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Determination of Land Use/Cover and Topographical/Morphological Features of River Watershed for Water Resources Management Using Remote Sensing and GIS

Derya OZTURK[1] Fatmagul BATUK[2] Sebahattin BEKTAS[1]

[1] Ondokuz Mayis University, Department of Geomatic Engineering, Kurupelit, SAMSUN

[2] Yildiz Technical University, Department of Geomatic Engineering, Davutpasa, İSTANBUL

*Sorumlu Yazar
dozturk@omu.edu.tr

Abstract: Optimal management and development of water resources can be achieved with the realization of planning and implementation stages of the plans correctly, completely and timely. Today, Remote Sensing (RS) with opportunities to collect data fast and belong to same area at different time periods and characteristics and Geographical Information Systems (GIS) with the capabilities of integration of different data groups, data-processing and updating, spatial and three-dimensional analysis, querying and modeling can be effectively used in water resources planning and management.

In this study, the utilization of RS and GIS for planning, design and management of water resources was explained; the topics of the determination of land use/cover and topographical/morphological characteristics at a river watershed level and the methods in detail were discussed. In this context, available data sources and structures to determine land use/cover, Digital Elevation Model (DEM), slope, aspect, watershed and sub-watershed boundaries and drainage network, the issues of data errors and uncertainty, automatically generation of watershed boundary and drainage network from DEM and the accuracy of results were examined, the impact of DEM's accuracy on the parameters automatically generated from DEM was investigated.

Key words: water resources management, GIS, remote sensing, topographical/morphological features, land use/cover.

INTRODUCTION

The need for global and integrated approaches to water resources management has long been recognized. Integrated Water Resources Management (IWRM) is the process of formulating and implementing shared vision planning and management strategies for sustainable water resources development and utilization with due consideration of all spatial and temporal interdependencies among natural processes and water uses [1, 2].

Remote Sensing (RS), Geographical Information Systems (GIS) and Decision Support Systems (DSS) are growing concerned about planning and strategic management of earth resources [3, 4].

Satellite images are an important source of data which enable continuous acquisition of data, help to receive up-to-date information (satellite remote sensing can be programmed to enable regular revisit to object or area under study), offer accurate data for information and analysis end serve as a large archive of historical data [5-7]. GIS allows the integration, storage, management, analysis, querying of a large number of data in different scales, different formats and structures obtained from the satellite imagery and other data sources, statistical calculations and consequently creation of a variety of graphics and tables [8-10].

There is a need of information about land use/cover, digital elevation model (DEM) and the basic topographic and morphological parameters derived from DEM in many studies on the management and planning of water resources. Today, GIS allows the creation of DEMs and the automatic derivation of topographic and morphological parameters from DEMs [11-13]. In determining the current status and temporal variation of land use/cover, today the RS is quite popular data source in both fast and economical terms. The temporal changes in land use/cover changes are the function of the economic, social, political and ecological conditions, and the concrete data about the amount and direction of this change is critical to determine the future requirements.

In this study, the current situation of land use/cover and temporal variation, DEM, slope, aspect, flow direction, flow accumulation, watershed-subwatershed and drainage network to be obtained by RS and GIS, that needed in the effective management of water resources and can assessed as the basic data, have been discussed; and in DEMs, main data sources, sources of errors affecting the accuracy of DEMs, the effect of the resolution of grid DEMs on the topographical and morphological data derived from DEM have been investigated.

Data and Error Sources in DEMs, Derivation of Topographic and Morphologic Parameters from DEMs.

Data and Error Sources in DEMs

DEM is the digital representation of topography and is represented by the structure of the grid (raster), TIN (triangulated irregular network) and the contour [14-19].

The geodetic measurements, GPS, stereo-aerial photographs, LIDAR, satellite imagery, the digitization of the elevation curves from existing printed maps are basic data sources for DEMs. DEMs contain some errors and uncertainties depending on the model and the data and these errors can systematically affect the details derived from DEMs. Therefore, the adequacy of the accuracy of DEMs for a study should be investigated [14-19].

