

# MORPHOTECTONIC PROPERTIES OF YENICAGA BASIN AREA IN TURKEY

G. Sarp<sup>a</sup>, R. Gecen<sup>a</sup>, V. Toprak<sup>b</sup>, S. Duzgun<sup>c</sup>

<sup>a</sup>METU, Geodetic and Geographic Information Technologies, Inonu Bulvari 06531 Ankara, Turkey,  
gsarp@metu.edu.tr, rgecen@metu.edu.tr

<sup>b</sup>METU, Geological Engineering Department, Inonu Bulvari 06531 Ankara, Turkey, toprak@metu.edu.tr

<sup>c</sup>METU, Mining Engineering Department, Inonu Bulvari 06531 Ankara, Turkey, duzgun@metu.edu.tr

**In this study Remote sensing and GIS analysis techniques are used in order to determine geological and morphometric properties of Yenicaga basin area. SRTM and drainage networks of the area are used for determine the morphometric properties of Yenicaga basin located on North Anatolian Fault Zone (NAFZ).**

**In order to determine tectonic activity of Yenicaga basin area five different morphometric indices including Mountain Front Sinuosity (Smf), Valley Floor Width To Height Ratio (Vf), Stream Length Gradient Index (SI), Hypsometric Curve And Integral (HI), Drainage Basin Asymmetry are applied to study area. Generated results are verified by 1/25000 scale faults maps of the area.**

**In the Yenicaga catchment area SL index is calculated for 72 location selected on 15 river channels. According to generated results SL values changes between 11,12 to 1780,24. Smf values computed for nineteen fronts. According to generated results; the most active mountain fronts associated with active faults of the area. Vf values range between 0,29 to 17,74 in the area. Deep and narrow valleys show low Vf values <1,0, these valleys can be classified as “V” shaped valleys and Vf values between 1 and 1,5 are indicate moderately active regions and Vf values greater than 1,0 can be classified as “U” shaped valleys. These areas subject to major lateral erosion due to right lateral motion of NAFZ. According to generated results, in the study area the HI values change between 0,106 and 0,787. High values of the hypsometric integral indicate deep incision and rugged relief. Intermediate low values of the integral are associated with more evenly dissected drainage basins. Asymmetry factor significantly greater than 50 suggesting tectonic tilt.**

**Keywords: GIS, Geomorphology, Morphometric Indices, NAFZ, Yenicaga Basin**

## 1. INTRODUCTION

Tectonic geomorphology is defined as the study of landforms produced by tectonic processes, or the application of geomorphic principles to the solution of tectonic problems (Keller, E.A. and Pinter N. 1996). The quantitative measurement of landscape is based on the calculation of geomorphic indices using topographic maps, aerial photographs and field work. The results of several indices can be combined in order to highlight tectonic activity and to provide an assessment of a relative degree of tectonic activity in an area (Keller, E.A. and Pinter N. 1996).

In recent years DEM data and GIS technologies have been extensively used to determine the morphometric properties of tectonically active regions. The main objective of this study is to define morphological properties of tectonic basin located on the NAFZ, by using GIS and RS techniques.

Morphometry is defined as quantitative measurement of landscape shape. At the simplest level, land forms can be characterized in terms of their size, elevation (maximum, minimum or average), and slope. Quantitative measurements allow geomorphologists to objectively compare different landforms and to calculate less straightforward parameters that may be useful for identifying a particular characteristic of an area such as level of tectonic activity. (Keller E A and Pinter N. 1996)

Geomorphic indices have been developed as basic reconnaissance tools to identify areas experiencing rapid tectonic deformation (Bull W. B. and McFadden L.D. 1977, Keller E A. and Pinter N 1996). These indices based on topography that are useful in studies of active tectonics. Some of the geomorphic indices used for active tectonic studies are:

Mountain Front Sinuosity (Smf), Valley Floor Width To Height Ratio (Vf), Stream Length Gradient Index (SI), Hypsometric Curve And Integral (HI), Drainage Basin Asymmetry

## 2. STUDY AREA

The study area is located North-western of Turkey. Tectonically active strike slip NAFZ passing along this area. Basin area mainly drained by Mengen, Caga, Capak and Aksu rivers. The main flow direction of those rivers is not consistent along the drainage basins due to the irregular topography of the area. The main flow directions of Aksu and Mengen rivers are controlled by the NAFZ. The area is within Zone 36 of Universal Transverse Mercator projection system. The total area covers 763 km<sup>2</sup> The main Location of Yenicaga basin area and its drainage networks are given in figure 1.

