PRODUCING LANDSLIDE RISK MAP OF SEBINKARAHISAR BY MEANS OF REMOTE SENSING AND GIS TECHNIQUES

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KEY WORDS: GIS, Landslide, Remote Sensing, Hazards, DEM/DTM

ABSTRACT:

The objective of this study is to determine a suitable methodology for predicting possible landslide areas and producing landslide risk map in the study area of Sebinkarahisar Township, which is located at the northeastern part of Turkey. In the study, various types of data were used to extract relevant information. These include the satellite sensor data taken in the year of 1987 and 2000, which are used for the extraction of land surface temperature and land use information. 1:25000 scale standard topographic map has been digitized and the obtained contours were used for the derivation of Digital Elevation Model (DEM) and slope map of the study site. Satellite images, DEM and slope map of the study area were used to investigate the possible landslide risk areas and reasons of this natural hazard which threat the study area frequently.

1. INTRODUCTION

Landslide is a slide of a large mass of dirt and rock down a mountain or cliff. Landslides have become one of the world's major natural disasters in the recent years in many countries. Prediction of potential landslide areas has been very difficult because of the complexity of the factors involved and the relationship to each other, which is wide ranging. The factors that are usually related to landslides are geology, soil type, land surface temperature, land cover, underground water level, slope aspect, slope inclination, elevation, etc. Normally, the causes of landslide are determined by carrying out sampling of the soil, rock, slope inclination, land cover, underground water level, geology, etc. at the site. It is a difficult and time consuming job to do this for a large area from time to time and by integrating it with GIS, all the information can be combined, manipulated and analyzed to determine potential landslide areas.

The integration of GIS with remote sensing data and thematic map may highly facilitate the assessment and estimation of regional landslide hazards (Yuan and Mohd, 1997). In this study, land surface temperature and land use information have been obtained from Landsat TM data taken in the 24 September 1987 and 17 July 2000. The elevation and slope inclination of the study area have been determined from DEM generated using contours digitized from 1:25000 scaled standard topographic map.

Researchers to predict landslide potential areas usually use the land surface temperature, which is closely related to underground water level. Land surface temperature is calculated using satellite sensor data. This process is done because according to previous researches, most landslide areas have temperature between 24-26 ^{o}C. According to previous researches, most of the landslides occur at slope inclination of 35^{o} - 45^{o}. The slope inclination map was generated from the DEM. Both the DEM and slope inclination maps were used to produce landslide risk map (Yuan and Mohd, 1997, Shikada, 1994).

All the data were manipulated and processed by using the ArcView and Erdas Imagine software. Several different risk map related to landslides in the study area were evaluated by different research groups and government institutions. In the different landslide maps obtained from previous studies, were classified into different risk zones. The most risky areas are classified. Remote sensing has been used to study characteristic properties of ground surface due to the advantages of its broad area observation and periodicity.

The integration of GIS with remote sensing data and thematic map data may facilitate greatly the assessment and estimation of regional landslide hazards. In the study, land surface temperature and land use information have been derived from Landsat TM data. The elevation and slope inclination have been determined from DEMs generated from standard topographic maps. Reliable data related to underground water level could not be obtained. Using all relevant data, simple algorithms were used and by combining all the risk maps using GIS techniques, final risk maps were produced which take into account all of the factors.

An integrated approach of remote sensing and GIS is highly useful in evaluation, management and monitoring of natural hazards. Routine use of remote sensing data and its analysis of a hazard prone area help to monitor the changes in surface feature. The digital image processing techniques enable the user to get the desired information in a more reliable, quicker and easier way. The goal of this study is to generate a landslide zonation map using GIS and remote sensing based methods. Use of satellite imagery has been incorporated in mapping the lineaments as a result of which are projected to better characterize the landslides of the study area. The landslide risk assessment has been studied in detail within the last 30 years. Various attitudes to a solution of this task have brought a large range of possible solution methods. They can be divided into five big groups. These groups are given in Table 1 (Halounova and Pavelka, 1998).

