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Assessment of Interaction Between Natural Hazards and Landuse Change in Uzungöl (Trabzon-Turkey) and Its Close Vicinity

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Abstract

Uzungöl is an important destination in Turkey for nature tourism and was declared a Nature Conservation Park in 1989. Uzungöl has been disturbed by various natural hazards due to its heterogeneous meteorological, geological and topographical conditions. The site has also been under serious threats due to recent increase in construction activities around the Lake Uzungöl. New settlements have also become subject to various natural hazards including snow avalanches, landslides, and rockfalls. The present study aims to illustrate the spatio-temporal change of landuse during the last 60 years in Uzungöl and its close vicinity and to understand its interaction with natural hazards. In order to assess landuse change, a time series of aerial images (1955, 1986, and 2015) have been used. All aerial images, obtained from Turkish General Command of Mapping, were co-registered in the same coordinate system; i.e. European Datum 1950. Following the co-registration of the aerial images, landuse types were mapped by digitizing in ArcGIS software. Since aerial imageries have high resolutions, all buildings could be individually mapped. Dense construction activities around the lake was clearly monitored from aerial imageries during the time series. Additionally, spatial changes in and around the lake have been determined. The assessment of interactions between natural hazards and landuse change could only be evaluated by overlapping snow avalanche hazard zones and buildings in the area.

Key words: Aerial images, Landuse change, Natural hazards, Natural park, Uzungöl

1. Introduction

Environmental events become natural hazards once they adversely threaten to affect the society and/or the environment. Most of them occur in remote sites and are rapidly forgotten. Indeed, until Homo sapiens begin to appear on the Earth, many geophysical events such as earthquakes, volcanic eruptions, mass movements (including avalanches), and/or flooding were only phenomena threatening the prevailing flora and fauna [1]. Today, natural hazards are highly associated with human-beings. Even though natural hazards have occurred throughout history, their recent impacts have been increasingly devastating. Especially mountainous regions are more subject to a variety of hazardous processes. The people who inhabit mountainous regions live in the face of various hazards and risks. Most mountainous areas are subject to not only single hazardous event but also multiple hazardous events. Mountains more frequently suffer from destructive natural processes than other sites. Because mountainous regions are relatively active geo-physically and hydrologically, and they are biologically diverse by virtue of an altitude – and aspect –driven variability in energy and moisture [2]. In addition to relief and geology, human activity can also have contributory influences over the impacts of hazards. Destruction of mountain forests, improper land use such as inappropriate agricultural practices can accelerate erosion and increase the risk of landslide, floods, and avalanches. Human activities, for instance the construction of roads, reservoirs and dams as well as mining activities increased the intensity and frequency of rock falls, landslides and debris flows [3]. In addition, progressive increase in demand for human settlements in exposed areas exacerbate risks of various categories of losses [4].

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Uzungöl, located in the Çaykara District of City of Trabzon, is a prominent nature and tourism destination in the eastern Black Sea Region of Turkey. Due to its rich plant and wildlife diversity and sightseeing potential, many domestic and foreign tourists visit the area. The surrounding spruce forests together with the lake present an attractive landscape. Hence, Uzungöl was declared a Nature Conservation Park in 1989 by the Ministry of Forestry. In addition, it was declared a "Tourism center" in 1990 and also a "Special Environmental Protection Area" in 2004 according to the decision of the Council of Ministers [5]. Dramatic increases in construction activities for additional highland settlements and touristic facilities around the lake Uzungöl have posed significant threats. [5] carried out a study for examining the size and stages of construction using 1973-2002 aerial photographs in the scale of 1/23000 and 1/16000 and base map of 2008. The study showed that the region has undergone a spree of construction between 1973-2008 (i.e. 35 years) [5]. A sharp increase in the number of buildings (91%) concentrated in a part of the watershed protection area around the lake has been identified. It was clearly indicated that, Uzungöl has been going through an unplanned development period. This increase in the housing in Uzungöl gained speed after 1980s when it has been subject to tourism. In 2005, 92348 domestic and 1790 foreign tourists stopped by and approximately 60000 people visited the site daily [5]. From 2005 to 2009, the number of domestic tourists and foreign tourists visiting the region increased by 69% and 290%, respectively. While total bed capacity of hotels, motels, and pensions in the region was 1191 for 2009 [5], it increased to 5646 in 2017, according to data obtained from Çaykara Municipality.