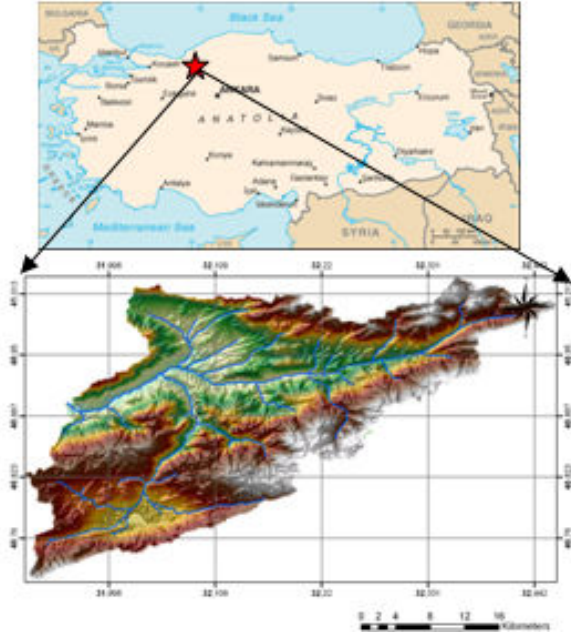


Figure 1: Study area

## 2.1. Mountain Front Sinuosity (Smf)

This index is based on the observation that tectonically active mountain fronts are often more straight than mountain fronts in regions where erosion dominates over tectonics. The index is defined as;

$$Smf = Lmf / Ls \quad (1)$$

Where Smf= mountain front sinuosity index  
 Lmf= straight line distance along a contour line  
 Ls= true distance along the same contour line

The morphology of a mountain front depends upon the degree of tectonic activity along the front. Active fronts will show straight profiles with lower values of Smf, and inactive or less active fronts are marked by irregular or more eroded profiles, with higher Smf values (Wells et al., 1988).

In the present study Smf values computed for nineteen fronts and generated Smf values are categorized according to Bull, W. B., and McFadden, L. D. (1977) (Figure 2). According to generated results values less than 1,4 indicates tectonically active areas. Smf values between 1,4 and 3 indicate slightly active areas, Smf values greater than 3 indicate inactive areas (Table 1.). This study concluded that the most active mountain fronts associated with active faults of the area.

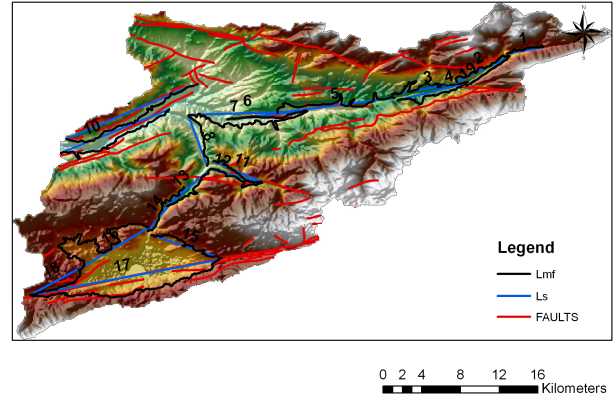


Figure 2: Mountain Front Sinuosity (Smf)

Table 1: Mountain Front Sinuosity values

No	Lmf	Ls	Smf= Lmf/Ls	Inferences
1	3.561	2.905	1.226	Tectonically Active
2	6.294	4.909	1.282	Tectonically Active
3	4.732	4.601	1.028	Tectonically Active
4	11.300	6.132	1.843	Slightly Active
5	7.087	5.662	1.252	Tectonically Active
6	15.190	9.238	1.644	Slightly Active
7	6.789	6.275	1.082	Tectonically Active
8	14.681	9.235	1.590	Slightly Active
9	5.954	5.408	1.101	Tectonically Active
10	5.069	4.337	1.169	Tectonically Active
11	5.621	4.263	1.319	Tectonically Active
12	6.380	5.119	1.246	Tectonically Active
13	6.757	5.380	1.256	Tectonically Active
14	8.376	6.004	1.395	Tectonically Active
15	18.921	15.258	1.240	Tectonically Active
16	21.004	6.361	3.302	Inactive Settings
17	6.249	5.227	1.195	Tectonically Active
18	12.496	9.586	1.304	Tectonically Active
19	14.423	11.796	1.223	Tectonically Active

