Historical development and future outlook of the avalanche hazard potential of residential areas in the Lake Uzungöl (Eastern Black Sea Region of Turkey) between 2004 and 2050

Abdurrahim Aydın[1], Remzi Eker[1*] and Yalçın Sefer[2]

[1] *Düzce University, Faculty of Forestry, Remote Sensing & GIS Laboratory, Düzce, TURKEY*
[2] *Düzce University, Institute of Natural and Applied Sciences, Düzce, TURKEY*
**Corresponding author, e-mail: remzieker@duzce.edu.tr*

ABSTRACT

The Lake Uzungöl is an important nature tourism area in Turkey and has been declared as a Nature Conservation Park in 1989. The lake areas has continued to face remarkable land use changes in the last decades. The area also suffers from snow avalanches due to its mountainous topography. In the present study, the historical development of residential areas (i.e. from 1955 to 2015) were evaluated using aerial photographs. The Dyna-CLUE model was applied to simulate land use changes between 2004 and 2050. The model was calibrated for yearly changes from 2004 to 2015, and then future projections were created based on the historical development trends of the residential areas. Residential area has increased significantly, especially since 2004. While the residential area increased from 57.35 ha to 108.38 ha between 1955 and 2015, the areas under potential snow avalanche hazard increased from 16.3 ha to 42.3 ha between 1955 and 2015. The projected land use change by Dyna-CLUE model showed that while the residential areas in 2030 were 138.0 ha (86.5 ha under avalanche hazard), those in 2050 increased to 202.3 ha (126.3 ha under avalanche hazard).

1. INTRODUCTION

The Lake Uzungöl, located in the Çaykara District of province 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 lake and the surrounding oriental spruce [Picea orientalis (L.) Link] forests present the visitors an attractive landscape. Hence, the Lake Uzungöl was declared as a "Nature Conservation Park" in 1989 by the Ministry of Forestry, a "Tourism center" in 1990, and a "Special Environmental Protection Area" in 2004 by the the Boards of Ministers (Atasoy, 2010). This region has however continued to face remarkable land use changes in the last decades due to many reasons including socio-economic, environmental, and societal changes (Piazza, 2016). The historical shift from agricultural-based society to the service-based society in the region has played an important role in the sharp change of the land use. This dramatic change in land use has occurred since 2004. However, the Lake Uzungöl has been experiencing severe natural hazards due to its heterogeneous meteorological, geological and topographical features. First of all, the lake has been formed by a historical landslide. A snow avalanche hazard indication map in the scale of 1/25 000, generated through a project by the General Directorate of Combatting Desertification and Erosion (ÇEM) is also available (Aydın et al. 2018). According to the snow avalanche hazard indication map, 3239 ha of the project area, which is the 42% of the total area, was located within the snow avalanche hazard zone. The present study aimed to evaluate both historical development and the future outlook of the residential area in the Lake Uzungöl using aerial imageries and dynamic land use change model, entitled Dyna-CLUE.

2. DATA AND MODEL SETUP

The study area covers 7690.5 ha in the Lake Uzungöl and its close vicinity (Figure 1). In order to evaluate historical development in the land use in the area, aerial imageries from 1955, 2004 and 2015 (during the last 60 years), were obtained from the Turkish General Command of Mapping (HGK). 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 as six classes in total. Additionally, areal change in landuse types was assessed for time series of the data. The spatial model of land use change were setup for analysing the possible trajectories of land use change in the future (between 2004 and 2050). For this aim, the Dyna-CLUE, a recent version (Verburg and Overmars, 2009) of the conversion of land use and its effects framework (CLUE model) developed by Tom Veldkamp and Louise Fresco in 1996, were employed. Both historical and future landuse maps were then overlapped with digitized snow avalanche hazard indication map, to evaluate interaction of landuse change with snow avalanche hazard (Figure 1).

