Multi-hazard Risk Assessment for Developing Risk Sensitive Land Use Plan using Geospatial Tools: A Pilot Project from Godawari Municipality, Sudur Paschim Province, Nepal

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Key words: Multi-hazard risk assessment (MHRA), risk sensitive land use plan (RSLUP), Nepal

ABSTRACT

The multi-hazard risk assessment (MHRA) is relatively a new tool which is based on the scientific modeling after analyzing the database obtained from the field and literatures. The research work is intended to apply the outcomes of MHRA in developing risk sensitive land use plan (RSLUP) as a pilot project of Godawari Municipality in Kailali District of Sudur Paschim Province. Since, MHRA is a major component of the RSLUP, commissioned under DRRM Act 2017, the study has been delineated through analyses of primary and secondary data by incorporating field hazard mapping, collection of information from building footprints, household surveys, institutional surveys, field and laboratory soil tests and historical hazard events. The KOBO mobile app was used to amass the required information from the field and inserted for both qualitative and quantitative determination and geospatial tools are implemented for the required results. For the scientific modeling, OpenLISEM (for flood hazard), existing literature data (for earthquake hazard, a tectonic hazard), statistical and heuristic method (for landslide susceptibility maps), global satellite datasets (for wind hazard), Spatial Multi-Criteria Evaluation (for animal attack and fire susceptibility maps) in GIS, globally accepted climate indices (for climate extremes) were applied to obtain individual hazards. On the other hand, elements-at-risk data were collected for building footprints, population, agricultural areas, and roads together with the exposure assessment for all relevant combinations of hazard types and elements-at-risk types to produce a combine hazard map. Hence, obtained MHRA map is utilized for the implementation of the proposed 'development nodes' concept for the two years: up to 2030 and between 2031 and 2050 AD. The concept of Primary, Secondary and Tertiary Development Nodes are recommended for eleven urban uses in the Godawari Municipality. Incorporating the safer and resilient structure under DRRM, one Central Business District (CBD) at Attariya Bazar area under a primary node, five secondary and five tertiary nodes are recommended for the well-defined urban planning in the entire municipality for the next thirty-year development plan.

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1. INTRODUCTION

The physiographic division and fragile rugged mountain terrain makes Nepal vulnerable to a wide range of geo-hazards such as earthquakes including climate related hazards (floods, landslides, storms, droughts, avalanches and Glacial Lake Outburst Floods (GLOF) and so on) that fed more than 80% of the total population of Nepal together with the presence of highly active seismic belt. The country itself stands among the 20^{th} most disaster-prone countries in the world, both natural and anthropogenic. It situates at 4^{th}, 11^{th} and 30^{th} in terms of climate change (CC), earthquake (a tectonic hazard) and flood risk respectively (Maplecroft 2011; UNDP/BCPR 2004). Further, it belongs to the 7^{th} most vulnerable nation in the world in terms of death tolls through floods, landslides and avalanches combined; 8^{th} for flood alone, and 23^{rd} in terms of total natural hazard (MOHA, 2009) respectively. Terai area is prone to flooding and fire whereas hill and mountain are subjected to landslides and GLOFs. On the other hand, valleys are highly susceptible to liquefaction due to the accumulations of alluvial and fluvio-lacustrine deposits. On the contrary, the middle and higher mountains are frequently affected through earthquake-induced landslides.

