Soil erosion assessment using geographical information system (GIS) and remote sensing (RS) study from Ankara-Guvenc Basin, Turkey

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(Received: September 05, 2007; Revised received: January 02, 2008; Accepted: February 12, 2008)

Abstract: The objective of this research was to assess vulnerable soil erosion risk with qualitative approach using GIS in Ankara-Guvenc Basin. The study area is located about 44 km north of Ankara and covers 17.5 km\(^2\). The selected theme layers of this model include topographic factor, soil factors (depth, texture, impermeable horizon) and land use. Slope layer and land use-land cover data were prepared by using DEM and Landsat-TM satellite image. According to land use classification, the most common land use type and land cover are rangeland (50.5%), then, rainfed (36.4%), week forest land (3.2%), irrigated land (0.7%) and other various lands (rock out crop and lake) (9.2%). Each land characteristic is also considered as a thematic layer in geographical information systems (GIS) process. After combination of the layers, soil erosion risk map was produced. The results showed that 44.4% of the study area is at high soil erosion risk, whereas 42% of the study area is insignificantly and slightly susceptible to erosion risk. In addition, it was found that only 12.6% of the total area is moderately susceptible to erosion risk. Furthermore, conservation land management measures were also suggested for moderate, high and very high erosion risk areas in Ankara-Guvenc Basin.

Key words: Erosion risk assessment, Land degradation, Geographical information systems (GIS), Remote sensing (RS)

PDF of full length paper is available with author (odengiz@omu.edu.tr)

Introduction

Soil erosion a natural process, occurring over geological time, and most concerns about erosion are related to accelerated erosion, where the natural rate has been significantly increased by human activity. As such soil erosion poses severe limitations to sustainable agricultural land use, as it reduces on-farm soil productivity and causes the accumulation of sediments and agrochemicals in waterways (Kirkby et al., 2004). Soil erosion control is vital to meet the increasing demand to feed to the world. Natural resources like soil, water and forest can be managed effectively, collectively and simultaneously within this unit. Both food security and environmental issues should therefore be addressed within the context of basin management.

Studies on the world’s resources showed that 83.7% of the land is exposed to wind and water erosion. According to the results of these studies, 0.5-2.0 ton ha\(^{-1}\) soil is lost each year and the total amount is approximately 2.4x10\(^9\) ton year\(^{-1}\) in the world (Turkey Irrigation Report, 2001). Because of the mismanagement of the land, some of the main degradation types in Turkey are erosion by water or wind, soil salinization and alkalization, soil structure destruction and compaction, biological degradation and soil pollution (Ozden et al., 2000). Soil erosion which occurs due to climatic and topographic condition is the biggest land problem in Turkey. Approximately 86% of land is suffering from some degree of erosion (Ozden et al., 2000).

Recent advances in space and computer technologies have provided us with the opportunity to process large amounts of data such as storing and interpreting both spectral and spatial data including elevation, slope, aspect and relief of the earth environment (Bayramin, 2000).

Simulation models and equations may be a more effective way to predict soil erosion processes and their effects using geographic information system (GIS) and remote sensing (RS) techniques. While GIS is used more extensively for georeferenced application, RS, as a called bits of information which translate into pixels on the screen representation of the world, can be used in most models applied for predicting soil loss or erosion risk estimation (Gitas et al., 2006).

The advantages of using GIS in environmental assessment were reported by Burrough (1986) Eedy (1995), Bojige et al. (1995). They introduced the principles of GIS tools for collecting, storing, manipulating, and displaying spatial data. Therefore, estimation of soil erosion and its spatial distribution using RS and GIS techniques could be performed with reasonable costs and better accuracy in larger areas (Millward and Mersey, 1999; Wang et al., 2003; Erdogan et al., 2007). Therefore, predicting models and GIS and RS techniques have the opportunity to make a major contribution toward the development of better conservation practices and improvement of the management of our land resources (Meyer, 1980).

