environments. Landslides on the hilly area also have a tremendously affect on the plain terrain raising the river bed by the carrying with a debris flow. Like other water-induced disasters, landslides or slope failures can have cascading effects (Vaidya R. A. et.al.). Landslides are only a threat to the roads and some buildings in the wards in the northern part of Godawari, especially Ward Nos. 4 and ward 12, since these are located in the Siwalik hills (RSLUP, MHRA, Report, 2021)

About 29.82% of the area are lies in the high-risk zone. Out of 29.82% of areas 59.79% and 40.16% areas are in Ward no 4 and 12 respectively, the highest number of houses effect by the landslides are as per the 100 years return period of time. But Medium risk is 21.17% only. The landslide effect is in hilly area of Ward Nos. 4 & 12 as sown in the **Table 4.6** and **Fig. 4.5**. From the scientific analysis It shows that 49.01% of the area of the municipality are on Low Risk. Most of the households from the different settlements are in terai area, So these settlements are free from landslide risks. About 514 or 124 Nos. of the households lies in the High-risk zone in ward no 4 and 12 respectively.


Wardwise Landslide Hazard Map
Ward 4
Godawari Municipality
N
W- 12
Chure
Rural
Municipality
W- 12
W- 4
Godawari
Municipality
W- 10
W- 2
W- 7
W- 8
W- 6
W- 1
0 0.75 1.5 3 Km
Legend
Hospital
Primary Health Center
Health Post
Clinic
One stop service
Secondary School
Campus
Highway
Feeder Road
Local Road
Ward Boundary
Municipality Boundary
Building_Footprint
Landslide Hazard.tif
Low
Medium
High

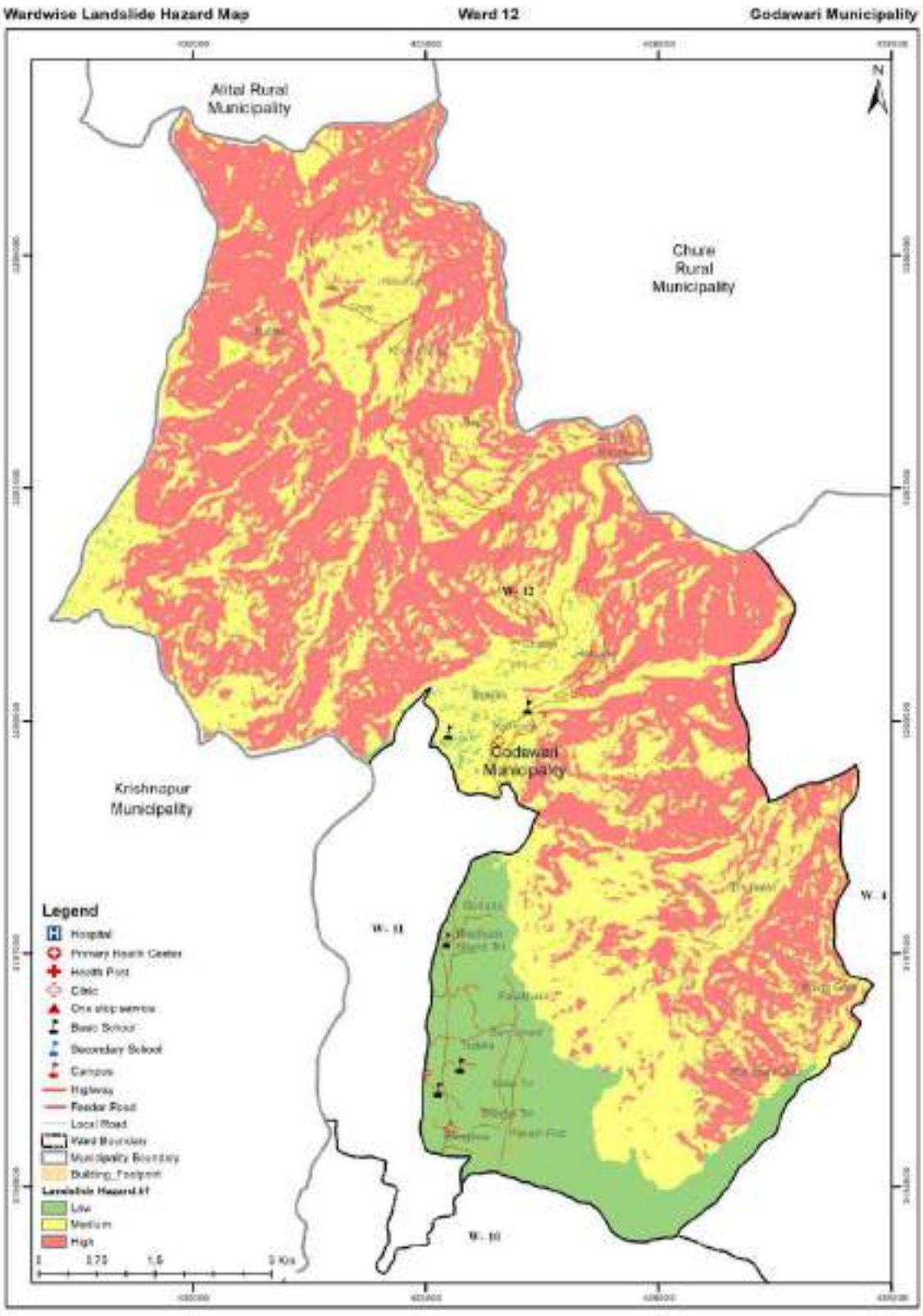


Fig. 4.5 Landslide map of Ward Nos. 4 and 12 of Godawari Municipality.

4.2.3 EARTHQUAKE HAZARD

About 2.72% of the buildings are lies in the high-risk zone considering the calculation of 475 years return period. In Ward no 3 has the highest number of buildings at risk with their construction type and code compliance, building constructed in the rural are not following the norms and standard provided by the municipality shown in **Table 4.7** and **Fig. 4.6**. The major cause is the house owner do not have the land registration certificate. So, people are not serious to take the permission for building permit from the municipality. This type of construction practice is common in the rural settlements. The practice of non-engineered building construction trends is encouraging the risk at the present context.

Table 4.6 Summary of Landslide Risk.

SUMMARY OF LANDSLIDE RISK			
S.N.	LANDSLIDE RISK	AREAS IN HECTRES	PERCENTAGE
1	Low	15076.19	49.01 %
2	Moderate	6512.94	21.17 %
3	High	9172.53	29.82 %
	Grand Total	**30761.66**	

Table 4.7 Summary of Earthquake Risk.

SUMMARY OF EARTHQUAKE RISK			
S.N.	EARTHQUAKE RISK	AREA IN HECTORS	PERCENTAGE
1	Low	4,918.30	15.99 %
2	Moderate	25,702.46	83.55 %
3	High	140.90	0.46 %
	Total	**30,761.66**	

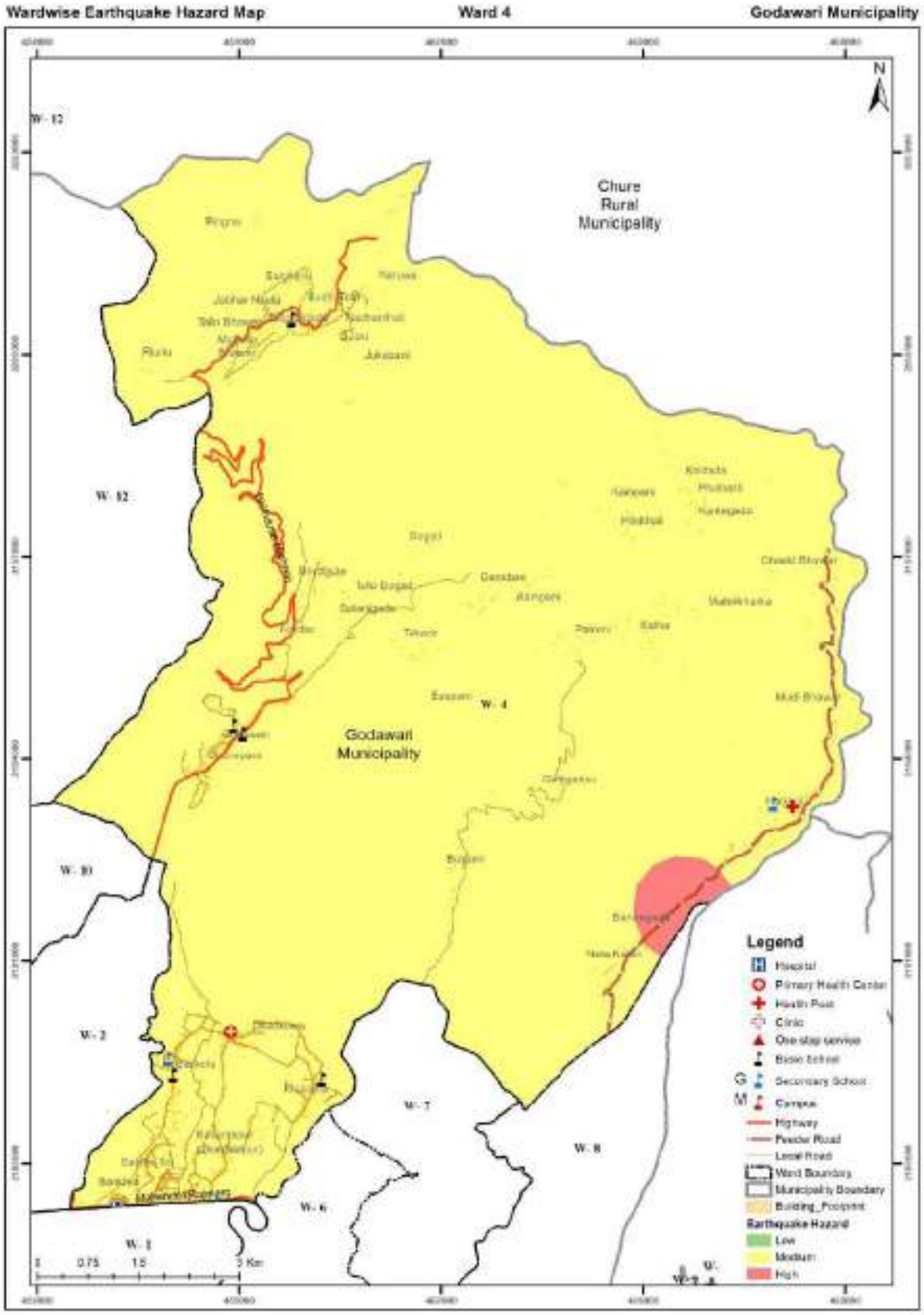


Fig. 4.6 Earthquake hazard map of Ward No. 4.

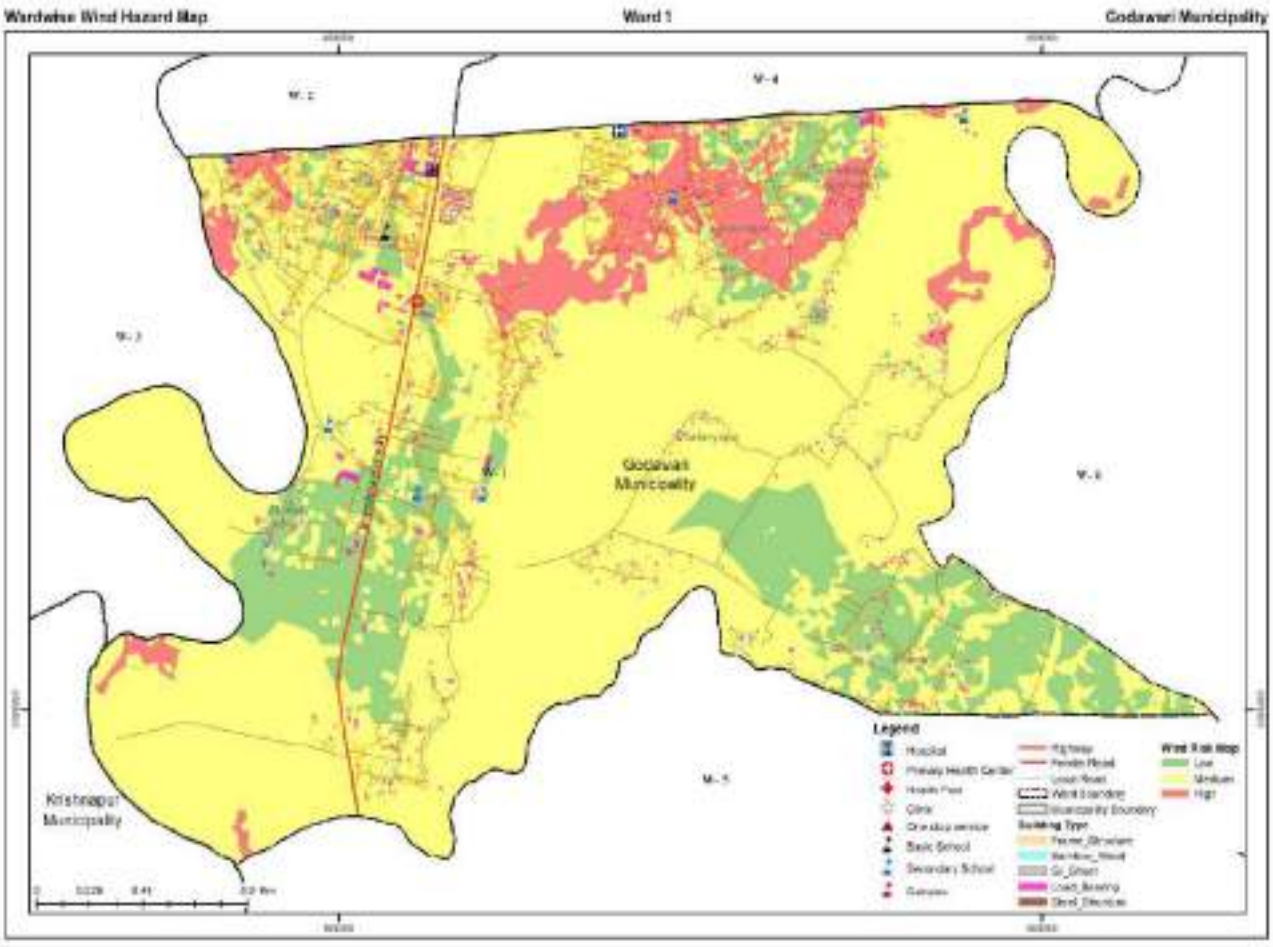


Fig. 4.7 Wind hazard map of Ward No. 1.

4.2.4 WINDSTORM HAZARD

About 11.30% of the buildings of rural area and different typology are lies in the high-risk zone considering the hit of windstorm in the different return period. In Ward No. 1 has been identified the highest number of buildings at risk with their construction type shown in **Fig. 4.7**. Effect of windstorm is critical for exposure elements i.e., buildings, crops in agricultural land and falling of trees in forest. Building constructed in slope roof with CGI sheets, tiles and thatch are more vulnerables as shown in **Fig. 4.8**. Loss and effects are depended on the types of structure and roofing materials. Construction type of CGI sheets, tiles and thatch in the rural area not following the norms and standard so, they encounter the problems. These types of construction practice are common in the rural settlements. The practice of non-engineered building construction trends is encouraging the risk at the present context.

4.3 URBAN GROWTH TREND

4.3.1 URBAN FORM

The term 'urban form' can be used simply to describe a city's physical characteristics. At the broad city or regional scale, urban form has been defined as the spatial configuration of fixed elements (Anderson et al., 1996). Features of urban form are the combination of settlement types, market centers, core business

area, and the fringe. However, urban form is closely related to scale and has been described as the 'morphological attributes of an urban area at all scales' (Williams et al., 2000). Urban form generally includes the individual building, street, urban block, neighborhood and city. The major elements of urban form are Transport Infrastructure, Land Use, Layout, Housing/Building Type and Density as shown in **Fig. 4.9**.

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Fig. 4.8 Most vulnerable rural houses during windstorm risk.

Table 4.8 Summary of Wind Risk.

SUMMARY OF WIND RISK			
S. N.	**Wind Risk**	**Area in Hectors**	**Percentage**
1	Low	5958.88	19.37 %
2	Moderate	21544.20	70.04 %
3	High	3258.58	10.59 %
	Total	**30761.66**	

Urban form of municipality and the major core area of the city is not defined in a planned manner. Building regulations for the uniformity in the design, aesthetic view of the city form which are not yet conceive. Due to the natural growth of the city fabric, these types of interventions are very important to maintaining the street view as well as the compatible building structures with physical infrastructures. Without the proper regulating mechanism in the municipality level plinth height, setbacks, floor height, and height of the buildings are seeming irregular.

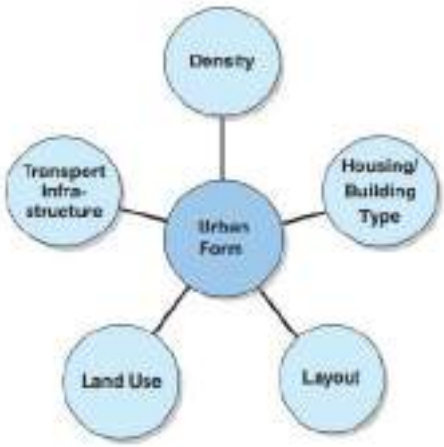

Fig. 4.9 Elements of Urban Form.

4.3.2 SETTLEMENT PATTERN

In the Godawary Municipality, few settlements are traditional villages of the Tharu ethnic community. The settlement pattern of the villages is wooden structures buildings with tile roof constructed in cluster. The form of the settlements is developed as per the need of the peoples' livelihood. The plot of the residential area is included with livestock/ cattle sheds, kitchen garden for the daily use of organic vegetables. Within the premise of the residence, there are hand pumps for drinking water

purposes, if the hand pumps are not affordable to all there is common well maintained by the community. These types of organic character settlements are on the outside of the urban fringe. Road connectivity as well the changing status of the living condition of the people, growth in the population, increase of individual income it changed the traditional settlements pattern in the proximity of market centers with the road networks facilities. It destroyed the social structure of indigenous settlements which have their own flavor of growth. From the past two decades, the road networks were developed and the urban form of the settlements are growing in the ribbon development pattern along the road without following the development norms and standards. These types of urban development pattern create pressure on the urban infrastructure which are costly due to the linear growth of the settlements. Traditional towns in Nepal did have a clear form, with compact settlements surrounded by agricultural land, but rapid urban growth has distorted this pattern without accompanying land-use regulations (Shrestha B. K., 2013)

Most of the settlements are specially developed from the farmhouse concept in the past few decades. Now the subdivision of land availability of physical and social infrastructure and connectivity with the nearby market centers and the facilities destroyed the urban form and encourage the sprawl expansion of the settlements. The built-up area has been increased in an unplanned way but with horizontal expansion without maintaining the urban density with road and other social infrastructural density.

4.3.3 HIERARCHY OF THE SETTLEMENT

Attariya Bazar is growing as a major urban center at the intersection of the East-West highway and Bhimdutta Highway of Kailali district. Being a large urban center different types of opportunities with quality education facilities and establishment of the bank and other financial institutions. Diverse types of business activities also emerging. Accessibility to the critical facility for emergency and prompt service Attariya became an area of attraction. As per the population, road, and building density Attariya is number one. In the year 2000 Shanti Tole is number one in the hierarchy, at present it is third in position as shown iin the **Table 4.9**. Likewise, Geta was aslo in third in position in 2000 whereas at present it does not in the list top three position. Ribbon development along the East-West highway also encourages linear expansion creating many problems with the unsecured life of the urban dwellers. Likewise, Teghari, Geta, Malakheti, Lalpur, and Syauli Bazar are developing along the highway, and Arjuntola, Chaukidada Gaudi, Goldada, Kolmuda Bazar, Mukta Kamaiya Sibir, Sehari, Shivarampur Sukumbasi basti and Tamauli are other settlements with their population, road, and building densities. Buditola is another destination of the attraction, where hill station allied activities with scenic beauty center of the people. But the Buditola settlements are growing on the marginal land created by the old landslide location with encroachment by the city dwellers. These settlements are growing their own way and also servicing as a market center for the neighboring locations which may lead to reducing the pressure on the major urban center.

Table 4.9 Herachy of the Settlements.

HIERARCHY OF THE SETTLEMENTS							
		HIERARCHY OF THE SETTLEMNTS AS PER 2000 AD BUILT UP			HIERARCHY OF THE SETTLEMNTS AS PER 2021 AD BUILT UP		
S.N.	NODES	AREA IN HA	%	HIERARCHY OF THE SETTLEMNTS	AREA IN HA	%	HIERARCHY OF THE SETTLEMNTS
1	Arjuntola	0.86	**1.33**		11.11	**17.15**	
2	Attariya	13.61	**21.01**	**II**	137.39	**212.01**	**I**
3	Chaukidada	2.40	**3.71**		29.11	**44.92**	
4	Gaudi	2.09	**3.23**		15.52	**23.96**	

HIERARCHY OF THE SETTLEMENTS							
		HIERARCHY OF THE SETTLEMNTS AS PER 2000 AD BUILT UP			HIERARCHY OF THE SETTLEMNTS AS PER 2021 AD BUILT UP		
S.N.	NODES	AREA IN HA	%	HIERARCHY OF THE SETTLEMNTS	AREA IN HA	%	HIERARCHY OF THE SETTLEMNTS
5	Geta	7.50	**11.57**	**III**	45.27	**69.86**	
6	Goldada	2.26	**3.48**		10.33	**15.94**	
7	Kolmuda bazar	2.16	**3.34**		7.39	**11.40**	
8	Lalpur	5.75	**8.87**		22.83	**35.22**	
9	Malakheit Chowk	1.21	**1.87**		7.34	**11.33**	
10	Mukta Kamaiya Sibir	1.64	**2.53**		3.92	**6.05**	
11	Sehari	1.79	**2.77**		7.09	**10.94**	
12	Service area				0.40	**0.61**	
13	Service area 2	1.18	**1.82**		0.99	**1.53**	
14	Shanti Tole	14.75	**22.76**	**I**	53.45	**82.48**	**III**
15	Shivarampur	1.19	**1.84**		3.53	**5.45**	
16	Sukumbasi basti	0.18	**0.29**		5.11	**7.88**	
17	Syauli Bazar	1.81	**2.79**		26.28	**40.55**	
18	Tamauli	1.53	**2.36**		8.23	**12.71**	
19	Teghari	2.88	**4.44**		71.18	**109.85**	**II**
	Grand Total	**64.80**	**100.00**		**466.47**	**719.84**	

4.4 TRANSPORTATION NETWORKS

East-west highway is the major strength of connectivity and providing transportation facilities to the major settlements along the highway of the Godawary Municipality. Along the highway 6 m setbacks on either side of the highway is mandatory provision for the future expansion and public facilities which will provide the widen view for city with public spaces for the public use. Without the proper traffic management, proper urban design, and lack of planning of traffic lane, it creates congestion in the city. There is no provision of pedestrian's walkway, traffic sign and signal, which lead to traffic accidents. Being a rural character and the economic condition of the people, most common mode of transportation are motorbike and cycle. There is no provision of separate dedicated lane for this mode of transportation.

Transportation networks in the Godawary municipality is seems satisfactory. 87.67 % is motorable road access whereas, still 4.11% mule track are existed and servicing with these facilities. Urban roads networks with different hierarchy covering the whole municipal areas for urban transport as shown in **Fig. 4.9** to **Fig. 4.11**. Attariay, Teghari, Malakheti, Geta, Lalpur, Bijaura, Syaule, and Shanti Tole and few other market centers are connected with blacktopped (8.22%) road network. Road density of main core area is comparatively high, which is 7 to 15 nos/sq. km. Most of the settlements are connected with the gravel road (87.67%), which are Gaudi, Haraiya, Baskota, Owleni, and Kolmuda Bazar and many others. Transportation networks in the hilly area are vulnerable from the landslide, and flood. But within the municipality almost all exposure elements including road also in high risk during 475 years return period of earthquake hazard.

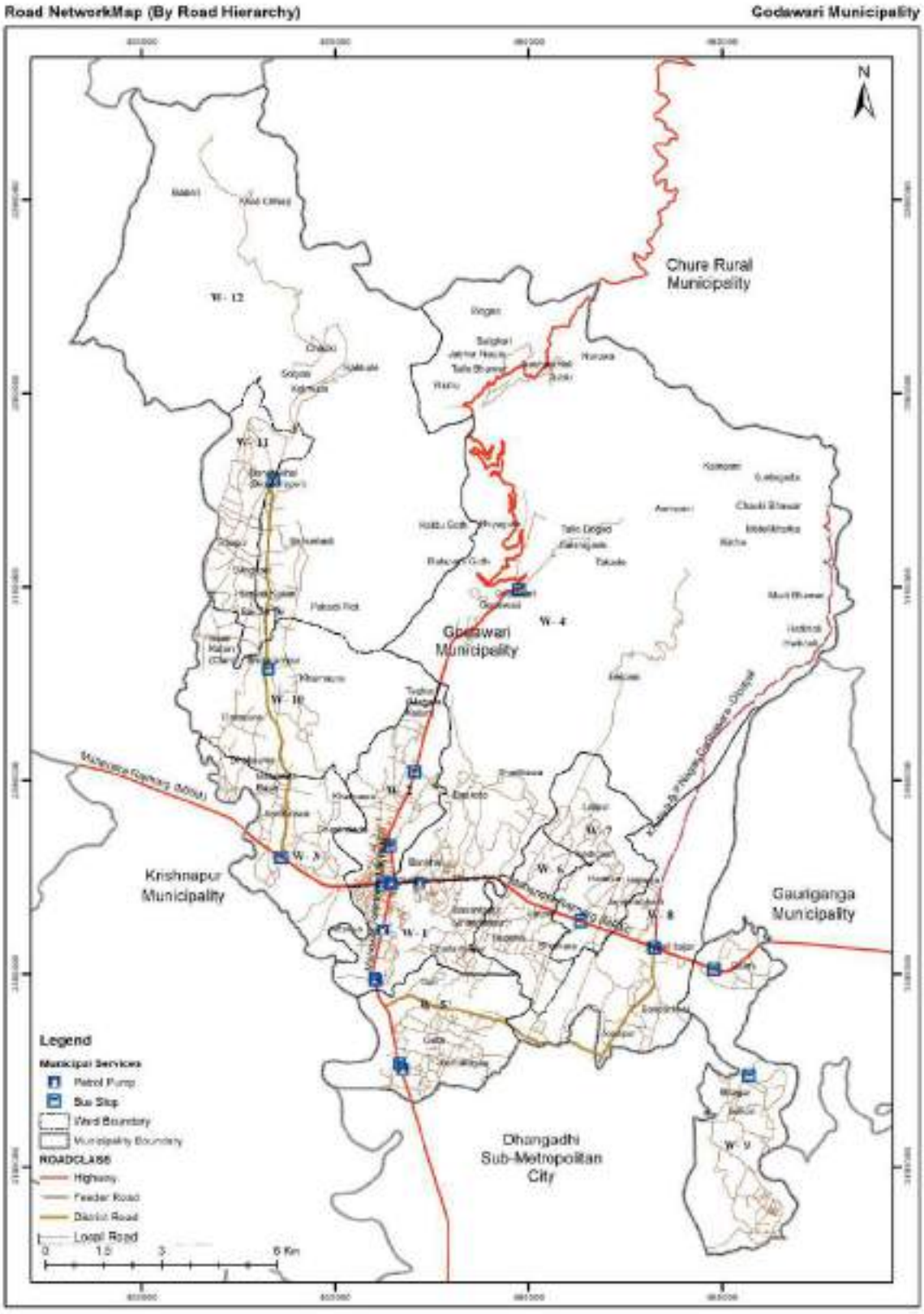

Fig. 4.9 Road network map.

