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Ecological properties of vegetation formations on karst terrains in the central Taurus Mountains (Southern Turkey)

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Abstract

There is a strict relationship between the formation of karst topography, soils and vegetation on karst terrains. The Central part of Taurus Mountains of southern Turkey is rich in terms of topographical variety and karstic landforms. Karst topography has a strong influence on the development of soil types and vegetation formations. Karst formations such as karren, doline, uvala, karstic valley and poljes create unique habitats with different micro-climatic, soil and vegetation characteristics that differ from neighbouring sites.

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Keywords: Ecology; vegetation formations; karst terrains; Taurus Mountains; Turkey.

1. Introduction

The relationships between topography, soil formation and vegetation distribution have been studied in karstic terrains by several scholars (e.g., Atalay, 1988, 1991, 1997; Cvijic, 1924; Efe, 1998, Barany-Kevei, 1983, 1987, 1999, Barany and Horvath 1996). The development of soils and successional evolution and establishment of vegetation in karst terrains are primarily affected by physical and chemical properties of limestone occurring in the study area (Atalay et al. 2008; Atalay and Efe 2008; Efe 2004). And, more specifically, the characteristics of

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vegetative cover are also dependent on dominant environmental conditions – especially the soil and climatic parameters being demonstrated on karstic terrains (Atalay and Efe 2010; Atalay and Efe 2011; Efe et al., 2008).

The study area is located within the northeast Mediterranean Basin in southern part of Turkey. In particular, this study is concerned with the relationships between geomorphology, soils and vegetation in the central part of the Taurus Mountains, specifically in the area between Ermenek, Gülnar, Hadim and Mut. The primary objectives of this work are to determine the scope of karst landforms, soil, and vegetation and to provide a description and explanation of their interrelationships.

Fig. 1. Study area

Distinctive climatic characteristics of the region include a hot, dry high-sun season, and a mild, wet low-sun period. The average monthly temperatures during the summer season can be as high as 27^{o}C.

Temperatures in January are mild and the average between 7-10^{o}C. Total annual precipitation ranges from 700 to 1,500 millimetres. More than half of the precipitation falls during winter and the rate varies with altitude. Overall, the Mediterranean region of Turkey is marked by an Alp-Himalayan orogenic system exhibiting high, folded, faulted, rugged mountains and hills often abruptly rising from the coast of the Mediterranean Sea. The geomorphology of the Taurus Mountains developed as a result of on-going tectonic and fluvial processes in the Late Tertiary and Quaternary periods. But, climate determines the mode and speed of external processes that are modifying the landscape. In summary, the geomorphic units in the Mediterranean region of Turkey can be considered to be shaped by tectonics, climate, and fluvial processes.

2. Findings

Close relationships have been observed between karst geomorphology soil types and vegetation in the Central Taurus Mountains. The lithologic properties of limestone, the thickness of rock layers, slope gradients, the depth of impermeable layers, and hydrologic properties are important contributors to the development of karst topography. The limestones belonging to the Jurassic, Cretaceous and Miocene eras have been deposited in a marine environment through a number of processes: detritically as gravel, sand and mud; partly by chemical deposition; and partly by organic processes.

Local Jurassic and Cretaceous limestones are rich in $CaCO_3$ (92%) and compact such that karst landforms develop effectively. However, limestones form the bedded horizontal layers in the basin exposed around Başyayla, Sarıveliler, Ermenek and Mut, and belong to the Miocene period. They contain clay and sand, which reduces their ability to karstify or slows down the relevant karstification process. Three factors determine the permeability of limestone: porosity, jointing, and their bedding. Of these three factors, jointing is particularly important to the development of karst geomorphology. The joints that connect the bedding-planes and lie vertically influence not only the appearance of the surface, but also the underground water systems.