At present, the quality of available data is extremely uneven. Land use planning based on unreliable data can lead to costly and gross errors. Soil erosion research is a capital-intensive and time-consuming exercise. Global extrapolation on the basis of few data
collected by diverse and non-standardized methods can lead to gross errors and it can also lead to costly mistakes and misjudgments on critical policy issues. Erosion risk assessment includes many different data sources, such as soil and topographic, land cover-land use maps, aerial photographs, hydrology maps etc. These data have provided a primary database for use with a GIS for the assessment of erosional features and developing conservation plans of an area (Dengiz and Baskan, 2006).

The main goal of this study was to determine and evaluate the soil erosion risk of Ankara-Guvenc Basin with qualitative approach using GIS-RS techniques and to give some suggestions to take some measurements against soil erosion and to make conservation planning for uses of sustainable use of land resources.

Materials and Methods
Description of the study area: The Guvenc Basin coordinated geographically in latitude 40° 09' to 40° 08' and longitude 32° 44' to 32° 48' is located about 44 km north of Ankara. The basin has an area of 17.5 km² and is situated between the altitudes of 1040 m (at the reservoir site) and 1458 m above see level (Fig. 1).

The average annual temperature and precipitation are 11.4 °C and 478.1 mm. The main channel (Kayaonu river) is a forth order, perennial stream at the outlet. The topographic and drainage characteristics of the catchments where the study are implemented are given in Table 1. Topography in the basin is moderately undulated with 21% average slope and the basin is characterized mainly by rounded hilltops. The soil texture ranges from sandy-clay to clay-loam. The soil depth is varying from 15 to 80 cm along stream side, the soil characteristics consist of abundant clay with 3% organic matter.

According to Soil Taxonomy (Soil Survey Staff, 1999), soil temperature regime and moisture regime were classified as mesic and xeric, respectively. There are 8 different soil series in the study area and they were classified as Entisol (59.9%), Inceptisol (34.2%), and Vertisol (1.7%) (Dengiz and Baskan, 2005).

The center of the basin is covered with limestone of the Saribeyli formation and loam sandy stone of the Dikmendere formation in the southeast part of the basin.

It is a qualitative approach based on the knowledge of the surveyor to detect and recognize during the field survey, different factors involved in the erosion dynamics: soil, geological, geomorphological, climatological, land cover and land use (Van Zuidam, 1986). Obtained results were analyzed and compared to the field data in order to evaluate a correspondence with the actual soil erosion. Four main categories of parameters were used for the qualitative assessment of soil erosion risk:
- slope gradient,
- soil/geology: soil depth, texture, surface sealing;
- vegetation/land use: vegetation cover, rainstorm frequency, conservation practices;
Qualitative assessment of soil erosion

- erosion and mass movement: rating of wind erosion, sheet erosion, rill/gully/ravine erosion, mass movement.

The morphology, soil and geology parameters are listed in Tables 2, 3 and 4, the vegetation and land use parameters are listed in Table 5 and the geomorphology processes are shown in the Table 6.

Each parameter was divided in classes and a rate was given, according to its contribution, to the erosion susceptibility. Regarding the climatologic condition factors, the rainstorm frequency was considered as homogeneous for all area and it was ascribed to value of three that corresponds to the heavy rainstorm frequency of several times during a year. It was not always possible to recognize the structure of the underlying geologic strata and the rock weathering or alternating degree. Therefore, the missing data were not reported and then rated as zero. In addition, as most of the study area is used for agricultural practices, the land cover was divided into the following vegetation density / land use conditions:

- agroforestry and forest plantation were rated as 1;
- natural vegetation was rated as 2;
- the fallow systems was rated as 12;
- the other types of agriculture areas like irrigated cultivation, rainfed arable cultivation were rated as 3.