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type of landslide risk assessment analysis	main characteristics
distribution analysis	direct field mapping of existing landslide movement
quality analysis	direct or half direct methods applied to geomorphologic maps
statistical analysis	indirect methods where statistical methods make it possible to determine potential landslides from parameter maps
deterministic analysis	indirect methods where parameter maps are combined with slope stability evaluation
frequent landslide analysis	indirect methods applying hydrological models, earthquake and rainfall data for correlation with

Table 1. Landslide Risk Assessment Analysis

The scale choice of a risk analysis assessment is given by the purpose of analysis. Table 2 shows an overview of data important for a relevant landslide risk assessment study (Halounova and Pavelka, 1998).

	data type
geomorphology	terrain map units geomorphological units recent landslides passive landslides
topography	digital elevation model slope map slope direction maps slope changes concavity/convexity
engineering geology	Lithology derived data (DEM e.g.) sample points faults, lineaments seismic events isolines of seismic intensity
land use	present infrastructure previous infrastructure present land use map previous land use map cadastral data
hydrology	water streams catchment areas meteorological data water level

Table 2. Overview of Significant Data for a Relevant landslide Risk Assessment Study

The objective of this study is to determine a suitable methodology of predicting possible landslide areas in the study area of Sebinkarahisar using Landsat TM data and GIS techniques.

2. STUDY AREA

Sebinkarahisar Township is selected as the study area (Figure 1). This area has a long history and is one of the most important inhabited areas of the region which has its own peculiar geographical features. It is located 108 km. away from Giresun province. Population of the study area is approximately 40,000 according to the last population census. Study area has very important historical backgrounds and its history date back to 3000 years. Koloneia and Kögonya are two different ancient name of the study area met in the historical documents.

Study area is located between Black Sea and Central Anatolian Region. Its climate is closer to Anatolian regime than Black Sea. According to the last five years meteorological data, yearly average temperature is 9 ^{o}C and average participation is between 500-700 mm. It is separated from the coastal region by the mountains which located along the coastlines and widening about 50-60 kms. Some of the peaks of these mountains reach up to 3000 meters. Study area generally covered with mountains, valleys and uplands. Total area is 1378 Km^2 and average altitude is 1350 meters. 24% of this area is agricultural area, 2.4% is covered with gardens and orchards, 1% is covered with vegetable garden, 2.8% is covered with pastures, 15.8% is covered with meadow and mountain pasture, 4.8% is covered with scrub, 7.1% is covered with forest and rest of the area is out of used area. Main economy of the township depends on agriculture (http://www.sebinkarahisar.com/site/cografya.asp)

The main problem of the town is landslides. This kind of disaster occurs frequently in the study area. After the flood and landslides occurred in 2003, 216 houses which are under landslide threat in study area were evacuated. Around 900 people were living in mentioned houses, which are considered as big threats for the life and property security. (http://www.hri.org/news/turkey/anadolu/1999/99-11-03.anadolu.html#40)

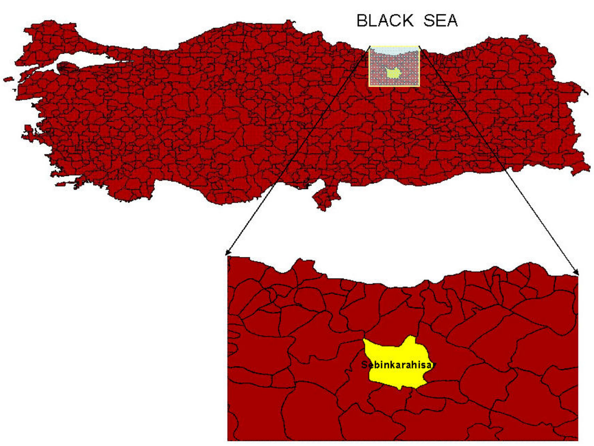

Figure 1. Study Area

Study area is topographically hilly and affected from landslides. Kelkit River is passing through the study area and affects the surface morphology and only well-irrigated agriculture is done around the river. In the study area, landslides occur frequently and represent a very real hazard to life and property in the region. Landslides are an inherent part of the environment that requires control and management strategies. Hence, a GIS and remote sensing-based study has been conducted in this study.

3. MATERIALS AND METHODS

In this study, 1987 and 2000 dated Landsat TM sensor data are used (Figure 2 and Figure 3). After the geometric correction of two images, radiometric and atmospheric corrections were performed and digital values on the images were converted into reflectance values. Reflectance values of the images were calculated using reflectance calculator. Flowchart of this model is given in Figure 4. To extract vegetation covers and the areas which were possibly affected from landslides, both images were classified separately. To find temporal changes in two images they were overlaid. Bands which have the same spectral interval in two images were analyzed and differences were determined (Figure 5).

