Landslide Risk Assessment in Kunduz Province-Afghanistan

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Abstract: ***In this research the landslide risk at Kunduz province, was assessed. The first step was to analyze the quality of data, and to evaluate to which extend this data could be used for landslide risk assessment. Several data layers were made new as the quality of the existing data was too low. For instance, a settlement map was made by digitizing from a high resolution image. The basic data layers were converted into the same projection and georeferenced and two sets of data layers were made: one for analyzing the hazard, and the others for the elements-at-risk. A landslide susceptibility map was made using spatial multi-criteria evaluation, using criteria for triggering factors, and causal factors. The next step in the analysis was the exposure analysis, which was carried out for the landslide hazard, and for 3 types of elements-at-risk: people, agricultural lands and roads. The results show that landslide is one of the serious problem in Kunduz province mainly for the transportation routes connecting this province Takhar and Baghlan province. This study shows that it is possible to make a basic and qualitative landslide risk assessment based on publicly available data. In the near future more of this type of analysis will be carried out in Afghanistan as a basis for risk reduction planning.***

Keywords: Landslide, Hazard, Risk assessment, Vulnerability, Kunduz.

1. Introduction

Landslide hazard driven by geological and hydrological processes affect many provinces in Afghanistan because of their geographical setting. In addition to the risk posed by landslide hazard, most of the provinces in Afghanistan are exposed to the risk of war and civil conflict. Due to these aspects the vulnerability of the people in these provinces exposed to landslide hazard is substantially increased. In provinces that are having major security problems because of war or civil conflict there are hardly efforts on disaster risk reduction, and there are many ways in which violent conflicts complicate, confuse, and obstruct the efforts of planners, engineers, and others to assist people in protecting themselves, their livelihoods, and their built environments from landslide hazard. Also sometime landslide hazard events make the work of aid organizations even more difficult in the areas which are affected by war or civil conflicts [19]. Due to civil war and war on terror millions people have been affected and are internally displaced in the country Afghanistan. Often the migration of these poor and unemployed people is directed to the dangerous areas where mostly they stay in self built houses in unsuitable locations, such as steep ravines, which poses a big problem to emergency management planners. In the past decades even though some important innovations in landslide and earthquake mitigation and preparedness have materialized, the total number of people displaced by conflict or violence threatens to overcome the hard work that was put into action [20].

In the past decades the capacity to prevent the damage and losses from different types of natural hazards was often deflected by violent conflict and its result. After the tsunami that seriously affected Sri Lanka and ten other countries, the government of Sri Lanka and the Tamil Tigers couldn't conclude on an agreement for relief and recovery support [4]. Therefore, for the benefit of both sides a discussion is needed to strengthen the link among disaster research and peace research, as we can find similar and overlapping histories between the two [7].

The reasoning first is that countries affected by war or civil conflicts are often more prone to natural disasters, because they do not put enough effort in disaster risk reduction activities, and the society is occupied with more urgent problems related to the conflict. Civil conflicts often cause large changes in the pattern of human occupation, because of refugees, and temporary settlements, which may often be located in dangerous areas. Also the vulnerability of displaced persons is much larger, as the structures in which they live are more vulnerable, and their coping capacity is much more reduced. They are depending on other organizations, such as NGO's. Access to the conflict affected areas is limited and dangerous, and therefore investigations related to hazard and risk related activities are difficult to carry out.

During the last decades the impact of natural disasters has resulted in a high number of lives lost and livelihoods destroyed, especially in countries which have weak governments and are affected by civil conflicts. In the last decades the fatalities and economic losses due to natural catastrophic events have increased [3].

2. Literature Review

Innovative approaches for risk assessment and risk management are required for the reduction of the effects of different catastrophic events and their direct or indirect impact, which allow the comparison of risk that accounts for all the possible risk interactions [12]. Many areas of the world are prone to landslide hazard and useful risk reduction is possible if all relevant threats are considered and analyzed. This refers to the assessment of the level of hazard and also to the vulnerability toward distinct processes, and to the arising risk level [11].

Landslide risk evaluation is a new field, until now developed only to some extent by professionals with different backgrounds (statistics, engineering, toxicology, seismology etc.). Among the limited works on this field, we quote the UNDRO study [14], Granger [8], Van Westen [16], Ferrier and Haque [6], Blong [1], Grunthal [10], Kappes [11], and Schmidt et al. [13]. However, the specific problem of possible interactions among different threats and/or cascade effects has been approached qualitatively only by Kappes (2010). This is, a synoptically view that enables planners and decision-makers to make adequate decisions on risk reduction and loss prevention programs [12].

It is clear that the availability of hazard and risk related spatial data is a very important requirement in order to make landslide-hazard risk assessments. Natural and technological disasters in the past have shown that such incidences significantly affect local and regional development [9]. The methodological approaches in risk assessment studies range from very coarse indices to elaborate assessments. An example of a coarse index approach is the methodology of Ferrier and Haque [6]. Based on readily available data and expert knowledge about the landslide hazard and its possible effects on the municipality, this method yields a ranking of the different risks in a community and provides guidance to both mitigation and preparedness priorities. Another coarse index was proposed by Munich Re (2003) and also uses available data and expert opinion [10].