In addition, Uzungöl has been experiencing natural hazards due to its heterogeneous meteorological, geological and topographical conditions. First of all, the lake was formed by a historical landslide. The cone of lake was formed by the rocks that had been carried by very short streams from the large quantities of weathering products which was deposited in the steep slopes in the south of the lake [6]. Moreover, Trabzon is one of cities where landslide events are common. Even though there is no up to date records of new landslides for Çaykara, such as landslide events occurred in 2010, 2016, and 2017 in Çaykara (learnt from websites of local newspaper), in the landslide inventory database generated by the General Directorate of Mineral Research and Exploration, landslides have been important hazard for Uzungöl. In addition, rock falls and snow avalanches have created huge threats for the site. Unfortunately, there are no proper records on falling rocks in Uzungöl. In terms of snow avalanches, a snow avalanche hazard monitoring map in the scale of 1/25 000, generated through a project by the General Directorate of Combatting Desertification and Erosion (ÇEM) is available. According to this hazard indication map, Uzungöl has been under serious avalanche risk.

In the present study, the spatio-temporal landuse change during the last 60 years was assessed, and its interaction with natural hazards in Uzungöl and its close vicinity was evaluated. A time series of aerial imageries (1955, 1986, and 2015) were used to assess landuse change. Since aerial imageries obtained had high resolutions, all buildings could be individually mapped. Dense construction activities around the lake was clearly monitored from aerial images in the time series. Additionally, a spatial change in the lake was determined. The assessment of interactions between natural hazards and landuse change could only be evaluated by overlapping snow avalanche hazard zones and buildings in the area.

2. Materials and Method

2.1. Study Area

The study area, covering 2106 ha, is the Lake Uzungöl and its close vicinity (Figure 1). The upper left coordinates are 607068, 449859, and the bottom right coordinates are 613807, 4493785 in ED1950 UTM Zone 37. The border of the study area, a catchment, was determined based on snow avalanches threatening Uzungöl.

