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Soil Erosion Risk Assessment of the Gölbaşı Environmental Protection Area and Its Vicinity Using the CORINE Model

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Abstract: The main objective of this study was to determine the soil erosion risk in Gölbaşı Environmental Protection Area and its vicinity using the CORINE model. The model consists of 6 steps, each of which using different overlaying combinations of soil texture, depth, stoniness, climatic data, land use and land cover information. In the first step, soil texture, depth and stoniness layers were extracted from a 1:25,000 scaled digital soil map and overlaid to form a soil erodibility map. Secondly Fournier and Bagnouls-Gaussen aridity indexes calculated from the climatic data were used to form the erosivity layer of the study area. The next step consisted of obtaining slope angle classes from digital elevation model of the study area. As the fourth step the land cover layer was prepared from the land use map considering the density of the plant cover. Then the potential soil erosion risk layer was produced by overlapping soil erodibility, erosivity and slope layers. For the final step, the land cover and potential soil erosion risk layers were combined to form the actual soil erosion risk map. The results showed that 72.9% of the study area had low, 23.8% of the area had moderate and a small part of the study area (1.0%) had high soil erosion risk. In addition, the study showed that the geographic information system (GIS) technique has an important role in the prediction of soil erosion risk studies.

Key Words: CORINE erosion model, soil map, geographic information system

Gölbaşı Özel Çevre Koruma Alanı ve Yakın Çevresinin CORINE Modeli ile Erozyon Risk Değerlendirmesi

Özet: Bu çalışma ile Gölbaşı Özel Çevre Koruma alanı ve yakın çevresinde yayılım gösteren arazilerin CORINE erozyon risk modeli kullanılarak erozyon risk durumlarının belirlenmesi amaçlanmıştır. Bu model, toprak bünye, derinliği, taşlılık, eğim, arazi kullanım ve arazi örtüsü bilgilerini kullanıldığı altı aşamadan oluşmaktadır. İlk aşama olarak, 1:25.000 ölçekli sayısal toprak haritasından bünye, derinlik ve taşlılık katmanları oluşturuldu. İklim verileri kullanılarak Fournier ve Bagnouls-Gaussen kuraklık indislerine göre çalışma alanının aşınabilirlik katmanı hazırlandı. Üçüncü aşama olarak, sayısal arazi modeli (SAM) kullanılarak eğim haritası hazırlandı. Dördüncü aşamada, toprak erodibilite, erosivite ve eğim katmanları birleştirilerek potansiyel erozyon risk haritası oluşturuldu. Bu sonuçlara göre, araştırma alanını % 72.9'u düşük, % 23.8'i orta ve % 1.0'lik gibi çok az bir kısmı ise yüksek erozyon riskine sahiptir. Ayrıca bu çalışma toprak erozyon risk tahminlerinde Coğrafi Bilgi Sistemi (CBS) tekniği kullanılmasının önemli bir rölü olduğunu da göstermiştir.

Anahtar Sözcükler: Corine erozyon modeli, toprak haritası, cografi bilgi sistemi

Introduction

A large number of environmental problems involve the destruction of the natural balance as a result of the misuse or abuse of nature. Since soil is one of the basic elements of nature, soil problems are important environmental problems. Foremost among soil problems is erosion, caused and exacerbated in particular by incorrect agricultural practices.

The control of soil erosion processes depends on appropriate land use and management planning. After processes of soil erosion caused by the interaction of soil, rainfall, slope, vegetation and management, the soil's physical, chemical and biological properties are changed undesirably, leading to yield reduction and more risky production (Pla, 1997).

Arable land in the world cover nearly $3.2x10^6$ ha and

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cultivated land occupies $1.475x10^6$ ha of total arable lands. The area of agricultural land per person decreased 14.3% in developed countries and 40% in developing countries recently. In addition, according to the FAO, the area of agricultural land per person will decrease to 0.21 ha in 2020. Increases in the world's population will bring about significant land degradation problems. Soil scientists have declared that mismanagement practices have caused a decrease of approximately 15% in the productivity of agricultural lands throughout the world until recently. 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 studies, 0.5-2.0 t ha^{-1} soil is lost each year and the total amount is approximately $2.4x10^9$ t $year^{-1}$ (Turkey Irrigation Report, 2001).