Landslide-hazard risk assessment using GIS can be carried out on different geographical scales, and for different purposes. Landslide-hazard risk assessment at the provincial level covers a vast area of information and resources. It is important to carry out landslide-hazard risk assessment on a provincial scale in order to provide awareness raising about the problems of landslide hazard and risks, to improve provincial planning, functioning of provincial disaster risk reduction policies and to allow for the development of disaster preparedness plans and insurance policies. provincial scale risk assessment forms the basis for disaster risk management policy development, and should be a first step in order to prioritize the areas that are most at risk [15].

The areas are evaluated in different size, also it important to mention that some countries like USA, China or India are larger than a continent like Europe, which counted in one administrative setup. Spatial resolutions may differ from 90 meters to one kilometer which depends on the application, and the scale of the maps is between 1:100,000 and 1:5 million [15].

Landslide hazard assessment applied at provincial scale is intended for disaster preparedness, insurance, for the purpose of national planning, implementation of risk reduction policies, and early warning systems. Zooming to a larger scale like the provincial level make the applications in planning more concrete. For example, hazard and risk assessment become an element of Environmental Impact Assessment for developments of infrastructure and regional development plans. Hazard and risk assessment carried out at municipal level is carried out for the design of risk reduction measures and as a base for land-use zoning. Hazard and risk assessment at a community level, carried out with involvement of local authorities and local communities, is used for the design of concrete risk reduction measures and as a clear means for obtaining commitment for disaster risk reduction programs [15].

Risk assessment and the quantification of risk are core parts of the risk management. However, an integrated landslide-risk assessment in still a major [13]. Reducing the potential for large scale loss of lives, numbers of casualties, and extensive displacement of populations that can result from natural disasters is a difficult challenge for the governments, communities and individuals that need to respond. Though it is really hard, if it is impossible, to predict the occurrence of most natural hazards; it is possible to take action before emergency events happen to plan for their occurrence when possible and to mitigate their potential effects. The increased vulnerability of many areas, especially in developing countries is a major reason of concern. Therefore, emphasis should be given to the reduction of vulnerability, which requires an analysis of potential losses in order to make recommendations for prevention, preparedness and response [16].

3. Problem Definition

The area of study in this research is located in Northern part of Afghanistan, a country with rough terrain and dominated by rugged mountain ranges. More than 3 decades of war in Afghanistan has affected all of the governmental organizations, including the key organizations that are supposed to be involved in collecting the Geospatial data in the country. At present time lack of spatial data is one of the major problems in order to come to landslide hazard and risk assessment. At present no base data is available for the country and at the same time most of the data is very sensitive in terms of security issues. Another problem is the very low level of collaboration between the various organizations. In most cases the data cannot be shared by the government or other involved organizations, which make it very hard to access to data. There is no spatial data infrastructure for disaster risk management in place, and the use of spatial data is often restricted to organizations with a military mandate, supported by international organizations (e.g. NATO)

So, taking into account the mentioned problems it is important to evaluate how in such a problematic situation in Kunduz province, the existed data can be utilized for making a provincial scale landslide-hazard risk assessment. In short the main problems regard to landslide risk in Kunduz province are as follows:

- The government does not put enough effort in disaster risk reduction activities, because the society is occupied with more urgent problems related to the conflict.
- The government organizations that would normally be involved in disaster reduction activities; do not have the resources to do so, because most resources are used in the civil conflict.
- Civil conflicts caused large changes in pattern of population occupation, because of refugees, and temporary

settlements, which are often located in dangerous areas, such as mountains. Also the vulnerability of displaced persons is much larger, as the structures in which they live are more vulnerable, and their coping capacity is much more reduced. They are depending on other organizations, such as NGO's.

- Access to the conflict affected areas is limited and dangerous due to landslide risk, and therefore investigations related to hazard and risk related activities are limited.
- They government generally focus very much on the disaster response or on disaster response planning, and are less involved in landslide risk assessment.

According to the location of Kunduz province in the Hindukush Himalaya region (HKH) and its rugged topography, yearly the province is experiencing different types of natural hazard events, like earthquakes, landslides, floods. The past events show that the damage to human lives, property and environment is dramatically high. Unfortunately, because of population growth, poor governance and planning, and urbanization the vulnerability is increasing day-by-day.

4. Methodology

The research was carried out as a desk study, without the possibility to actually visiting Kunduz province. During this research a landslide-risk assessment was done for Kunduz province. The research was divided into four stages:

- The first stage was the establishment of a landslide hazards database. The data base is based on published papers, the international agencies that offer free web-based data, and some data was requested from specific agencies that worked in Afghanistan through the war period. Then the recorded events were analyzed in order to verify their reliability. For example, Landslides areas were mapped from high resolution images.
- The second stage was the collection of the baseline data. Baseline maps include high resolution imagery, DEMs, geology, geomorphology, landuse and precipitation data. The baseline database was established based on the availability of the data from internet. The DEM was established using the ASTER GDEM with a spatial resolution of 30 m. The other maps were digitized from the published work, if they were not available digitally.
- The third stage of the research was the generation of the elements-at-risk maps. This research focused on the vulnerable people and settlements which include the buildings, agricultural land, and the road network that can cause the obstruction in the supply of vital materials like food, fuel and medicine in case of hazards. The settlements map was made by image interpretation from a high resolution images, through screen digitizing.
- The fourth stage was the analysis of landslide hazard and the overlay of the hazard map with the elements-at-risk maps in order to quantify the exposures. The hazard map for landslides was made using a Spatial Multi Criteria Evaluation (SMCE) approach.
- The fifth stage included the producing of the vulnerability and risk map that are produced also using a multi-criteria analysis of landslide hazard map and the elements-at-risk in the ILWIS software. The results are displayed per pixel or by administrative units.
- An overview of methodology is presented in figure 1.

