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Hydrological characteristics of one of the most important humid watersheds in Turkey: the Upper Zamantı River watershed

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Abstract Meteorological parameters such as precipitation, temperature, humidity, evapotranspiration and wind are important for hydrological analysis. They have a large affect on the water balance of humid regions. Water is lost from the system by evapotranspiration and so vegetation is another important parameter in hydrology, as are geology and geomorphology. To determine such losses, hydrological investigations have been made with care and in detail in the Upper Zamantı River watershed which is a humid watershed in Turkey. This watershed has a karstic area of 35% and the depth of karstification is well developed because of the humid climate. High temperatures and big differences between day-time and night-time temperatures during winter, sudden fluctuations in wind speed and direction, snow depth, flow regime and spring discharges, are properties of the watershed. Temperature and humidity effect the hydrology during summer, and snowfall (sometimes heavy snowfall) and snowmelt effect the hydrology during winter. In this study, the hydrological characteristics of the watershed are determined and hydrological analyses are made.

Caracteristicas hidrologicas de una de las principales cuencas humedas en Turquia: la Cuenca Alta del Rio Zamanti

Resumen Los parámetros meteorológicos tales como precipitación, temperatura, humedad, evapotranspiración y viento tiene gran importancia en los análisis hidrológicos y han tenido mayor efecto sobre el balance hídrico en las regiones húmedas. El agua se pierde del sistema por evapotranspiración. La vegetación es otro parámetro que afecta la hidrología, así como también la geología y la geomorfología. Para evitar tales pérdidas se han llevado a cabo cuidadosas y detalladas investigaciones hidrológicas. La cuenca superior del río Zamanti es una de las cuencas húmedas de Turquía. Esta cuenca tiene un 35% de área kárstica y la profundicad de la karstificación se ha desarrollado a causa del clima húmedo. Las elevadas temperaturas y grandes diferencias de las mismas entre el día y la noche durante el invierno, así como las repentinas fluctuaciones de la velocidad y dirección del viento, el espesor de la capa de nieve, régimen de flujo y caudal de primavera, son características de esta cuenca. La temperatura y la humeda afectan durante el verano, la nieve (a veces fuertes nevadas) y la fusión nival afectan a la hidrología en invierno. En el presente estudio se determinan las características hidrológicas de la cuenca y se llevan a cabo análisis hidrológicos.

INTRODUCTION

Hydrology, which is the physical and mathematical description of the water cycle, gives different results and interpretations according to the hydrometeorological conditions, vegetation and characteristics of watersheds. Differences in hydrometeorological parameters such as precipitation, air temperature, soil temperature, humidity, air pressure, evapotranspiration, and characteristics of the watershed (e.g. type of soil, infiltration capacity) influence the humidity of the watershed. Hydrological validations of humid watersheds are more complex than for others and particularly if karstification properties have to be allowed for. Sudden fluctuations of parameters have a large impact on results and so all parameters that are used in the solution of the problem must be quantified.

The Upper Zamantı River watershed is a humid watershed in Turkey. The heat air flux coming from the Mediterranean Sea causes the humid climate. Thirty-five percent of the total area catchment area is karstic.