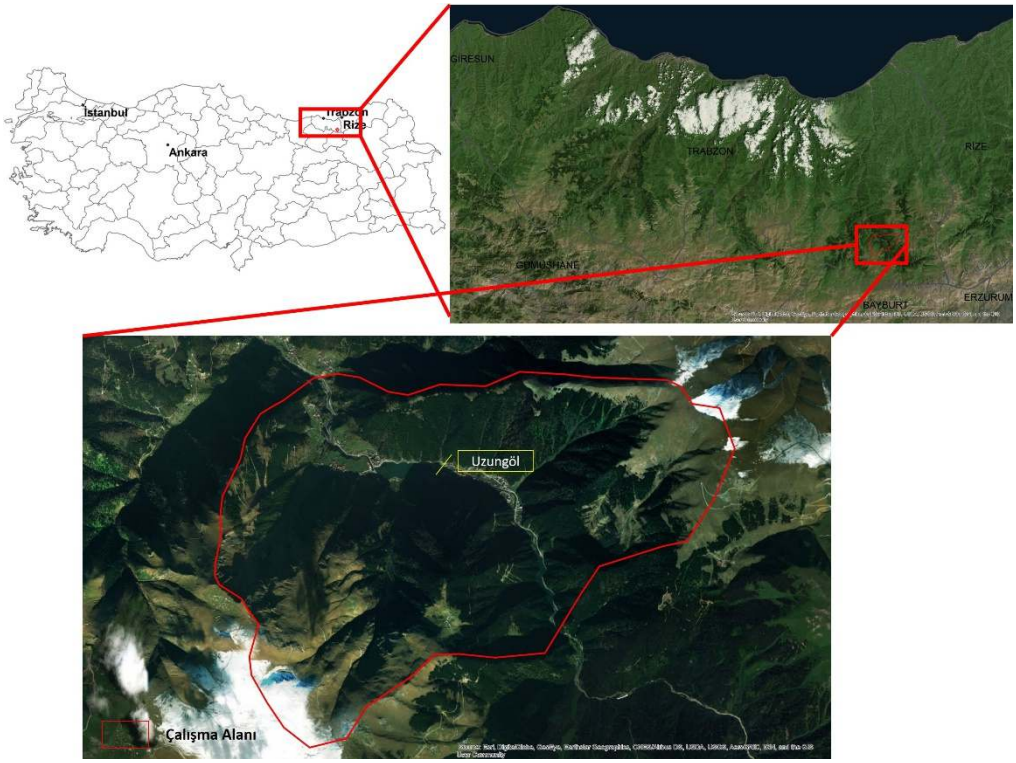

Figure 1. Location of study area

2.2. Available Data and Applications

In order to evaluate the change in the landuse in Uzungöl and its close vicinity during the last 60 years, aerial imageries from 1955, 1986 and 2015 were obtained from the Turkish General Command of Mapping (HGK). For this study area selected, only one scanned black and white aerial imagery in the scale of 1:40 000 (Figure 2) for 1955, 8 scanned black and white aerial imageries in the scale of 1:16 000 (Figure 3) for 1986, and 12 aerial digital color imageries that have 30 cm ground sampling distance (Figure 4) for 2015, were obtained. All aerial imageries were then georeferenced in the projected coordinate system of ED1950 UTM Zone 37 by correcting geometrically in ArcGIS 10.3. Landuse types were digitized based on the aerial imageries, and database was created by classifying landuse types as forest, agriculture, pasture, settlement, open forest and water in six classes. Additionally, road network and buildings were digitized, and database was created from the georeferenced imageries for each year of the data. Then, areal change

in landuse types and number of buildings were evaluated between time series of data. All applications were carried out by using ArcGIS 10.3. Buildings and snow avalanche hazard zones were then overlapped in order to determine how many buildings are located in the hazardous zones in terms of snow avalanches because only snow avalanche hazard indication map obtained from ÇEM is available in the study area (Figure 5).