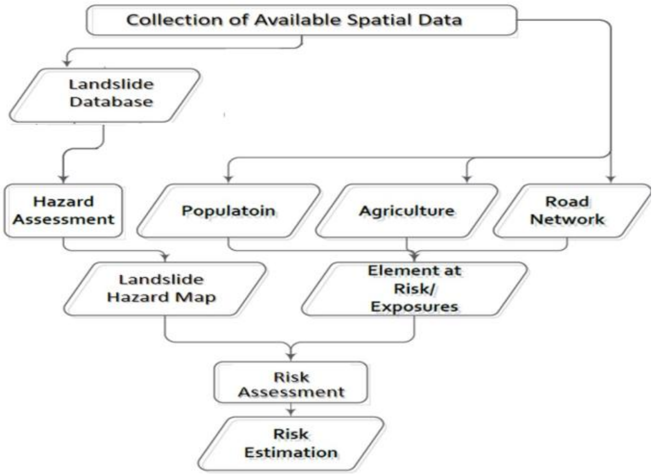

Figure 1: Flowchart of the methodology used in this research

4.1 Study Area

Kunduz is one of the provinces in northern Afghanistan, with an area of 8040 km^2. The total population is about 935600. The province is divided into seven districts. Kunduz city is the center of the province, which is highly populated and the city is linked by highway to the Tajikistan border in the north, Kabul to the south and Mazar-i-Sharif to the west. Kunduz province is dominated by the Kunduz river valley. The flow direction of the river is from south to north part of Kunduz and joins the Amu Darya (Oxus) river. The river also forms the international border between Afghanistan and Tajikistan. The province has borders with Takhar, Balkh, and Baghlan provinces [18]. (See figure 2) See annex 1 for details map. The canals that are diverted from the river provide the chance of irrigation to the cultivated areas. There is also open rangeland and rain fed fields. Approximately three quarter of the total area is flat land and about 13% of the topography is mountainous terrain [17]. (See table 1)

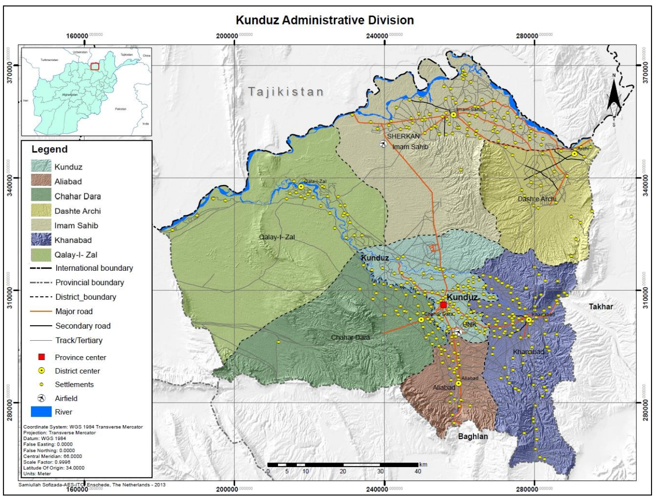

Figure 2; Kunduz Administrative division map

Table 1; Topography type of Kunduz province

Topography type				
Flat	Semi Flat	Semi Mountainous	Mountainous	Total
78.80%	7.80%	8.20%	5.20%	100.00%

Source: CSO/UNFPA socio economic and Demographic Profile

From the total population of Kunduz, 75.35% lives in the rural area and 24.64% in urban areas. About 50.89% of the population is male and other 49.11% is female. The main ethnic groups living in Kunduz are Pashtun and Tajik, remaining are Turkmen, Uzbek, Hazara and other [17]. Kunduz is among the provinces which have part of the population of Kuchi (Nomads). The numbers of Kuchi are diverse in different season of the year, 3.8% of overall Kuchi population or 88208 individuals stay during the winter in Kunduz. Aliabad, Qala-i-Zal, Archi, Chahar Dara and Imam Saheb districts [17]. (See Table 2 for total population of Kunduz province)

Table 2: Kunduz province population by district

District	*Nr. Males*	*Nr. Females*	*Total population*
Ali Abad	22800	22300	45100
Char Darah	35700	34500	70200
Dasht-i-Archi	41100	39800	80900
Imam Saheb	113000	108800	221800
Khan Abad	77700	75800	153500
Provincial center	152100	145700	297800
Qalay-i-Zal	33800	32500	66300
Total	476200	459400	935600

Source: Central Statistics Office (CSO) of Afghanistan 2018

Kunduz province is located in the lowlands and in the center of irrigated area in the north of Afghanistan. The soils of the irrigated area of three Qataghan provinces (Kunduz, Baghlan and Takhar) have exceptional fertility, which is one of the main reasons of the dense population before the destruction by Changiz khan in the year 1220. The mentioned area never recovered completely, and Murad Beg one of the Uzbeks Amir in Kunduz in the 19th century tried to colonize the fertile green plains by depopulating the mountainous of Badakhshan province [5].