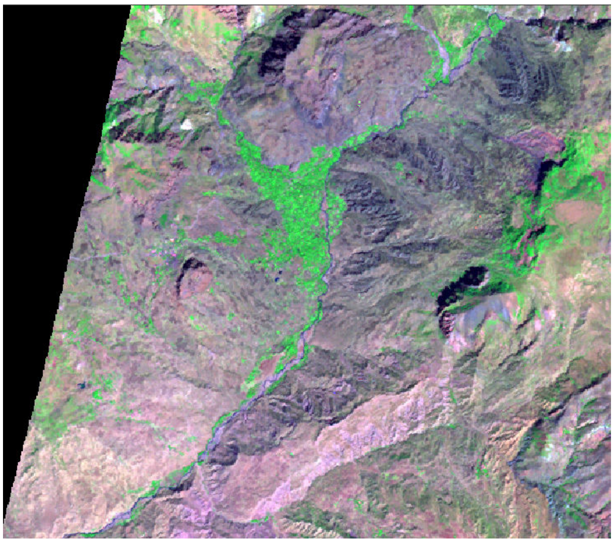

Figure 2. 1987 Landsat TM Image

3.1 Radiometric and Atmospheric Corrections

Several band enhancements and corrections are applied to the rectified imagery to normalize the DN (digital number) values, facilitating direct spectral comparisons between imagery bands and a comparable set of values as input to indices and clustering programs.

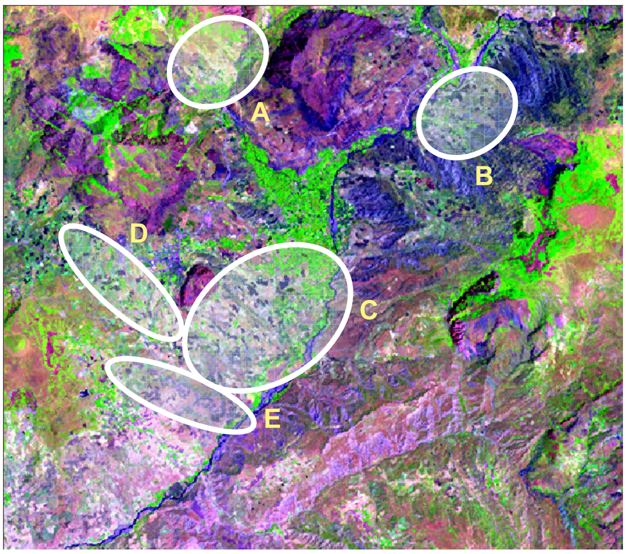

Figure 3. 2000 Landsat TM Image

Radiometric calibration, conversion to reflectance or solar correction, and atmospheric correction are conducted on every image. The adjustments rely heavily on data contained within the header file, including gain, bias, and solar zenith angle. Programs have been written in-house to facilitate the first two adjustments.

The atmospheric adjustment still relies on a visual/manual assessment of dark water values, although it may also be automated eventually.

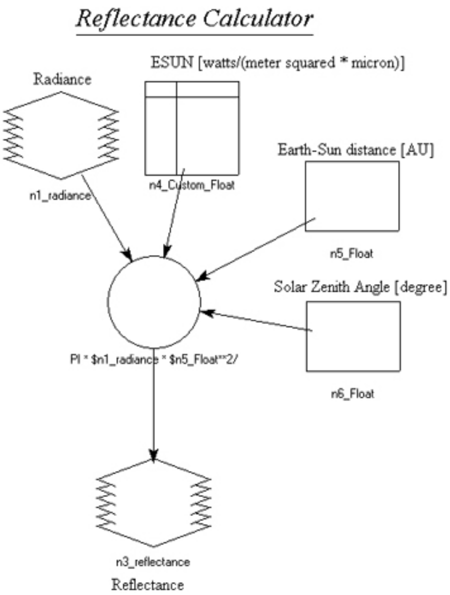

Figure 4. Flowchart of the Model Used for reflectance Calculation

3.2 Integration of GIS and Remote Sensing Data

Remote sensing data can be readily merged with other sources of geo-coded information in a GIS. This permits the overlapping of several layers of information with the remotely sensed data, and the application of a virtually unlimited number of forms of data analysis. On the other hand, the land cover data generated by a classification might be used in subsequent queries and manipulations of the GIS database (Musaoglu et al, 2002).

As the use of geographic information systems expands, the availability of timely and up-to-date spatial data in digital format is an essential requirement for its success. For the user, it is a requirement, which is expected to be easily fulfilled. Satellite imagery combined with the increased processing capabilities of current image analysis systems have made it possible to generate meaningful data sets which represent new knowledge not available in previous technologies (Palko et al, 1995).