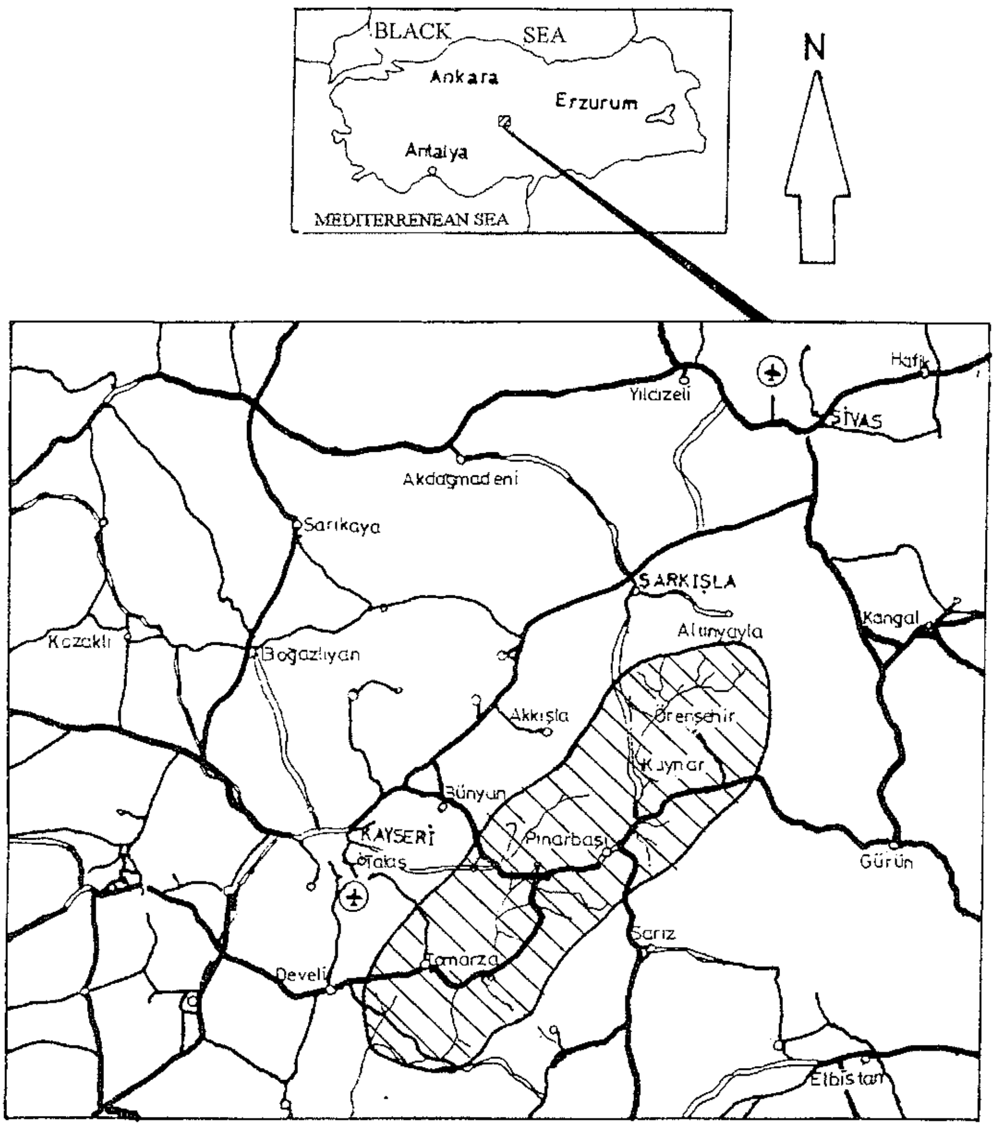

Fig. 1 Location map of the study area.

STUDY AREA

The Upper Zamantı River watershed is located between 38°10′–39°10′N and 35°30′–36°55′E, with 6334.8 km^2 area (Fig. 1). The Zamantı River has an outlet point at 1270 m a.m.s.l. and is one of the main tributaries of the Seyhan watershed. The higher section of the watershed forms its east and southeast borders (Fig. 2). In general, the watershed has poor vegetation and a humid climate dominates. The watershed is covered by perennial snow cover on average for four months a year and melting continues until the beginning of June (especially above 2000 m a.m.s.l.). The average elevation of the mountainous parts of central and eastern Anatolia is between 1800 and 1100 m a.m.s.l. These parts are generally covered by snow cover during the winter season (Gürer & Türksoy, 1981). In the watershed, the average snow depth is 925 mm and it increases from west to east. The snow cover period is changeable everywhere due to the effect of climate. For example, while the snow cover period is about two months (January–February) on lower plateaux (e.g. Tomarza and Şeyhbarak), it can be six months (November–April) over 2000 m a.m.s.l. (e.g. at Gezbel and Yedioluk) (Fig. 2). The areal distribution and the period of perennial snow cover change according to climatological and topographical conditions. Sometimes the ratio of snowmelt flow to the streamflow is higher than rain. Therefore, in this study, the snow component had to be analysed in detail.

Generally, the big rivers are fed by meltwater from surrounding mountains (Moussavi *et al.*, 1989). Martinec (1976) stated that snowfall is the most complex precipitation type.