Soil and water are the most important resources for ensuring the sustainability of food production. Among the different land degradation processes, water erosion is the major threat to the conservation of soil and water resources. One of the basic objectives of sustainable land management is to reduce production risks. Therefore, it is essential to better understand and predict the efficient use of rainfall water and soil properties. Moreover, as a rule of thumb, conservation requirements should be evaluated and incorporated in agricultural development plans for the opening up of new lands as well as for changes in land uses aimed at increasing production (Dudal, 1980). However, due to inappropriate agricultural practices, uncontrolled grazing and deforestation, the production capacity of land has decreased as a result of increasing rates of soil erosion and land degradation, which in turn lead to the restriction of producing food for the needs of growing population in many countries of the world (Reusing et al., 2000).

Turkey is a mountainous and hilly country. The average altitude is approximately 1250 m above sea level, and 59.0% of the total land has more than 12% slope. Because of the topographic conditions, soil erosion is the biggest problem in Turkey; some 72.6% of the land is exposed to severe and very severe soil erosion problems (Doğan, 1998).

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).

A simulation model may be a more effective way to predict soil erosion processes and their effects using geographic information system (GIS) and remote sensing (RS) techniques. Therefore, models 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). Sazbo et al. (1998) investigated land degradation and mapping of erosion using RS and GIS techniques, and Bojie et al. (1995) indicated that GIS analysis could help organize erosion survey and mapping by integrating DEM, slope and land use.

According to the CEC report (1992) using the CORINE model, while approximately 19% of the rural land surface of EU countries had low erosion risk, 36% was classified as having a moderate actual erosion risk and a similar amount (37%) was classified as low erosion risk.

Doğan et al. (2000) determined the soil erosion risk status of Dalaman Basin, located in the west Mediterranean region, using the CORINE model. According to their results, 27% of the basin soils had low, 40% had moderate, and 29% had high levels of actual erosion.

Because it is very difficult to estimate soil erosion risk in considerably large areas in terms of cost, labour and time, a number of simulation models have been developed to predict soil erosion. The aim of this study was to determine and evaluate the soil erosion risk in Gölbaşı Environmental Protection Area and its vicinity using a simulation model called CORINE.

Materials and Methods

The study was conducted in the Gölbaşı area and its vicinity, located south of the city of Ankara (Figure 1) at coordinates 4410120N-471156E, 4410120N-488742E, 4386390N-471156E, 4386390N-488742E. The study area covers approximately 34,695.6 ha and includes Mogan and Emir Lakes. These lakes cover 798.6 ha (2.3 %) in total area. The study area consists of various topographic features (flat, hilly, rolling etc.). Flat and rolling physiographic units are particularly common in the study area. Elevation varies from 900 m to 1259 m above sea level. Average annual precipitation and temperature are 410.5 mm and 11.8 ^{o}C, respectively (DMI, 2003). According to soil taxonomy (Soil Survey Staff, 1999), the soil temperature regime and moisture