With reference to the hazardous scenarios in the country, a pilot project has been recently accomplished in Nepal with developing risk sensitive land use plan (RSLUP) by assessing the detailed multi hazard risk assessment and multi vulnerability assessment for the planned future urban planning and urban development in Godawari Municipality, one of the emerging urban centers of the Kailali district, the capital city of the Kailali District of Sudur Paschim Province **(Fig. 1).** The geographical location lies within latitudes of 28º 81’ North to 28º 92’ North and longitudes of 80º 55’ East to 80º 8’ East. The northern part of this municipality is covered by Siwalik hills whereas the southern part is basically plain area fed through alluvial-colluvial sediments of Siwalik and Lesser Himalayan metamorphic rocks. The municipality is surrounded by Gauri Ganga Municipality and Chure Rural Municipality on the east, Kanchanpur District on the west, Chure Rural municipality on the north and Dhangadhi Sub-Metropolitan City on the south. As the recently emerged municipality, the multi-hazard risk assessment (MHRA) has become a major component of the

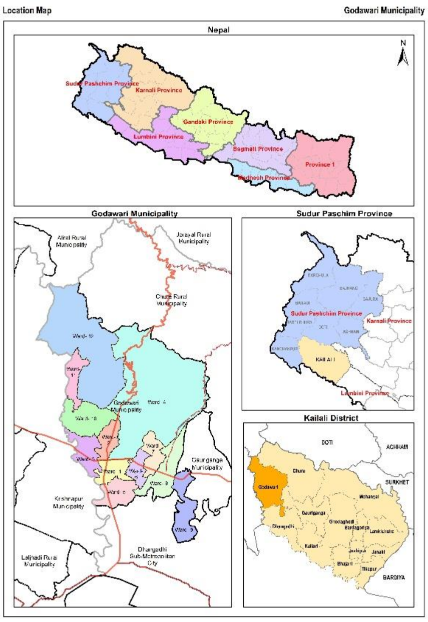


Fig. 1. Location of Lamkichuha Municipality of Sudur Paschim Province.

RSLUP, commissioned under the USAID/Nepal's TAYAR Nepal- Improved Disaster Risk Management Project. In this context, the main objective of this study is focused to delineate multi-hazard risk assessment at the municipal level and identify types of multi hazards of the area and implement with the proposed "development nodes" adopting Disaster Risk Reduction and Management (DRRM) for major hazards to reduce and manage risks using land use and urban planning techniques in developing RSLUP.

1.1 Reviews in terms of Disaster & Geo-hazards

With reference to MOHA (2018b), 28,597 disaster events occurred in Nepal 595.77 events per year (1.63 events per day) in the past 48 years between 1971 and 2018, causing on average more than 2 deaths, 5 injuries and 341 people affected along with damages of 76 houses per day. The first three devasting disasters were identified as epidemic (16,598 death), earthquake (9,771 death) and landslide (5,141 death) with reference to human death; flooding (3,726,261 family), earthquake (890,995 family) and landslides (559,347 family) with reference to affected family number; and earthquake (982,855 houses), flood (230,900 houses) and fire (90,044 houses) in terms of number of damaged houses. Drought is the singular most devastating disaster causing loss of farm land, followed by flood and hailstorm as second and third type of disasters. The event of natural disaster is higher in comparison to the anthropogenic disaster in the nation.

Out of 26,665 disaster events reported in the past 46 years (1971-2016) in Nepal, Sudur Pachhim province shares 9% (2,312 events) (Nepal desinventar database, 2016). Out of total death of 43,868 in the same period, this province alone had accounted 11% (4,789 death) with the highest rate of injured persons (13%) after Bagmati Province and Province No. 1. Data analysis between 1971 to 2013 reveals that the Far western region of Nepal had three major disasters in terms of death: 72% of the total death related to epidemic, 9% linked to landslide and 5% associated with flood (UNISDR, no date). Earthquake, flood and landslide, major causes of destruction and damaging houses, represent 56%, 27% and 6% respectively (ibid). Though, 38% of total affected population belongs to famine, flood and landslide related affected persons accounts 34% and 8% respectively (ibid). If preventive and corrective actions are yet to carry out, the impacts will likely be greatly aggravated and would become much more expensive to overcome.

