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Multi-Hazard (Flood&Landslide), Risk Vulnerability Assessment & Mapping Using Rs & GIS Techniques: A Case Study of Kindo Didaye Woreda (District), Wolaita Zone, Southern Nations, Nationalities & Peoples Regional State (SNNPRS) of Ethiopia

Niguse Geressu[1], Barana Babiso[2], Dr. Ajitesh Singh Chandel[3]
[1]*Senior Expert, Ministry of Agriculture, Ethiopia*
[2]*Senior Lecturer, Department of Geography and Environmental Studies, Wolaita Sodo University, Ethiopia*
[3]*Assistant Professor, Department of Geography and Environmental Studies, Wolaita Sodo University, Ethiopia*

Abstract:** This study aimed to help communities and makes risk-based choices to address vulnerabilities, mitigate hazards (flood & landslide) and prepare for response to and recovery from these events with the help of remote sensing and geographical information system techniques. According to Kindo Didaye woreda agriculture and natural resource report, there are 340 displaced households due to flood and landslide hazards in 8 kebeles of the woreda were selected as a sample frame of the study for the purpose of identifying and assessing root causes and vulnerability of multi-hazard and risk. Both primary and secondary data sources were used. In this study non-probability and probability sampling techniques were implemented. For the purpose of spatial and surveyed data analyses Multi-Criteria Evaluation (MCE) method, ArcGIS 10.1, Erdas-Imagine 2010, Statistical Package for Social Science (SPSS 21) and Garmin GPS 72 software were used. Result and field observation showed that the study area is vulnerable to flood and landslide hazards. The frequency of landslide hazards rapidly increased in the last one decade. Heavy rainfall, climate change, land use or land cover change, soil type, slope, elevation and drainages are the main causes of flood and landslide hazards in the study area. The forest cover change in the study area is seriously decreasing. Therefore, this study provides information on both flood and landslide hazard and risk as well on multi-hazard/risk at Kindo Didaye woreda. Thus, the local level participatory land use planning is seriously needed in this woreda. In addition to land use planning, soil and water conservation mechanisms and practices should be strengthened and mitigation measures should be implemented for reducing vulnerability of elements at risk to flood and landslide hazard and risks in the woreda.
***Keywords:** Flood, Kindo Didaye Woreda, Landslide, Multi-Hazard/Risk, Geographical Information System & Remote Sensing.*

I. INTRODUCTION

Flood and landslide hazards are the most destructive acts of nature. World-wide, Flood and landslide hazards damage-agriculture, houses and public utilities amount to billions of dollars each year in addition to the loss of precious human and cattle lives. Ethiopia is no exception as far as floods and landslide hazards are concerned. Severe floods and landslides occur almost every year in the country and causing tremendous loss of life, large scale damage to property and untold misery to thousands of people. Flood and landslide are the most common natural hazards happening in the country due to the land features and its related undersurface conditions and, other natural and man-made triggering factors. These hazards are the most destructive and life threatening worldwide and in national level (Beto D, 2007; Leta A., 2007; World Bank, 2010), and sometimes their integrations/interconnections make the hazards more serious.

Flood is one of the major natural hazards in Ethiopia – affects lives and livelihoods in parts of the country. Flood in Ethiopia is mainly linked with torrential rainfall and the topography of the highland mountains and lowland plains with natural drainage systems formed by the principal river basins (Flood Alert, 2014). These flood cases are relatively common during rainy seasons between June and September especially in areas adjacent to main rivers of the country. Flood has been occurring at different places and time with varying magnitude. Some parts of the country do face major flooding. These flood cases occurred following the major rivers of the country have serious damage on the lives and economy in which a lot of peoples died, missed and affected from time to time.

In Ethiopia landslide problems are also common in the central, northern and southwestern highlands and nearby rift valley margins (Fikre, 2010; Beto, 2007; Kisanet, 2016; Yodit, 2005; Jemal, 2011; Zerihun, 2016; Leta, 2007 and Samuel, 2011). They result in loss of human life, property and severe damage to agricultural lands and the environment as a whole. Different researches also showed that landslides have considerable impacts on human life, infrastructures, fertile farm lands and natural environment (Lulseged, 1999).

Ethiopia is amongst the developing country and most vulnerable to natural and man-made hazards. Among these flood and landslide are the major events that, over the past many years, have been causing suffering to communities and millions of dollar worth of property destructions (Mulugeta, A, 2009). Flood hazards are occurring in different parts of the country according to the scholars, (Destaye, 2009; Woubet, 2007; Marie, 2008; Abebe, 2007; Mersha, 2007; Solomon, 2012; Alemu, 2010). The 2006 flood in Ethiopia is the one which caused death of 639 lives and thousands of live stocks; washed away 228 tons of harvested crops, loss of 147 tons of export coffee beans (and machinery ruined) and 42,229 hectors of crop land were inundated (Semu, 2010). Landslide problems are also common in the central, northern and southwestern highlands and nearby rift valley margins of Ethiopia according to Fikre (2010), Beto (2007), Kisanet (2016), Yodit (2005), Jemal (2011), Zerihun (2016), Leta (2007) and Samuel (2011). In the years between 1990-1998 alone, landslide-generated hazards have claimed about 300 human lives, damaged over 100 km asphalt road, demolished more than 200 dwelling houses and devastated in excess of 500 hectares of land in different areas of the highlands of Ethiopia (Lulseged, 1999). According to Kifle Woldearegay (2005), 135 human lives have been lost, about 3500 people were displaced and an estimated 1.5 million US Dollar worth property has been damaged in the highlands of Ethiopia in the years 1998-2003.

These hazards of landslide and flood listed are life threatening and the most destructive which are occurring mostly due to torrential rain fall, are more serious in the rainy season of the country between June to August, and sometimes extends in highland areas of the country. Kindo Didaye woreda, the current study area is seriously affected by multi-hazards of both flood and landslide in the year 2016. According to the woreda report of Kindo Didaye Agricultural and Natural Resource, both flood and landslide have been causing serious problems on human life, animals , crops and property in the woreda. Among these, heavy rainfall during mid-August 2007 caused landslide in which 16 peoples were dead and more than 200 households were displaced in Kindo Didaya woreda (UN-OCHA, 2007). August 31, 2010 landslide hazard has killed 8 people and caused destruction of houses and property. In May 9, 2016 both flood and landslide have jointly caused the death of 39 peoples and 172 livestocks, displaced more than 340 households, destroyed about 35 houses, affected 839.5 hectares of different crop types, 15.5 hectares of grazing lands and 250 coffee trees (KDWANR, 2016). The report from local people and office of the woreda agriculture and natural resources also indicates that from 2005 to 2016 alone, landslide have resulted death of 51 people and damaged agricultural lands, houses and infrastructures in Kindo Didaye woreda. As the woreda also characterized by mountain, rugged and hilly terrain with large plain valleys and gorges and settlement of peoples around steep slope, lack of soil and water conservation mechanism and over usage of natural resources, which exacerbated negative impact to the occurred hazards. However, there are no studies taken place before regarding multi-hazard (flood and landslide) in the study area. These motivated the researchers to have a research on this area, in order to identify the causative factors of each hazards as well as to assess the risk and vulnerability and, to map the hazard prone areas which will be affected by these multi-hazard risks in the woreda. GIS technology along with remote sensing has become the recent key technology for forecasting areas that are likely to be affected by multi-hazard risk and mapping the hazards and its prone areas.