Fig. 4.10 Exsisting landuse map.

4.5 NATURAL RESOURCES

Natuarl resources are major life line of people attached with daily livelihood specially in the rual settlements. Conservation of natural evironments for the sake of people rsiding in the neighborhood is

Fig. 4.11 ROW and mode of transportation in the municipality.

important. Pressure on the over utilization on these resouse is increasing day by day ceating the adverse impact on it.

4.5.1 FOREST

Forest is another important sector of resources for the urban as well as rural dwellers. Forest products are directly related with the daily livelihood of people. As per the present land use about 63% of land within the municipality covered by the forest. Use of firewood for cooking is most common practice in the rural area. It is also a main source of earning in the rural settlements. There is still pressure on the forest products, which are causing deforestation, degradation in biodiversity and soil erosion. Concept of community forest are most common and providing the need fulfillment to the beneficiaries. Two types of community forest are running within the Godawari municipality.

I. Community forest- under control of community are 84 nos.
II. Community forest- under control of women management are 22 nos.

4.5.2 WATER BODIES

Water bodies includes the rivers, ponds, wetland kulos and canals. In Godawari Municipality nearly 4.61% of land area is covered by water bodies. There are total 33 numbers of major and minor rivers flowing within the municipality. These water bodies are the life line of the rural dwellers. Water bodies are the natural beauty of the city, but in sometimes water induced disaster creates the vulnerable situation during monsoon season. Due to nearby of this water drainage system of the settlements flooding, inundation and bank erosion, problems are arising. People may to reach in the land less condition. Marginal lands left by the river promote the chance of encroachment, and which encourage the informal settlements in flood prone area. Poorer segments of the population are particularly vulnerable, since they tend to live in more hazardous settlements and lack the necessary safety nets to recover from economic or environmental shocks (The World Bank, 2020).

4.5.3 AGRICULTURE

Agriculture is the main occupation of people in Godawary Municipality. 85.53% households have the agriculture land holding capacity holding and directly Involved in this occupation. In Godawary Municipality nearly 23.63% of land area is covered by cultivation. After the forest area agriculture is the dominated land use. Agriculture types activities dominated by the rural character. Large number of populations are engaged in the agricultural sector but the contribution in GDP is very low approximately 15.58%. Whereas urban and other sector contribution is more than 84.42%.

4.6 CRITICAL FACILITIES

4.6.1 HEALTH SERVICES

Critcal facilities are at the risk during earthquake with a return period of 475 years. Most of the hopital facilities are in the Terai area, so those are out of risk from the lanslides. No any hopitals are lies in the high-risk area. Health facilities in the high-risk zone should be take in consideration during the preparation of risk sensitive land use planning.

4.6.2 SCHOOLS

School buildings are at the risk during earthquake with a return period of 475 years. Most of the School facilities are in the plain area so, those are out of risk from the lanslides. Some school are in the hilly areas. None of the school are lies in the high risk of earthquake prone area. Roof with CGI sheets are also at the risk of wind hzard. Schools in the risk zone should be taken in consideration during the preparation of risk sensitive land use planning. Relocation of such social infrastrure is important.

5. DEVELOPMENT PLANNING

5.1 MUNICIPAL VISION GOAL

Planning of any city is based on the analysis of present situational trends, past historic events and future prospective goals to reach. As part of planning process, vision setting executes the participatory approach of setting out aspirational destination of city. It is a way to form a structural guide for the development and provides guidelines for a holistic development of the city. By defining the position of the future, the municipality needs to be aware of the significant trends and other factors that will influence the direction in which the future unfolds.

Through the participatory process of discussion and induction, the planning team carried out vision setting exercise along with objectives to brief the civil society representatives and the key persons of the Municipality about the preparation of risk sensitive land use planning as shown in the **Fig. 5.1**. The workshop discussed about the opportunity the municipality can explore and the weaknesses it is facing like: unplanned urbanization, natural and man-made hazard risks and unsafe building practices. Furthermore, the ward level FGDs and discussion with key informants additionally clarifies the potential development prospects of the municipality along with the different GIS mapping studies, SWOT analysis, identification of potential lead sectors and trend developments of the municipality.

To accomplish the ideal state for the municipality, municipal government highlights the priority sectors as **agriculture**, **tourism** and **infrastructure**.

The municipality is gradually developing but still lacks the urban amenities. It has beendeclared as provincial Capital which is attracting large numbers immigration, so the goal is to achieve its prosperity through managed and sustainable use of its natural resources, human resources and development of infrastructures. The municipality thus need to improvise the urban amenities, health and environment, social security and plan the city analyzing risk and disaster.

5.2 SWOC ANALYSIS

The analysis of municipality was based on the computation of Strength, Weakness, Opportunities and Constraints (SWOC) jointly through the vision setting workshop at the municipal level and expert judgments. The SWOC analysis is aimed to maximize the strengths and take advantage of opportunities with minimizing weaknesses and constraints. **Table 5.1** shows the SWOC analysis of the entire municipality.

The strength of the municipality is the major transportation which passes through East-West Highway also known as Mahendra Highway. The Bhimdutta Highway is also the strength of the road connectivity of the municipality. The declaration of Municipality as Provincial Capital of Sudur Paschim Province is another ample oppurtunity. The municipality is further fed with the availability of array of productive cultivable land with the presence of irrigation canal along the western part of the municipal area. Similarly, Geta Eye Hospital and under construction of Geta Medical College are another attractive area which strengthen the urban growth together with quality health services in the future. In terms of industrial zone, Haraiya is planned as the SEZ. Besides, religious tourism development has been declared at Godawaridham and Budhi Tola area is being developed as touristic place.

Fig. 5.1 MHRA output and vision setting workshop at Godawari Municipality.

Due to declaration of provincial capital, the municipality has developed numerous programs which are reflecting at present. But unplanned development with poor implementation of building by-laws, poor condition and inadequate infrastructures such as roads make the major weakness of the municipality. Lack of providing advanced technology in agriculture and incentive-based program have been reducing the lack of interest in agro-based lifestyles. On the other hand, lack of sufficient technical resources along with skill and knowledge are the major weakness of the municipality.

Though there occur several weaknesses in the municipal zone, the above-mentioned strength has produced opportunities for the municipal urban and/or rural people. For instance, connectivity of two highways, market centers and market access together with announcement of priority programs of Federal and Provincial government at health, agriculture etc. are the better opportunity to grow economically. The announcement of provincial capital, SEZ and Geta area are further attracted to develop industries, housing, hotels etc.

There are some serious constraints in the municipality although there are several strength and opportunities. For instance, depletion of highly arable land due to unplanned urban growth with the appreciation in land prices. On the other hand, global warming has caused climatic challenges such as

extreme heatwave/coldwave, unusal flooding etc. Proceeding, lack of industrial revolution and unemployment have attracted the youth to migrate other countries and cities.

5.3 GUIDING PRINCIPLE FOR PLANNING

The vision of any place, though generally bound by time-frame, should be idealistic in nature and it should always guide the strategies, plans and programs towards achieving that state of development. A development strategy is about finding the best way for the municipality to meet a development objective. Following guiding principal will be adopted to achieve the municipal vision goal of Godawari municipality.

- RSLUP is planning framework that promotes integrated safer settlement through allowing settlement and urban infrastructuredevelopment only in safer locations-excluding risk prone and environmentally sensitive areas.
- Improved connectivity, enhancing nodal development and demotivating linear development around strategic roads.

The main guiding principal is to control the urban sprawl and ribbon development along the east-west highway. According to the State of Washington's Department of Commerce, urban sprawl is defined as scattered, poorly planned urban development that occurs in the urban fringe and rural areas (Massion et al.,). After the turned off the agricultural land in the residential and other commercial use. These types of urban sprawl increase the pollution and destruction of natural resources. It can be reduced. It also destroys the environmental, economic and aesthetic value of natural resource lands.

Develop the prompt public transportation system to the market centre from the neighboring settlements is the option of rural-urban linkage. Investment in older settlements with a potential to accommodate the safer future growth and resilient community. Getting the opportunities in the neighborhoods, it will stop the people to move in the city core area. Once these settlements are improved the municipality and private companies can find the ways to attract the people in living in neighborhoods. For example, municipality can provide some incentives types of mechanism and other financial institutions can offer special mortgages facilities for the people interested in moving back into the neighborhoods. Creating the environmental problems, pollution, encroachment of natural resources it is very essential to preserve the natural resources such as agricultural land, parks, open spaces and unused land.

Table 5.1 SWOC analysis.

SWOC ANALYSIS	
STRENGTH	WEAKNESS
• Road Connectivity - East West (Mahendra) Highway and Bhimdutta Highway. • Declaration of Municipality as Provincial Capital of Sudur Paschim Province. • Huge array of Productive agriculture land along with Irrigation Canal on the western part of municipal area • Existence of Geta Eye Hospital and nearly completion of Geta Medical College. • Planning of SEZ at Haraiya. • Godawari Dham Area having high potential for religious tourism development. • Budhi Tola area developed as touristic area.	• Unplanned development with poor implementation of building by-laws. • Poor condition and Inadequate infrastructures; roads and others. • Unmanaged and inadequate agriculture support infrastructures within the municipality to cash agricultural products. • Inadequate skill transformation and development. • Insufficient technical resources.
OPPORTUNITY	CONSTRAINTS
• Highway connectivity and market access	• Land use conversion; depletion of high productive land

SWOC ANALYSIS	
STRENGTH	WEAKNESS
• Attractions for Priority programs of Federal and Provincial government (Agriculture, Health etc.) • Investors can be attracted for establishment of hotels, housing, industries etc.	• High escalation on land price • Climatic stress • Youth migration to other cities/countries

The land market in Nepal is predominantly informal and operates without a land information system, so that buyers and sellers usually rely on unlicensed brokers to facilitate land transactions. A lack of transparent information on prices and ownership is a common reason given for the propensity of new land buyers to leapfrog to unplanned peripheral greenfield areas—thus worsening residential and industrial sprawl (ADB, 2019).

Land fragmentation is a major factor behind haphazard urbanization. Individuals can subdivide their land as they please, with the only restriction being that plots must maintain a minimum size of 80 square meters (m^2) in the Kathmandu Valley and urban areas of adjacent hill districts. Fragmentation occurs as agricultural land on the periphery is sold in small lots to maximize returns, and on account of inheritance entitlement structures, which often lead to the division of property among family members (ADB 2020).

5.4 GROWTH NODE

Analyzing the existing settlements within the municipal area on the categorized 6 main indicators, hierarchy of settlements are identified. Mostly the existing settlements are along the highways and major strategic roads within the municipal indicating linear development along the road. For the managed planning of the municipal area, the nodal growth concept has been adopted to demotivate linear development Nodes are planned as focal point to serve large areas and take on a more prominent role in increasing population and employment density while at the same time serving larger areas. The larger areas around the nodeswill benefit from the growth and can take advantage of many of thesame essential elements that make attractive places for people.

Depending upon the ability to support the mixed-use neighborhood structure, and the required infrastructure and utilities to accommodate additional growth, the development modality of the growth node within the municipal area has been proposed. Some potential node locations proposed are currently undeveloped but has potential of development. The development nodal modality proposed different growth nodes for development including **Primary**, **Secondary** and **Tertiary Nodes**. The growth nodes proposed with an analysis of the major constraints and opportunities in those area which will include in the plan and provides major development intervention as directed by the policies.

Table 5.2 Node Population, Area and Density.

NODE POPULATION, AREA AND DENSITY			
NODE	YEAR 2021		
	POPULATION	AREA (HA)	DENSITY (PPHA)
Attariya	12599	174.60	73.00
Teghari	2830	72.67	39.00
Geta	2017	25.10	81.00
Budhi Tola	534	10.21	53.00
Patreni	107	3.24	34.00
Bhulhara	1312	20.86	63.00
Haraiya	1862	23.76	79.00
Sehari	415	5.60	75.00
Khaurmara	818	11.29	73.00
Godada	411	5.24	79.00
Sim	59	1.87	32.00

Proposition of growth node in the different location of municipality is to Providing a Sense of Place. It is very important to provide residents with a sense of place, major social infrastructure i.e., schools, parks stadiums and other facilities should be built in neighborhood. It will help to create a better sense of community and also reduce the travelling time. Deriving factors are mentioned as follows;

- Conservation of arable agricultural land from further subdivisions,
- To accommodate the immigration population,
- Reduce the pressure of housing lots in city core area,
- Minimize the road accidents rates on the highway,
- To reduce the pressure on urban infrastructure, creating congestion in the primary nodes,
- To encourage the efficient transportation mode for urban dwellers,
- To break the chain of tendency to do the untradeable business,
- Lack of public spaces for the additional social infrastructures,
- Encourage balance urban development as per the National Urban Development Strategy (NUDS, 2017)
- connecting urban and rural spaces,
- spatial inequalities within the municipality,
- linking peoples to the better opportunities,

Economic activities and other opportunities are mainly concentrated in core are of the municipality. These types of concentration in the city core are is inevitable, and it is also desirable. But it's very important and judicious decision to bringing people and businesses closer to each other, to boost the productivity, job creation, and economic growth.

Proposition of these growth node strategy is to build resilience to disasters and climate change. Global average annual losses from weather-related and other disasters in cities were estimated at about US$314 billion in 2015 and are expected to increase to US$415 billion by 2030, which significantly drain public investment especially in poorer countries (World Bank, 2020).

Nodes economic growth is important, therefore local governments provide incentive mechanism to attract the private invest to make the cities livable. There should be place for urban poor and participatory approach with gender equality social inclusion (GESI). Municipal investment should be focus for the development of infrastructure and services in the priority nodes. Provide the opportunities for the affordable housing and land development activities. Local governments should focus on the efficient urban

management, finance, and good governance system. Create the pleasant built environment with risk free resilient community. Expanding Opportunities for the Urban Poor, encourages cities in the region to ensure inclusive, equitable urban growth through a multi-dimensional approach to planning, incorporating aspects of economic, spatial, and social inclusion to foster economic growth and reduce poverty (The World Bank, 2020).

After the scientific findings of multi hazard risk assessment (MHRA), whole municipal area is identified in three zones RED, Yellow and Green with its magnitude and direction of the risk. Three types of nodes are proposed as per the scale, dimension, settlement pattern, connectivity and available social infrastructures following safer zone from the risk.

5.4.1 PRIMARY NODE

Attariya Chowk located at the junction of Mahendra Highway and Bhimdutta Highway, is planned as the primary node which possesses uniquely urban characteristics. Attariya bazar area is the prime city core area of Godawari municipality. Planning team proposed to develop the Attariya bazar as a primary node as well as the Central Business District (CBD). Being a junction of Mahendra Highway and Bhimdutta Highway connecting to the hilly district headquarters and other cities of the terai area. the organic growth of the city was taken place in the existing settlements. Supported with the commercial activities, financial institutions, commercial banks and major trading business should be promoted to create the employment opportunities as per the demand of local leaders during workshop. There was no proper physical planning regulation and building regulating norms endorsed till the date. At present, the building and road density in the primary node is more than 1350, and more than 15 nos./sq.km. respectively. (Source municipal profile, 2075). For short term - 2030 BS (10-year time frame) 353.64 ha area has been proposed to encourage the dense infill development and facilities of additional floor as defined by the building construction bye laws. Out of that 216.31 ha of land seems constraint area due to water bodies, forest area and existing built up. The development controlling mechanism should be applied outside the nodal boundary. The main objective is to confine urban expansion within delineation of primary node for 2030. Out of total area for short term plan 137.33 ha, land covered by different land use are as shown in the **Fig.5.2.** In the primary node 60.55 ha of land lies in red zone which is restricted for the further development due to the high risk. In the medium risk zone 248.43 ha of land is covered whereas only 44.56 ha is in the low-risk zone. Total developable area within the short-term designated area is only 137.33 ha. Likewise, in long term -2050 BS (20-year time frame) 842.83 ha area is proposed whereas 289.53 ha of additional land is available for the future development. The density is assumed 200 ppha and 350 ppha for 2030 and 2050 BS respectively. This node is spatial concentrations of employment and housing that are drivers of municipal economy and has potential of provincial as well. These are mixed use urban districts that contains a variety of commercial, office and urban services. This proposed node is expanded upto Shantitole in the East and Chaukidanda in the West. Tables 5.9 and 5.10 show the net area (developable area) , constraint area along with high risk area as per multi hazard risk assessment for the year 2030 and 2050 respectively.

5.4.2 SECONDARY NODE

Secondary Node are mid-sized centers that provide a range of daily needs and specialized services. These nodes consist of mix of office area, small size commercial facilities and service sectors.

Secondary Node are mid-sized centers that provide a range of daily needs and specialized services. These nodes consist of mix of institutional area, medium size commercial activities and educational and health service facilities. Teghari and Geta are also the emerging market center of Godawari municipality. Planning team has proposed 5 nos. of **Secondary Node** to develop the Teghari, Geta, Khamaura, Haraiya, and Bhulhara has been proposed as secondary node within the municipal area as shown in **Table 5.8**. These settlements are developed in a ribbon development pattern along the Bhimdutt highway and other urban roads connecting the neighborhood. Without proper physical development planning and building construction bye laws the areas are developing in haphazard way. Another development node is in the existing settlements of Khamaura, Haraiya, and Bhulhara locations. For short term period-2030 BS (10 years) total 834.31 ha area is proposed to encourage for the development. The development controlling mechanism should be applied outside the boundary. The main objective is to confine urban expansion within delineation of secondary node for 2030. Out of total area for short term plan 834.31 ha, land covered by different use are as shown in the **Fig. 5.2 and Fig 5.3**. In the secondary node 25.30 ha of land lies in red zone which is restricted for the development due to the high risk. In the medium risk zone 309.39 ha of land is covered whereas 499.62 ha is in the low risk zone. Total developable are within the short-term designated area is only 617.12 ha. Out of this total area 20% will covered by road, 10% by the public open spaces and public utility service and 70% for the building and housing. If the only 50% of the land used as ground coverage for the construction propose with two stories build, it will accommodate more than 21599 population. It is 22.96% more than the projected population for short term period of 2030 AD. If the growth rate will be increased after the development of secondary node the delineated boundary for 2030 looks satisfactory. Urban regeneration activities should be done in the existing settlements by improving the quality of the road and social and physical infrastructures. Nearly 25.30% of area is lies in the high-risk zone so the application of mitigation measure in the hazard prone zone is very important. Structural and nonstructural interventions can be applied for the resilient communities. As per the scale and dimension of the hazards that can be create resilient if the proper intervention is done in a need-based manner. Development in the different risk zone is clearly mentioned in the physical development planning and building construction bye laws. Land use policy for the municipal level also guide the planned development with development controlling mechanism. Preliminary the population density of the secondary node for 2030 and 2050 is assume 25 to 100 ppha and 75 to 250 ppha respectively considering the service facilities of the proposed nodes. The gross area of five secondary nodes is 834.31 ha for 2030 and 2275.30 ha for 2050 to accommodate the projected population of 17,566 and 69,684 respectively. Within the gross area net developable area is only 73.97 %, out of that 3.03% area is in red zone where new development will restrict as per the physical development planning regulation and building construction byelaws. The exposure elements in red zone should be redeveloped and retrofitted as per the intensities of the hazard risk and its categories. 26.03 % of land is occupied by the forest, water bodies and existing built up area, if the population will growth tremendously there is also a space for the infill and additional floor development. These secondary nodes proposed for the balance urban development within the municipal area. Teghari is a provincial capital of the Sudur Pashchim Province. Geta is developing as a heath education and quality health service facilities centre of Sudur Pashchim Province with Geta medical college. Khamaura is a agriculture service center, Haraiya is developing as a special economic zone (SEZ), and Bhulhara will be developed as a housing and apartment, corporate building with trading business and sports and recreational facilities. The people will agglomerate into these nodes who are leaving rural areas sparsely populated. The main function of these nodes is for institutional, commercial activities educational and health facilities including corporate and trading business hub. It will also have a potentiality of medium density housing and apartment including public open spaces and development of environment friendly

parks with green developments. **Tables 5.9** and **5.10** show the net area (developable area), constraint area along with high risk area as per multi hazard risk assessment for the year 2030 and 2050 respectively.

5.4.3 TERTIARY NODE

Tertiary node are local market centers and retail outlet that serve to a neighborhood population. Godawari municipality have 5 nos. of tertiary nodes for balanced and inclusive development. Sim, Godada, Buditola, Sehari and Patreni has been proposed as tertiary node as shown in **Table 5.9**. Different nodes have different types of potentiality and capacity to accommodated the particular size of population in the future. Which is clearly mentioned in the physical development planning and building construction bye laws. Buditola bazar is along the Bhimdutt highway and have a potentiality to develop as a hill station and organic resort development related tourism promotion activities. Enforcing the development controlling mechanism is the major principle to control the haphazard, sprawl urbanization and the ribbon development along the Mahendra highway. Some Other tertiary nodes are smaller in size and needs to include basic urban services such as basic schools, health post or pharmacy etc. which provides basic daily needs. These nodes are proposed for the uses of agriculture service, cultural promotion and tourism development, recreation facility, conservation of traditional settlements etc. It can be developed as a tourism associated services and facilities for daily life activities are must in the residential area of tertiary nodes. The gross area of all the tertiary nodes are 635.68 ha for 2030 and 1471.35 ha for 2050 to accommodate the projected population of 2,902 and 10,508 respectively. Out of these gross areas, the net developable area is 399.37 ha only for 2030 and 515.61 ha for 2050. These areas are excluding forest area, water bodies area and existing built-up area. In these nodes as per the multi hazards risks assessment red zone area is 82.71 ha and 149.86 ha for the year 2030 and 2050 respectively. These red zone areas are restricted for new development for mass gathering activities in building structures, critical facilities like hospital buildings, clinics, schools, security and financial institutions. Existing residential buildings can be upgraded by the applying retrofitting techniques as per the intensities and scale of individual hazards. Development activities in these nodes should be restricted within the designated boundary for 2030 and 2050 AD. no planning permit is allowed just outside the development nodes according to the provision of physical development planning regulation. In these nodes considering the capacity of individual node the population density is assumed for 2030 AD is 75 ppha and for 2050 AD is 150 ppha. **Tables 5.9** and **5.10** show the net area (developable area), constraint area along with high risk area as per multi hazard risk assessment for the year 2030 and 2050 respectively.

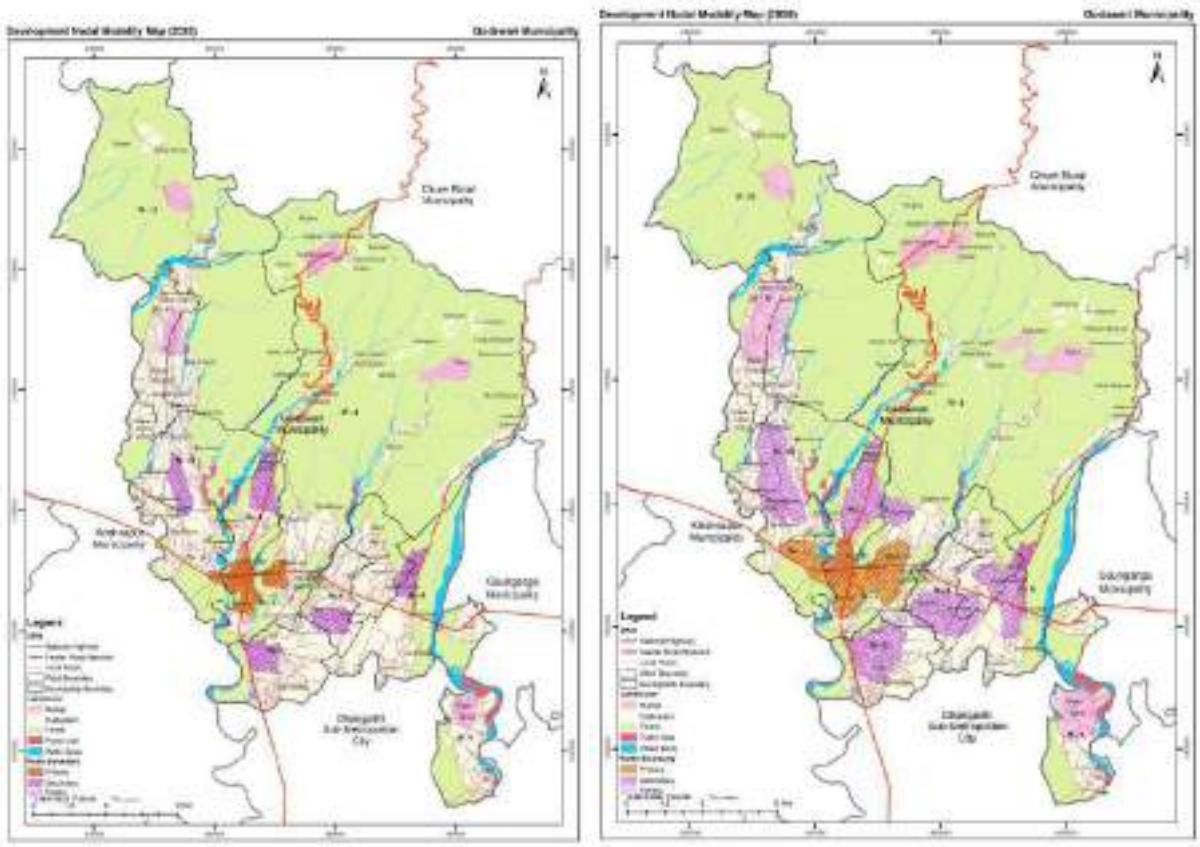

Fig. 5.2 Development Node for 2030 of the Municipality. Fig. 5.3 Development Node for 2050 of the Municipality.