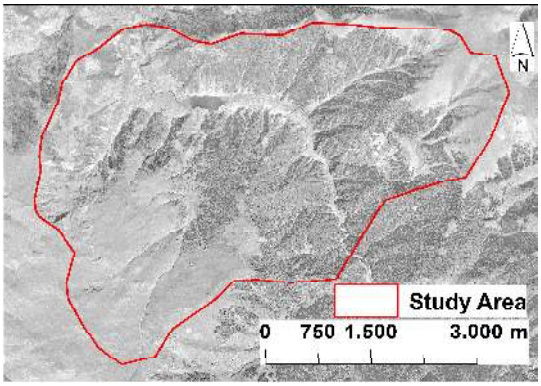

Figure 2. Aerial imagery of 1955

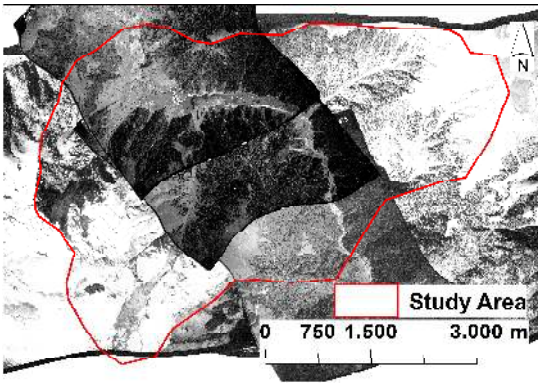

Figure 3. Aerial imagery of 1986

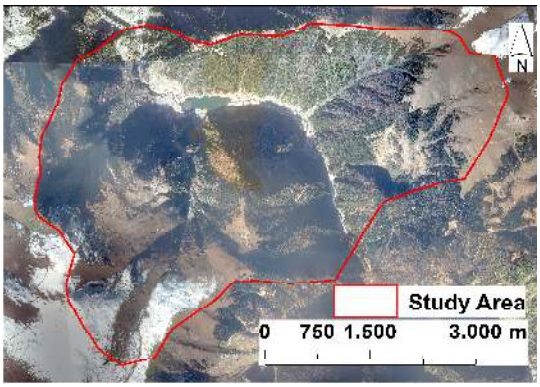

Figure 4. Aerial imagery of 2015

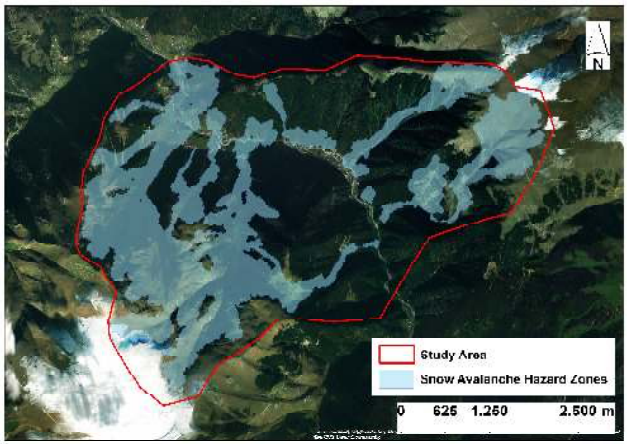

Figure 5. Snow avalanche hazard zones

3. Results and Discussion

Landuse maps generated are given in Figure 6. Area of each landuse types for each year were provided in Figure 7 and Table 1. According to landuse maps generated, area of settlement increased significantly. While this increase was 5.7% between 1955 and 1986, 207.5% between 1986 and 2015. The settlement development occurred mostly around the lake especially following the declaration of the areas as "Tourism center" in 1990. While the area of settlement increased, most significant decrease appeared in agricultural area. In addition, open forest area showed a decrease between the time series evaluated; this was due to increase in the forested areas but not due to increase in the settlement.

