EROSION RISK MAPPING OF CAPAKCUR STREAM WATERSHED USING GEOGRAPHICAL INFORMATION SYSTEM AND REMOTE SENSING

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ABSTRACT

Capakcur stream watershed located in the southwest of Bingol city, in Turkey, covers a 106 km^2 area. The watershed with higher slope degrees faces severe soil erosion due to vegetation destruction, lithological and climate properties, except for a limited area located in the west of the watershed. Settlements in the watershed are usually take place near the valley base due to the rugged surface, which may generate costly land-slide events. To describe the basin with high risks and to create sufficient preventative steps, erosion sensitivity maps were obtained using a statistical analysis by the superposition principle. Digital Elevation Model (DEM) was acquired from the digitization of topographic map of the watershed, then the used for calculations of slope degrees. The erosion risk maps were attained by using the parameters of the slope degree, precipitation, Normalized Difference Vegetation Index (NDVI), stream density and soil texture calculated from soil brightness index (SBI) by applying Tasseled Cap transformation to satellite images. During the calculation of the map risks, each parameter was initially divided into subclasses and given a weight point according to the degree of influence upon the erosion, the sensitivity map was then created by adding each parameter map. Results from the sensitivity map indicate that 50% of the watershed is under high and 15% is under severe erosion risk while only 11% of the watershed is under low or very low erosion risk. The rugged structure of the watershed has necessitated the establishment of the settlement to the valley bed. Materials transported by rivers in the watershed where the erosion is severe, are deposited in the stream bed. The reduction in carrying capacity of streams causes floods affecting settlements. The sensitivity maps clearly indicate that the precautionary steps such as protection of the vegetation cover, plantation or relocating settlements away from the valley base will be immediately undertaken for further soil erosion in the watershed.

KEYWORDS:
Bingol, Capakcur Stream Watershed, Erosion

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1. INTRODUCTION

Erosion is removal of topsoil by water and wind after wearing by natural or manmade agents [1]. This removal is created by wind in arid and semi-arid zones, by glaciers in glacial zones and by streams in fluvial zones [1,2]. Bedrock erosion triggered by external factors is a usual geomorphological process, and the eroded topsoil can be compensated during the course of this process [2]. Soil in areas subject to degrading and erosion can be replaced with natural soil formation processes, and rejuvenate by the help of wind or runoff. Human interference in the natural erosion areas progressing with its own specific rules in the natural balance may cause natural destructions which cannot be reversed or corrected. Accelerated water erosion created by human interference may time to time result in costly floods associated with losses of lives and property [3].

The amount and severity of erosion are chiefly related to topographic features, drainage areas, vegetation type and cover, surface drainage development and geological layers [1]. The amount of eroded soil is also affected by these factors at different degrees. Thus, setting off the problem is possible only after effective factors which involve in erosion must be well surveyed and assessed [2].

Soil erosion may cause not only adverse social but economical outcomes as well [4, 5]. Erosion has a very strong effect upon water sources and protections [5, 6]. Therefore, the interest in producing erosion sensitivity maps of basins/watersheds have been recently increased [7]. Detecting high-erosion-sensitive areas with erosion sensitive maps is one of the preliminary steps taken towards to conservation [4].

Previous studies have indicated that erosion sensitivity may be generated by a variety of empirical or physical methods [7-12]. Empirical methods help to predict erosion by collecting physical parameters while physical methods with a mathematical base is used for determining the amount of eroded and deposited soil [4].

Recent literatures have also shown that there were some studies using geographical information technology and erosion sensitivity maps for complicated empirical methods. These methods used for producing erosion sensitivity maps in basin or watershed scales are logistic linear models, statistical and weighted superposition procedures [4, 7, 12-14].

The aim of the research was to generate an erosion sensitivity map of Capakcur Stream Watershed with a 1/25.000 scale by employing the weighted superposition procedure.

2. MATERIALS AND METHODS

2.1 Study Area

Capakcur Stream Watershed located in the southwest of Bingol city, in Turkey, covers a 106 km^2 area. Bordered by Karaomer mountains' spurs in the southwest, Capakcur watershed's running water and runoff are collected by Capakcur Stream (Figure 1.). Capakcur stream after merging with Goynuk stream in Bingol joins to the Murat River.

Capakcur Stream Watershed is vulnerable to severe erosion. Cutting the watershed with dip-slip faults and faulty topographic structure cause an increase in slope and slope variability's. Water density is very high in the watershed where the lithology is made up of resistless marls and volcanoes. Deforestation and degradation of vegetation are also very high in the watershed where the natural vegetation is mainly composed of steppe species.

The elevation in the watershed decreasing in the direction of the northwest to southwest ranges from 1140m to 2505m with an average of 1776m. The watershed is cut with dip-slip faults in the southwest which contributes to increase in the elevation and causes Capakcur stream settles more into its stream bed. This settlement can reach up to 500m in some sections. Young tectonic movements and fluvial erosion have created a faulty topographic structure in the watershed. The slope ranges from 25% to 45% in 38% of the watershed and the average slope is 22% with a maximum value of 61%.

Lithology of the watershed is made up of ophiolite of Yuksekova melange, marble and schist of Bitlis matamorphite, marl, pebble and sandstone of Gevla Stream formation as well as basalt, tuff and agglomerate of Solhan formation [15]. (Fig. 2). Surface water flow increases due to especially impermeable futures of the marls in the watershed. Thus, the area with marl structures are susceptible to ravine erosion.