Table 5.3 Primary Node proposed for short term period of 2030 (10 years period), area in ha.

PRIMARY NODE PROPOSED FOR SHORT TERM PERIOD OF 2030 (10 YEARS PERIOD), AREA IN HA						
NODE/LANDUSE	BUILTUP	CULTIVATION	FOREST	PUBLIC USE	WATER BODY	GRAND TOTAL
Attariya	166.36	99.53	41.15	37.80	8.80	353.64

Table 5.4 Primary Node proposed for short term period of 2050 (20 years period), area in ha.

PRIMARY NODE PROPOSED FOR SHORT TERM PERIOD OF 2050 (20 YEARS PERIOD), AREA IN HA						
NODES/LANDUSE	BUILTUP	CULTIVATION	FOREST	PUBLIC USE	WATER BODY	GRAND TOTAL
Attariya	243.22	361.34	139.01	65.52	33.73	842.83

Table 5.5 Secondary Node proposed for short term period of 2030 (10 years period), area in ha.

SECONDARY NODE PROPOSED FOR SHORT TERM PERIOD OF 2030 (10 YEARS PERIOD), AREA IN HA						
NODE/LANDUSE	BUILTUP	CULTIVATION	FOREST	PUBLIC USE	WATER BODY	GRAND TOTAL
Bhulhara	22.37	124.68		5.04		152.09
Geta	16.33	74.41	1.20	57.86	3.80	153.59
Haraiya	13.89	66.13	0.07	69.03	0.00	149.11
Khamaura	17.30	136.65	0.39	4.57	3.06	161.98
Teghari	59.80	72.08	78.92	6.67	0.07	217.53
Grand Total	**145.6**	**662.93**	**139.13**	**152.09**	**11.7**	**1111.44**

Table 5.6 Secondary Node proposed for short term period of 2050 (20 years period), area in ha.

SECONDARY NODE PROPOSED FOR SHORT TERM PERIOD OF 2050 (20 YEARS PERIOD), AREA IN HA						
NODES/LANDUSE	BUILTUP	CULTIVATION	FOREST	PUBLIC USE	WATER BODY	GRAND TOTAL
Bulhara	39.39	368.17	1.90	9.17	2.75	421.38
Geta	40.88	275.79	8.06	65.75	6.28	396.76
Haraiya (SEZ)	59.02	262.79	37.87	80.21	0.03	439.93
Khamaura	38.54	444.23	3.09	10.16	10.87	506.90
Teghari	114.22	249.09	120.51	16.49	10.02	510.33
Grand Total	**342.53**	**2084.27**	**351.63**	**200.46**	**38.03**	**3016.94**

Table 5.7 Tertiary Node proposed for short term period of 2030 (10 years period), area in ha.

TERTIARY NODE PROPOSED FOR SHORT TERM PERIOD OF 2030 (10 YEARS PERIOD), AREA IN HA						
NODE/LANDUSE	BUILTUP	CULTIVATION	FOREST	PUBLIC USE	WATER BODY	GRAND TOTAL
Patreni	0.40	50.81	84.58	0.00	0.00	135.79
Sehari	6.38	97.53		3.12	0.25	107.27
Godada	15.91	107.97		3.66	4.77	132.31
Budhitola		81.01	58.55	5.26	0.00	144.83
Sim	0.95	48.97	64.53	1.04	0.00	115.48
Grand Total	**7.73**	**197.31**	**149.11**	**4.16**	**0.25**	**358.54**

Table 5.8 Tertiary Node proposed for short term period of 2050 (20 years period), area in ha.

TERTIARY NODE PROPOSED FOR SHORT TERM PERIOD OF 2050 (20 YEARS PERIOD), AREA IN HA						
NODES/LANDUSE	BUILTUP	CULTIVATION	FOREST	PUBLIC USE	WATER BODY	GRAND TOTAL
Patreni	0.40	91.88	199.53	0.09	0.80	292.70
Budhitola	0.00	131.27	170.09	8.24	0.00	309.60
Godada	50.48	352.93	10.11	10.44	8.08	432.04
Sehari	22.39	258.33	0.14	7.09	0.25	288.19
Sim	0.95	53.36	93.18	1.34	0.00	148.82
Grand Total	**23.74**	**403.57**	**292.85**	**8.52**	**1.05**	**729.71**

Table 5.9 Intervention area upto 2030

INTERVENTION AREA (UP TO 2030)					
	Intervention area (upto 2030)				
Nodes	**Gross area**	**Constraint area**	**Net area**	**MHRA 'High'**	**Public Use Area**
Primary					
Attariya	353.64	216.31	137.33	60.55	37.80
Secondary					
Bhulhara	152.09	22.37	129.73	5.28	5.04
Geta	153.59	21.33	132.27	0.01	57.86
Haraiya	149.11	13.96	135.16	6.89	69.03
Khamaura	161.98	20.75	141.22	0.80	4.57
Teghari	217.53	138.79	78.75	12.32	6.67
Tertiary					
Budhitola	144.83	58.55	86.27	21.64	5.26
Godada	132.31	20.67	111.63	9.39	3.66
Patreni	135.79	84.98	50.81	34.42	0.00
Sehari	107.27	6.63	100.64	0.36	3.12
Sim	115.48	65.47	50.01	16.89	1.04
Grand Total	**1823.63**	**669.81**	**1153.82**	**168.56**	**194.05**

Table 5.10 Intervention area upto 2050

INTERVENTION AREA (UP TO 2050)					
	Intervention area (upto 2050)				
Nodes	Gross area	Constraint area	Net area	MHRA 'High	Public Use Area
Primary					
Attariya	842.83	553.29	289.53	64.54	27.72
Secondary					
Bhulhara	421.38	173.77	247.61	0.27	4.13
Geta	396.76	187.47	209.29	1.04	7.91
Haraiya	439.93	232.07	207.86	6.92	11.20
Khamaura	506.90	193.73	313.17	5.79	5.59
Teghari	510.33	323.50	186.84	31.01	9.83
Tertiary					
Budhitola	309.60	256.36	53.23	51.15	2.97
Godada	432.04	180.30	251.74	8.97	6.78
Patreni	292.70	251.54	41.17	53.71	0.09
Sehari	288.19	123.41	164.78	29.39	3.97
Sim	148.82	144.13	4.69	6.64	0.31
Grand Total	**4589.48**	**2619.56**	**1969.91**	**259.43**	**80.49**

5.4.4 URBAN EXPANSION IN GROWTH NODE

Development Strategy of Municipality reveals the denser settlement in node areas. The main strategy is to provide the site and services to the selected node depending on the existing infrastructure and site suitability, so that the people migrate to these nodes for better services. Most of the existing settlement are planned for node development but some are demotivated as most of existing developed settlements are along the highway and major roads in linear development.

The urban population in growth will be increased as per the facilities and opportunities available in the nodes. To accommodate the future population in these nodes' experts' team has been adopted a density as per the potentiality of the node. The urban expansion area in the nodes is within the delinated boundary. Wheeas the infill development and additional floors policy has been introduced in the primary node. But hazard prone area is restricted for the fewtypes of activitiesas per the intensities, scale and dimension of the riak. The proposed density in the different nodes is as shown in the **Table5.11**

Table 5.11 Proposed Node Population, Area and Density.

PROPOSED NODE POPULATION, AREA AND DENSITY				
NODE	YEAR 2030		YEAR 2050	
	AREA (HA)	DENSITY ADOPTED(PPH)	AREA (HA)	DENSITY ADOPTED(PPH)
Attariya	353.64	129	842.83	285
Teghari	217.53	75	510.33	127
Geta	153.59	91	396.76	125
Budhi Tola	144.83	28	309.6	67
Patreni	135.49	19	292.7	41
Bhulhara	152.09	60	421.38	101
Haraiya	149.11	72	439.93	122
Sehari	107.27	19	288.19	40
Khaurmara	161.98	34	506.6	55
Godada	132.31	46	432.04	72
sim	115.48	52	148.82	121

From the strategic development of the Godawari Municipality, the node can be developed with the dense population providing better infrastructure and services to the local area. The population density of 285 ppha has been achieved in primary node of Attariya. The other proposed secondary and tertiary node also has achieved the higher density but still for the further growth infill development can be done in these areas. The ward wise proposed density in the planned year 2030 and 2050 also is illustrated in **Table 5.12**

Table 5.12 Proposed Wardwise Density.

PROPOSED WARDWISE DENSITY							
WARD NO.	AREA 'SQ.KM.'	YEAR 2021		YEAR 2030		YEAR 2050	
		POPULATION	DENSITY PPHA	POPULATION	DENSITY PPHA	POPULATION	DENSITY PPHA
1	8.96	12,824	14.31	18,577	20.73	47,255	52.72
2	8.58	9,432	11.00	11,713	13.65	28,242	32.92
3	11.95	8,869	7.42	10,244	8.57	17,620	14.75
4	114.25	10,675	0.93	14,564	1.27	35,116	3.07
5	11.85	6,723	5.67	7,203	6.08	12,389	10.45
6	6.78	8,746	12.89	12,778	18.84	27,991	41.26
7	9.13	5,731	6.27	7,038	7.71	16,971	18.58
8	18.25	9,307	5.10	11,791	6.46	24,380	13.36
9	16.02	8,298	5.18	10,569	6.60	21,849	13.64
10	18.82	8,180	4.35	10,258	5.45	20,563	10.93
11	9.20	5,849	6.35	6,772	7.36	11,593	12.60
12	73.81	5,864	0.79	6,275	0.85	9,506	1.29
Grand Total	**307.62**	**100498.00**	**3.27**				

5.5 CONNECTIVITY

Land use and transportation has the functional link for the development of the spatial planning which is the important basis for urban development planning. For the study of the transportation planning it is important to study about the land use and transportaion. The transportation system is depending on the population growth of the city and the vehicle ownership and usage, which is creating problems in the transportation mangement. So, the transport and land use planners have come to realize the importance and potentiality of the transport to shape the urban environment by providing the accessibility of the locations within the urban area (Khadka, T.B, 2003). Road Network are linear travel routes that move people and goods from one location to another. The primary role of road network is to provide mobility and accessibility. The growth of the urban areas is mainly guided by the urban road hierarchy and their alignment which is illustrated in the figure below.

Road Network are linear travel routes that move people and goods from one location to another. The primary role of road network is to provide mobility and accessibility. The growth of the urban areas is mainly guided by the urban road hierarchy and their alignment which is illustrated in the figure below.

A well-formed road hierarchy will reduce overall impact of traffic by concentrating longer distance flow onto routes in less sensitive locations, ensuring land uses and activities that are incompatible with traffic flow are restricted from routes where traffic movement should predominate and preserving areas where through traffic is discouraged. It also identifies the effects of development decisions in and on surrounding areas and roadways within the hierarchy.

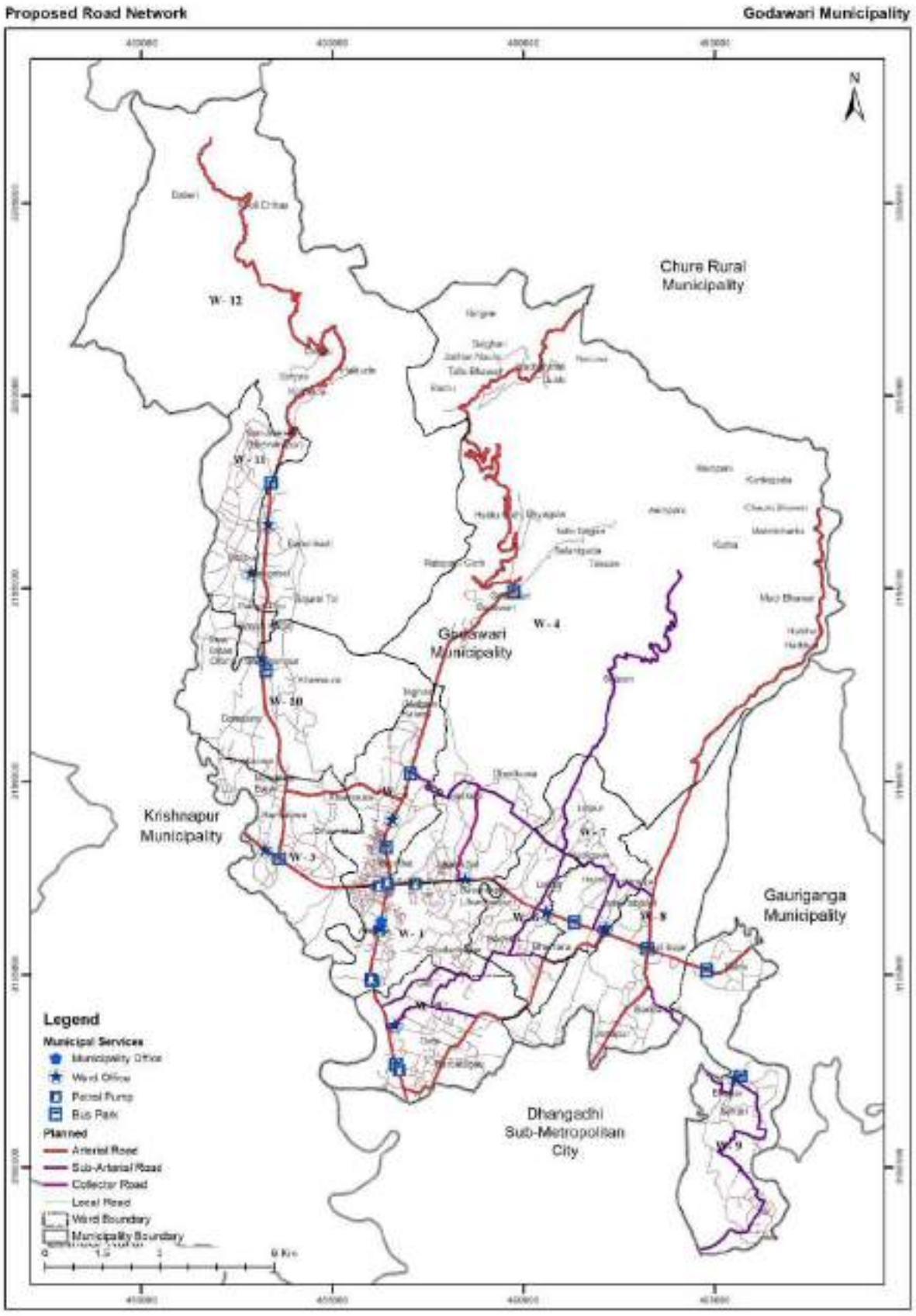

Fig. 5.4 Proposed road network of the municipality.

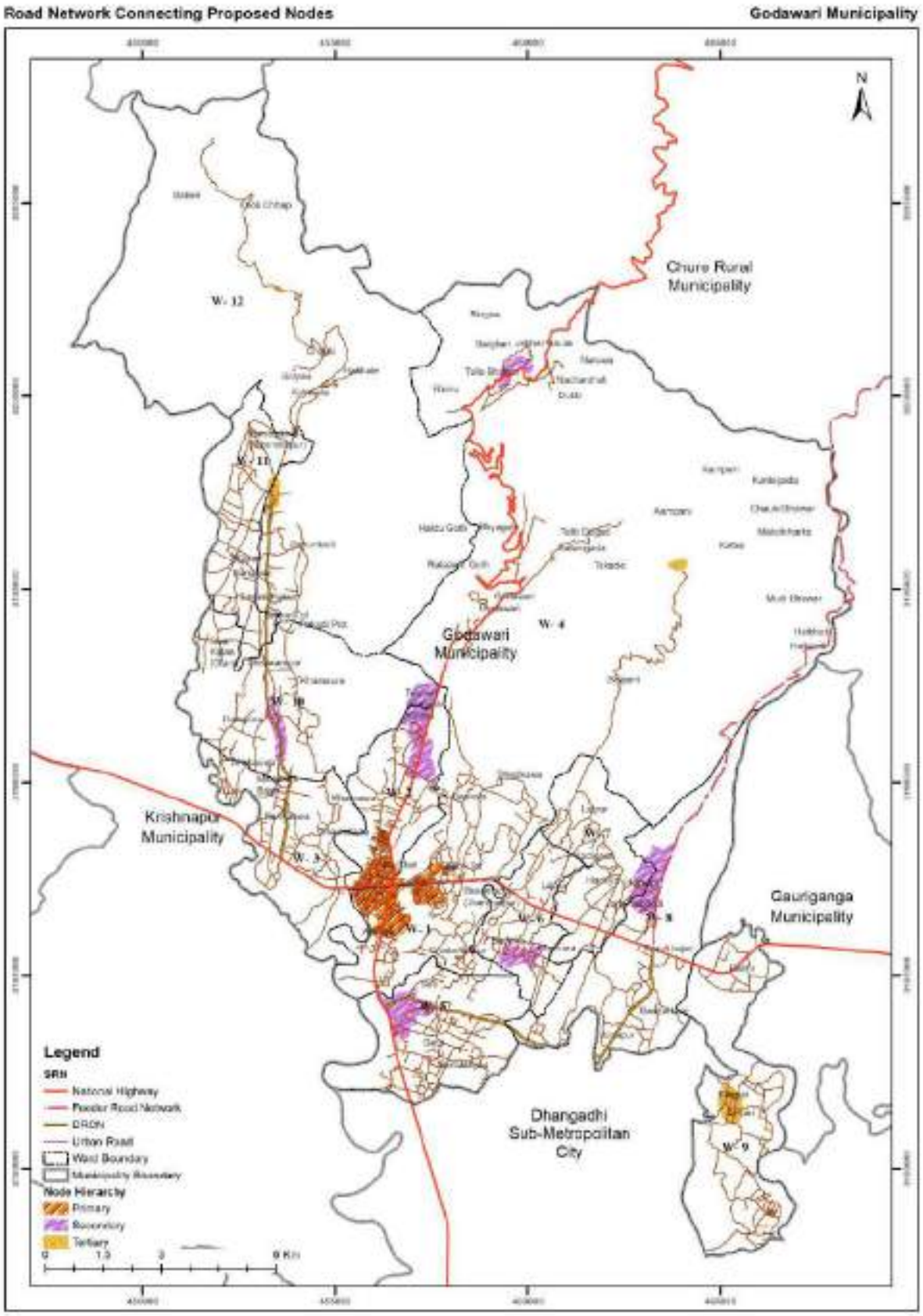

Fig. 5.5 Road network connecting proposed nodes.

A well-formed road hierarchy will reduce overall impact of traffic by concentrating longer distance flow onto routes in less sensitive locations, ensuring land uses and activities that are incompatible with traffic flow are restricted from routes where traffic movement should predominate and preserving areas where through traffic is discouraged. It also identifies the effects of development decisions in and on surrounding areas and roadways within the hierarchy. The proposed road network is shown in **Fig. 5.4** and road network connecting proposed nodes in **Fig. 5.5**.

5.6 SECTORAL DEVELOPMENT PLANS

The Development Plan tells us how much development is appropriate, **where** it should be located, **when** it is required, and **how** it should be judged.

The sectoral development plans need to be aligned with reference to individual and multi-hazard of the entire municipality. Besides, the development plans should be focused on the proposed primary, secondary and tertiary development nodes. This will mitigate and abate the risk of hazards in the development sectors that will drive towards the safer settlement. The sectoral development plans help to identify key resources, leading activities that fosters the overall development and finally to attain the goal of the municipality. In order to proceed for the sectoral development plans, the route cause of risks need to be identified which may be physical, socio-economic, environmental, disaster management and spatial specific. The sectoral development plans include the Physical development plan, Socio-Economic development plan, Environment management plan, and Disaster risk reductio and management plan. These plans are formulated on the basis of SWOC analysis, gap analysis, spatial analysis and MHRA.

Overall development plan may not address efficiencies and role of the specific sectors in development activities. To utilize sectorial strength and opportunities, it is necessary to focus development strategies of the local government on potential sectors of the municipality. So, to utilize sectorial resources in optimal level, to attain maximum possible level of development, it becomes necessary to have sectoral plans separately. In addition to that, sectorial plans help to identify key resources, leading activities that fosters the overall development and finally to attain the goal of the municipality.

The sectoral plans include the Physical development plan, Socio-Economic development plan, Environment management plan, and Disaster management plan. These plans are formulated on the basis of SWOC analysis, Gap analysis, spatial analysis and all other sectoral analysis.

5.6.1 RISK SENSITIVE LAND USE ZONE

Through the Multihazard Risk Assessment (MHRA), the risk zone is identified as High-Risk Zone, Moderate Risk Zone and Low Risk Zone. The area coverage of each zone is provided in **Table 5.13** Below. In Godawari Municipality, the highest geographical coverage is of Moderate Risk zone with more than 15379.61 ha followed by Low risk, whereas 7219.27 ha is in high-risk zone out of that 6108.61 ha is lies in the forest area.

Table 5.13 Multi Hazard Risk on Different Land Use.

MULTI HAZARD RISK ON DIFFERENT LAND USE									
S. N.	LAND USE	MULTI HAZARD RISK						TOTAL AREA IN HA	%
		LOW	%	MODERATE	%	HIGH	%		
1	Builtup	565.20	1.84	695.10	2.26	136.77	0.44	1397.07	**4.54**
2	Cultivation	3793.29	12.33	2914.60	9.47	551.72	1.79	7259.61	**23.60**
3	Forest	3152.63	10.25	10980.33	35.69	6108.61	19.86	20241.57	**65.80**

MULTI HAZARD RISK ON DIFFERENT LAND USE									
S. N.	LAND USE	MULTI HAZARD RISK						TOTAL AREA IN HA	%
		LOW	%	MODERATE	%	HIGH	%		
4	Public Use	137.86	0.45	234.46	0.76	88.89	0.29	461.22	**1.50**
5	Water Body	514.03	1.67	555.12	1.80	333.28	1.08	1402.43	**4.56**
	Grand Total	**8163.02**	26.54	**15379.61**	50.00	**7219.27**	23.47	**30761.89**	**100**

Low Risk Zone are identified as Safe Zone for any kind of urban and settlement development whereas Moderate Risk Zone are identified as Controlled Development Zone for urban and settlement development. Similarly, High Risk Zone is not suitable for urban and settlement development but there are existing settlements which are vulnerable to multiple hazards. The likelihood of shift from low and moderate risk zone to high-risk zone is possible due to impact of human induced inappropriate activities. Therefore, proper mitigation measures and preparedness programs should be implemented in all hazard zones.

Risk Sensitive Land Use plan is established to support efficient urban activities, achieve a pleasant urban environment, and create townscape with significant features. Based on existing scenario and development analysis, the land use pattern changes in response to urban growth and development of infrastructure. So, land use plan for 2030 and 2050 has been prepared on concept of growth node and corridor under the consideration of Multi Hazard Risk Assessment. Other than the proposed node of different hierarchy the existing settlements are planned for infill development. Godawari Municipality has diverse topography from hilly to Terai. The majority of settlements lies in southern Terai plain with huge array of available agricultural lands. Settlement development is mostly scattered and elongated in linear forms along the road. The trend of development results the development along the major strategic roads of the municipality area, so the concept of node and corridor development has been planned. The proposed nodal area for 2030 and 2050 are illustrated in **Figs. 5.1** and **5.2** and **Table 5.14.** The proposed node exposure in different level of risk zone is illustrated in **Table 5.16**.

Table 5.14 Proposed nodal area for 2030 and 2050.

PROPOSED NODAL AREA FOR 2030 AND 2050					
S. NO.	NODES	AREA OF NODES AS PER 2030 PLAN		AREA OF NODES AS PER 2050 PLAN	
		AREA IN HA	%	AREA IN HA	%
1	Attariya	184.59	33.06	293.20	25.78
2	Bhulhara	47.44	8.50	131.63	11.57
3	Budhitola	36.10	6.47	53.24	4.68
4	Geta	43.92	7.87	123.03	10.82
5	Godada	16.87	3.02	37.93	3.34
6	Haraiya	50.96	9.13	116.78	10.27
7	Khamaura	45.33	8.12	99.71	8.77
8	Patreni	10.58	1.89	17.56	1.54
9	Sehari	45.15	8.09	89.30	7.85
10	Sim	2.34	0.42	4.14	0.36
11	Teghari	75.08	13.45	170.70	15.01
	Grand Total	**558.35**	**100.00**	**1137.23**	**100.00**

Table 5.15 Different Land Use area in proposed nodes for 2030 and 2050.

DIFFERENT LAND USE AREA IN PROPOSED NODES FOR 2030 AND 2050				
LAND USE TYPE	AREA AT 2030 A.D.		AREA AT 2050 A.D.	
	HECTORS	%	HECTORS	%
Builtup	1711	5.56	2194	7.13
Cultivation	6946	22.58	6463	21.01
Forest	20242	65.80	20242	65.80
Public Use	461	1.50	461	1.50
Water Body	1402	4.56	1402	4.56

DIFFERENT LAND USE AREA IN PROPOSED NODES FOR 2030 AND 2050				
LAND USE TYPE	AREA AT 2030 A.D.		AREA AT 2050 A.D.	
	HECTORS	%	HECTORS	%
Total	**30762**	**100**	**30762**	**100**

Table 5.16 Area of Nodes on Multi Hazard Risks as per 2030 Plan.

AREA OF NODES ON MULTI HAZARDS RISKS AS PER 2030 PLAN						
S. N.	NODE	NAME OF SETTLEMENT	MULTI HAZARD RISK			GRAND TOTAL
			LOW	MODERATE	HIGH	
1	**Primary Node**	Attariya	44.56	248.53	60.55	353.64
2		Bhulhara	85.49	61.33	5.28	125.09
3		Geta	100.71	52.88	0.01	153.59
4	**Secondary Node**	Haraiya	52.42	89.80	6.89	149.11
5		Khamaura	137.88	23.29	0.80	161.98
6		Teghari	123.12	82.09	12.32	217.53
7		Budhitola	0	123.18	21.64	144.83
8	**Tertiary Node**	Patreni	0.92	100.45	34.42	135.79
9		Godada	73.70	49.22	9.39	132.31
10		Sehari	72.13	34.78	0.36	107.27
11		Sim	5.75	92.85	16.89	115.48
		Grand Total	**696.69**	**958.39**	**168.56**	**1823.63**

Table 5.17 Area of Nodes on Multi Hazards Risks as per 2050 Plan

AREA OF NODES ON MULTI HAZARDS RISKS AS PER 2050 PLAN						
S. NO.	NODE	NAME OF SETTLEMENTS	MULTI HAZARD RISK			GRAND TOTAL
			LOW	MODERATE	HIGH	
1	**Primary Node**	Attariya	150.82	566.92	125.09	842.83
2		Bulhara	301.23	114.60	5.55	421.38
3		Geta	280.03	115.67	1.05	396.76
4	**Secondary node**	Haraiya (SEZ)	194.43	231.68	13.81	439.93
5		Khamaura	407.48	92.83	6.59	506.90
6		Teghari	219.56	247.44	43.33	510.33
7		Budhitola	0	236.80	72.79	309.60
8		Godada	276.71	136.97	72.79	309.60
9		Patreni	1.63	202.94	88.13	292.70
10	**Tertiary Node**	Sehari	179.97	78.46	29.76	288.19
11		Sim	12.49	112.80	23.53	148.82
		Grand Total	**2024.36**	**2137.12**	**427.99**	**4589.48**

5.6.2 PHYSICAL DEVELOPMENT PLAN

These spatial tools allow urban planners and managers to visualize various natural hazard and climate change impact scenarios to better understand risks and vulnerabilities within urban areas. This information can then support the development of risk reduction measures such as disaster risk mitigation and climate change adaptation measures as part of the overall urban development planning process (ADB, 2020). Godawari Municipality has diverse topography from hill to Terai. The majority of settlements lie in southern Tarai plain with huge array of available agricultural lands. Settlement development is mostly scattered and elongated in linear forms along the road. The trend of development results the development along the major strategic roads of the municipality area, so the concept of node and corridor development has been planned. These nodes are proposed in the old settlements area for short term for 2030 (for 10 years time) and long term for 2050 (for 20 years time) planning.