A. Study Area

Kindo Didaye woreda (district) is a part of Wolaita zone, Southern Nations Nationalities and Peoples Regional State (SNNPRS) of Ethiopia. The woreda is situated north of the equator between 6°40'11.48''N to 6°51'54.18''N latitude and 37°13'26.89''E to 37°29'27.97''E longitude in a pentagon shape. In the north and west it is bounded by Loma Bosa woreda of Dawaro zone, in the north-east by Kindo Koysha woreda, in the south by Kucha woreda of Gamo Gofa zone and the south-east to east bay of a woreda (See Fig. 1.). The elevation of woreda ranges from 652 to 2699 meters from mean sea level, with a total area of 380.47 km². It has a land frontier of 92.69 kilometers from which shares the boundary with Loma Bosa woreda 34.02 km (36.70%) of Dawaro zone, Kindo Koysha woreda18.70km (20.17%), Kucha woreda 20.41km (22.01%) of Gamo Gofa zone and Ofa woreda 19.54km (21.08%). Administratively, the district has been subdivided into 18 kebeles. The climate is stable, with temperature variation between 24 and 30 °C during the day and 16 to 20 °C at night, all year round. The area is characterized by unimodal rainfall pattern. From October to February the area receives low rainfall whereas from May to September it receives high rainfall. The monthly average temperature of the study area between 1995-2015 is 21 °C. The year is divided into two seasons: the wet season (balguwa) from June to October, and the dry season (boniya) from October to June, broken in February by a short period of so-called "little rains" (baddessa). The average rainfall for the entire region is 1350 millimeters per year. The vegetation types of the woreda are scattered bushes, wild grass and some trees are the types of vegetation which most parts of the ridges in the study area is covered. The gorges and river sides are relatively densely vegetated, the steeper parts are sparsely vegetated and foot of the mountain is cultivated by different kinds of crops and vegetables. The dominant crop production in the area is sorghum, maize, teff, enset, mango, banana, casaba and vegetables. The soil of the study area is of heavy red color which becomes brown and black during the rains and has the fragility and the softness of sand. The dry period makes the soil hard as brick, one reason why people can plough and dig only after the rains. One can hardly find any stone except on the river banks, whose soil is light and easy to excavate. The layer of soil is very deep an average of 30 meters in both the plains and the hills, as verified during the drilling of wells. The soil is very fertile and produces two crops per year when the rains are regular. The projected total population of the woreda according to the 2007 Ethiopian Population and Housing Census is about 131,582 and of which 51% were women (CSA, 2008). The woreda has estimated population density of 347 people per square kilometer which is greater than the zonal average 156.5 people per square kilometer. Urbanization in the study area is below 2%. This shows that most of the populations are living in rural areas and agriculture is the dominant economic activity. The study area is under northern catchment of Omo basin in areas around Gilgel Gibe III dam reservoir. In a very broad term, most of the northern catchments of the Omo-Gibe Basin are under extensive cultivation with increased land pressure, meaning the expansion of cultivated areas in to increasingly marginal lands at the expense of wood lands. Deforested areas are now confined to areas too steep and inaccessible to farm. The flatter poorer drained bottom lands of the northern catchments are usually not cultivated but are used for dry season grazing and eucalyptus tree plantations.

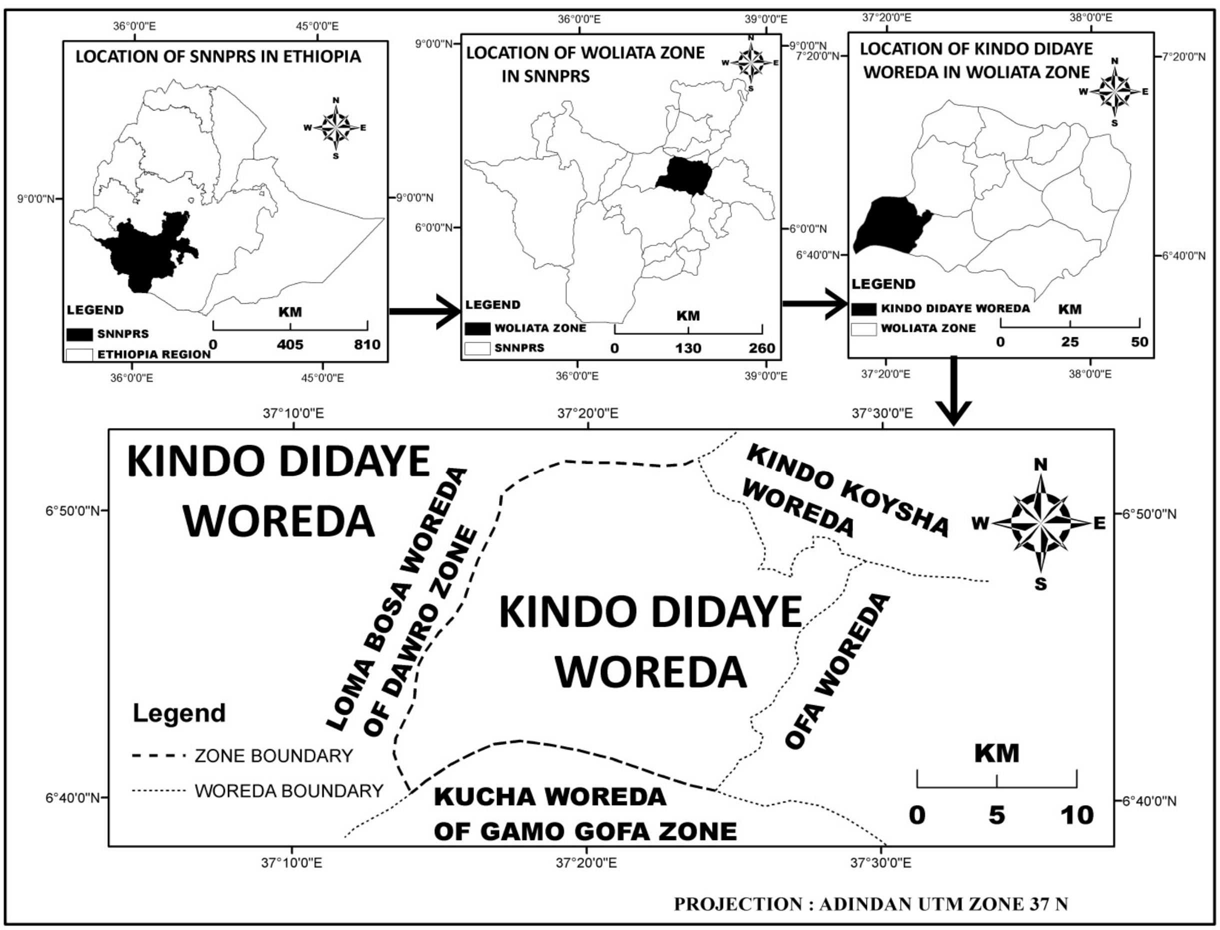

Fig. 1 Location map of the study area

B. Objectives

1) General Objective

a) The main objective of this Study was to assess and map vulnerability of integrated flood and landslide hazard using GIS and remote sensing techniques.

b) The major purpose of multi –hazard (flood & landslide), risk and vulnerability analysis (MHRVA) is to help a community and make risk-based choices to address vulnerabilities, mitigate hazards and prepare for response to and recovery from hazard events. Risk-based means based on informed choices of alternate unwanted outcomes. In other words, communities make risk reduction choices based on the acceptability of consequences and the frequency of hazards.