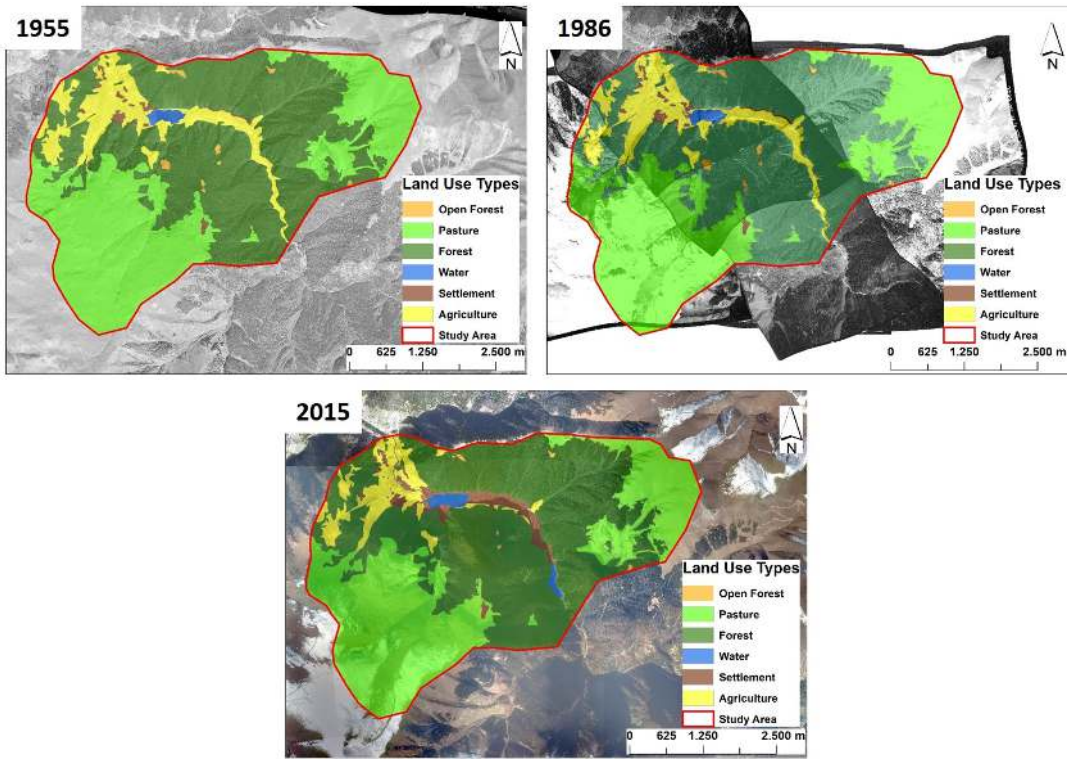

Figure 6. Landuse maps of the study area

Table 1. Area of landuse types for each year of data

Land Use Types	Area (Ha) in Each Year		
	1955	1986	2015
Open Forest	8.53	8.39	3.16
Pasture	802.85	801.68	791.97
Forest	1064.19	1064.03	1097.58
Water	11.91	11.91	19.32
Settlement	21.79	23.05	70.87
Agriculture	204.58	204.79	130.95

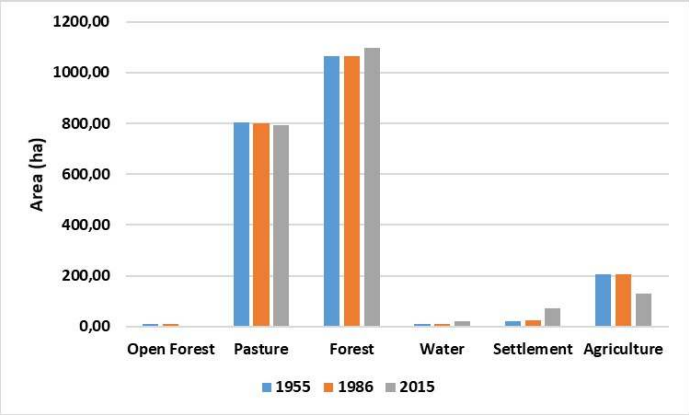

Figure 7. Areal change graphs of landuse types for each year of data

In the present study, buildings were also digitized for each year from aerial imageries (Figure 8). According to this, there were 334 buildings in 1955, 428 buildings in 1986, and 636 buildings in 2015 in the area. While the increase in amounts of buildings between 1955 and 1986 was 28%, the increase between 1986 and 2015 amounted to 49%. A similar significant increase in the amounts of buildings (i.e. 91%) between 1973-2008 (i.e. 35 years) has also been reported [5]. In the area, 11 of all buildings in 1955 had not existed in 1986. In total, 117 new buildings were constructed between 1955 and 1986. Between 1986 and 2015, amount of constructed building was 304, which means that 94 of buildings in 1986 had not existed in 2015. While the length of motor road was 3,7 km in 1955, it increased to 21.8 km in 1986 and 40.9 km in 2015. Road network in the study area increased depending on development in the settlement (Figure 9). In addition, while there was no change between 1955 and 1986, the area of lake increased (about 2 hectares) between 1986 and 2015.

In addition, snow avalanche hazard indication map of the area was used to to evaluate the situation of settlements in terms of avalanche hazards by overlapping with buildings in the study area. According to snow avalanche hazard indication map, 861.27 ha of study area (2106 ha), which is equal to 41% of the total area, was located within the snow avalanche hazard zone. According to the results of buildings overlapped with the snow avalanche hazard zones, 140 of 334 buildings in 1955, 199 of 428 buildings in 1986, and 370 of 636 buildings in 2015 were located in the snow avalanche hazard zones (Figure 10).