Later on in the 20th century the Amir Abdur Rahman Khan king of Afghanistan, in order to occupy the fertile plains in north transmigrated the Pashtuns ethnic group from the south of Hindu Kush, the transmigrated people started some irrigation work in the north, later in when the irrigation canals were built in the Khanabad region up to Poli Khumri in 1930. Two major movements of people resulted because of the very low price of land in the region. The first one was from the south part of Hindu Kush, generally Kandahar and Jalalabad provinces and the second one was from the north. The region in the center of Kunduz province is one of the most intensively cultivated, populated and ethnically complex area of Afghanistan [5].

The geology of Kunduz province consists of rocks ranging from the Cretaceous to the recent sediments. The pre Quaternary lithologies consist mainly of lagoonal to marine to continental sediments which have evaporates for example Anhydrite and Gypsum. Also in Kunduz province a high percentage of Quaternary units are present such as continental fluvial deposits and alluvial fan. The formation of Pliocene Bukhara hosts the Celestite deposits in the northern part of Afghanistan. Celestite is an important mineral and the principal source of the element strontium, commonly used in fireworks and in various metal alloys.

The north-eastern part of Afghanistan is geologically active and due to that Kunduz province and other neighboring provinces are experiencing earthquakes. Also the Geomorphological formation of Kunduz province is in such a way that it is affected by different types of natural hazards like, landslide, flood, drought etc.

5. Landslide Hazard Analysis

The territory of Kunduz of province due to its geological setting, geomorphology, climate and landscape has favorable conditions for active geological process like landslides. Landslide processes are affecting the roads, agriculture lands and population. For the qualitative assessment of landslide in this research the Spatial Multi Criteria Evaluation (SMCE) method has been applied. The hazard assessment for landslides was made by using ILWIS 3.3 Academic and ArcGIS 10.5. The method used for this map is presented in figure 6. The following layers were used for generating the landslide susceptibility map:

- Digital Elevation Model, which slope steepness and aspect was created
- Geology
- Road network
- Land Cover
- Stream
- Peak Ground Acceleration (PGA)
- Precipitation map

The hazard assessment started with structuring of the criteria tree, followed by the selection of indicators, standardization and weighting. In order to make it possible to do the multi criteria analysis all the input layers were standardized from their original values to a new value range between 0-1, by evaluating the relative importance of the classes and values with respect to landslide occurrences. It is important to mention that the indicators do not have similar measurement scales such as interval, nominal, ordinal and ratio, and they had different cartographic projections and geo-references. Therefore prior to the standardization all data were converted to the same projection system. Taking into account the mentioned elements, different standardization methods were applied for each of the indicators. For example, maps with classes were standardized using expert-based values, and continuous data was standardized using curves.

In the criteria tree the indicators were divided into two groups. The first one is related to the triggering factors which contain two indicators: Rainfall and Peak Ground Acceleration (PGA). The second group is related to the causal factors, which contains the following indicators: land cover, geology, slope, distance to major rivers, slope aspect and distance to roads. One constraint was also used in order to mask out the flat areas. (See figure 3)

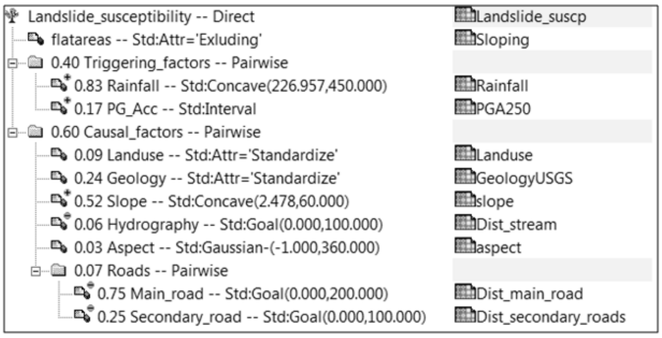

Figure 3: Landslide susceptibility criteria tree

For the weighting of the indicators both the direct method and the pairwise comparison method were used. The indicators of the triggering factors were weighted using the pairwise comparison method, and the rainfall was considered more important for landslide triggering than the peak ground acceleration. The indicators of the causal factors were also weighted using the pairwise comparison method. (See Figure 4 for the respective weights). The indicator "distance to roads" was classified into two groups: main roads and secondary roads among the indicators in the causal factor the highest importance was given to the slope and geology. For the general weighting of the input layers the direct method was applied, the value given for triggering factors is 0.400 and for the causal factor is 0.600.

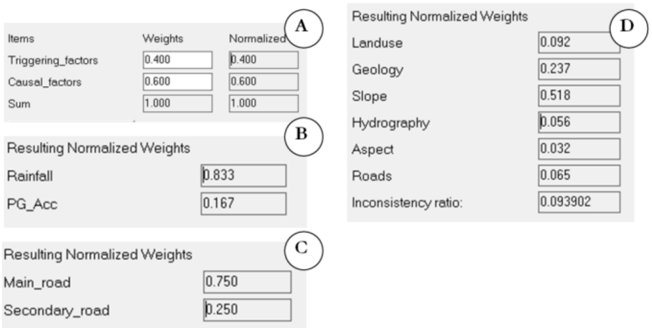

Figure 4; A) Overall weighting value of all layers. B) Weighting value for triggering factors. C) Weighing value of roads, D) weighting value for causal factors

After generating the score map, the landslide susceptibility map was sliced into four main classes: high, moderate, low, and flat. The resulting landslide susceptibility map is not static; it should be regularly updated because a number of the given indicators (e.g. land-cover) change over time. The landslide susceptibility map was validated with the result of the landslide inventory mapping which has been carried out in Kunduz province (See figure 10). The landslide susceptibility map shown in figure 5, (See annex 2 for details map).