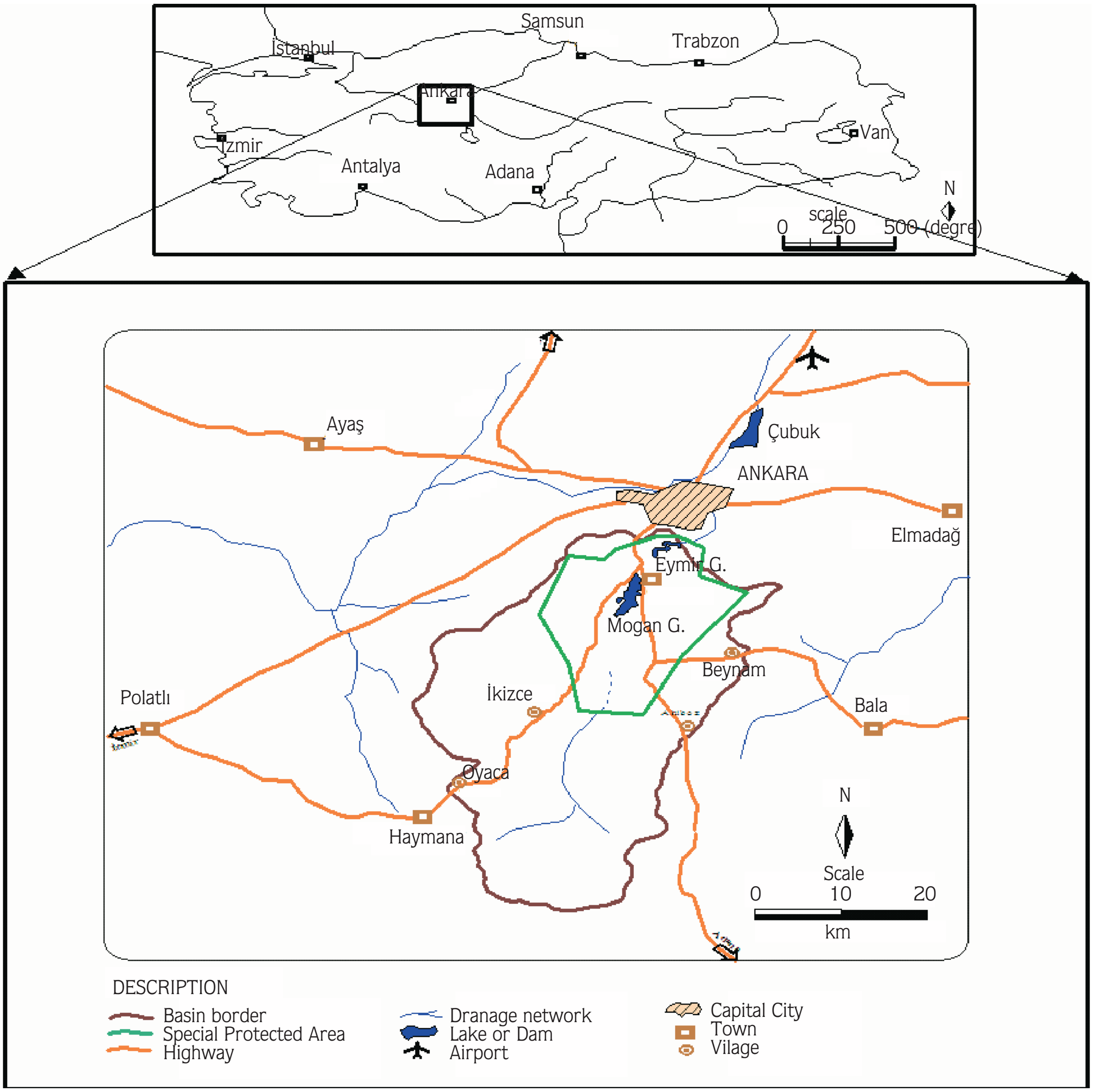

Figure 1. Location of the study area.

regime were classified as mesic and xeric, respectively. There are 19 different soil series in study area and they were classified as Mollisol (33.6%), Inceptisol (32.8%), Entisol (26.8%), and Alfisol (6.8%) (Dengiz, 2002). Forest and forage areas generally cover the northern part of the study area, whereas irrigated agriculture is practiced on a very small part located on both sides of the Suksen River and near the other irregular flowing rivers. Dry farming and forage areas are common in the southern part of the study area.

The DEM digital soil map and land use map prepared by Dengiz (2002) and meteorological data were used in the CORINE model (Commission of the European Communities, 1992) and all the data were analysed using TNT Mips 6.4 GIS software.

The CORINE model, which has been applied by many countries in the European Community, is constituted by combining 4 parameters, soil erodibility, erosivity, topography and vegetation cover (Figure 2). Risk assessment is carried out in mainly 2 steps. First,