Meteorological data were obtained from Bingol Meteorological Station located in the watershed. The average annual temperature is 12°C and precipitation is 891 mm which increases in winter and spring while summer is comparatively dry. Erosion can be severe on stepper slopes due

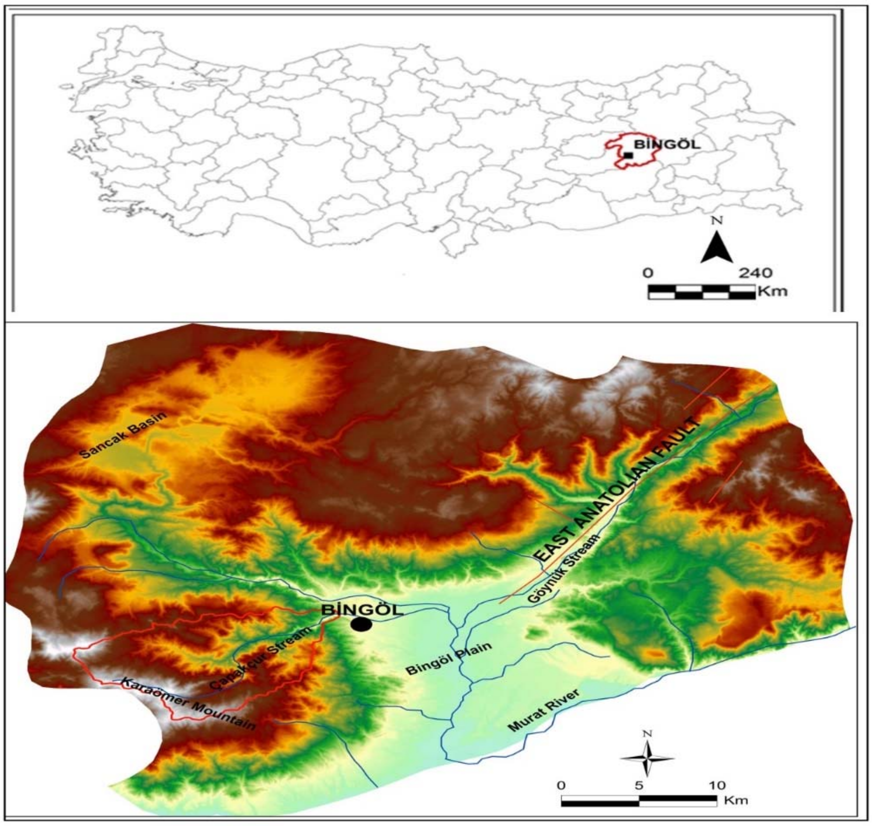

FIGURE 1 - Location map of Capakcur Stream Watershed

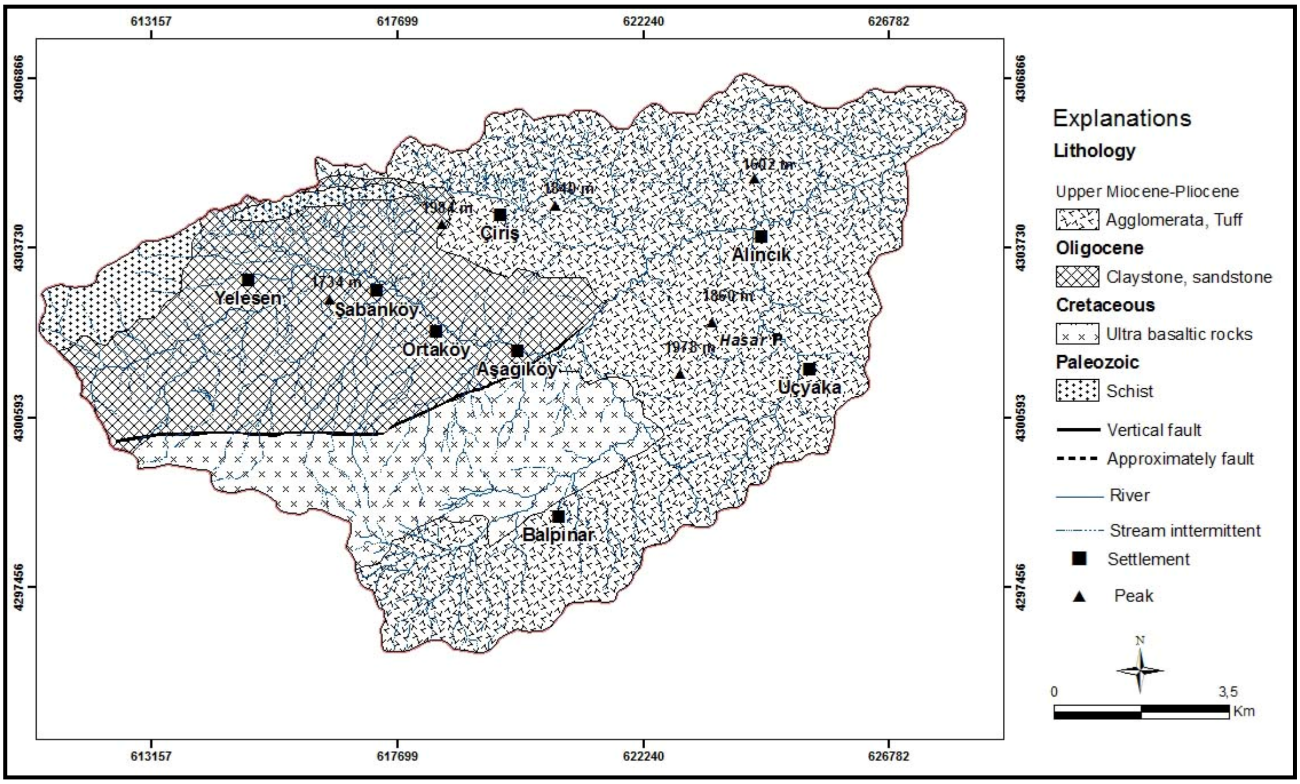

FIGURE 2. Geological map of Capakcur Stream Watershed.

to the increased precipitation and downpour during spring. Although the watershed has a higher precipitation rate, vegetation is sparse and composed of steeper species. Oak tree formation has emerged due to high precipitation in the south west of the watershed, however, forest vegetation is sparse due to deforestation.

2.2 Generating Erosion Sensitivity Map

Major factors affecting soil erosion are slope, aspect, precipitation, vegetation, soil type and land use [16-20]. Therefore, slope degree, precipitation, vegetation, stream density and soil brightness index were used to create erosion sensitivity map in the present study.