Nepal government has already committed to the goals stipulated in global agendas and has already set targets at national and provincial levels. The restructuring of local areas in 2017 after adaptation of New Constitution of Nepal, 2015 has empowered local governments for the planning, and implementation of development activities within its municipal boundary. Among numerous newly formed municipalities in Nepal, Godawari Municipality located in Kailali district of Sudur Pachim province got municipal status on March 2017. Integration of disaster mitigation components and techniques into urban development activities at municipal level is essential.

The study area has been analysed through the different types of disasters occurred from 1981 to 2021 for the period of 40 years including road accident and epidemic for MHRA analysis in the following sections.

With consideration to the risks, the vulnerability and the hazards, there is an urgent need to develop the RSLUP that focuses on reducing the probable disaster risks and build resilient communities. Under this initiative, the Rajdevi Engineering Consultant P. (Ltd.) 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, are implementing the municipal level multi-hazard risk assessment and have recently applied the results in developing RSLUP that will be further discussed in the following sections.

2. MHRA METHODOLOGIES & TOOLS

A novel technique in computing hazards is being advanced with the appropriate usage of spatial distribution of disasters using geoinformatics and satellite imagery. Pioneer researchers carried out study on landslide hazard (Crozier, et.al., 2005), risk assessment by geomorphic hazard (Westen, 2010), flood hazard (Nashrullah et al., 2013), multi-hazard risk analyses (Marzocchi, et. al., 2009, Liu et. al., 2016) together with disaster risk management ESCAP/APCICT (2020) have led the development of safer and resilient community/society acting in local community with adopting globally proven scientific modeling through geospatial tools. A Multi-hazard is referred to the adoption of potential physical damages, phenomena or human activity impacted directly to human society and property along with socio-economic imbalances reflected to degradation of environment. Multi-hazards are caused by different triggering factors that are often superimposed with complex relations between the individual hazards. Multi hazard Risk Assessment (MHRA) is relatively newly approached tool to support DRRM through integrating urban risk assessment in 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. Individual hazards have their own limitations which need to be integrate with cascading as well as other hazards into the combined form. In this instance, Liu et. al. (2016), Kappes et al., 2012, European Commission (2011) have studied and developed the complex and variable interrelationships between multiple hazard risk and their potential effects to approach a single standard form to minimize the risk and vulnerabilities of the particular area by correlating with different hazards as elucidated by Marzocchi et al. (2009).

MHRA requires historical data, frequency of events, causes that need to be processed and validate the scientific modeling through field verification which is incorporated through the identification of hotspot or by measuring risk reduction approach (ISO, 2009). The MHRA is carried out by thorough and systematic analysis utilizing geographical area, spatial scale into the local context. The multiple hazards in Nepal were 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.

A systematic approach is implemented to carry out MHRA combining quantitative and qualitative methods with expert-based knowledge, decision and local experience and knowledge at community level. The main aim is to generate risk information for the sub divisions within the municipality, for a combination of hazard types (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. 2**).

Table 1 summarises 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 adopting various literatures (Papathoma- Köhle, 2016; Ciurean et al., 2017; Fuchs et al. 2019).

The multi-hazard risk assessment (MHRA) was entirely based on two activities- analysis of the primary and secondary hazard data and the scientific modeling. The assessment was first carried out for individual hazards viz. flood, landslide, earthquake, windstorm, heatwave and coldwave, animal attack and fire hazard. The study was covered with the collection of primary and