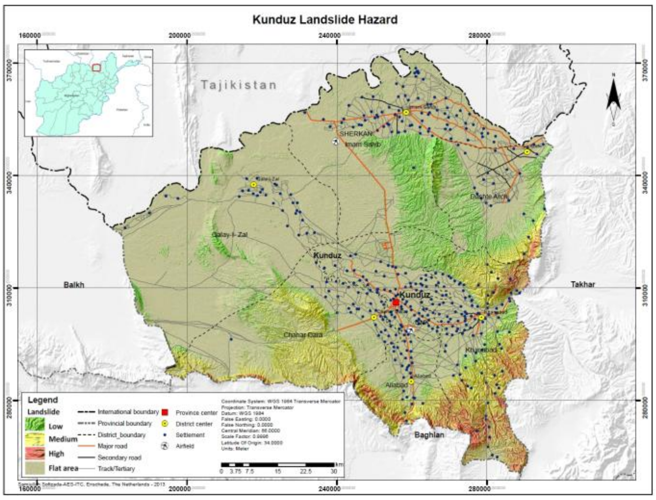

Figure 5: landslide hazard map of Kunduz

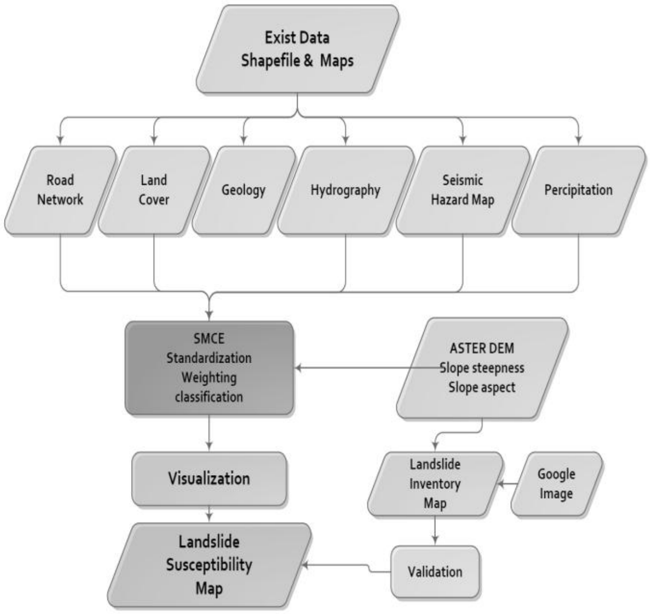

Figure 6: Landslide susceptibility flow chart

In this research one of the most important components related to the risk assessment was the exposure analysis. The level of exposure can be directly defined by the interaction of hazard zones and element at risk.

The following types of exposure were analyzed: population (number of people); roads (length of main roads and secondary roads in km); agriculture (total area of agricultural land in hectare) and were grouped according to the administrative units (districts). The procedure of generating exposure map shown in (figure 7).

6. Exposure Analysis (Result)

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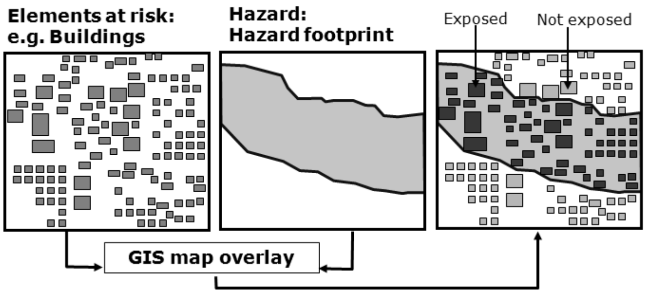

Figure 7: Overlay of hazard map and elements-at-risk presents information on exposure.
Source: Multi-hazard risk course, ITC-2012

The calculations of different types of exposure have been done using script files in the ILWIS 3.3 Academic software. In general, the main steps in calculating the exposure were as follow:

- Overlay of the landslide hazard map with element at risk using the cross operation
- Creating a joint frequency table with all combinations of both maps, in addition a map containing all possible combinations
- Overlay the resulted map with the administrative units (district)
- Aggregation of the number of elements-at-risk.
- Calculation of the total percentage of different types of element-at-risk in the landslide hazard, per district.
- Storing all the analysed values in tables of exposure linked to the district map, which contains all the exposure information per district.