2) Specific Objectives

a) To assess vulnerability of flood, landslide hazard and risk.

b) To identify factors that cause flood and landslide hazard.

c) To evaluate impacts of the recent flood and landslide hazards.

d) To prepare flood and landslide hazard and risk map of the study woreda.

e) Investigate prominent natural and human-caused events.

f) Identify any threats that may require a timely and coordinated response to protect lives, property, and to reduce economic losses.

g) Definition of measures to be included in the mitigation plan.

h) Evaluation of the effectiveness of the mitigation and emergency plans and implementation of training activities such as simulation, seminars and workshops

II. MATERIALS & METHODS

The 340 households in 8 kebeles who are displaced from their homes due to flood and landslide hazards according to Kindo Didaye woreda agriculture and natural resource office report, were used as sample frame of the study for the purpose of identifying and assessing causes and vulnerability of multi-hazard and risk of study area. In this study both non-probability and probability sampling techniques were implemented. The probability sampling technique was used to select sample households from target population. Among the common types of probability sampling techniques, simple random sampling method was employed to identify households (HHs) from those 340 households who are affected by the occurred flood and landslide hazard. In addition to this, the non-probability sampling /purposive sampling technique was employed in order to select participants for focus group discussions. The individual household was used as the sampling unit for risk vulnerability assessment and individual persons were used as a sample unit for focus group discussions. Both primary and secondary data Sources were used in this study. The primary data sources for this study were interviews, focus group discussions, field observations and field survey using handheld GPS. In addition to this, the study used Landsat images for the purpose of analyzing LU/LC change; therefore Landsat images which are downloaded from USGS were used as a primary source of data for this study. To use scientific facts and to support the study with findings of other scholars, using secondary data sources is very important. Having this, secondary data sources have been used in this study include various written documents related to the topic of study, related documents from electronic sources, reports, shape files, maps and others. For the purpose of spatial and surveyed data analyses, Multi-Criteria Evaluation (MCE) method, ArcGIS 10.1, Erdas-Imagine 2010, Statistical Package for Social Science (SPSS 21) and Garmin GPS 72 software were used.

III. RESULTS & DISCUSSION

A. Vulnerability Assessment of the Woreda to Flood and Landslide

Both flood and landslide are the major natural hazards in Ethiopia – affects lives and livelihoods in parts of the country. Flood in Ethiopia is mainly linked with torrential rainfall and the topography of the highland mountains and lowland plains with natural drainage systems formed by the principal river basins (Flood Alert, 2014). This is also the case in the current study area based on the researchers' field observation in which there are highland mountains and lowland plains. In addition to these, (Flood Alert, 2014 and Flood Alert, 2016) listed the woreda in under risk list of flood hazard zone in the region in 2014. According to Ayalew (1999) in the densely populated highland area of Ethiopia, where altitudes exceed 1750 m, landslides are increasing in the number and size during the last 30 years. Since, almost half of the study area altitude exceeds 1750m; the woreda is vulnerable to landslide as well.

Based on the results about 89.4% of the respondents, all three focus group discussions in three kebeles (PAs), elders asked and field observations show that the study area is vulnerable to both flood and landslide hazards and risks. The landslide hazard is more serious as compared to another's according to 70% of the respondents, all FGDs and field observations. Even though both flood and landslide hazards in the study area are common, the frequency of landslide is increasing in recent years as compared to previous and the risk is also more serious in recent years like the last year hazards and risks which caused the death of 39 peoples and 172 live stocks, destruction of about 35 houses, affected roads, agricultural lands, crops, fruits and vegetables, coffee trees and other trees.

B. Causes of Flood and Landslide in the Study Area

Based on the respondent's response, topography of the study area, heavy rainfall, climate change, land use land cover change, soil type, slope, elevation and drainages are the main causes of flood in the study area. The forest cover change in the study area is seriously decreasing. Deforestation, the main cause for land use land cover change is one of the major causes of floods (Alemu, 2010), the vast majority of floods are linked to precipitation (rain or snow) (Leta A., 2007). The casual factors of landslide are slope, rainfall, soil characteristics, land use land cover, etc. (Jane, 2014). Therefore, the results shows that the factors that cause both flood and landslide in the study area are the common and known factors.

Whereas population and land use land cover of the study area are directly vulnerable to the flood and landslide hazards. The study area, Kindo Didaye woreda is one of densely populated woreda in the zone as well as in the region. Due to lack of flat areas, peoples settled even in steep slopes which were not recommended for living and ploughing. In addition to these, since there is high population density, population growth is also high, which makes people to deforest jungles in order to have agricultural lands for their livelihoods which is the basic cause for the decreasing land use land cover of the study area.

C. Flood Hazard and Risk Assessment

Natural hazard is the probability of occurrence, within a specified period of time and within a given area, of a potentially damaging phenomenon. It is a physical event that can have an impact on human beings and their environment and, unless the event affects something, there will be no damage/disaster or hazard. The hazard involves the human population placing itself at risk from physical events. Flood hazards result from a combination of physical exposure and human vulnerability to geophysical processes. Physical exposure reflects the type of flood events that can occur, and their statistical pattern at a particular site, whilst human vulnerability reflects key socioeconomic factors such as the numbers of people at risk on the flood plain and landslide areas, the extent of any flood and landslide defense works and the ability of the population to anticipate and cope with hazard (smith, 1998).

Based on the derived weights for each factor the reclassified factor maps were overlaid together in model builder window for flood hazard and risk. The flood hazard and risk of the study area is assessed using GIS and remote sensing and mapping the hazard zones, as well as calculating the hazard zone areas respectively.

D. Flood Hazard Assessment

The flood hazard map of the study area was generated by overlaying rainfall, slope, elevation, soil type, drainage density and land use land cover based on their respective weights. The final generated flood hazard map (Fig. 2) shows that 4,208 hectares (11.06%) of the study area is under very low flood hazard zone, 6,007 hectares (15.78%) is on low flood hazard zone, 10,245 hectares (26.93%) is under moderate flood hazard zone, 7,890 hectares (20.74%) is under high hazard zone and 9, 697 hectare (25.48%) is under very high flood hazard zones. In addition to this, the hazard assessment of each kebele (Table 2) in the study area is generated from the flood hazard map of the study area.