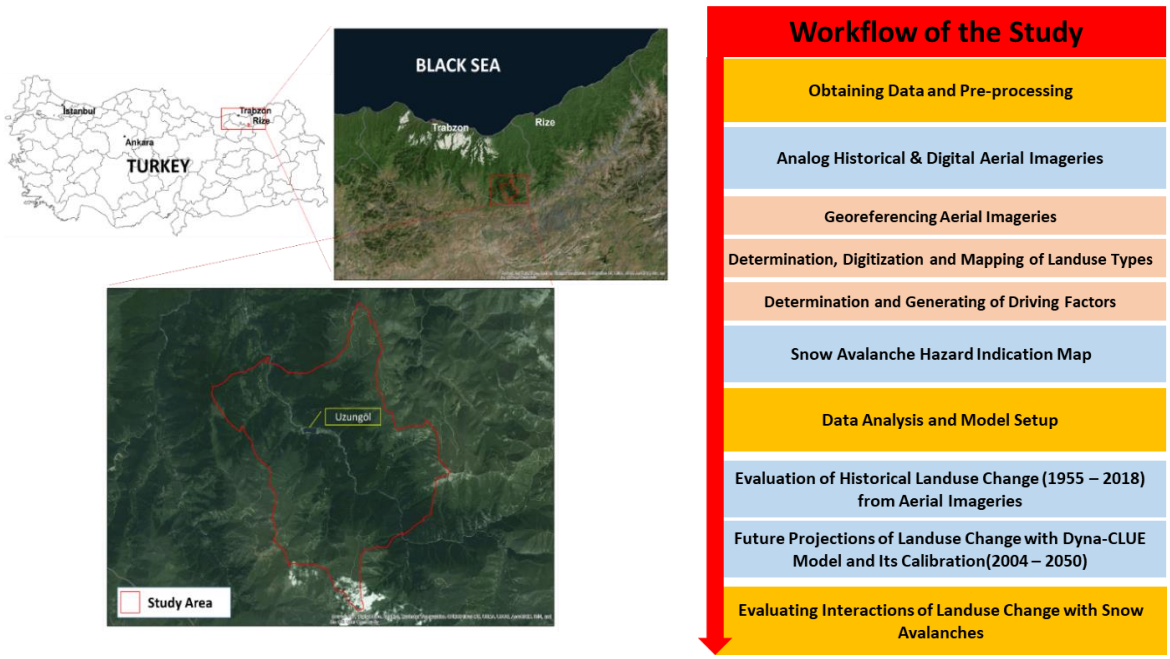

Figure 1 Location of study area (left) and workflow of the study (right).

3. RESULTS

Landuse maps generated for the years of 1955, 2004, and 2015 from aerial imageries were given in Figure 2. The areal size of landuse types determined is given in Table 1. In the study area, forested area covers the largest land use type whereas settlements covers the smallest area. This is mostly due to the fact that the area is located in the eastern Black Sea Region of Turkey. The evaluation of the historical development of residential areas revealed that the residential area increased significantly. While residential area covered 57.35 ha in 1955, it increased to 108.38 ha in 2015. The pace of the increase in the residential area accelerated after 2004 due to the upsurge in the constructions of hotels and pensions in the vicinity of the lake. While the growth rate of residential area for the period of 1955-2004 was 0.24 ha/year, it increased by almost 15-times (i.e. 3.57 ha/year) between 2004 and 2015. The Dyna-CLUE model was setup for the period of 2004 and 2015 for the study, and then calibrated based on the 2015 data. Following model calibration, landuse simulations between 2004 and 2050 were carried out for the future outlook of landuse change (Figure 2).

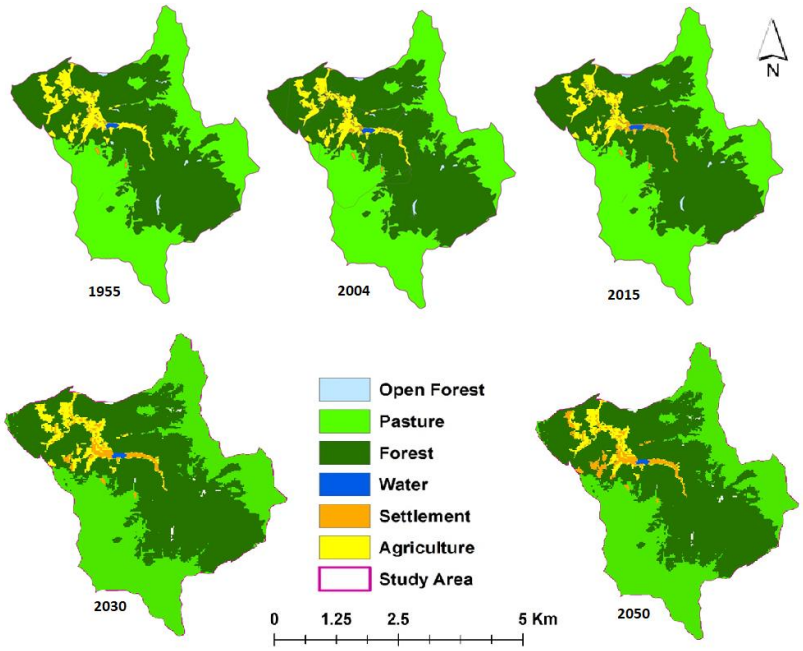

Figure 2 Landuse maps of 1955, 2004, and 2015.

