LITHOLOGICAL AND MORPHOLOGICAL CONTROL ON THE AGRICULTURAL TERRACES IN BOZBURUN PENINSULA, TURKEY

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submitted by SELİM SATICI in partial fulfillment of the requirements for the degree of Master of Science in Geological Engineering Department, Middle East Technical University by,

Prof. Dr. Canan Özgen
Dean, Graduate School of Natural and Applied Sciences _______________

Prof. Dr. Erdin Bozkurt
Head of Department, Geological Engineering _______________

Prof. Dr. G.M. Vedat Toprak
Supervisor, Geological Engineering Dept., METU _______________

Examining Committee Members:

Prof. Dr. Asuman Türkmenoğlu
Geological Engineering Dept., METU _______________

Prof. Dr. G.M. Vedat Toprak
Geological Engineering Dept., METU _______________

Prof. Dr. Numan Tuna
Settlement Archaeology Dept., METU _______________

Assoc. Prof. Dr. Bora Rojay
Geological Engineering Dept., METU _______________

Dr. Arda Arcasoy
General Manager, Arcasoy Consulting _______________

Date: 24.01.2013

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have full cited and referenced all material and results that are not original to this work.

Name, Last Name: SELİM SATICI

Signature:

ABSTRACT

LITHOLOGICAL AND MORPHOLOGICAL CONTROL ON THE AGRICULTURAL TERRACES IN BOZBURUN PENINSULA, TURKEY

Satıcı, Selim

M.Sc., Department of Geological Engineering
Supervisor: Prof. Dr. G. M. Vedat Toprak

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This study is carried out in Bozburun Peninsula where agricultural terraces exist. The purpose of the study is to investigate the effect of lithology and morphology of the area on the distribution of terraces.

The data used in the study is composed of necessary analog and digital topographic maps and geological maps which are revised by field data. Morphological settings of the regions, where terraces were placed, are classified into three types as coastal, valley and karstic. The methodology of the study consists of the analysis of elevation and slope values of terraces and three main rock units (alluvium, clastics and limestone) in ten selected areas.

Results of the analysis suggest followings on the relationship between terraces and lithological/morphological features: 1) the units are ordered from lowest to highest values of elevation and slope as alluvium, terraces, clastics and limestone; 2) agricultural terraces were highly and inversely influenced by limestone among all rock units; 3) terraces are mostly built in alluvium and clastics. 4) low elevation and slope values are preferred for agricultural terracing; 5) three landform types (coastal, valley and karstic) have different patterns in elevation and slope values of rock types as well as terraces.

Keywords: agricultural terrace, geology, morphology, GIS, Bozburun.

ÖZ

LİTOLOJİ VE MORFOLOJİNİN BOZBURUN YARIMADASI (TURKİYE) TARIM TERASLARI ÜZERİNDEKİ KONTROLÜ

Satıcı, Selim

Yüksek Lisans, Jeoloji Mühendisliği Bölümü
Tez Yöneticisi: Prof. Dr. G. M. Vedat Toprak

Ocak 2013, 93 sayfa

Bu çalışma tarım teraslarının yeraldığı Buzburun Yarımadasında gerçekleştirilmiştir. Çalışmanın amacı alanın litolojisinin ve morfolojisinin, terasların dağılımı üzerindeki etkisini araştırmaktır.

Çalışmada kullanılan veri analog ve sayısal topografik haritalar ile arazi çalışmaları ile revise edilen jeolojik haritalardır. Terasların yeraldığı alanlar morfolojik olarak üç tipe ayrılmıştır: kıyı, vadi ve karstik. Çalışmanın metodolojisi seçilmiş on alanda, teraslar ile üç ana kaya grubunun (alüvyon, kırıntılılar ve kireçtaşı) yükseklik ve eğim analizinden oluşmaktadır.

Analiz sonuçları teraslar ile litolojik/morfolojik özellikler arasında şu ilişkileri ortaya koymaktadır: 1) Birimler en düşükten en büyük yükseklik ve eğim değerlerine göre alüvyon, teras, kırıntılılar ve kireçtaşı şeklinde sıralanır; 2) diğer tüm kaya birimlerine oranla teraslar en çok kireçtaşlarından ters orantılı olarak etkilenmiştir; 3) teraslar çoğunlukla alüvyon ve kırıntılılar içerisinde inşa edilmiştir; 4) teraslar için düşük yükseklik ve eğim değerleri tercih edilmiştir; 5) kıyı, vadi ve karstik olarak saptanan üç arazi biçimi kaya birimi ve terasların yükseklik ve eğim değerleri için farklı desenler göstermektedir.

Anahtar Kelimeler: tarım terası, jeoloji, morfoloji, CBS, Bozburun.

To My Sleeping Beauty

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LIST OF ABBREVIATIONS

DEM	Digital Elevation Model
GIS	Geographical Information Systems
GPS	Global Positioning System
HGK	Harita Genel Komutanlığı (General Command of Mapping)
Lst	Limestone
PTP	Poly To Point
Qal	Quaternary Alluvium
RS	Remote Sensing
TIN	Triangulated Irregular Networks

CHAPTER 1

INTRODUCTION

1.1 Purpose and Scope

Agriculture is one of the main food sources for human being since almost the beginning of modern human himself. Agriculture has been practiced over different landforms varying from flat and large plains to rough mountainous areas. The strong need for food forced people to overcome problems created by the rough topography of the area. Bozburun Peninsula, displays a good example of such agricultural activity that has no or limited potential for cultivation due to topographic characteristics (Figure 1.1). People in the area solved the problem by artificially created terraces over steep slopes.

The main motivation behind this study is to understand the effect of lithological and/or morphological features of the area on the construction of these terraces. One can claim that the intensity of the terraces can change from place to place based on the assumption that the rock units and morphological characteristics are different in different parts of the area,.

The purpose of this study is, therefore, to investigate the geological and morphological control on the terraces built in Bozburun Peninsula. The scope of the study is limited by various aspects that can be summarized as follows:

- Study area is limited geographically to ten selected areas (polygons) where agricultural terraces are available. These areas will be introduced in later chapters.

- Geology of the area is based on the available literature. However, geological map of the selected areas are revised and rock units are reclassified according to the purpose of the study. The rock units used in the study will be introduced in the next chapter.

- Age(s) of terraces is/are not investigated in this study. Presence of the terrace is the only criterion for considering them in the study. This is basically due to the fact that the terraces are identified from recent data (images).

- Typology, geometry and frequency of the terraces are not considered in this study. Two main reasons for these are: 1) There is not suitable data to determine and quantify the physical parameters of the terraces, and 2) This is considered as a separate topic for a more specific study.

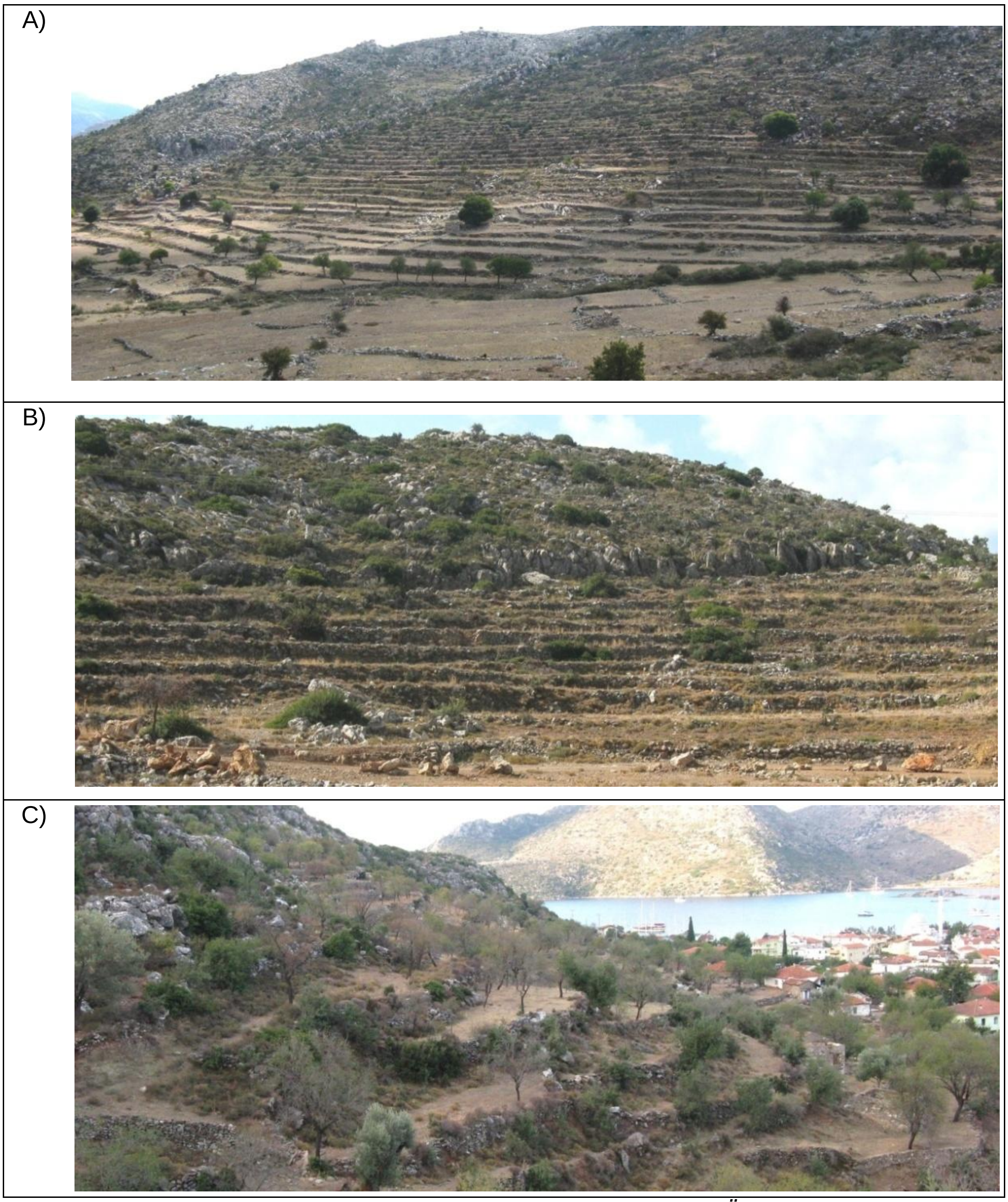


Figure 1.1: General views of agricultural terraces east of Örteren (A), west bank of Üçören (B) and close vicinity of Bozburun (C).

1.2 Location of study area and general characteristics

The study is carried out in Bozburun Peninsula southwest of Marmaris in Muğla province (Figure 1.2). The area is accessible through modern roads about 40 km from Marmaris and 100 km from Muğla City center. Bozburun is the main settlement within the study area with other 8 residential areas. Total population of the peninsula is 9185 ("Beldemiz Bozburun," 2013).

Bozburun peninsula is the southwestern extension of Balaban Mountains. It is characterized by hundreds of small bays and morphological diversities. Lowland flat plains are almost absent in the area with the exception of small plains in the vicinity of Selimiye and Turgut settlements. Physical nature of the area is highly affected by Hisarönü gulf at north and Bozburun gulf at south. Bozburun settlement is located in the north of the Gulf of Bozburun with very irregular coastal line. The region is declared as a "Special Environmental Protection Area" in 22.10.1997 by the Ministry of Culture and Tourism of Republic of Turkey.

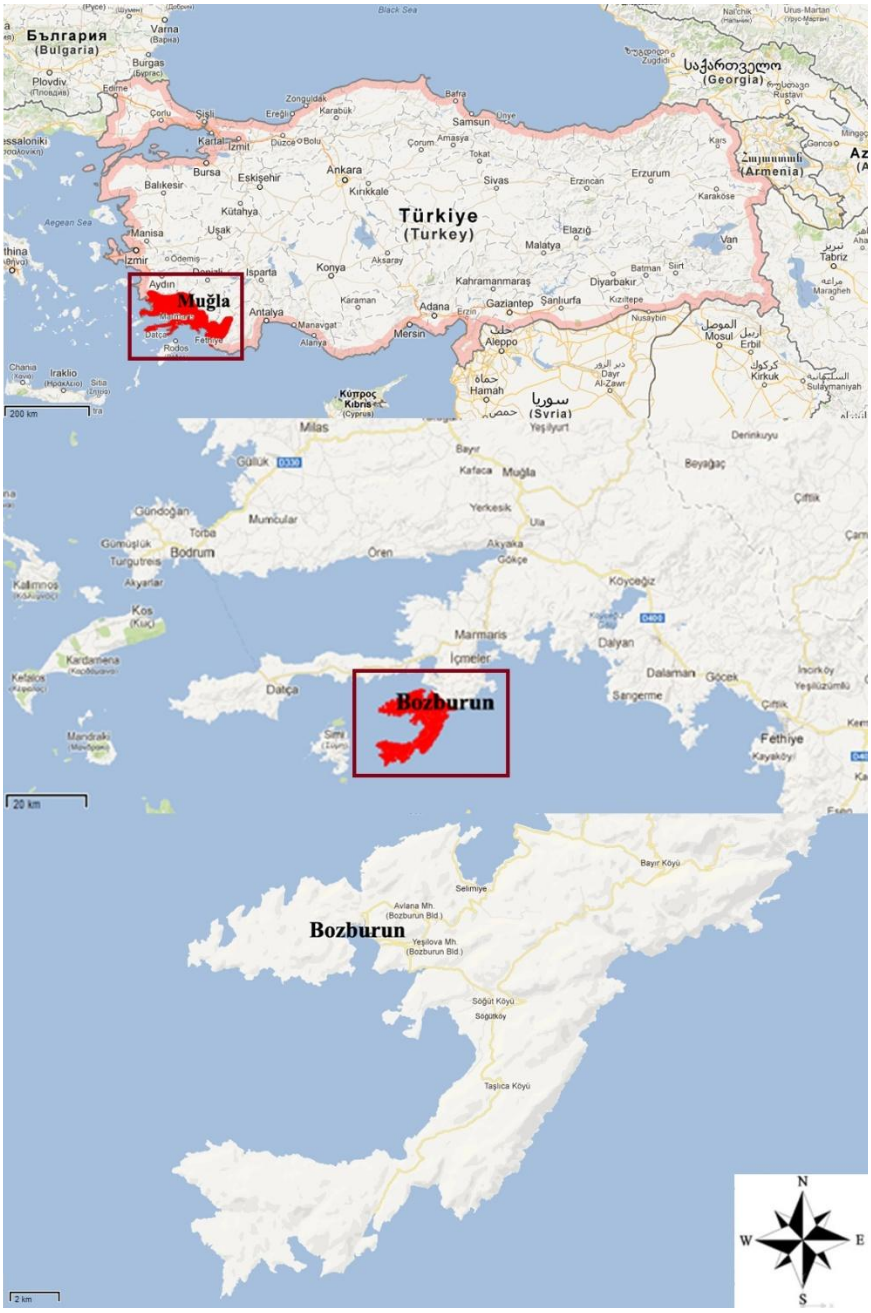


Figure 1.2: Location map of the study area (Bozburun Peninsula).

The peninsula as a whole is rich in plant diversity. Flora of the region is defined by 100 families, 45 genera and 968 species. Forests, scrub vegetation, valley bottom vegetation and coastal sand vegetation are general vegetation types of the peninsula ("Coğrafi Yapı Bozburun," 2013).

The peninsula has a typical Mediterranean climate characteristic. Summers are hot and dry and winters are mild and rainy. The peninsula was named in accordance with its physical characteristics which can be linked to the climate of the area. The name “Bozburun” in Turkish is a combination of two words where "boz" means; gray, bleached and "burun" means; nose. Nose here refers to the peninsula. The name itself gives a brief summary about the peninsula.

1.3 Previous works

Agricultural terraces which are the subject of this study are artificial (man-made) structures built over the earth surface. There are, however, terraces formed by natural processes which are studied for their mode of origin. The name used for these natural terraces in the literature is “terracette” which can be defined as “a small, step-like ridge on a steep surface”. Examples of these structures are reported by Rahm (1962), Gallart et al. (1993), Bielecki and Mueller (2002) and Leopold and Voekel (2007). These studies usually focus on the determination of the geological and/or surface processes responsible for the development of these structures. Bielecki and Mueller (2002), for example, list the proposed origins for the terracettes in San Joaquin Valley (California) including slumping and active folding. These terraces are out of the scope of this study and will not be investigated in detail.

Man-made agricultural terraces, on the other hand, are common structures observed in different parts of the world (Figure 1.3). There are several studies carried out in these regions for different purposes. Some selected studies are briefly explained below.

Collins and Neal (1997) studied the direct impact of hydro-chemicals on terraced agriculture in Nepal. The study emphasizes that storm-flow in cultivated catchments is dominated by low-alkalinity rainwater which dilutes the higher-alkalinity stored waters, often causing a decrease in stream pH. The drains and irrigation canals associated with terraced agriculture provide quick flow-paths causing rainfall to bypass the soil horizons.

Inbar and Llerena (2000) pointed out that abandoned agricultural terraces constitutes a process that increases erosion and sediment yield values following the collapse of supporting walls. In order to quantify the degree of erosion they carried out analysis by installing eight plots in the Santa Eulalia basin (Peru) at altitudes of 2800 m and up to 3650 m. Terrace degradation was noticeable by wall swelling, collapse, and deterioration of wall and terrace structure. Terrace degradation is a function of physical, economic, and social processes, which are linked and irreversible.

Figure 1.3: Examples of modern agricultural terraces: Inca type terraces in Peru (A), Rice terraces in Yunnan, China (B), Rice terraces in Bali, Indonesia (C). (Source: http://en.wikipedia.org/wiki/ Terrace_(agriculture))

Lasanta et al (2001) analyzed the process and impact of farmland abandonment in Camero Viejo (Spain) where the Spanish Mediterranean Mountains become a marginal territory with few inhabitants and limited economic activity that resulted in significant land use changes. The study also investigates geomorphologic evolution of terraced fields after cultivation was given up.

Koulouri and Giourga (2007) conducted a two-year field study in Lesvos Island (Greece) to monitor the change in abandoned agricultural fields. The study was based on the determination of water erosivity, measuring parameters such as rainfall characteristics, sediment losses and water runoff volume; and on the determination of soil erodibility, measuring parameters related to vegetation, soil, slope profile description and drystone terraces. Results show that abandonment of traditional extensive cultivation has different impacts on soil sediment losses according to slope gradient. When slope is steep (25%), soil erosion is increasing significantly. When slope is very steep (40%), soil sediment losses remain at the same high levels after cultivation abandonment because slope gradient is the main factor controlling soil erosion, although soil and vegetation properties are changing.

Lesschen et al. (2008) attempt to assess the extent and causes of erosion and terrace failure on abandoned fields in the Carcavo basin, a semi-arid catchment area in southeast Spain.

Schönbrodt (2010) developed a model (TerraCE model) to assess the spatial variability of terrace condition and the resulting soil erosion risk potential. She applied the model in the Three Gorges Area (China) where a dam built in the region is expected to increase the soil erosion dramatically.

Hencket et al. (2009) used an interdisciplinary approach to investigate the geology, ecology, and cultural history of terrace development within Jiuzhaigou National Park, Sichuan Province, China. They indicate that "terracettes" occur on south facing, 20° slopes at 2500 m elevation, which appears to coincide with places people historically preferred to build villages. Ethnographic interviews suggest that traditional agricultural cycles removed tree roots, causing the loess sediments to lose cohesion, slump, and the terrace risers to retreat uphill over time. This evidence is supported by landslide debris at terracette faces.