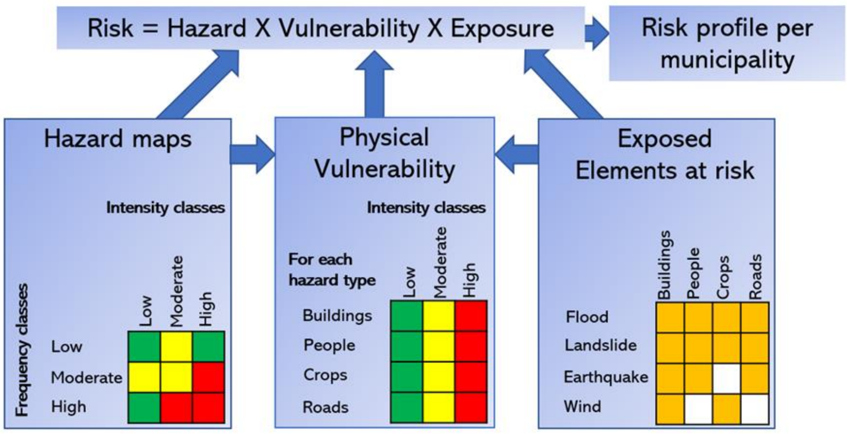


Fig. 2. Methodology for analyzing the multi-hazard risk analyses.

Table 1. 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	Suscepti bility	Statistical-Heuristic-Expert
Animal attack	4 susceptibility classes		Relative class	Suscepti bility	Heuristic-Expert
Fire	4 susceptibility classes		Relative class	Suscepti bility	Heuristic-Expert
Heatwave/Coldwave	only statistical analysis; no spatial representation				Statistical

secondary datasets including field hazard mapping, household surveys, institutional surveys, field and laboratory soil tests and historical hazard events. The individual hazards were further combined, modeled to produce the combined hazard map. Assessments were carried out for elements at risk and multi-sectoral vulnerability followed by risk and loss analyses.

The hazard intensities such as water depth (flooding), acceleration (earthquake), speed (wind) were modelled using separate modelling approaches. The frequencies of these hazards were calculated 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), 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 and the area of the susceptibility classes. All hazard maps were classified into three or four classes of frequency and intensity (or susceptibility and spatial probability). This classification was done considering 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. Afterwards, all the individual hazard maps and vulnerability assessment were combined to form a combined hazard map.

OpenLISEM (for flood hazard), existing literature data (for earthquake hazard), statistical and heuristic method (for landslide susceptibility maps), global satellite datasets (for wind hazard), Spatial Multi-Criteria Evaluation (for animal attack and fire susceptibility maps) in GIS, globally accepted climate indices (for climate extremes) were used for the scientific modeling results. Geospatial tools viz., Arc GIS, Arc Map, Ilwis tools etc. are used for modeling the assessments.

In order to perform the analyses as mentioned above, on the basis of DRRM Act 2017, the study was carried out by delineating primary and secondary data through detailed field hazard mapping, collecting detailed building footprints, household surveys, institutional surveys, field and laboratory soil tests and historical hazard events. The KOBO mobile app was used to store the required data through field survey and used as the primary sources of input parameters for geospatial analysis for MHRA and develop RSLUP in detail for the thirty-year planning.

3. Multi-hazards of Godawari Municipality

Multi-hazard is referred to the adoption of potential physical damages, phenomena or human

In order to assess the multi-hazard, data of the past disaster events occurred and their impacts in Godawari Municipality from 1971 to 2013 was collected through UNDRR DesInventar Sendai portal (no date). Similar information from 2013 to till now for the municipality was gathered from Nepal Disaster Risk Reduction Portal (NDRRP) of MOHA, GON. Also, historical disaster events were taken from the municipality too. All these information was summarized based on hazard type (**Table 2**). There are different types of disaster events occurred from 1981 to 2021. In the period of 40 years, those events including road accident and epidemic killed 137 persons, 2 persons missing, 482 family affected, 30 persons injured and

3021 number of houses damaged. If the road accident and epidemic were removed, then the natural disaster alone including fire caused death of 84 person, missing 2 persons, 482 family affecting together with 436 people injured and damaged 3020 houses in the same period. Among different hazards, flood incident took place 77 times whereas the earthquake damage did not record in the past 40 years. Climate change associated events such as flooding, windstorm, river erosion, thunderbolt and hailstorm have frequently occurred in the past 40 yrs

Table 2. Historical disaster events occurred in Godawari Municipality.