Karren fields, small depressions (dolines, uvalas) and karst valleys are the main exokarst landforms which were created by the dissolving effect of precipitation in the study area. Karstic depressions (e.g., doline, uvala, karst valley and dry valley) are suitable for agriculture in terms of suitable soil and groundwater conditions. The most common karst landforms in the area include the following: karrens, dolines, valleys, uvalas and poljes. These are formed as the result of corrosion and the solvent effects of precipitation.

2.1. Lapies (karren)

Lapies (karren) are the most common karstic forms in the study area and are smaller features measuring a few mm to a few meters. There is a strict connection between the type of rock involved and the development of lapies. Depending on the characteristics of the limestone, two types of lapies can develop: groove or hollow. Lapies are well-developed on limestone where the $CaCO_3$ percentage is greater (Habic, 1991; Sweeting 1973). In the higher mountains, the lapies were deformed due to climatic conditions, especially diurnal temperature differences. Solution by rainwater induces pits and hollows. There are 3 primary types of karren (lapies):

a-Free karren, where water flows unimpeded over the limestone surface.

b-Half-exposed karren, where bare limestone surfaces are covered by patches of soil which attack the rock by means of biogenic CO_2, thereby creating corrosion troughs and humus-water grooves (Bögli, 1980).

c-Buried karren, which is common under the red soils (alfisols) which occur widely in karst terrains.

2.2. Dolines

Dolines are the most widespread karst formations in the study area and are covered karstic cavities with underground drainage plus a diameter, which is greater than their depth. Dolines in the study area are formed when the limestone is dissolved underneath the presence of soil. They can appear as cattle-shaped, funnel-shaped, bowl-shaped, or as flat, dish, and trough-shaped dolines. The diameter of the doline varies between a few and 300 meters, with a depth of up to 50 meters. While they appear singly around Soğukpınar, Hadim and Mut, they form doline fields in the plateau. Dolines are widely seen on the horizontally bedded limestones of plateau areas between Çekiç Mountain and the Geyik Mountains. There are more than 300 dolines between Sulugöl peak and Sarıçal Mountain. They are formed as the result of dissolution or collapse. Some dolines are circular and their sizes can range from between 30 to 100 meters in diameter.

2.3. Uvalas, poljes and karst valleys

Uvalas are larger, broad-bottomed karst hollows with broken ground. Uvalas are the product of two or more dolines that have grown or merged together. Uvalas have irregular shapes compared to dolines. Fluvial processes have affected the formation and appearance of uvalas in the study area. There are several poljes, which vary in size in the study area. In area, the Çandıralanı polje is 2.5 square km. and is used for agricultural purpose. Alfisols are the main soil type occurring on the floor of the poljes in the study area. Karst valleys and dry valleys are formed by water (i.e., fluvial processes). Canyon valleys are common between Ermenek and Mut. The size and shape of the valleys depends upon the nature of the limestone. Collapses of limestone blocks tend to enlarge the valleys.

2.4. Karst plateaus

The vast plateau developed on calcareous formations on the Gökçay and Ermenek river basins. These large high plateaus have been cut by both the Göksu River and its tributaries. Deep valleys cut vast surfaces through erosion at an average altitude of 1500 meters. All of these conditions contribute to maximum development of karst landforms such as different kinds of lapies, dolines, uvalas, poljes, blind valleys, ponors, resurgences, travertine terraces, caves, avens, and natural bridges. Subterranean river courses form one of the dominant elements of the topography.

Valley sides are cut into horizontally-bedded limestone layers rising up like walls on both sides of the Ermenek and Gökçay river valleys. There are about 1500 meters between the valley floor and the top of the slope in analogous places around Mut and Ermenek. On the plateau, the topography is quite different from the valleys. In fact, some hills rise on the plateau. The average elevation of the plateau is approximately 1500 meters. Individual mountains (e.g., Kızıl, Oyuklu, and Gökbel) rise above 2500 meters around the source area of the Ermenek River. The plateau surface appears to have been cut by several streams (e.g., Fındık, Karapınar, and Güney) which are tributaries of the Göksu River (Efe, 2008).