Bevan and Conolly (2010) carried out a study at Antikythera (Greece) demonstrating that surficial geology, terrain slope, pre-existing terraces and pre-existing patterns of human habitation are all important structuring features of agricultural terraces. They claim that terraces are clearly dependent on island physiography (principally surficial geology and slope) but also show strong co-dependency with built structures.

Sandor et al. (2010) investigated the soil-geomorphic relationship at some prehistoric agricultural terraces in Sapillo and Mimbers Valleys in southwestern New Mexico to learn about agricultural management in the semiarid area, to evaluate soil productivity and determine long-term effects of agriculture on the physical environment. The results indicate that the landscape was modified by terracing, which served to reduce runoff velocity, increase soil moisture, and thicken naturally thin soil. This study was intensified on how prehistoric agricultural terraces affected the present geological features.

Sole-Benet et al. (2010) investigated the soil erosion mechanism in two different types of abandoned agricultural terraces in mountain environments in the Filabres range in Almería (SE Spain). In order to know both magnitude of soil erosion and controlling factors in different types of abandoned terraces, a rainfall simulation campaign was carried out in 45 representative microsites. Runoff, derived-infiltration and sediment production were measured and their relationships to basic soil parameters (particle size distribution, pH, EC, organic matter content, aggregate stability), geomorphic position, and ground cover, were examined. The results indicate that, under the average applied rainfall intensity narrow bench terraces from steep hill-slopes, have larger infiltration values and deliver less sediments than large bank terraces in alluvial plains. The presence of stony pavement sieving crusts on narrow-bench terraces and also on un-terraced alluvial fans, play an essential armoring effect against soil erosion while favoring water infiltration.

Stelian (2010) attempted to model evolution of agricultural terraces in Bihor county (Romania). The parameters used in the study area are the shape and form of the terraces, soil texture, slope angle and geomorphological processes. Accordingly, the evolution of the terraced slope is controlled by different factors such as geology, structure, degree of vegetation cover, type of vegetation but the most important controlling factor; is the human intervention which could turn the evolution of the slopes towards completely new directions and implicitly towards new forms.

CHAPTER 2

GEOLOGY OF STUDY AREA

2.1 Stratigraphy

Study area is geologically located in a region characterized mainly by nappes. The nappes exposed in the area are collectively known as “Lycian nappes”. The term “Lycian nappes” is first mentioned by Philippson (1915) and is later used by several researchers (Bernouilli et al., 1974; Brinkmann, 1975; Şengör and Yılmaz, 1981; Meşhur et al., 1989; Ersoy, 1990; Bilgin et al., 1997).

Lycian nappes are located in the western part of the Taurides and extend between the Menderes Massif and the Beydağları platform in southwestern Turkey. They are represented by thrust slices of ophiolitic melange, platform carbonates and clastics (Poisson, 1985; Özkaya, 1990; Güngör and Erdoğan, 2001). Most of the researchers suggest that the Lycian nappes are originally formed in the northern edge of the Menderes massif and were tectonically transported southward (e.g. Şengör and Yılmaz, 1981; Okay, 1989; Collins and Robertson, 1997) although some other claim the opposite (e.g. Poisson, 1985; and Özkaya, 1990).

According to the studies of Güngör and Erdoğan (2001) in Söke-Selçuk region, based on the deformational features, stratigraphic relations and orientation of linear fabrics, the nappes were emplaced on the Menderes Massif along a low-angle normal fault after Middle Eocene and before Middle Miocene. Arslan et al. (2010), on the other hand, evaluated the kinematic data identified in Milas area and suggested the presence of three deformation phases: The first deformation phase (D1) suggests that the lowermost unit of the Lycian nappes was emplaced initially from southwest to northeast onto the Menderes Massif during the Early Eocene. The second deformation phase (D2) is characterised by an E–W-trending stretching lineation. A third deformation phase (D3) is characterized by south-dipping normal faults that can be related to southward movement of the Lycian nappes along a low-angle décollement (detachment) zone.

A simplified geological map of the area between Marmaris and Bozburun is given in Figure 2.1. Three Lycian nappes identified in the area are, from north to south, Marmaris ophiolite nappe, Gülbahar nappe and Bodrum nappe. Each nappe is characterized by a distinct rock association. Rock units identified within each nappe and their boundary relationships are also given in Figure 2.1. Study area is located over the rock units of Gülbahar and Bodrum nappes; the third nappe (Marmaris ophiolite nappe) is out of the area further north. Therefore, here only the units exposed in the study area that belong to Gülbahar and Bodrum nappes will be described.

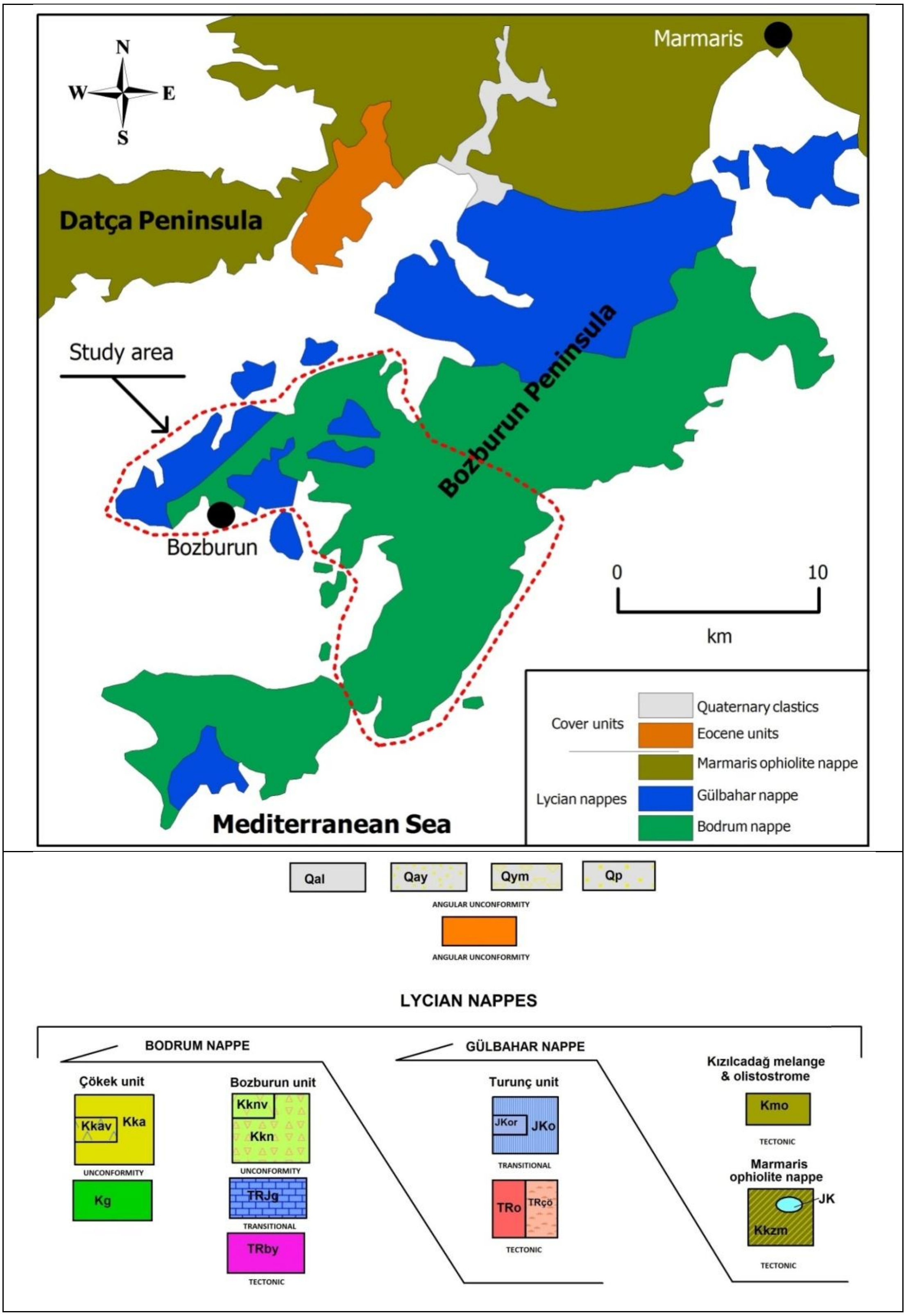
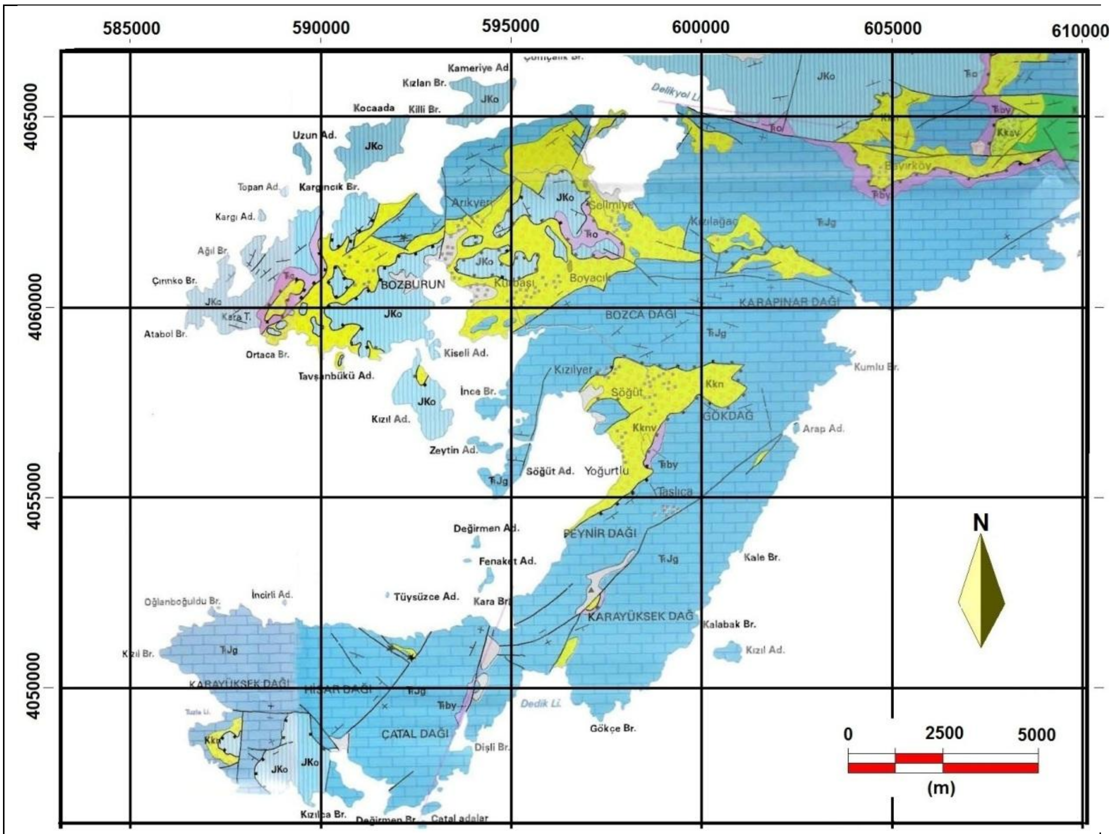


Figure 2.1: Simplified geological map showing major rock units in the vicinity of the area (Şenel and Bilgin, 1997a, b).

Geological map showing the distribution of units within the study area is shown in Figure 2.2. Four rock units seem to dominate the study area, which are: Güverdağı formation, Karanasıflar formation, Orhaniye formation and Quaternary units. Other rock units are either not exposed or exposed only in very limited regions of the study area. Brief descriptions of these four units are as follows:



ROCK UNITS

Cover units
Qal, Qay, Qym, Qp: Quaternary clastics
Gülbahar nappe:
JKo: Jurassic-Cretaceous Orhaniye formation (limestone, cherty limestone)
TRo: Middle-Upper Triassic Orluca formation (limestone, dolomite, claystone, sandstone)
Bodrum nappe (Bozburun unit)
Kkn: Karanasıflar formation
Kknv: Upper Senonian volcanics
TRJg: Triassic-Liassic Güverdağı formation (limestone, dolomitic limestone)
TRby: Upper Triassic Bayırköy formation (dolomite, claystone, siltstone)
Bodrum nappe (Çökek unit)
Kka: Upper Senonian Karaböğürtlen formation (wild flysch)
Kkav: Upper Senonian volcanite member (basalt, spilite)
Kg: Dogger-Cretaceous Gögediği formation (micrite, cherty micrite, calciturbidite)

Figure 2.2: Geological map of the study area (from 1/100000 scale map of MTA, Şenel and Bilgin, 1997a, b). See Figure 2.1 for boundary relations of rock units.

Güverdağı formation: Güverdağı formation (TRJg) is a rock unit within the Bozburun unit and is named by Bilgin et al (1997). Most of the area is covered by this unit as large and continuous outcrops. The unit is composed of grey, thick to massive limestone and dolomitic limestone (Figure 2.3-a). Fossil content suggests an age of Upper Triassic-Liassic deposited in a shallow shelf environment (Bilgin et al., 1997; Şenel and Bilgin, 1997).

Karanasıflar formation: Karanasıflar formation (Kkn) is named by Şenel et al. (1989) north of Fethiye and adopted by Şenel and Bilgin (1997b) in the region. The formation belongs to Bozburun unit and conformably (transitionally) overlies Güverdağı formation (Şenel and Bilgin, 1997b). However, the field observations indicate that, the unit is tectonically overlain by either Güverdağı or Orhaniye formations (Figure 2.3-a and b) within the area. It is observed in the northern and central parts of the area mostly at lower elevations or in the dissected valleys (Figure 2.2). The unit is composed of a clastic sequence of sandstone, siltstone, and mudstone alternation. In most of the outcrops, certain metamorphic features are developed within the units (Figure 2.3-b) which can be attributed to the overlying thrust.

Orhaniye formation: Orhaniye formation (JKo) is named by Meşhur et al. (1989) in western Taurus and adopted by Şenel and Bilgin (1997b) in the region. The formation is the uppermost unit of the Turunç tectonic unit. It is exposed as limited outcrops in the north-eastern part of the area (Figure 2.2). Orhaniye formation is composed of beige-cream-grey, medium to thick bedded limestones and cherty limestones. Based on the various species of Globotruncana, an age of Jurassic-Cretaceous is assigned by Meşhur et al. (1989), Şenel et al. (1994) and Bilgin et al. (1997).

Quaternary deposits: Quaternary deposits cover limited areas in the MTA geological map (Figure 2.2). Field studies, however, indicate that these deposits cover larger areas than shown in geological map. This might be due the scale of the map in which smaller outcrops are neglected. Based on the depositional setting and mode of origin, three types Quaternary deposits can be suggested in the area (Figure 2.4): a) Karstic deposits, b) Valley floor deposits, and 3) Coastal deposits. Brief description of each type is as follows

- Karstic deposits: These deposits are formed within the karstic depressions in the area. These features geometrically are in the form of ellipse/circle and located in the vicinity of faults (Figure 2.4-A). Most of these deposits are located at high altitudes relative to other Quaternary deposits.
- Valley floor deposits: These deposits are found along the active valley floors where the cross-sectional profile of the river is U-shape (Figure 2.4-B)
- Coastal deposits: Coastal deposits are formed along the shoreline at lowest altitudes at the mouth of the streams (Figure 2.4-C).

Quaternary deposits are assigned an age of “Quaternary” because they are the youngest deposit in the area and are still in process of deposition. However, the actual date might be slightly older (e.g. Pliocene). Since there is no direct evidence of age for these units all deposits in the area are considered as Quaternary.

An important feature of the Quaternary deposits is the groundwater hold by these units. Since there is no permanent stream in the area, groundwater is the main source of the water and is always associated with Quaternary deposits in the area whatever the type is. This is approved by presence of water-wells constructed in these deposits (Figure 2.5).

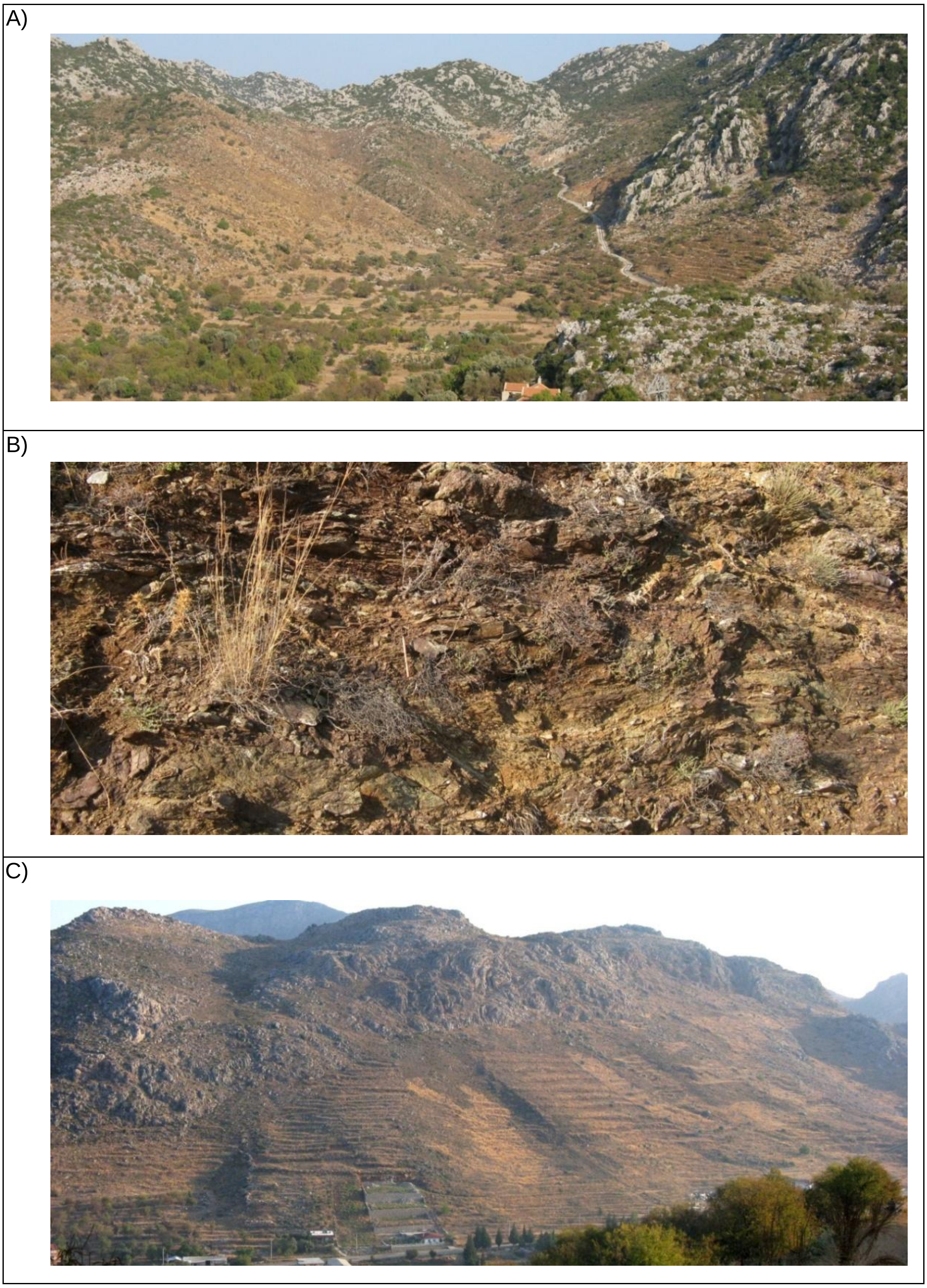


Figure 2.3: Rock units exposed within the study area. A: Tectonic boundary between Güverdağı (top) and Karanasıflar (bottom) formations; B: Close-up view of Karanasıflar formation; C: Tectonic boundary between Orhaniye (top) and Karanasıflar (bottom) formations.