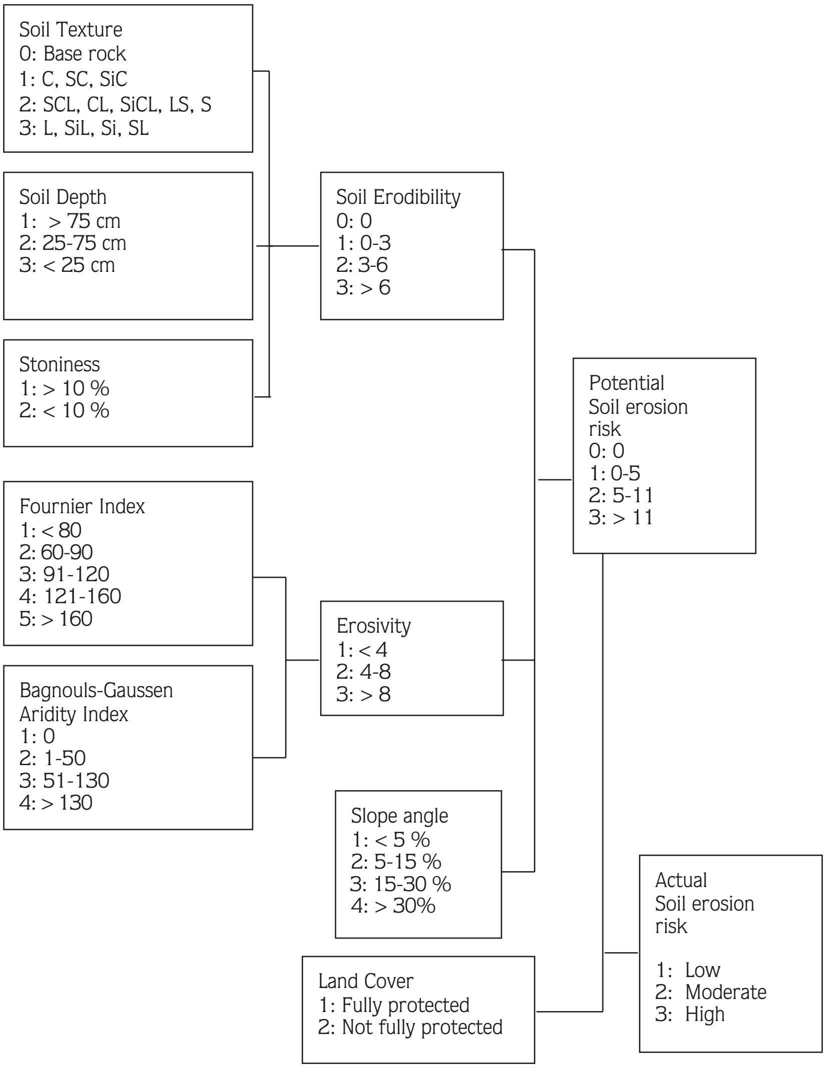

Figure 2. Flow diagram of the CORINE model.

potential soil erosion risk is calculated by integrating the indexes on soil erodibility, rain erosivity and slope angle. Thus, we can determine the inherent susceptibility of the land to erosion. The second step involves the actual soil erosion risk, which refers to the estimated present risk calculated by combining the vegetation cover index and the estimated potential erosion risk. In order to determine the potential soil erosion risk in the study area, first of all, soil depth, soil texture and stoniness maps were derived from 1:25,000 scaled digital soil maps. The second step is the determination of soil erosivity. Erosivity, which depends on the intensity and the amount of rainfall collected from DMI (2003), is calculated using the Fournier and Bagnouls-Gaussen aridity indexes. These 2 climatic indices are combined to generate the erosivity indexes. The Fournier index is formulated as follows:

$$FI = \sum_{i=1}^{12} \frac{Pi^2}{P}$$

where Pi = total precipitation in a month, and P= total mean annual precipitation.

The second climatic index is the Bagnouls-Gaussen aridity index (BGI), which is defined as follows;

$$BGI = \sum_{i=1}^{12} (2t_i - P_i)k_i$$

where ti: the mean temperature for the month, Pi: total precipitation in month i, and ki represents the proportion of the month during which 2ti-Pi > 0.

The slope layer was derived from the DEM and classified in 4 groups. The slope, soil erodibility, and soil erosivity layers were then overlapped in order to prepare the potential soil erosion risk map. The vegetation cover consists of 2 classes: fully protected (forest, permanent pasture, and dense scrub) and not fully protected (cultivated or bare land). The land use map was used to produce the vegetation cover layer, which was then merged with the potential soil erosion risk layer to generate the CORINE actual erosion status map.

Results and Discussion

Soil erodibilty refers to the susceptibility of the soil to erosion and depends on the structural stability of the soil and on its ability to absorb rainfall. For that reason, soil texture, depth, and stoniness layers derived from a digital soil map were used to generate the soil erodibility map of the study area. Table 1 shows that 48. 6% of the study area has moderate, 29.6% has heavy (clay and silty clay) and the rest (19.5%) has loam, sandy loam and silty loam textures. In addition, it can be seen that the depth approximately more than half of the study area is 25-75 cm. The depth of nearly 1 % of the study area is less than 25 cm, whereas that of 35.6% is more than 75 cm. The stoniness layer was derived from the soil map and it was found that about 69.0% of the study area has less than 10 % stoniness, and the rest has more than 10% stoniness. After overlapping these 3 layers, the soil erodibility map was prepared (Figure 3). The soil erodibility classes are presented in Table 1. More erodible soils, which cover 15.1% of the total area, are common on the Taşpınar and Mogan soil series and 23.7% of the study area has low soil erodibility risk.