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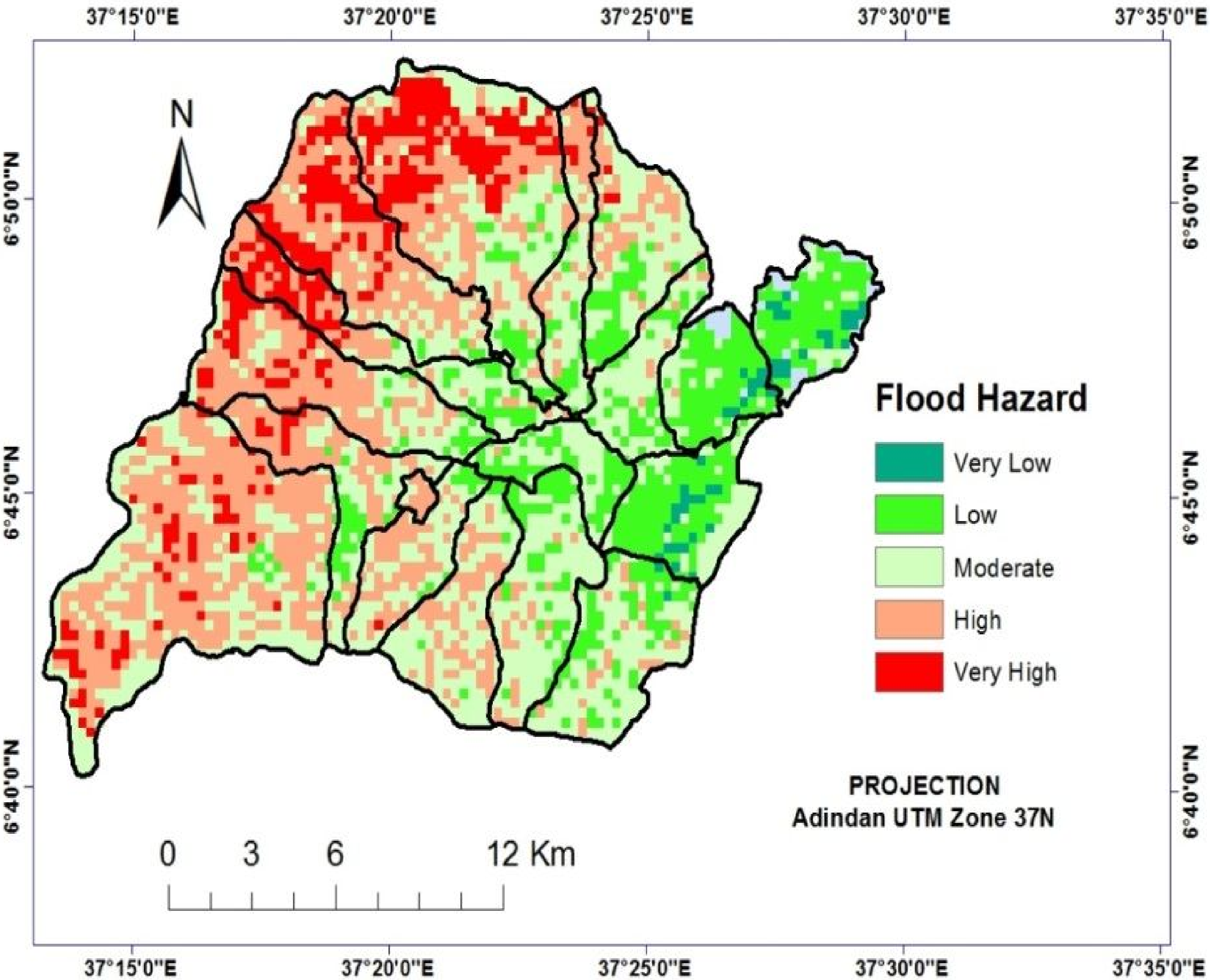

Fig. 2 Flood hazard map of the study area

TABLE 1
The cross-tabulation of land use land cover and flood hazard in the study area

Land Use land cover type	Flood Hazard (Area in Hectare)					
	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)	Area total
Agricultural Land	1292.694	1618.49	3062.421	1006.14	4.255	6984
Bare Land	1495.572	55.999	1240.096	2124.89	9053.441	13970
Built Up Area	326.864	296.593	1738.394	2745.96	422.189	5530
Forest	983.039	3304.38	3524.339	1845.54	215.702	9873
Grass Land	109.831	731.547	679.75	167.453	1.419	1690
Total	4208	6007.009	10245	7889.983	9697.006	38047

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TABLE II
Flood hazard assessment of each PAs in the study area

PAs Name	Very Low	Low	Moderate	High	Very High	Total Area of PAs
Halale Town	1		112		27	140
Zero	259	633	393	895	831	3011
Goc'he	223	541	745	1860	1434	4803
Mogisa	110	44	381	242	455	1232
Patata	289	329	293	310	749	1970
Wamura	13	0	126	352	737	1228
Chew kare Kindo	128	0	138	262	798	1326
Lasho	309	0	9	0	1145	1463
Chew Kare Ofa	295	0	245	0	1125	1665
Zereda	379	670	431	292	362	2134
Bosa Borito	65	441	466	810	265	2047
Wamura Berikos'he	0	0	652	0	337	989
Bereda	59	672	617	101	338	1787
Zebo	216	1232	713	298	273	2732
Shela Mek'ira	558	712	3943	1311	38	6562
Kinidohala	529	476	296	105	357	1763
Sime Dolaye	198	88	368	478	203	1335
Bosa manera	577	169	317	574	223	1860
Total Area of hazards	4208	6007	10245	7890	9697	38047

E. Flood Risk Assessment

In general, risk as a concept incorporates the concepts of hazard {H} (initiating event of failure modes) and vulnerability {V} (specific space/time conditions). It is customary to express risk (R) as a functional relationship of hazard (H) and vulnerability (V).

Risk (R) = Hazard {H} x Vulnerability {V} …………………………………………… (2)

The flood risk map of the study area is generated based on overlaying elements at risk (vulnerability) factors (population density and land use land cover) with flood hazard map of the study area. Hence, the reclassified land use land cover and reclassified population density of the study area were overlaid with the generated flood hazard map of the study area. The generated flood risk map shows that 101 hectares (0.27%) of the woreda is under very high risk zone, 12,156 hectares (31.95%) of the woreda is under high risk zone, 15,128 hectares (39.76%) of the woreda is under moderate risk zone, 7,145 hectares (18.78%) of the woreda is under low risk zone and 3,517 hectares (9.24%) of the woreda is under very low risk zone.