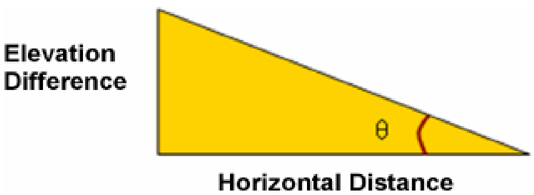
Table 1. Technical specifications of STMs [23]

1. Name of Product		Topographic Map	Topographic Map	Topographic Map
2. Description of Product		Standard topographic maps produced by aerial photogrammetry method	Standard topographic maps produced by generalization method from 1/25.000 scale maps	Standard topographic maps produced by generalization method from 1/50.000 scale maps.
3.Features of Product	A. Scale	1/25.000	1/50.000	1/100.000
	B. Serial	K-816	K-716	K-613
	C. Projection	Transversal Mercator (Gauss-Kruger)	Transversal Mercator (Gauss-Kruger)	Transversal Mercator (Gauss-Kruger)
	D. Datum	ED-50,WGS84	ED-50	ED-50
	E. Production date	Various acc. to regions	Various acc. to regions	Various acc. to regions
	F. Dimensions	51x69 cm. (7,5’ x 7,5’)	53x69 cm. (15’ x 15’)	53x70 cm. (30’ x 30’)
	G.Accuracy	Horizontal: 5 m. (Average) Vertical: 2,5 m.	Horizontal: 10 m. (average) Vertical: 5 m.	Horizontal: 20 m. (average) Vertical: 10 m.
	H. Source	Aerial Photographs	K-816 serial 1/25.000 scale maps	K-716 serial 1/50.000 scale maps
4. Production Method of Product		Photogrammetric	Cartographic generalization from 1/25.000 scale maps	Cartographic generalization from 1/50.000 scale maps
5. Product Archiving Environment		Paper	Paper	Paper
6. Amount		5554	1456	393

In geodetic measurements, the main error sources in obtainment of the elevation data can be listed as frequency of the measuring points, the measurement method, precision of measuring instrument used; aerial photographs and resolution of satellite imagery, scale of printed maps, and in which intervals the elevation curves pass in meters, the methods used to obtain the printed map, the deformation in maps, scanning and digitization errors.

In GIS-based analysis, the DEM in the grid structure is usually used because of their simplicity and computational efficiency. The grid values represent mean elevation for each grid cell. The accuracy of DEM is expressed by the resolution of the position and elevation. The spatial accuracy of DEMs is associated with the data source, the elevation accuracy of DEMs is associated with both the data source and grid-pixel size [20-22].

Today, the DEM has been generated with digitization of elevation curves on printed maps in many GIS application. 1/1.000, 1/2.000 and 1/5.000 scale present maps and and 1/25.000, 1/50.000 1/100.000 scale STMs produced by HGK are main data sources of the GIS applications. According to the Large Scale Map and Map Information Production Regulation, the equal elevation curves have been drawn at intervals of 5 m for 1/5.000 scale, 2 m for 1/2.000 scale, and 1 m for 1/500 scale to determine the status of the terrain topography. The technical specifications related to 1/25.000, 1/50.000 and 1/100.000 scale STMs are given in Table 1.



$$\tan\theta = \frac{Elevation\ Difference}{Horizontal\ \mathrm{Distance}}$$

Figure 1. Slope [24]

Extraction of Topographic and Morphologic Details from DEMs

The slope is the elevation change between two points on a surface. For raster data, the slope is maximum rate of change between each cell and its neighbors (Figure 1), for example, the steepest downhill descent for the cell (the maximum change in elevation over the distance between the cell and its eight neighbors). Every cell in the output raster has a slope value. The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain. The output slope raster can be calculated as percent of slope or degree of slope. Aspect identifies the steepest downslope direction from each cell to its neighbors. It can be thought of as slope direction or the compass direction a hill faces [24].