Mitigation measures and development controlling tools has been applied for use of land in high-risk areas. Physical Infrastructure play the critical role to support social and economic development, efficient and effective functioning of urban core areas of municipality. Therefore, the integrated planning approach between urban infrastructure sectors to build resilience to multi hazard risks.

Municipalities investment should focus on critical infrastructure to located away from hazard zones. In some cases, it is not possible to eliminate exposure to risk. In such case it should be ensured that those infrastructures, are resilient to various risks as per the engineering norms and standards. Activities should be focus towards the safer settlements from the risk. Diverse and root cause of the disaster should be dig out and proper solution with intervention shall applied. For example, if the few buildings situate in the flood prone areas. It is very difficult to relocate these buildings in the risk-free zone. For that the local intervention with appropriate engineering solution can be applied by making raised embankment to protect the buildings from risk. Reforestation and plantation can be done in flood prone are. These types of intervention are in local and spatial specific or may be in the outside the location as per magnitude and direction of the individual risk.

After developing a good understanding of the risks facing urban centers from various natural hazard events and climate change, this information can be used to inform urban development strategies, policies, and regulations. Similarly, risk information can be used by sector agencies for infrastructure planning and design purposes (ADB, 2013). The urban risk reduction measures that can be used to build urban resilience communities.

Risk-sensitive land use planning incorporates multi hazard risk assessment as part of the land use planning process. Risk-sensitive land use planning is based on the principle that, to the greatest extent possible, development should be avoided in high-risk "hot spots" that are exposed to natural hazards and climate extremes (ADB, 2013). Spatial risk information generated from the MHRA are useful in planning the future development avoiding the high-risk areas. Infill development with mass gathering activities should be discouraging in high-risk zones. But it very difficult to relocate traditional communities and human settlements from the high-risk areas. Protect the lifelines and critical facilities should be ensured that their functionality during disasters is uninterrupted.

Zoning regulation can be used to regulate building heights, density control, and setbacks in the proposed nodes and high-risk zones as development controlling mechanism. It also a important tools to move the critical facilities and mass gathering activities from the risk to resilience. Relocate the vulnerable settlements from high-risk area of landslide to safer location, and give the priority to the people from high-risk area in the land pooling projects.

5.6.3 APPLICATION OF BUILDING CODES

To standardize the disaster mitigation measure in the social and physical infrastructure application of building codes is more useful regulatory tool to ensure that all structures should be complained with requirements against the risk. For example, if the building codes applied in the new buildings, vulnerability from wind-storm and earthquake can be reduced. As per the MHRA building exposure in the urban area of the municipality are in the high-risk, retrofitting technique should be used to minimize the risk of exsiting builidings.

5.6.4 ECOSYSTEM- BASED ADAPTATION

Ecosystem-based adaptation can be applied to mitigate risk and reduce the vulnerability to hazards. Ecosystem-based solutions are often also less expensive to maintain than engineering solutions, and they can provide multiple benefits whether or not a disaster event occurs Similarly, encouraging slope stabilization measures through reforestation can protect urban settlements from rainfall runoff associated with flooding and landslides (ADB, 2013). Bio-engineering, slope stabilization, reforestation, ecological and other slope protection measure should be applied.

5.6.5 LOCAL AREA DEVELOPMENT PLAN

Local area Development Plan has been planned in growth node concept. The major settlements with developed services and infrastructures is proposed as primary node which provides the services and facilities to the whole municipality. Analyzing the infrastructure development, the mid-sized developed nodes are proposed as secondary nodes. To demotivate the linear development along the highway and other strategic roads, the secondary nodes has been planned away from the highway. Likewise, the rural service center is proposed as tertiary nodes. These proposed nodes are connected through corridor concept. The concept of compact settlement development has been planned in proposed nodes. The main strategy is to provide the site and services to the selected settlement depending on the existing infrastructure and site suitability, so that the people themselves migrate to these settlements for better services. **Table 5.18** represents the list of settlement development projects.

Settlement Development Plan includes several projects such as planning and implementation of identified nodes with better service and infrastructure.

5.6.6 URBAN INFRASTRUCTURE DEVELOPMENT PLAN

The basic facilities, services and installations needed for the functioning of a community or society, such as waters supply, electricity, transportation is included in urban infrastructure. This part mostly focuses on strategic development of mentioned urban infrastructure for the integrated planning of municipal area.

5.6.7 TRANSPORTATION

Road is the major urban infrastructure and the growth of the urban areas is mainly guided by urban road hierarchy and their alignment. Godawari Municipality is accessed through East West Highway and Bhimdutta Highway and is connected to surrounding municipalities / rural municipalities through Highway and Feeder Road. The settlement within municipality boundary are scattered and are connected through Arterial road, Collector and Local Roads.

Land use development results in a demand for transportation and the provision of transportation linkages encourage land use to take place in a planned way. Land use and transportation planning are interconnected with each other and integrated planning develops the planned area. So, for road network planning, the strategic road network has been planned connecting the nodes, services, tourism and agricultural areas. **Fig 5.6** shows shows the Proposed Road network connecting node boundary (2050). Municipal strategic roads have been proposed which connects the nodes with each other and other connecting neighboring municipalities / rural municipalities. The detail of proposed municipal strategic roads is presented in **Table 5.19**. and the cross section of the 20m, 30m, and 50m proposed road is shown in the **Fig 5.7, Fig 5.8** and **Fig 5.9** respectively.

Table 5.18 List of Settlement Development Projects

LIST OF SETTLEMENT DEVELOPMENT PROJECTS		
S.N	PROJECTS	UNIT
1	Preparation of Integrated urban development plan of Attariya as Primary Node	1 no.
2	Preparation of Physical Development Plan of Teghari, Geta and Khamaura, area.	3 nos.
3	Land Development of Haraiya, Bhulhara and Sehari Area	3 nos.
4	Preparation of Physical Development Plan of Buditola area as hill station area.	1 nos.
5	Preparation of Physical Development plan of Sim, Godada, Patreni and Sehari as rural service center area.	4 nos.

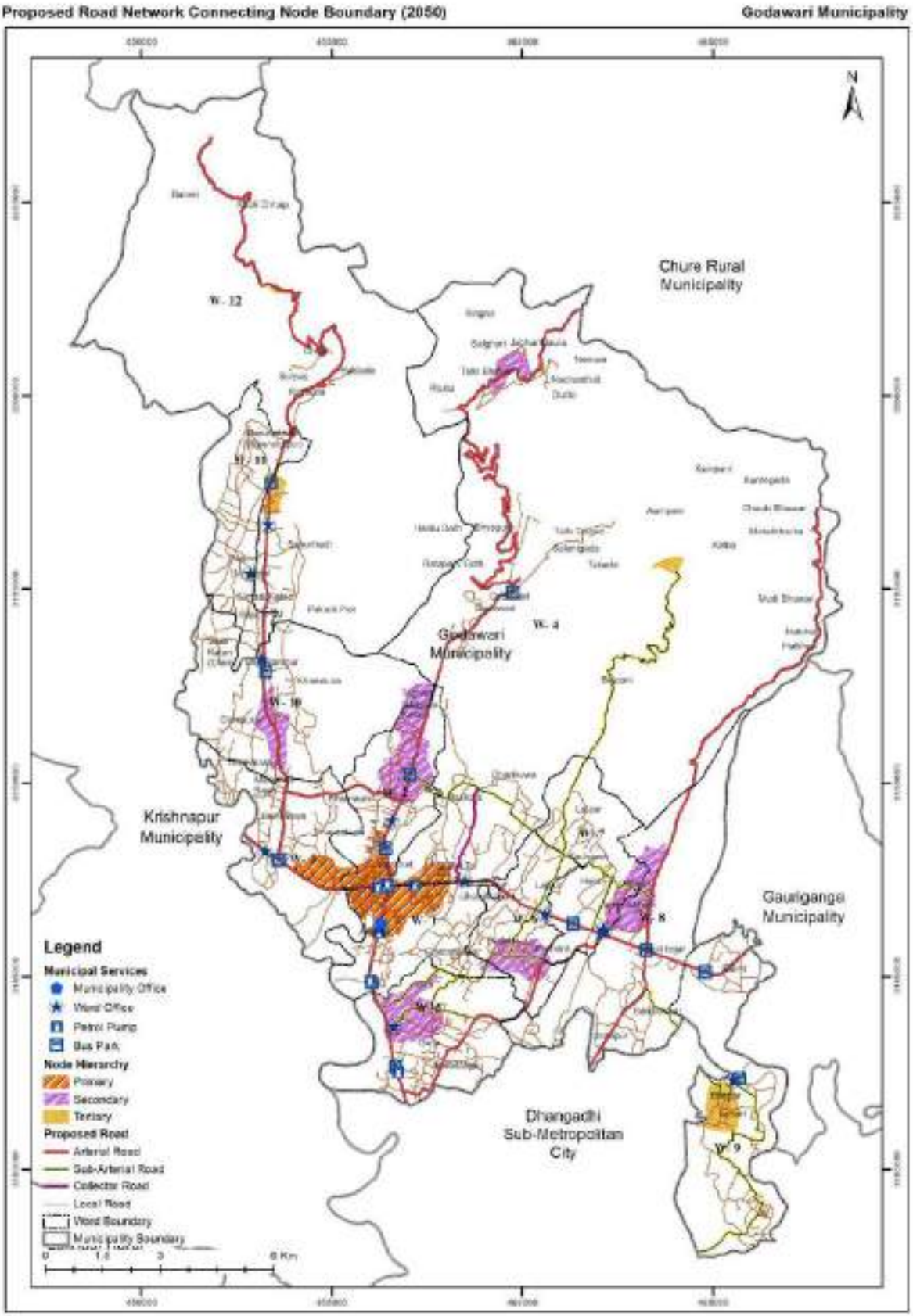

Fig. 5.6 Proposed Road network connecting Node Boundary (2050).

Fig. 5.7 Proposed road cross section for 20 m road.

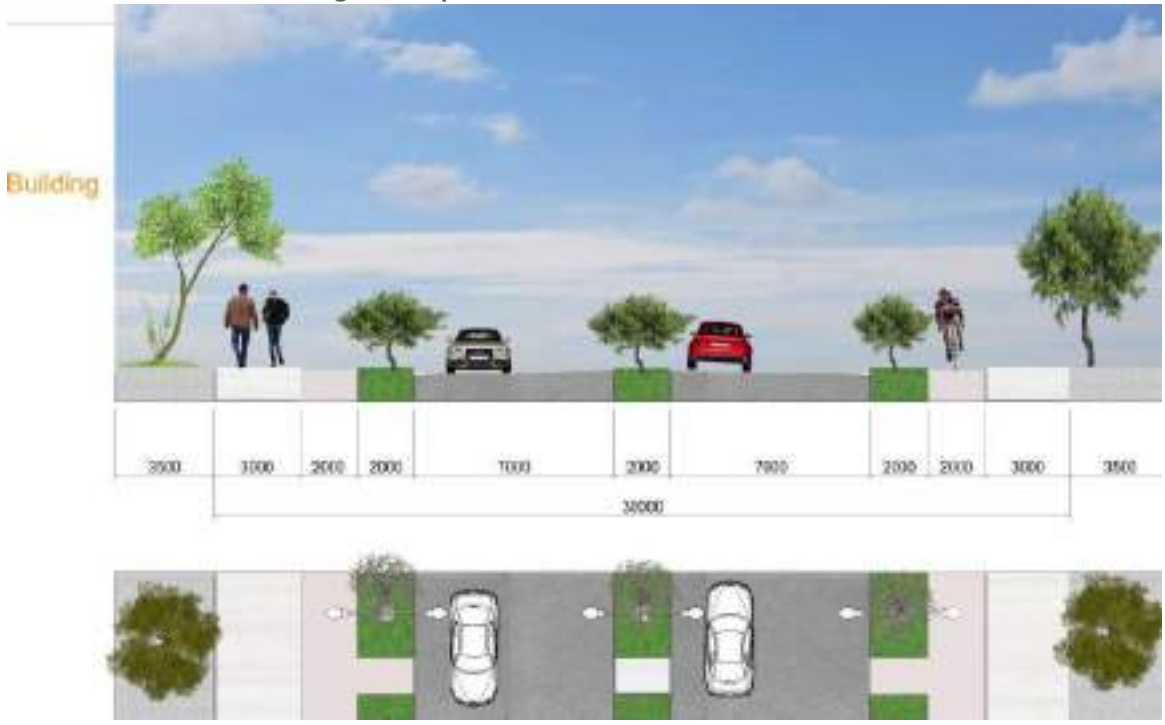

Fig. 5.8 Proposed road cross section for 30 m road.

Fig. 5.9 Proposed road cross section for Mahendra Highway.

Table 5.19 Proposed Municipal Strategic Road.

PROPOSED MUNICIPAL STRATEGIC ROAD				
S.N.	PROJECTS	CATEGORY	ROW (M)	LENGTH (KM)
1	Malakheti – NaharSadak	Arterial Road	50	27.65
2	Teghari – Khamaura Road	Arterial Road	30	3.32
3	Teghari – Dhadkuwa – Haraiya Road	Sub - Arterial Road	20	8.74
4	Lalpur – Gaudi Sadak	Sub - Arterial Road	20	13.67
5	Syaule – PahadSadak	Arterial Road	30	14.15
6	Geta – Bhuihara – Lalpur Road	Arterial Road	50	5.89
7	Syaule – Sehari – Murkatti Road	Sub - Arterial Road	20	12.58

Besides municipal strategic road planning, parking management is another important sector of transportation which not only impacts environment but also causes hazard for pedestrian traffic. East West Highway and Bhimdutta Highway intersects at Godawari Municipality creating urban intersection which demands the regional bus park. The existing bus park at Attariya is not managed is at the center of the primary node, so the bus park is proposed at the west of Attariya at Chaukidanda area along East-West Highway.

In addition to construction of Regional buspark at Chaukidanda, transport Village and Auto village needs to be planned within the municipality. Godawari has been declared as Provincial Capital and SEZ is also been in plan at Haraiya, so to minimize the traffic congestion within the municipal in long run, the transportation infrastructures need to be proposed (**Table 5.20**).

5.6.8 WATER SUPPLY, DRAINAGE AND ELECTRICITY INFRASTRUCTURE

Majority of Households in Godawari Municipality depends on tube well. There is less piped water supply within municipality. So, the for better water supply distribution, the proposed projects are shown in **Table 5.21**.

5.6.9 SOCIO-ECONOMIC DEVELOPMENT PLAN

Socio-economic activities play the important role to enhance the living standard of the people. As per the MHRA 26.65% areaof the municipality are in vulnerable against disaster risk. The livelihood of the people is directly related with economic earning from the agro based activities and informal and untradeable business in the municipality. So, it is very important to encourage the people towards insurance policy system. To support emergency response and post disaster recovery efforts, catastrophe insurance can play a key role in providing immediate financial resources to support post-disaster needs (ADB, 2013). The effective and efficient rescue and relief to the residents when a natural hazard strikes the urban centre of municipality is also important. For this, municipal investment in the development of early warning systems to provide sufficient time to run away the safest area protecting the property as well. It will definitely minimize the loss of life and property

Analysing the gap and SWOC of the municipality, it can be presumed that social services such as educational, health and security is sufficient enough in the municipality. Moreover, only the quality of services needs to be upgraded. Besides, education, health and services, other socio-economic infrastructures need to be planned in municipality to meet the norms and standard of municipality (**Table 5.20**).

5.7 MODEL RESILIENT BUILT-UP AREAS

The protection of the livelihood and property of the city dwellers is the primary concern. Therefore, the main responsibility of the government is to make a city safe and livable city should be safer from the risk of natural disasters. In order to develop model resilient built-up areas, the municipality needs to focus on their plans and programs. The municipal area is reflected through the presence of high, medium and low risk zones in terms of different types of disasters. Therefore, it is imperative to study each risk locally and apply mitigative and preventive measures to minimize the risks. For instance, it is important to apply engineering and technical solutions and/or other measures to protect households in flood prone areas. If any houses/buildings are in danger of flood or river bank erosion, such buildings should be immediately relocated to safer areas and measures should be taken by the municipality to prevent such flooding/erosion. It is necessary to relocate victims adopting land pooling scheme through providing the housing lots with minimal price. Proceeding, it is necessary to relocate emergency and critical facilities from the risk sensitive zones to safer zones and make up to date required equipment/tools and rescue/relief experts at the time of disaster in a well-managed and consolidated form. The most vulnerable population such as elderly/old aged, differently able people, children, single women, widows, marginalized people, slums should be prioritized to keep safe during disasters such as flood, landslide, earthquake, fire, windstorm and other natural disasters.

5.8 MODAL DEVELOPMENT PLANS

A modal developments plans has been proposed to reduce the disaster risk. The safer areas have been identified for the municipal service center, new planned land developments and other facilities essential for the municipal uses. The major principle of model resilient built up areas should be safe and livable, for the sake of people with public good which should contain important values such as cultural life, conservation of nature and environment and sustainable development to make the city resilient. Regeneration of the neighborhood should be in a proper way where the indigenous locals shouldn't be displaced. With the output assessment of MHRA the whole municipal area has been planned and Master Plan of the municipality also proposed as follows;

5.8.1 MASTER PLAN

As per the results of multi hazard risk assessment the whole municipality area has been planned proposing the development nodes for the planned urban development, protection of arable agricultural land, conservation of natural resources, forest, water bodies in a risk free or moderate risk zones. Development Nodes are proposed for short term phase (for 2030 AD) and long-term phase (for 2050 AD). To mitigate the high hazard of the risk disaster risk reduction intervention in the particular location also proposed and disaster risk reduction management plan has been proposed. Humanitarian open space were also identified for the rescue operation. Escape route has been proposed connecting to the safer locations during disaster for the rescue and relief of the victims. Developments Nodes in the **Godawary Municipality** are proposed with their potentialities with a hierarchy of primary, secondary and tertiary. Mainly the primary node is proposed as a Center Business District (CBD) with a facility financial and service provide public institution, educational center, tradable and untradeable business and activities on the formal and informal sectors. Secondary Nodes are proposed for the different types of uses with their potentialities. Some nodes are for administrative and institutional center as well as the capital of the province. In some area quality health service center is proposed. Some area is identified for modern types of development with recreational, entertainment and sports with the planned urban development. Agricultural service center with agro-based industries and agriculture market centers are also proposed in the existing facility which seems necessary to protect the agricultural land. Likewise, tertiary nodes are proposed for mainly residential, conservation of cultural and traditional settlements and tourism service center. Detail proposed Master Plan for short term (for 2030 AD) and long term (for 2050 AD) respectively incorporating the multi hazard risk, development nodes and DRRM interventions are shown in **Fig 5.10 and Fig 5.11.**

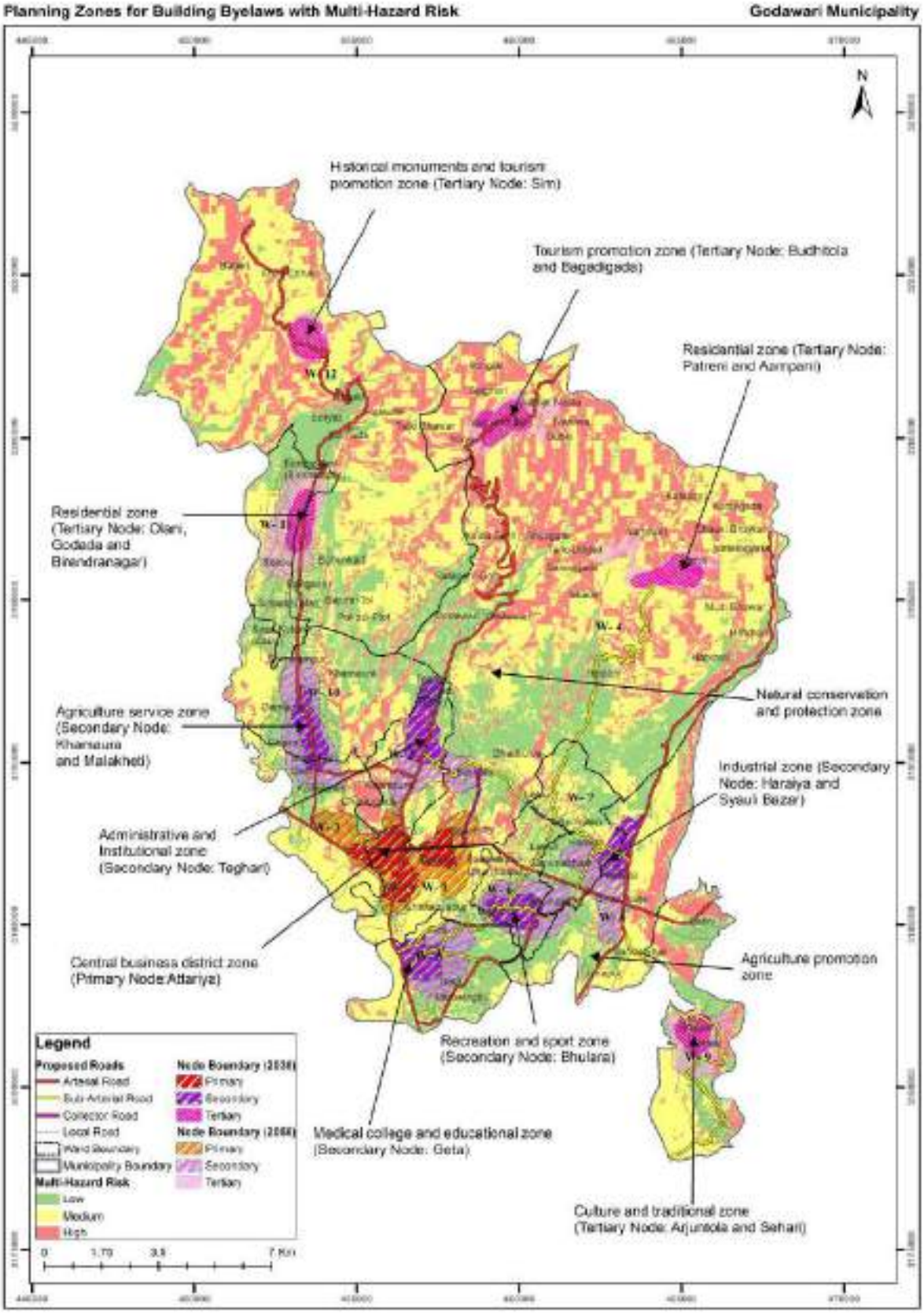

Fig. 5.10 Detail Master Plan Showing Development Nodes with Land Use.

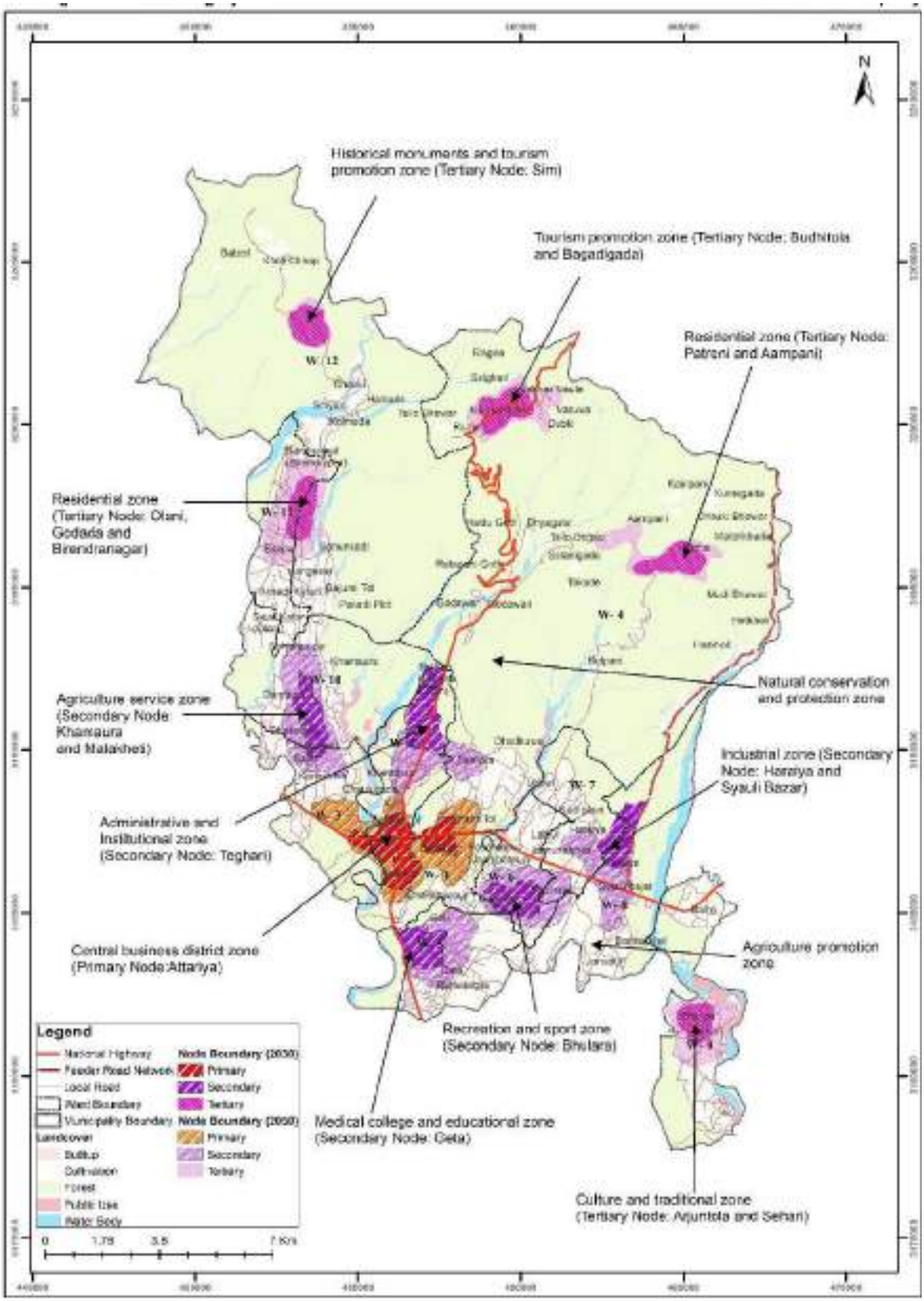

Fig. 5.11 Detail Master Plan of Development Nodes for 2030 and 2050 AD with Land Use Zone.