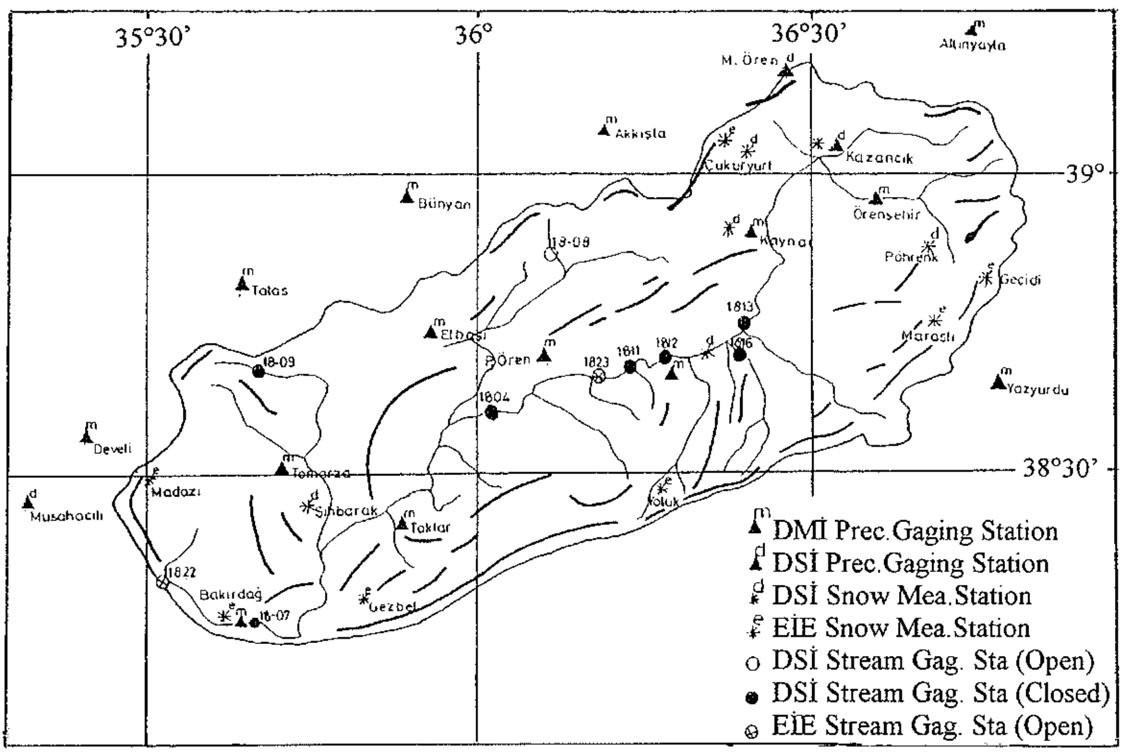

Fig. 2 A detailed map of the study area showing drainage area and hydro-meteorological gauging stations.

It requires certain conditions: (a) a decrease to 0°C of the temperature above ground, and (b) the ground temperature to be at freezing point (Ward & Robinson, 1990).

The internal structure of snow cover has always changed locally from the falling of snow till the end of melting season. The internal structure of snow cover is controlled by evaporation, wind, melting, slope of ground, topography, vegetation, elevation, etc. According to Linsley *et al.* (1983), snow cover takes the energy that is required for melting or changing its structure through the following factors: (a) solar (shortwave) radiation, (b) longwave radiation, (c) conduction and convective transfer of sensible heat from the overlying air, (d) condensation of water vapour, (e) conduction from the underlying soil, and (f) heat supplied by rainfall.

Snowmelt is affected by albedo, wind, soil temperature, cloudiness, vegetation, slope, etc. (Chow *et al.*, 1988). These meteorological parameters are measured at synoptic stations in Turkey. Although they are insufficient in number, these factors are used to calculate the melting amount. More observations are required but more observations need more financial support (Yavaş, 1992). The degree-day method, which is the most common method used in calculations of melting, is not applicable for large watersheds. The energy-balance approach, which is another effective calculation method, can also hardly be applied because of the unavailability of the required data.

GEOLOGY AND HYDROGEOLOGY

In this watershed, the different types of rock can be summarized as follows: Paleozoic limestone, schist, calcschist and quartzite are bed rock components in the watershed and they are covered by Mesozoic limestone. Paleocene and Eocene limestones overlie Mesozoic limestone. Quaternary rocks, including loose conglomerate, marl, travertine, andesitic tuff, basalt and alluvium overlie Eocene limestone. Among all these formations there are unconformities (Dinçer, 1963, 1971). Big folds, which extend in a northeast–southwest direction, can be seen in these formations in the watershed. Faults show different directions (DSİ, 1971).