Slope (degree)=θ

$$\text{Slope (\%)}= \frac{Elevation\ Difference}{Horizontal\ \mathrm{Distance}} x100$$

The flow on one surface always occurs in the highest to lowest direction. If the flow direction of each cell is known, how much cell flows into any cell can be determined (Figure 2 and Figure 3). This information is used to determine the river systems and watershed boundaries. The direction of flow is calculated as maximum descent direction from each cell, and each direction is encoded as Figure 2 [25].

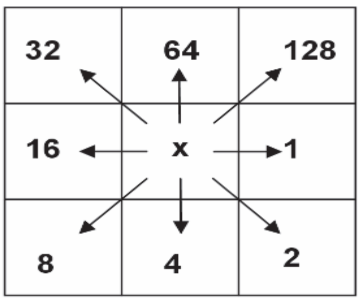


Figure 2. Flow Direction [25]

45	37	44	45
40	34	50	60
58	31	30	53
50	45	32	22

1	4	8	16
1	4	4	8
1	1	2	4
128	64	1	?

0	1	1	0
0	5	0	0
0	9	12	0
0	0	0	15

Figure 3. DEM, Flow Direction, Flow Accumulation [25]

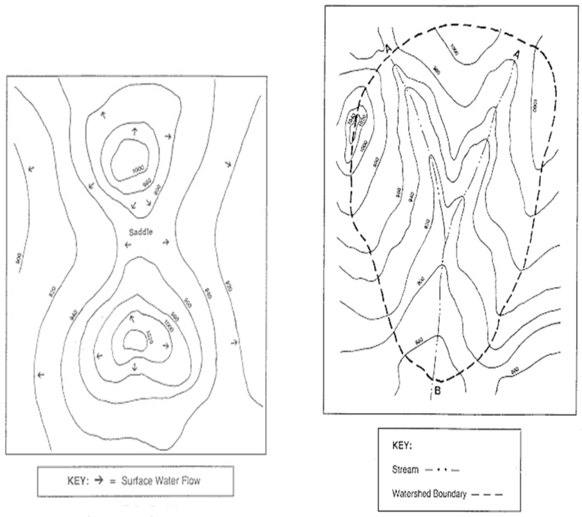


Figure 4. Determination of Watersheds [28]

The calculation of water flowing to the each cell below from the upper cells is done with flow count. Given that 1 unit water is at each cell, the water flowing from the upper cells reaches 2 units at lower neighboring cell. This flow process continues until the last cell [26].

The general rule of the flow of water is that water flow is perpendicular to contour lines. In the case of the isolated hill, water flows down on all sides of the hill. The water flows down and firstly reaches to larger waters and later sea. The drainage area of each branch of river can be determined seperately. (Figure 4) [27].

In the automatic delineation of watersheds with computer software, respectively, the direction of flow from DEM and the flow accumulation from the direction of flow were calculated (Figure 5) [27, 28].

Determination of Land Use/Cover from Satellite Images

Land use and land cover are not equivalent. They may, however, overlap, and therefore be intermixed, because the distinction between the two is not always straightforward [29]

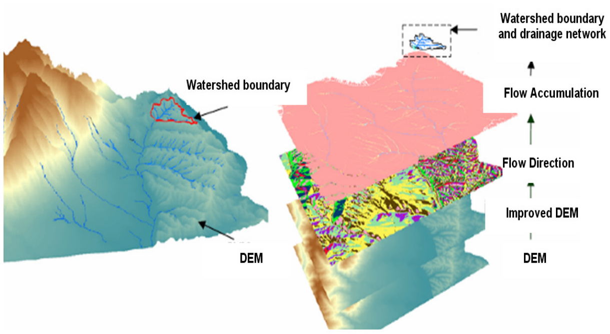


Figure 5. Automatic creation of watershed boundary

The land cover defines the biophysical state of the earth's surface and immediate subsurface, thus embracing the soil material, vegetation, and water status. Land use defines the human activities which are directly related to land, making use of its resources, or having an impact on them. The term includes both rural and urban or industrial uses [7, 30-32]).

Remote sensing has provided an efficient method and perfect alternative of data acquisition for land use and land cover and updating. Land cover can be directly interpreted and mapped from satellite images, while land use requires land cover and additional information on how the land is used.