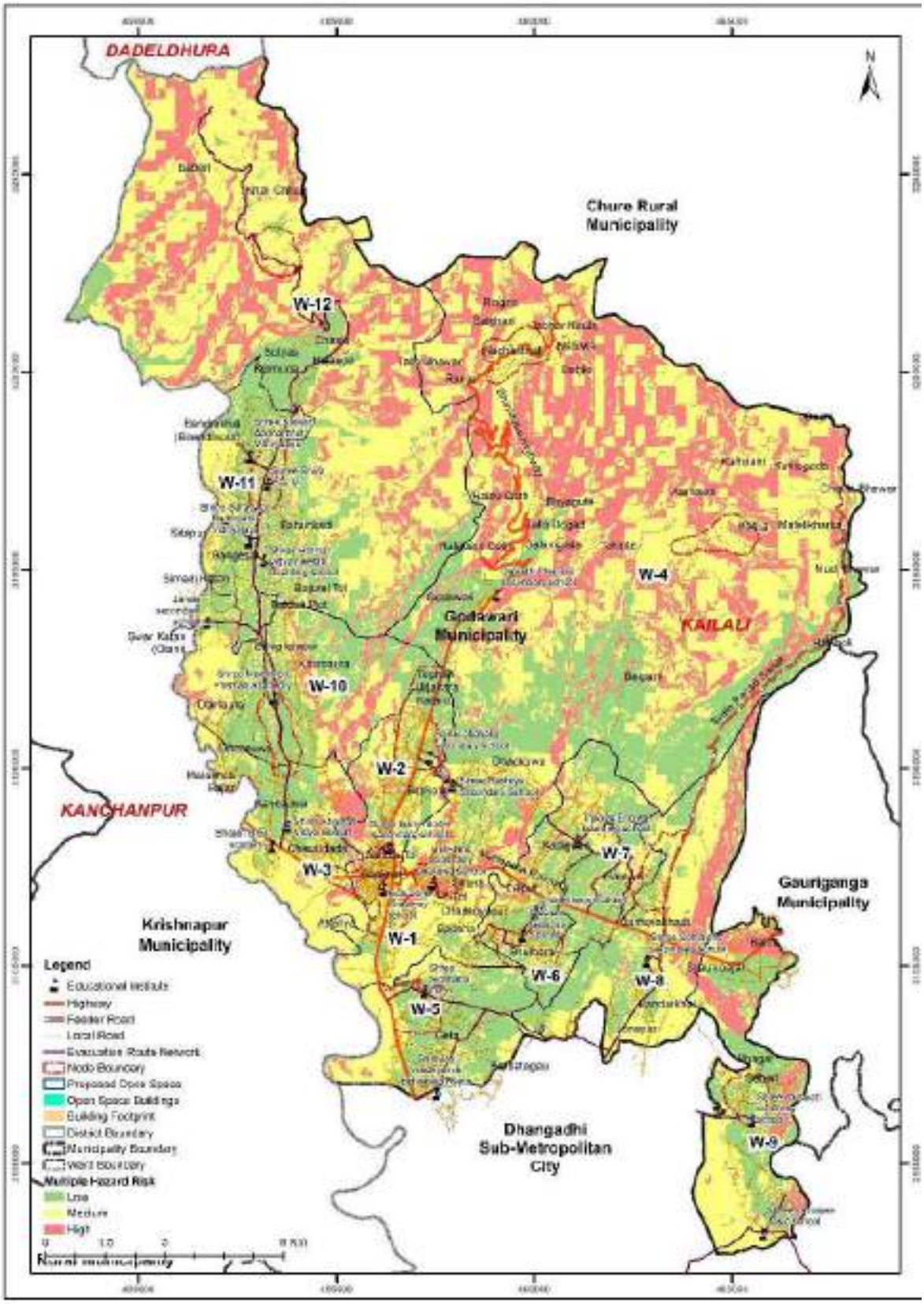

Fig. 5.12 Master Plan of Ward wise Humanitarian Open Spaces and Escape Routes with Multi Hazard Risk.

5.8.2 SITE PLAN/LOCAL AREA PLAN

As per the recommendation by the Risk Sensitive Land Use Plan of the Godawary municipality should play the special role for the preparation of the Local Area Plan considering the hazard risk of the particular locations. The output of MHRA is high risk, moderate and low risk zone as per their intensity and direction. To mitigate the risk in the high-risk area some intervention is proposed to make the area safer for the developments. Some techniques and tools are proposed to minimize the risk. GLD plan, retrofitting techniques and recession on buildings system should enforced for the safer escape routes during the disaster. River training, soil stabilization and plantation are proposed as a DRRM plan. Escape routes connecting the open spaces are also proposed and shown in **Fig. 5.13** for rescue and relief propose. Ward wise details of open space and evacuation routes are mentioned in DRRM report

Fig. 5.13 Local Area Plan of Humanitarian Open Space with Escape Route in Ward No. 9.

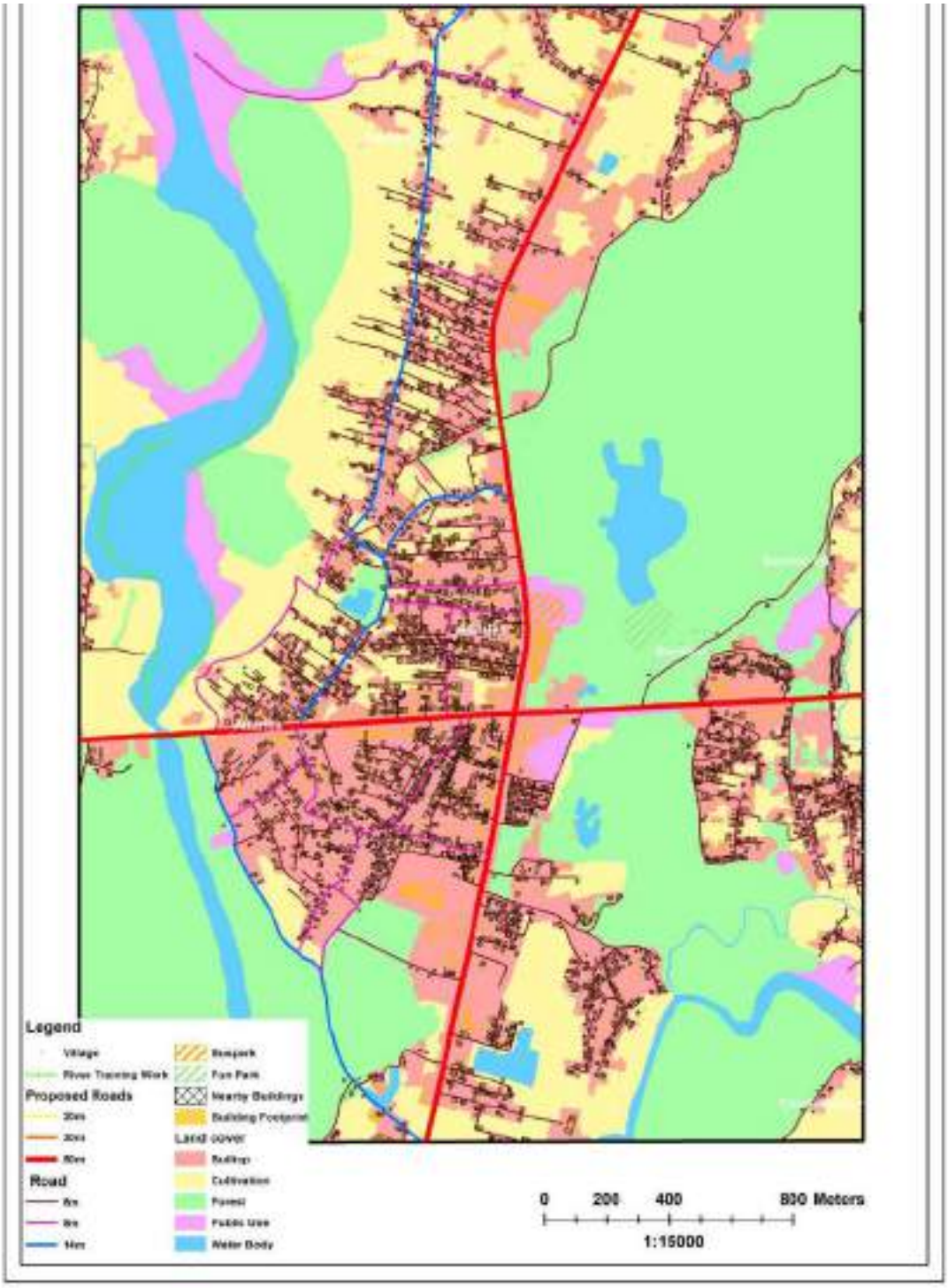

Fig. 5.14 Local Area Plan of Proposed GLD Road Networks and Land Use.

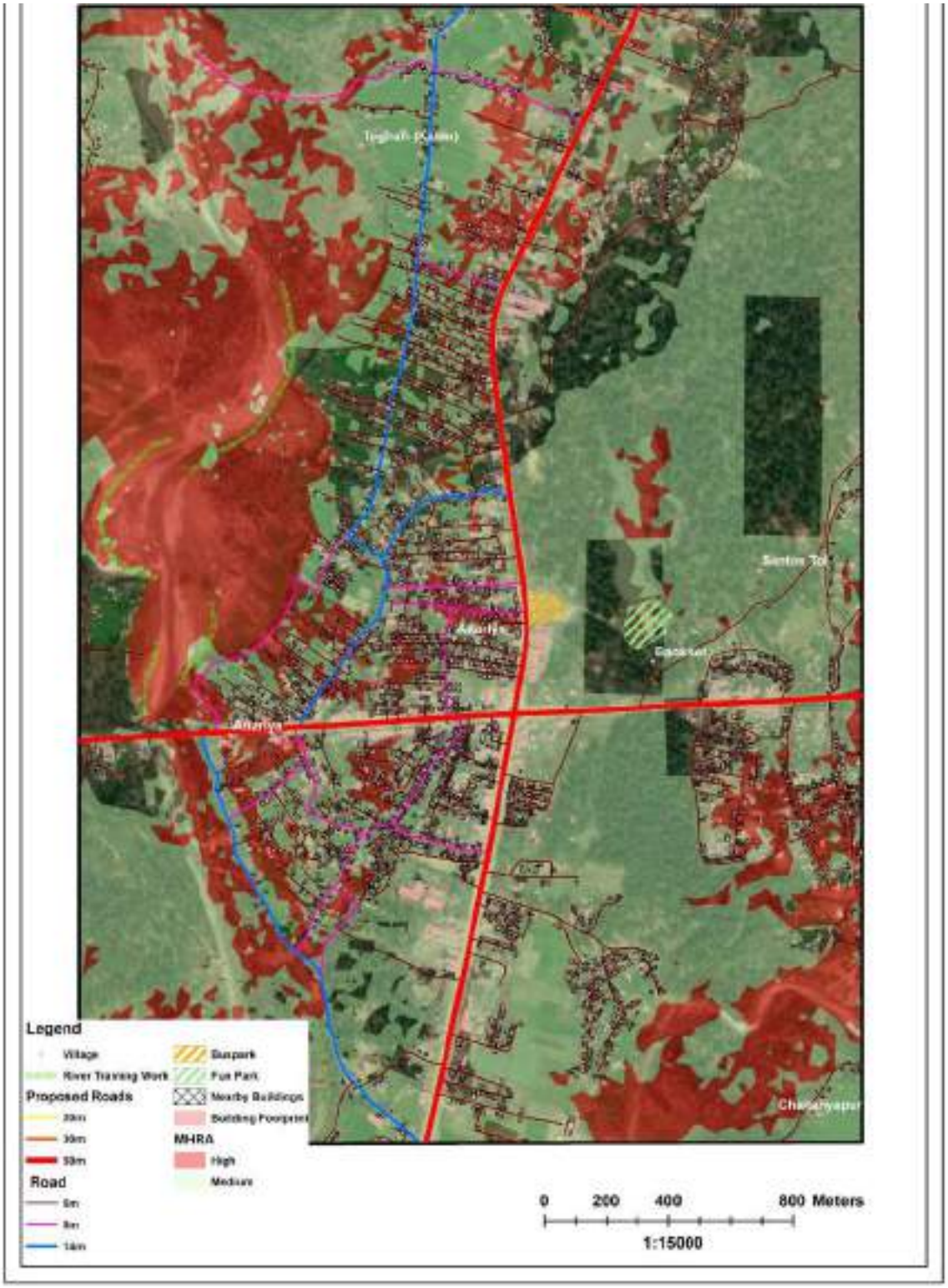

Fig. 5.15 Local Area Plan of Proposed GLD Road Networks and Land Use for 2050.

5.8.3 INFRASTRUCTURE PLAN

In the proposed development plan physical infrastructures are proposed for the new developments. Road networks with different hierarchy has been proposed for the mobility of the people and transportation of the goods in the development nodes. Transit Oriented Developments (TOD) could be implement to create the people and job closer. Planning team proposed the arterial, sub arterial and connecter road with a width of 50m, 30m and 20m respectively to fulfill the objective of the

development's nodes serve as a TOD in the neighborhoods. Road networks connecting the developments nodes are shown in **Fig.5.16** with its road hierarchy. These TOD policies have a successful example in the developed and developing countries. Where the developments nodes have been privileged for FAR bonus as an incentives mechanism to accommodate the existing populations, attracting and absorbing new populations, and attract the private investment for the new developments. Compact and dense settlements with a development of smooth road networks between the development nodes promote the walkability and mixed-use confining within the nodes. And other supporting infrastructures for instance, regional bus park, water supply system with water treatment plant and overhead storage tank.

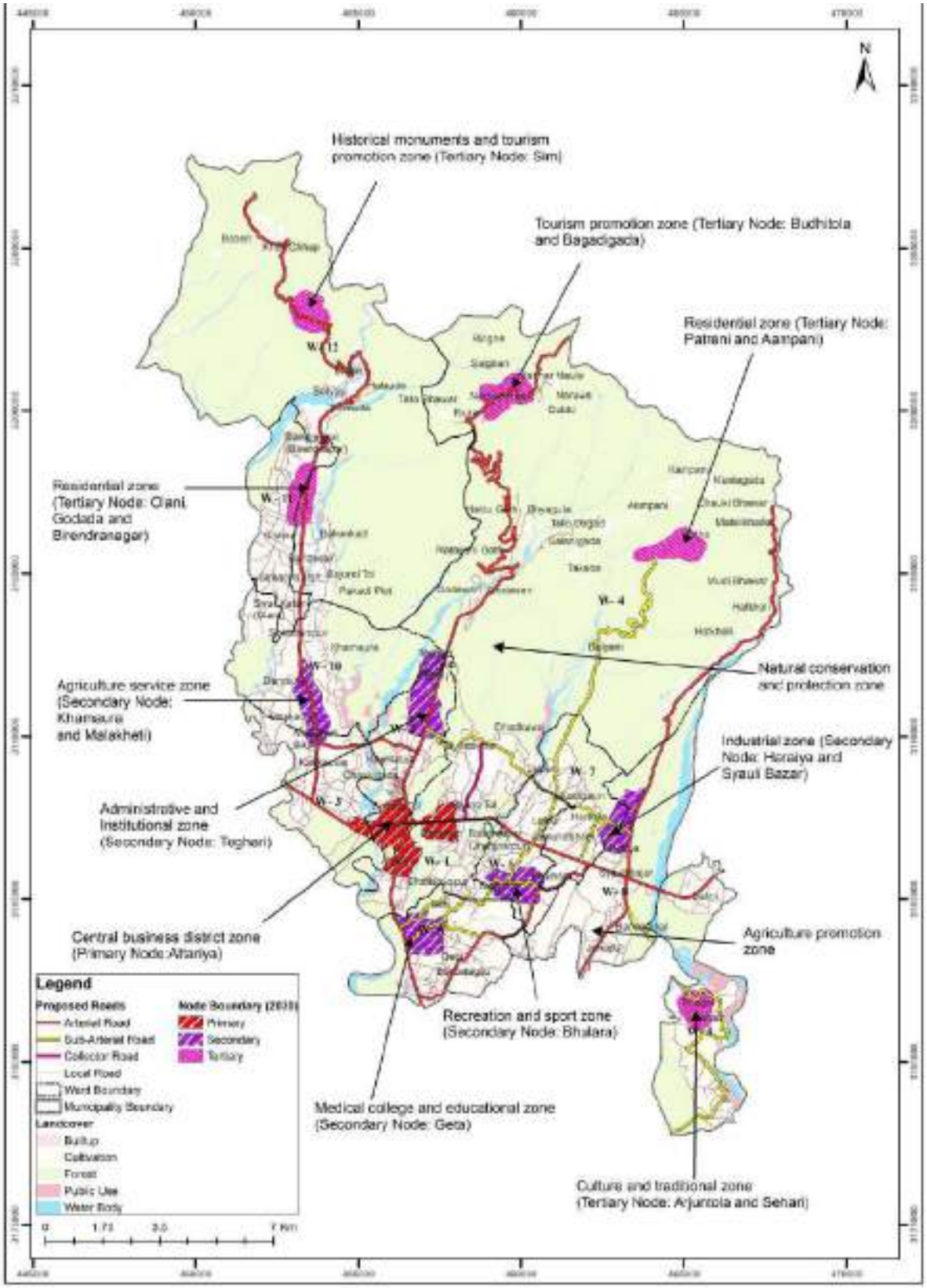

Fig. 5.16 Infrastructure Plan of Proposed Road Networks and Development Nodes with land use for 2030.

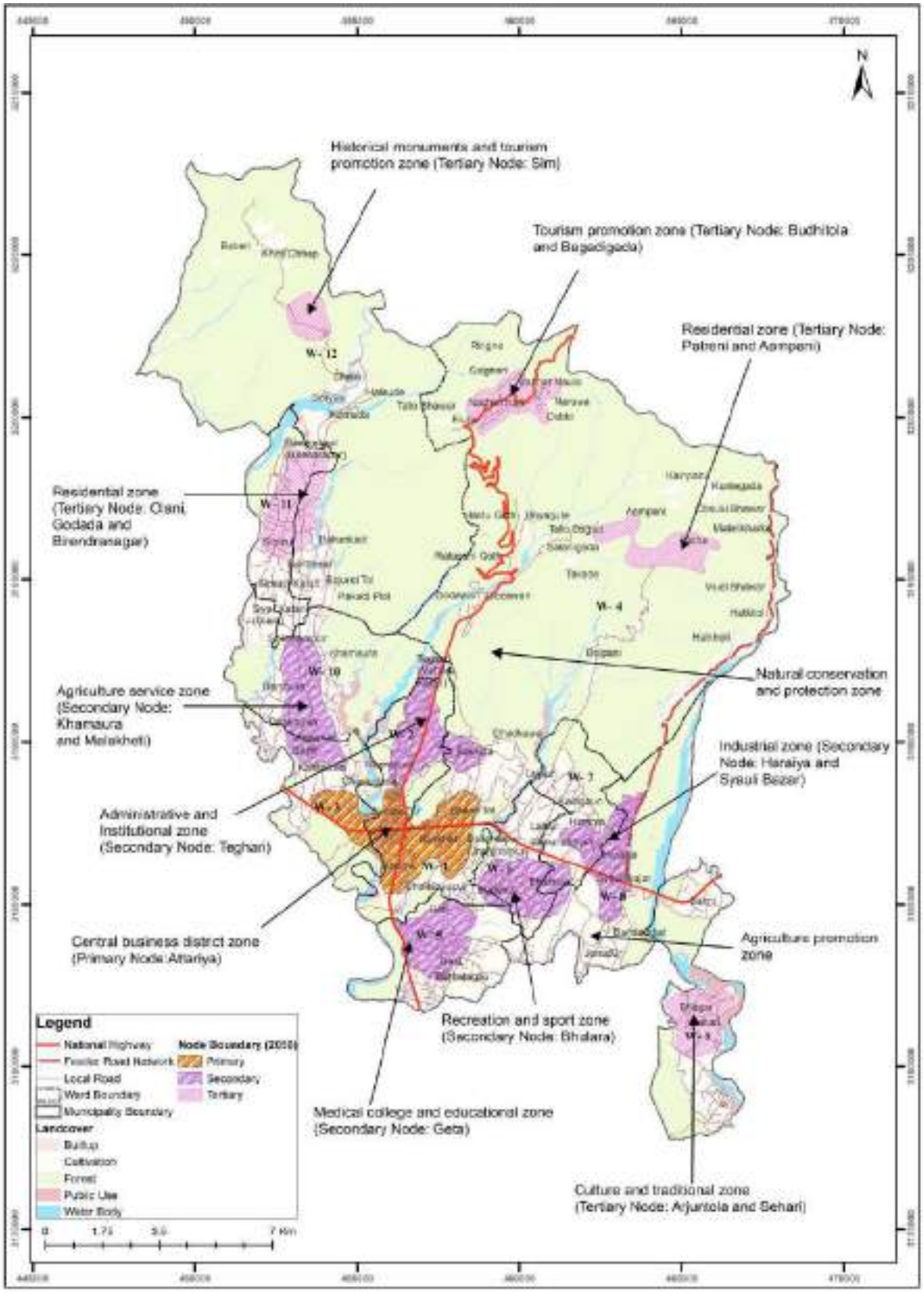

Fig. 5.17 Infrastructure Plan of Proposed Road Networks and Development Nodes with Land use for 2050.

5.9 URBAN REDEVELOPMENTS

It is very important to encourage the public and private sector for urban redevelopments in the risk prone areas. Where the transfer of developments rights and relocate the existing settlements is not possible and against the will of the people. These principles have the following in common: it is a consensus on possible outcomes of regeneration; it includes new paths and methods developed in order to resolve problems in declining urban areas in a coordinated way, and it is a comprehensive and integrated vision and action that is performed to constantly improve economic, physical, social, and environmental conditions (Urban Regeneration and Bursa Report, 2008).
The main objective of urban redevelopment is to transform /renovate existing urban areas which are in the risk-prone zone as per the multi-hazard risk assessment. The urban redevelopment integrating disaster risk considerations in location-based development should be as follows; (i) retrofitting techniques for the vulnerable building structure for area improvement, (ii) urban renewal in the vulnerable community (redevelopment), and (iii) developed street network for a rescue operation, propose GLD plan for the road widening (iv) Upgradation plan for school, hospitals, security areas, financial institution, renovate of urban services and other critical structures. To achieve the goal of above approaches for the redevelopment of existing urban core areas, to make the urban resilient human settlements following strategies shall be applied for.

5.9.1 URBAN REDEVELOPMENT STRATEGIES

STRATEGIES:

- Promote safer areas for new development, apply the incentive mechanism in high hazard areas for development control.
- Make accessible the existing settlements of high and moderate risk areas for the emergency vehicles.
- Apply the incentives approach to recess the road side buildings for the wide range of sky line to the street.
- Apply the mandatory rule for the building in a flood plain area to raise the plinth height.
- Apply the participatory approach for the planning and implementation of Guided Land Development Plan to widening the street networks.
- Make sure the public open spaces and public buildings ready to use during disaster time.
- Proper application of physical planning regulation and building byelaws in existing as well as in new development areas.
- Extensive consultation with the land/house owner and public should be done.
- Apply the structural and non-structural intervention in risk prone areas for resilient settlements.
- Ensure the protection agricultural land for agro-based industries and food security.
- Enhance the quality of crop pattern with respect to climate change adaptation.

- Ensure the conservation of natural resources and water bodies to maintain the eco-system to improve the environmental conditions.
- Provide the incentives for the insurance premium to payback the monitory value just after the disaster.
- Develop the coordinating system with the other local government bodies for the early alarm system during flood.
- Provide incentives to the land developers incorporating water bodies as a fire hazard mitigation measure in their design.
- Apply the disincentives mechanism to the fuel refilling stations located in the major city core areas.
- Ensure the structural safety of the public building where mass gathering activities are allowed.

The proper implementation of Urban Redevelopment strategy is very important. Co-existence, cooperation and coordinating system should be developed to encourage the private sector with incentive mechanism. The Urban redevelopment is essential in existing urban areas, where lack of urban infrastructure such as roads, electricity, water supply, sewerage, public parks with deteriorating urban environment. Redevelopment is directly related with the land. In our context land ownership is with the private sector. Construction of building is a voluntary construction activity done by the personal capacity of the land owners. It is very difficult to implement depending on the private funding. So local government with the support of the provincial and federal government "redevelopment" fund should be arranged. Otherwise, it is not only abhorrent but also have an adverse impact on the planned urban development. Redevelopment Master Plan has been prepared to develop the resilient built-up areas which is shown in **Fig. 5.18** of Site Plan/Local Area Plan.

5.9.2 IMPLEMENTATION OF GUIDED LAND DEVELOPMENT PLAN

The current city market center is being developed on its own way regardless of designing the urban structures in terms of population density, infrastructure development and accessibilities to the settlements are not systematic. Proceeding, the constructed roads do not appear to be followed according to norms and standards; for instance, the dense settlements in the municipality is occupied with 3/4 m wide road with lacking proper setbacks on both sides. Consequently, these roads cannot be utilized for two-way in ordinary days which is not amiable during calamities and cannot be served. Therefore, the width of the road should be operated in a two-way traffic not only during ordinary time but can also be made functional during disaster for rescue and relief even if some parts of the road are blocked or damaged through the guided land development process the roads within the core urban areas should be widen as shown in the **Fig. 5.7**. In order to maintain this activity, cooperation and coordination of the locals, municipal investment for the redevelopment of resilient urban road is imperative. The budget management is necessary for urban redevelopment not only in the municipal level but the financial support on project from the Provincial government and Federal government are also necessary. As an example, typical guided land development plans are proposed in primary node in Attariya (**Fig. 5.7)**.

