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EVALUATION OF DENIZLI SKI CENTRE IN TERMS OF AVALANCHE SUSCEPTIBILITY

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ABSTRACT

Avalanches, which occur in areas far from settlements and where the human population is relatively less, have started to occur more frequently and cause more loss of life and property due to the increasing human population, the gradual expansion of settlements and road networks, and the increasing interest in ski resorts, nature sports and winter tourism. Avalanches, which can reach speeds of up to 400 kilometres per hour, occur very suddenly and most people cannot escape. Today, it is not possible to change the nature of avalanches and prevent avalanches. In order to prevent damages caused by avalanches, it is necessary to prepare potential avalanche susceptibility maps. In this way, dangerous areas can be identified and it will be possible to predict, prevent and reduce the impact of avalanches. In this study, it was aimed to evaluate Denizli Ski Centre and its immediate surroundings in terms of avalanche susceptibility. For this purpose, Geographical Information Systems programme was used and land use, elevation, slope slope, aspect and slope shape parameters were used for avalanche susceptibility analysis and potential source areas for avalanche development were determined. After this stage, areas with high, medium and low avalanche susceptibility were determined by using Conefall software. Thus, it is aimed to make healthier planning for decision makers and local administrations by making use of susceptibility maps for Denizli Ski Resort and to reveal areas with high, medium and low avalanche safety in terms of runways, roads and ski facilities.

1. INTRODUCTION

Avalanche is a natural hazard that occurs in mountainous regions of middle and high latitudes and threatens settlements, transport and human structures in these areas. In our country, factors such as rapid population growth, rapid development of transport networks, decrease in forest areas, expansion of settlements have caused an increase in the number of structures and living things damaged by avalanches. Sloping slopes and ski slopes where winter sports, which have become popular in recent years, are favourable environmental conditions for avalanche events. Touristic facilities in these regions also face the same danger [3]. The 2009 avalanche disaster in Gümüşhane-Zigana, which resulted in the death of 11 people, is due to the increasing interest in winter sports, and the possibility of similar events in the future is increasing every year. It has been reported that there is an average of 250 deaths due to avalanches worldwide every year, this number is around 100 in Europe, and the number of people killed and injured in our country is 26 on average per year [1,12].

The concept of susceptibility is defined as the relative classification of the regions where the disaster is likely to develop in the future as a result of the analyses made by considering the variables that are thought to be effective in the formation of the disaster [4]. Avalanche susceptibility maps are an important step to prevent loss of life and property. Controlling natural disasters is a national task of paramount importance to ensure maximum safety through sustainable strategies for integrated risk management of natural disasters in mountainous catchments [9]. The priority in risk assessment is to be able to predict the hazards that may occur. Before the preparation of avalanche hazard maps, avalanche-susceptibility areas with avalanche hazards should be mapped. Geographic Information Systems (GIS) applications are frequently used in determining risk levels. The purpose of use is to determine the planning and development processes to minimise the damage in case of avalanche.

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The main factors affecting avalanche formation can be divided into four groups as meteorological conditions, topographical conditions, snow layer structure and natural-artificial triggers. Meteorological conditions depend on factors such as precipitation, wind, temperature and sunshine-cloudiness, while topographical conditions are the slope, aspect, height above sea level and slope type. The high number of variables causing avalanche formation makes the prediction of the onset of avalanches difficult and far from precise [7].

In this study, avalanche susceptibility maps were prepared for Denizli Ski Resort and its immediate surroundings by using GIS software and Conefall software. Elevation, slope, aspect, slope shape, land use and vegetation parameters of the region were used as the main criteria in the creation of susceptibility map models.

2. STUDY AREA

Denizli Ski Resort, the largest ski resort in the Aegean Region, is located within the borders of Nikfer Quarter of Tavas District, Denizli Province (Figure 1). It is 85 km to the centre of Denizli, 39 km to Tavas District and 14 km to Nikfer Quarter. Located at an altitude of 2420 metres in Bozdağ, Denizli Ski Resort serves under Denizli Metropolitan Municipality. There are 2 chairlifts, 1 chairlift and a walking belt in the facility, the longest of which is 1700 metres, and there are 3 facilities of 1500 metres and 700 metres. The facility lines with a total length of 3950 metres have a capacity of 2700 person/hour. The centre, which is located in the transition zone between sea and land in terms of climate, has an advantageous structure in terms of winter sports due to its low fog and low wind [10].