The most basic methods used to determine land cover from satellite images are image classification and normalized difference vegetation index (NDVI) algorithm [7, 33-37].

Rectification of Satellite Images

The satellite images obtained from remote sensing techniques include systematic and non-systematic geometric errors [6].

Data on sensors and ephemeris information are modelled and applied to the raw imagery as part of systematic corrections. Non-systematic errors caused primarily by satellite altitude and attitude require image to map rectification, and this process can use Ground Control Points (GCPs) to tie image pixel coordinates to their corresponding map coordinates [5].

The geometric rectification of satellite images is an essential step for the exploitation of the remotely sensed data. The determination of control points on a digital image is a difficult operation. The most appropriate GCPs to choose on a satellite image are easily visible phenomena such as road intersections, bridges over streams, the corner of building, street corners etc. In order to increase the accuracy of the process, the proper distribution of GCPs must be provided on the image. The number of ground control points depends on the size and properties of the land. For example, only a few ground control points may be sufficient for rectification of the image of plain terrain while many GCPs are needed for rugged terrain [5, 6, 37]

Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetative Index (NDVI,) is a calculation, based on several spectral bands, of the photosynthetic output (amount of green stuff) in a pixel in a satellite image. It measures, in effect, the amount of green vegetation in an area. NDVI calculations are based on the principle that actively growing green plants strongly absorb radiation in the visible region of the electromagnetic spectrum while strongly reflecting radiation in the Near Infrared (NIR) region. The spectral reflection curves of soil and vegetation have been given in Figure 6. The NDVI for a pixel is calculated from the following formula [7, 38]:

$$NDVI = \frac{NIR - R}{NIR + R}$$

Where:
NIR: Reflection value in near infrared band
R: Reflection value in red band

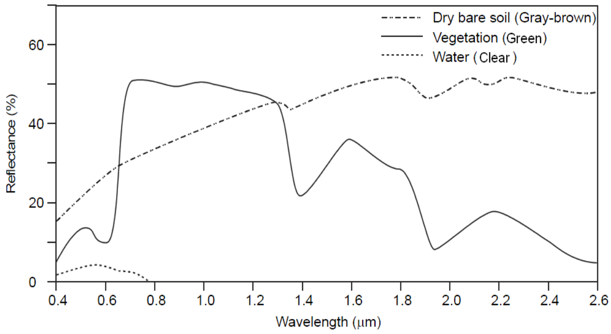


Figure 6. Typical spectral reflectance curves for vegetation, soil and water [7]

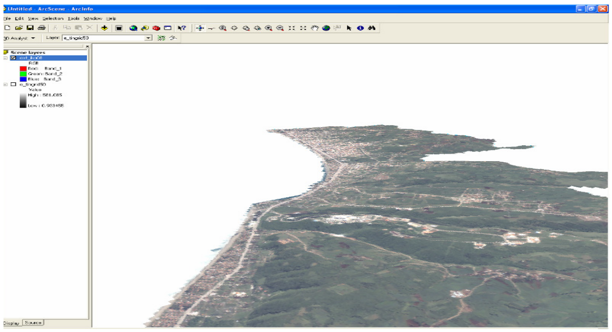


Figure 7. Study area: 3-dimensional image of the district of Samsun-Atakum

This formula yields a value that ranges from -1 to +1. The vegetation gives high positive values and water gives negative values. The values for soil and rock etc. are about 0 [7].

Classification of Satellite Images

To classify satellite images, the pixel-based and object-oriented approaches are applied [38, 39]. Pixel based approach is based on conventional statistical techniques and classifies an image pixel by pixel and one pixel can only be classified into one class [6, 7]. Normally the different physical properties of earth objects have different spectral information and can be specified pixel based approach. Object oriented image analysis approach combines spectral and spatial information to classify the images. This approach segments the pixels into objects according to the tone of the image and classifies image by treating each object as a whole. Object oriented image analysis utilizes the texture and contexture information of the object in addition to spectral information [39].