S. N.	INCIDENT	TOTAL DEATH	MISSING PEOPLE	AFFECTED FAMILY	INJURED PEOPLE	HOUSE DAMAGED	ESTIMATED DAMAGE	YEAR
1	Flood	17	1	325	0	1437	Drinking water, grain & agriculture lands, animals killed, land cut off; Nrs. 49453846	1983-2019
2	Animal attack	0	0	1	0	1	Crops, vegetables & fruits, domestic animals died, people injured	2001-2021
3	Coldwave	0	0	0	0	0	Production decreased in cash crops; respiratory & cold related diseases attacked people	2010-2015
4	Drought	0	0	0	0	0	Decreased in production of some grains/vegetables; skin diseases, viral diseases spread in human	2014-2015
5	Fire	4	0	101	3	46	Animals killed; grains destroyed; NRs. 40280000	1976-2021
6	Rainfall	1	1	1	1	1	NA	2020
7	Hailstorm	1	0	0	0	0	Crops and vegetable farm lands damaged and economic lost	1977-2019
8	Hot wave	0	0	0	0	0	Decreased in production of some grains/vegetables; skin diseases, viral diseases spread in human	2015
9	River erosion	0	0	0	0	5	River bank destroyed; agricultural land and community forest land cut off; crops damaged and some houses displaced	2007-2013
10	Landslide	0	0	1	0	1	NRs. 150000	1983-2021
11	Pest attack	0	0	0	0	0	Spread of diseases in some crops subjected to decline in production	2001
12	Windstorm	6	0	21	15	1492	Many houses destroyed, damaged; roofs blew away; schools damaged, electric poles flew away; domestic animals injured and died; people died	1983-2021
13	Thunderstorm	5	0	0	0	37	Roofs of houses blown away, trees fell down, electric poles fell down, houses damaged, cattle sheds damaged, people and animlas killed; some crops damaged	2013-2020
	Total	***84***	***2***	***482***	***436***	***3020***	***NRs. 89883846 + animals killed, crops and grains damaged***	***1981-2021***
14	Accident	53	0	0	10	1		2008-2011
15	Epidemic	50	0	32	416	1		1983-2021
Grand total		**137**	**2**	**482**	**446**	**3021**	***NRs. 89883846 + animals killed, crops and grains damaged***	**1981-2021**

Source: Compiled data from municipality, and UNDRR, no date; MOHA, no date

Table 3. Hazard raking based on past disaster impacts Godawari Municipality.

DISASTER RANKING	NO. OF EVENTS	DISASTER BY TYPE			REMARKS
		HUMAN LOSS/INJURED PEOPLE/MISSING PEOPLE	NO. OF HOUSES DAMAGED	NO. OF LIVESTOCK LOSS (BUFFALO, COW, GOAT, CHICKEN)	
First	77 (Flood)	Flood [17/0/1]	Windstorm 1492	Fire 309	1983-2021 (flood)
Second	71 (Fire)	Windstorm [6/15/0]	Flood 1437	Windstorm 7	1976-2021(fire)
Third	51 no. of windstorms/15 no. of thunderstorm	Thunderstorm [5/0/0]	Fire 46	Windstorms 7	1983-2021 (windstorm) and 2010-2020 (Thunderstorm)

Note: (a) Disaster event data was collected from multiple sources: UNISDR portal, MOHA portal and information received from the municipality including survey outcome, (b) Losses from road accidents and epidemics were not considered.

Source: UNDRR, no date; MOHA, no date

in Godawari Municipality. During the same period, losses of crops, vegetables and fruits including cut off agriculture land occurred, besides killed domestic animals and destroying infrastructure. Epidemic together with the recent Covid-19 alone killed 21 number of people.