Slope degree characteristics of watershed were obtained from Digital Elevation Model (DEM) generated from the Digitization of topographic maps. The distribution of precipitation in watershed was obtained through interpolation technique. Normalized Difference Vegetation Index (NDVI) was obtain from satellite images of Landsat ETM [(May 2013) acquired from the study area and perimeter was used to estimate vegetation. NDVI was calculated through proportioning of subtraction and addition of near infrared and red bands [21]. The formula used to calculate is;

$$NDVI = \frac{\text{Band4} - \text{Band3}}{\text{Band4} + \text{Band3}} \quad .$$

Soil brightness index (TPI) was used to calculate soil texture [22]. TPI was subjected to Tasseled Cap transformation before the calculation. The formula [23] is:

$$TPI = 0{,}3561 * Band1 + 0{,}3972 * Band2 + 0{,}3904 * Band3 + 0{,}6966 * Band4 + 0{,}2286 * Band5 + 0{,}1596 * Band7$$

Stream density expressed as $km^2\ km^{-1}$ was attained after digitizing streams on a 1/25.000 scale map. Erosion sensitivity map of Capakcur Stream Watershed was generated by using weighted superposition assessment method which assumes different input values in the same cell size. Superposition were acquired from reclassified data from many raster analyses or from data containing integers. Therefore, the raster's intended to use in the analysis had to be reclassified or should contain directly integers (Arcgis Desktop). Raster's with decimal values were reclassified to convert integers. [24].

A value was assigned to every level according to erosion effectiveness rate, each factor was labeled with a risk score based on erosion effectiveness rate, and these levels were transformed a 10-grid map and super positioned. Higher values indicates the areas with high erosion sensitivity while low values indicate the areas with low erosion sensitivity.

3. RESULTS AND DISCUSSION

3.1 Effects of Slope on Erosion

Slope can help to generate runoff such as stream or rain wash, resulting in an increase in fluvial erosion. The increase in severity of erosion with higher slope degrees indicates a positive correlation between slope degree and erosion. Soil wearing and carrying effects of runoff or stream will occur only after the runoff/stream speed reaches to a critical flow rate [2]. Moreover, the amount of water to carry soil depends upon the slope degree [2], which is often used in erosion sensitivity studies since surface erosion is directly associated with the slope morphology [25].

The slope degrees acquired from DEM were divided into 5 subclasses: 0-2, 2-15, 15-25, 25-45 and over 45^0%. The slope in watershed ranges from 0 to 61% with an average of 22% (Figure 4). The areas with slope between 25 to 45% corresponded to a 38% of the total area, indicating a high risk of erosion severity (Figure 3, 4; Table 1).

TABLE 1 - Slope degree groups and sensitivities of Capakcur Stream Watershed.

Slope degree %	Total coverage area km^2	%	Sensitivity values
0-2	2.8	3	1
2-15	23.8	22	2
15-45	39.1	37	3
25-34	40.3	38	4
> 45	0.3	0	5

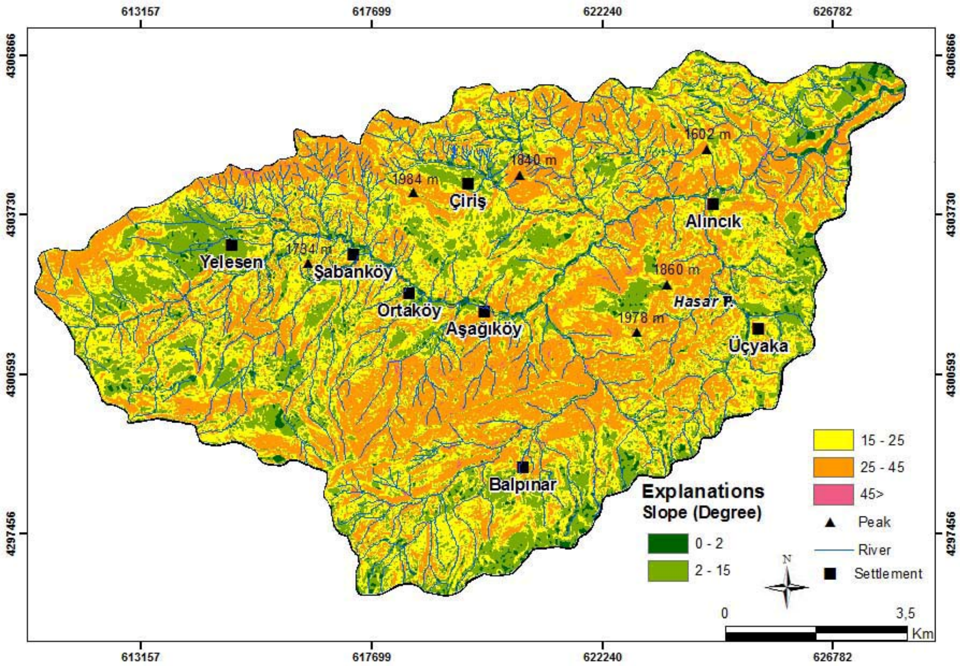

FIGURE 3 - Slope degree map of the Capakcur Stream Watershed.

FIGURE 4 - Severe erosion is visible in Capakcur Stream Watershed (Photo: A. Yüksel)

Tectonic activities and drainage densities have contributed to the variation of slope degrees. Thus, the south of the watershed has higher slope degrees owing to tectonic activities and drainage densities.

3.2 The Effects of Precipitation on Erosion

Precipitation is the solely and main factor for water erosion [26]. Rain water can cause surface flow by carrying soil particles [27]. An irregular pattern of precipitation as well as dry summer season in terms of physical conditions may also contribute to an increase in erosion [28]. The average long term annual temperature of watershed is 12 °C and total precipitation is 891 mm. The Taurus mountain range called The Southeast Taurus lies in the southeast of watershed. The Southeast Taurus blocks most of the humidified air mass from entering the southwest direction. The humidified air mass having able to pass the blockage confronts with the second blockage Bingol city perimeter. After confronting, air mass rises and causes a turbulence in the atmosphere over the watershed, which leads to heavy rainfall in the area [29]. Heavy precipitation mostly occurs as snow in the winter time (Figure 5). Erinç (30) and Tonbul [29] attributed the heavy precipitation in winter to Bingol lowland and perimeter located near on the border of "Mediterranean Secondary Air Current". The variability of elevation in the watershed is quite high. Thus, a variation in climate factors over the watershed is very common.