5.9.3 APPLICATION OF RETROFITTING TECHNIQUE

Similarly, when we study the multi hazard analyses of the municipality, there are single storey to maximum five storey buildings in the area. Apart from newly constructed buildings, there are mostly

single storey to three storey structures in the municipality. The structural vulnerability in the building showed that the buildings were constructed without consulting with an engineer; for instance, the size of the column is 10″ x 10″. Besides, 4 numbers of 12 mm diameter rebar have been used in single storey building with a total area of 452 mm^2. In fact, the structural analysis shows at least 1256 mm^2 (4 numbers of 12 mm and 4 numbers of 16 mm) area is required for the construction. Similarly, it has been measured 804 mm^2 (4 numbers of 16 mm diameter) area of rebar has been used for 2-3 storey buildings while there requires at least 1256 mm^2 to 1884 mm^2 area is required according to structural analysis. The current practice in the municipality shows that any types of natural disasters such as earthquake, flood and windstorm may have a impact force to collapse the existing building structures and would impact loss of public property together with hinder the proposed escape route and evacuation route at the time of disasters. Therefore, a notice should be issued and the vulnerable structures along the roadside need to be advanced with the earthquake resistant infrastructure. The municipality should deploy the team under the leadership of structural engineer and enlist the vulnerable structures through rapid assessment for the retrofitting of such infrastructures. In order to minimize cost, the municipality can arrange the volunteer-based program and can lead to deploy students of structural engineering students studying in different academic institution.

In this section, a model resilient settlement is excepted for risk sensitive settlement area for planned urban development. The model resilient settlement should encompass through easy access of escape and evacuation routes/exits, open humanitarian spaces including spacious school infrastructures for immediate rescue, treatment of injured people and livestock in the health post and hospitals applied as the first aid treatment. These critical facilities should be created, retrofitted and can be immediately run at the time of disaster event in an emergency.

Proceeding, the essential facilities need to be minimized/eliminated possible losses from the disasters by relocating facilities to safer zones, for example, electrical appliances should be relocated at higher places or needs to be raised to higher place to prevent from electric shocks if the flood/inundation occur. The essential services such as electricity distribution system, communication services, ambulance, fire brigade etc. should be placed in ready position with necessary maintenance in advance to tackle with disasters response. The municipality should pay attention to form disaster resilient city and protect from all possible natural disasters adopting following guidelines.

- Requires to provide strong leadership, coordination and responsible role.
- Needs to integrate with necessary policy and strategy.
- Allocate adequate budget management for swift emergency service delivery.
- Arrange for the rehabilitation of the families and communities at risk.
- Make mandatory use of National Building Code and its compliance.
- Regulate new building construction standards literally followed.
- Enhance the capacity of the municipality for the implementation of above-mentioned guidelines effectively.
- Establish/Form Disaster Risk Management branches to mobilize the concerned organizations for the emergency services required during the disaster and for its proper management.
- Arrange for essential emergency services, infrastructure, utilities and service facilities.

5.9.4 UPGRADATION PLAN OF SCHOOLS AND HOSPITALS

Timely rescue and distribution of relief materials are the prime task at the time of natural disasters. It is necessary to supply relief materials to the rescued victims. The school premises are the most useful locations to the rescued victims. The alternative measures therefore need to be equipped in terms of

Disaster Risk Reduction Management (DRRM) with the formation of clean classrooms, water supply (potable and clean utensils/clothes), backup power with adequate electricity facilities. Besides, necessary steps should be taken in all sectors of health and hygiene, gender friendly wash rooms for the upgradation. It is necessary to check the critical services and facilities periodically and ensure that the upgradations to tackle with disasters. Electricity and electrical appliances should be kept away from flood and inundation levels to protect from fire and electric shocks. Hospitals, financial institutions and school buildings should be located at safer zones. If these critical services are located in high-risk zones, it needs to be gradually relocated to safer area by applying land pooling technique. The land pooling project should be developed by the municipality and investment from the municipal level and private sector, should be managed. The healthcare infrastructures should strictly follow the norms of earthquake resistant buildings construction technology.

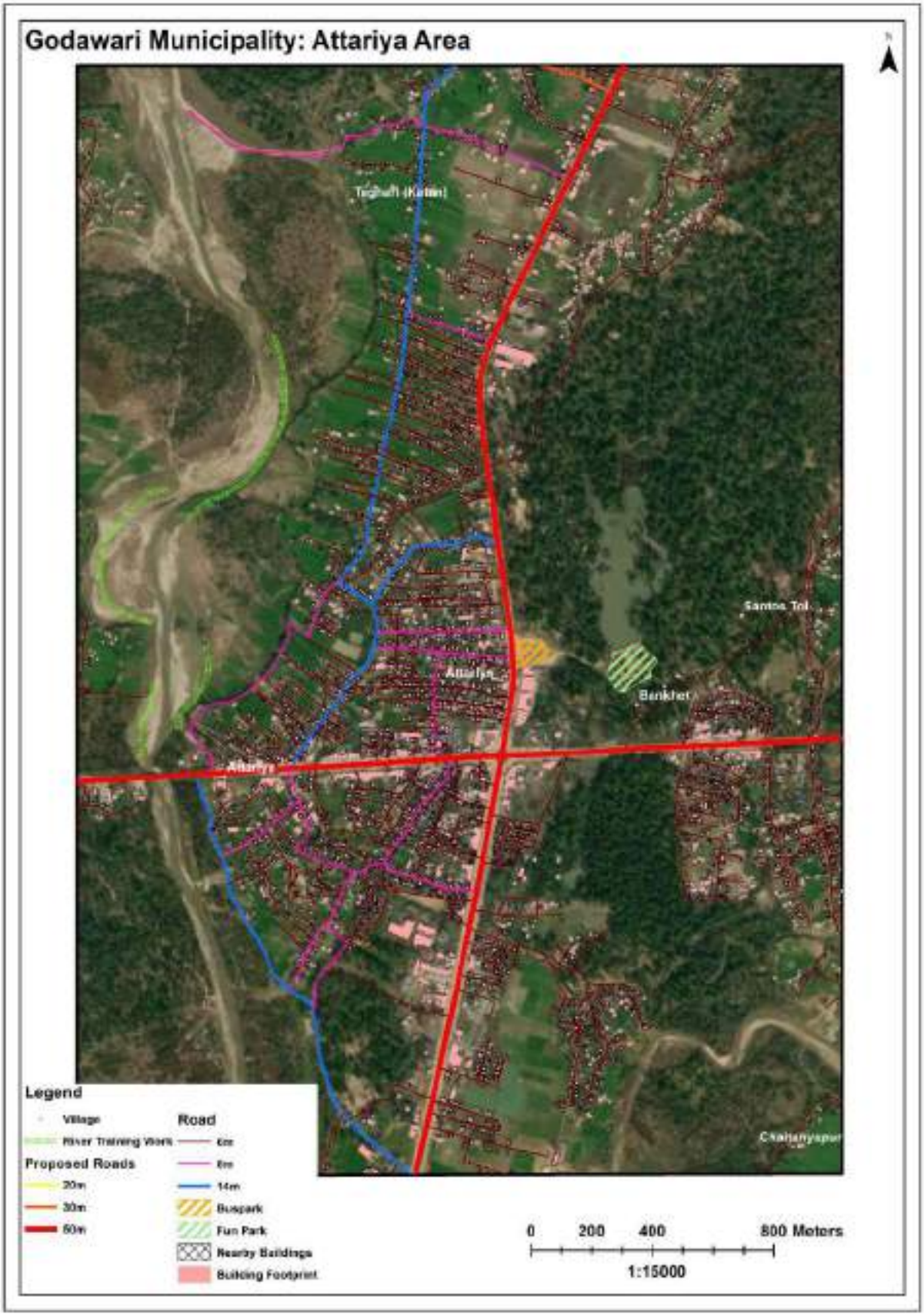

Fig. 5.18 Attaria settlements with GLD planning and River Training Work.

Table 5.20 Transportation Infrastructure Plan.

TRANSPORTATION INFRASTRUCTURE PLAN	
S.N.	PROJECTS
1	Feasibility Study, Design and Construction of Regional Bus Park at Chaukidanda
2	Establishment of Autovillage at Tamauli Area
3	Establishment of Transport Village at Tamauli Area

Table 5.21 Water Supply Infrastructure Development.

WATER SUPPLY INFRASTRUCTURE DEVELOPMENT	
S. N	PROJECTS
1	Integrated Water Supply Project in Municipality to have access to piped water
2	Establishment of water treatment and storage tank for supply of potable water
3	Preparation of Municipal Drainage Master Plan and Implementation
4	Extension and expansion of electricity infrastructure to all settlements

Table 5.22 Socio-Economic Development

SOCIO-ECONOMIC DEVELOPMENT	
S.N.	PROJECTS
1	Proper Management and Construction of Football, Cricket and Volley ball ground
2	Development of Tourism Cultural Area at Godawaridham Area
3	Construction of multipurpose/conference hall
4	Detail Feasibility study and construction of Agro based industries at Khamaura Area
5	Establishment of slaughter house

School premise and critical health facilities are another important place for the rescue and relief during the catastrophic disaster. Most of the school have their own open spaces, these open spaces can be utilized at the time of disaster (**Fig. 5.19**). So, the facilities of gender friendly sanitation system should be maintained. Other facilities i.e., water supply, power backup, communication and social security vigilance system should be updated through the municipality. Ensure the functions of the critical facilities should be checked and upgraded to cope with disaster events. Placement of the electronic and electrical appliances out reach of flood and other disaster. Highly vulnerable emergency facilities, i.e., hospitals, and schools should be out of high-risk areas.

Longer-term planning that incorporates disaster risk is especially important to protect critical infrastructure and public facilities. After the critical and rigorous analysis of the hzards it will help to determine the projects to mitigate the long-term impacts of disaster and interventions should be adopted where it necessary.

5.9.5 RIVER TRAINING WORK

During the monsoon season most of the area are affect from the natural disaster special flooding, inundation, flash flood and landslides. Selected area for the urban regeneration and resilient model is also in the hazard prone area where the risk of flood and flash flood are common. To mitigate the risk measure of the hazard, expert team identified some portion of the river should be trained for the bank protection. Gabion work along the river bank is proposed to channelized the flood during rainy season. Launching apron and embankment raise seems necessary in the Attariya location to control the flash flood effect on the settlements fed by the Godawari River to save the life and property of the people during monsoon. River Embankment, Guide Banks, Launching Apron, Spurs, and such other types of Gabion box should be laid along the identified location of hazard prone area to mitigate the risk from the flash flood. These locations are shown in the **Fig. 5.18**.

It is necessary to create coordination and cooperation with volunteers, security agencies, and various other agencies. The development of such a "risk-free model" used to contribute for long-term

Fig. 5.19 Open area of educational institute for the rescue operation during disaster. And retrofitting of road side building structure for resilient community.

development opportunities which are conceptualized in Sendai Framework to establish Disaster Prevention Model School as one of the rescue centers by retrofitting schools during disasters.

5.10 ENVIRONMENTAL PLANNING AND MANAGEMENT

In order to substantially reduce the environmental hazards, municipality should be aware of specific hazard prone areas. Preventive as well as mitigating measures should be adopted in order to minimize the risk associated.

5.10.1 MANAGEMENT PLAN TO REDUCE IMPACTS FROM PLANNED PROVINCIAL CAPITAL

The capital city of the province is proposed in the municipality. As the proposed site is located in the forest area (as shown in **Fig. 5.9**), the activities will have impacts on existing environment.

Measures to Reduce Vegetation Loss

The impacts especially on trees, vegetation and biodiversity after shifting the capital in the forest area is of serious concern. However, the corrective action for the loss of vegetation in the municipality is but not limited to plant new tree saplings. Municipality should give tree saplings and sapling of different fruits and vegetable to the local people of the municipality so that the people are motivated and

encouraged to plant the saplings. Moreover, the municipality itself should take a lead to restore the vegetation by planting trees in open spaces. In case of unavailability of enough space and short time, a tree plantation technique named as Japanese technique of tree plantation can be adopted. In this technique about 40-45 nos. of tree saplings are planted in a dome shaped land of approximate area of 200 sq. ft. The concept behind planting trees so dense is that the plant will compete with each other

for growth and hence grows faster in short period of time. This type of forest is especially used as the habitat of different animals and birds. Also, the vehicular traffic inside the municipality is likely to increase after the shifting of provincial capital. Proper maintenance of road should be done to minimize accidents and air pollution. Proper care should be taken to minimize the possible risk of encroachment of forest area. However, the detailed Environmental Assessment should be conducted in order to assess and minimize the possible threats to the environment.

5.10.2 INDUSTRIAL HAZARDS MANAGEMENT

The municipality consisted of a total of 10 industries including five brick industries, two gas refilling station, one sand collection center and two stone crushers. These industries covered an area of 452755.76 m^2. The map showing the area coverage by industries in this municipality is presented in **Fig. 5.20**. The major industry is the brick industry which covers 50% of the total industrial area followed by stone crusher which covers 35% of the total industrial area. Also, the municipality has a plan to make a separate industrial state, the area and location are marked in the **Fig. 5.21**. These industries contribute to dust/air pollution.

Dust and particulate matter management: As part of the occupational health and safety of workers: mask, googles, boots and gloves should be provided to the workers in such industries. Dust and Particulate matter pollution including noise pollution from brick as well as timber industries should be minimized by upgrading the equipment used.

Air pollution from brick and crusher industries: The brick and crusher industries that exists in the municipality has higher contribution to air pollution. Mitigating measures that shall be implemented by the municipality to control air pollution are listed below:

- The stack height of the brick kiln should be increased so that the plume is exhausted at a greater height and the particles are deposited back at a greater distance from the emission point.
- In open burning of waste generated from brick, crusher and other industries should be prohibited and appropriate solid waste management techniques should be applied.
- Municipality should closely work with experts, provincial and central government to produce a guideline for emission standards for air for these industries.
- Municipality should strongly monitor the Environmental management plans as suggested in Initial Environmental Examination (IEE) and Environmental Impact Assessment (EIA) for specific industry.

Management of generated solid waste from industries: Segregating of waste generated at their source is an important step in handling, storage and their further treatment and disposal. At first, industries should do waste segregation at source of production to separate the bio-degradable and non-biodegradable waste. Organic manure can be used as fertilizer in the agricultural field as soil conditioner for improving soil fertility. If not then the organic and inorganic waste can be collected separately by the municipality and should make action plan for the management of the waste. The recyclable waste from the industries should be sold to recycling sectors, who are currently working as informal sectors, i.e., scavengers should be formalized and recycling should be promoted. Production of same materials with degraded quality/grade can be done through these recycling industries.

Management of industrial wastewater: Direct discharge of wastewater into natural water bodies should be strictly prohibited. Wastewater treatment plants should be made compulsory for all industries. Decentralized wastewater treatment plants should be promoted. Municipality should prepare master plan for construction of sewerage networks and centralized wastewater treatment

plant. Municipality should prepare master plan for construction of sewerage networks and centralized wastewater treatment plant.

5.10.3 IMPROVING QUALITY /QUANTITY OF DRINKING/DOMESTIC WATER

- The major source of drinking water in municipality is tube well or hand pumps. It is being reported that availability of groundwater is decreasing and the quality of drinking water is also declining. The decrease in availability of groundwater is due to decreased infiltration. In order to increase the amount of groundwater, the infiltration area should be either be increased for natural infiltration or means for artificial recharge should be adopted. For natural infiltration, permeable pavements can be made in open area of buildings, roads and footpaths; hollow concrete blocks can be used to pave the surfaces; etc. Groundwater can be artificially recharged by redirecting water across the land surface through canals, infiltration basins, or ponds. Municipality could also allocate some space to make infiltration basins.

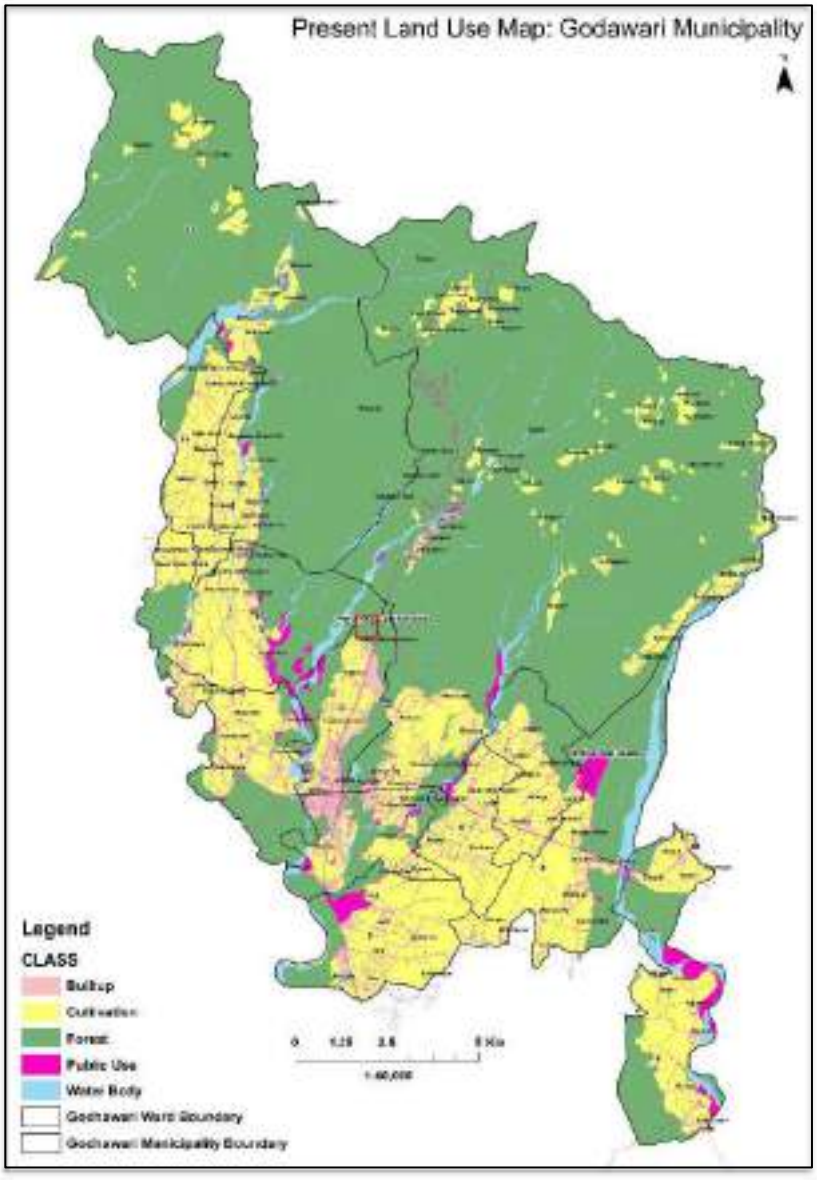

Fig. 5.20 Map showing present land use of Godawari municipality including the proposed site for provincial capital.

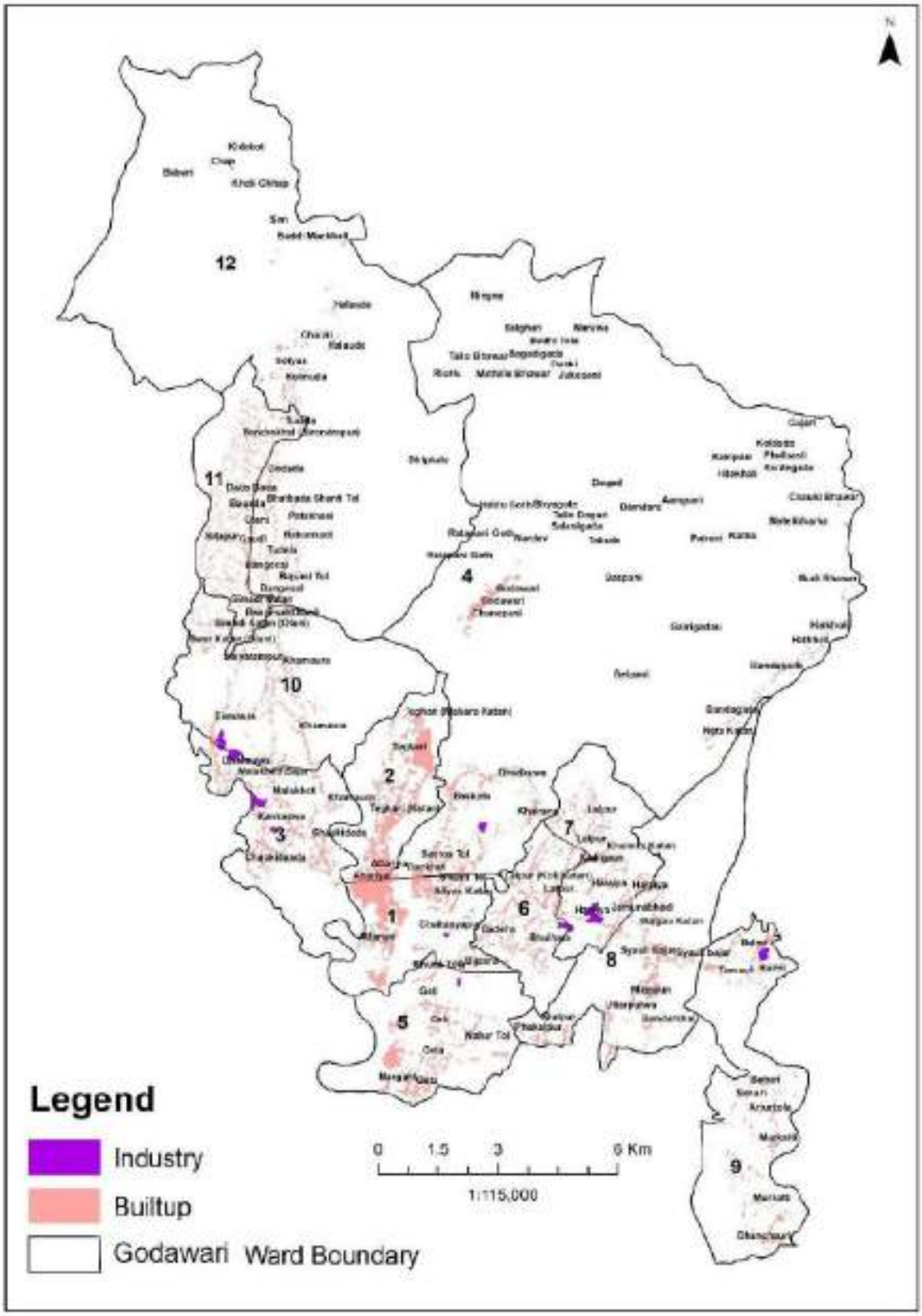

Fig. 5.21 Map showing the coverage of industries in the Godawari Municipality.

- The quality of groundwater is declining in the municipality mainly because of the huge consumption of chemical fertilizers in the agricultural land by the local people and also due to

loss of vegetation. To reduce the use of chemical fertilizers, organic waste from households, agricultural waste and crop residues should be converted to organic manure to be used in the agricultural field. In this regard, municipality could also play a vital role by providing training to the farmers to aware them about the advantages of organic waste and disadvantages of using chemical fertilizer. In this way the groundwater pollution will be decreased and organic waste will also be managed.

5.10.4 MUNICIPAL SOLID WASTE MANAGEMENT

Segregating of waste generated at their source is an important step in handling, storage and their further treatment and disposal. At first the municipality should promote waste segregation at household level. Municipality should encourage people to separate the bio-degradable and non-biodegradable waste and either use them for feeding their livestock or make compost manure out of the organic waste and use them in their agricultural field. Organic manure can be used as fertilizer in the agricultural field as soil conditioner for improving soil fertility. If not then the organic and inorganic waste can be collected separately by the municipality and should make action plan for the management of the waste. Most common forms of treatment/final disposal of solid waste that can be adopted by the municipality are listed below:

i. **Recycling:** Recycling sectors, who are currently working as informal sectors, i.e., scavengers should be formalized and recycling should be promoted. Production of same materials with degraded quality/grade can be done through these recycling industries.
ii. **Incineration:** Municipality can use incineration technique to manage the hazardous waste from the industries and hospital waste. Incineration is a process of controlled burning of solid waste at extremely high temperatures often as high as 2000°C. Its main advantage includes reduction of volume and weight (approx. 90% vol. and 75% wt. reduction) and it can be done at generation site. While its main disadvantage is that it requires high capital cost and skilled operators.
iii. **Landfill:** Landfilling/land disposal of waste can also be implemented by the municipality for the management of waste. It is the most common disposal route for all wastes, including those with hazardous properties. It is the process of final disposal of waste by landfilling with proper engineering techniques in an environmentally acceptable manner.

5.10.5 MEASURES FOR AIR POLLUTION CONTROL IN THE MUNICIPALITY

The main reason of the degrading air quality in the municipality is due to industries. However, other sectors such as vehicular emission; open burning of waste and crop residues; and dust emission from the unpaved roads. Mitigating measures that shall be implemented by the municipality to control air pollution are listed below:

a. Open burning of waste should be prohibited and solid waste management techniques should be applied.
b. Open burning of crop residues should be prohibited and crop residue management techniques such as livestock feed, mushroom cultivation, incorporation of Crop Residue in the soil to recycle the nutrients, use of crop residues as animal bedding and compost, etc.
c. The vehicles should do the maintenance at regular period and municipality should frequently monitor the maintenance record and green stickers in the vehicles.
d. The unpaved roads should either be blacktopped or water sprinkling should be done 3-4 times a day by the municipality to suppress the dust generated.

5.10.6 FLOOD AND SOIL EROSION MANAGEMENT

As southern part of the municipality consists of larger portion of cultivable land and built-up areas, increase in discharge of the rivers flowing across may subject the risk of flood and soil erosion. In order to prevent the risk, afforestation in the river banks should be promoted. Intensive grazing of domestic animals' nearby riverbanks either at southern part (built up and cultivable land) or northern part (forest) should be avoided. Gabion wall should be constructed along the river bed by identifying the fragile embankments and also at the narrow river beds where the water velocity is subjected to be high. The velocity of water is usually high at concave or outer bank of the meandering river which likely to erode the bank. Thus, the gabion walls need to be constructed at the concave or outer banks. Doing so will protect the river beds and river embankments against soil erosion. This will save the valuable cultivable land, forest area and settlements from the subjected risk.

Check dams needs to be constructed in order to slow down the velocity of the water during flash floods. These are constructed across the river to reduce erosion, by lowering water speed and accumulating sediments during floods. They are often introduced in already degraded areas, where natural or agricultural vegetation cover are lost or not capable of holding the top soil. Usually, they are built in areas hit by intense runoff events, where conventional erosion control techniques are not sufficient. Check dams need to be built at the right places, ideally where water can be directed to suitable areas for groundwater recharge.