Based on the past disaster events and their impacts, flood hazard ranks first followed by fire and river erosion (**Table 3**). The flood event took place 77 times killing 17 persons, missing 1 person. Similarly, fire hazard (including forest fire) occurred 71 times, which killed 6 persons, injured 15 persons. However, river erosion comes to the second rank as it damaged 46 number of houses. Though thunderstorm killed 5 persons, nonetheless, windstorms become the most devastating disaster in terms of damaging houses (1,492 number). In terms of killing 7 domestic animals, it stood at the second position. In terms of damaging houses, flood ranked up at the second position with affecting through 1,437 number of houses while fire alone stood up at the first rank in livestock losses (309 number of domestic animals affected) during the disaster period.

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. In this study, a combined hazard map was produced to assess the hazards of the entire municipality and implemented by overlying development nodes in safer and resilient zones for the next 30-years of urban planning.

4. RESULTS & DISCUSSIONS OF MHRA FOR IMPLEMENTING RSLUP

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 hazard. For this Spatial Multi-Criteria approach was used in which a criteria tree was developed 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, 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. The combined hazard map with High, Moderate and Low classes is shown in the **Fig. 3**. 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. The hazard severities are especially reflected by landslides and wind along the hills and flood hazards along the river courses and settlements are affected through wind hazards. According to the MHRA the whole area of the municipality was divided in three zones red, yellow and green with its magnitude and direction of the risk. As a consequence, 23.42% of land falls under the high-risk zone denoted by the Red Zone. Likewise, 49.93% of land fall in moderate risk zone with a reference of Yellow Zone and 26.65% of land fall under low-risk zone with a reference of Green Zone, **Table 4** represents the areal distribution of hazards in the municipality.

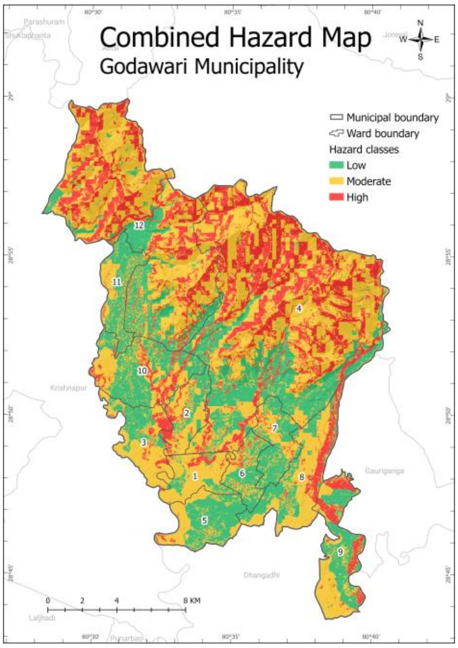
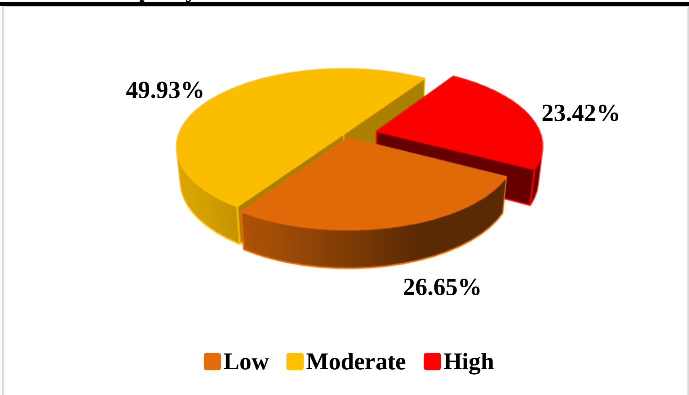


Fig. 3. Combined hazard map of Godawari Municipality, Sudur Paschsim Province.