Figure 2.4: Example of Quaternary deposits in the area. A: Karstic depressions (north of Taşlıca village); B: Valley floor deposits (south of Kızılköy village; C: Coastal deposits (Yeşilova village).

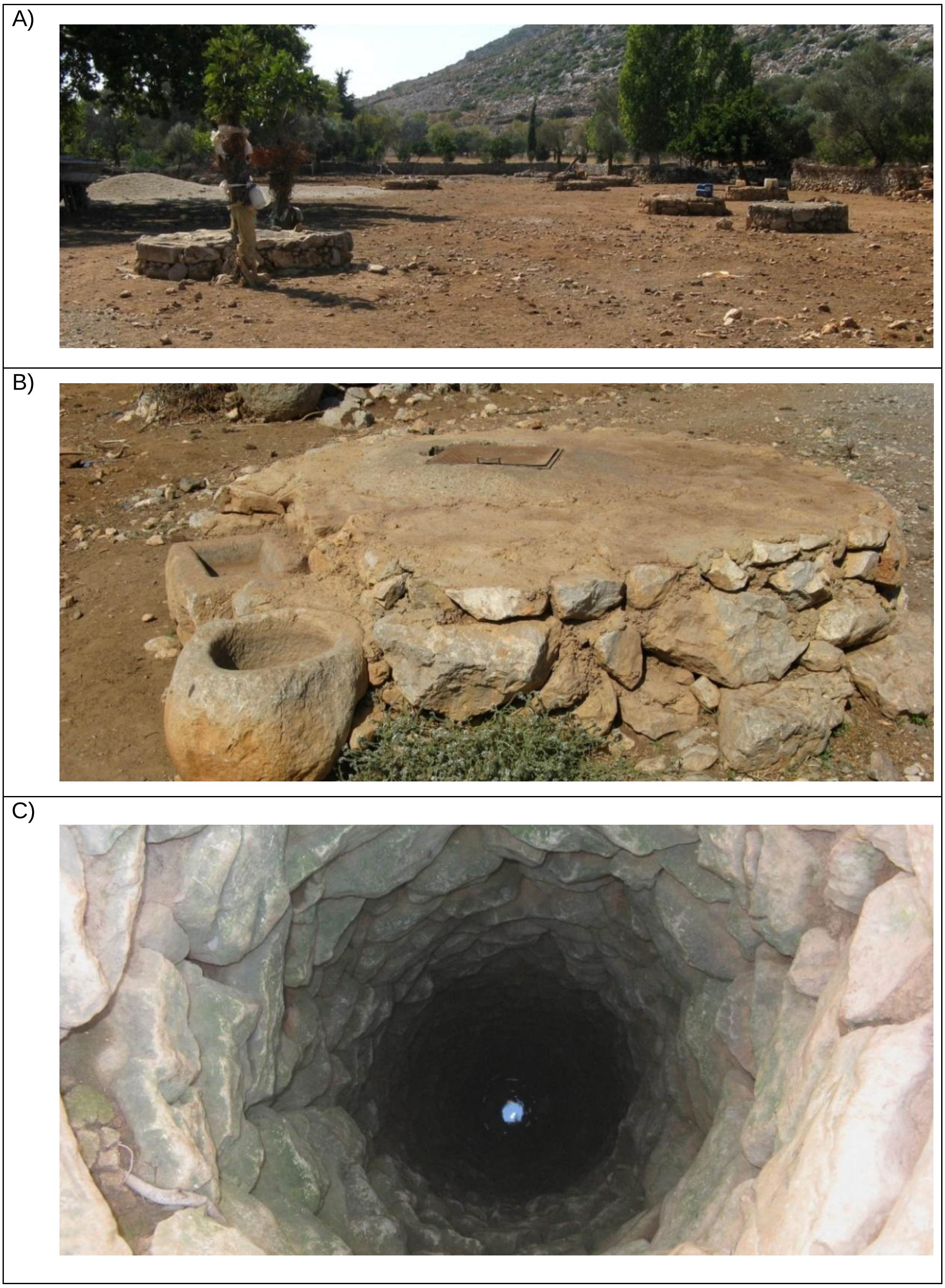


Figure 2.5: Examples of wells within Quaternary deposits south of Taşlıca village. A: Numerous closely-spaced wells, B: A close-up view of a water-well, C: Some wells are still in use today.

2.2 Structures

Nappes are the most important geological structures in the area. A geological study is not made on these structures considering the scope of the thesis. Therefore, all information about the nature, distribution and age of these nappes are compiled from literature and are given in Figures 2.1 and 2.2. There is, however, a direct influence of these structures on the origin of agricultural terraces which are the main theme of this study and will be dealt later.

Normal faults are other structures of the area most of which are shown in Figure 2.2. The ages of the faults are estimated as Pliocene (Şenel and Bilgin, 1997b) suggesting a neotectonic origin. These faults are important for the formation of karstic depressions in the area and shaping the landform in the region. A new fault map is not prepared in this study because most of them are already mapped (Figure 2.2). The main strike for the normal faults is NE-SW particularly in the central, southern and western parts of the area.

2.3 Geological Model

The relationship between rock units and geological structures is important to understand the lithological control on the agricultural terraces. For this reason, a simple model is introduced in Figure 2.6 that integrates all rock units and structures. The terraces are not shown in this figure and will be discussed after all data are analyzed.

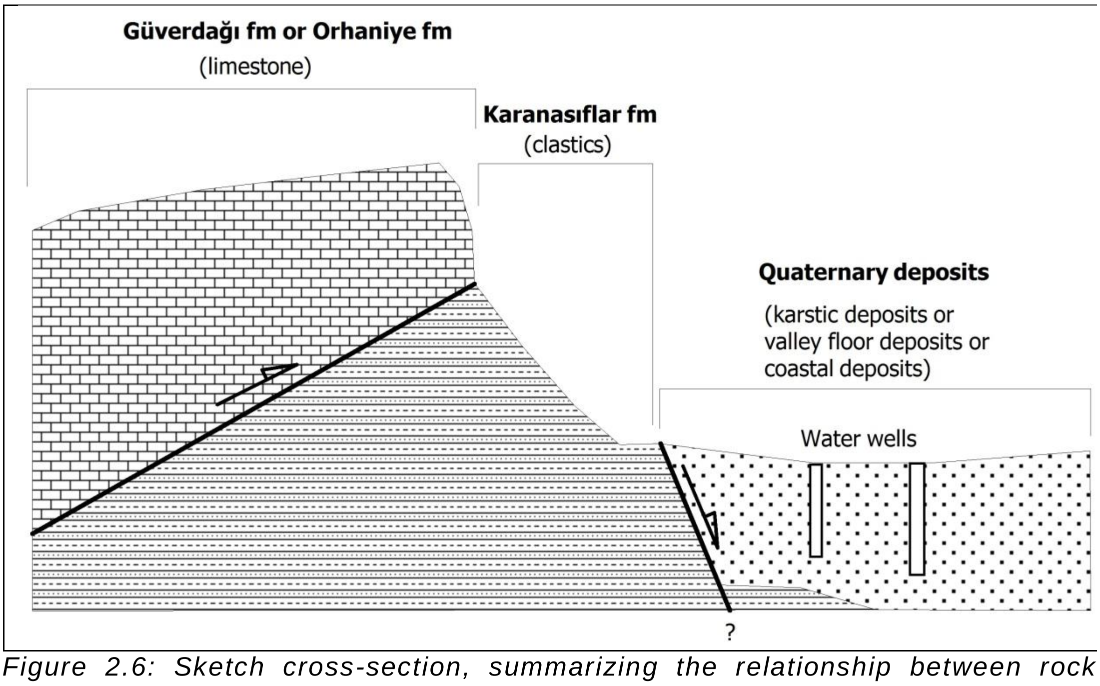


Figure 2.6: Sketch cross-section, summarizing the relationship between rock units and geological structures.

The main highlights of the model are as follows:

- The higher elevations in the area are covered by resistant limestones of either Güverdağı formation or Orhaniye formation. The bottom boundary of these units is defined by thrust faults which explain the metamorphic imprints in the underlying Karanasıflar formation.

- Karanasıflar formation is almost everywhere overlain by a tectonic slab. The exception of this observation can be seen only locally where the overlying slab is totally eroded.
- Quaternary units are usually at relatively lower elevations. This is sometimes a karstic depression at high attitudes where a nearby fault is expected. For the valley floor deposits or coastal type deposits, however, a fault is not essential.
- All the water wells are located within the Quaternary deposits. The “cisterns”, on the other hand, which have a totally different function, are not considered in the model.

In the rest of the thesis, the rock units exposed in the area will be categorized into three types in order to simplify the explanation and avoid confusion. The terms for these rock units are as follows:

- Limestone: It refers to Güverdağı and/or Orhaniye formations.
- Clastics: It refers to Karanasıflar formation
- Alluvium: It refers to Quaternary deposit of any type described above.

CHAPTER 3

DATA AND METHODOLOGY

This chapter describes the sources, types and formats of data being used and methods of how they were converted from raw data to graphs, maps and tables during this study.

3.1 Data Used in the Study

Since the study is mainly carried out by GIS and RS technology methods, the source data was mainly in digital format. There are five datasets used in this study which are: 1) Scanned 1/25000 scaled topographic maps, 2) Digital 10 m elevation contours, 3) Analogue 1/5000 scaled topographic maps, 4) Satellite images, and 5) Field data. Detailed information of these data sets is given below.

3.1.1 Scanned 1/25000 Scaled Topographic Maps

One of the data inputs of this study is a set of topographic maps with scale of 1/25000 taken from General Command of Mapping of Turkey (Harita Genel Komutanlığı, HGK). Three 1/25000 scaled topographic sheets used in this study are: O20-d1, O20-d2 and O20-d4. Maps are taken in Jpeg format (Jint Photographic Experts Group). Data was converted by TNTmips 2011 pro into RVC (TNTmips file format extension). Georeference process, extraction and mosaicing (merging) processes were also carried out by TNTmips 2011 pro. The output is given in Figure 3.1.

This data set is much coarser than the other data sets and was used for completing missing parts of topographic data (Digital 10 m Elevation Contours).

3.1.2 Digital 10 m Elevation Contours

One of the main data inputs of this study is a set of digital 10 m elevation contours obtained from General Command of Mapping of Turkey (HGK). These data were generated by the maps given at the previous section (scanned 1/25000 scaled topographic maps). This data was initially composed of three separate sheets which were merged and united. Some complications and errors were detected and corrected by the help of Scanned 1/25000 scaled topographic maps and digitized analogue 1/5000 scaled topographic maps with the software TNTmips 2011 Pro. After merging and corrections the data combined into a single continuous contour map (Figure 3.2).

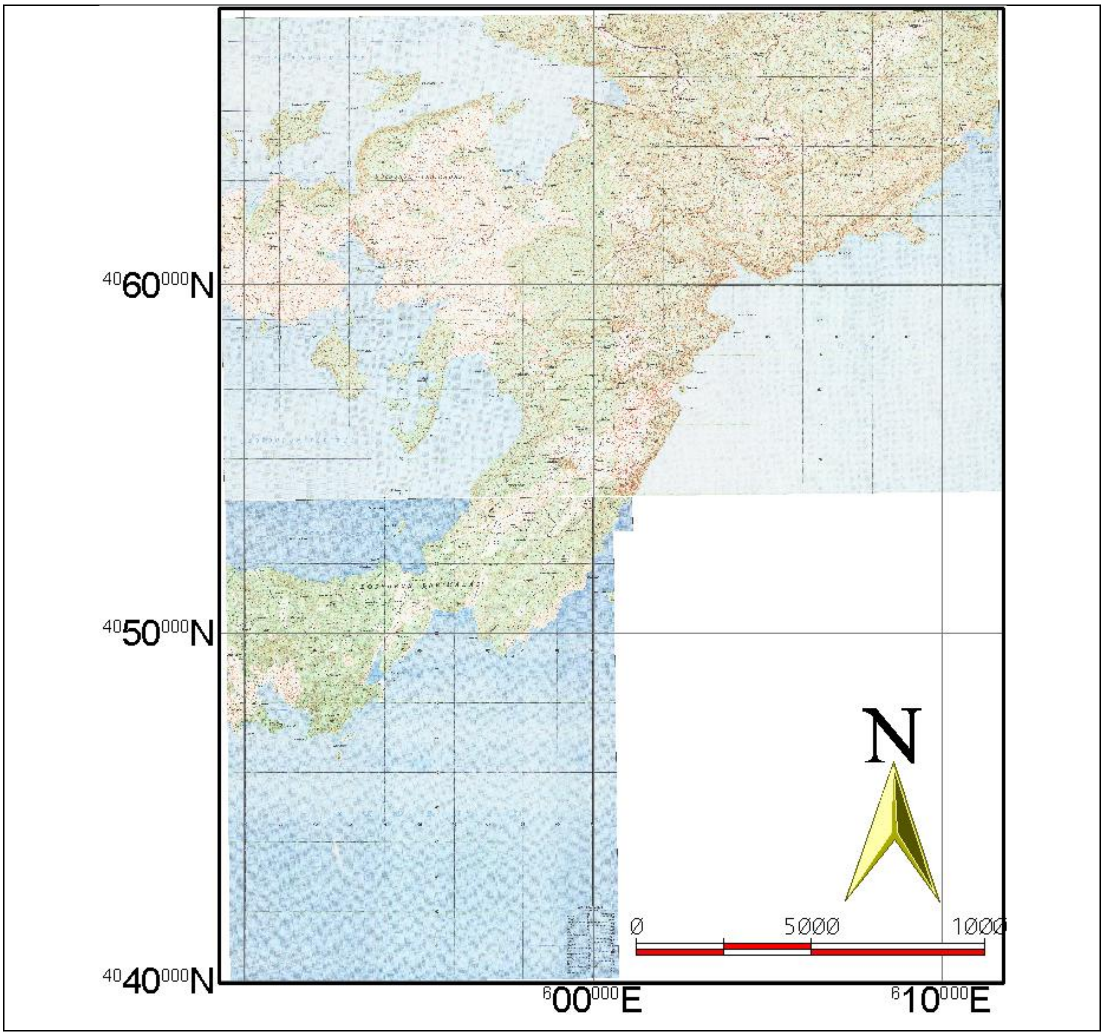


Figure 3.1: Mosaic of topographic maps with scale of 1/25000.

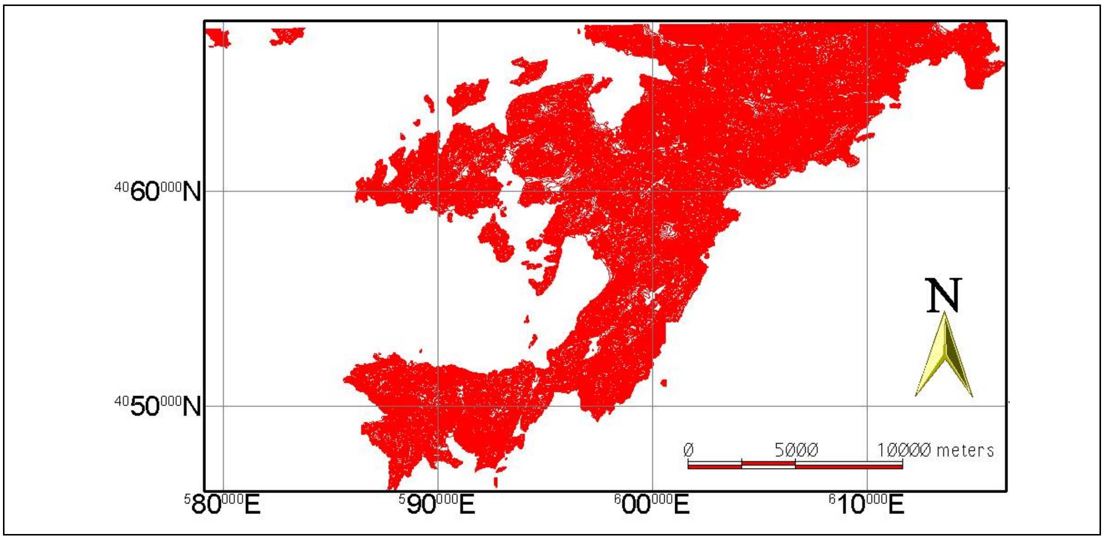


Figure 3.2: Merged and corrected 10 m Digital Elevation Contours of Bozburun.