### Table - 1: Topographic and drainage characteristics of Guvenc Basin

<table>
<thead>
<tr>
<th>Description of the basin</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basin area (km²)</td>
<td>17.42</td>
</tr>
<tr>
<td>Minimum altitude (m)</td>
<td>1040</td>
</tr>
<tr>
<td>Maximum altitude (m)</td>
<td>1459</td>
</tr>
<tr>
<td>Average altitude (m)</td>
<td>1249.5</td>
</tr>
<tr>
<td>Average slope (%)</td>
<td>21</td>
</tr>
<tr>
<td>Length of main waterway (m)</td>
<td>6500</td>
</tr>
<tr>
<td>Profile slope of main waterway (%)</td>
<td>5.33</td>
</tr>
</tbody>
</table>

### Table - 2: Rating for slope factors of Guvenc Basin

<table>
<thead>
<tr>
<th>Slope gradient in percentage</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2</td>
<td>1</td>
</tr>
<tr>
<td>3-7</td>
<td>2</td>
</tr>
<tr>
<td>8-13</td>
<td>4</td>
</tr>
<tr>
<td>14-20</td>
<td>8</td>
</tr>
<tr>
<td>21-30</td>
<td>24</td>
</tr>
<tr>
<td>&gt;30</td>
<td>32</td>
</tr>
</tbody>
</table>

### Table - 3: Rating for soil / geology factors of Guvenc Basin

<table>
<thead>
<tr>
<th>Description</th>
<th>Value (cm)</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very shallow</td>
<td>0-24</td>
<td>4</td>
</tr>
<tr>
<td>Shallow</td>
<td>25-49</td>
<td>3</td>
</tr>
<tr>
<td>Moderately deep</td>
<td>50-99</td>
<td>2</td>
</tr>
<tr>
<td>Deep</td>
<td>&gt;100</td>
<td>1</td>
</tr>
</tbody>
</table>

The rating classes of erosion risk parameters were obtained combining the spacing and the depth of rill/gully/ravine erosion process. The rating of the vegetation cover was multiplied by the frequency of rainstorm, and consequently the result was added to all other factors ratings; the obtained sum was compared to the erosion susceptibility class as shown in Table 7.

Consequently, the final rating of the texture was affected by the value of the slope gradient: if the slope gradient was lower than 3%, the clay texture was not taken into account and a new value of 1 was given. The areas belonging to the urban, airport, military zones, and quarries were excluded from the assessment and were classified as not relevant.

### Database creating and mapping process: GIS and RS or image processing

GIS and RS (or image processing) were used to handle, process and generate land use-land cover, soils, topographic layers, Digital Elevation Model (DEM) and soil erosion risk maps. After obtaining data from Landsat-5-TM scene acquired in 2002 (Fig. 2), land use classification of the study area was determined, and in order to support the interpretation of different land uses and land covers field study was performed to get ground information. For this aim, the classification results were supported by field study using GPS at some control points.

Soil erosion models requirement soil data were taken from 1:25,000 scaled digital soil map (Fig. 3). The diagnostic factor of topography is combination of land form and slope gradient that were extracted from satellite imagery and DEM. Each land characteristics is considered as a thematic layer in the GIS. Each of land qualities with associated attribute data is digitally encoded in a GIS database to generate soil erosion layer.

### Results and Discussion

After the data analysis process, slope groups derived from DEM, vegetation cover used Landsat-5 TM satellite image and soil erosion maps were generated using GIS and RS.

Study area 13.1% has less than 13% slope (very gentle and gentle), 26.8% of the area is between13-20% slope gradient and 68.6% of the study area has more than 20% slope varying from steep to very steep from which runof can easily occur. Steep and very steep areas are located on some part of the Tabyabayar, Yasmine, and Kervanyolu soil series.

Land use and vegetation cover is the most crucial element in erosion models, since it is the only factor that can readily be
altered, and provide effective soil erosion control. In addition, soil erosion has accelerated due to inappropriate land uses and continuous cultivation on steeper land (Millward and Mersey, 1999). Hacisalihoglu (2007) determined and compared the soil erosion amounts between the different land use types such as forest lands, grasslands, shrubs and new forestations. According to his results, the soil erosion amount differs in a high ratio between the land use types. The main land uses of the study area are rangeland, rainfed, forest, rock out crops, week forest and irrigated land (Table 8).