The valleys were cut in the horizontally-bedded limestone and form canyons. Many small streams also cut the plateau extending between the Ermenek and Gökçay rivers. The topography rises in steps to the south of Ermenek and reaches up to 2000 meters in the Gülnar plateau. There are several uvalas, dolines and poljes on the Gülnar plateau. The base level of karst in the area is determined by the Ermenek and Gökçay rivers and their tributaries. Dolines are the most common karstic landforms on the Gülnar and Taşeli plateau. Their sizes vary, but they measure from a few meters to 1 kilometer, and are mostly 1-2 meters deep and from 10 cm to 5 m in diameter. Two or more dolines join and form uvalas and karstic valleys.

2.5. Soils

Alfisols, inceptisols and entisols are common soil types in the study area. Alfisols are found on the bottom of karstic depressions or on gentle slopes developed on limestone. They develop along the fissures, cracks and beddings of the layers. Reddish in color, as a result of mineral decomposition to sesquioxides of iron (Fe_2O_3), alfisols are very rich in clay so that clayey texture in general. Mountain soils are thin and demonstrate a strong relationship to the parent material from which they were formed. On gentle slopes, soils with well-developed agrillic horizons predominate. The karren forms of the soil do not appear on the surface. It develops within the cracks and contact zones where water can easily infiltrate. Ground water levels are high in the bottom of dolines and this facilitates the formation of small streams on the floor. The thickness of soil increases in the flat areas whereas thin soils are common on steeper slopes. The higher mountainous areas do not have the necessary conditions required for the development of thicker soils (Gerrard, 1995).

Table 1: Physical and chemical characteristics of soils.

Location	Altitude	Sand %	Silt %	Clay %	pH	$CaCO_3$ %
Sarıveliler	1500	21	35	44	7.3	5
NW of Mut	1200	40	15	45	7.4	15
Gülnar	1450	28	31	41	7.8	25
Kazancı	850	32	30	38	7.3	14
Ermenek	550	37	21	42	7.4	21

Biological activity is dependent on the vegetative cover of the soil beds. Inceptisols are immature soils with A, B (C) horizons. The pH, acidity, alkalinity and the $CaCO_3$ content represent the salient chemical characteristics of alfisols. The alfisols in the study area are mildly alkaline (i.e., the average pH is 7.5). As mentioned earlier, soils are notably dependent upon the parent material and climate. Within the more mountainous areas, the parent material is a reliable indicator of physical and chemical properties of soil. The strong seasonal contrast (i.e., wet winters and dry summers) of this climatic regime results in only a modest profile development in the area. Relict soils are widespread at higher altitudes (e.g., 1,700 meters). Mountain soils are thin and show a strong relationship to the parent material from which they were formed. On gentle slopes, soils with well-developed argillic horizons predominate. Many local areas exhibit paleosols giving evidence of past climatic conditions different from those that are evident today.

The thickness of soils is extremely varied in the study area. For example, at the south of the Gezende and Gülnar plateau, the thicknesses of the inceptisols attain 20 cm, but around Sarıveliler the thickness can reach up to 100 cm. Soils formed on Jurassic limestones are generally basic, but there is a tendency for acidification in some localities on the northern slopes.

Alfisols, inceptisols and entisols are common soil types in the study area. Terra Rosa (an alfisol) is dense, acidic clay with a high iron content which produces its characteristic red color. Terra Rosa is a residual soil whose deposits form as a result of the corrosive weathering of limestone. Alfisols in general are found on the flat or gentle slopes developed on limestone, and develop in the cracks and beddings of the layers.