3.1.3 Analogue 1/5000 scaled Topographic Maps

Another main data input is the set of topographic maps at 1/5000 scale taken from HGK as 31 hard copies (Figure 3.3). All of these 31 maps were scanned and converted to RVC file format (TNTmips file format). Each map was

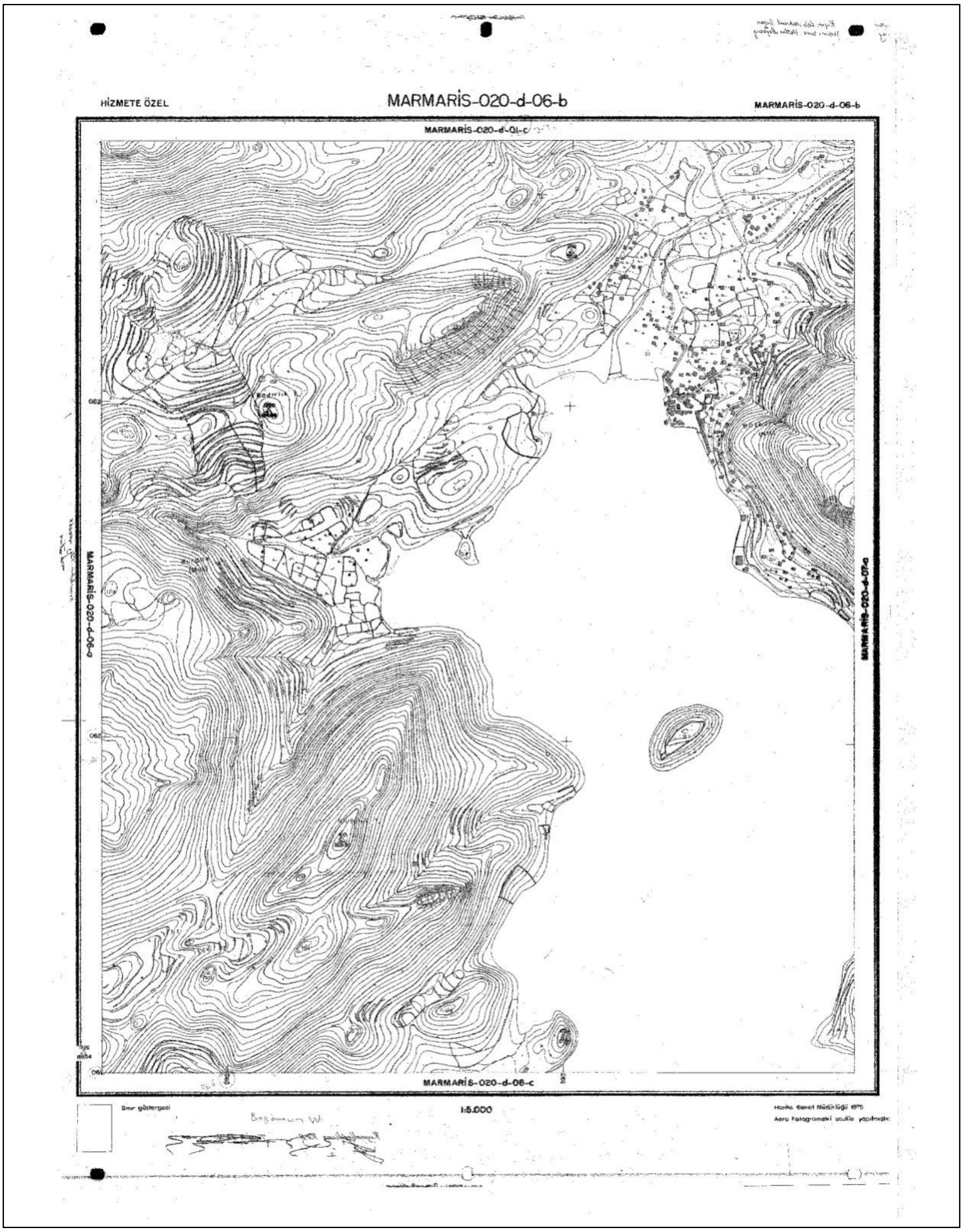


Figure 3.3: Example of analogue topographic map of Bozburun center with 1/5000 scale.

georeferenced and extracted from its frame. The reference system of these maps is "European Datum 1950 (ED50) / 3^o Gauss-Kruger CM27 (Zone 9)". Each map was resampled and re-projected into the reference system "ED50 / 6^o UTM zone 35N (CM 27E)". All processes were done by the software TNTmips 2011 pro. Finally after mosaic (merge) process one single map was created. This data was used for three main purposes:

1. Complete and refine elevation data: Digital 10 m elevation data were corrected and refined by the help of this dataset.
2. Drawing Quaternary alluvium boundary accurately by using sudden change in slope as an indicator.
3. Determine catchment areas and draw their boundaries for selected regions. Selected catchment areas will represent the study area for this thesis. More detailed information about this areas will be given in Chapter 4.

3.1.4 Satellite Images

Three satellite images have been used during this study: two Digital Globe images and one GeoEye image. Dates of the Digital Globe images are 20.01.2006 and 18.05.2011 (Figure 3.4). Date of the GeoEye image is 14.05.2010. Images were acquired by the software Google Earth v6.1. Images were used for discrimination of terraced areas, the clastic and limestone units. For example, white units in Figure 3.4 were defined as limestone. Therefore, geologic boundaries were drawn over these satellite images. Using three different dates provided an alternative way of increasing the accuracy of resultant geologic maps. All borders were verified at all different dated images for better results. Mapping was carried only on specified regions where the study has been intensified.

Figure 3.4: Part of Digital Globe Image acquired at 18.05.2011. 1.5 Km West of Bozburun.

3.1.5 Field Data

A fieldtrip was organized to Bozburun on September 2010. This fieldtrip clarified three main aspects of the study in relation to the purpose and scope of the thesis:

1. Identification of rock units: The field studies helped to identify the rock units that will be used in this study. According to field observations, in spite of complicated geology, rock units were classified into three main units covering all the selected regions. Three main units are 1) Quaternary alluvium, 2) clastic Unit, and 3) limestone.
2. Determination of boundary relationship: The nature of the boundaries between the rock units in the area were revised considering previous studies. For example; limestone of Karanasıflar formation is described to conformably overlie Güverdağı formation by Şenel and Bilgin (1997b). The field studies, however, indicated that this boundary is tectonic.
3. Determination of Morphologic Classes: The importance of assigning a morphologic class to the selected areas was noticed during the field studies. Three classes suggested in this study are: 1) Coastal, 2) Valley Floor, and 3) Karstic.

Besides the geologic problems given above, areas were also classified as "terraced areas" and "non-terraced areas" for later evaluation purposes (Figure 3.5). Systematic photographs were taken to contribute mapping of terraces by the help of GPS device, where the coordinates and direction of the photograph is noted.

Figure 3.5: Agricultural terraces located west of Bozburun settlement.

3.2 Methodology

This section describes the methodology of how the raw data was transformed to graphics, maps and charts indicating relationship between terraces and topographic properties and lithologic units. The methodology is divided into three main stages: 1) Data Input, 2) Processing, and 3) Output (Figure 3.6).

3.2.1 Data Input

At this stage all data needed was defined and provided from related institutions. In addition to data provided from institutions a field trip was organized to Bozburun for gathering field data needed. Before processing the data, each was pre-processed and classified:

1) Scanned 1/25000 scaled topographic maps: Data went through georeferencing, extracting and mosaicing processes.
2) Digital 10 m elevation contours: Data was merged and one single file was obtained.
3) Analogue 1/5000 scaled topographic maps: Data went through georeferencing, extracting, resampling and mosaicing processes.
4) Satellite images: Best image for the area defined. Units are mapped.
5) Field data: Units are re-classified and study regions are selected.

3.2.2 Process

Second part of methodology consists of correction, definition, merging, drawing, conversion and calculation over the input data. The main purpose of this stage was to define regions at Bozburun; and extract valid fine elevation and slope data for each region. In each region elevation and slope data for geologic units and terraced areas was also needed to seek relationship between elevation, slope, lithology and terraces.

Corrections were done on digital 10 m elevation contours. Some missing parts were completed manually by scanned 1/25000 scaled topographic maps and analogue 1/5000 scaled topographic maps. Completed contours were converted to point data (PTP, Poly-To-Point) at each node of the contours. Only this process was done on MapInfo 10.5 Vertical Mapper. Interpolation was done with the triangulation method (TIN, Triangular Irregular Network). A Digital Elevation Model (DEM) with 1m pixel size was created from the TIN for whole Bozburun region (Figure3.7a). Slope map of Bozburun was generated which is a derivative of the DEM (Figure3.7b).

Characteristic regions were defined during the fieldtrip to Bozburun. Later eliminations have been done and ten of total regions were decided for detailed studies. The drainage divide was assumed to be the border of the region which is drawn manually from the analogue 1/5000 scaled topographic maps for ten selected regions. Geologically defined three main units and terraced areas were mapped based on the field data and satellite images.

For each region elevation data and slope data were extracted and units were defined. Histogram data for elevation and slope were exported as text files for each region and for each unit in the region. Data was transferred to Microsoft Office Excel Software for massive percentage calculations. Percentage of terraces was also calculated and tables were created for graphic creations.

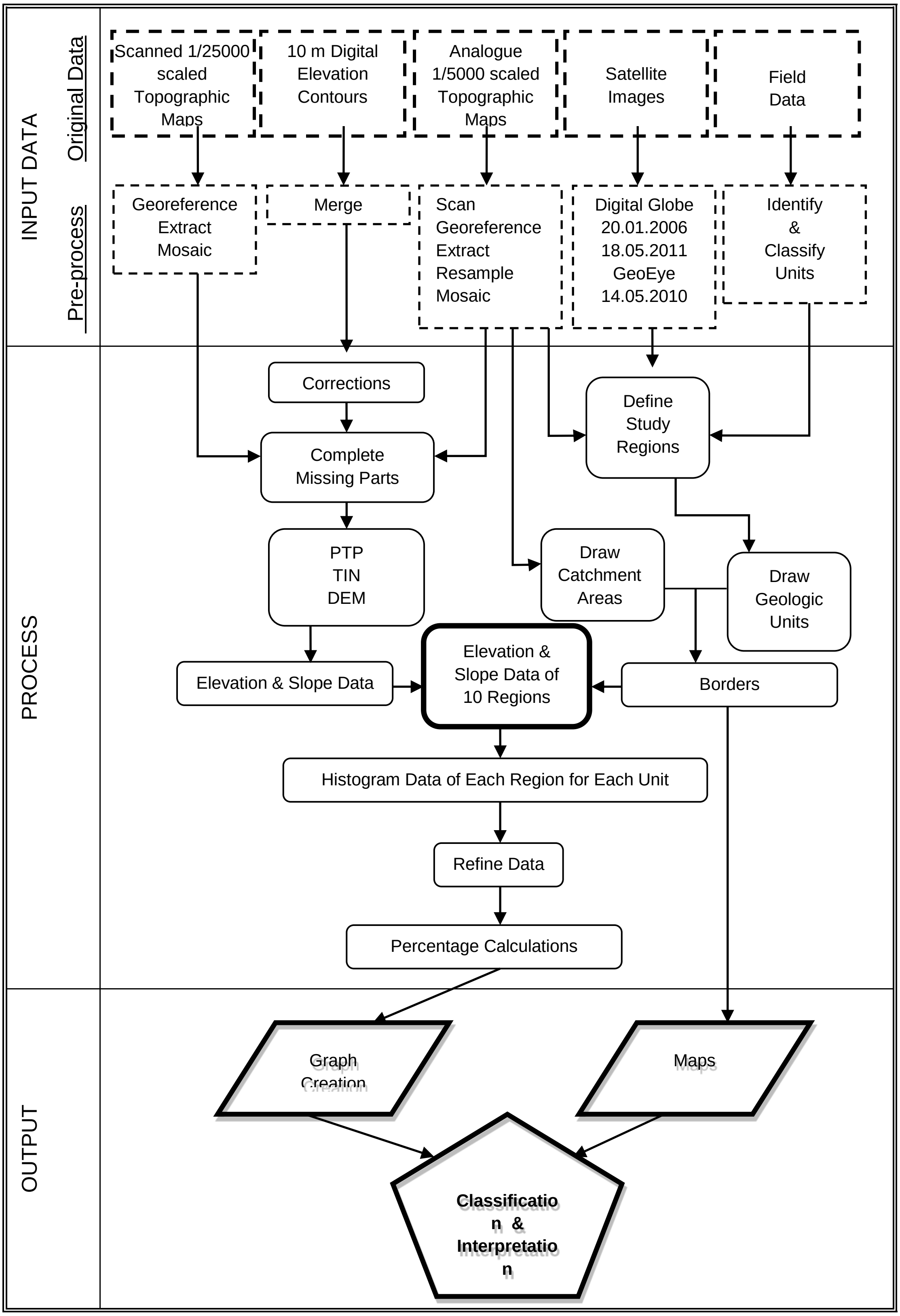


Figure 3.6: Flowchart of Methodology.

3.2.3 Output

In the last stage of methodology, histogram graphics were created from the tables calculated. Maps of the specified regions were created. For all regions elevation, lithological and terrace maps, elevation slope statistics and graphs, terrace slope and elevation graphics and the interpretation graphics were given (Chapter 4).

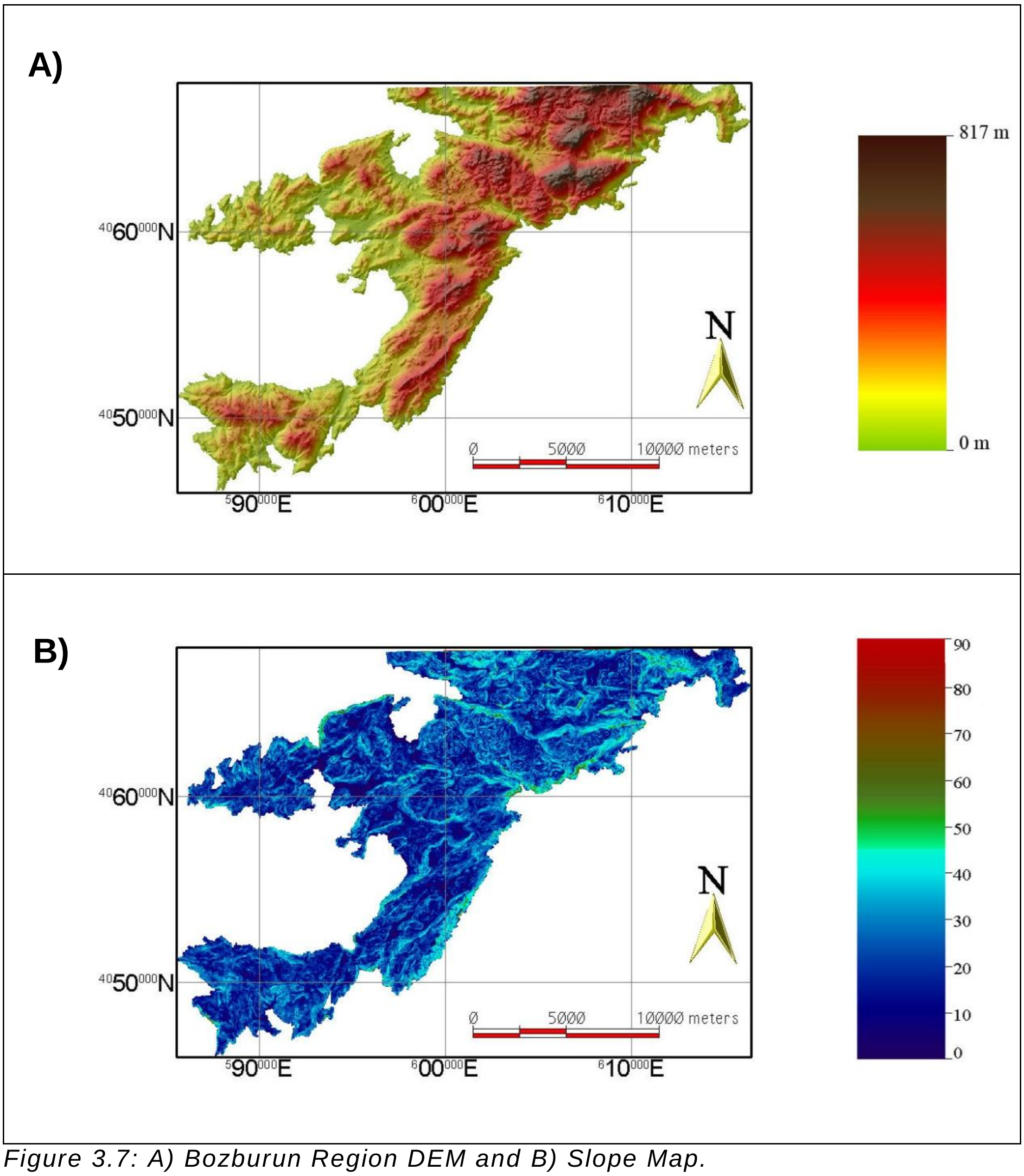


Figure 3.7: A) Bozburun Region DEM and B) Slope Map.

One of the most commonly used graphic during the evaluation of the results is the "difference histogram". This histogram is used to compare the values of specific parameter (elevation and slope) in relation to the values of whole area. A hypothetical example of this type of histogram is given illustrated in Figure 3.8. The line in the histogram is obtained by subtracting the percentage values of a parameter (e.g. slope) from the percentage values of the full area. The result might be positive or negative.

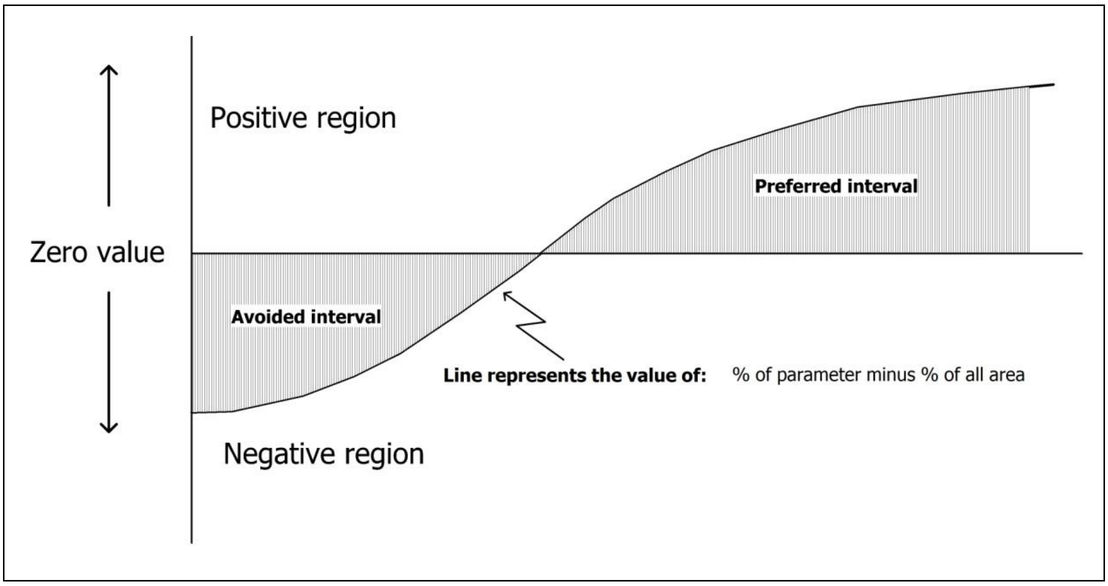


Figure 3.8:.Hypothetical difference histogram example.

If the value is positive it means the percentage of the parameter is greater than the percentage of the area, which indicates that this value is preferred due to its suitability. It is vice versa if the value is negative.

Table 3.1: An example of slope value.

Sample Slope	Parameter	Area	Difference
5^o	10%	5%	5%
		10%	0%
		15%	-5%

Finally, all the outputs will be integrated to quantify the relationship of agricultural terraces and lithological and morphological properties (Chapter 5).

CHAPTER 4

ANALYSIS

This chapter gives the results of the analysis explained in the previous chapter for specified ten regions of Bozburun area. Only areas with agricultural terraces have been selected according to their different lithological and morphological settings. Areas having same settings were omitted to prevent repetitions.

For each area, a Digital Elevation Model, a lithological map, a terrace map has been given in one figure, elevation and slope statistics are given in a table and additionally an evaluation of suitability of terraces in relation to slope and elevation is shown in difference histograms.

The name assigned to each region is informal and were given according to the nearest modern settlement name or geographic locality. The regions are described in a geographical order following clockwise from northwest to south (Figure 4.1). Details of each area will be given in the following sections.