The application of results of MHRA needs to be overlayed in the present land use incorporating existing population growth and future urban growth. In this reference, the expected future urban development trend has been traced for two different years: up to 2030 and between 2031 to 2050 respectively and proposed the nodal concept of urban development for the safe land utilization adopting free and control zones of hazards. For this context, a 'nodal development' concept is proposed as per the scale, dimension, settlement pattern, connectivity, and available social infrastructure within a defined boundary through land use zonation following the safer

Table 4. 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

zone. The Primary, Secondary and Tertiary Development Nodes are recommended on the basis of existing urban sprawl and future possible growth trend. The whole municipal area is zoned into eleven urban uses grouped into these proposed development nodes such as central business district zone, institutional and commercial zone, recreation and sport zone, culture and tourism promotion zone, residential development zone and so on.

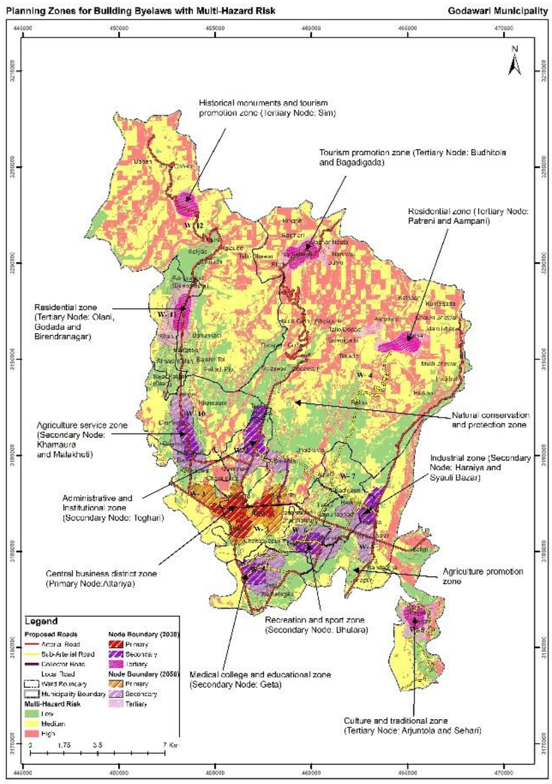


Fig. 4. Master Plan of Development Nodes for 2030 and 2050 AD overlayed on Multi Hazard Risk Assessment map.

Fig. 4 shows the location of development nodes with multi-hazard risk zones overlayed on multi-hazard map. ***A primary node development*** is proposed at **Attariya** as a Central Business District (CBD). It is located at the junction of East-West Highway and Bhimdutta Highway and possesses unique urban characteristics. Commercial activities, financial institutions, commercial banks and major trading business should be promoted in this node to create the employment opportunities. Net developable area (after deducting various constrains such as forest area, MHRA high risk area, rivers and water bodies) available is 137.33 ha for 2030 and 289.53 ha for 2050, respectively. In the primary node 60.55 ha of land lies in red zone which is restricted for further development. The population density is assumed as 200 ppha and 350 ppha for 2030 and 2050 respectively. The nodes are proposed for a balanced and inclusive city design avoiding the future growth area along the high-risk zones shown by results of MHRA. Five ***secondary node developments are proposed*** at **Teghari**, provincial capital of Sudur Pashchim Province. **Geta** is developing as a health and education service facilities center of Sudur Pashchim Province. While **Khamaura** is an agriculture service center, **Haraiya** is developing as a special economic zone (SEZ), and **Bhulhara** will be developed as a housing and apartment, corporate building area with trading business and sports and recreational facilities. The gross area of five secondary nodes is 834.31 ha for 2030 and 2,275.30 ha for 2050 which is sufficient to accommodate the population of 13266 and 61270 respectively. The population density of the secondary node for 2030 and 2050 are assumed to be 25 to 100 ppha and 75 to 250 ppha, respectively. In the secondary node 25.30 ha of land lies in red zone which is restricted for development. Proceeding, five ***tertiary development nodes*** are proposed at **Sim** (historical monuments and tourism promotion uses and services), **Godada** (residential uses and facilities), **Buditola**, (tourism promotion uses and facilities), **Sehari** (culture and tourism related uses and facilities) and **Patreni** (residential uses and facilities). The gross area of all the tertiary nodes is 635.68 ha for 2030 and 1471.35 ha for 2050 to accommodate the population of 10,899 and 28956 respectively. Out of these gross areas, the net developable area is 399.37 ha for 2030 and 515.61 ha for 2050 excluding forest area, water bodies 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 years 2030 and 2050 respectively. For conservation of natural resources and agriculture land, two more zones namely natural conservation and protection zone and agriculture zone are also proposed.