Limestones have high porosity and permeability values, and they have an important role in the hydrogeological character of the watershed. The basalts also have high permeability due to cracking. Marl, which overlies the limestones with unconformity, cause the spring discharges from limestones (DSİ, 1971; DSİ, 1978). There are 70 springs in the watershed. Eight of them flow continuously with 3.8 $m^3 s^{-1}$ of total discharge (Table 1). The other springs are temporary and their total average discharge is about 150 $l s^{-1}$ (DSİ, 1971).

HYDROLOGY OF THE BASIN

Total precipitation

Figure 2 shows 18 raingauging stations (YGİ), nine streamgauging stations (AG) and 14 snow gauging stations (KG) which have been operated by the Turkish Meteorological Service (DM), State Hydraulic Works (DS) and General Directorate of Electrical Power Resources Survey and Administration (EIEI). According to World

Table 1 Some characteristics of main springs in the watershed.

Name of spring	Mean discharge ($l\ s^{-1}$) *	Formation
Tacin	1138	Paleozoic Limestone
Şerefiye	1000–2000	Eocene Limestone
Kaynar	384	Paleozoic Limestone
Tersakan	40–60	Eocene Limestone
Elbaşı	120–400	Paleozoic Limestone
Pınarbaşı	700	Mesozoic Limestone
Taf-Akin	200	Mesozoic Limestone
Panlı	250	Mesozoic Limestone
Total	**3832**	

*From DSİ (1971).

Meteorological Organization standards (WMO, 1974), the numbers of YGİ stations is insufficient to define the real distribution of rain in the watershed. According to available data extending from 1978 to 1996, the amount of rain increases up to 1500 m a.m.s.l., and then decreases; that is, snow is more dominant than rain in the higher parts of the watershed. About 72% of the annual precipitation falls during the November–May period. The mean annual precipitation value is calculated as 386.8 mm by the isohyetal method. During the study period five years were dry and three years were wet (Fig. 3) (Gürer & Yavaş, 1992; Şimşek & Yavaş, 1994; Gürer & Yavaş, 1995).

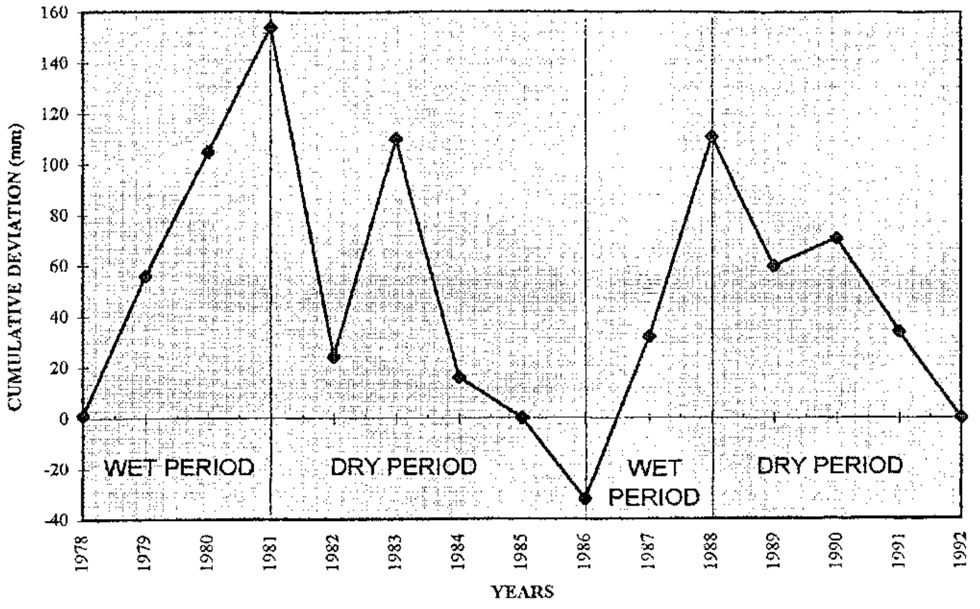

Fig. 3 Cumulative deviation graph of Tomarza raingauging station in the watershed.