The regions are:

1) Örteren-1

2) Örteren-2

3) Üçören

4) Yeşilova

5) Kızılköy

6) Kızılyer

7) Bahçeli

8) Taşlıca-1

9) Taşlıca-2

10) Taşlıca-3

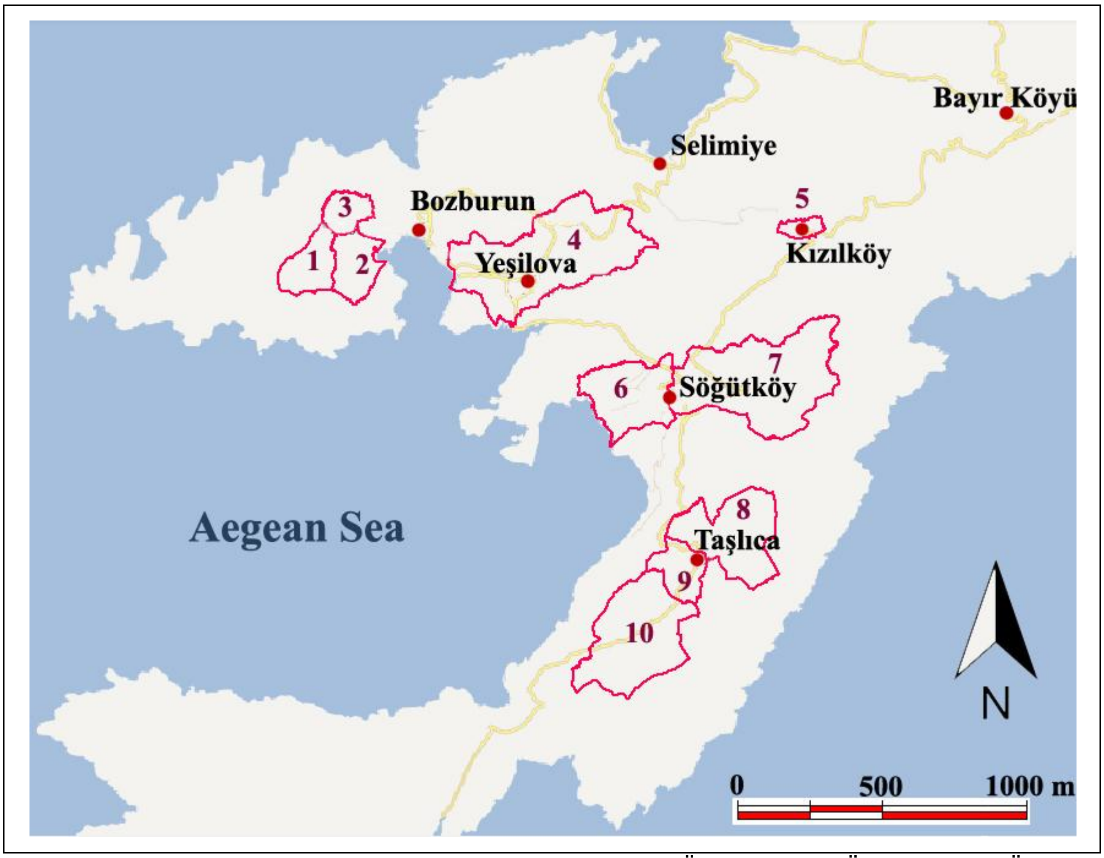


Figure 4.1: Location map of specified Regions. 1) Örteren-1, 2) Örteren-2, 3) Üçören, 4) Yeşilova, 5) Kızılköy, 6) Kızılyer, 7) Bahçeli, 8) Taşlıca-1, 9) Taşlıca-2, 10) Taşlıca-3.

4.1 Örteren-1 Region Analysis

The region is located 2.2 km south-west of Bozburun settlement, west of Örteren-2 and south of Üçören region. Örteren-1 region was named according to the local region's name Örteren. Örteren region was divided into two parts according to their different geo-morphological features. Örteren-2 region will be discussed in the next section. Örteren-1 region is one of the most characteristic regions having terraces in Bozburun. The elliptical shape, non-terraced resistant limestone unit at higher elevations, soft and easy to excavate clastic unit at moderate height, steep terraces in clastic unit and alluvial unit at the lowest elevation with wide agricultural terraces are the characteristic features of Örteren-1 (Figure 4.2).

Figure 4.2: 3-D Google Earth view of Örteren-1 region with 2x elevation exaggeration.

Access is available through Üçören Region by a dirt road. Elevation of this region ranges from 76.53 to 302.72 m (Figure 4.3a) where the highest elevation is indicated by white and the lowest elevation by blue color. Sudden change in color indicates high slope values. High slope values can be seen at the outer margin of the region whereas areas with gentle slope are located at inner parts of the region.

Distribution of the rock units in the area is shown in Figure 4.3b. Areas and percentages of the units are given in Table 4.1. Clastic unit is exposed as en ellipsoidal form extending in NE-SW direction and covers 40.95 percentage of the area. Limestone crops out as an ellipse and covers 44.35 percent of the area and is exposed as a ring surrounding the region. Quaternary alluvium is confined to a small area in the west central part of the region and covers 14.70 percentage of the region. Agricultural terraces are almost all located in clastic unit or in alluvial unit (Figure 4.3c). It is noticeable that terraces were not constructed in limestone units.

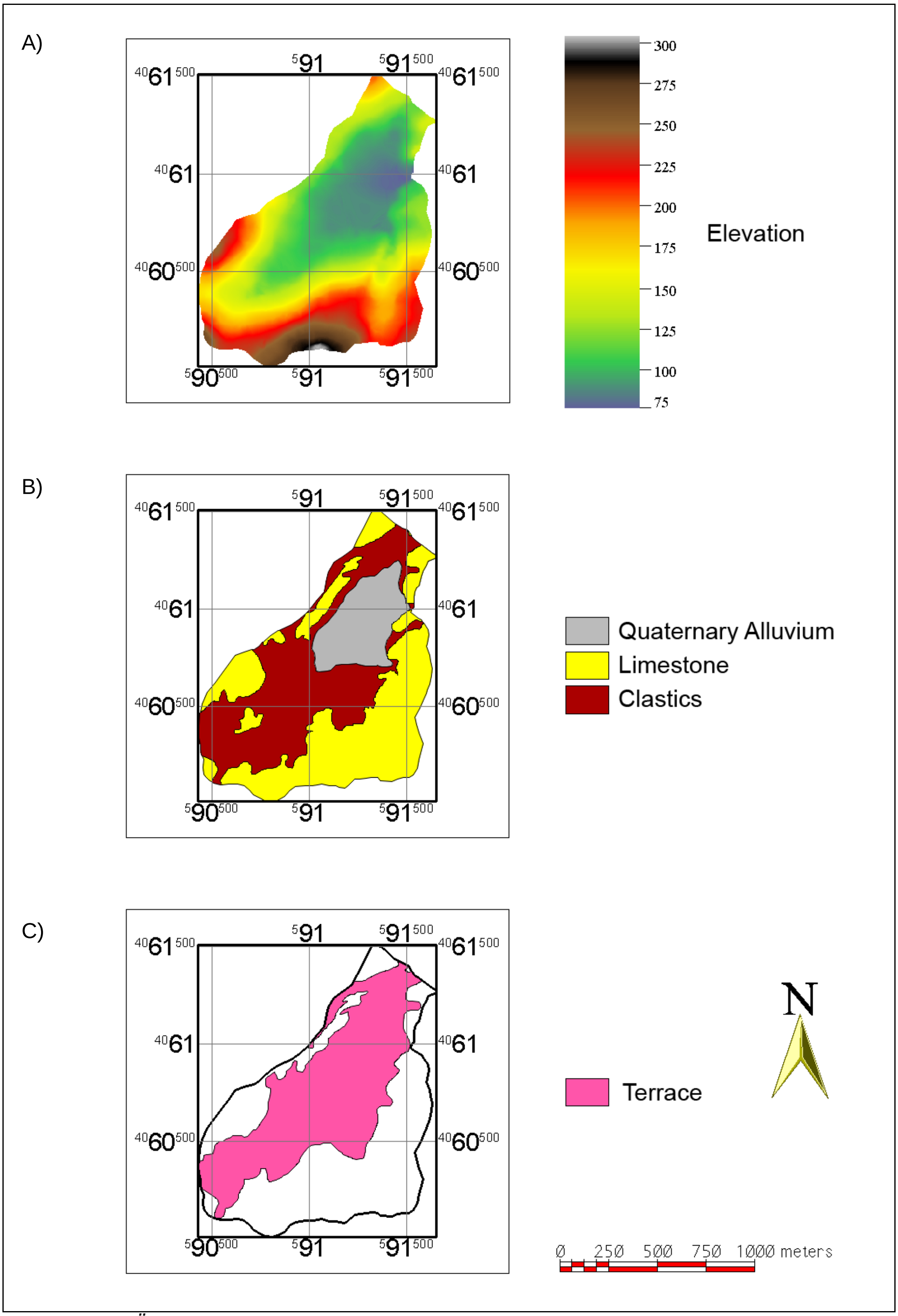


Figure 4.3: Örteren-1 Region Maps. Elevation map (A), Lithological map (B) and Terrace map (C).

Table 4.1: Area percentages of units in Örteren-1 Region.

Lithology	Area (m²)	Percentage (%)
Alluvium	162573	14.70
Clastic	452869	40.95
Limestone	490394	44.35
All	1105836	100.00

The relationship between rock units and topographic attributes are shown in histograms in Figure 4.4 and Table 4.2. Elevation values of 3 rock units show distinct differences. The average elevation values of Quaternary alluvium, Clastic rocks and limestone are 88.69, 136.32 and 186.93 meters, respectively. For all three rock units, minimum elevation and slope values are not indicators whereas maximum values are significant indicators. In this region it can be seen that no Quaternary alluvium unit exceeds the elevation of 99.39 meters. Among three rock units only limestone units can be seen above 250.49 meters elevation. Slope values also have differences. The average slope value of Quaternary alluvium is 5.90 degrees which is the minimum slope among all others. Clastic rocks and limestone have average values of 17.92 and 20.11 degree, respectively. Slope range values are close to each other. Only maximum values can be used as indicators of rock units.

Table 4.2: Elevation and Slope Statistics of Örteren-1 Region.

	Elevation (m)			Slope (^{o})		
	Min	Max	Mean	Min	Max	Mean
All Area	76.53	302.72	151.78	0	74.67	17.12
Alluvium	76.53	99.39	88.69	0	52.06	5.90
Clastic	77.28	250.49	136.32	0	64.71	17.92
Limestone	76.78	302.72	186.93	0	74.67	20.11

The difference histograms for the terraces in relation to slope and elevation are given in Figure 4.4. The elevation difference histogram is generated by subtracting “elevation values of terrace” from “elevation values of all area”. The histogram clearly indicates a positive interval between 70 and 140 degrees and a negative interval with a slope value greater than 140 degrees. Therefore, terraces in this region are preferred to be constructed in low elevation values. The difference histogram for elevation clearly indicates that the elevation value about 85 meters is the most preferred elevation where terraces have been built for this region.

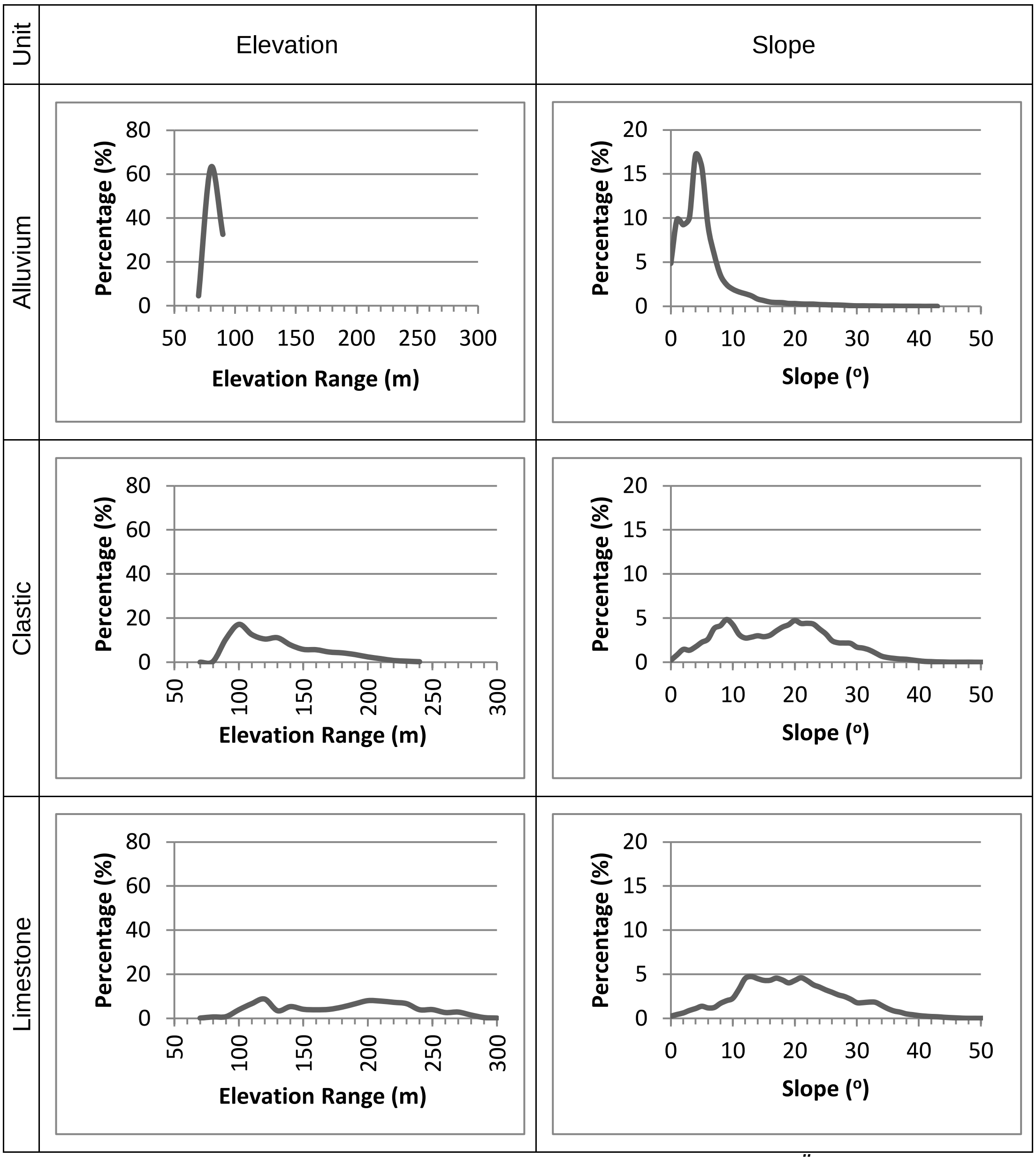


Figure 4.4: Histograms of slope and elevation for rock units in Örteren-1 region.

The slope difference histogram has a similar pattern to that of the elevation histogram. According to the histogram terraces are preferred to be constructed at the range of 0 to 10 degrees. The difference histogram makes a peak between at 7.5 degrees, indicating the favorite slope values chosen for terrace locations.

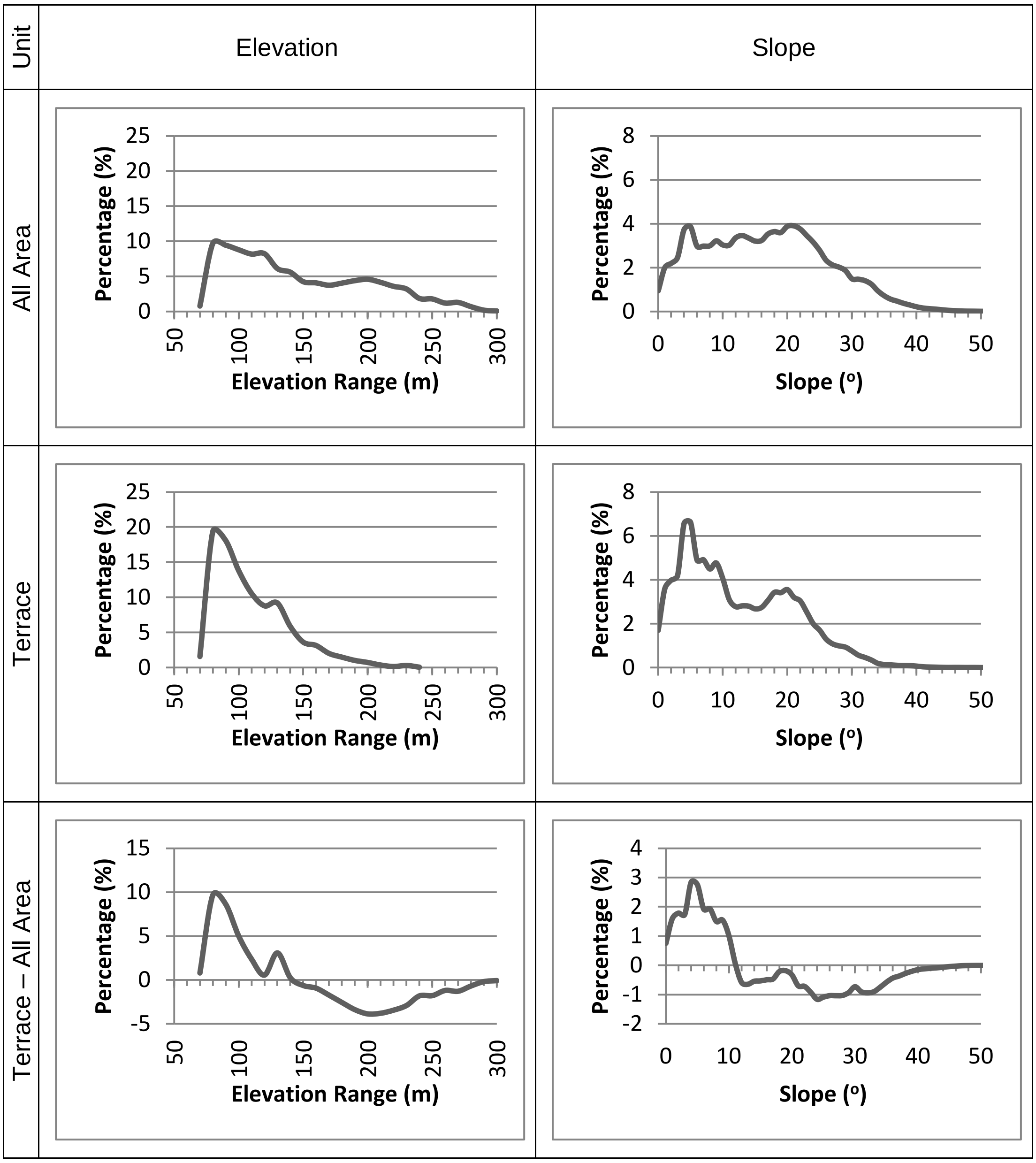


Figure 4.5: Difference histograms of terraces for elevation and slope in Orteren-1 region.

4.2 Örteren-2 Region Analysis

The region is located 1.4 km southwest of Bozburun center, east of Örteren-1 and south of Üçören region. Örteren-2 region is the second part of Örteren which is the continuity of Örteren-1 region connected by a tight neck. Örteren-2 region is one of the characteristic regions having a coastline like Yeşilova and Kızılyer region. A shipyard is constructed at the shoreline part of the region (Figure 4.6).