As a result of analysis, while 35.1% of the total area has heavy texture (clay), 45.7% is light and moderate soil texture. Heavy texture soil was found on Kervanpinar soil series was classified as Vertisol. Therefore, this soil has high surface sealing and according to model its rating value is six. Soil depth map results showed that while 58.4% of soils has shallow and very shallow depth, approximately half of the study area soils (40.6%) have between 50-100 cm. There are no common conservation practices such as benching, terracing and in the study area contouring. It was observed that general types of erosion are rill and sheet erosions. While, rill erosion have commonly occurred on Tabyabayir soil series, Cayirinkafa, Yasmese, and Acisu soil series have sheet erosion due to mismanagement agricultural activities. Each land characteristics is considered as a thematic layer in the GIS. In the final step, each of the land qualities with associated attribute data was digitally encoded and combined all layers in a GIS database to generate erosion risk map (Fig. 4). According to soil erosion risk map results, the study area has 50.8% low, 12.6% moderate, and 44.4% high and very high erosion risk levels, respectively.

**Soil conservation strategies:** To reduce soil erosion and improve land conditions, some alternative strategies were given for the study area. In the Ankara-Guvenc Basin, on slightly or insignificantly erosion risk soil, intensive agriculture is possible, whereas on very high potential erosion risk soil only special crops or forestry can be

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**Table 4:** Rating for vegetation/land use factors of Guvenc Basin

<table>
<thead>
<tr>
<th>Description</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF (Agroforestry), FP (Plantation forestry), NV (Natural vegetation), HE1 (Nomadism), AA1 (Shifting cultivation), AA4 (Rainfed arable cultivation), AA6 (Irrigated agriculture), AP1 (Non-irrigated perennial field cropping), AT1 (Non-irrigated tree crop cultivation), AA2 (Fallow system cultivation)</td>
<td></td>
</tr>
<tr>
<td>1, 2, 3, 4, 8</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5:** Rating for soil factors of Guvenc Basin

<table>
<thead>
<tr>
<th>Texture</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>C, SiCL</td>
<td>8</td>
</tr>
<tr>
<td>SC, CL, SCL, L, SiL, Si</td>
<td>4</td>
</tr>
<tr>
<td>SL, S</td>
<td>1</td>
</tr>
<tr>
<td>C, SiCL in flat area</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 6:** Rating for erosion of Guvenc Basin

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slight</td>
<td>1</td>
</tr>
<tr>
<td>Moderate</td>
<td>2</td>
</tr>
<tr>
<td>Severe</td>
<td>4</td>
</tr>
</tbody>
</table>

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Fig. 3: Soil map of the study area of Guvenc Basin

Table 5: Rating for vegetation/land use factors of Guvenc Basin

<table>
<thead>
<tr>
<th>Vegetation cover (%)</th>
<th>Rainstorm frequency</th>
<th>Conservation practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF, FP</td>
<td>1</td>
<td>Exceptional</td>
</tr>
<tr>
<td>NV</td>
<td>2</td>
<td>Once in a year</td>
</tr>
<tr>
<td>HE1, AA1, AA4, AA6, AP1, AT1</td>
<td>3</td>
<td>Several times in a year</td>
</tr>
<tr>
<td>AA2</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

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Hacisalihoglu (2007) determined and compared the soil erosion amounts between the different land use types such as forest lands, grasslands, shrubs and new forestations. According to his results, the soil erosion amount differs in a high ratio between the land use types. The main land uses of the study area are rangeland, rainfed, forest, rock out crops, week forest and irrigated land (Table 8).

As a result of analysis, while 35.1% of the total area has heavy texture (clay), 45.7% is light and moderate soil texture. Heavy texture soil was found on Kervanpinar soil series was classified as Vertisol. Therefore, this soil has high surface sealing and according to model its rating value is six. Soil depth map results showed that while 58.4% of soils has shallow and very shallow depth, approximately half of the study area soils (40.6%) have between 50-100 cm. There are no common conservation practices such as benching, terracing and in the study area contouring. It was observed that general types of erosion are rill and sheet erosions. While, rill erosion have commonly occurred on Tabyabayir soil series, Cayirinkafa, Yasmese, and Acisu soil series have sheet erosion due to mismanagement agricultural activities. Each land characteristics is considered as a thematic layer in the GIS. In the final step, each of the land qualities with associated attribute data was digitally encoded and combined all layers in a GIS database to generate erosion risk map (Fig. 4). According to soil erosion risk map results, the study area has 50.8% low, 12.6% moderate, and 44.4% high and very high erosion risk levels, respectively.