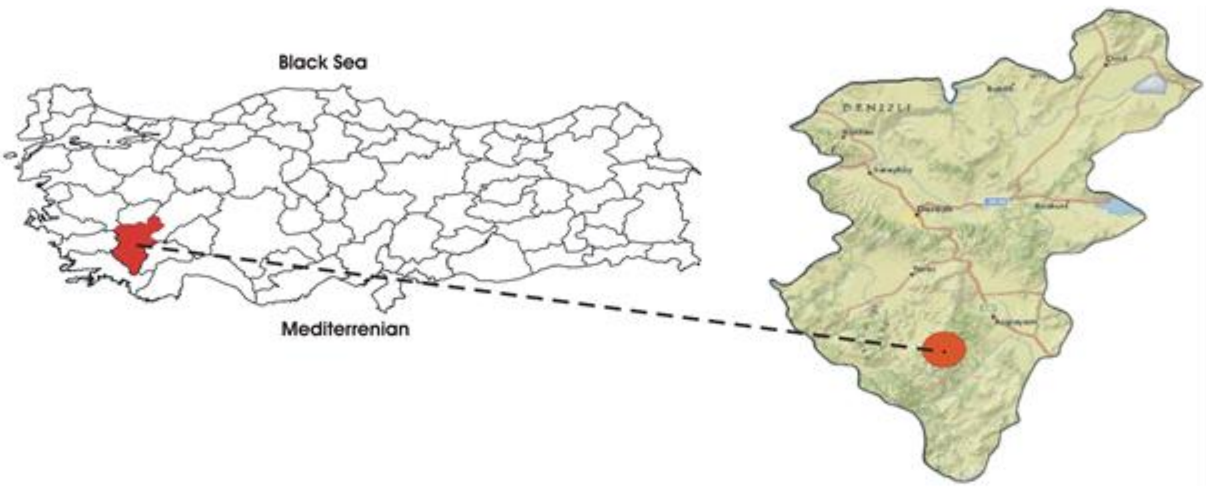

Fig. 1. Denizli ski centre location map

3. MATERIAL AND METHOD

GIS is one of the most frequently used models to eliminate the negative effects of avalanches. Avalanche susceptibility maps correspond to the principle of spatial prediction of areas with similar preparatory conditions, which are made by taking into account the parameters that are thought to be effective in their formation. In other words, they are maps that predict where avalanches may occur within the study area [2]. In such studies, GIS offers significant advantages as it enables to create a database, update the database and perform technical analyses.

In the past, the parameters that are effective in avalanche formation can be classified into separate layers in the GIS programme and these parameters can be given points according to their effect on avalanche formation. Then, all these parameters can be analysed together with the overlap analysis by taking into account their weight scores and the result susceptibility maps can be produced. The important point here is the selection of parameters that may cause avalanche formation and the classification of these parameters into appropriate subclasses. In the literature reviews, it is seen that there is no consensus on the parameters. Within the scope of this study, land use, elevation, slope gradient, aspect and slope shape parameters, which are most frequently used in the literature and considered to be effective in avalanche formation, were used (Table 1).

Table 1. Parameters and weight values used in avalanche susceptibility maps

Parametre	Class Range	Score	% Weight	Total Score
Slope	0-10	0	30	0
	10-28	1		30
	28-45	3		90
	45-55	2		60
	>55	1		30
Altitude	<1000	0	15	0
	1000-1500	0		0
	1500-2000	2		30
	2000-2500	3		45
Aspect	Flat	0	20	0
	North (0-45, 315-360)	3		60
	East (45-135)	2		40
	South (135-225)	1		20
	West (225-315)	2		40
Curvature	Concave (< -0.2)	3	20	60
	Flat (-0.2-0.2)	2		40
	Convex (> 0.2)	1		20
Land Cover	Non-irrigated arable areas	1	15	15
	Mixed agricultural areas	1		15
	Agricultural areas with natural vegetation	1		15
	Coniferous forests	0		0
	Mixed forests	0		0
	Natural meadows	1		15
	Sclerophyll vegetation	1		15
	Plant exchange areas	1		15
	Bare rocks	3		45
	Sparse plant areas	3		45

Parameters and weight values used.