Precipitation map was created for the watershed to exert precipitation effects on erosion. The formula suggested by Schreiber was used to create the map [31]. The formula is; $Ph = Po + 54xh$ where pH indicates precipitation for apre determined elevation point, Po indicates the total precipitation of a meteorological station whose elevation is predetermined, *54* is the coefficient number for each of 100-m elevation, and h is the elevation difference between the meteorological station and the predetermined elevation point as hectometer. The precipitation ranges from 1033 to 1830 mm and increases in the southwest area owing to the higher elevation (Figure 6, Table 2).

The precipitation ranges from 1100-1300 mm in most of the watershed area (48%) with a sparse vegetation cover.

TABLE 2 - Precipitation and sensitivity values of Bingol Stream Watershed.

Precipitation mm	Total covered area km^2	Total covered area %	Sensitivity values
1033-1100	6.50	6	1
1100-1300	50.40	48	2
1300-1500	32.01	30	3
1500-1700	16.10	15	4
1700>	1.40	1	5

3.3 Effects of Vegetation Cover on Erosion

Vegetation cover is a very crucial element for the protection of fluvial erosion [32]. Land cover determining the relation between the precipitation with water infiltration and blats effects of rain drops is a very important factor [2]. Resistance to erosion increases with the increased vegetation cover of a land. Therefore, the slopes with sparse vegetation cover tend to have higher erosion rates [32]. In order to evaluate vegetation cover in the watershed and its perimeter, NDVI was calculated from satellite images of Landsat 7 ETM in May 2013. The vegetation was not ob-

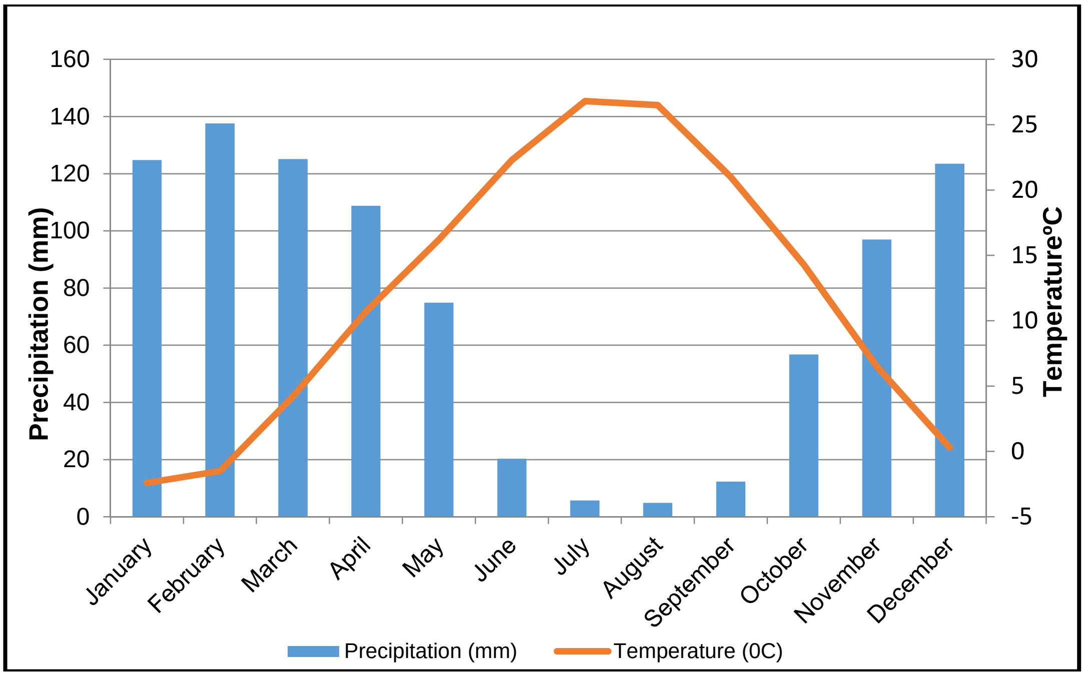

FIGURE 5 - Monthly average temperate and precipitation from 1975 to 2013 (DMI).