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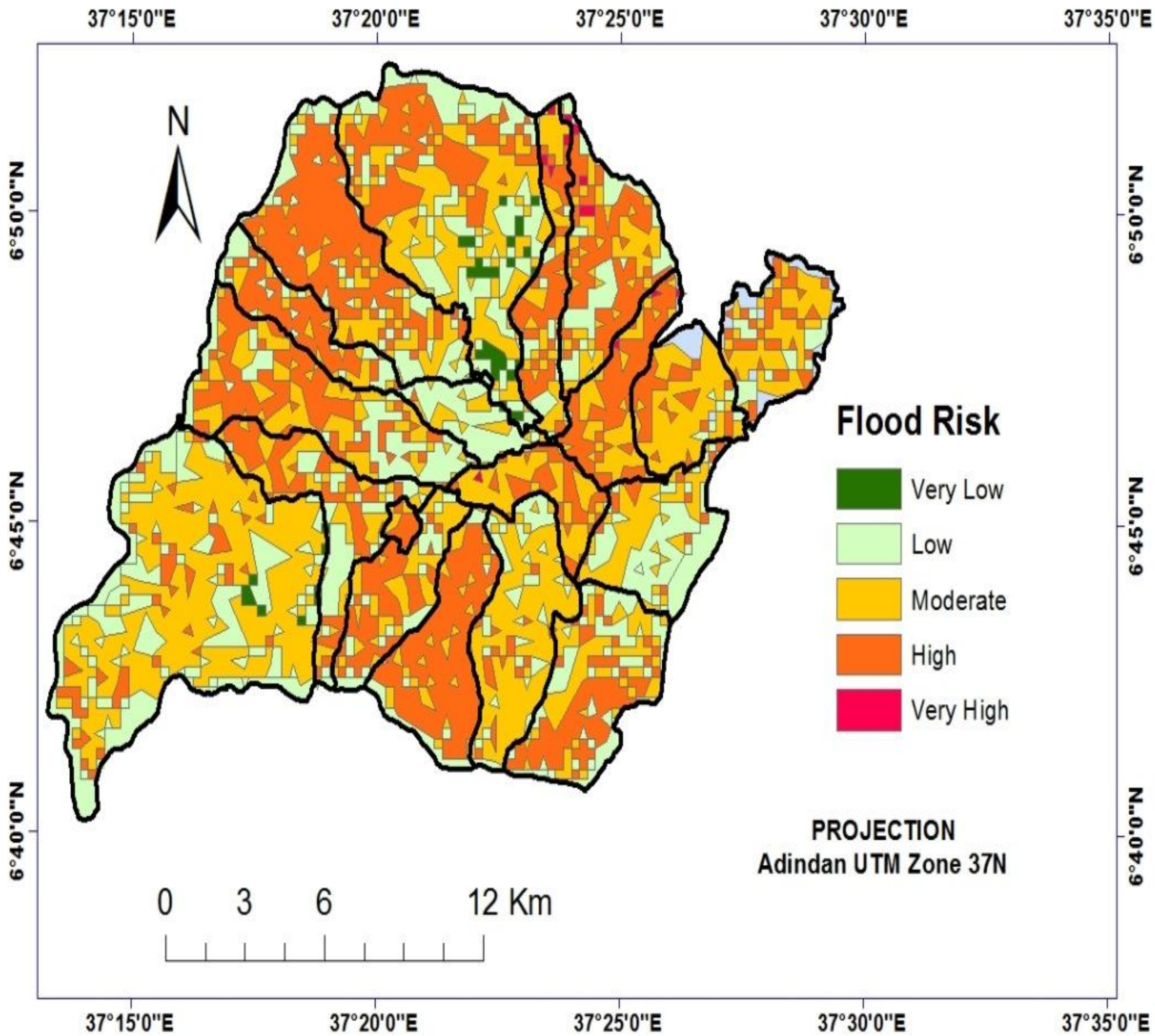

Fig. 3 Flood risk zone map of Kindo Didaye woreda

TABLE III
Cross tabulation of land use land cover and flood risk in the study area

Land use land cover type	Flood Risk (Area in Hectare)					
	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)	Area total
Agricultural Land	1269.99	951.51	2721.13	2035.7	5.68	6984.01
Bare Land	945.77	1274.17	5099.92	6588.15	61.98	13969.99
Built Up Area	368.02	740.77	2862.33	1539.72	19.16	5530
Forest	844.68	3713.79	3652.77	1648.99	12.77	9873
Grass Land	88.54	464.76	791.87	343.42	1.42	1690.01
Hazard area total	3517	7145	15128.02	12155.98	101.01	38047.01

TABLE IV
Distribution of flood risk in each peasant associations

PAs Name	Very Low	Low	Moderate	High	Very high	Each PA Total area
HalaleTown	0	4	45	91	0	140
Zero	185	474	635	1717		3011
Goc'he	686	1035	1832	1249	1	4803
Mogisa	21	162	466	550	33	1232
Patata	229	299	522	875	45	1970
Wamura	23	7	436	746	16	1228
ChewkareKindo	120	80	820	306	0	1326
Lasho	270	203	658	332	0	1463
ChewKareOfa	304	603	608	150	0	1665
Zereda	185	492	682	775	0	2134
BosaBorito	27	400	1449	171	0	2047
WamuraBerikos'he	0	17	587	379	6	989
Bereda	110	692	394	591	0	1787
Zebo	129	583	891	1129	0	2732
ShelaMek'ira	1006	1317	3753	486	0	6562
Kinidohala	30	482	614	637	0	1763
SimeDolaye	45	227	467	596	0	1335
Bosamanera	147	68	269	1376	0	1860
Total area of hazards	3517	7145	15128	12156	101	38047

F. Landslide Hazard and Risk Assessment

Based on the derived weights for each factor the reclassified factor maps were also overlaid together in model builder window to generate landslide hazard and risk map and its assessment. The landslide hazard and risk of the study area is assessed using GIS and remote sensing and mapping the hazard and risk zones, as well as calculating the hazard and risk areas respectively.

G. Landslide Hazard Assessment

The landslide hazard map of the study area was generated by overlaying rainfall, slope, and soil type, proximity to drainage, lithology and land use land cover based on their respective weights. The study shows that 1825 hectares (4.8%) area is under very low landslide hazard zone, 7,200 hectares (18.92%) low landslide hazard zone, 23,121 hectares (60.77%) is under moderate landslide hazard zone and 5,901 hectares (15.51%) is under high hazard zone. In addition to this, the hazard distribution in each kebele (table 6) in the study area is generated from the landslide hazard map of the study area.

TABLE V
Cross tabulation of land use land cover and landslide hazard in the study area

Land Use land cover type	Landslide Hazard (Area in Hectare)				
	Very Low (1)	Low (2)	Moderate (3)	High (4)	land use Area total
Agricultural Land	969.34	651.106	4088.54	1275.03	6984.016
Bare Land	437	3427.62	8749.61	1355.77	13970
Built Up Area	109.24	1603.46	3239.34	577.96	5530.004
Forest	261.47	1347.28	5991.77	2272.47	9872.99
Grass Land	47.95	170.53	1051.74	419.77	1689.99
Hazard level area total	1825	7200	23121	5901	38047