3.1. Slope

Slope angle is the most important factor for avalanche formation. In the literature reviews, different slope grades were emphasised for avalanche formation. It was emphasised that hillside with slopes below 100 are insufficient for avalanche formation, hillside slopes between 100-280 are low, slopes between 280-450 are very high and slope slopes greater than 450 have high avalanche potential [6]. Theoretically, at slope gradients less than 300, there is no gravitational effect that will cause the onset of an avalanche event; at slope gradients greater than 600, there is not enough snow accumulation [5]. The slope class ranges given in Table 1 were used in the preparation of slope maps and the slope map obtained is shown in Figure 2A.

3.2. Altitude

Factors such as decreasing temperature with altitude, increasing snowfall and wind speed increase the avalanche hazard. Snow falling at low altitudes melts more quickly with the effect of the temperature factor and sufficient accumulation does not occur. Therefore, avalanches generally do not occur at altitudes below 1000 meters [12]. The altitude within the study area varies between 1020-2400 meters. In obtaining the elevation map, a digital elevation model (DEM) map with a resolution of 20 meters was used (Figure 2B) and divided into the class ranges shown in Table 1.

3.3. Aspect

Aspect is defined as the direction of maximum slope on the topographic surface [7]. Snow avalanches can occur on both north and south slopes. Since freezing and thawing occur more frequently on south-facing slopes due to the effect of the sun, more wet snow avalanches are observed on these slopes, while more dry snow avalanches occur on the northern slopes. The aspect map of the site was obtained by using DEM map with GIS programme (Figure 2C). Class ranges and weight values used for aspect are shown in Table 1.

3.4. Curvature

The slope profile is generally defined as concave-flat or convex. In the slope slope maps obtained by using DEM maps with GIS programmes, positive curvatures indicate convex slopes and negative curvatures indicate concave slopes. While the compression effect is higher on concave slopes, the tension effect is observed on convex slopes due to the tension. When evaluated in terms of avalanche formation, there are different opinions on this issue. While some researchers have stated that the avalanche potential is higher on concave slopes [5], some researchers have stated that flat slopes are more effective in terms of avalanche formation [6]. The slope shape map obtained from the DEM map is shown in Figure 2D; class ranges and weight values are shown in Table 1.

3.5. Land Cover

Avalanches occur mostly on slopes where forests and vegetation are absent or scattered and sparse. Even if all parameters are suitable for avalanche initiation, if this area coincides with a forested area, the onset of the avalanche event will be prevented. Due to the fact that forested areas prevent the onset of avalanche, land cover maps are mostly used as a filtering tool. In this study, Corine data were utilised for mapping the land cover [11]. According to the data obtained, 11 land cover classes were determined in the study area and their weight values are shown in Table 1; the land cover map of the study area is shown in Figure 2E.