6.1 Population exposure to landslide hazard

Population exposure to landslide hazard was calculated based on the number of people per cell for the three landslide susceptibility classes (high, moderate and low).
From the population of Kunduz 21013 people (2.5 %) are exposed to landslide hazard and remain 914587 people (97.5 %) are not exposed to landslide hazard. Among the total population of Kunduz 15,853 people are exposed to low landslide hazard, 4,684 people are exposed to moderate landslide hazard and 476 people are exposed to high landslide hazard. (See figure 8)

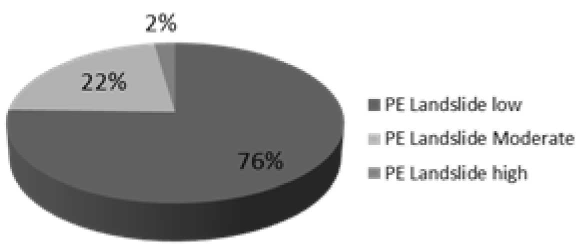

Figure 8: Kunduz population expose to landslide hazard in percentage of the total exposed population to landslides (which is 2.5% of the total population of Kunduz).

The districts Khanabad and Kunduz city are having the highest number of people exposed to landslide hazard, as well as the smaller settlements in the mountainous parts in the East of the state. (See table 3)

Table 3: Population exposed to landslides by district

Districts	PE Landslide low	PE Landslide Moderate	PE Landslide high	Expose to landslide risk	Not expose to landslide	Population
Aliabad	1469	744	0	2213	42887	45100
Chahar Dara	753	0	0	753	69447	70200
Dasht-i- Archi	1270	104	0	1374	79526	80900
Imam Sahib	1048	0	0	1048	220752	221800
Khanabad	4415	3825	476	8716	144784	153500
Kunduz City	6878	11	0	6889	290911	297800
Qalay-I-Zal	20	0	0	20	66280	66300
Total	15853	4684	476	21013	914587	935600

6.2 Agriculture exposure to landslide hazard

Agricultural land exposed to landslide hazard was basically calculated in the same way as for other element at risk. The landslide map was classified in 3 classes (high, moderate and low). The results were also calculated as the number of hectares. According to the result 39,256 hectare of agricultural lands (15% of the total) is exposed to landslide hazard, and the remaining 22, 8013 hectares are not exposed.

From the total agriculture lands expose to landslide hazard 9690 hectare (25% of the total agricultural land exposed to landslide hazard) is in the category of high landslide hazard, 216001 hectares (55%) is exposed to moderate landslide hazard and 7927 hectares (20%)to low landslide hazard. (See figure 9) Based on the landslide classes, agriculture exposure analysis, the different types of plant expose to landslide hazard calculated, among all the plants cultivated in Kunduz irrigated crops 2 and rainfall crop area having the highest exposure value to flood hazard and the rain fed crop sloping has the lowest exposure value in regard flood hazard. (See Table 4)

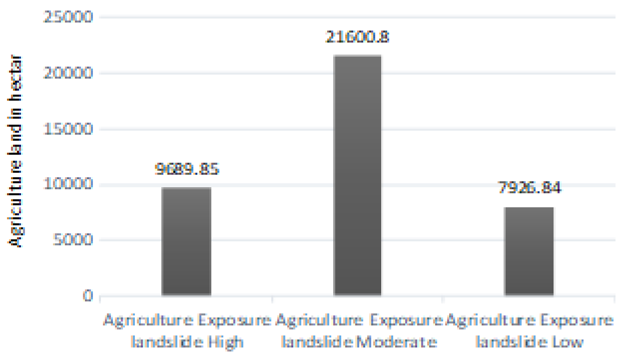

Figure 9; Agricultural land exposed to landslide hazard in hectares.

Table 4: Agricultural land exposed to landslide hazard by type of crop in hectares

Type	*AE landslide Low*	*AE landslide Moderate*	*AE landslide High*	*Total*
Gardens	1.35	0.18	0	1.53
Irrigated_1_crop	1214.55	160.65	0	1375.2
Irrigated_2_crops	516.15	41.31	0	557.46
Irrigated intermittently	122.04	10.35	0	132.39
Rain fed crops flat	3297.69	1041.48	19.8	4358.97
Rain fed crops sloping	2775.06	20346.8	9670.05	32792
Total in %	20%	55%	25%	100%
Total	7926.84	21600.8	9689.85	39217.5

Road exposure to landslide hazard

Road exposure to landslides was calculated by crossing the road network with the landslide hazard map. After that for each class of road (main roads and secondary roads) the number of pixels for each class was calculated. In order to find the length of roads exposed to landslide, the number of pixels were multiplied by 30 (pixel size is 30 by 30 meter) and recalculated into kilometers. (See table 5)

Table 5: Roads exposed to landslide hazard

Districts	*Main road low*	*Main road moderate*	*Main road high*	*Second road low*	*Second road moderate*	*Second road high*	*total road length in km*
Aliabad	1680	2700	570	9420	3840	1110	19.32
Chahar Dara	150	0	0	6570	5550	0	12.27
Dasht Archi	180	0	0	8580	9150	1230	19.14
Imam Sahib	5190	4500	0	9750	5160	0	24.66
Khanabad	270	2460	180	18060	42480	24270	87.72
Kunduz City	4170	2730	0	13680	2370	0	22.95
Qalay-I-Zal	0	0	0	5010	2580	0	7.59
Total in Meter	11640	12390	750	71070	71130	26610	193590
Total in Km	11.64	12.39	0.75	71.07	71.13	26.61	193.59