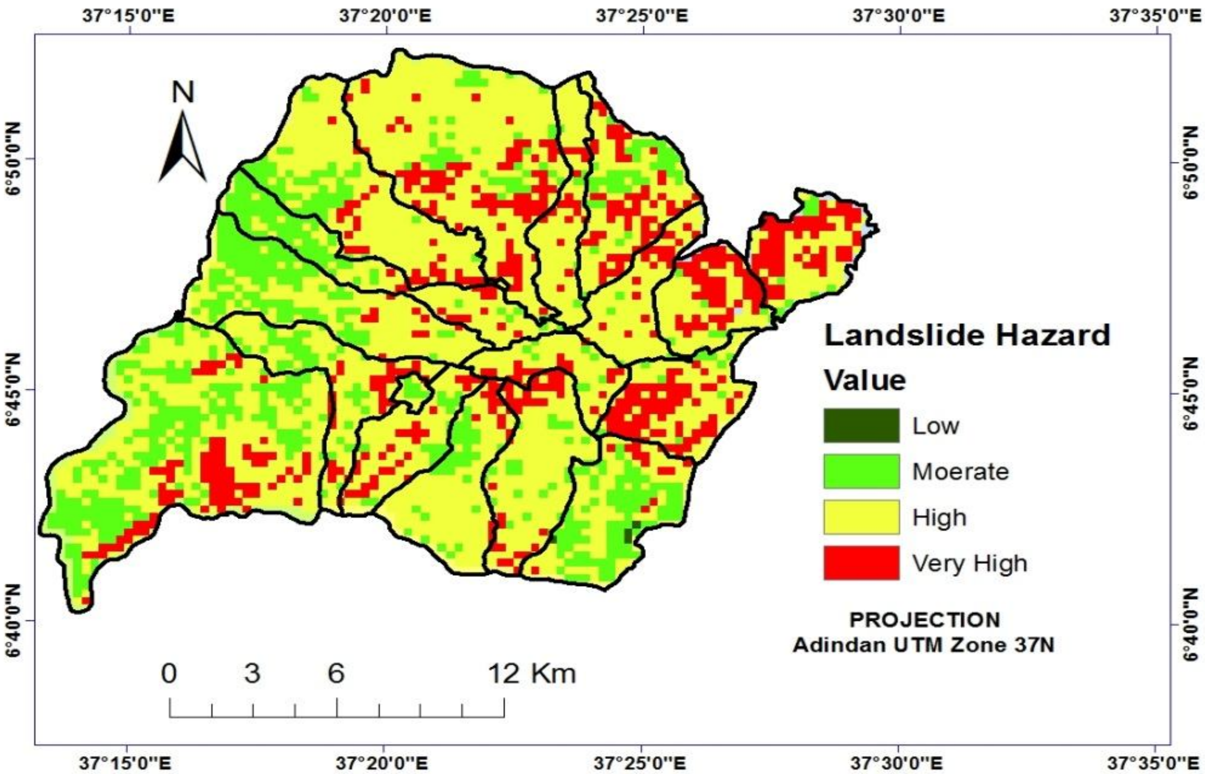

Fig.4 Landslide hazard map of the study area

TABLE VI
Landslide Hazard distribution in the study area

PAs Name	Low	Moderate	High	Very high	Area of PAs
HalaleTown	1	49	83	7	140
Zero	89	503	2152	267	3011
Goc'he	127	364	3496	816	4803
Mogisa	10	45	1033	144	1232
Patata	100	368	970	532	1970
Wamura	15	26	1010	177	1228
ChewkareKindo	49	65	703	509	1326
Lasho	154	92	587	630	1463
ChewKareOfa	74	94	856	641	1665
Zereda	162	917	936	119	2134
BosaBorito	30	151	1537	329	2047
WamuraBerikos'he	1	56	767	165	989
Bereda	42	693	948	104	1787
Zebo	140	1060	1468	64	2732
ShelaMek'ira	627	1918	3212	805	6562
Kinidohala	15	344	1194	210	1763
SimeDolaye	45	156	887	247	1335
Bosamanera	144	299	1282	135	1860
Total Hazard Areas	1825	7200	23121	5901	38047

Even though the technique used is different from this study, the study undertaken by Zerihun (2016) landslide hazard zonation in around five kebeles (Sime Dolaye, Bosa Manara, Offa Chewkare, Wamura Borkoshe and Bosa Borito) in Kindo Didaye woreda shows that there are very high, high and moderate landslide hazard in these kebeles which have almost the same result as the landslide hazard zones of this study. This shows that it is possible to map the hazard zones by using different types of approaches.

H. Landslide Risk Assessment

The landslide risk map of the study area is generated based on equation (1) overlaying elements at risk/vulnerability factors (population density and land use land cover) with landslide hazard map of the study area. Hence, the reclassified land use land cover and reclassified population density of the study area were overlaid with the generated landslide hazard map of the study area shows that 42 hectares (0.11%) of the woreda, 7,392 hectares (19.43%) of the woreda, 21,218 hectares (55.77%) of the woreda, 7,101 hectares (18.66%) of the woreda, and 2,294 hectares (6.03%) of the woreda were under very high, high, moderate, low and very low landslide risk zone respectively.

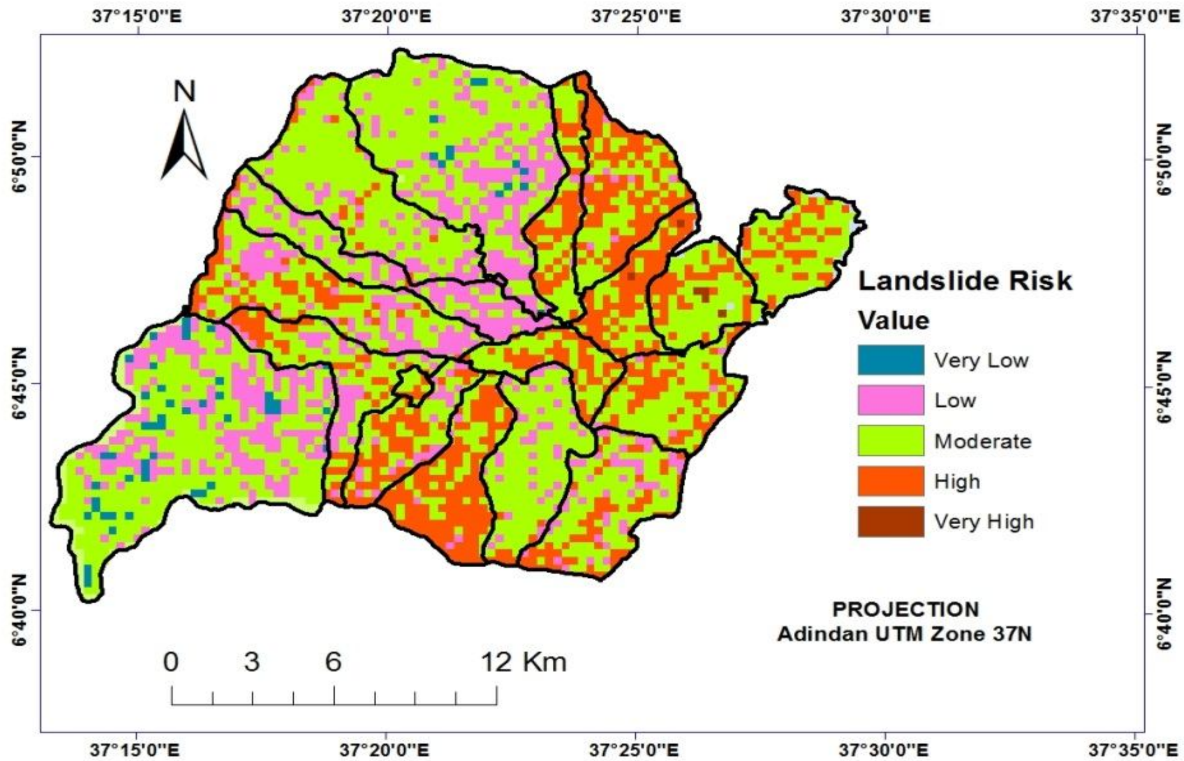

Fig. I Landslide risk map of the study area

TABLE VII
Cross tabulation of land use land cover and landslide risk in the study area