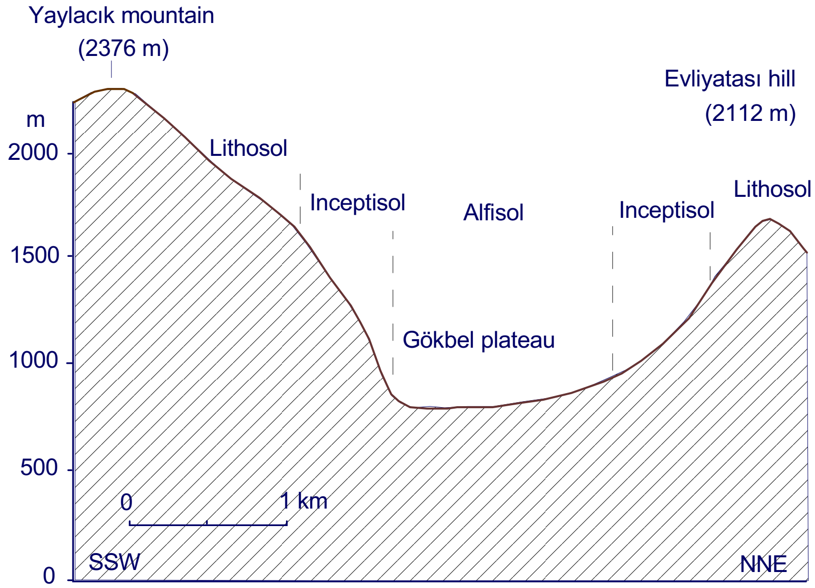

Fig. 2. Relationships between soils and geomorphology

In the mountainous areas, two soil suborders are also common: grey-brown podsolic soils and xeralfs. Xeralfs predominate with greater organic content and moderate lime accumulation on a variety of rock types. Karren formations do not appear on the surface, but develop within the cracks and contact zones where water can easily infiltrate. The vegetation on the karst terrain varies. In most parts of the higher mountains, the barren limestone is exposed and entisols are common soil types on the steep slopes. Rendzina (mollisol) is common around Gülnar and Gezende. Mollisols are dark, alkaline, shallow, and loamy with a high infiltration rate and usually contain residual rock fragments (Efe, 1998).

2.6. Vegetation

Overall, vegetation has an important role in forming the karst landforms such as lapies, dolines, uvalas, and poljes. The roots and organic remnants of plants mostly affect the dissolution of limestone with the organic acids they contain. On the other hand, the roots grow into the cracks of the limestone, thereby enlarging them. Successful tree and bush growth is occurring on slopes where the soil is found in the cracks of the limestone (Efe, 2010).

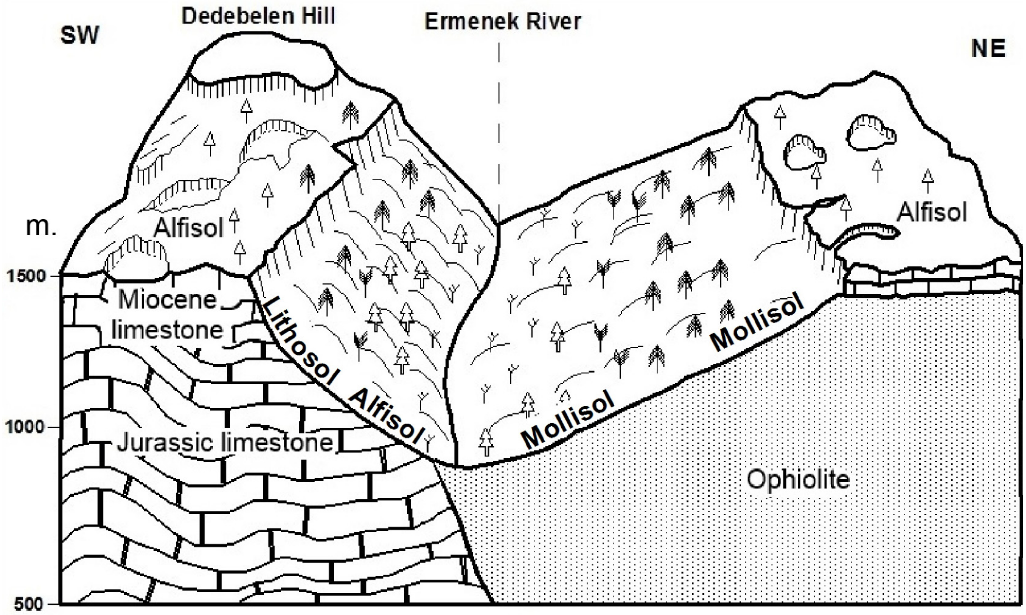

Fig. 3. Relationships between soils, vegetation and morphology (Efe, 2008)