**Soil conservation strategies:** To reduce soil erosion and improve land conditions, some alternative strategies were given for the study area. In the Ankara-Guvenc Basin, on slightly or insignificantly erosion risk soil, intensive agriculture is possible, whereas on very high potential erosion risk soil only special crops or forestry can be
and Ceyrûkfa soil series due to heavy clay texture and intensive 
field traffic (soil compaction). Strategies which appear particularly 
useful are: reduce tillage, deep-ploughing, add organic manure, 
counter residue incorporation, surface and sub-surface drainage 
are recommended for these soils to diffuse water and root in the soil 
profiles. In addition, proper timing of cultivation helps especially 
during planting. Therefore, the farmer should wait until soils are dry 

enough to permit tillage.

The present works show that GIS and RS have an important 
role to collect, record, analyze and overlap of the data in very short 
time in erosion risk assessment and basin management studies. In 
addition, erosion models are very useful tool for evaluation of soil 
erosion risk status of significantly large areas. Because, the 
conventional methods require high labour cost and time to collect 
data and measure soil erosion in heterogeneous, patchy of the 
significantly large areas can be hard. This could be very useful for 
deciding restoration practices to control the soil erosion of the sites 
to be severely influenced. Bayramin et al. (2003), Lufafa et al. 
(2002), Dengiz and Akgül (2005), Misir et al. (2007) indicated that 
these problems can be overcome by using predictive models and 
new techniques.

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Dengiz, O. and O. Baskan: Comparison of three different erosion risk 
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Table 7: Rating sum and corresponding class for erosion assessment

<table>
<thead>
<tr>
<th>Description</th>
<th>Rating sum</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not or significantly susceptible to erosion</td>
<td>0-16</td>
<td>1</td>
</tr>
<tr>
<td>Slightly susceptible to erosion</td>
<td>17-24</td>
<td>2</td>
</tr>
<tr>
<td>Moderate susceptible to erosion</td>
<td>25-29</td>
<td>3</td>
</tr>
<tr>
<td>Highly susceptible to erosion</td>
<td>30-48</td>
<td>4</td>
</tr>
<tr>
<td>Very highly susceptible to erosion</td>
<td>&gt; 48</td>
<td>5</td>
</tr>
</tbody>
</table>

Fig. 4: Soil erosion risk map of the study area of Guvenc Basin

Table 8: Distribution of land use and vegetation covers of the study area 
of Guvenc Basin

<table>
<thead>
<tr>
<th>Class</th>
<th>Area (ha)</th>
<th>Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rangeland</td>
<td>882.6</td>
<td>50.5</td>
</tr>
<tr>
<td>Rainfed</td>
<td>636.2</td>
<td>36.4</td>
</tr>
<tr>
<td>Rock out crops</td>
<td>143.3</td>
<td>8.2</td>
</tr>
<tr>
<td>Week forest</td>
<td>55.9</td>
<td>3.2</td>
</tr>
<tr>
<td>Irrigated land</td>
<td>12.2</td>
<td>0.7</td>
</tr>
<tr>
<td>Lake</td>
<td>17.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

applied. Since Tabyabayır, Yasmese and some part of the Kervanyolu 
soil series have almost the same restricting root growth factors such 
as high slope degree, shallow soil depth, stoniness etc., they 
require similar soil conservation management to reduce runoff 
velocity and improve soil condition. These measurements are 
diversion channels, reduced-tillage, mulch-tillage, residue 
incorporation, organic manures, retention terraces, continuous 
bench terraces

Moderately eroded soil can be used with semi-sentensive 
agriculture such as vertical-tillage against to slope, cover crops, 
retention terraces, and so on. Low aeration capacity and high bulk 
density were recorded under the surface soil of Aciisu, Kervanpınar