Land Use land cover type	Landslide Risk (Area in Hectare)					
	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)	Area Total
Agricultural Land	1112.75	646.56	3137	2076.79	10.9	6984
Bare Land	480.96	1694.31	9141.48	2646.24	7.01	13970
Built Up Area	278.79	1439.58	2879.16	930.13	2.34	5530
Forest	404.78	3047.9	5064.03	1334.54	21.75	9873
Grass Land	16.72	272.65	996.33	404.3	0	1690
Hazard area total	2294	7101	21218	7392	42	38047

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TABLE VIII
Landslide Risk distribution of the study area

PAs Name	Very Low	Low	Moderate	High	Very high	Area of PAs
HalaleTown	0	1	87	52	0	140
Zero	91	515	2310	95	0	3011
Goc'he	229	1470	3091	13	0	4803
Mogisa	8	39	640	545	0	1232
Patata	90	82	750	1048	0	1970
Wamura	19	0	400	796	13	1228
ChewkareKindo	40	3	901	353	29	1326
Lasho	152	0	932	379	0	1463
ChewKareOfa	79	51	1003	532	0	1665
Zereda	140	379	1181	434	0	2134
BosaBorito	29	281	1655	82	0	2047
WamuraBerikos'he	0	13	538	438	0	989
Bereda	45	857	862	23	0	1787
3Zebo	130	812	1334	456	0	2732
ShelaMek'ira	1027	1905	3626	4	0	6562
Kinidohala	23	413	895	432	0	1763
SimeDolaye	45	221	544	525	0	1335
Bosamanera	147	59	469	1185	0	1860
Total Hazard Areas	2294	7101	21218	7392	42	38047

I. Multi-Hazard Risk Assessment

As from its name 'multi-risk' it shows that there are two or more than two risks were assessed in multi-risk assessment. In this study the generated risks of both flood and landslide maps were aggregated together in multi-hazard/risk assessment map. Multi hazard/risk map of the study area is generated based on overlaying the two final flood and landslide risk maps together with equal influence each to the final multi-hazard risk map of the study area (Warit et al, 2009). The generated multi-hazard/risk map (Fig 6.) also was classified into four risk levels of low, moderate, high and very high and shows that 146.97 hectares (0.38%) of the woreda, 13016.36 hectares (34.22%) of the woreda, 16244.40 hectares (42.69%) of the woreda, and 8640.26 hectares (22.70%) of the woreda, were under very high, high, moderate and low multi-hazard risk zone respectively. From the map it is analyzed that 147 hectares in five kebeles (Mogisa, Patata, Wamura, Wamura Borkoshe and Chewkare Kindo) are under very high risk whereas all the kebeles in the study area have their own share from low to high hazard.

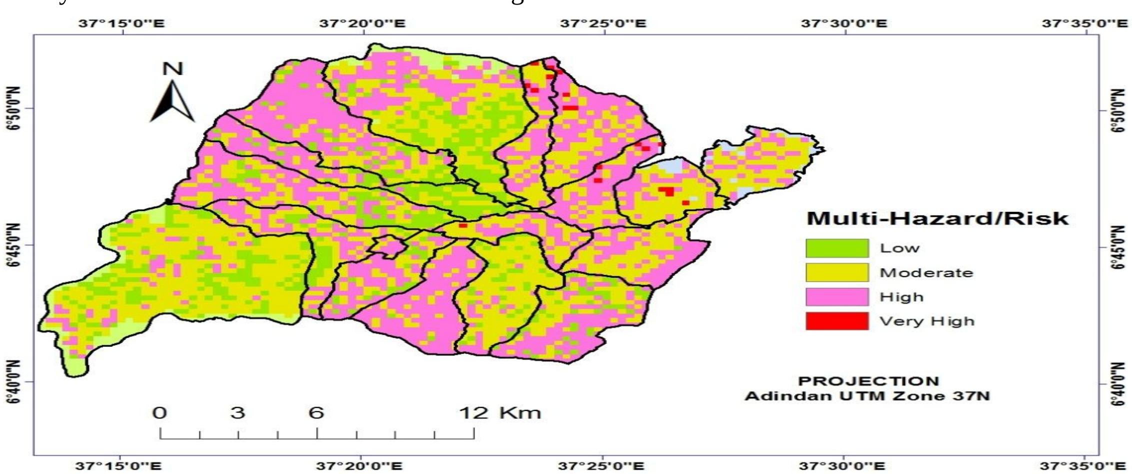

Fig. 6 Multi-hazard/risk of the study area

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TABLE IX

Cross tabulation of land use land cover and multi-hazard/risk in the study area

Land Use land cover type	Multi-Risk (Area in Hectare)				
	Low (2)	Moderate (3)	High (4)	Very High (4)	land use Area total
Agricultural Land	1849.43	2704.40	2414.95	15.19	6984
Bare Land	2092.01	5128.75	6667.65	81.6	13970
Built Up Area	1005.19	2838.04	1672.77	13.99	5530
Forest	3384.87	4638.33	1815.03	34.77	9873
Grass Land	308.5	934.48	445.6	1.42	1690
Hazard Area Total	8640	16244	13016.36	146.97	38047

TABLE X

Multi-Hazard/Risk distribution on the peasant associations of the study area

PAs Name	Low	Moderate	High	Very high	Area of PAs
HalaleTown	2	41	97	0	140
Zero	630	672	1709	0	3011
Goc'he	1617	1949	1236	1	4803
Mogisa	24	619	556	33	1232
Patata	227	699	998	46	1970
Wamura	26	411	759	32	1228
ChewkareKindo	115	840	342	29	1326
Lasho	268	843	352	0	1463
ChewKareOfa	316	881	468	0	1665
Zereda	566	705	863	0	2134
BosaBorito	329	1477	241	0	2047
WamuraBerikos'he	13	536	434	6	989
Bereda	793	400	594	0	1787
Zebo	671	911	1150	0	2732
ShelaMek'ira	2255	3824	483	0	6562
Kinidohala	356	734	673	0	1763
SimeDolaye	258	405	672	0	1335
Bosamanera	174	297	1389	0	1860
Total Hazard Areas	8640	16244	13016	147	38047

IV. CONCLUSIONS

This study is aimed to assess vulnerability of the flood and landslide hazard. Based on the designed methods such as individual interviews, FGDs and field observation results, the woreda is vulnerable to both flood and landslide hazards and risks. Hence, the designed methods best fit to assess the vulnerability of the woreda to flood and landslide hazards and risks.

The causative factors were identified based on methods such as individual interviews, FGDs, field observations and review of related literatures. The identified factors for both flood and landslide hazards are the common factors, which are the causes for these types of hazards in different parts of the world. Thus, the identification methods are useful methods to identify causative factors for natural hazards. The methods used to identify causative factors are also the best method to evaluate impacts of natural hazards.