The agricultural area appeared to decrease by 15% between 2015 and 2030, whereas the residential area increased by 63.7% for the same period (Table 1). The projections revealed that in the 20 years between 2030 and 2050, the residential areas increased by 47% while the agricultural areas decreased by 24.1%. In the region, snow avalanche hazard seems to be prevailing in the future as has been in the past. 53% (16.25 ha) of the total residential area (30.5 ha) in 1955 were subject the threat of avalanche. With the increase in growth pace of residential area especially after 2015, a greater area will be endangered by snow avalanches. In 2030, 66% (87 ha) of the residential areas will be under snow avalanche hazard. In the year 2050, this ratio will increase dramatically, and 62% (126.3 ha) of the total settlements (203.8 ha) will be threatened by potential avalanches. Simulation results and landuse maps given in Table 1 and Figure 3 respectively.

Table 1 Areas of landuse types in the study area.

	Year	Open Forest (ha)	Pasture (ha)	Forest (ha)	Water (ha)	Settlement (ha)	Agriculture (ha)	Total (ha)
Actual	1955	32.45	3194.36	3954.35	11.82	57.35	440.33	7690
	2004	26.57	3173.94	4016.95	11.82	69.14	392.24	7690
	2015	**20.95**	**3147.93**	**4055.49**	**13.99**	**108.38**	**343.92**	**7690**
Simulation	**2015**	**19.3**	**3174.8**	**4045.8**	**12.5**	**138.0**	**353.5**	**7690**
	2030	19.3	3174.0	4046.5	12.5	138.0	299.8	7690
	2050	21.8	3177.5	4048.5	12.5	202.3	227.5	7690

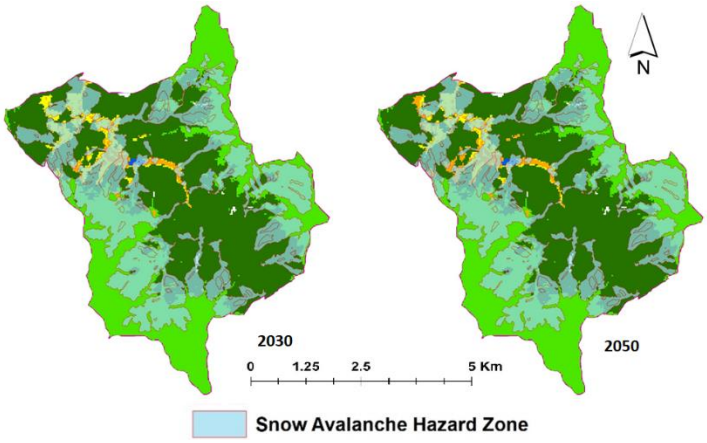

Figure 3 Landuse maps of 2030 and 2050 overlapped with snow avalanche hazard zones.

4. CONCLUSIONS

The Lake Uzungöl with the statues of Tourism Center since 1990 and Special Environmental Protection Area" since 2004 has undergone dramatic land use changes in the last decades. The region also suffers from snow avalanches due to its mountainous topography. The aim was to find out an answer the question of what if the uncontrolled growth of residential areas continues as similar as in the past, how land use change will occur in the future (up to 2050), and how its interactions with snow avalanche hazard will change. For this aim historical aerial imageries were used. Also, Dyna-CLUE model was successfully set up for future projections. Depending on the model, interactions of growth of residential area with snow avalanche hazard were evaluated.

ACKNOWLEDGEMENT

This study was supported by Turkish Scientific and Technical Research Council –TÜBİTAK (Project Number: 117O929).

REFERENCES

Atasoy M. 2010. Monitoring land use changes in tourism centers with GIS: Uzungöl case study. Scientific Research and Essays, 5(8), 790–798.

Aydın, A., Sefer, Y., Eker, R. Assessment of interaction between natural hazards and landuse change in Uzungöl (Trabzon-Turkey) and its close vicinity. In proceeding of 2ND International Symposium on Natural Hazards and Disaster Management (ISHAD2018), Sakarya, Turkey, May 04–06, 2018, pp. 151–159.

Piazza, G. 2016. Influence of land-use dynamics on natural-hazard exposure. Master Thesis, Department of Civil Engineering and Natural Hazards, Institute of Mountain Risk Engineering (IAN), University of Natural Resources and Applied Life Sciences, Vienna, Austria, pp. 112.

Verburg, P.H., Overmars, K.P. 2009. Combining top-down and bottom-up dynamics in land use modeling: exploring the future of abandoned farmlands in Europe with the Dyna-CLUE model. Landscape Eco, 24, 1167–1181.