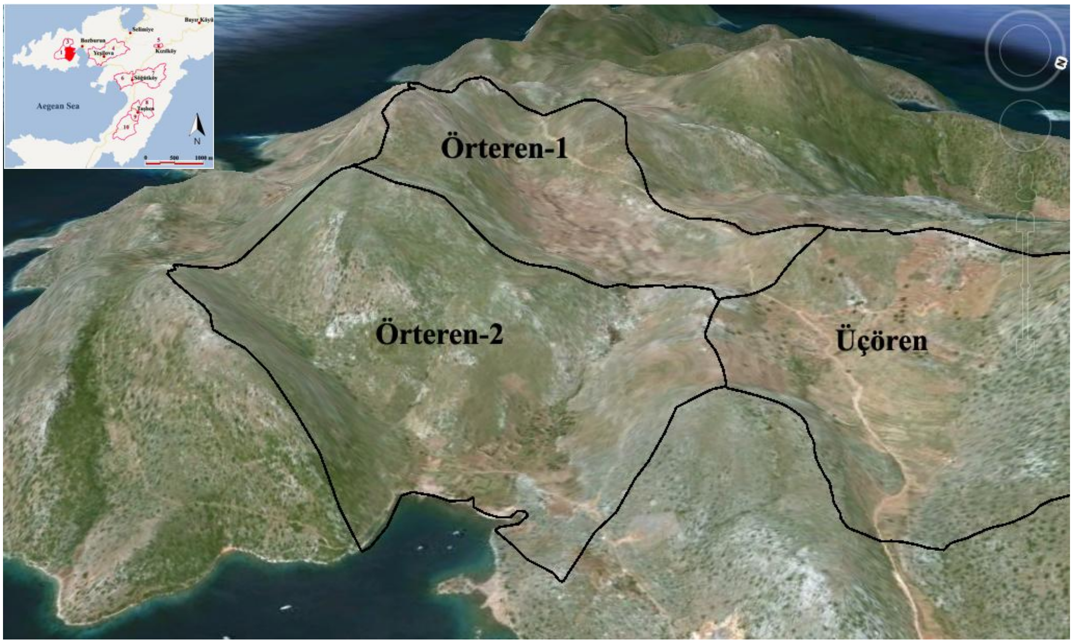


Figure 4.6: 3-D Google Earth view of Örteren-2 region with 2x elevation exaggeration.

Access is available through a coastal road up to the regions coastline. An antique Roman path is leading up to Örteren-1 region through the connecting neck. Elevation of this region ranges from 0 to 241.30 m (Figure 4.7a) where the highest elevation is indicated by white and the lowest elevation by blue color. Sudden change in color indicates high slope values. High slope values can be seen at the outer margin except north-east part of the region whereas areas with gentle slope are located at inner parts and coastal part of the region.

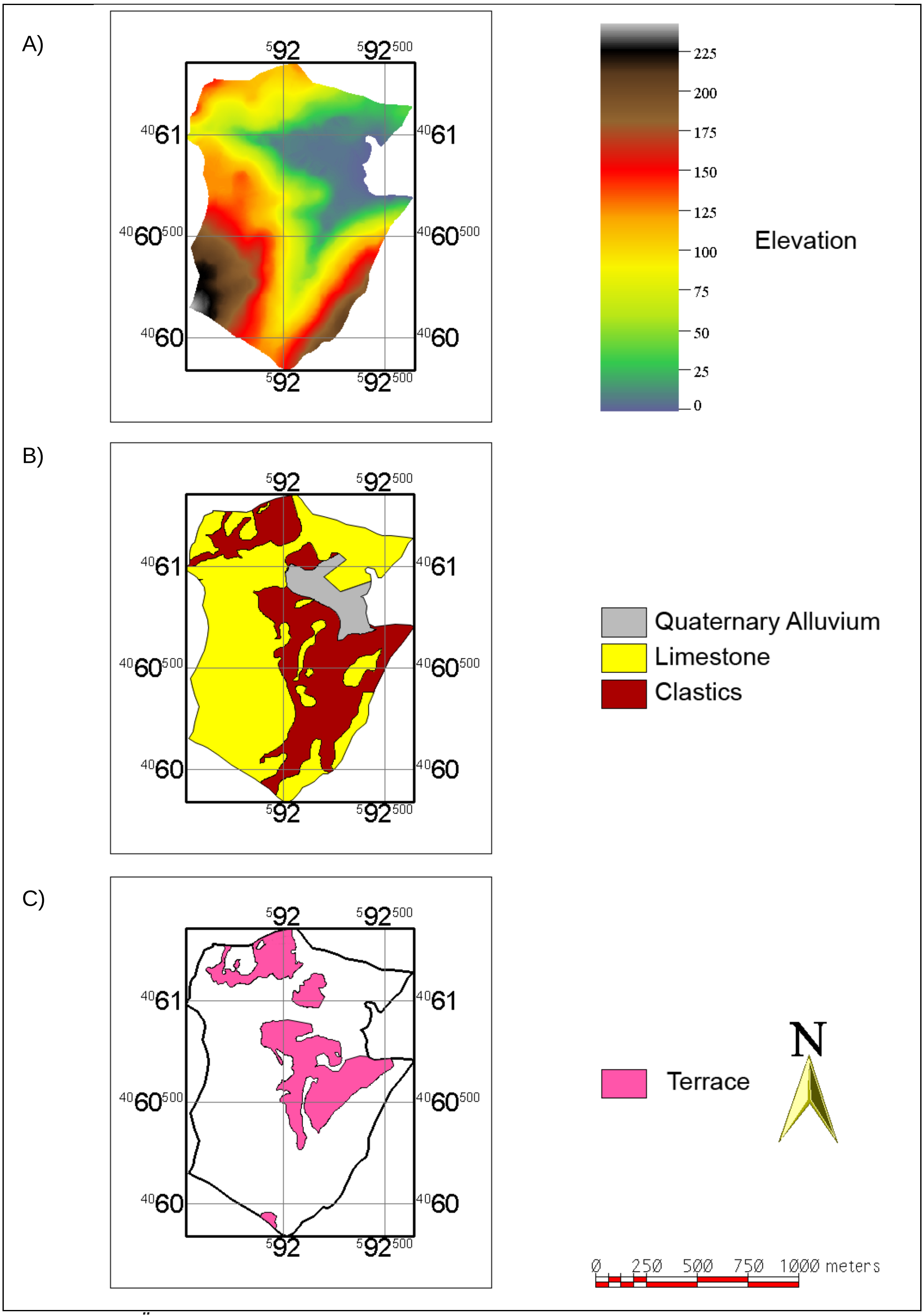


Figure 4.7: Örteren-2 Region Maps. Elevation map (A), Lithological map (B) and Terrace map (C).

Distribution of the rock units in the area is shown in Figure 4.7b. Areas and percentages of the units are given in Table 4.3. Clastic unit is exposed irregularly mostly at mid-range elevation and covers 34.09 percentage of the area. Limestone crops out almost everywhere and covers 59.21 percent of the area. Quaternary alluvium is confined to a small area in the north-east part of the region and covers 6.71 percentage of the region. Agricultural terraces are almost all located in Clastic soft unit or in alluvial unit (Figure 4.7c). It is noticeable that terraces were not constructed in limestone units.

Table 4.3: Area percentages of units in Örteren-2 Region.

Lithology	Area (m²)	Percentage (%)
Alluvium	75696	6.70
Clastic	385195	34.09
Limestone	669156	59.21
All	1130047	100.00

The relationship between rock units and topographic attributes are shown in histograms in Figure 4.8 and Table 4.4. Elevation values of 3 rock units show differences. The average elevation values of Quaternary alluvium, Clastic rocks and limestone are 5.16, 74.88 and 113.72 meters, respectively. For all three rock units, minimum elevation and slope values are 0 m whereas maximum values are significant indicators. In this region it can be seen that no Quaternary alluvium unit exceeds the elevation of 15 meters. Among three rock units only limestone units can be seen above 201 meters elevation. Slope values also have differences. The average slope value of Quaternary alluvium is 4.32 degrees which is the minimum slope among all others. Clastic rocks and limestone have average values of 23.29 and 19.47 degrees, respectively.

Table 4.4: Elevation and Slope Statistics of Örteren-2 Region.

	Elevation(m)			Slope(^{0})		
	Min	Max	Mean	Min	Max	Mean
All Area	0	241.30	93,21	0	70,49	19,76
Alluvium	0	14,71	5,16	0	49,90	4,32
Clastic	0	200,52	74,88	0	70,48	23,29
Limestone	0	241,30	113,72	0	66,67	19,47

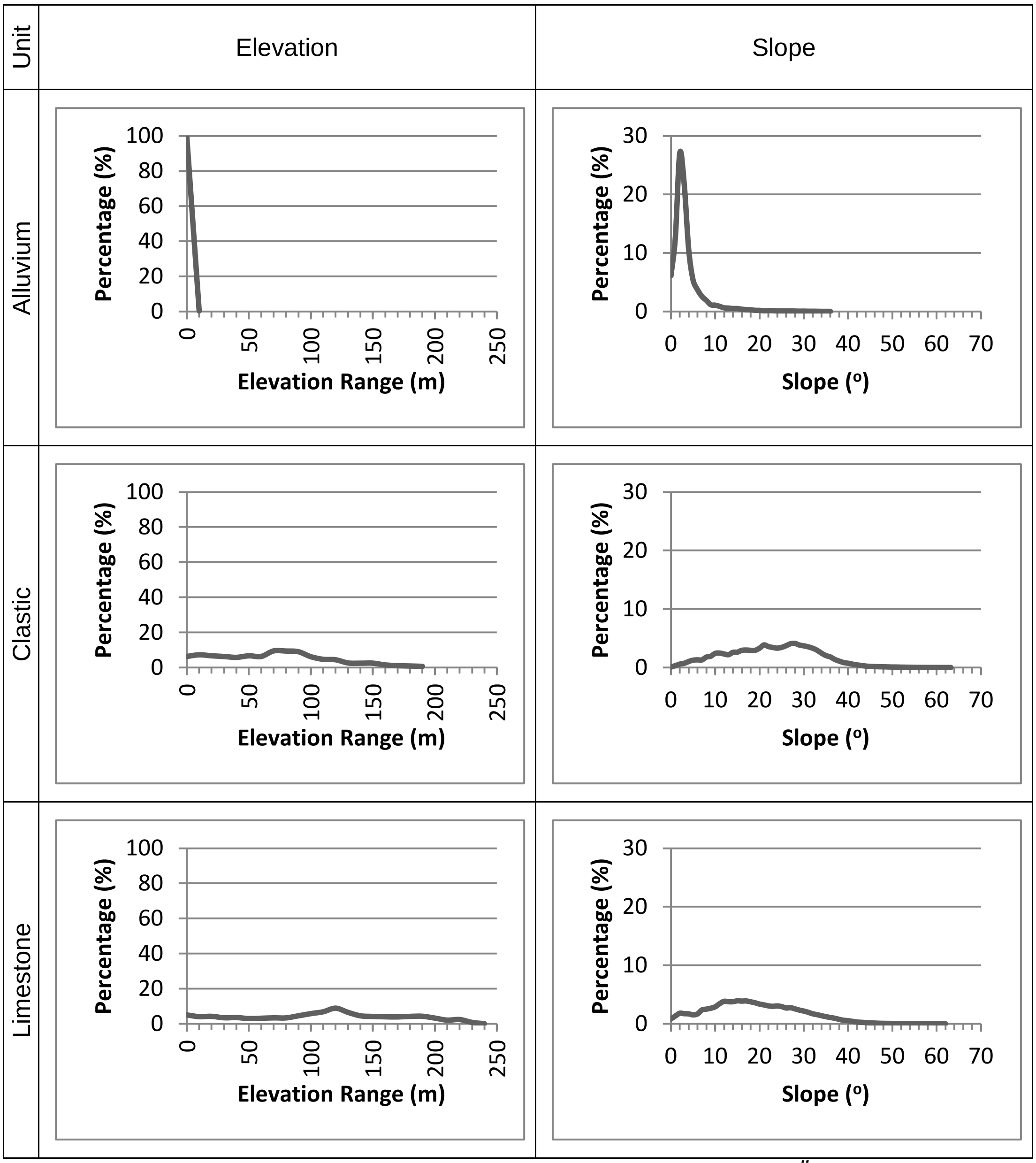


Figure 4.8: Histograms of slope and elevation for rock units in Örteren-2 region

The difference histograms for the terraces in relation to slope and elevation are given in Figure 4.9. The elevation difference histogram is generated by subtracting "elevation values of terrace" from "elevation values of all area". The histogram clearly indicates a positive interval between 0 and 100 meters and a negative interval with an elevation value greater than 100 meters.

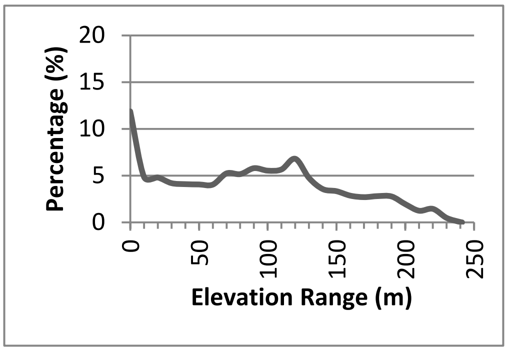
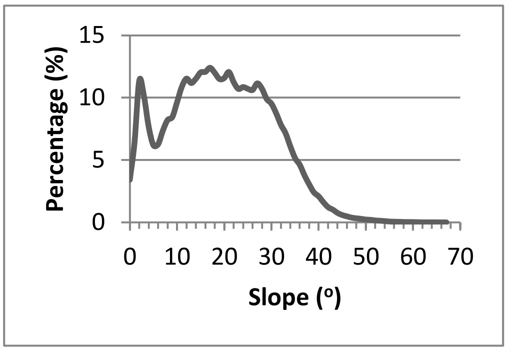
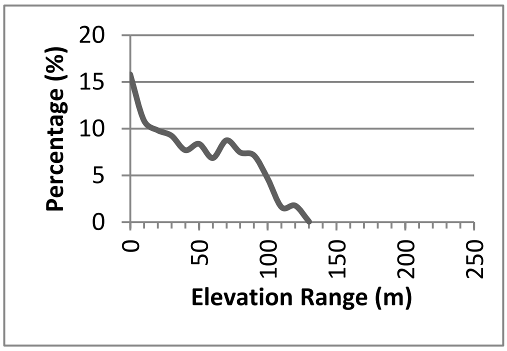
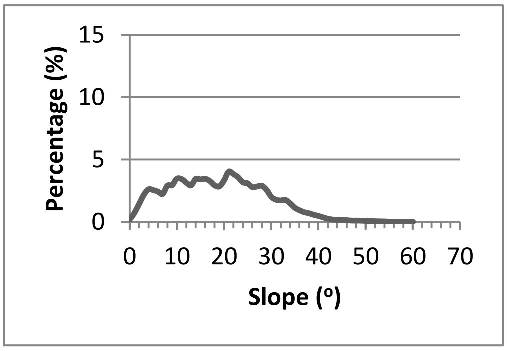
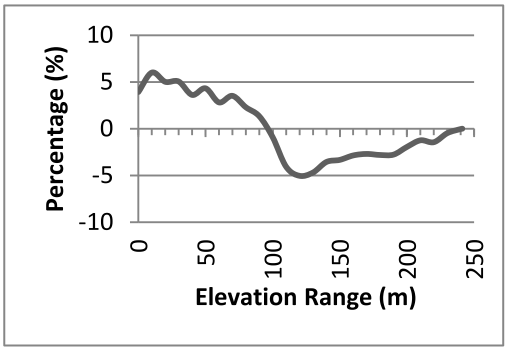
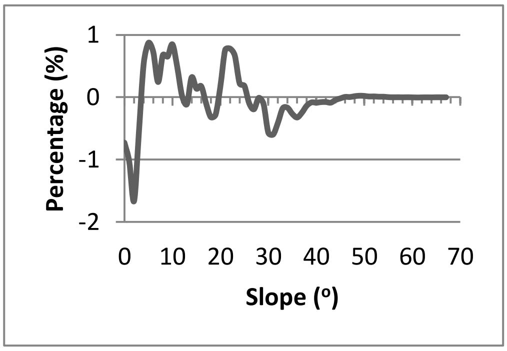
Unit	Elevation	Slope
All Area		
Terrace		
Terrace – All Area		

Figure 4.9: Difference histograms of terraces for elevation and slope in Orteren-2 region.

Therefore, terraces in this region are preferred to be constructed in low elevation values. The difference histogram for elevation clearly indicates that the elevation value about 15 meters is the most preferred elevation where terraces have been built in this region.

The slope difference histogram has a fluctuating pattern to that of the elevation histogram. According to the histogram terraces are preferred to be constructed between 4-12, 13-15 and 20-26 degrees. The difference histogram makes a peak at 5, 10 and 22 degrees, indicating the favorite slope values chosen for terrace locations for Örteren-2 region.

4.3 Üçören Region Analysis

The region is located 1.5 km west of Bozburun center and north of Örteren-2 region. The region's local name is Üçören. The region respectively covers a smaller area of 282,322 m². Üçören region appears to be the northern continuity of Örteren-1 region but is significantly divided by a catchment area borderline (Figure 4.10)

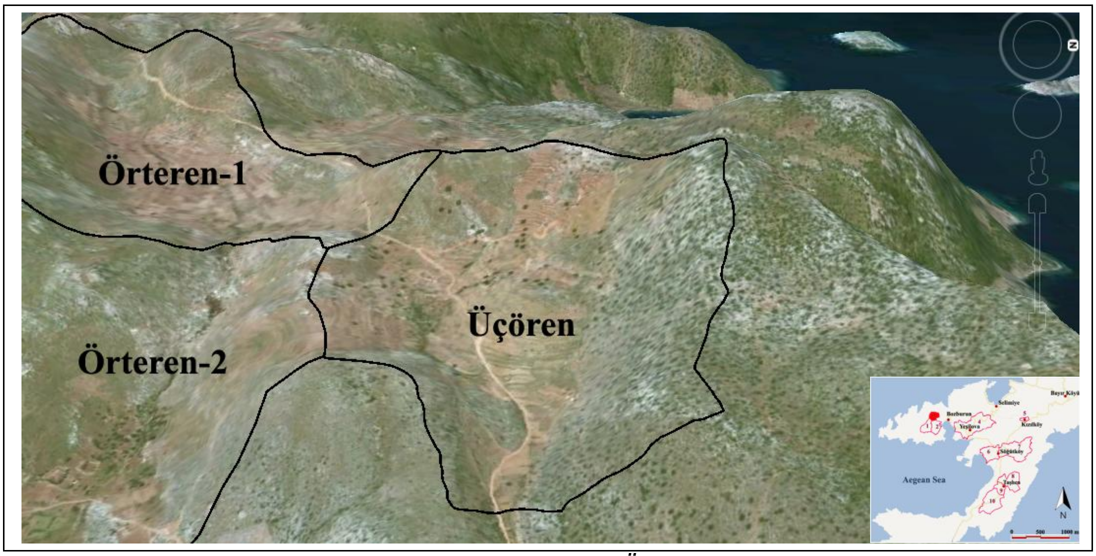


Figure 4.10: 3-D Google Earth view of Üçören region with 2x elevation exaggeration.

Üçören region has similar geo-morphologic features to Örteren-1 region. Non-terraced resistant limestone unit at higher elevations, soft and easy to excavate Clastic unit at moderate height can be seen. Steep agricultural terraces in Clastic units and alluvial unit at lowest elevation with wide agricultural terraces are the characteristics of Üçören region.

Access is available by a dirt road beginning north of Bozburun up to Üçören. Elevation of this region ranges from 57.73 to 285.85 m (Figure 4.11a) where the highest elevation is indicated by white and the lowest elevation by blue color. Sudden change in color indicates high slope values. High slope values can be seen at northwestern parts of the region, whereas areas with gentle slope are located at rest of the region especially at inner and eastern parts of the region.

Distribution of the rock units in the area is shown in Figure 4.11b. Areas and percentages of the units are given in Table 4.5. Clastic unit is mainly exposed elongated in E-W direction and covers 41.09 percentage of the area. Limestone crops out mostly at northern parts and covers 46.52 percent of the area.

Quaternary alluvium is confined to a small area in the west central part of the region and covers 12.39 percentage of the region. Agricultural terraces are almost all located in clastic soft unit or in alluvial unit (Figure 4.11c). It is noticeable that terraces were avoided to be constructed in limestone units.