Visual Image Interpretation and On Screen Digitizing

Classification schemes also played an important role in the success of image classification. The use of a classification scheme with classes that could not be directly related to the spectral classification might lead to a lower accuracy result. Similarly, classification scheme with classes relevant to spectral differentiation could lead to less accurate result when it was used for classifying imagery using non-spectral approach. In addition, there was another problem of relating classification schemes and remote sensing methods. Most digital classification methods were used for land cover/land use with limited number of classes, i.e. equal or less than 10 [40-43], while many applications related to planning require more detailed categorization. Because detailed classification of land-use based on digital processing of remotely sensed imagery is rarely available, visual image interpretation and manual, on screen digitizing approach can be used. Visual image interpretation could normally generate land

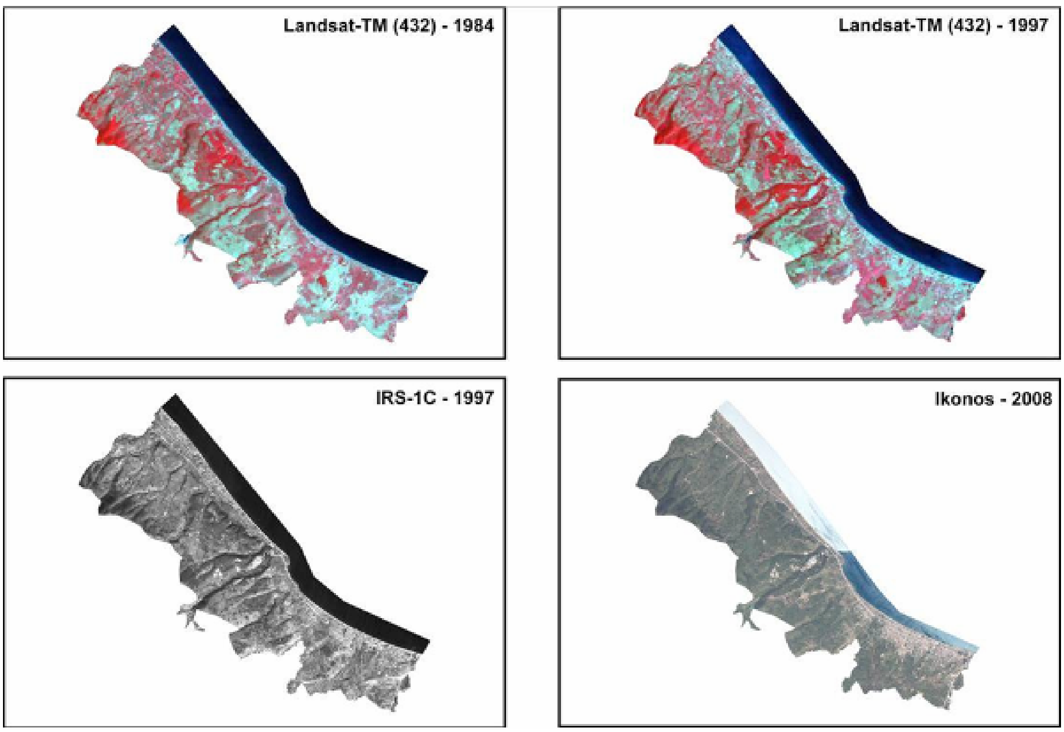


Figure 8. Samsun-Atakum Landsat-TM(432)-1984, 1997; IRS-1C-1997; Ikonos-2008

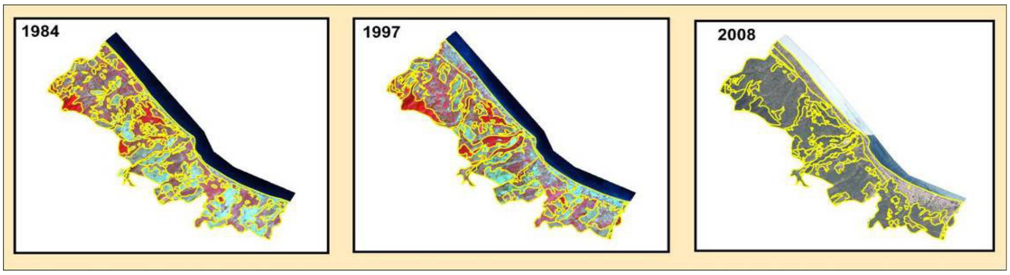


Figure 9. Classified images of Samsun-Atakum in 1984, 1997 and 2008

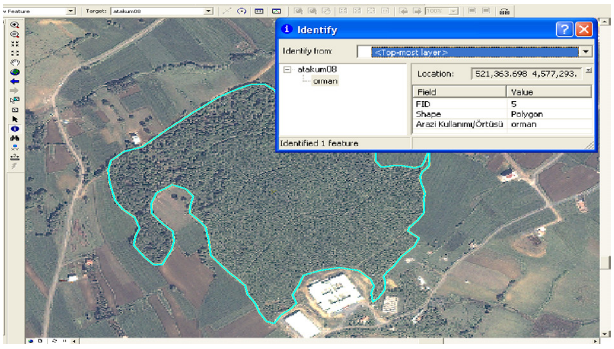


Figure 10. Query Screen

use information by combining a set of interpretation elements including colour/tone, texture, shape, shadow, size, pattern, site and association [7]. With digital multispectral classification, only land cover could usually be extracted, as the land cover types are related to their spectral responses recorded by the remote sensors [44, 45]. The recorded spectral responses are comparable to tones or colours in visual interpretation.

CASE STUDY

In this study, Landsat-TM in 1984 and 1997, IRS-1C in 1997 and Ikonos in 2008 were used to determine changes of land use/cover (Figure 7) of Samsun-Atakum. 