Snow

The KGİs started to work in 1978 with 14 stations and almost all of them are still operating. Although one KGİ represents about 452.5 km^2, the elevation distribution is limited due to inaccessibility. The highest KGİ, Gezbel, is located at an elevation of 1960 m a.m.s.l. and, there is no KGİ above this elevation. Climatological and road conditions render access to the higher levels impossible and therefore telemetric KGİ had not been implemented.

The Upper Zamantı River watershed is covered with snow on average from mid-November till the beginning of April. The perennial snow line is about 1400 m a.m.s.l. in the watershed. The amount of snowfall increases going from the southern part to the northern part. Snow depths at the higher parts of the watershed can reach 120–140 cm at the beginning of May. The mountain peaks are covered by permanent snow. Although snow measurements were not recorded above 1960 m a.m.s.l. in the watershed, available data show an increase in snow depth (S_d) from south to the north (Yavaş, 1994) (Fig. 4). At some KGİ, which are located on south facing slopes, smaller snow amounts than normal are observed. According to the snow measurements from Gezbel KGİ and Yedioluk KGİ, which are located at the most upper part of the watershed to measure snow and for field observation, snow depths at certain locations at higher elevation may reach several metres. Because of this, and the increase in temperature in some seasons, the snowmelt period starts in March and may extend to May.

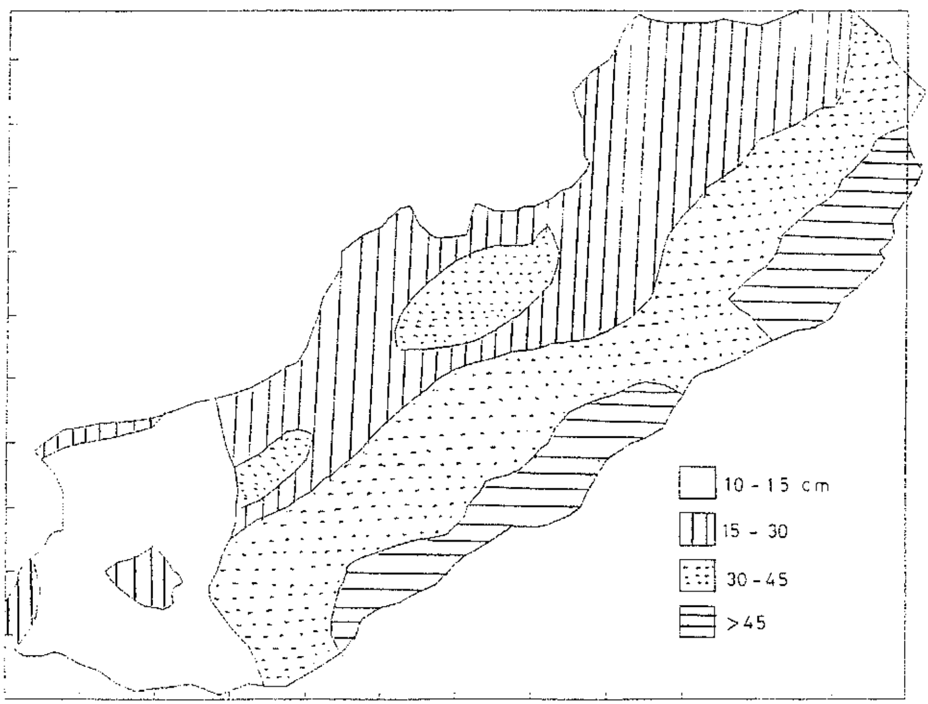

Fig. 4 Equal snow depth lines in February in the watershed.

Runoff

There are three AGİ stations; two of them are operating on the main river course, the other one is at Tacin tributary. The number of AGİ on the main river is sufficient to monitor the flow regime but a single station on the tributary is not enough to monitor the regime, because of spring discharge contribution to some tributaries. According to measurements, 15% of the total peak flow occurs in March, 30% in April and 15% in May. As Fig. 5 shows, the snowmelt period for the watershed is realized between March and May. The effect can be observed as two and half or three times more than normal flow in Emeğil AGİ and four times more than normal flow in Fraktin AGİ, because a rainstorm before snowfall can cause peak flows in December and January, as was the case in 1984.