Meteorological data were used to prepare the erosivity layer of the model for the study area. For this aim, the Fournier and Bangouls-Gaussen aridity indexes were taken into consideration. The Fournier index was calculated as less than 60 for the study area and coded as 1 in the CORINE model. The second climatic index was found between 50 and 130 and was coded as 3. After combining these two parameters, erosivity code was determined as 1 in the model.

Slope is undoubtedly one of the most important determinants of soil erosion. Erosion only occurs when slope exceeds a critical angle and it increases with the absence of vegetation cover. Slope groups (Figure 4) derived from DEM are presented in Table 2. It can be seen that 75.3% of the study area has less than 15 % slope (very gentle and gentle) and 24.7% has more than 15% slope, varying from steep to very steep, from which runoff can easily occur. Steep and very steep areas are located on the Taşpınar, Ahlatlıbel, Doğutepe, Örencik soil series and on some parts of the Recepli and Ulugüney Sırtı series.

Soil erodibility, erosivity and slope layers were combined to produce the potential soil erosion risk map, which did not consider vegetation cover or land uses, and its results are presented in Table 2. As most of the study area has very gentle and gentle as well as low and moderate erodibility, from the table it can be seen that 96.6% of the area has low and moderate, and only a small part of the area (1.1%) has high potential soil erosion risk.

Table 1. Distribution of soil texture, depth, stoniness and soil erodibility in the study area.

Soil Texture				Soil Depth				Stoniness				Soil Erodibility			
	Class	Ha	%		Class	Ha	%		Class	Ha	%		Class	Ha	%
1	C, CS, SiC	10,261.3	29.6	1	75	12,337.1	35.6	1	10	9961.4	28.7	1	Low	8228.7	23.7
2	SCL, CL, SiCL, LS,S	16,867.6	48.6	2	25-75	17,420.6	50.2	2	10	23,935.6	69.0	2	Moderate	20,456.7	58.9
3	L, SiL, Si, SL	6768.1	19.5	3	25	4139.2	11.9	-	-	-	-	3	High	5211.5	15.1