1/100.000 and 1/25.000 scale standard topographic maps (STMs) and 1/1.000 scale maps belonging to districy were used for creation of DEM. ErMapper 7.1 software for satellite image processing and ArcG IS 9.2 software was used for database creation and GIS analysis For rectification of images, 1/25.000 scale standard topographic maps (STM) and 1/1.000 scale present maps were used and images were georeferenced in UTM system. The information of land use/cover was obtained for the years 1987, 1997 and 2008 by visual image interpretation depending on colour/tone, texture, shape, shadow, size, pattern, site and association etc. and on-screen digitizing. For interpretation of images, different band combinations, NDVI, STMs and present maps have been used. The classes of land use/cover have been created according to CORINE classification systems. The classes were determined as forest, urban green area, agricultural areas, dense residential, low-density residential areas, bare areas and water-covered areas and database was created (Figure 9 and 10).

When the land use/cover of Atakum, on highways of Samsun-Ankara and Samsun-Sinop, and having 20 km coast, has been examined for the years 1984, 1997 and 2008; it has been found that there is a significant increase in residential areas (Figure 6). Especially the Samsun-Sinop highway axle, formerly a region where the city's summer residential areas, has shown a rapid development because of presence of university and hospital in this

Table 2. DEM-Statistical Information

Pixel Size	Data Source					
	1/100.000		1/25.000		1/1000	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
250	550	0				
200	550	0	559.66	0		
100	550	0	581.24	0		
50	550	0	584.59	0	581.08	0.93
25	550	0	585	0	583.40	0.92
10			585	0	584	0.87
5					584	0.84
2					584	0.84

Table 3. Slope-Statistical Information

Pixel Size	Data Source					
	1/100.000		1/25.000		1/1000	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
250	26.40	0				
200	27.77	0	28.90	0		
100	33.28	0	34.28	0		
50	36.62	0	36.69	0	51.27	0
25	40.11	0	40.90	0	53.45	0
10			49.88	0	71.82	0
5					80.44	0
2					86.83	0

field, actualization of tourism and trade in this region and public housings close to the university and it has been the city's priority preferred region for permanent housing by taking continuous migration from the city center. However, because of the ever-changing political conditions and pressures in our country, as in many places because of failure to implement zoning law and related legislation; county coastal, forest and irrigation areas have been occupied and it has been opened for settlement in an uncontrolled manner.