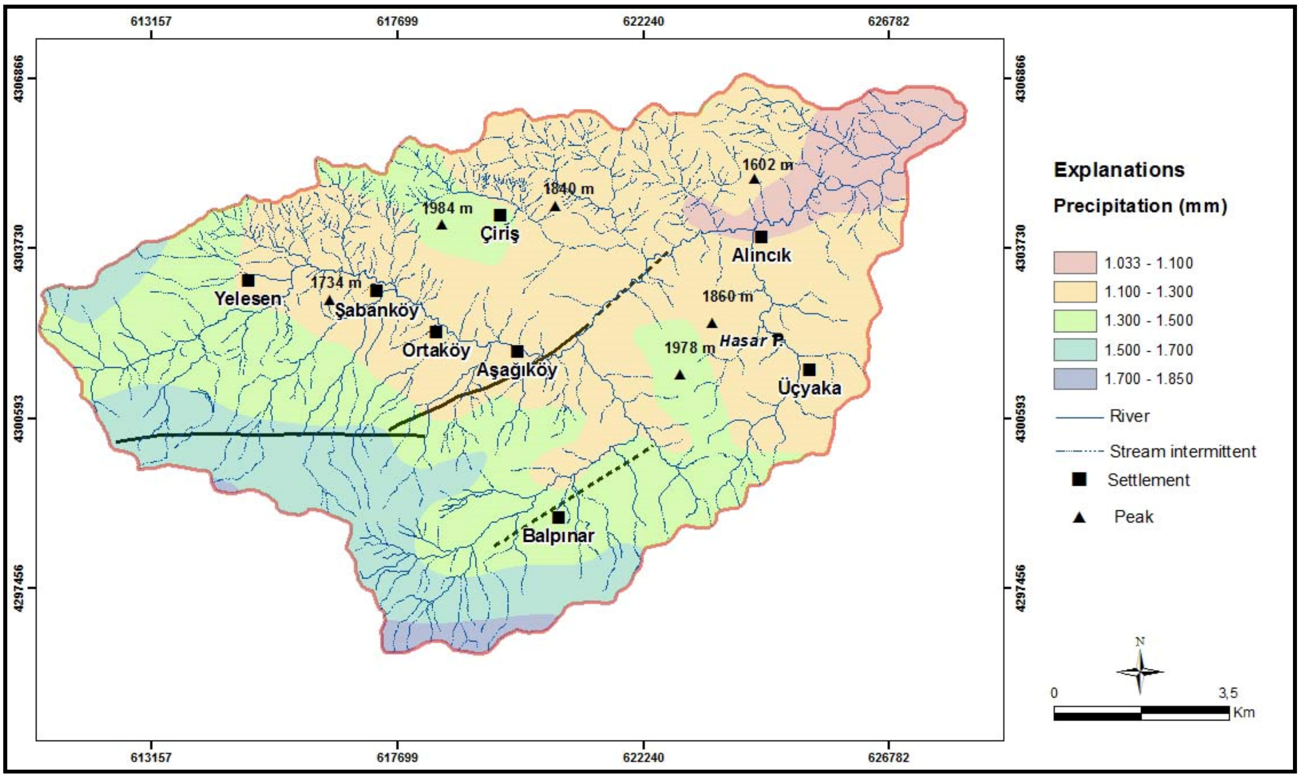

FIGURE 6 - Precipitation map of Bingol Stream Watershed.

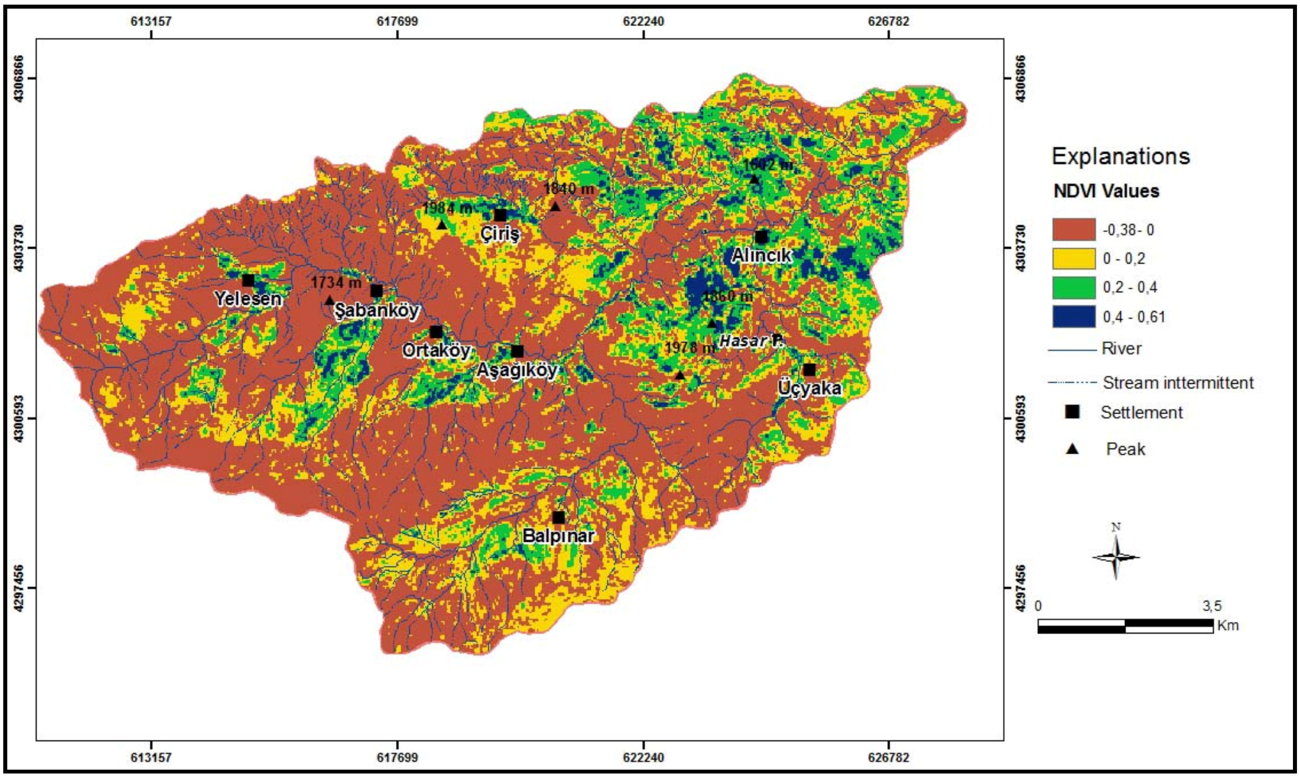

FIGURE 7 - NDVI map of the Capakcur Stream Watershed.

TABLE 3 -NDVI ranges and sensitivity values of Capakcur Stream Watershed.

NDVI	Total covered area		Sensitivity values
	km^2	%	
-0.38 – 0.00	65.08	61	5
0.00 - 0.20	24.14	22	4
0.20 - 0.40	13.62	13	3
0.40 - 0.61	3.88	4	2

served on 61% area of the watershed based on the NDVI. High vegetation cover of the watershed covered only 4% of the whole area (Figure 7, Table 3). Sparse or no vegetation cover in the watershed contributes the erosion severity.

There is a direct relation between erosion severity and vegetation cover in the watershed. The bedrock surface is visible due to the vegetation in the north of watershed.

3.4 Effect of Stream/Runoff Density on Erosion

High relief properties, sparse vegetation cover and low soil infiltration rate are associated with higher stream/runoff density while low relief properties, high vegetation cover and soil infiltration rate are related to the low stream/runoff density. Thus, as the drainage becomes denser, the erosion possibility increases or vice versa [33].