5.10.7 OUTBREAK OF ANY PANDEMIC DISEASE SUCH AS COVID-19

The Global pandemic of COVID-19 is prevailing in the society. To prevent the spread of the virus, public gathering should be avoided and people must be aware while going in the public places. Other preventive measures that should be adopted are as follows:

- Maintain social distance to reduce spread of the disease;
- Wash hands frequently by using alcohol-based hand rub or soap and water.
- Use mask, gloves and cover mouth and nose with flexed elbow or tissue when coughing and sneezing; Check the body temperature on daily basis;
- Avoid contact with anyone that has fever and cough;
- Make an isolation center in the municipality with proper facilities and disinfect public places.

5.10.8 COMMUNITY/FOREST FIRE

Fire truck should be arranged by the municipality. Road should be constructed or expanded wide enough for fire truck to reach at every household. A fire break or fire line should be constructed in forest area in order to slow down or stop the progress of possible bush fire.

5.10.9 COLD WAVES AND DISEASES

Vulnerable groups should be identified and shelter, proper clothes and enough food should be arranged or managed for them. People should be provided with proper health facilities. Awareness about precautionary measures to the susceptible diseases should be spread.

5.11 DRR PRIORITY AREA & DISASTER RISK REDUCTION MANAGEMENT PLANNING

Reducing disaster risk through urban land use management processes requires long-term systemic thinking and involvement of multiple stakeholders from diverse sectors. It also requires reducing the exposure or vulnerability of communities and assets to hazards using policies, structural measures and

planning tools, such as Risk Sensitive Land Use Planning, RSLUP and disaster risk reduction management plan. Among a number of disaster-resilient planning techniques used, the RSLUP is regarded as an evidence-based tool to understand risk, plan and to reduce risk (Hada et. al., 2021). The RSLUP process starts with: i) mainstreaming disaster risk reduction/management into land use planning with integrated multi-sectoral plans; ii) formulating institutional bodies and with legal mandates, roles and responsibilities; iii) institutional strengthening through capacity building/support; iv) endorsement of plan, policy and legislation; v) plan implementation, enforcement; and vi) monitoring and evaluation. The following sub-sections provides the snapshots of existing status and scenario of the municipality on various DRRM related aspects and finally identifies the Gaps and suggests DRRM interventions/projects at local level. The detail DRR intervention and project levels are include in the **Separate Volume**.

6. DEVELOPMENT CONTROL AT VARIOUS LANDUSE/PLANNING ZONE

Development control is a backbone of the urban development planning. It caters the city development in a desired direction for the good faith of the people. It is an important tool for balance and planned urban development of the municipality. Development control is a process of ensuring development applications act in accordance with municipal land use policy, planning regulations, norms and standards, physical development plan and municipal building by-laws. If the development controlling mechanism is failure to do so it will chaos and reduce the livability of the cities. As per the findings of MHRA the spatial location of the high, medium and low risk area of municipality was identified. According to magnitude of risk the municipal area is further zoning in the development nodes, for 2030 BS (Short Term for 10 years) and 2050 BS (Long Term for 20 years), joining with proposed road networks. The basis of land use planning within the municipality area can be summed up by the phrases "urbanization area" and "urbanization control area" as specified in the building by-laws for the desired development of the nodes

Standard have to be achieved in certain condition to create a better place. Municipal land use policy is guiding legal documents to directing the city in the planned development. It also controls the building bulk, height, setbacks, building lines for planned street pattern, ground coverage by the implication of building by-laws. For the planned urban development planning permit system is also a control system to direct the city. Infill development inside and outside the development node are also incentive and disincentive type intervention. Discouraging the mass gathering activities in the high-risk zone know as risk sensitive land use. Right of way for proposed road networks is guide for to fix the setbacks and develop the road corridor for future widening. The force implication of the building by-laws, regulations, municipal land use policy and planning permit system is very challenging job for the municipality. The appreciation on the cost of land it is the key threat on the affordable housing and commercial lots. Developers are profit oriented to minimize the facilities and optimize the size of lot to cover the investment cost with significant profit. Therefore, new developments are facing challenges related to inadequate parking lots within residential areas, encroachment on road ROW, pressure on infrastructural services and environmental degradation.

- Tools to control illegal development
- review of building by-laws and development control strategy
- Equal development opportunities for the urban and rural settlements to avoid rural-urban migration seeking for the better living conditions.

6.1 DEVELOPMENT CONTROL AT VARIOUS LANDUSE ZONE

6.1.1 PLANNING ZONE

Zoning is a planning control tool for regulating the built environment and creating functional real estate markets. It does so by dividing land that comprises the statutory area of a local authority into sections, permitting particular land uses on specific sites to shape the layout of towns and cities and enable various types of development. Zoning has a relatively short history as a tool for land-use planning. It determines the location, size, and use of buildings and decides the density of city blocks (City of New York 2015a). The purpose of zoning is to allow the municipality to regulate, control the development in a preferred land and location to ensure harmonizing the city growth. It also provides the opportunity to stimulate or slow down development in specific areas.

6.1.2 SUB ZONE

Sometimes it needs to sub-zone in the particular built-up area to apply the incentive or disincentive mechanism for development control. It depends on the intensity of the risk of the hazards. For instance, if the small area of the settlement is in the high-risk zone of the flood. It is necessary to sub-zone, and restrict the development functions in those areas. It should be regulated for further extension of the floors and restriction on the mass movement activities.

6.1.3 NODES

Development nodes are proposed for the densification of the built-up area. These nodes are to control the ribbon and sprawl development along the highways. And proposed for the planned urban development to fulfill the housing needs. Encourage private investment in tradable business and social and physical infrastructures to generate employment opportunities. Provide the level of service to the urban dwellers. Nodes are the privileged place of investment and center of opportunities with risk resiliences. So, it is very critical to apply the development controlling mechanism within and outside the nodes.

6.1.4 EXISTING SETTLEMENTS

Development control in the area of the existing settlements is also important those are preserved for future or different use. Arable agricultural land with irrigation facilities is an example.

7. RSLUP IMPLEMENTATION MONITORING AND EVALUATION GUIDELINES

Land-use planning that is carefully designed and rigorously implemented is the most useful approach to managing urban population growth and minimizing associated risks (EMI, 2014). Implementation means transfer of the plan from the paper to the actual field for the good faith of the public interest. It is very easy to develop the plan applying the scientific theory and modeling. But it is very hard to implement in the actual field. All the development plans are directly related with the land resources. As per the MHRA recommendation some area lies on the high-risk and some are in the low-risk zone. It is very important to convince the people who are actually living in the high-risk areas. The spatial location is attached with sentiment of the people who are residing from the past few decades

In our context land ownership is privately owned system. It is attached with daily livelihood of the people. So, the implementation of RSLUP is very critical. It enforces the people "not to use" their property if that is in high-risk zone or have to take the mitigation measure for use if meet the standard.

Municipality should operate the Risk information web portal for the public use to disseminate the hazard prone area for the safer future use of private investment. These types of information shall be tie up with land related offices, i.e. Survey Office and Land Revenue Office. It will help the private investor for encouraging their investment in the risk-free areas. Municipality has to manage a grievance handling team to redress grievances during implementation. It is very important to convince the people, it's for the well of the people to develop the resilience community or safer settlements free from the natural disaster. Contingent Emergency Response (CER) component to rapid respond during the natural disaster events and pandemics period. The Component of reconstruction, rehabilitation, and associated studies (Emergency Response Activities) should be financed during the implementation phase. These critical facilities are mentioned in the development plans.

This is Common Responsibility of Politician to adopt the RSLUP and its proper implementation. Political parties actively involved in the development activities of the municipality with have to take the ownership.

7.1 INSTITUTIONAL CAPACITY BUILDING

Strengthening municipality's capability and capacity is important for the proper implementation of the RSLUP. Lack of municipal capacity at the technical and managerial level the performance seems poor in the past. The importance of capacity building is realized in the context of urbanization and increasing complexity within the municipality. The municipal-level functionaries do not have the necessary skills, knowledge and training to handle the RSLUP, its sectoral development plans, and development control tools for the effective implementation. Enhance the capacity of technical manpower is essential. So, it has been realized the major capacity building program and parallelly have to increase the knowledge and skills of municipal staff.

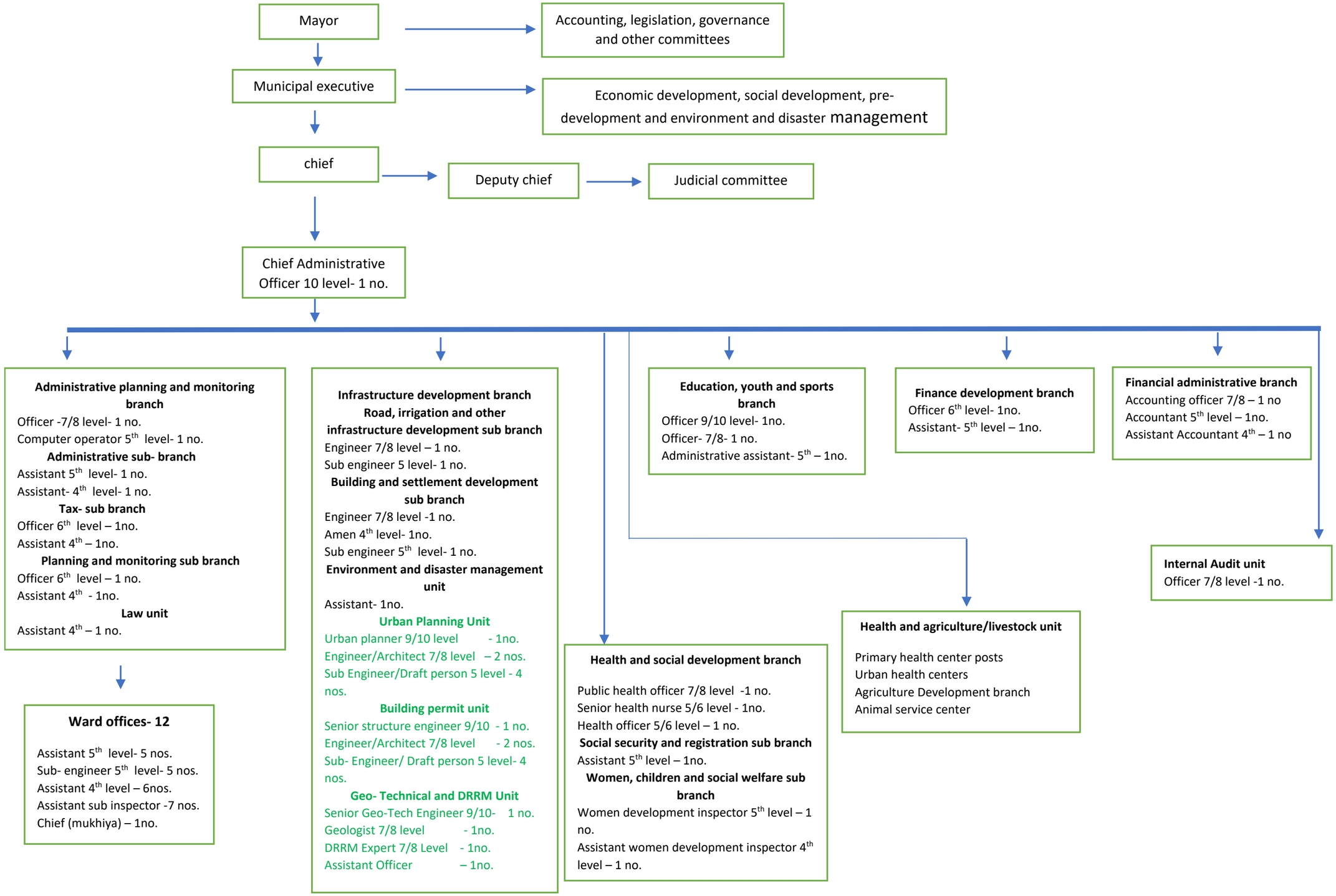

Fig. 7.1 Proposed organizational structure for RSLUP implementation.

7.2 EFFICIENT MONITORING SYSTEM

Proper monitoring system enhances the efficient implementation of risk sensitive land use plan. It will provide feedback on the plans. Regular and Periodic monitoring system can be adopted for timely address the problems. Help to improve coordination between agencies involved in various aspects of urban management and disaster response.

7.3 RSLUP IMPLEMENTATION TOOLS

Efficient and effective implementation tools for the sectoral development plan and development controlling is realized. Which can be use for planned urban development purpose as well as meet the objective of municipal land use policy and relocate the vulnerable communities to the safer and built environment. These tools support for the successful implementation of Risk Sensitive Land Use Plan. Creating awareness program to the politicians, government agencies, land owners, stakeholders. Civil society, local communities for the successful implementation.

7.3.1 LAND POOLING

Land pooling technique is the appropriate tools for the implementation Risk Sensitive Land Use Plan in designated areas for the future urban expansion. The concept of land pooling was developed to fulfill the housing demands of the city's dwellers with a level of urban infrastructures creating the pleasant urban environment. It will also provide the different plots size as per the purchasing capacity. These types of planning are carried out in the land of private land owner located at the low-risk areas. It will help to regulate the future urban development only in the confined node. Benefits of the land pooling are as follows;

- Necessary Urban infrastructures amenities with public open spaces.
- basic Urban infrastructures at the cost of land owners.
- Development of planned urban development and appreciation of land price to encourage the land owners.
- Project development cost covered by the selling of developed plots.
- Project will generate employment opportunities to the local people.
- It will discourage the haphazard growth
- It will help to develop the better urban environment
- Readjust the irregular plots in the regular plot size for optimum use of land.

7.3.2 POLICY OF INCENTIVES/DISINCENTIVES

The Incentives and Disincentives tools can be use for the effective implementation of the RSLUP. It provides the choice to the land owners for the optimum use of land with the maximum allowed ground coverage is small for all types of buildings in 'Primary Node (proposed for 2030-2050). Besides that, allowable ground coverage just outside the boundary of 'Primary Node is high. This is disincentives type tools to discourage the urban expansion outside the development nodes.

Proposed zoning should be maintained and construction and development should not be allowed other than permitted land use. Violation of rule and regulation should be stopped immediately. If not followed penalty should be imposed.

As per the assessment of Multi Hazard Risk the 23.42% of land is in the high-risk zone denoted by the Red Zone. Likewise, 49.93% in Moderate Risk with a reference of Yellow Zone and 26.65% of land is covered with Low Risk, which is know potential developable area. Regulatory measures usually cover

two types of measures: location and design. The goal of the 'location approach' to risk reduction is to limit development in hazardous areas, while the 'design approach' is to build safe constructions in safe or in hazardous areas (Burby, 1998; Greiving et al. 2012). Hence, gaining access to information about future development and risk reduction plans, the ability to participate in decision making, demand greater public accountability and offer local knowledge can be very empowering and provide strong incentives to gain ownership over planning and risk reduction (Burby, 2003; Fordham, 1999; Pearce, 2003).

Incentives to the private sector may actually create more risk than reduce it. In countries with little insurance coverage, both public and private domains bear the cost of disaster and both are responsible for creating and reducing it, while where public insurance programs have been implemented, these may exert perverse disincentive effects. Since many insurance companies may not be willing to insure homeowners living in hazard zones, governments may provide them with reinsurance backing, rather than encourage homeowners to relocate elsewhere or retrofit their houses. Secondly, public policies and relief compensation for disaster losses from national governments may encourage people to rebuild their homes in the same dangerous places, rather than move to higher ground or away from coasts (Burby, 1998). Regulations regarding land use for DRR would seem to be the most effective way to prevent development in unsafe locations (Timothy and Earl, 2008).

INCENTIVES IN RED ZONE

- Financial incentives from the federal and provincial governments to the local governments for the implementation of RSLUP and applying the mitigation measure on the disaster risk reduction projects.
- Encourage homeowners of high hazards risk area for insurance of there assets, crops, livestock and building providing subsides from municipal fund on insurance premium.
- Provide public service area to the critical facilities i.e. hospital, school etc. designated during land pooling projects to relocate the critical facilities in the planned urban development area of safer zone.
- Provide tax reduction or subsides to the recreational park and such other types of facilities for the amusement park to the land owner of this areas.
- Encourage the homeowner to retrofit the existing building structure by providing rebates in building permit fee and subsides in the construction materials to develop the resilient communities.
- Provision of soft loan, concessional loan or credit facilities to the land owners for the transfer of the development rights in the safer zone.
- Provide free advice on design, construction and retrofitting of housing in hazard prone areas.
- Provide subsidies on building construction materials and tools in compliance with building codes.

DISINCENTIVES IN RED ZONE

- Discourage the purchasing of the housing plots in this area by increasing the registration and local tax to the buyers and sellers.
- Restriction in the construction of building structures where the mass gathering activities organized.
- Discourage house owners on additional floor extension in the existing buildings as per the intensities of the risk.
- Increase the rate of property tax, business tax, building permit fee and other charge in the new building construction work in highly risk prone areas.

For the proper implementation of the risk sensitive land use plan different types of incentive mechanism should be applied which will be financial or nonfinancial. Financial incentives can be used to change the behavior of the people by offering a monetary reward. The financial incentives include:

- Grants: From the Federal and Provincial government to the local government
- Credits Facilities
- Rebates on company tax
- Subsidies
- Discounts on insurance premiums
- Access to concessional loans or soft loan
- Rebates on fees for planning permit approvals

Nonfinancial incentives provide the knowledge, technique and access to the different types of facilities which includes:

- Provide appropriate guidance and training on risk sensitive urban development
- Trained people in disaster resilient construction
- Provide access to the new technology for the disaster resilient
- Provide access to the reliable and credible information about the recent and probable risks
- Knowledge about risk prone zone for the investment on the business
- Enforcement of building regulation and building byelaws
- Effective and smart building permit system
- Well establishment of integrated emergency response centre
- Enforcements on the planning permit system
- Accessibilities of the web portal for public to widen the knowledge about high risk and moderate risk areas

INCENTIVE MECHANISM USED BY LOCAL GOVERNMENTS

- Simplified on the investment approval process in safer zone to attract the private sector investment to the trading business for employment generation.
- Incentives to the developers to encourage developments to avoid high risk zone are as follows:
  - Extra floor area
  - Provision of density bonus
  - Transfer of development rights
  - Reduction or rebate in registration fee on developed plot register
  - Reduction or rebate in registration fee in land and building register
  - To empower the women additional reduction in land and building register
  - Provide access to the training for the masons, bar bender, carpenters to construct earthquake resistant construction with the opportunities for enhancing their daily incomes
  - Exemption on the local taxes, charges and fees

Web portal to make available the information regarding high, moderate and low risk area with different types of hazards, to support the investors to make investment decision in appropriate location. It is very important to launch the awareness program by the municipality to attract the private sector investment. This incentive mechanism definitely attracts the developer, builders, business investor and industrialist, for that municipality also implement the basic essential physical infrastructures as per the requirement of the development nodes. It will also enhance the balance urban development with the pleasant urban environment.

7.3.3 MUNICIPAL LAND USE POLICY

Municipal land use policy is the important documents for the municipality as a out of RSLUP. It will control the sprawl development within the market centers. It will ensure the balanced use of land for present needs and future growth of the population. Provide space for the new development in a hazard free area. It also addresses the preservation of agricultural land with the conservation of natural resources. For the proper implementation of the land use policy it is essential to enhance the land administration system.

7.3.4 BUILDING BY-LAWS

Building by-laws is the important documents as a regulating tool to the municipality as a out of RSLUP. It will discourage the uncontrolled sub-division of plots restricting the building construction only in minimum plot area. Provision of control on building bulk (length, breadth, height of the building). It is a development controlling tools discouraging in hazard prone area.

Table 7.1 Roles and Responsibilities of Municipalities in the Implementation of RSLUP.

ROLE AND RESPONSIBILITIES OF THE MUNICIPALITY ON THE IMPLEMENTATION OF RSLUP	
ENTITY / PERSON	**ROLES AND RESPONSIBILITIES**
LEGISLATIVE	
Municipal Assembly/ Council	▪ Ownership on the Risk Sensitive Land Use Plan ▪ Approval of Municipal Land Use Policy ▪ Approval of Risk Sensitive Land Use Plan ▪ Building By-Laws ▪ Exercise on the Execution and Administrate during the Implementation
EXECUTIVE	

ROLE AND RESPONSIBILITIES OF THE MUNICIPALITY ON THE IMPLEMENTATION OF RSLUP	
ENTITY / PERSON	**ROLES AND RESPONSIBILITIES**
Mayor	▪ Responsible for proper coordination between political authorities of different parties. ▪ Play the Lead role on the implementation of RSLUP
Executive Committee	▪ Facilitate in the RSLUP implementation ▪ Arrange the necessary set up on the monitoring and evaluation of RSLUP
ADMINISTRATION	
Chief Administrative Officer	▪ Responsible for coordinating the overall Administrative and Financial arrangement ▪ Monitoring and Evaluation of sectoral development plan
Administration and Finance Unit	▪ Prepare budget for RSLUP sectoral development plan. ▪ Allocation of budget for training program. ▪ All financial arrangement related to RSLUP sectoral development plan. ▪ Allocation of budget for the purchase or transfer of development rights from high hazards area to the safer settlements. ▪ Allocation of budget for rescue, relief, rehabilitation and reconstruction after disaster. ▪ Arrangement of revolving fund for Land Pooling Projects as a seed money.
URBAN PLANNING & DEVELOPMENT CONTROL	
Urban Planning Unit	▪ Preparation of sectoral and urban infrastructure development plan for the development Nodes. ▪ Ensuring the involvement of various stakeholders on the implementation of the RSLUP ▪ Enforcement of Building By-laws and Physical Planning Regulation for development control. ▪ Enforcement of Municipal Land Use Policy for development control providing incentive mechanism. ▪ Work out on the purchase or transfer of development rights from high hazards area to the safer settlements. ▪ Encourage the private investment in the secondary and tertiary nodes for the land pooling projects providing the FAR incentives. ▪ Provide incentive on the planning permit system and attract private investment on the unban infrastructures in development nodes. ▪ Prepare municipal transportation network Master Plan providing connectivity on the development Nodes as proposed in RSLUP. ▪ Prepare incentive and disincentive policy for the neighborhood industries for transfer to the particular locations. ▪ Proper implementation of Urban Redevelopment Plan proposed by the RSLUP. ▪ Proper implementation of recommendations on Model Resilient Built-up Area plan proposed by the RSLUP. ▪ Revise and Update the plan as per the MHRA. ▪ Public hearing for public good
Building Permit Unit	▪ Mandatory on the building permit system following the Building By-Laws. ▪ Mandatory on the implementation of National Building Code. ▪ Mandatory on the retrofitting of existing building structures seeking for additional floor following the Building By-Laws. ▪ Provide the Training of Trainer's training for the engineers and conduct masons training for earthquake resistant safer building construction. ▪ Discourage the investment on the building structure in high-risk areas ▪ Develop the proper monitoring system during construction time ▪ Zoning and Land use map with final demarcation on cadastral map.
DISASTER RISK REDUCTION & MANAGEMENT	
Geotechnical and DRRM Unit	▪ Preparation of the priority projects in the risk-free zone ▪ Ensure the municipal investment on hazards free or low risk zone ▪ Mandatory submission of the geo-technical investigation for the large and mass gathering structures ▪ Proper implementation of sectoral development plan proposed by the RSLUP ▪ Ensure the major municipal investment on development nodes ▪ Display the Map of open space and evacuation route near high risk zone and prime public space of the mass movement. ▪ Preparation of volunteer team for rescue and relief operation. ▪ Arrangement of Integrated Emergency Rescue Center (IERC) for disaster time rescue & relief operation. ▪ Provide adequate open space and public space within new development areas for disaster rescue and relief activities. ▪ Dissemination of RSLUP recommended outputs for public awareness. ▪ Dissemination of RSLUP related Handbook/ Map book as a knowledge transfer. ▪ Prepare ICT based documents.

For the proper implementation of RSLUP, MLUP, PPR&BB and DRRM plan documents, the responsibilities of each line agencies, stakeholders have been allocated with the Time Bond Action Plan. The sector wise Action Plan has been proposed for the proper implementation of Risk Sensitive Land Use Plan with the supporting Plan, Policy, Norms and Regulations i.e. Municipal Land Use policy, Physical Planning Regulations and Building Bylaws and Disaster Risk Reduction Management Plan.

Table 7.2 Time bound RSLUP implementation action plan.