7. Conclusion

As most of the settlements in Kunduz province are located in flat area, the risk due to landslide hazard is not very serious. Though there are some settlements in Aliabad district in the south east of Kunduz province which may have a considerable risk to landslides, and also a second area with relatively high risk to landslides is located in the east of Khanabad district. The mentioned areas are sensitive for both settlements and the main road. Most of the settlements are located on flatter parts on alluvial fans and valley floors, and therefore they are not expected to experience major landslide problems in terms of landslide initiation, but rather for landslide runout. As the landslide susceptibility assessment was concentrating on the identification of potential initiation areas, and no runout modelling could be done over such large areas, the majority of the settlements in these mountainous areas are not located in the highest classes of landslide susceptibility. Future work should also take into account an analysis of landslide runout, but more information is needed for that. In case of the roads most parts of the main roads are located very close to steep slopes which can increase the risk of land slide hazard, the main road which connects Kunduz with Takhar province in the east and the rest of the country is very important and large parts of this road are running below steep slopes with high to moderate landslide hazards. Therefore, future work should concentrate on assessing the landslide hazard along this road in more detail.

Landslide risk assessment at this scale could be analyzed if more information is available on historical landslides and their location. Currently we only have information from landslide points that were digitized using digital image interpretation. These were mapped as points, and lack information on the date of occurrence. The points were used to validate the landslide susceptibility map. The landslide points which were mapped during inventory mapping were overlain with the landside susceptibility map. We found that the majority of the mapped landslide points (75%) were located in the high susceptibility class and 20% in the moderate class. Due to time problems only a limited number of landslide points could be digitized. However, as can be seen from some of the examples in Figure 10 there are severe landslide problems in this study area, and landslide features can be well recognized on the high resolution images.

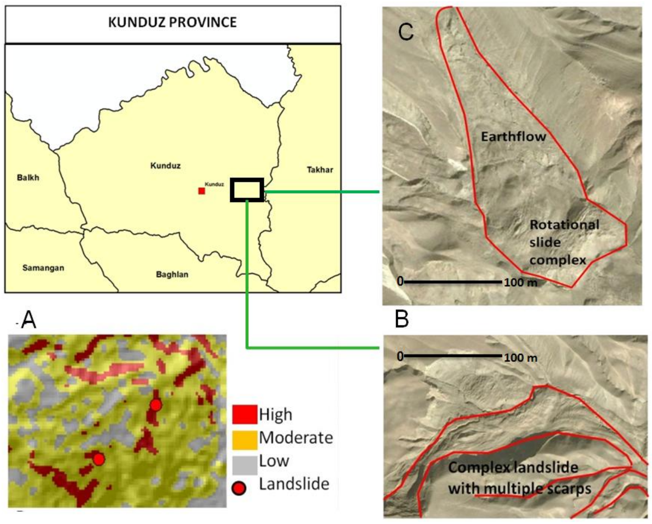

Figure 10; A) Example of the comparison of the landslide susceptibility map with mapped landslide points. B) Example of a complex landslide with many scarps and individual components. C) Example of an earthflow starting as a rotational landslide.

To estimate landslide risk, we would need to calculate the density of landslide within the three susceptibility classes in order to get an estimation of the spatial probability. If these landslides are also of a particular time period, we could then also attach a value of temporal probability. Due to the unavailability of multi-temporal landslide data this was not possible to do in this study.