Table 4.5: Area percentages of units in Üçören Region.

Lithology	Area (m²)	Percentage (%)
Alluvium	85914	12.39
Clastic	284962	41.09
Limestone	322655	46.52
All	693561	100.00

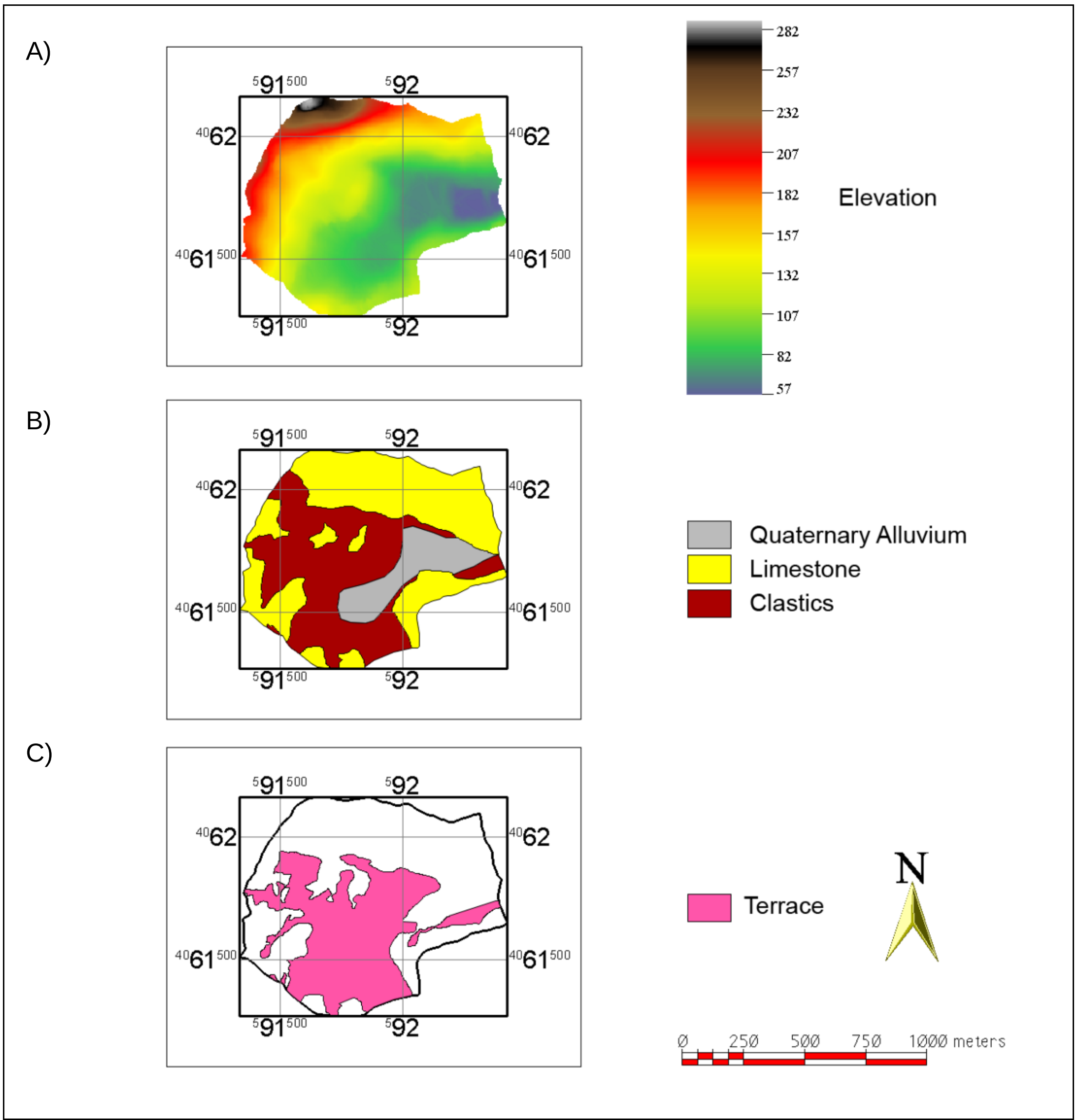


Figure 4.11: Üçören Region Maps. Elevation map (A), Lithological map (B) and Terrace map (C).

The relationship between rock units and topographic attributes are shown in histograms in Figure 4.12 and Table 4.6. Elevation values of 3 rock units show distinct differences.

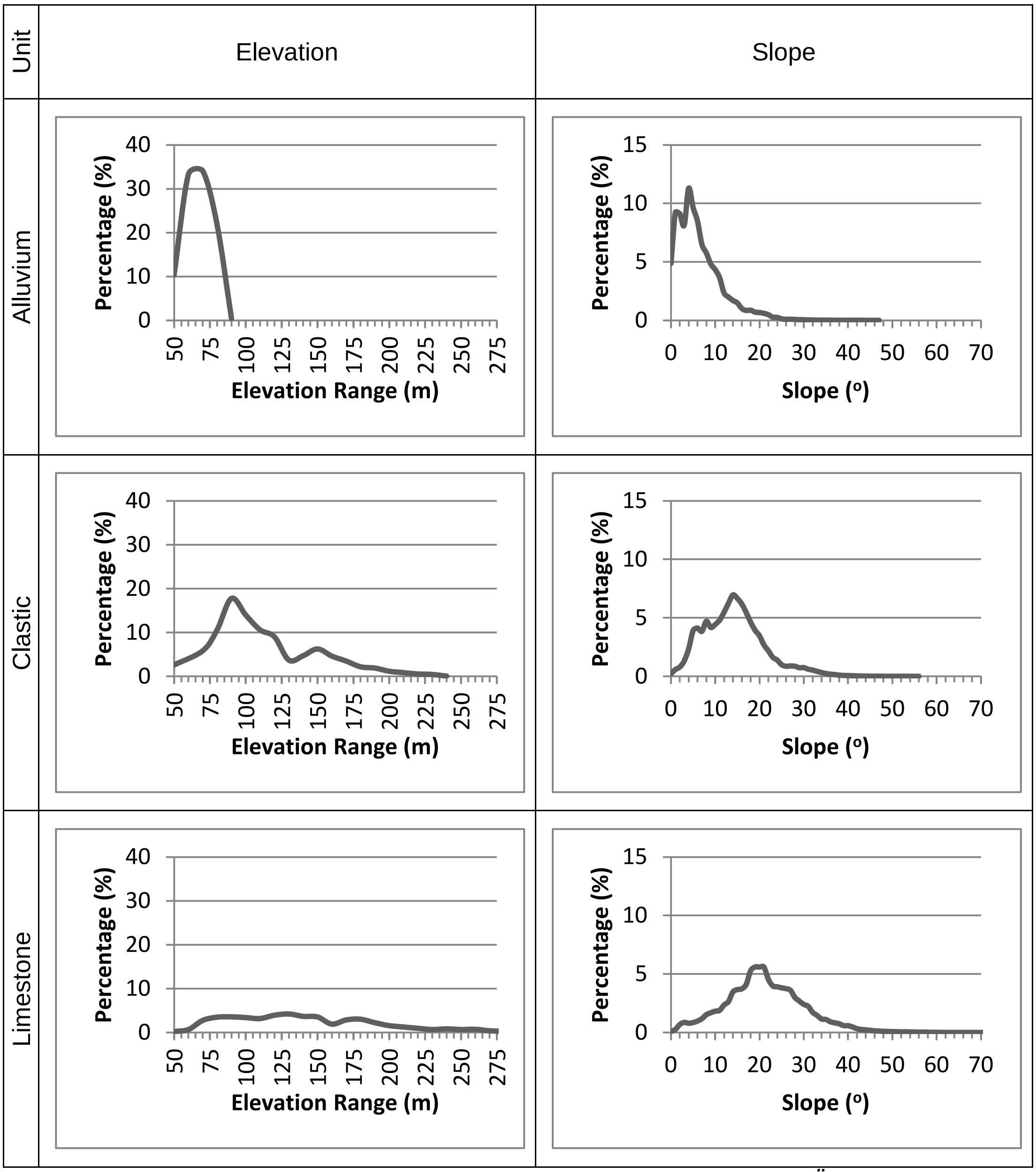


Figure 4.12: Histograms of slope and elevation for rock units in Üçören region

The average elevation values of Quaternary alluvium, clastic rocks and limestone are 73.14, 119.22 and 145.62 meters, respectively. For all three rock units, minimum elevation and slope values are no indicators whereas maximum values are significant indicators. In this region it can be seen that no Quaternary alluvium unit exceeds the elevation of 91.46 meters.

Among three rock units only limestone units can be seen above 244.95 meters elevation. Slope values also have differences. The average slope value of Quaternary alluvium is 7.01 degrees which is the minimum slope among all others. Clastic rocks and limestone have average slope values of 14.83 and 21.77 degrees, respectively. Slope range values are close to each other for clastic rocks and Quaternary alluvium unit. Slope values over 56.46 degrees can only be seen at limestone.

Table 4.6: Elevation and Slope Statistics of Üçören Region.

	Elevation(m)			Slope(^{0})		
	Min	Max	Mean	Min	Max	Mean
All Area	57.73	285.85	125.81	0	72.94	17.08
Alluvium	57.73	91.46	73.14	0	53.11	7.01
Clastic	58.10	244.95	119.22	0	56.46	14.83
Limestone	57.96	285.85	145.62	0	72.94	21.77

The difference histograms for the terraces in relation to slope and elevation are given in Figure 4.13. The elevation difference histogram is generated by subtracting “elevation values of terrace” from “elevation values of all area”. The histogram clearly indicates a positive interval between 60 and 120 meters and a negative interval with a elevation value greater than 120 meters. Therefore, terraces in this region are preferred to be constructed in low elevation values. The difference histogram for elevation clearly indicates that the elevation value about 90 meters is the most preferred elevation where terraces have been built in this region.

The slope difference histogram has a similar pattern to that of the elevation histogram. According to the histogram terraces are preferred to be constructed at the range of 0 to 17 degrees. The difference histogram makes a peak between at 5 degrees, indicating the favorite slope values chosen for terrace locations in this region.

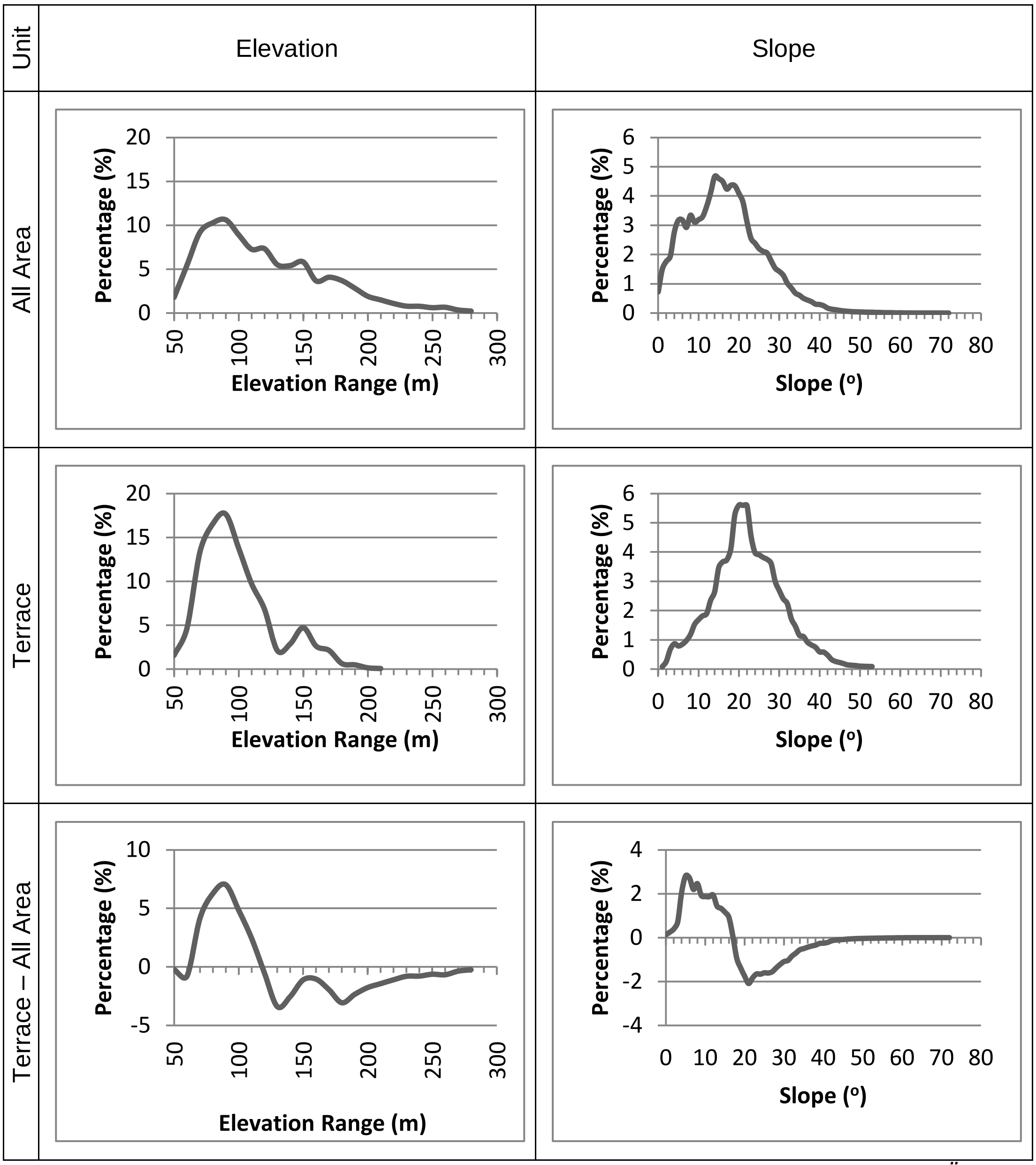


Figure 4.13: Difference histograms of terraces for elevation and slope in Üçören region.

4.4 Yeşilova Region Analysis

The regions' center is located 2.8 km east of Bozburun center, northeast of the hill Adatepe. The region has two coastal borderlines divided by the hill Adatepe at south. Yeşilova region was named according to the district which is located in the center of the region.

Yeşilova region is one of the most characteristic regions having terraces in Bozburun. Yeşilova has an elliptical shape elongating northeast to southwest (Figure 4.14). Among all other specified regions Yeşilova with 5686361 m² area has the largest area of all. The same model of the other regions can be seen in Yeşilova too. There are non-terraced resistant limestone unit at higher elevations, soft and easy to excavate clastic unit at moderate height, steep terraces in clastic unit and alluvial unit at lowest elevation with wide agricultural terraces. The district at the center was highly distorted by modern settlement. It was observed that settlements were established on Quaternary alluvium unit and have terraces distributed.

Figure 4.14: 3-D Google Earth view of Yeşilova region with 2x elevation exaggeration.

Access is available through Avlana (a district in Bozburun) from west or a direct coastal road connecting Yeşilova and Bozburun from southwest. Elevation of this region ranges from 0 to 451.80 m (Figure 4.15a) where the highest elevation is indicated by white and the lowest elevation by blue color. Sudden change in color indicates high slope values. High slope values can be seen at the outer margins of eastern part of the region whereas areas with gentle slope are located at inner parts and coastal parts at western parts of the region.

Distribution of the rock units in the area is shown in Figure 4.15b. Areas and percentages of the units are given in Table 4.7. Clastic unit is scattered randomly and covers 46.29 percentage of the area. Limestone also crops out randomly at higher parts and covers 28.92 percent of the area. Quaternary alluvium is confined to an area in the center up to the coastal borderlines in the west and covers 29.84 percentage of the region. Agricultural terraces are almost all located in clastic soft unit or in alluvial unit (Figure 4.15c). It is noticeable that terraces were not constructed in limestone units.

Table 4.7: Area percentages of units in Yeşilova Region.

Lithology	Area (m²)	Percentage (%)
Alluvium	1409316	24.71
Clastic	2631969	46.29
Limestone	1645076	28.92
All	5686361	100.00

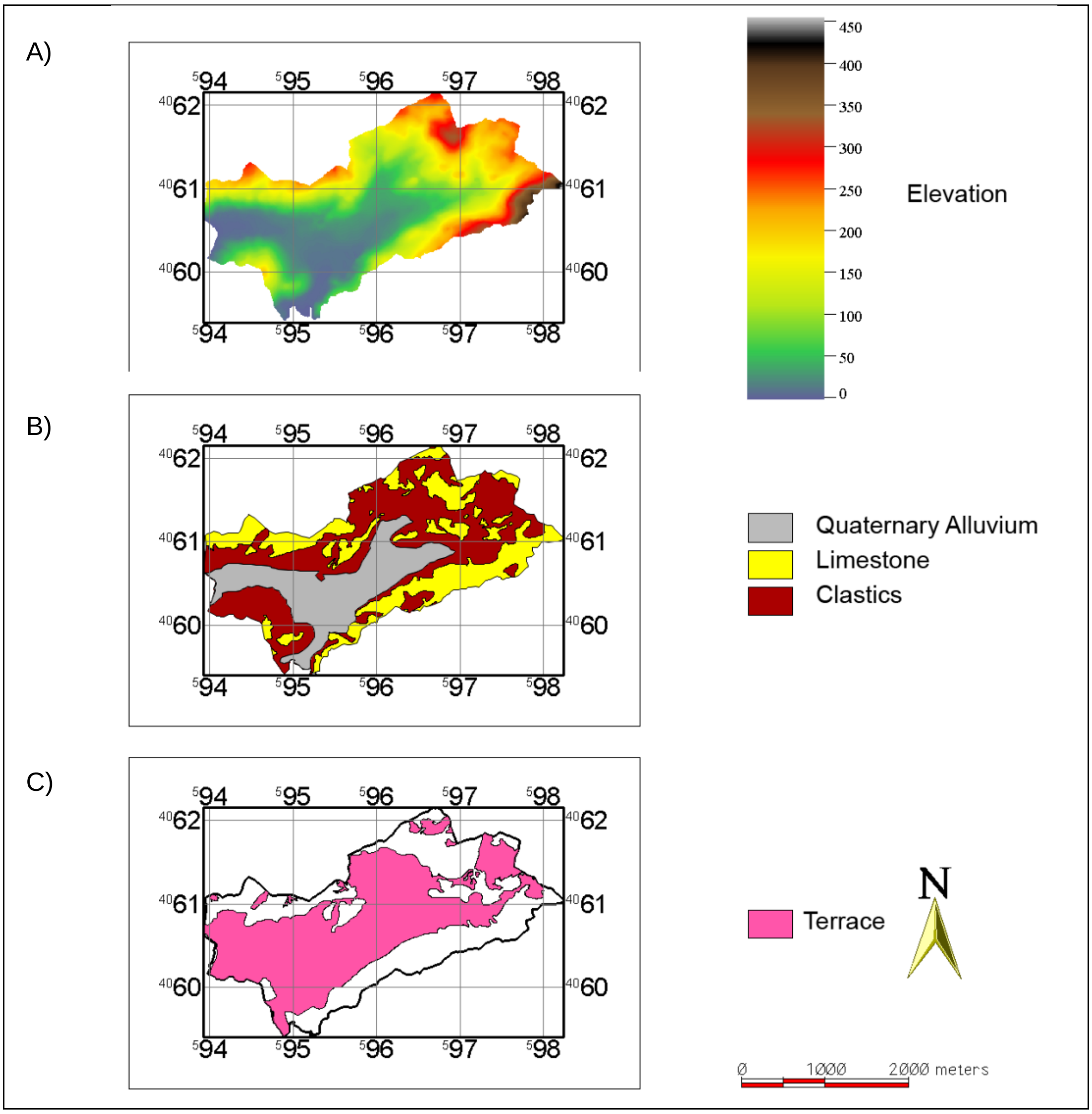


Figure 4.15: Yeşilova Region Maps. Elevation map (A), Lithological map (B) and Terrace map (C).