Since plants provide organic matter to soils, the soils of degraded areas around Mut and Gülnar are very low in organic matter. Degradation of vegetative cover inhibits soil forming processes and also increases soil erosion of existing material. The percentage of organic matter decreases in the alfisols and inceptisols on the south facing slopes around Gezende, Kazancı and Ermenek. The organic layer is thicker in the inceptisols (brown and immature soils) where such species as the following are present: Cedar (*Cedrus libani*), pine (*Pinus nigra* ssp. *pallasina*), fir (*Abies cilicica*) and juniper (*Juniperus excelsa*).

The characteristic climatic features and geomorphology of the Central Taurus Mountains has promoted comparable vegetation zones. Red pine (*Pinus brutia*) – both in pure stands and mixed with maquis – is common up to 1000 meters. Maquis formations consisting of evergreen, sclerophyllous, woody shrubs and small trees such as myrtle (*Myrtus communis*), jasmine box (*Phillyrea latifolia*), pistachio (*Pistacia terebinthus*), and strawberry tree (*Arbutus unedo*) are widespread up to 800 meters. Maquis is a secondary vegetation formation that grows after the clearing or deforestation of red pine stands. The karstic depressions create local micro-climate and soil conditions. The hydrophytic species belonging to the Black Sea phytogeographical region such as ash (*Fraxinus excelsior*), cornel (*Cornus mas*), chequer tree (*Sorbus torminalis*), and hornbeam (*Ostrya carpinifolia*) can be seen in the depressions. The Taurus fir (*Abies cilicica*) and Taurus cedar (*Cedrus libani*), which have hardy roots that can penetrate into the cracks of limestone, are the most common species that have adapted to the karstic environment at higher altitudes.

As stated, karstic depressions such as dolines, uvalas, karst valleys and dry valleys are covered by maquis formations up to 800 meters. The forest formation at higher altitudes consists of black pine (*Pinus nigra ssp. pallasina*), Taurus fir (*Abies cilicica*), cedar (*Cedrus libani*), and juniper (*Juniperus excelsa, J. foetidissima)*, which are widespread between 900 to 2,100 meters. At these altitudes, other representative species can include Turkish oak (*Quercus cerris*), dyer's oak (*Q. infectoria*), valonia oak (*Q. ithaburensis* ssp. *macrolepis*), Macedonian oak (*Q. trojana*), and black pine (*Pinus nigra* ssp. *pallasina*) (Atalay and Efe 2010).

Vegetative cover exercises a strong influence on the soil processes of karst formations. Historically, there has been extensive clearing of the natural vegetation in the region of the Central Taurus Mountains. In particular, land degradation processes have increased dramatically in the 20th century and barren surfaces occur over 1700 meters. In the mountains and on the plateaus in the most of the degraded areas, juniper occurs following deforestation.

3. Conclusions

In this study, it has been indicated that soil formation processes in karstic terrains in the Central Taurus Mountains depend primarily upon the characteristics of parent materials and vegetative cover. The soils on the bottom of poljes, uvalas and dolines are thicker than the plateau surfaces and slopes. Bush and tree formations tend to develop better in karstic areas due to the fact that rood easily develops along the cracks. Hydrologic conditions affect the development of grass formation in the area, and thereby influence erosion processes. Nevertheless, surface run-off is not high because of the overall porosity of limestone and other factors. Karst terrain in the study area is highly conducive to plant growth due to a combination of nutrient-rich soils, good drainage and sound rooting. In the inceptisol and mollisol profiles, the boundary between soil and underlying rock is pronounced.

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