TIME BOUND RSLUP IMPLEMENTATION ACTION PLAN							
S.N.	MAIN ACTIVITIES	TIME PERIOD	RESPONSIBILITIES		BUDGET NPR	SOURCE OF FUNDING	REMARKS
			PRIMARY	SECONDARY			
I	**Implementation of Risk Sensitive Land Use Plan**						
1.1	Enhanced Capacity of Municipalities for the proper implementation of RSLUP	12 months	Local Government	Province Government	3 million	LG/ PG/ FG	
1.2	Conduct Awareness Workshop on RSLUP	12 months	Local Government	Province Government	3 million	LG/ PG/ FG/ DA/ NGOs	ward wise
1.3	Approval of RSLUP Documents	1 months	Local Government Municipal Council	Local Government	0.5 million	LG	
1.4	Develop Financial Strategy	2 months	Local Government	-	0.5 million	LG	
1.5	Deputation of Technical human resources in the municipalities	60 months	Province Government	Donor Agency	10 million	LG/ PG/ FG/ DA	
1.6	Trained the municipal staff for implementation of RSLUP	6 months	Province Government	Donor Agency	5 million	LG/ PG/ FG/ DA	
1.7	Prepare ICT based documents	6 months	Local Government	Province Government	5 million	LG/ PG/	

TIME BOUND RSLUP IMPLEMENTATION ACTION PLAN							
S.N.	MAIN ACTIVITIES	TIME PERIOD	RESPONSIBILITIES		BUDGET NPR	SOURCE OF FUNDING	REMARKS
			PRIMARY	SECONDARY			
				/ Donor Agency		FG/ DA	
1.8	Transformation of Multi Hazard Risk boundary in the cadastral map	12 months	Local Government Province Government	Survey Office Province Government / Donor Agency	50 million	LG/ PG/ FG/ DA	ward wise
2	**Sectoral Development Plan within the development Nodes of municipality.**						
2.1	Enhanced capacity of municipalities to develop investment plan for new development and improvement of existing urban infrastructure and services	12 months	Local Government	Private Sector/ Consulting firm/ Donor Agency	2 million	LG/ PG/ FG/ DA	
2.2	Project Preparation	6 months	Local Government	Private Sector/ Consulting firm/ Donor Agency	2 million	LG/ PG/ FG/ DA	
2.3	Enhanced the capacity of municipal staff for prioritization of potential projects mentioned in RSLUP report	6 months	Local Government	Private Sector/ Consulting firm/ Donor Agency	3 million	LG/ PG/ FG/ DA	
2.4	Prepare pre-feasibility reports	6 months	Local Government	Private Sector/ Consulting firm/ Donor Agency	5 million	LG/ PG/ FG/ DA	
2.5	Prepare detailed project reports focusing on the planned urban development	12 months	Local Government	Private Sector/ Consulting	20 million	LG/ PG/ FG/ DA	

TIME BOUND RSLUP IMPLEMENTATION ACTION PLAN							
S.N.	MAIN ACTIVITIES	TIME PERIOD	RESPONSIBILITIES		BUDGET NPR	SOURCE OF FUNDING	REMARKS
			PRIMARY	SECONDARY			
				firm/ Donor Agency			
2.6	Prepare bankable projects to develop investment plan	12 months	Local Government	Private Sector/ Consulting firm/ Donor Agency	3 million	LG/ PG/ FG/ DA	
2.7	Development of Nodes with respects to their individual potentiality and MHRA scenario i.e. Primary, Secondary and Tertiary	36 months	Local Government	Private Sector/ Consulting firm/ Donor Agency	3 million	LG/ PG/ FG/ DA	
2.8	Preparation of Local Area Development Plan	6 months	Local Government	Private Sector/ Consulting firm/ Donor Agency	50 million	LG/ PG/ FG/ DA	
2.9	Initiate Land Development I.e. Land Pooling Projects and Guided land Development Plan though citizens participation within the Land suitability areas of development Nodes of municipalities.	12 months	Local Government	Private Sector/ Consulting firm/ Land Revenue/ Survey Office	50 million	LG/ PG/ FG/ DA	
2.10	Preparation of Urban Infrastructural Development Plan	12 months	Local Government	Private Sector/ Consulting firm	20 million	LG/ PG/ FG/ DA	
2.11	Preparation of Municipal Transportation Master Plan	12 months	Local Government	Province Government Consulting firm/ Donor Agency/	20 million	LG/ PG/ FG/ DA	
2.12	Conduct awareness program for public participation	12 months	Local Government	Private Sector/	3 million	LG/ PG/	

TIME BOUND RSLUP IMPLEMENTATION ACTION PLAN							
S.N.	MAIN ACTIVITIES	TIME PERIOD	RESPONSIBILITIES		BUDGET NPR	SOURCE OF FUNDING	REMARKS
			PRIMARY	SECONDARY			
				Donor Agency		FG/ DA	
2.13	Trained municipal staff for public participation in planning and budgeting process	4 months	Local Government	NGOs Consulting firm/ Donor Agency	5 million	LG/ PG/ FG/ DA	
2.14	Encourage Private Sector investment in Land Pooling Projects.	12 months	Local Government	Private Sector/ Consulting firm/ Donor Agency/ Survey Office	3 million	LG/ PG/ FG/ DA/ PS	
2.15	Ensure the developed plots for the critical facilities and social infrastructure for the purchase or transfer of development rights from high hazards area to the safer settlements.	36 months	Local Government	Private Sector/ Consulting firm/ Donor Agency/ Survey Office	3 million	LG/ PG/ FG/ DA/ PS	
2.15	Support municipalities to planning permit process	12 months	Local Government	Province Government /Donor Agency	5 million	LG/ PG/ FG/ DA	
2.16	Conducted the Public Hearing program	4 months	Local Government	NGOs/ Tole Committee/ Consulting firm/ Donor Agency	3 million	LG/ PG/ DA	
2.17	Provide assurance for Grievance Handling	6 months	Local Government	NGOs/ Private Sector/ Donor Agency	3 million	LG/ PG	

TIME BOUND RSLUP IMPLEMENTATION ACTION PLAN							
S.N.	MAIN ACTIVITIES	TIME PERIOD	RESPONSIBILITIES		BUDGET NPR	SOURCE OF FUNDING	REMARKS
			PRIMARY	SECONDARY			
2.18	Focus on to identified risk sensitive area for Urban Redevelopment for Municipal Investment including PPP projects	6 months	Local Government	Province Government / Private Sector/ Donor Agency	3 million	LG/ PG/ DA	
3	**Model Resilient Built up Area**						
3.1	Identified the risk sensitive area for urban redevelopment	12 months	Local Government	Province Government /Donor Agency	5 million	LG/ PG/ DA	
3.2	Preparation of GLD Plan and Conduct awareness program on people's participation with public hearing for urban redevelopment	12 months	Local Government	Province Government / Donor Agency/ Tole Committee	20 million	LG/ PG/ DA	
3.3	Intervention of the river training works in the flood prone areas	12 months	Local Government	Province Government / Donor Agency	50 million	LG/ PG/ FG/ DA	
3.4	Application of the Eco-system-based adaptation	12 months	Local Government	Province Government / Donor Agency	50 million	LG/ PG/ FG/ DA	
3.5	Conduct seminar/workshop on interest of private investment	12 months	Local Government	Province Government / Donor Agency	5 million	LG/ PG/ FG/ DA	
4	**Municipal Land Use Policy**						
4.1	Approval of MLUP	3 months	Local Government	Province Government	3 million	LG/ PG	

TIME BOUND RSLUP IMPLEMENTATION ACTION PLAN							
S.N.	MAIN ACTIVITIES	TIME PERIOD	RESPONSIBILITIES		BUDGET NPR	SOURCE OF FUNDING	REMARKS
			PRIMARY	SECONDARY			
4.2	Implementation of MLUP	12 months	Local Government	Province Government / Donor Agency/ Private Sector	5 million	LG/ PG/ FG/ DA	
4.3	Develop Proper Monitoring and evaluation system for effective implementation	12 months	Local Government	Province Government /Donor Agency	10 million	LG/ PG/ FG/ DA	
5	**Physical Planning Regulations & Building Byelaws**						
5.1	Approval of PPR & BB	3 months	Local Government	Province Government	3 million	LG/ PG	
5.2	Implementation of PPR & BB	12 months	Local Government	Province Government / Donor Agency/ Private Sector	3 million	LG/ PG/ FG/ DA	
5.3	Transformation of nodal boundary in the cadastral map	12 months	Local Government	Province Government / Donor Agency/ Survey Office/ Consulting Firm	20 million	LG/ PG/ FG/ DA	
5.4	Develop Proper Monitoring and evaluation system for effective implementation	12 months	Local Government	Province Government / Donor Agency	10 million	LG/ PG/ FG/ DA	
6	**DRR Priority area & DRRM Planning**						

TIME BOUND RSLUP IMPLEMENTATION ACTION PLAN							
S.N.	MAIN ACTIVITIES	TIME PERIOD	RESPONSIBILITIES		BUDGET NPR	SOURCE OF FUNDING	REMARKS
			PRIMARY	SECONDARY			
6.1	Identified the priority area for Disaster Risk Reduction and Management	6 months	Local Government	Province Government / Donor Agency/ Consulting Firm	20 million	LG/ PG/ FG/ DA	
6.2	Prepare disaster risk reduction, climate resilient and sustainable urban infrastructures development plans	12 months	Local Government	Province Government / Donor Agency/ Consulting Firm	20 million	LG/ PG/ FG/ DA	
6.3	Intervention of the river training works in the flood prone areas.	12 months	Local Government	Province Government / Donor Agency/ NGOs/ Tole Committee/ Consulting Firm	50 million	LG/ PG/ FG/ DA	
6.4	Application of the Eco-system-based adaptation	12 months	Local Government	Province Government / Donor Agency/ NGOs/ Tole Committee/ Consulting Firm	20 million	LG/ PG/ FG/ DA	
7	**Environmental Planning and Management**	12 months	Local Government	Province Government / Donor Agency/ NGOs/ Tole Committee/ Consulting Firm	40 million	LG/ PG/ FG/ DA	

TIME BOUND RSLUP IMPLEMENTATION ACTION PLAN							
S.N.	MAIN ACTIVITIES	TIME PERIOD	RESPONSIBILITIES		BUDGET NPR	SOURCE OF FUNDING	REMARKS
			PRIMARY	SECONDARY			
8	**Development Control Mechanism in Development Nodes**	12 months	Local Government	Province Government /	10 million	LG/ PG/ FG/ DA	
9	**Conduct training, workshop, seminar program**	12 months	Local Government	Province Government / Donor Agency/ NGOs/ Tole Committee/ Consulting Firm	10 million	LG/ PG/ FG/ DA	
10	**Conduct exposure visit for proper implementation and awareness development**	3 months	Local Government	Province Government / Donor Agency/ NGOs/ Tole Committee	20 million	LG/ PG/ FG/ DA	
11	**Publication and information dissemination of best practices and lesson learned**	12 months	Local Government	Province Government / Donor Agency/ NGOs	5 million	LG/ PG/ FG/ DA	
12	**Develop the Third-party monitoring system for feedback of proposed plans**	12 months	Province Government	Donor Agency/ Tole Committee Consulting Firm	20 million	LG/ PG/ FG/ DA	

7.4 CHALLENGES IN IMPLEMENTATION OF RISK SENSITIVE LAND USE PLAN

Risk Sensitive Land use plan preparation and implementation is one of the most challenging tasks because of diverse range of land price in the different location of the municipality. Where the land is scarce, it becomes more difficult to implement the plan because it creates the question on, who is in risk and who is going to be benefitted. It is scientific method of preparation of RSLUP and lack of people participation in every stage of planning, so it became differ from other participatory planning approach. However, natural disaster risk cannot be control - there may be some amount of risk.

8. REFERENCES

Adger, W.N., & P.M. Kelly, 1999: Social vulnerability to climate change and the architecture of entitlements. Mitigation and Adaptation Strategies for Global Change, 4, 253-266.

Adhikari, J.N., Bhattarai, B.P. & Thapa, T.B. (2018). Diversity and Conservation status of birds in Barandabhar Corridor Forest, Chitwan, Nepa. Journal of Biodiversity and Conservation, 1(2): 60-75.

ADPC, NGI & CECI. (2010). Nepal Hazard Risk Assessment. Retrieved from https://www.adpc.net/igo/category/ID276/doc/2013-b27lym-ADPC-NHRA_Report.pdf.

Agni Boring & Soil Test Pvt. Ltd. (2020). Final Report on Geotechnical Soil Investigation of Navjiban Sahakari Sanstha Ltd. Kendriya Karyalaya Dhangadi Building, Kailali. (Unpublished)

Aryal, KR. (2012). The History of Disaster Incidents and Impacts in Nepal 1900–2005 Int. J. Disaster Risk Sci. 2012, 3(3): 147-154 doi:10.1007/s13753-012-0015-1.

Asian Development Bank. 2018. Enabling Smart Urban Redevelopment in India through Floor Area Ratio Incentives.

Bhujel, K.B., Byanju, R. M., Gautam, A.P., Sapkota, R.P. & Khadka, U.R. (2020). Fire. induced carbon emissions from tropical mixed broad-leaved forests of the Terai-Siwalik region, central Nepal. DOI: 10.1007/s11676-020-01256-x.

Building By-Laws of Lamkichuha and Godawari Municipality.

Cardona, O.D., Bernal, G.A., Ordaz M.G., Salgado, M.A., Singh, S.K., Mora, M.G>, Yamin, L.E., & Barbat, A.H. (2013). GLOBAL ASSESSMENT REPORT ON DISASTER RISK REDUCTION – GAR 2013. International Center for Numerical Methods in Engineering Centro Internacional de Métodos Numéricos en Ingeniería & ITEC S.A.S. – INGENIAR LTDA. – EAI S.A. Retrieved from http://www.agr.una.py/descargas/biblioteca_digital_gestion_riesgos/G/GAR%202013/CIMNE%20et.al.%202013a.pdf.

Castellanos E., and Van Westen C.J. (2008). Qualitative landslide susceptibility assessment by multicriteria analysis; a case study from San Antonio del Sur, Guant'anamo, Cuba. Geomorphology, 94 (3--4), pp. 453-466.

CBS (2011). Census survey of Nepal, Central Bureau of Statistics, Ramshah Path, Kathmandu, Nepal.

CBS (2014). Population monographs of Nepal, Vol II (Social Demography), Central Bureau of Statistics, Ramshah Path, Kathmandu, Nepal.

Chalise, D., Kumar, L. and Kristiansen, P. (2019). Land degradation by soil erosion in Nepal: A Review. Soil Systems, 3, 12; doi:10.3390/soilsystems3010012.

Ciurean, R. L., Hussin, H., Van Westen, C. J., Jaboyedoff, M., Nicolet, P., Chen, L., ... & Glade, T. (2017). Multi-scale debris flow vulnerability assessment and direct loss estimation of buildings in the Eastern Italian Alps. Natural hazards, 85(2), 929-957.

Disaster Risk Reduction National Strategic Plan of Action, 2018 – 2030, The Government of Nepal Ministry of Home Affairs, 2018.

Dixit, A.M., Shrestha, S.N., Guragain, R., Shrestha, H., Prajapati, R., Oli, K.S., Adhikari, S.R., Marasini, N. (2017). What WORKS is Earthquake Preparedness and Risk Reduction and NOT Earthquake Prediction: Lessons Learned from Nepal's Gorkha Earthquake of 2015 [Conference paper]. Kyrgyzstan Conference. Kyrgyzstan Science and Technology.

EC (2011). Risk assessment and mapping guidelines for disaster management. European Commission Commission staff working paper, European Union.

FAO (2003). Policy Options for Socioeconomic Vulnerability Analysis: conflict analysis and long-term development programs and strategies, FAO International Workshop on "Food Security in Complex Emergencies: building policy frameworks to address longer-term programming challenges" Tivoli, 23-25 September 2003.

Frasson, R. P. de M., Wei, R., Durand, M., Minear, J. T., Domeneghetti, A., Schumann, G., Williams, B. A., Rodriguez, E., Picamilh, C., Lion, C., Pavelsky, T., & Garambois, P. A. (2017). Automated River Reach Definition Strategies: Applications for the Surface Water and Ocean Topography Mission. Water Resources Research, 53(10), 8164–8186. https://doi.org/10.1002/2017WR020887

Fuchs, S., Keiler, M., Ortlepp, R., Schinke, R., & Papathoma-Köhle, M. (2019). Recent advances in vulnerability assessment for the built environment exposed to torrential hazards: Challenges and the way forward. Journal of hydrology, 575, 587-595.

Giglio, L., van der Werf, G. R., Randerson, J.T., Collatz, G.J. & Kasibhatla, P. (2006). Global estimation of burned area using MODIS active fire observations. Atmos Chem Phys. 6 (4):957-974.

Green, W. H., & Ampt, G. A. (1911). Studies on soil phyics. The Journal of Agricultural Science, 4(1), 1–24. https://doi.org/10.1017/S0021859600001441

Guragain, R., Dixit, A. M., & Meguro, K. (2012). Development of fragility functions for low strength masonry buildings in Nepal using applied element methods. In *15th world conference of earthquake engineering, Lisbon, Portugal*.

Guragain, R., Shrestha, S. N., Pradhan, S., & Meguro, K. (2020). Numerically Developed and Field Observed Seismic Fragility Functions for Nepalese Buildings. In *17th world conference on earthquake engineering, Sendai, Japan*.

Hada C.L., Shaw R., Pokhrel A. (2021) Preparation and Adoption of Risk Sensitive Land Use Plans in the New Federal Context of Nepal. In: Djalante R., Bisri M.B.F., Shaw R. (eds) Integrated Research on Disaster Risks. Disaster Risk Reduction (Methods, Approaches and Practices). Springer, Cham. https://doi.org/10.1007/978-3-030-55563-4_10.

Handbook for Gender -inclusive Urban Planning Design, 2020. Washington, DC: World Bank. c World Bank."

Handbook or Risk Sensitive Land Use Planning for Upazilas and Municipalities in Bangladesh, Urban Development Directorate (UDD), 82, Segunbagicha, Dhaka 1000, Bangladesh.

Hengl, T., Mendes de Jesus, J., M Heuvelink, G. B., Ruiperez Gonzalez, M., Kilibarda, M., Blagotić, A., Shangguan, W., Wright, M. N., Geng, X., Bauer-Marschallinger, B., Antonio Guevara, M., Vargas, R., MacMillan, R. A., Batjes, N. H., B Leenaars, J. G., Ribeiro, E., Wheeler, I., Mantel, S., Kempen, B.,

Gonzalez, R. M. (2017). SoilGrids250m: Global gridded soil information based on machine learning. https://doi.org/10.1371/journal.pone.0169748.

Holzmann, P., Boudreau, T., Holt, J., Lawrence, M., & O'Donnell, M. (2008). The Household Economy Approach: A guide for program planners and policy-makers: Save the Children UK.

Huang, CY; Namangaya, A.; Lugakingira M. W.; Cantada, I. D. 2018. Translating Plans to Development: Impact and Effectiveness of Urban Planning in Tanzania Secondary Cities. Washington, DC: World Bank. c World Bank."

Huizinga, J., Moel, H. de, Szewczyk, W. (2017). Global flood depth-damage functions. Methodology and the database with guidelines. EUR 28552 EN. doi: 10.2760/16510

Incentives for reducing disaster risk in urban areas: experiences from Da Nang (Viet Nam), Kathmandu

International Organization for Migration (IOM), 2020. *Updated Report on 83* Open Spaces Identified for Humanitarian Purposes in Kathmandu Valley. International Organization for Migration, Kathmandu, Nepal.

International Organization for Migration, Kathmandu, Nepal.

IOM (2020). Strengthening disaster Risk reduction and Management at the local level: A report on capacity and needs assessment of six rural and urban municipalities of Nepal. International Organization for Migration, Kathmandu, Nepal.

IOM (2020). Updated Report on 83 Open Spaces Identified for Humanitarian Purposes in Kathmandu Valley. International Organization for Migration, Kathmandu, Nepal.

IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press

Jennigs, P.C. (1980). Earthquake Engineering and Hazards Reduction in China. CSCPC Report No. 8, National Academy of Sciences, Washington, D.C.

Kappes, M. S., Keiler, M., von Elverfeldt, K., & Glade, T. (2012). Challenges of analyzing multi-hazard risk: a review. Natural hazards, 64(2), 1925-1958.

Khadka, TB, 2003. Improvement of Kathmandu Rind Road, Thesis report of MSc in Urban Planning, IOE, TU, Nepal.

Li, H., R.P. Berrens, A.K. Bohara, H.C. Jenkins-Smith, C.L. Silva & D.L. Weimer (2004). Would developing country commitments affect US households' support for a modified Kyoto Protocol? Ecological Economics, 48: 329-343.

Liu, B., Siu, Y.L., & Mitchell, G. (2016). Hazard interaction analysis for multi-hazard risk assessment: a systematic classification based on hazard-forming environment. Nat. Hazards Earth Syst. Sci., 16, 629–642.doi:10.5194/nhess-16-629-2016.

Maharjan S., and Shrestha, S. (2017). Disaster risk management: from preparedness to response in Thecho of Kathmandu Valley. The Third Pole. Vol. 17: 99-108. DOI: http://dx.doi.org/10.3126/ttp.v17i0.19986.

Marzocchi, W., Mastellone, M., & Di Ruocco A (2009). Principles of multi-risk assessment: interactions amongst natural and man-induced risks. European Commission. URL: http://cordis.europa.eu/documents/documentlibrary/106097581EN6.pdf.

Massion, Kristie. "What Is an Urban Settlement?" bizfluent.com, https://bizfluent.com/info-7890851-urban-settlement.html. 18 December 2021.)

Matin, M., Chitale, V., Murthy, S.R., Uddin, M., Bajracharya, K., Pradhan, Sudip, B. (2017). Understanding forest fire patterns and risk in Nepal using remote sensing, geographic information system and historical fire data. Int J Wildland Fire. **26** (4):276.

MoEST, 2008. State of the Environment (Agriculture, Forest and Biodiversity), Ministry of Science, Technology and Environment, Singh Durbar, Kathmandu.

MoFE. (2021). Vulnerability and Risk Assessment and Identifying Adaptation Options: Summary for Policy Makers. Ministry of Forests and Environment, Government of Nepal. Kathmandu, Nepal.

MOHA (2018). National Policy for Disaster Risk Reduction:2018. Ministry of Home Affairs, Kathmandu, Nepal.

MoHA (2019) Nepal Disaster Report 2019. Available at http://drrportal.gov.np/uploads/document/1594.pdf.

MoPE (2017). Vulerability and Risk Assessment Framework and Indicators for National Adaotation Plan (NAP) Formulation Process in Nepal. Ministry of Population and Environment, Government of Nepal.

Moret, W. (2017). ASPIRES Vulnerability Assessment Handbook for Economic Strengthening Projects. Washington, DC: FHI 360.

Moving from risk to resilience: sustainable urban development in the Pacific. Mandaluyong City, Philippines: Asian Development Bank, 2013.

MOWCSC (2014). Initial report Government of Nepal on measures taken to give effect to the Convention on the Rights of Persons with Disability. Kathmandu, Nepal.

Municipal Profile of Godawary Municipality, 2076 BS.

National Urban Development Strategy (NUDS), 2017. Ministry of Urban Development, Nepal.

Nicholls, R.J., Hansen, S.E., Lowe, J., Vaughan, D.A., Lenton, T., Ganopolski, A., Tol, O'Brien, K., L. Sygna, R. Leinchenko, W.N. Adger, J. Barnett, T. Mitchell, L. Schipper, T. Tanner, C. Vogel, & C. Montreux, (2008. Disaster Risk Reduction, Climate Change Adaptation, and Human Security. GECHS Report 2008:3, Global Environmental Change and Human Security, Oslo, Norway.

Nordhaus, W.D. & Boyer, J., (2000) Warming the world: economic models of global warming, MIT Press, Cambridge MA.

NPC (2015). Nepal Earthquake 2015: Post Disaster Needs Assessment. National Planning Commission, Government of Nepal, Kathmandu, Nepal.

Numbeo (2021). Cost of living in Nepal. https://www.numbeo.com/cost-of-living/country_result.jsp?country=Nepal.

Panjamani, A., Bajaj, K., Moustafa, S. S. R., & Al-Arifi, N, S. N. (2016). Relationship between Intensity and Recorded Ground-Motion and Spectral Parameters for the Himalayan Region. Bulletin of the Seismological Society of America, Vol. 106, No. 4, pp. 1672-1686, doi: 10.1785/0120150342

Papathoma-Köhle, M. (2016). Vulnerability curves vs. vulnerability indicators: application of an indicator-based methodology for debris-flow hazards. Natural Hazards and Earth System Sciences, 16(8), 1771-1790.

Prasad, L. N. (2003). Status of people with disabilities in Nepal. Kathmandu: Modern Printing Press.

R.S.A. & Vafeidis, A.T., (2006), Metrics for assessing the economic benefits of climate change policies: sea-level rise, Organization for Economic Co-operation and Development.

Reducing disaster risk by managing urban land use: Guidance notes for planners. Mandaluyong City, Philippines: Asian Development Bank, 2016.
Saxton, K. E., & Rawls, W. J. (2006). Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions; Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. https://doi.org/10.2136/sssaj2005.0117

Saxton, K. E., Rawls, W. J., Romberger, J. S., & Papendick, R. I. (1986). Estimating Generalised Soil-water Characteristics from Texture. Soil Science Society of America Journal, 50(4), 1031–1036. https://doi.org/10.2136/sssaj1986.03615995005000040039x.

Schmidt, J., Matcham, I., Reese, S., King, A., Bell, R., Henderson, R., Smart, G., Cousins, J., Smith, W., & Heron, D. (2011). Quantitative multi-risk analysis for natural hazards: a framework for multirisk modelling, Nat. Hazards, 58, 1169–1192.

Shrestha, K. K., Rajbhandary, S., Tiwari, N.N. Poudel, R.C. and Uprety, Y. (2003). Non-timber forest products in the critical bottlenecks and corridors of Terai Arc Landscape, Nepal: documentation, utilization, trade and people's livelihood. Report. WWF Nepal, Kathmandu, Nepal.

Stevens, V. L., Shrestha, S. N., & Maharjan, D. K. (2018). Probabilistic seismic hazard assessment of Nepal. Bulletin of the Seismological Society of America, *108*(6), 3488-3510.

The Sphere Project (2004) Humanitarian Charter and Minimum Standards in Disaster Response. The Sphere Project: Geneva, Switzerland.

Tuladhar, G. (2012). Disaster management system in Nepal: Policy issues and solutions. Journal of Risk Analysis and Crisis Response, 2(3), 166-172.

UNFCC (2006). Integrating socio-economic information in assessments of impact, vulnerability, and adaptation to climate Background paper change, Retrieved from https://unfccc.int/files/adaptation/sbsta_agenda_item_adaptation/application/pdf/background_paper_tt_web.pdf.

UN-Habitat. (2015). Cities and Climate Change Initiatives, A bridge report Kathmandu Valley, Nepal - Climate Change Vulnerability Assessment. United Nations Human Settlements Programme- UN-Habitat.

UNISDR (2009). 2009 UNISDR Terminology on Disaster Risk Reduction. United Nations International Strategy for Disaster Risk Reduction, Geneva, Switzerland. https://www.preventionweb.net/files/7817_UNISDRTerminologyEnglish.pdfUSAID (2018). Land links, Retrieved from https://www.land-links.org/country-profile/nepal-2/.

Valley (Nepal), and Naga City (Philippines). Mandaluyong City, Philippines: Asian Development Bank, 2016.
van den Bout, B., Jetten, V., De Roo, A., van Westen, C. J. & Ritsema, C. (2018). *OpenLISEM Multi-*Hazard Land Surface Process Model. https://blog.utwente.nl/lisem/.

von Ruette, J., Lehmann, P., & Or, D. (2013). Rainfall-triggered shallow landslides at catchment scale: Threshold mechanics-based modeling for abruptness and localisation. Water Resources Research, 49(10), 6266–6285. https://doi.org/10.1002/wrcr.20418.

WHO & WEDC (2013). Technical notes on drinking-water, sanitation and hygiene in emergencies. Water, Sanitation, Hygiene and Health Unit. Geneva, Switzerland.

Wood, N. & Ratliff, J. (2011). Population and Business Exposure to Twenty Scenario Earthquakes in the State of Washington. Retrieved from http://pubs.usgs.gov/of/2011/1016/.

World Bank (2000), World Development Report 2000/2001: Attacking Poverty (Chapters 8 and 9).

WWF Nepal. (2017). Biodiversity, people and climate change: Final Technical Report of the Hariyo Ban Program, First Phase. WWF Nepal, Hariyo Ban Program, Kathmandu, Nepal.