GIS is suitable to meet the requirements of synthesizing the available information. The strength of a GIS lies in its capability of storing interpreted and available information as maps and linked attributes. For developing a GIS application as a landslide hazard management tool, a three-tiered GIS approach is adopted as follows: Hazard Assessment, Vulnerability Assessment and Risk Assessment. The parameters considered for assessment of the landslide hazard, vulnerability and risks include a landslide map (both of active and old landslides), major land use/cover categories and topographic factors. The resulting landslide hazard management tool will aid in the identification of the occurrence of landslides, the degree of loss as a factor of vulnerability and will ultimately allow the assessment of risk from landslides. Therefore, risk assessments are a combination of hazard and vulnerability measurements that will assist with predicting locations where landslide events may be cause damage.

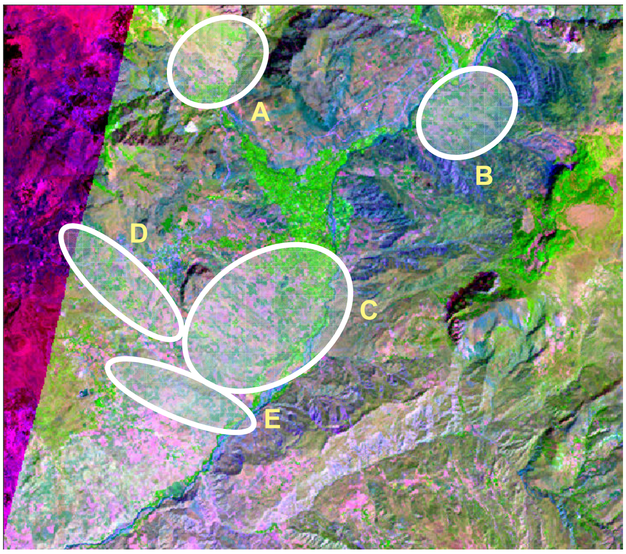

Figure 5. Merged Image

3.3 Digital Elevation Model

Quantifying a 1:25000 scaled topographical map of the study area has developed a digital elevation model. This model gives reasonably reliable information about the field's general structure. The study area's digital elevation model obtained from both ArcView and ERDAS are given in Figure 6.

4. RESULTS AND DISCUSSION

According to the ground observations, cavities were seen as a result of slumps on the landslide areas which are around 5-10 meters. Similar features are distinguished from the satellite images. These areas were generally seen in the south, west and north-east direction of the Township as well as the several districts. On the northern direction of the town, high landslide areas have been investigated. This area is located on the main road goes to Giresun province and closes very often because of the landslides that occur almost after every heavy rain or snow.

In order to determine the changes due to landslides, images taken at different dates have been merged and a new image obtained (Figure 5). In the image given as Figure 3, possibly landslide areas are displayed as dark blue and have the similar reflectance values with the water bodies. In Figure 5, the merged image and differences occurring at the study area can be seen. Changes in areas are displayed with the cyan colour in the figure. As seen in both figures, potential landslide areas were indicated with from A to E.

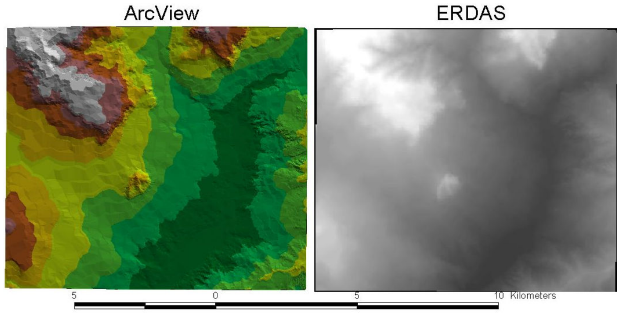

Figure 6. Digital Elevation Model of Study Area

By applying density slicing technique to the thermal band, temperatures of landslide areas were differentiated from the other areas. This is given in Figure 6. Areas which show the differences in the merged images have been selected and converted into polygons to use in GIS. All relevant data were used in GIS and landslide risk map of study area was obtained**.**

Successful interpretation of thermal imagery have been made in many fields of applications such as; determining rock type and structure, location geologic faults, mapping soil type and soil moisture, locating irrigation canal leaks, evapotranspiration from vegetation, locating cold water spring, locating hot spring and geysers, determining and extend and characteristics of thermal plumes in lakes and rivers and studying the natural circulation patterns in water bodies. Terrain temperatures are normally, higher than water temperatures during day and lower during the night. In all cases, darker image tones represent cooler radiance temperature and lither image tones represent warmer radiance temperature (Lillesand and Kiefer, 2000).

There are three risky regions in the area which face with landslides periodically. Interpretation of density sliced thermal images show that these regions can be easily identified using these images. These risky regions showed higher thermal differences than other parts of the study area (Figure 7). The regions obtained from thermal band were matched with other data and results showed that there is a great consistency between them. Risky areas seen on the images taken in the year of 2000, most probably occurred because of the underground water and these areas shows the potential of underground water in the study site. So this underground water might be main reason for the landslides.