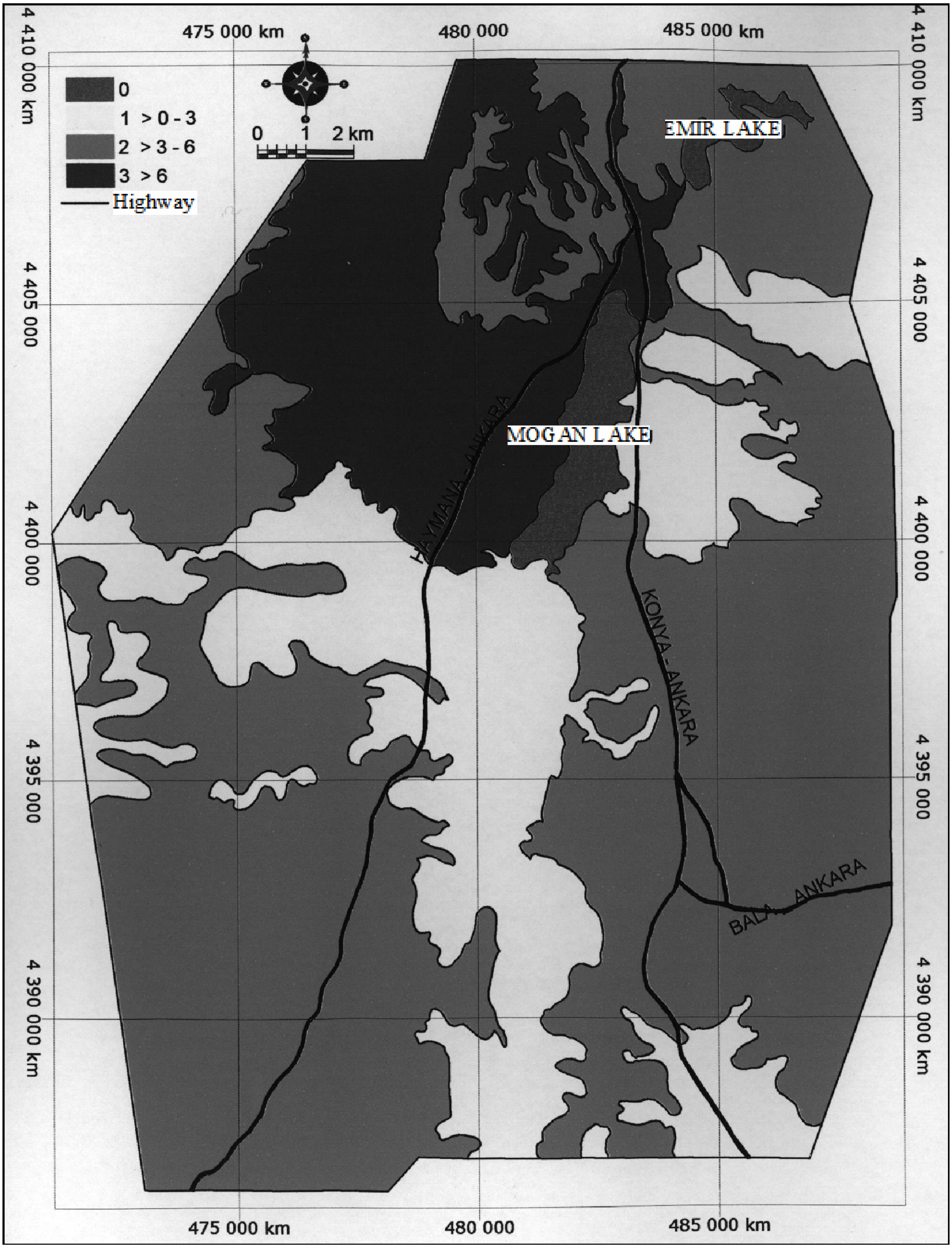

Figure 3. Soil erodibility map of the study area.