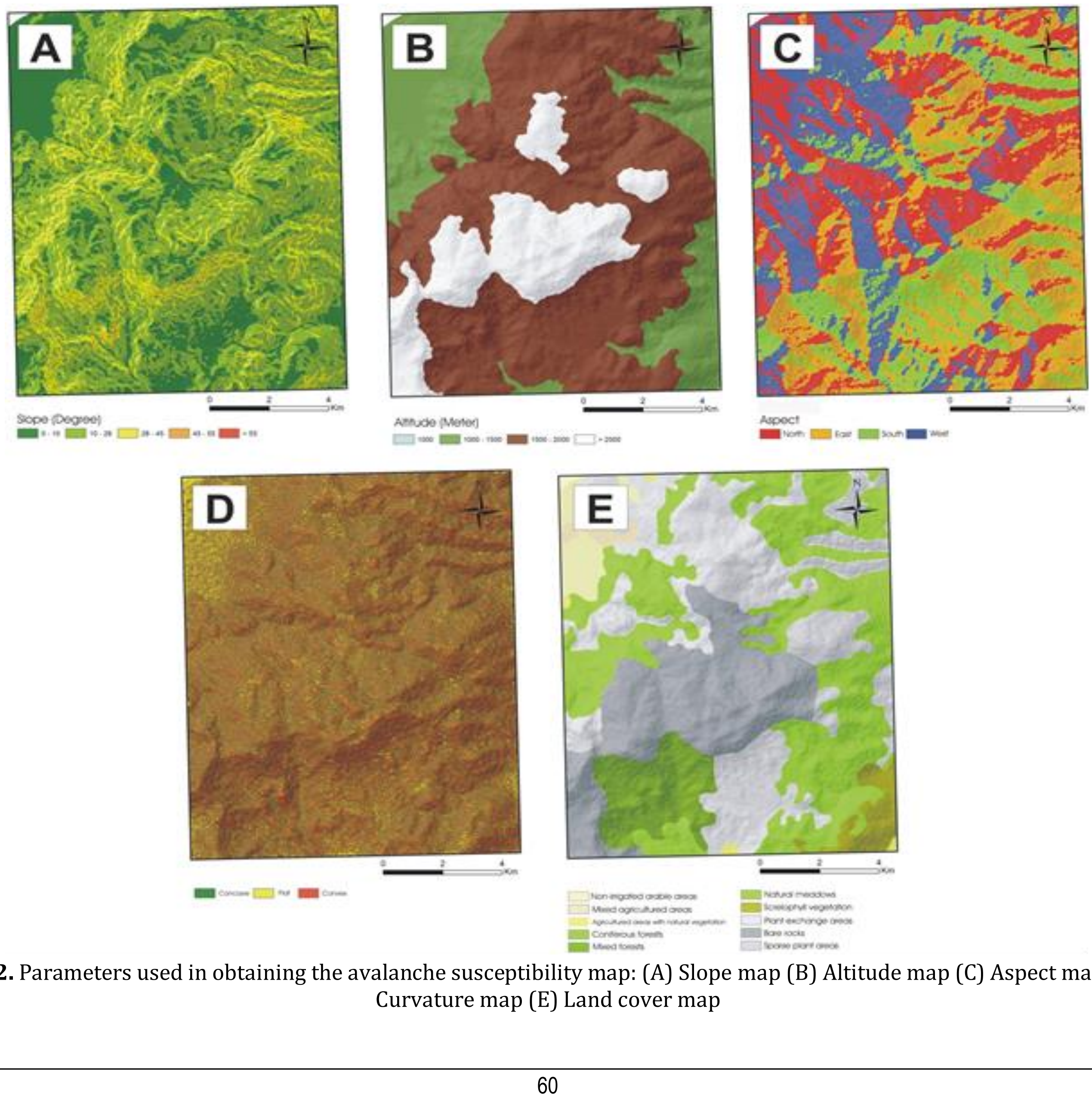

Fig. 2. Parameters used in obtaining the avalanche susceptibility map: (A) Slope map (B) Altitude map (C) Aspect map (D) Curvature map (E) Land cover map

3.6. Identification of Potential Avalanche Start Zones

In order to determine the potential avalanche starting zones, the raster maps of the 5 parameters obtained were subjected to the summation process and a scored map showing the potential avalanche starting zones was obtained. The resulting map was divided into 5 class intervals between 40 and 300 points and the class interval value was found to be 52 (Class interval: (300-40)/5=52) (Table 2).

Table 2. Class range values of avalanche onset potential

Potential to be Avalanche Start Zone	New Class Code	Description
40-92	0	Very Low
92-144	0	Low
144-196	0	Middle
196-248	1	High
248-300	1	Very High

The map obtained according to this class range was subjected to the reclassification process and the areas showing the characteristics of being a source area in terms of avalanche (high-very high) were determined according to the new class code (Figure 3A). After this stage, the parameter sub-groups in Table 1, which received a score of 0, were reclassified by assigning a value of 0 and a value of 1 for the sub-parameter groups with other scores. The purpose of this map is to eliminate areas that correspond to high and very high areas in the potential avalanche onset map, but which cannot be avalanche onset areas (such as forested areas or areas with very low slope). This filter map was multiplied arithmetically with the previously obtained potential avalanche starting zone map to obtain a map showing the potential source areas for avalanche development (Figure 3B).