From 1/100.000 scale map elevation data 25, 50, 100, 200 and 250 m pixel sized DEM, from 1/25.000 scale map elevation data 10, 25, 50, 100 and 200 m pixel sized DEM, and from 1/1.000 scale map elevation data 2, 5, 10, 25 ve 50 m pixel sized DEM were created; and from each DEM, slope, aspect, drainage network and watershed data were produced separately.

When examined statistical data of DEMs in Table 2; it has been found that the higher pixel sizes in DEMs produced from data of 1/1.000 scale maps (the lower resolution) causes the higher minimum value; the bigger pixel sizes in both 1/1.000 and 1/25.000 scales causes the lower maximum value; and in larger scale-high resolution data, this effect is more than smaller scale – lower resolution data. The higher scales cause the rapid changes in maximum values in DEMs in same pixel sizes.

When examined the slope statistical information in Table 3, it is understood that the bigger pixel sizes cause very rapid decrease in maximum values; the effect of this change is more at high resolution data.

When examined 50 m grid sized data in Figure 11 and examined Figure 12, it is understood that the scale of map being data source for watershed and drainage network is so effective, the scale largely affects the accuracy of

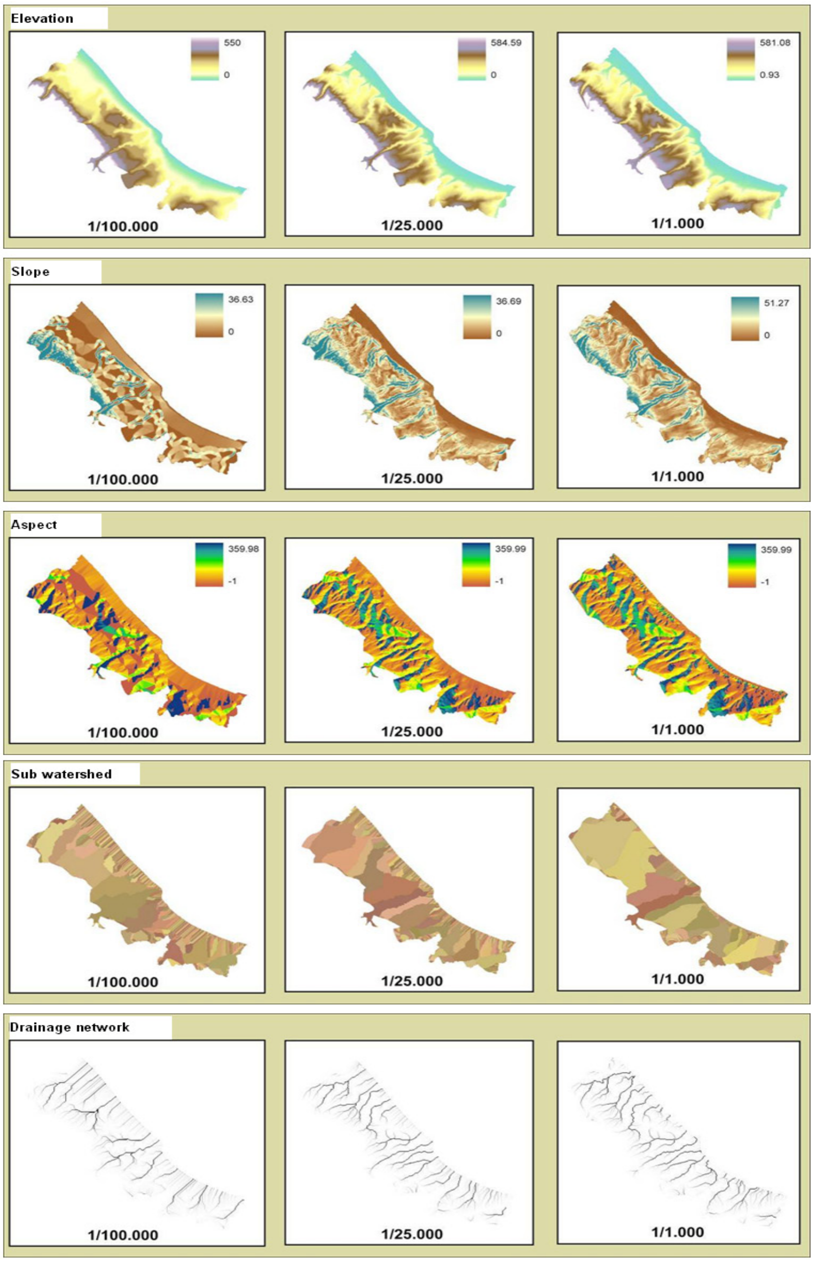


Figure 11. The comparison of DEM, Slope, Aspect, Watershed and Drainage networks obtained in 50 m pixel size from 1/100.000, 1/25.000 and 1/1000 scale map data.

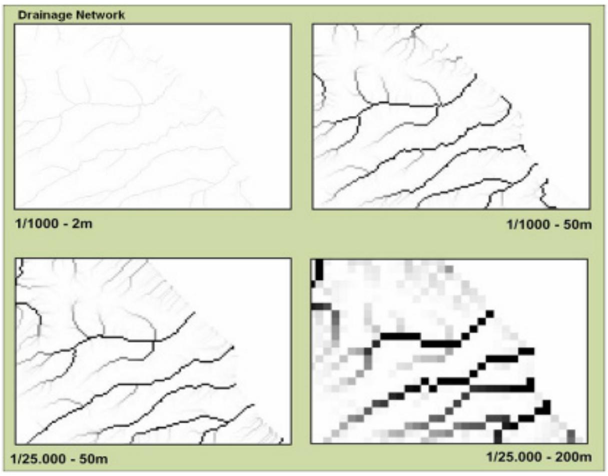


Figure 12. The comparison of drainage network obtained from 1/1000 and 1/25000 scale data

process of automatic determination of watershed, and in large scale data, the faulty watersheds created in coasts is less created.

RESULT AND DISCUSSION

In our country, especially the rapid population growth in urban areas accelerated changes in land use/cover. Because of failure to manage urban development and failure to prevent squatter houses, the shores, forests, agricultural lands disturbed unconsciously converted into residential and industrial areas and therefore land and water resources suffer from it. The current knowledge on land use/cover and change information between certain dates helps avoid misuse of the land, and develop the right strategies in order to ensure protection and planned development. The DEMs and topographic/morphological details derived from DEM are data needed in the soil and water resources planning and design study.