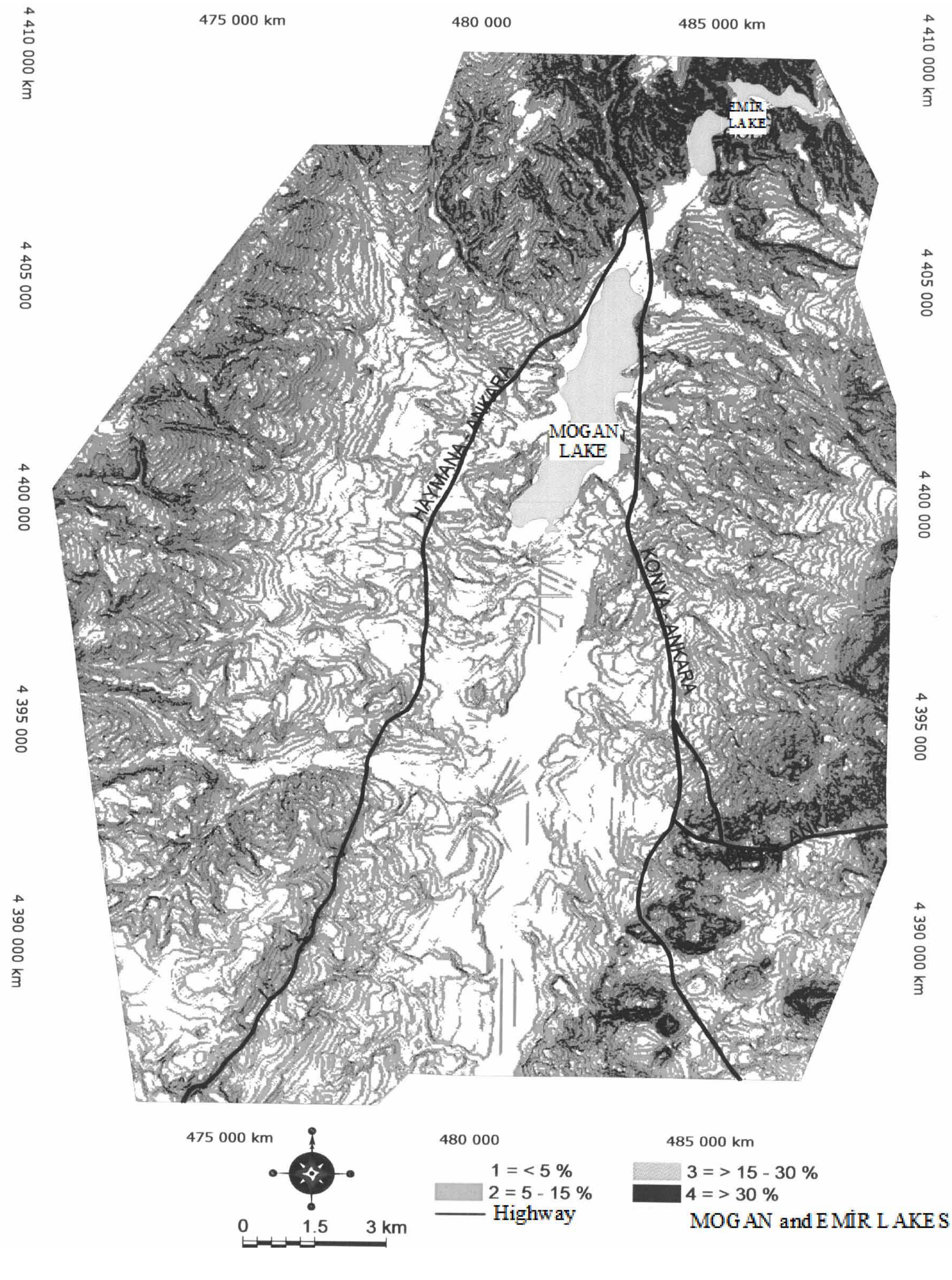

Figure 4. Slope map of the study area.

Table 2. Distribution of slope, potential erosion risk and actual soil erosion risk in the study area.

Slope				Potential Erosion Risk				Actual Soil Erosion Risk			
Class (%)		Ha	%	Class		Ha	%	Class		Ha	%
1	0-5	10,245.3	29.5	1	Low 0-5	24,025.7	69.1	1	Low	25,307.6	72.9
2	5-15	15,897.6	45.8	2	Moderate 5-11	9532.9	27.5	2	Moderate	8251.2	23.8
3	15-30	5917.9	17.1	3	High 11 +	379.1	1.1	3	High	379.0	1.0
4	30 +	2671.6	7.6	-	-	-	-	-	-	-	-

Vegetation cover is the most crucial element in erosion models, since it is the only factor that can readily be altered, and provides effective soil erosion control. In addition, soil erosion has accelerated due to inappropriate land uses and continuous cultivation on steeper land (Millward and Mersey, 1989). The main land uses of the study area are dry farming, rangeland, forest, settlements, and irrigated land. According to the model, forest and irrigated lands were classified as fully protected areas covering 2382.6 ha and the rest of the study area was classified as none fully protected areas covering 31,514.4 ha.

In the final step, the CORINE actual soil erosion risk map was generated by overlapping the land cover map and the potential soil erosion risk map, and the results are presented in Table 2 and Figure 5. Actual soil erosion risk map results showed that the study area has 79.2% low, 23.8% moderate, and 1.0% high erosion risk levels, respectively. From the results, it can be observed that the difference between the areas of potential and actual erosion risk reflects the protective influence provided by the present land cover. In particular, 27.5% of the area classified as having moderate erosion risk in the potential soil erosion risk map decreased to 23.8% in the actual soil erosion risk map. In addition, while about 69 % was classified as having low erosion risk in the potential soil erosion risk map, after overlapping the vegetation layer, low erosion risk areas increased to about 73%.

Conclusion

This study demonstrated that a large part of the study area is under low erosion risk. Although northern parts of the study areas have very steep slopes, these areas have low erosion risk due to being covered by forest. In addition, eastern and western parts of the area are hilly and have rolling topographic conditions and cover generally rangeland and dry farming. Therefore these areas need good management practices for effective erosion control.

Although the Fournier index gives an acceptable measure of rainfall variability, it does not take into consideration short intense storms, which may be significantly erosive. In addition, according to the Fournier index, the amount and the intensity of rainfall are equally distributed throughout the area. However, every point in the area may not receive the same amount and intensity of rainfall due to different topographic conditions. For that reason, topographic conditions may in a way be considered in the calculation of the erosivity.

In this study, soil properties (texture, depth and stoniness), topographic conditions and land cover are the main factors in the determination of the soil erosion status in the model. On the other hand, the combination of the Fournier and Bagnouls-Gaussen indexes, which gave the erosivity index was found to have no effect on actual soil erosion risk.

Among these factors, soil properties such as texture, depth and stoniness were used to determine the soil erodibility. In addition to these parameters, other factors or layers such as organic matter and carbonate content of the soil, parent material properties and existence of hard pan can be incorporated in the model to determine the condition of the soil more realistically for the calculation of soil erodibility.