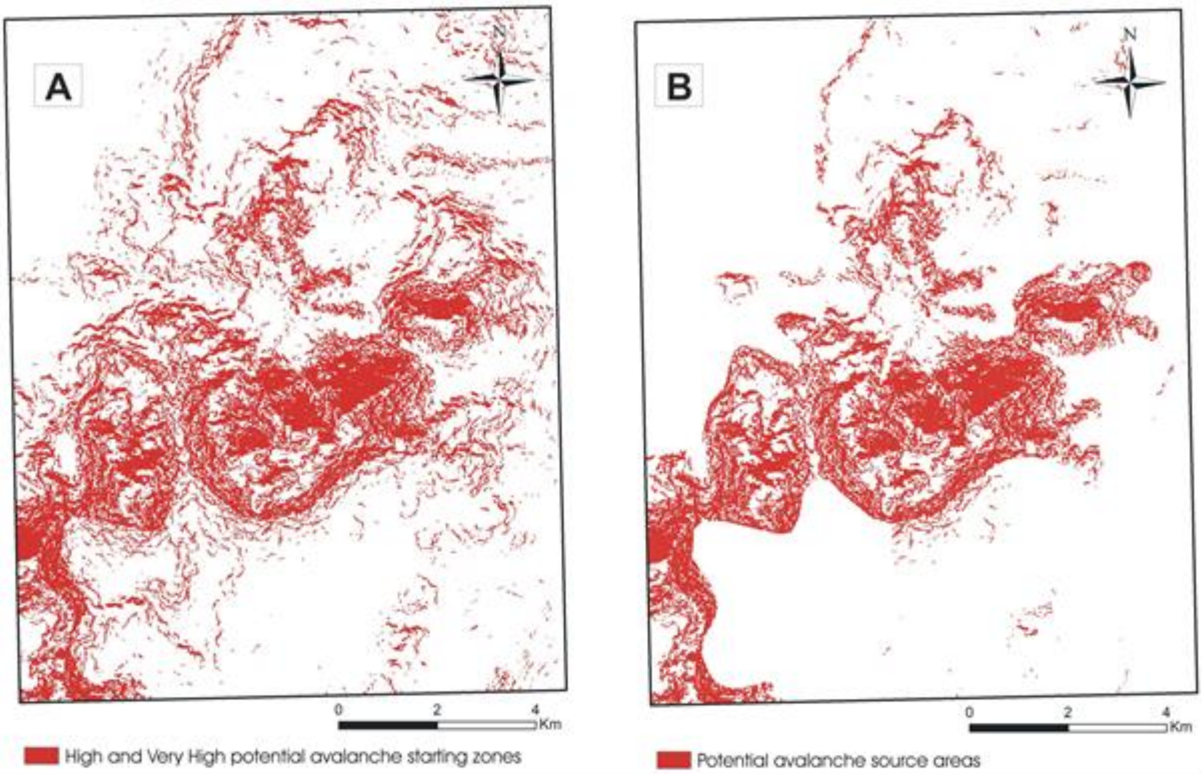

Fig. 3. (A) Map of high and very high avalanche onset zones **(B)** Map of potential avalanche source areas

3.7. Obtaining Avalanche Susceptibility Maps

Conefall software was used to obtain avalanche susceptibility maps. The DEM map and potential resource maps previously obtained were used in the programme and ASCII format conversions were applied. After this stage, 400-350 and 300 values, which are the critical conical angle values for avalanches, were taken into consideration and maps showing the areas with high, medium and low avalanche susceptibility were obtained respectively. In the last step, these maps were converted to KMZ file format and displayed in Google Earth programme (Figure 4 A-B).