After seasonal and continuous streams having been digitized on topographic maps, a risk point was assigned according to water density (km^2 km^{-1}) and effectiveness scales. Water density was 2.4 km^2 km^{-1} calculated from

$$Dd = \frac{YL}{A}$$

where total drainage length (*YL*) was 363.2 m and area of the watershed (*A*) was 106.2 km^2 for throughout the watershed [1]. Reddy et al., [35]. stated that if drainage density is over 1.75, it is expressed as high, if over 2.5, it is expressed as very high. The number 3.4 calculated for the watershed indicated very high water density that was due to the lithological properties, high slope degrees and sparse vegetation covers (Figure 8, Table 4).

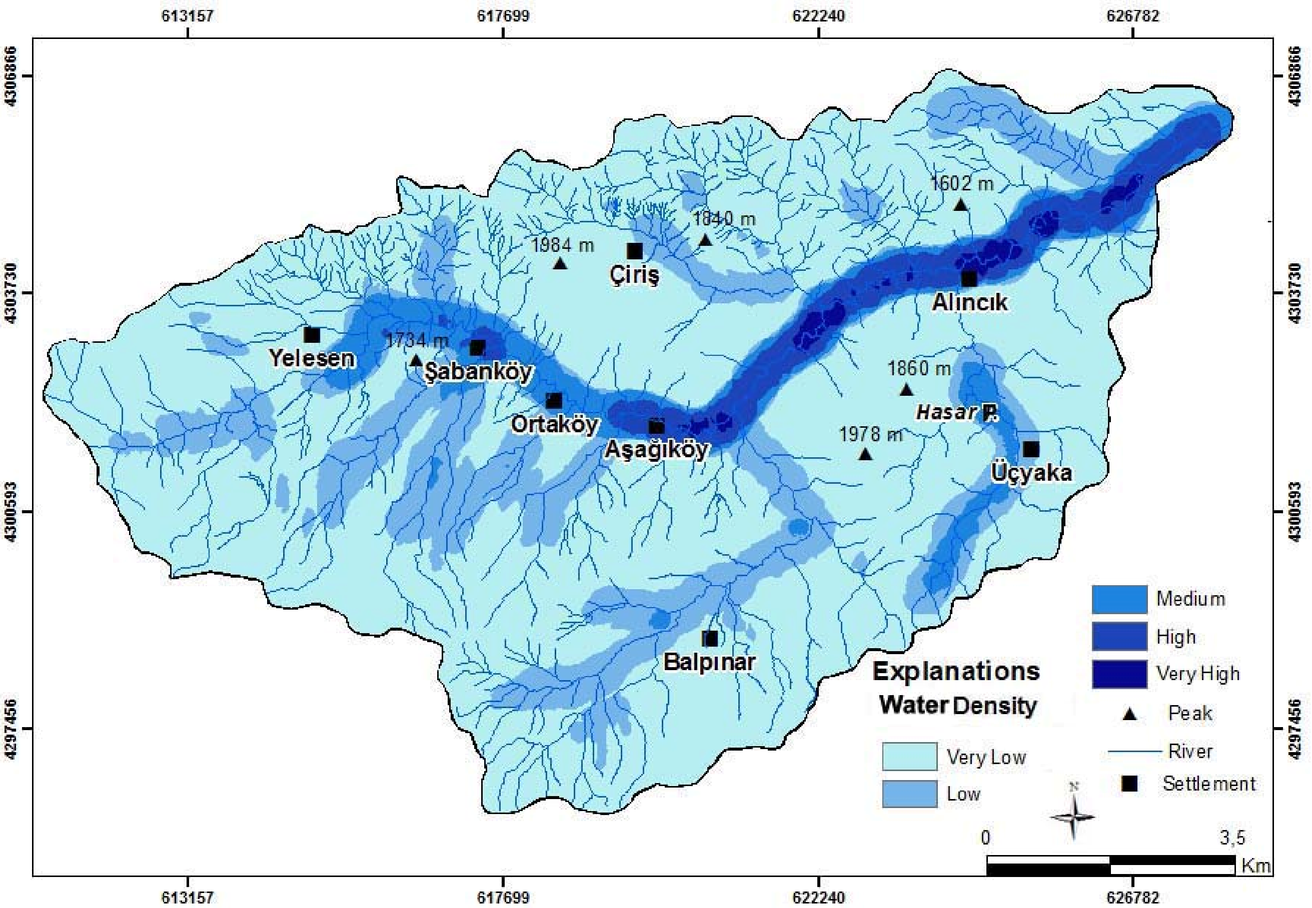

FIGURE 8 - Water density map for Capakcur Stream Watershed.

TABLE 4 - Distribution of water density and sensitivity of Capakcur Stream Watershed.

Water density	Total covered area		Sensitivity values
	km^2	%	
Very low (0-5)	75.1	71	1
Low (5-10)	19.7	18	2
Fair (10-20)	6.2	6	3
High (20-30)	4.6	4	4
Very high (30-40)	0.9	1	5