The CORINE erosion model is very useful for the assessment of erosion risk status, because the conventional methods require high labour cost and time to collect data and measure soil erosion in heterogeneous, patchy and significantly large areas. Therefore, Bayramin et al. (2003) and Lufafa et al. (2002) indicated that these

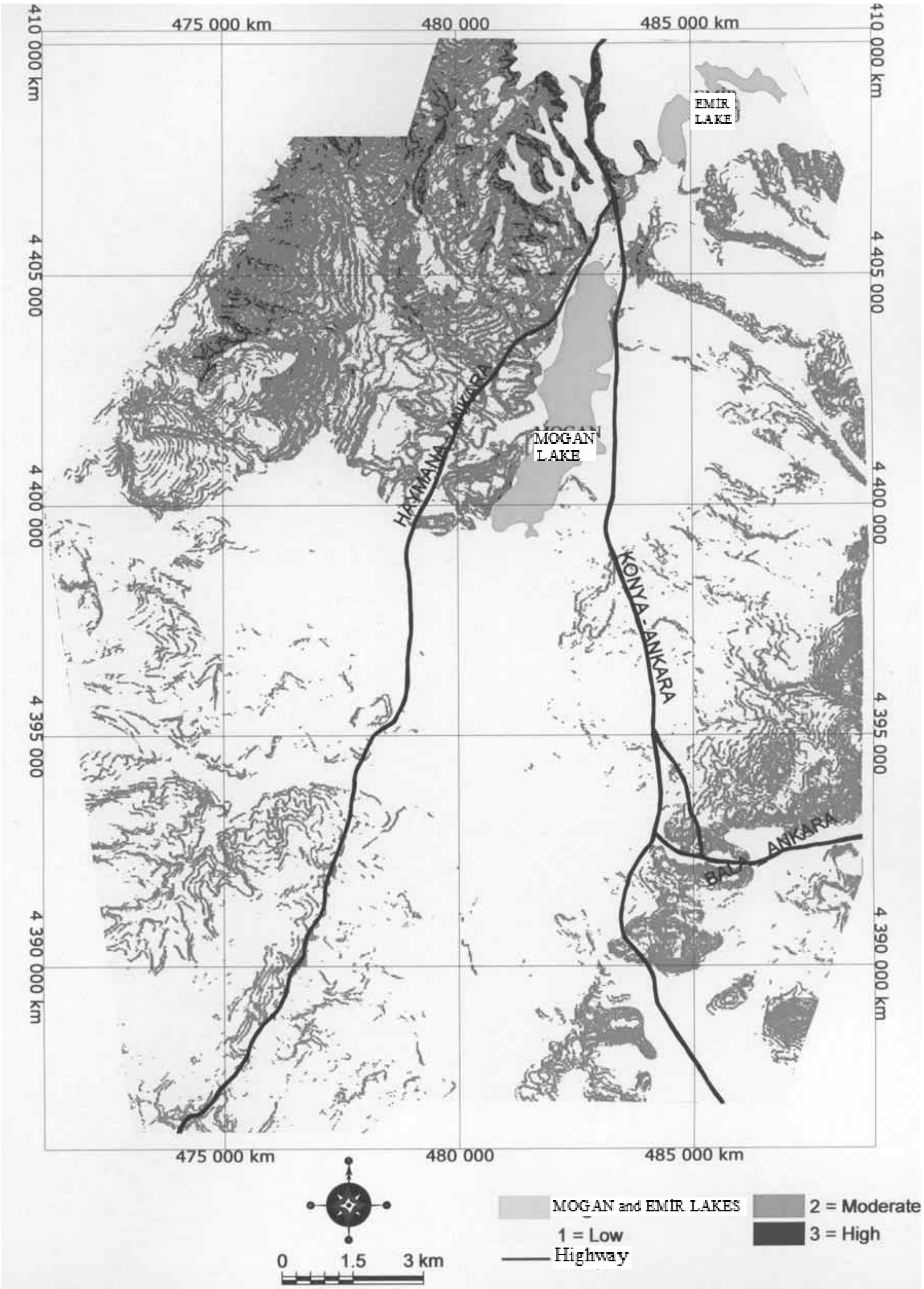

Figure 5. Actual soil erosion map of the study area.

problems can be overcome by using predictive models and new techniques. On the other hand, by means of GIS and RS, the data collected from the environment can easily be analysed and evaluated to map soil erosion risk and to prepare a future land management plan for the sustainable use of land resources.

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