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Author Profile

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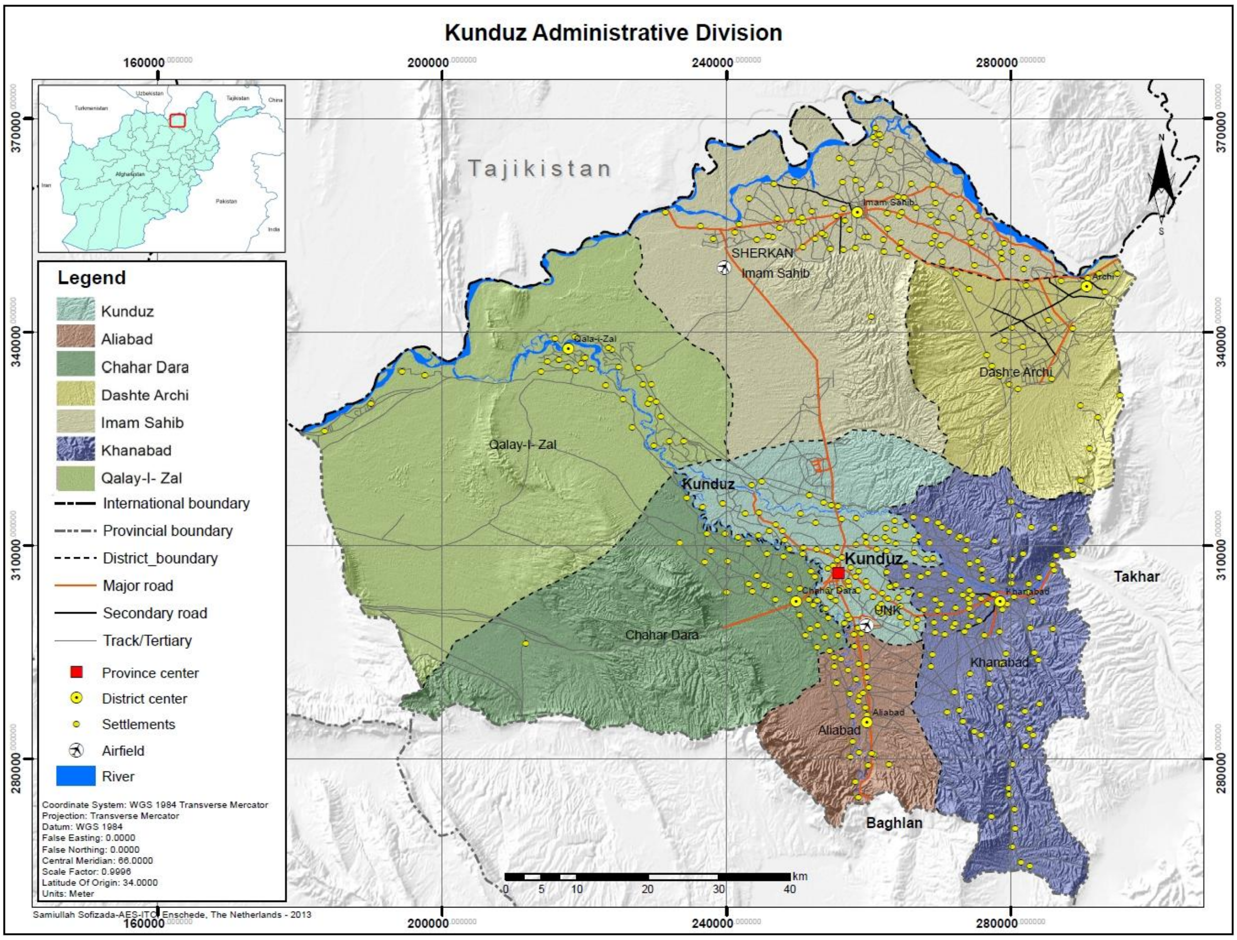
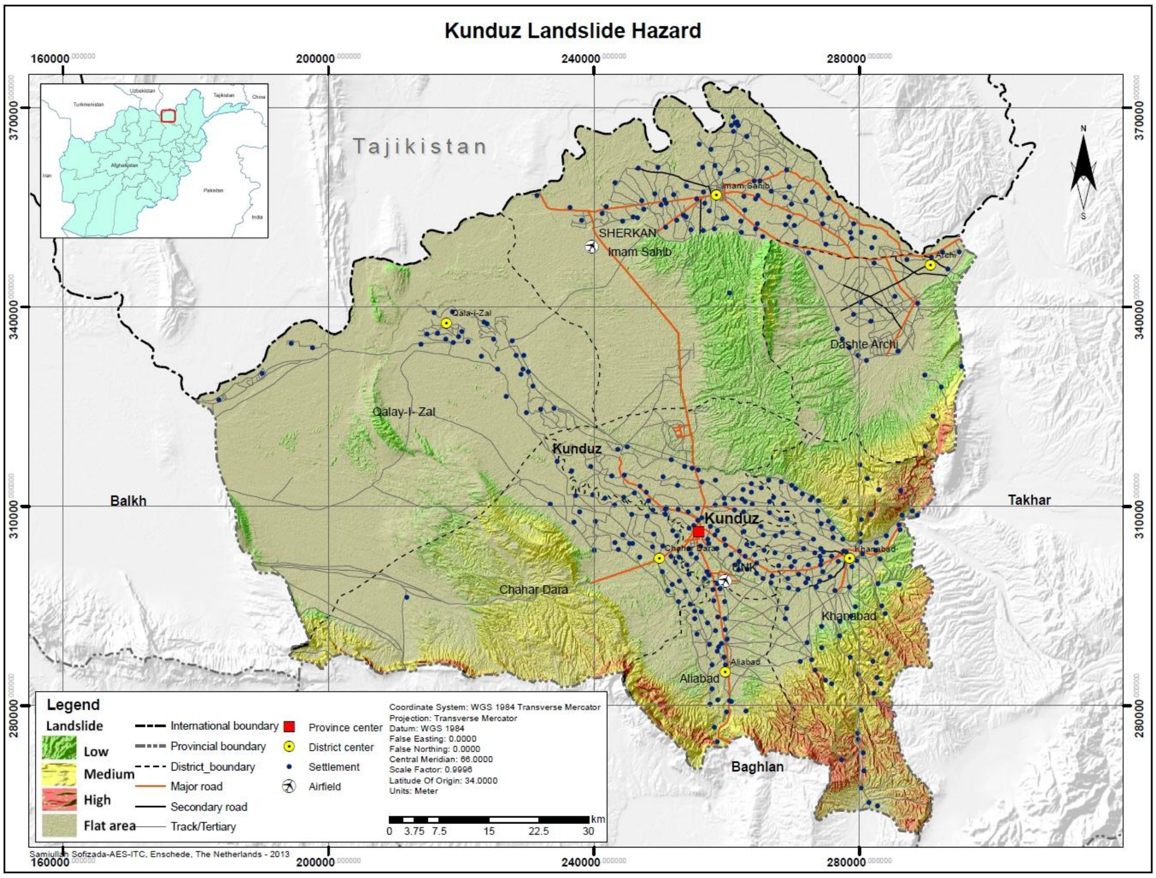


Annex 1; Administrative Map of Kunduz Province



Annex 2; Landslide susceptibility map of Kunduz province