## 2.2. Valley Floor Width To Height Ratio (Vf)

This index is based on the observation that areas undergoing rapid uplift are marked by incised streams, with narrow valley floors and v-shaped valley profiles. The index is defined as:

$$Vf = 2Vw / [(Eld - Esc) + (Erd - Esc)] \quad (2)$$

Where Vf= Index  
 Vw= width of the valley floor  
 Erd= elevations of the left and right hand valley divides as you look down stream  
 Esc= Elevation of the stream channel or valley floor

High values of Vf correspond to wide, flat valley floors, and low values correspond to actively uplifting v-shaped valleys.

Comparison of the floor width of a valley to the height provides an index suggesting whether stream is actively down cutting or primarily eroding laterally into the adjacent hill slopes. In the present study Vf ratios ranges between 0,29 to 17,74 in the area deep and narrow valleys show low Vf values <1.0 this valleys can be classified as “V” shaped valleys and Vf values between 1 and 1,5 are indicates moderately active regions and Vf values greater than 1,0 can be classified as “U” shaped valleys these areas subject to major lateral erosion due to right lateral motion of NAFZ.

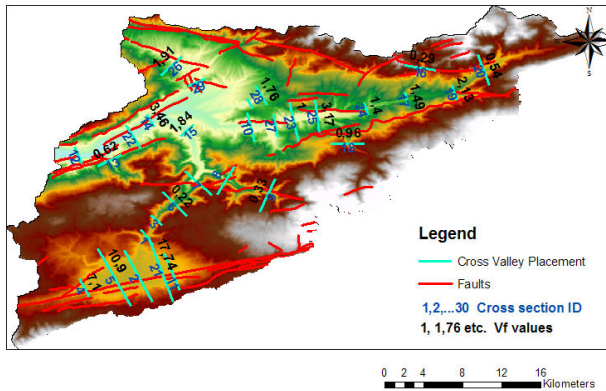


Figure 3: Valley Floor Width To Height Ratio

### 2.3. Stream Length Gradient Index (SI)

Rivers that are not tectonically perturbed typically develop a smoothly changing, concave longitudinal profile. Departures of the river gradient from this ideal smooth shape may reflect variations in the lithology of the river bed, or tectonic activity. Rivers that are tectonically disturbed are predicted to approach a gradient profile rapidly (Snow and Slingerland, 1987) once such disturbance cases. Thus, perturbations in river profiles may be interpreted as response to ongoing tectonism.

The stream length-gradient index is calculated for a particular reach of interest and defined as:

$$SI = (\Delta H / \Delta L) * L \quad (3)$$

Where SI= Stream length gradient index  
 $\Delta H$ = Change in elevation of reach  
 $\Delta L$ = Length of the reach  
 L= Total channel length from the point of interest where the index is being calculated upstream to the highest point on the channel.

The SL index is very sensitive to changes in channel slope, and this sensitivity allows the evaluation of relationships among possible tectonic activity in the area.

In the selected catchment area SL index is calculated for 72 location selected on 15 river channel. According to generated results SL indices changes between 11,12 and 1780,24. The SL index values are relatively low where rock types are alluvion and SL index increases dramatically where the river channel crosses the hard rocks (Figure 4).