As discussed above, the woreda is vulnerable to both flood and landslide hazards. Therefore, it needs to map both flood and landslide as well as multi-hazard/risk areas of the woreda. Hence, pair wise comparison matrix which is used to weigh each causative factors, influences in relation to the other for both hazard map generation is a good approach to deduce a sound decision for a forthcoming natural hazards and disasters. One of the Multi Criteria Evaluation techniques known as Weighted Overlay in GIS environment was shown to be useful for delineating areas at different rating in terms of natural hazards and risks. As discussed above previous studies, field observations, and the final result of this study based on Multi-Criteria Evaluation techniques are agreed together. Thus, this study confirmed that the method used was capable to integrate all the causative factors for the respective hazards and the components of risks as well in a GIS environment. In this fashion, composite maps were generated to assess flood and landslide hazard and risk as well as multi-hazard/risk of the study area. Therefore, MCE technique in GIS environment is the best technique and it should be used in hazard and disaster studies.

V. SUGGESTION & RECOMMENDATION

This study showed very high, high and moderate landslide hazards in the study woreda. In addition to this, even though there are no studies regarding flood hazard in the study area before, this study used almost all the common factors used in other studies and incorporated with individual interview to generate the hazard and risk maps of both flood and landslide as well as multi-hazard/risks of the study area. Therefore, this study provides information on both flood and landslide hazard and risk as well on multi-hazard/risk at Kindo Didaye woreda. Thus, the responsible bodies of the woreda, zone as well as the region should incorporate the natural hazard and risk assessment studies in their development strategies and take the studies as an input for their decision making.

The local level participatory land use planning is seriously needed in this woreda. Land use planning guidelines should be taken into consideration and implemented by the decision makers and concerned bodies for reducing vulnerability of elements at risk to flood and landslide hazard and risks in the woreda. In addition to land use planning, soil and water conservation mechanisms and practices should be strengthened and mitigation measures should be implemented.Due to May, 2016 flood and landslide hazards, it is known that there are more than 340 households who were displaced and sheltered in temporary shelter for almost one year. From the displaced households currently more than 250 households were taken to the newly built resettlement areas in Shele Sade kebele (previous Shele Mekira) in May, 2017. Whereas, beyond those more than 90 households who are still living in temporary shelter, the concerned bodies should give attention to those who are not displaced but living in under risk areas of specially Mogisa, Patata, Wamura, Chewkare Kindo, Wamura Bokoshe kebeles, etc. The selected resettlement area (Shele Sade kebele) is the right place from the woreda in relative to other kebeles based on the generated hazard and risk maps of this study. But this selected resettlement kebele is not enough to resettle those who are living in under risk areas. Therefore, the concerned bodies should lookout for other opportunities based on researches. The research related to land use land cover change, strong mitigation measures of natural hazards should be undertaken.

Satellite Remote Sensing and GIS techniques have emerged as a powerful tool to deal with various aspects of flood management in prevention, preparedness and relief management of flood disaster. They have greater role to play as an improvement over the existing methodologies. GIS is ideally suited for various floodplain management activities such as, base mapping, topographic mapping, and post-disaster verification of mapped floodplain extents and depths. Remote sensing and GIS techniques can replace, supplement or complement the existing flood management system. Extensive use of these technologies have great prospect in creating long-term database on flood proneness, risk assessment and relief management.

To avoid construction failure due to instability of the area and presence of close mountainous area which have high probability of sliding, remote sensing images must be used in such a project and integration of GIS to generate hazard map is very powerful tool which generates many layers also very useful. Remedial work must take place in the hazardous area immediately before starting constructions; the hazard map using GIS gives very good information about landslide and must be applied for the areas that have large probability of slides.

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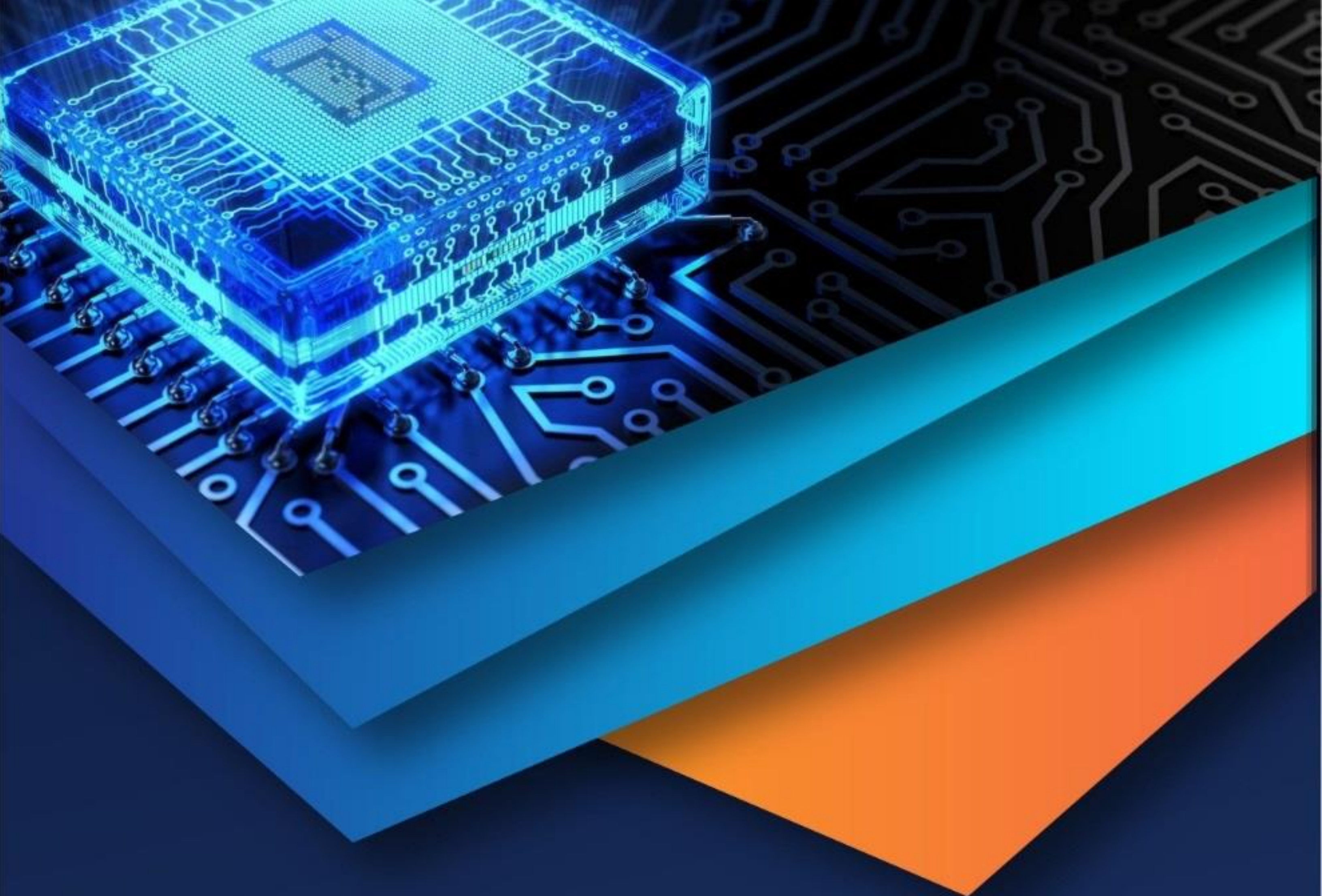

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