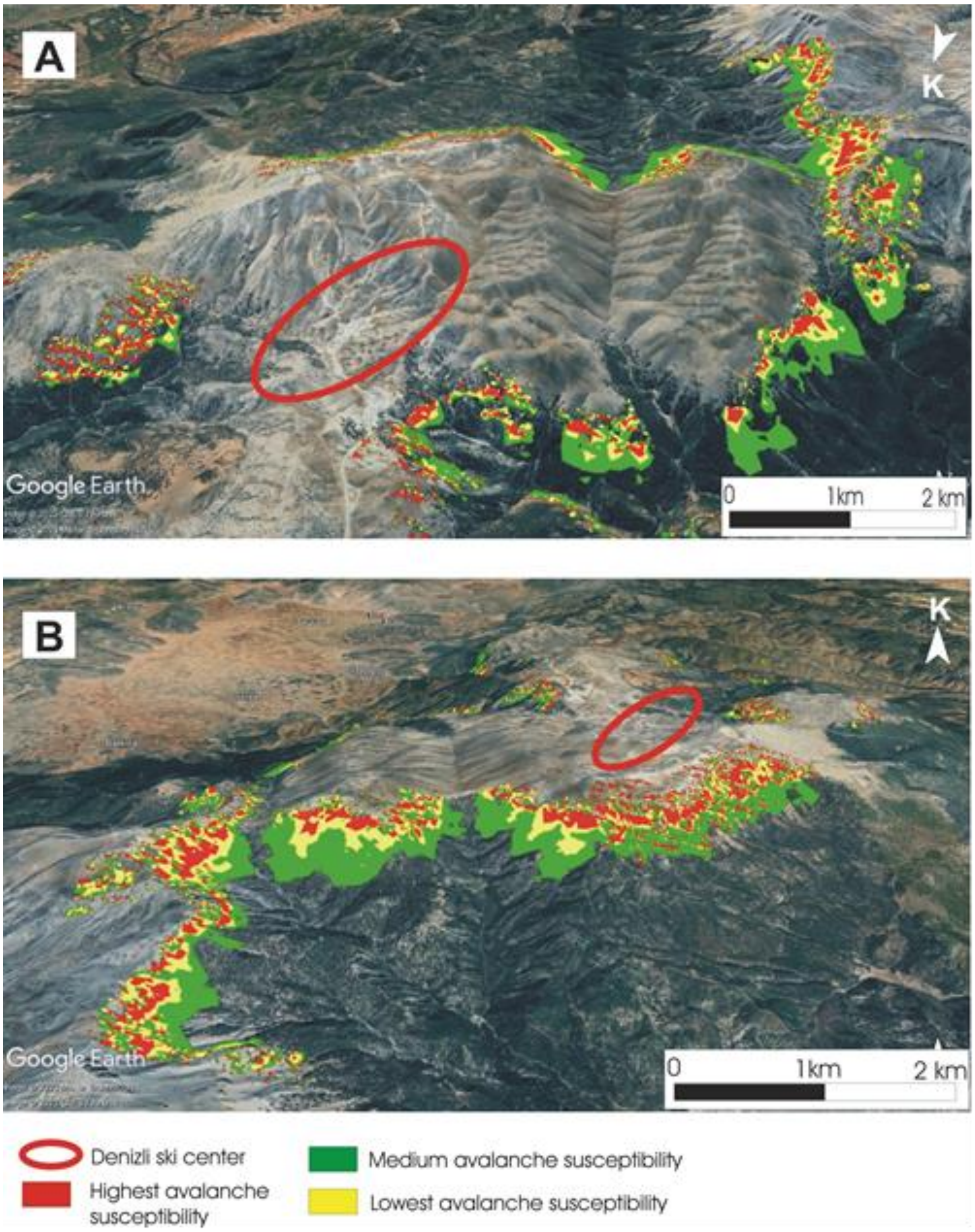

Fig. 4. Avalanche susceptibility zones for Denizli Ski Resort **(A)** North facing direction **(B)**

4. CONCLUSION

With this study, high, medium and low degree avalanche potential susceptibility maps were created for Denizli Ski Resort. According to the results of the study, it is seen that there is no danger in terms of avalanche susceptibility in areas where ski slopes and facilities are located. It was determined that the areas with high avalanche susceptibility are located in the south and southwest of Bozdağ and these areas are far from settlements and facilities.

The main purpose of producing susceptibility maps is to minimise the loss of life and property. In this study, the areas with high, medium and low avalanche susceptibility in terms of avalanches in Denizli Ski Resort and its immediate surroundings were mapped. Thus, it is aimed to prevent loss of life and property and to take necessary precautions by management and decision makers.

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