One of the important parameter that affects the thermal sensing is the water amount. According to data taken from the meteorological station of Sebinkarahisar, rain was not observed during the July 2000. On the image taken on the July 17, 2000, land cover changes show the landslide areas. This situation indicates that there might be potential underground water in the study area.

In the previous studies, one of the main indicators for the landslide areas indicated as the slope of the area. Areas have the slope between 35^{o}-45^{o} are the most risky areas. Slope map of the area was generated from DEM model which already prepared by using elevation data of study area. Obtained slope map is given in Figure 8. In the ground truth measurements, slope of areas most of the landslides occurred were less than %25. Main reason of landslide might be underground water. Risky areas seen on the images taken in the year of 2000 and merged image most probably occurred because of the underground water and these areas shows the potential of underground water in the study site. According to the visual interpretation, these areas are matched with the landslide areas. So, underground water might be main reason for the landslides.

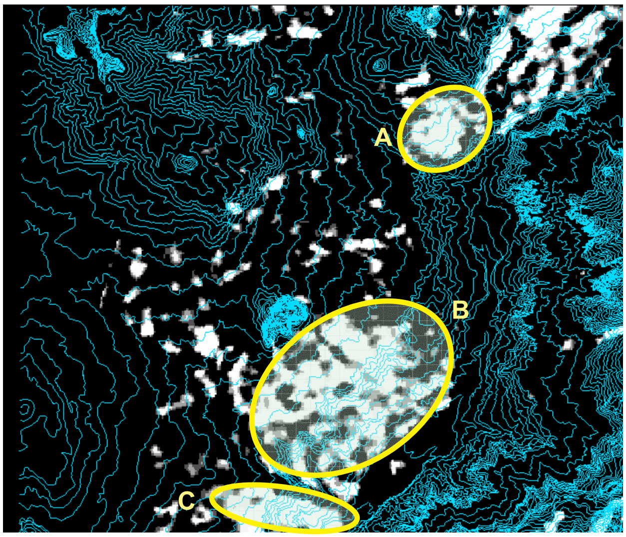

Figure 7. Temperature Differences seen on the Image.

The large block represented with K, located in the middle of the Figure 8, and has the same geological features with L, located north-west direction of the figure. The area between K and L is called as Headwall Scarp in geomorphology and it generally indicates a landslide. This kind of large landslides explained only with a discontinuity surface which is spread on large areas. This kind of discontinuity could only be expected on the area which has high steep terrain. Slope of the area between K and L is very low to cause this kind of heavy landslides. This discontinuity surface might indicate different geological formation or existence of high level underground water. In the study area, geological structure and potential of underground water should be examined by means of deep soundings.

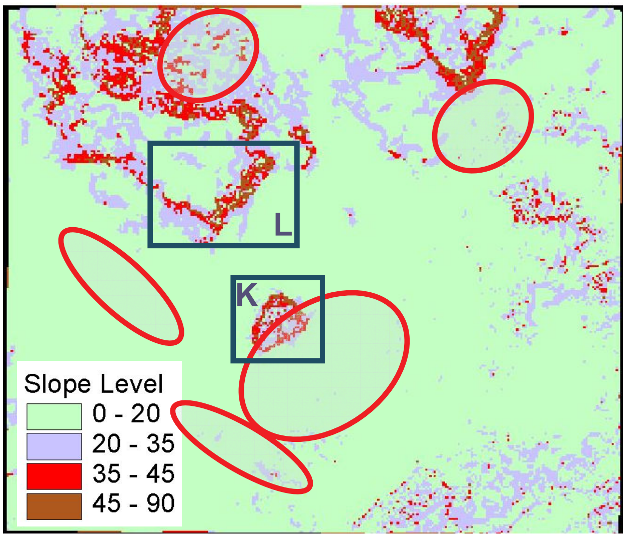

Figure 8. Slope Map of the Study Area

5. CONCLUSIONS

Using obtained results, future studies which are in the project step, ground studies will be carried out in the study area. In the future studies, several different data such as; geologic and geomorphological structures, soil types are going to be considered.

Investigation of landslides by means of satellite imagery is very difficult. Study area is frequently faced with the landslides. In this study, landslides are defined with the integration of satellite images and GIS. In the following steps of the study, interferometric SAR data will be used to investigate the surface land cover changes.

The study shows that remote sensing techniques when integrated with GIS can provide a useful tool to study potential landslide areas. However, the accuracy of the final results depends in the par parameters that are included in the data set.

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