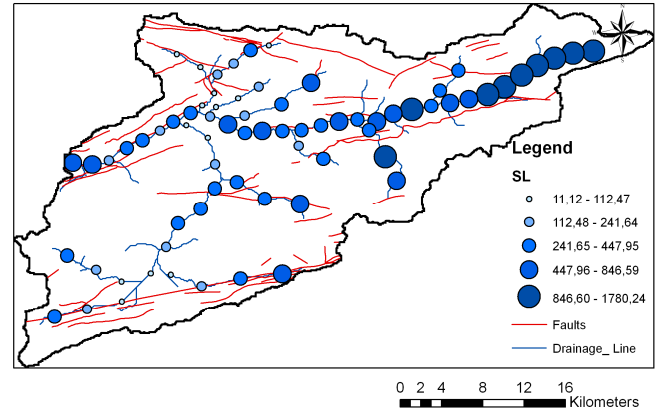


Figure 4: SL Indices

### 2.4. Hypsometric Curve and Integral (HI)

The hypsometric curve of a catchment represents the relative area below (or above) a given altitude (Strahler, 1952).it describes the distributions of elevations across an area of land, from one drainage basin to entire planet. It is a powerful tool to differentiate between tectonically active and inactive areas (Keller and Pinter 1996).

The shape of the hypsometric curves — and the HI values— provide valuable information not only on the erosional stage of the basin, but also on the tectonic, climatic, and lithological factors controlling it (e.g., Moglen and Bras, 1995; Willgoose and Hancock, 1998; Huang and Niemann, 2006).

The simple way to characterize the shape of hypsometric curve for a given drainage basin is to calculate its hypsometric integral. The integral is defined as the area under the hypsometric curve. One way to calculate the integral for a given curve is as follows.

$$\frac{MeanElevation - MinimumElevation}{MaximumElevation - MinimumElevation} \quad (4)$$

High values of the hypsometric integral indicate that most of the topography is high relative to the mean, such as a smooth upland surface cut by deeply incised streams. Intermediate low values of the integral are associated with more evenly dissected drainage basins.

According to generated results, in the study area the HI values changes between 0,106 and 0,787. High values of the hypsometric integral indicate deep incision and rugged relief. Intermediate low values of the integral are associated with more evenly dissected drainage basin (Figure 5).

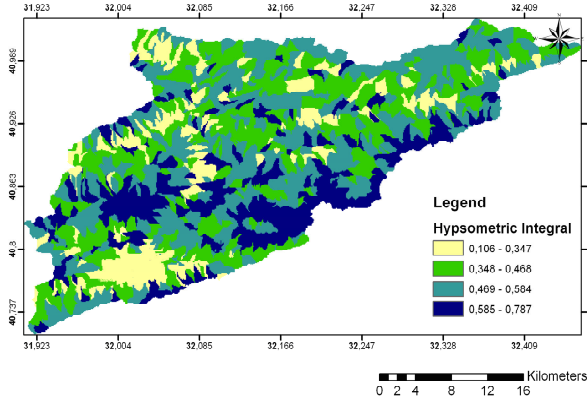


Figure 5: Hypsometric Integral

### 2.5. Drainage Basin Asymmetry

Asymmetry factor analyzed for the basin to determine there any tectonic tilt in the area due to strike slip motion of tectonically active fault zones and its related branches. The asymmetry factor of the basin is calculated using formula as;

$$AF = 100(Ar / At) \quad (5)$$

Where AF= Asymmetry Factor  
 Ar = Area of the basin belongs to right trunk of the stream  
 At = Total area of basin

In Yenicaga basin AF determined as 33,97 suggesting tectonic tilt, due to tectonic influences of the NAFZ in the area (Figure 6).

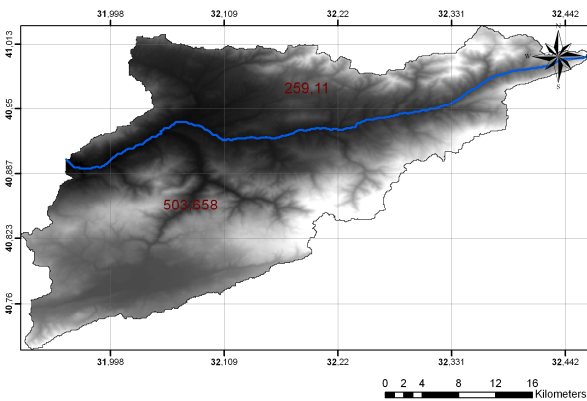


Figure 6: Asymmetry factor

Transverse Topographic Symmetry Factor (T) is another way that used for determining the possible tilt direction. Perfectly symmetric basin has value of transverse topographic symmetry (T) as zero, as the asymmetry increases T increases and approaches the value of one. In order to determine T values of the area drainage basin is divided into sections by the straight line then the value of T calculated at seventeen locations of the basin the generated results varies between 0 and 0,712. According to generated results the basin indicates perfect

symmetry at the middle of the basin area indicating T values as '0' east part of the basin indicates more asymmetric pattern than west part of the basin in that area T values as 0,712-0,758-0,75-0,709 approaching to 1. (Figure 7)