Conclusions

As a result of uncontrolled development in settlements due to highland and lake tourism in Uzungöl and its close vicinity in recent years, various environmental and socio-economic issues have occurred. This development has especially played a role in the change of the land use. The region has already been under threats from natural hazards including snow avalanches, landslides, rock falls, and floods, due to its mountainous topography. Understanding spatio-temporal changes in land use helps make better decisions in the management of natural hazards/disasters. Nevertheless, natural hazards have not been taken in consideration in the planning the settlement. This study aimed to monitor landuse change in Uzungöl during 60 years (1955-2015), taking into account of the characteristics in the past.

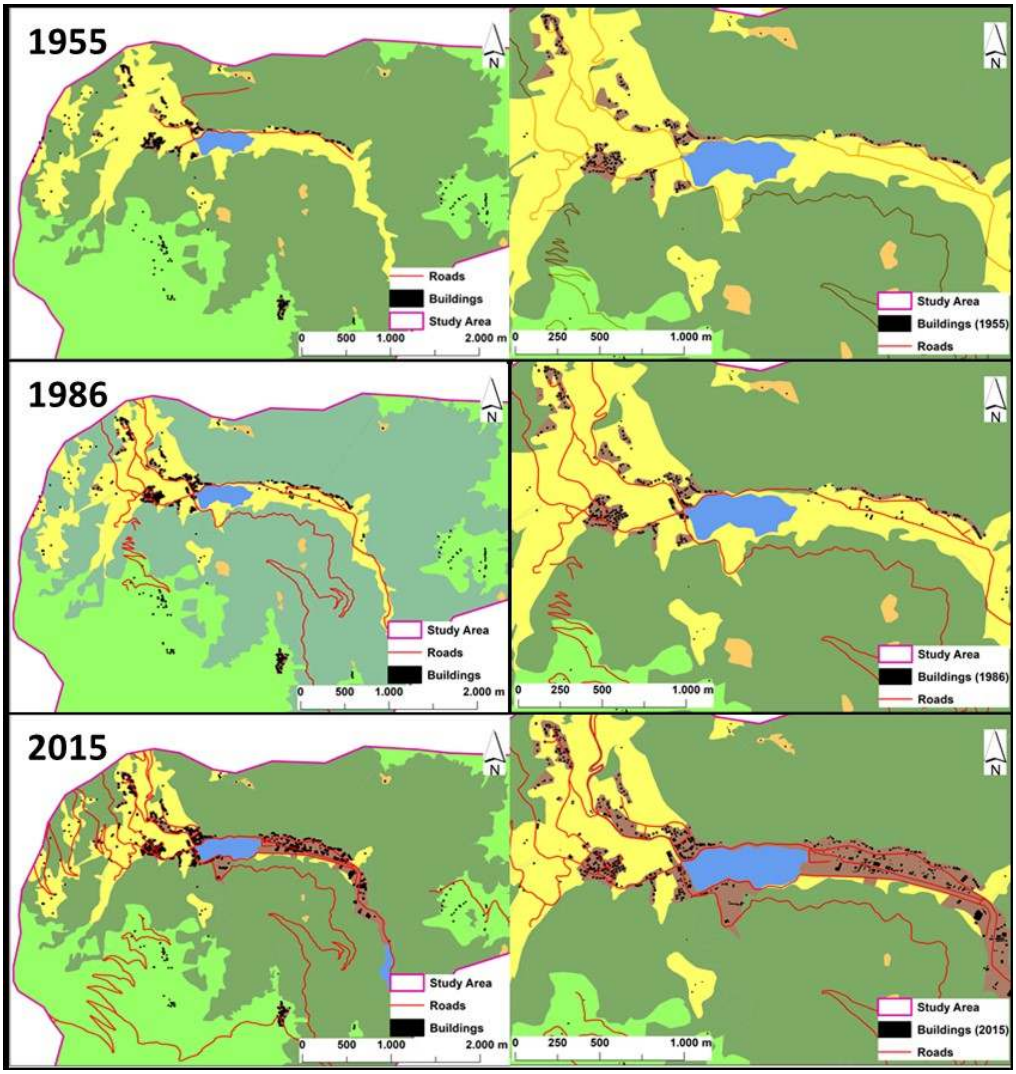

Figure 8. Buildings and roads in the area digitized for 2015

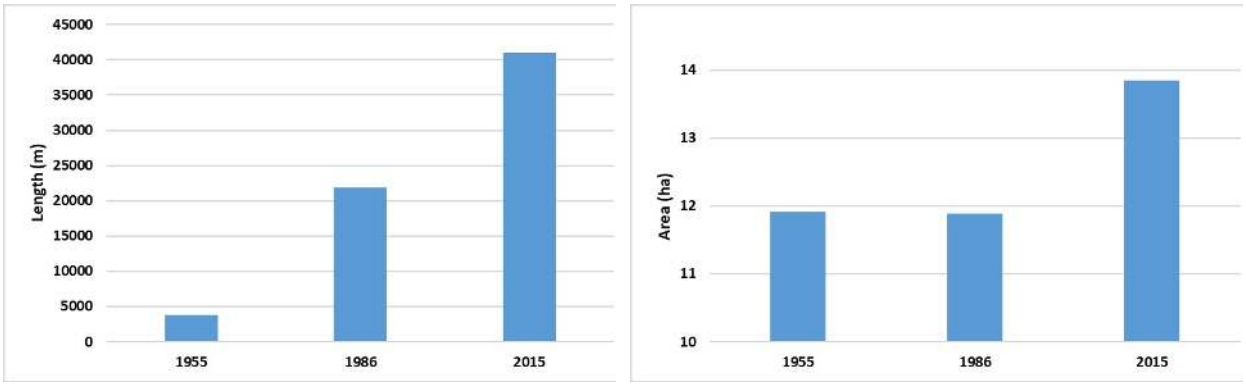

Figure 9 Road lengths (left) and area of lake Uzungöl (right)