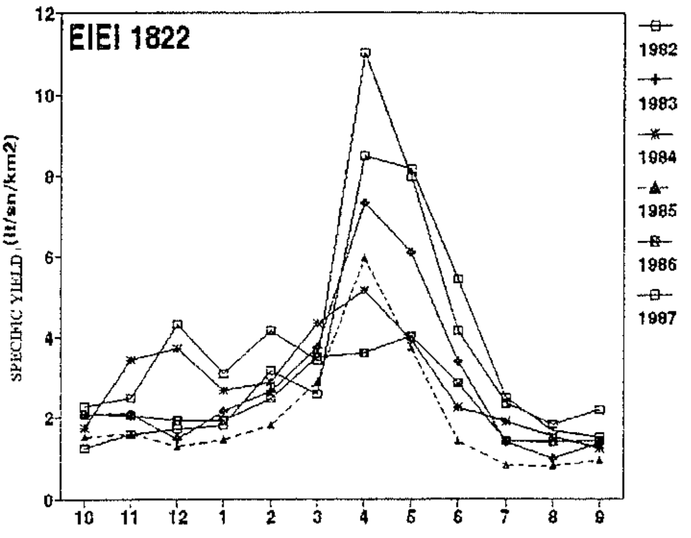

Fig. 5 Variations of specific yields with time at the Fraktin streamgauging station.

Temperature

Temperature decreases from south to north across the watershed. In winter, the northern sector is colder and has more days with temperatures below 0°C. The temperature difference between day-time and night-time is about 30°C in winter. Winter is longer and colder in the higher parts, with big temperature differences between day- and night-time and these parts have more snow storage, because while temperature starts to rise over 0°C in the middle of March in the southern parts of the watershed, it starts to rise in the middle of April in the northern parts. Temperature increases from west to east also. So, there is a big difference in snow depth between west and east.

Water budget

According to available data obtained from the existing hydrometeorological stations in the watershed, the hydrological budget of the watershed has been calculated by using the hydrological budget approach that is defined:

$$\text{Inflow} - \text{Outflow} = \text{Storage in the watershed } (\Delta S) \tag{1}$$

In the watershed, ΔS has a minimum change in a water year in a long period, thus, ΔS can be assumed as 0 and, the equation can be written as:

$$\text{Precipitation} = \text{Evaporation} + \text{Surface flow} + \text{Flow through Groundwater} \tag{2}$$

The parameters for the watershed are:

Precipitation	386.8 mm (by isohyetal method)
Evapotranspiration	65% of precipitation (this is assumed for non-karstic areas by the Geological and Geophysical Research Institute of Yugoslavia
Mean flow	100 mm (20.254 m^3 s^{-1}) (average discharge from the watershed)

By using these parameters in equation (2), flow through groundwater can be estimated as 30 mm (218.8×10^6 m^3 $year^{-1}$). Of course, by analysing the period covering 1978–1996, which has most of the rain, evaporation and flow data, the amount of flow through groundwater is the amount of water seeping from rain and snowmelt together. Since it is not possible to make an exact computation of the snowmelt part of the contribution to flow, the ratio of snow to total flow can only be estimated. In the December–April period, the ratio is 62% of precipitation according to Gürer & Türksoy (1981) and 60% according to Yavaş (1994) for the whole watershed is used as a criterion. It can be said that approximately 20 mm (131.32×10^6 m^3 $year^{-1}$) of groundwater is estimated to come from snowmelt.

RESULTS

According to the available data from the existing hydrometeorological stations, a decrease in snow amount, increase in flow and numbers of degree days are encountered in the period 1974–1976.

The highest gauging station is located at an elevation of 1960 m a.m.s.l. All measurements were recorded below 1960 m a.m.s.l. in the watershed and all analyses and evaluations have been done with these records. According to these analyses, approximately 20 mm (130×10^6 m^3 $year^{-1}$) water comes from snowmelt to the groundwater. This value will be greater if the measurements recorded up to 1960 m a.m.s.l. are also included. So, if the distribution of all gauging stations met the world standards, all calculations would give quite correct results. But, now in Türkiye, a million cubic metres of water flows for nothing because of planning strategies.

Sixty percent of precipitation falls as a snowfall in a watershed during a year. Thus, the importance of KGİ is more than YGİ. The number of KGİs should be increased as soon as possible.

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