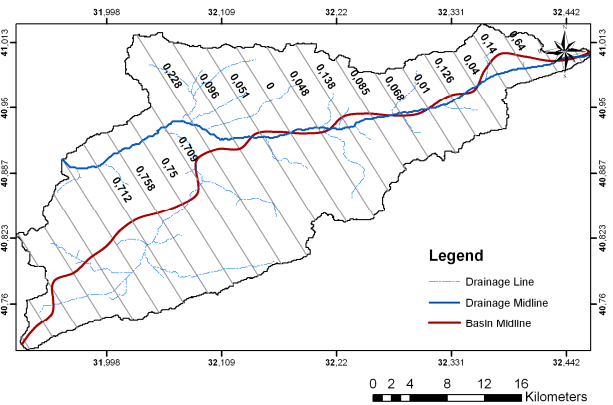


Figure 7: Transverse Topographic Symmetry Factor

### 3. CONCLUSION

According to generated results, the Yenicaga basin mainly influenced by NAFZ. The results of the applied indices: SL indices changes between 11, 12 and 1780,24 meaning of that tectonically influence of the area by NAFZ. Smf values computed for nineteen fronts show that the most active mountain fronts associated with active faults of the area. Valley Floor Width To Height Ratio (Vf) ranges between 0,29 and 17,74 in the area deep and narrow valleys show low Vf values <1.0 this valleys can be classified as "V" shaped valleys and Vf values between 1 and 1,5 are indicate moderately active regions and Vf values greater than 1,0 can be classified as "U" shaped valleys. These areas subject to major lateral erosion due to right lateral motion of NAFZ. HI values changes between 0,106 and 0,787 High values of the hypsometric integral indicate deep incision and rugged relief. Asymmetry factor significantly greater than 50 suggesting tectonic tilt.

### REFERENCES

Bull, W. B., and L. D. McFadden, 1977. "Tectonic geomorphology north and south of the Garlock fault, California". *Geomorphology in Arid Regions. Proceedings of the Eight Annual Geomorphology Symposium* (Ed. D. O. Doehring): 115-138. Binghamton, NY: State University of New York at Binghamton.

Huang and Niemann, 2006 X.J. Huang and J.D. 2006. "Niemann, Modelling the potential impacts of groundwater hydrology on long-term drainage basin evolution", *Earth Surface Processes and Landforms* 31 (2006), pp. 1802-1823.

Keller E A and Pinter N 1996 "Active tectonics: Earthquakes Uplift and Landscapes"; Prentice Hall, New Jersey.

Moglen and Bras, 1995 G.E. Moglen and R.L. Bras, 1995. "The effect of spatial heterogeneities on geomorphic expression in a model of basin evolution", *Water Resources Research* 31, pp. 2613-2623.

Snow and Slingerland, 1987 R.S. Snow and R.L. Slingerland, Mathematical modelling of graded river profiles, *Journal of Geology* 95 (1987), pp. 15–33.

Strahler, A. N. (1952), "Hypsometric (area-altitude) analysis of erosional topology", *Geological Society of America Bulletin* 63 (11): 1117–1142

Wells, S.G., Bullard, T.F., Menges, T.M., Drake, P.G., Karas, P.A., Kelson, K.I., Ritter, J.B. and Westling, J.R. 1988. "Regional variation in tectonic geomorphology along segmented convergent plate boundary, Pacific coast of Costa Rica". *Geomorphology*, 1: 239–265.

Willgoose and Hancock, 1998 G. "Revisiting the hypsometric curve as an indicator of form and process in transport-limited catchment", *Earth Surface Processes and Landforms* 23, pp. 611–623