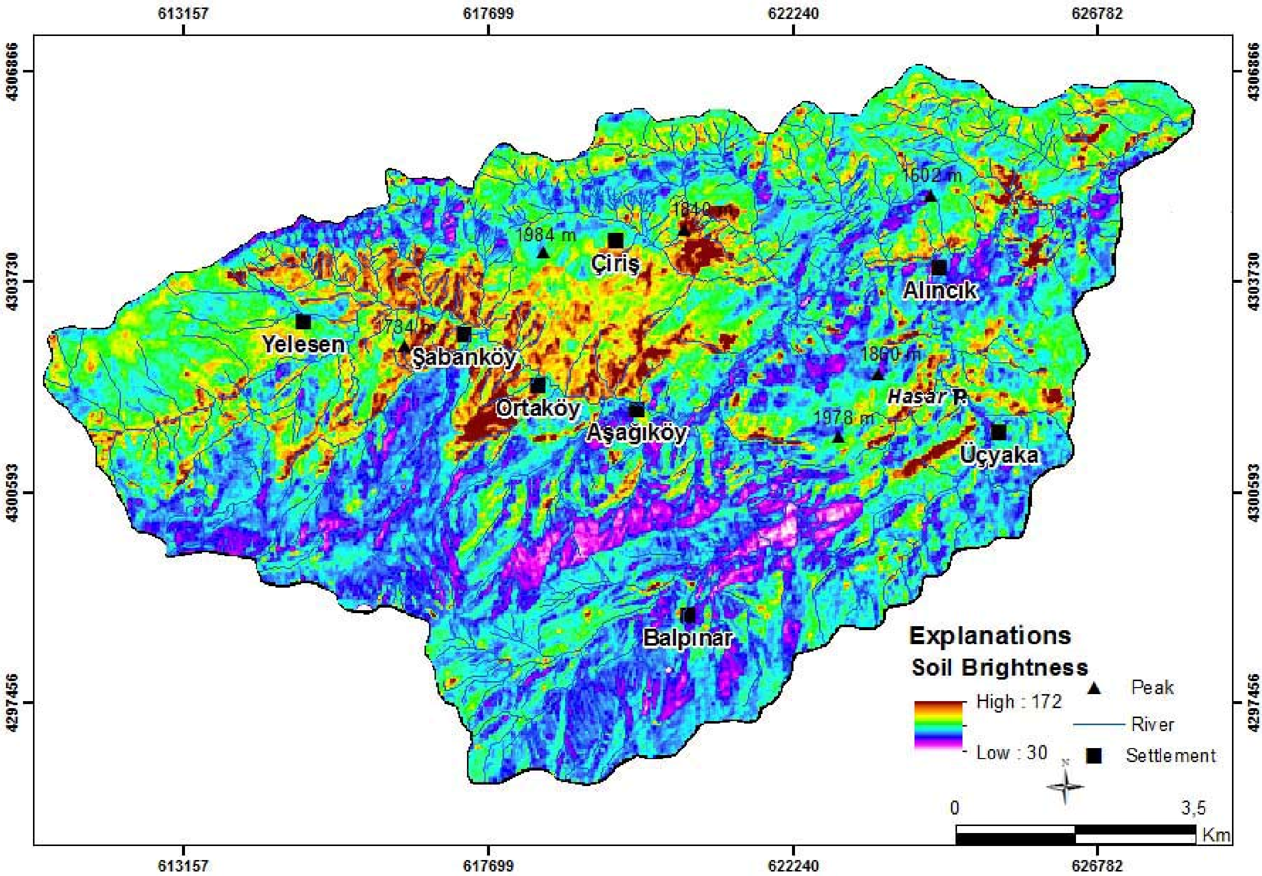

FIGURE 9 - Soil Brightness Index of Capakcur Stream Watershed

TABLE 5 - Distribution of Soil brightness and sensitivity of Capakcur Stream Watershed

Soil brightness	Total coverage area		Sensitivity values
	km^2	%	
30-65	1.70	2	1
65-95	81.40	76	2
95-125	22.60	21	3
125-155	0.80	1	4
155-172	0,02	-	5

3.5 Effects of Soil Brightness on Erosion

As soil particles become finer, soil brightness usually increases [36]. Further detachment of soil into fine granules causes a very distinctive color changes, statistically increases the soil brightness [7]. Each individual components such as and, silt or clay are attached together by organic materials, clay or lime to form stable soil aggregates which increase light absorption by the soil. Consequently, with lower reflection rates, brightness of soil aggregates becomes weaker, which leads to lower reflection values compared to disturbed soil samples [39]. Soil brightness index (SBI) was used to estimate the soil texture of watershed [22]. Tasseled Cap Transformation was applied to satellite images of Landsat ETM for the soil brightness index (Figure 9).

Texture of soils was categorized from fine to coarse textured with the help of satellite images and coarse textured soils covered wider areas compared to fine textured soils in the watershed (Table 5).

4. CONCLUSIONS

The erosion sensitivity map acquired by slope degrees, precipitation, vegetation covers, water density and soil brightness revealed that erosion sensitivity is high (48 %) and very high (12%) in majority of the watershed. Areas labeled with high and very high erosion sensitivity lie in the north, west and southwest of the watershed. These areas not only have high slope degrees but sparse vegetation as well. Because of the steep slopes and high water wearing power, erosion sensitivity increases throughout the watershed. Areas labeled with low and very low erosion sensitivity cover a very limited area (% 11 of total) where vegetation density are high as well as slope degrees are rather low (Figures 10-12).