5. CONCLUSIONS

The utilization of geospatial tools such as Arc GIS, Arc Map, Ilwis have been incorporated the assessment of individual hazards in the Godawari Municipality, Kailai District, Sudur Paschim Province of Nepal. The scientific modeling has been implemented as per individual hazard types and provided the ratings with reference to the field verification and iterative processes. Hence, the MHRA outcomes are obtained from both qualitative and quantitative techniques on the basis of utilization of primary and secondary datasets including field hazard mapping, household surveys, institutional surveys, field and laboratory soil tests and historical hazard events. Usage of literature, global satellite data sets, statistical tools, SMCE, etc., are the key factors for the modeling the individual hazards and computed physical vulnerability, and developed the combined multi-hazard risk map. Hence developed combined hazard map has been implemented to identify the safer and high-risk zones. On the basis of the results of MHRA, the ‘development nodes’ has been proposed in the risk-free areas for the next thirty years of safe and resilient urban development under DRRM Act 2017 and applied to produce RSLUP. The development nodes are categorized into three parts following the hierarchical system such as primary, secondary and tertiary development nodes. The analysis shows that Attariya is situated at the primary development node as per its existing demand and future projection of urban growth together with the possibility of central business development zone. where possible hazard can be controlled. Remaining 5 secondary and 5 tertiary development nodes are proposed in RSLUP along risk-free zones with the help of MHRA outcomes. This indicates, the usage of MHRA tool is more effective and can reduce the hazard, risk and vulnerability in long-term urban development and provides the better socio-economic structure of the people.

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BIOGRAPHICAL NOTES

Dr. Suman Manandhar received Doctor of Engineering degree in Civil & Structural Engineering, specializing in Geotechnical Engineering from Kyushu University, Japan in 2010. He completed his Master's Degree in Geology from Tribhuvan University from Kathmandu, Nepal in 1998.

He has served 2 years as Post-Doctoral Research Fellow at Geotechnical Engineering Laboratory, Kyushu University from 2010-2012. Afterwards, he served as lecturer and research fellow in Saga National University at the Institute of Lowland and Marine Research for twenty-six months and promoted as Visiting Associate Professor for the period of one year and 4.5 months. He also served as a Lecturer in Tribhuvan University, Kathmandu University in the field of geo-engineering. He is currently working as a **Research Fellow** at Global Institute for Interdisciplinary Studies for last three years. He is also a **Campus Chief** and **Associate Professor** of Sulakshan Kirti Campus, in collaboration between Lumbini Buddhist University & Sulakshan Kirti Vihar. He has more than 20-years of academic as well as professional experiences with more than 30 publications in journals and more than 40 proceedings. He has also received awards such as **Nepal Vidya Bhushan "ka" Presidential Award** and **Mahendra Vidya Bhushan "kha" Kingship Award** for ***Doctoral Degree*** and securing the ***top position in the university during Master's Study respectively***. Besides, **Master's thesis Award** by **National Science and Technology Academy** in ***Master Level*** and **MEXT Japanese Scholarship** for ***Doctoral Degree*** are the awards received during his academic career. Furthermore, **Best Paper Awards** and **Best Appreciation Awards** recognized him for his scientific contribution.

He is also a life member of Nepal Geological Society and former members of Japanese Geotechnical Society and JSCE general member.

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