The remote sensing is most important data source to be used with the aim of determination of land use/ cover today because of bearing many information in order to have many possibilities of imaging same area in different dates, to be rapid and economical data source for especially larger areas, and to make sensing in different areas of electromagnetic spectrum. The GIS is a powerful tool in order to store all data in a database in monitoring changes in land use/cover and to prepare temporal analysis, querying, and map, tables, graphics printouts The GIS similarly offers a quick and practical solution for the creation of DEMs and related details.

In this study, as in many studies using spatial data for planning and management of water resources and the basic data which can be described as the necessary land use / cover, slope, aspect, flow direction, flow count, the watershed -sub- watershed and drainage network information are possible to obtain in very short period of time with RS and GIS

In the study, the land use/cover classes have formed according to the system the CORINE (Coordination of Information on the Environment). When results have been examined, it is clearly seen that the rapid and uncontrolled increase in urban areas directly and indirectly threats soil and water resources. When examined analysis results related to DEM, it is understood that the effect of DEM grid resolution is too much on surface analysis and grid DEMs resolution depends on both the original elevation data, and on the size of the grid sampled. While creating DEM, the largest selection of grid size significantly shortens the computation time, but on the other hand as a result of modeling there is a significant loss of detail. When compared sources of data obtained from different scale (1/100.000, 1/25.000 and 1/1.000) and the DEM sampled in the same pixel size; it is understood that grid size does not mostly affect result model accuracy in DEM creation from data having low accuracy and sensitivity and thus not sufficiently representing the topography. Thus DEM elevation data source and grid size should be determined according to the purpose and requirements for each study.

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