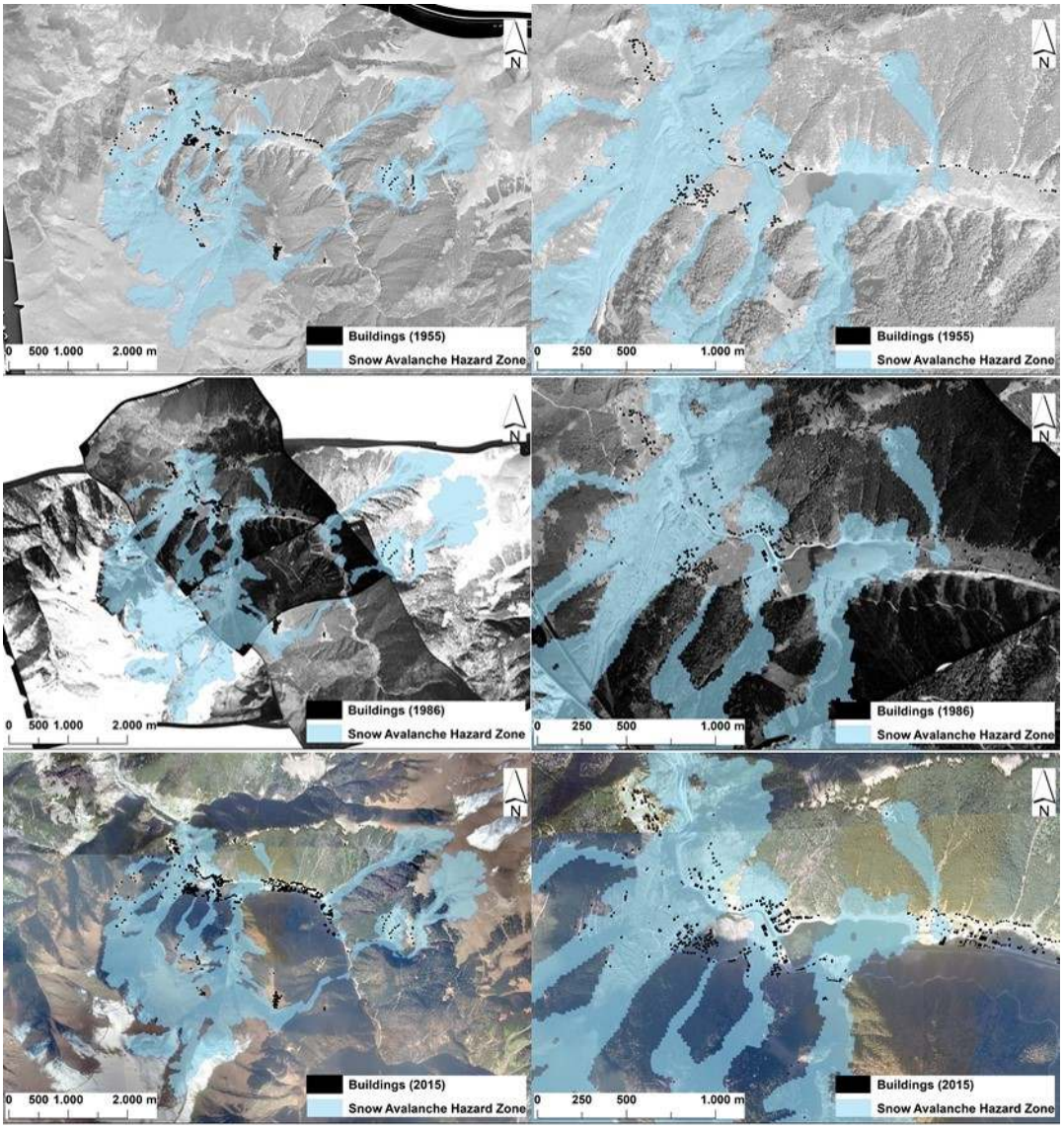

Figure 10. Buildings overlapped with snow avalanche hazard zones

Remote sensing data available for Uzungöl and its close vicinity allowed to observe both change of landuse and increase in the amount of buildings constructed especially following the declaration of the area as a tourism center. This showed that an important increase in construction (mostly hotels, motels and pensions) in the area especially around the lake. According to data obtained from Çaykara municipality, total 5446 beds existed in all hotels and hostels in 2017. In the present study, distinguishing between building types (e.g. hotels vs. hostels) on the map was not possible. Most significant change in settlement area appeared especially between 1986 and 2015. The area of settlement increased 207,5% during the last 20 years between 1986 and 2015. Accordingly, most decrease was observed in the area of agriculture, which was already limited.

Additionally, existence of snow avalanche hazard indication map of the study area allowed to evaluate how increase growth of buildings in terms of avalanche hazard. Unfortunately, due to the

absence of the data for other natural hazards such as landslide, rock fall and floods, an evaluation of increase in the buildings could not be carried out. Snow avalanche hazard indication map showed that 41% of total area is under avalanche hazard. The overlapping analysis showed a significant increase in the amount of buildings located within the hazardous areas during the time series. Since Uzungöl and its close vicinity are subject to many natural hazards, a comprehensive study which aims to 1) present how landuse change from the past to present, 2) simulate how landuse change is going to change in the next 5, 10, 20 etc. and 3) allow to evaluate interactions of these changes with multiple natural hazards that threaten the region, such as snow avalanches, landslides, rockfalls, and floods, will help make the local managers better decisions in the planning of land use in Uzungöl.

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