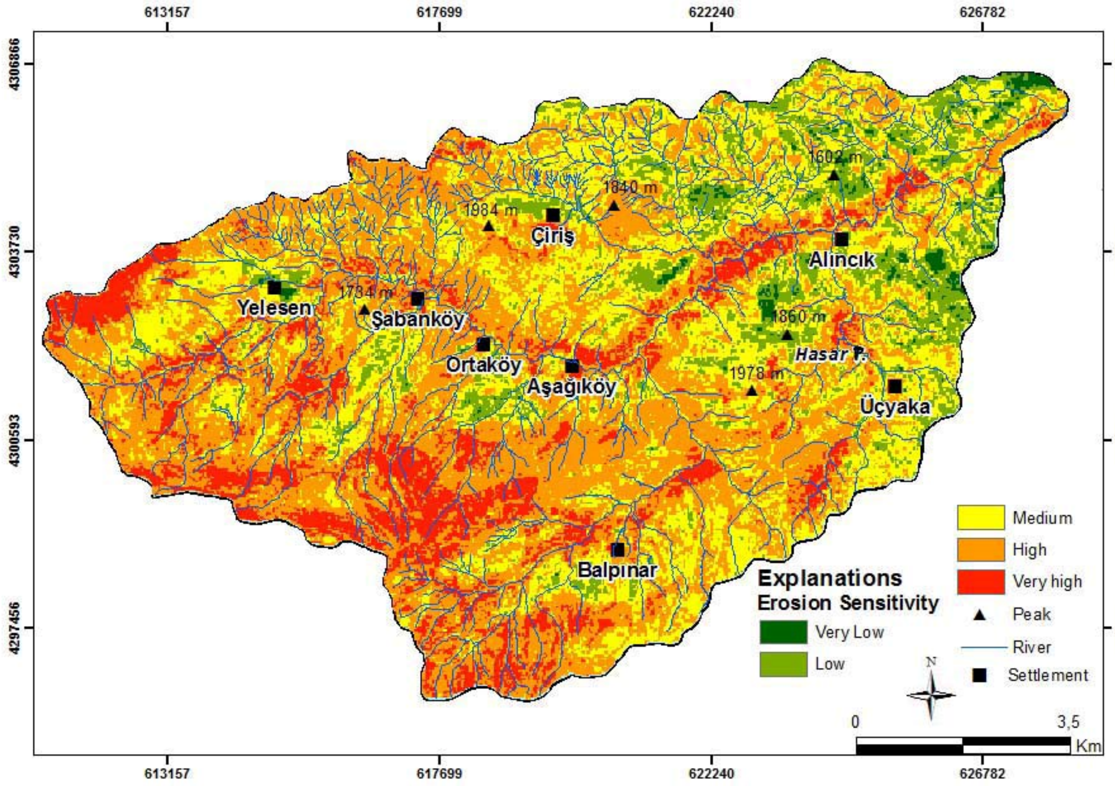

FIGURE 10 - Erosion Sensitivity Map of Capakcur Stream Watershed

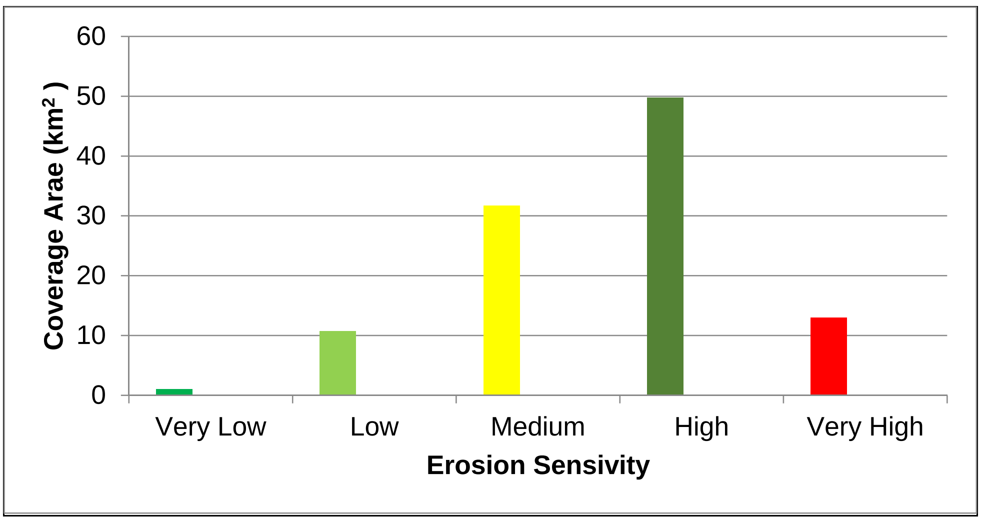

FIGURE 11 - Distribution of areas based on erosion sensitivity

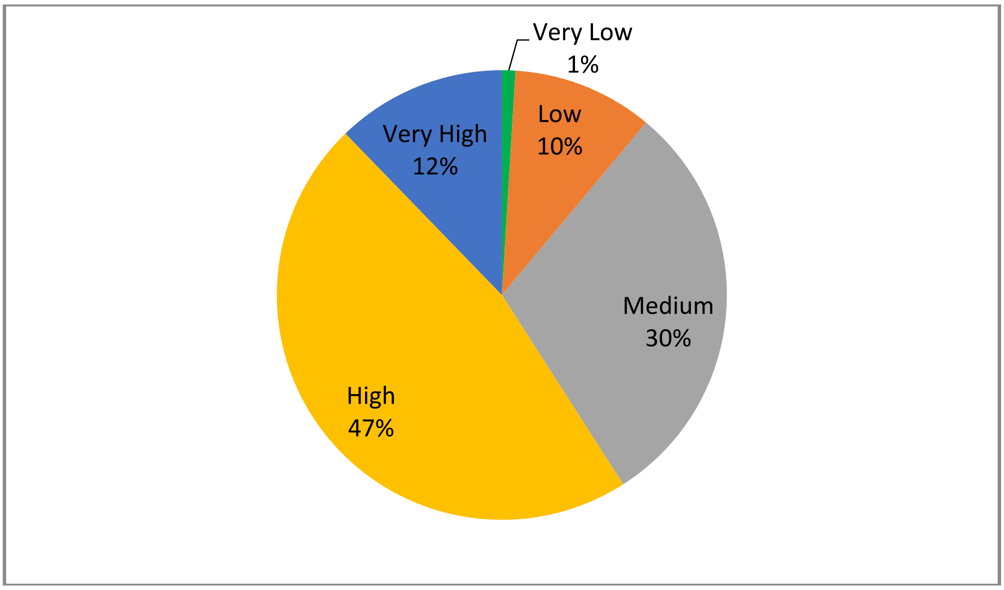

FIGURE 12 - Proportional distribution of erosion sensitivity for Capakcur Stream Watershed

The results concluded that high slope degrees, sparse vegetation cover along with degraded vegetation, high precipitation and favorable lithological wearing caused severe erosion in the Capakcur Stream Watershed. The severity of erosion has been further accelerated by human interference particularly by over grazing. Severe erosion has caused slopes being cleft and vegetation degraded. Fluvial erosion has increased extrinsic substances in streams and decreased the water holding capacity, increased the potential of flood risk nearby settlements throughout the watershed.

The authors have declared no conflict of interest.

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Received: April 16, 2015
Accepted: June 15, 2015

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FEB/ Vol 24/ No 10/ 2015 – pages 3068 - 3078