The relationship between rock units and topographic attributes are shown in histograms in Figure 4.16 and Table 4.8

Table 4.8: Elevation and Slope Statistics of Yeşilova Region.

	Elevation(m)			Slope(^{0})		
	Min	Max	Mean	Min	Max	Mean
All Area	0	451.80	114.97	0	78.38	18.35
Alluvium	0	85.37	20.85	0	56.91	5.40
Clastic	0	359.66	117.74	0	76.33	20.29
Limestone	0	451.80	191.20	0	78.38	26.37

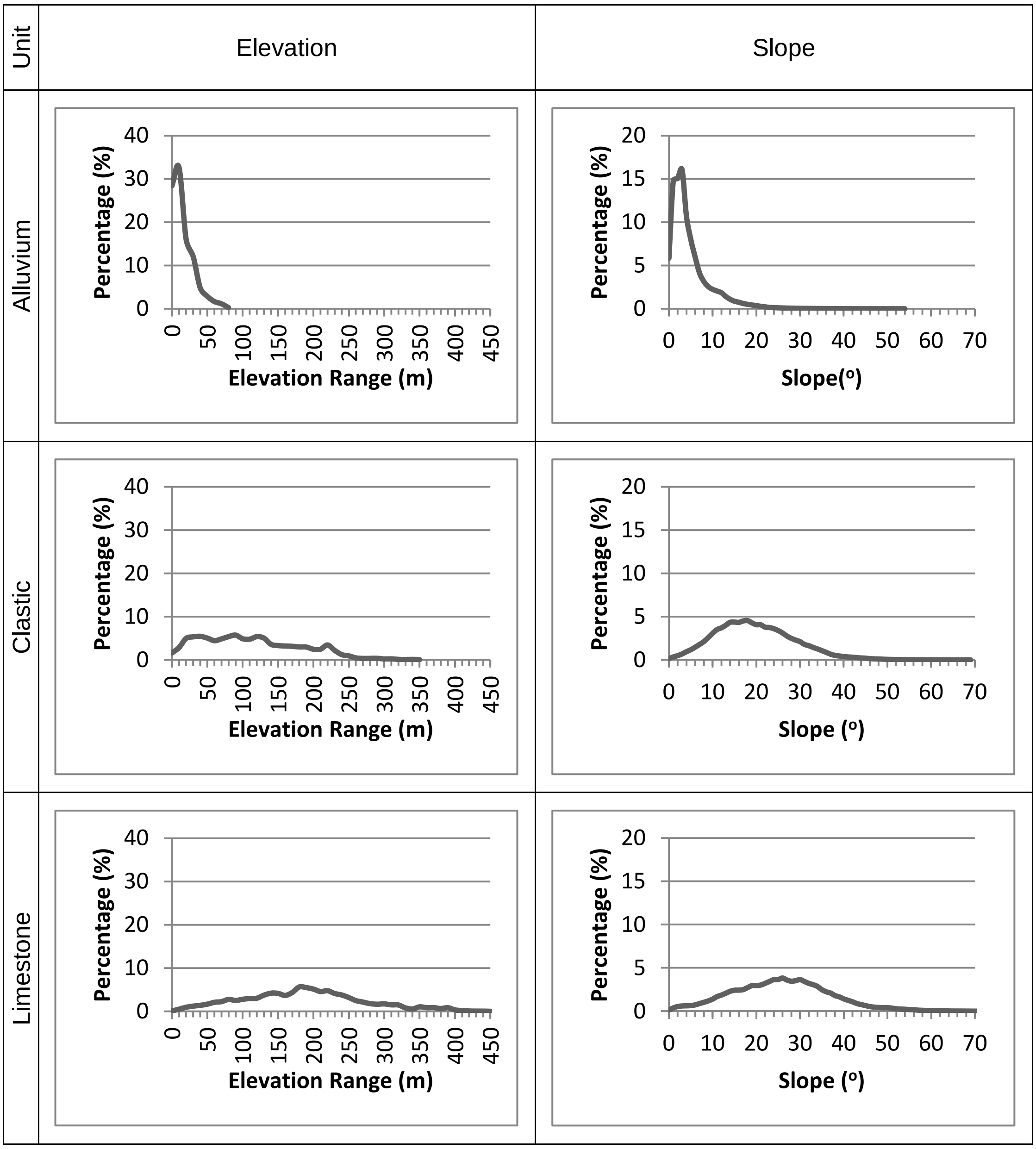


Figure 4.16: Histograms of slope and elevation for rock units in Yeşilova region

Elevation values of 3 rock units show distinct differences. The average elevation values of Quaternary alluvium, clastic rocks and limestone are 20.85, 117.74 and 191.20 meters, respectively. For all three rock units, minimum elevation and slope values are no indicators whereas maximum values are significant indicators. In this region it can be seen that no Quaternary alluvium unit exceeds the elevation of 85.37 meters. Among three rock units only limestone units can be seen above 451.80 meters elevation. Slope values also have differences. The average slope value of Quaternary alluvium is 5.40 degrees which is the minimum slope among all others. Clastic rocks and limestone have average values of 20.29 and 26.37 degrees, respectively. Slope range values are close to each and is low only for Quaternary alluvium.

The difference histograms for the terraces in relation to slope and elevation are given in Figure 4.17. The elevation difference histogram is generated by subtracting “elevation values of terrace” from “elevation values of all area”. The histogram clearly indicates a positive interval between 0 and 120 meters and a negative interval with a elevation value greater than 120 meters. Therefore, terraces in this region are preferred to be constructed in low elevation values. The difference histogram for elevation clearly indicates that the elevation value about 15 meters is the most preferred elevation where terraces have been built in this region.

The slope difference histogram has a similar pattern to that of the elevation histogram. According to the histogram terraces are preferred to be constructed at the range of 0 to 20 degrees. The difference histogram makes a peak between at 4 degrees, indicating the favorite slope values chosen for terrace locations in this region.

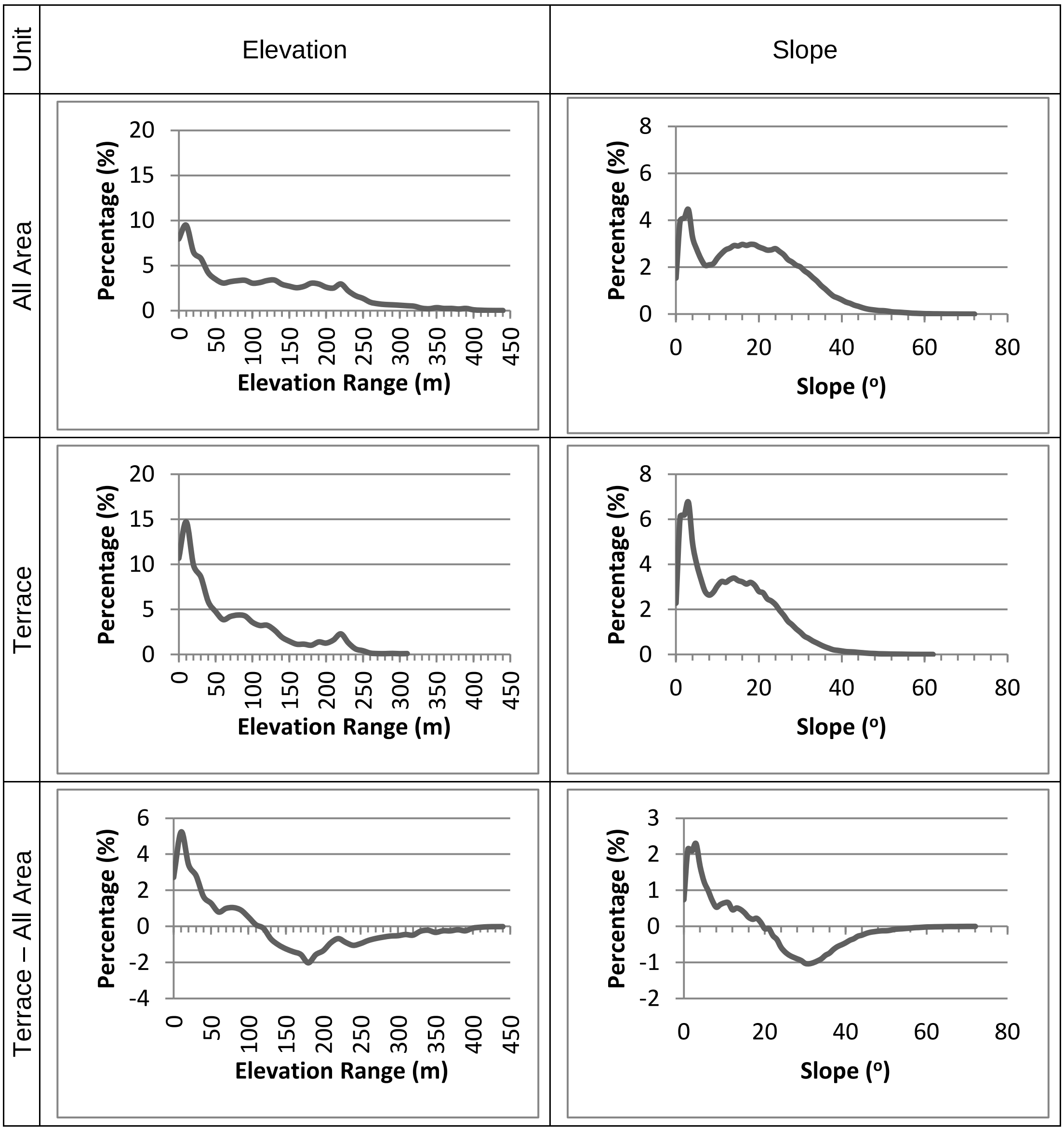


Figure 4.17: Difference histograms of terraces for elevation and slope in Yeşilova region.

4.5 Kızılköy Region Analysis

The region is located 7.8 km east of Bozburun center. Kızılköy region was named according to the village Kızılköy located 0.7 km northwest of region. Kızılköy region is one of the typical small regions of Bozburun having the same geo-morphological features (4.18). The region represents many small regions of Bozburun.

Characteristic features can be seen across Kızılköy like the other regions having terraces in Bozburun. The elliptical shape, non-terraced resistant limestone unit at higher elevations, soft and easy to excavate clastic unit at moderate height, steep terraces in clastic unit and alluvial unit at lowest elevation with wide agricultural terraces are the characteristic features of Kızılköy (Figure 4.18).

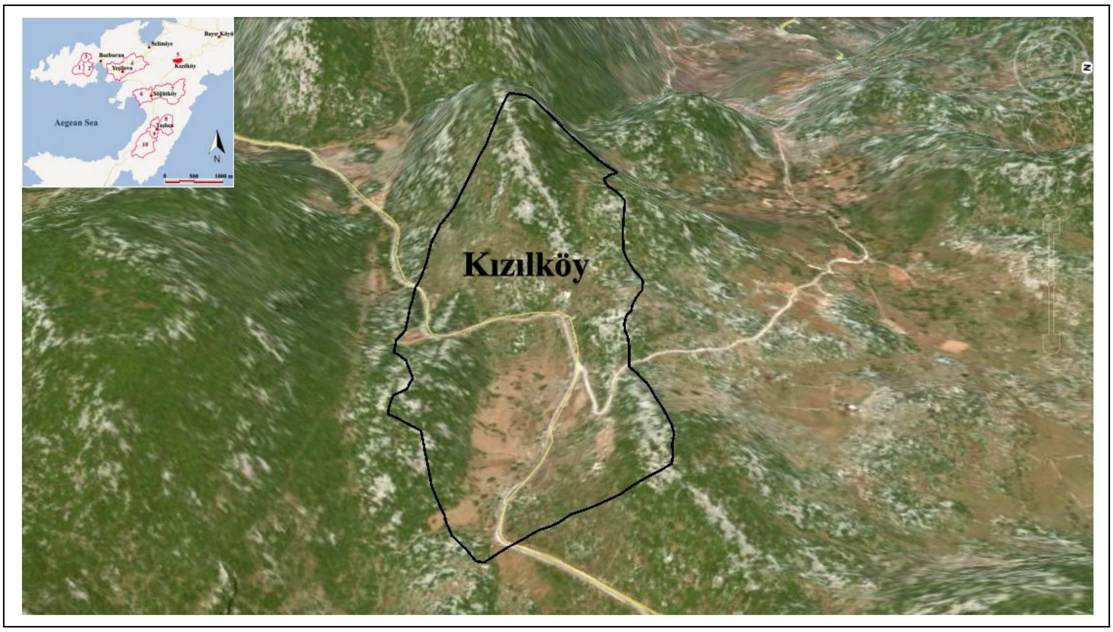


Figure 4.18: 3-D Google Earth view of Kızılköy region with 2x elevation exaggeration.

Access is available through Selimiye (a town north of Bozburun) by a moderate asphalt road. Elevation of this region ranges from 237.31 to 400.76 meters (Figure 4.19a) where the highest elevation is indicated by white and the lowest elevation by blue color. Elevation has a main attribute of decreasing from west to east in this region. Sudden change in color indicates high slope values. High slope values can be seen at the western parts .

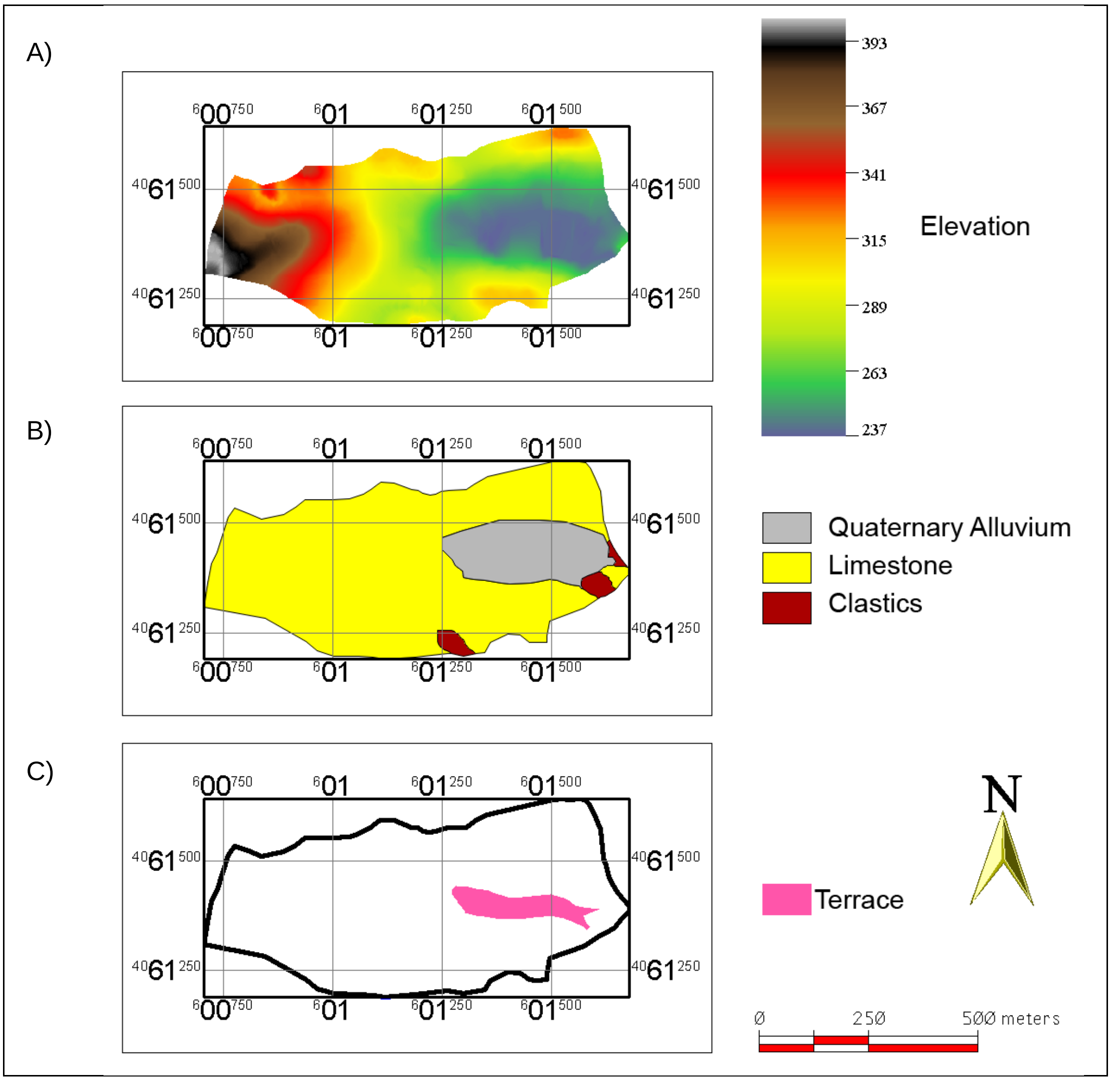


Figure 4.19: Kızılköy Region Maps. Elevation map (A), Lithological map (B) and Terrace map (C).

Distribution of the rock units in the area is shown in Figure 4.19b. Areas and percentages of the units are given in Table 4.9. Clastic unit is almost nonexistent and covers only 2.37 percentage of the area. Limestone acovers almost the full area except the small area at east and covers 82.74 percent of the area and is exposed as a ring surrounding the region. Quaternary alluvium is confined to a small area in the east central part of the region and covers 14.89 percentage of the region. Agricultural terraces are all located in alluvial unit (Figure 4.19c). It is noticeable that terraces were not constructed in limestone units.

Table 4.9: Area percentages of units in Kızılköy Region.

Lithology	Area (m²)	Percentage (%)
Alluvium	45589	14.89
Clastic	7254	2.37
Limestone	253529	82.74
All	15303	100.00

The relationship between rock units and topographic attributes are shown in histograms in Figure 4.20 and Table 4.10. Elevation values of 3 rock units show low differences. The average elevation values of Quaternary alluvium, Clastic rocks and limestone are 243.46, 257.64 and 303 meters, respectively. For all three rock units, minimum elevation and slope values are no indicators whereas maximum values are can be used as indicators. In this region it can be seen that no Quaternary alluvium unit exceeds the elevation of 256.15 meters. Among three rock units only limestone units can be seen above 287.66 meters elevation. Slope values also have differences and in this region they are better indicators than elevation values. The average slope value of Quaternary alluvium is 9.23 degrees which is the minimum slope among all others. Clastic rocks and limestone have average values of 12.10 and 22.37 degrees, respectively. Slope range values are different from each other.

Table 4.10: Elevation and Slope Statistics of Kızılköy Region.

	Elevation (m)			Slope (^{o})		
	Min	Max	Mean	Min	Max	Mean
All Area	237.31	400.76	293.06	0	71.42	20.17
Alluvium	237.31	256.15	243.46	0	59.33	9.23
Clastic	238.63	287.66	257.64	0	48.61	12.10
Limestone	237.60	400.76	303.00	0	71.42	22.37

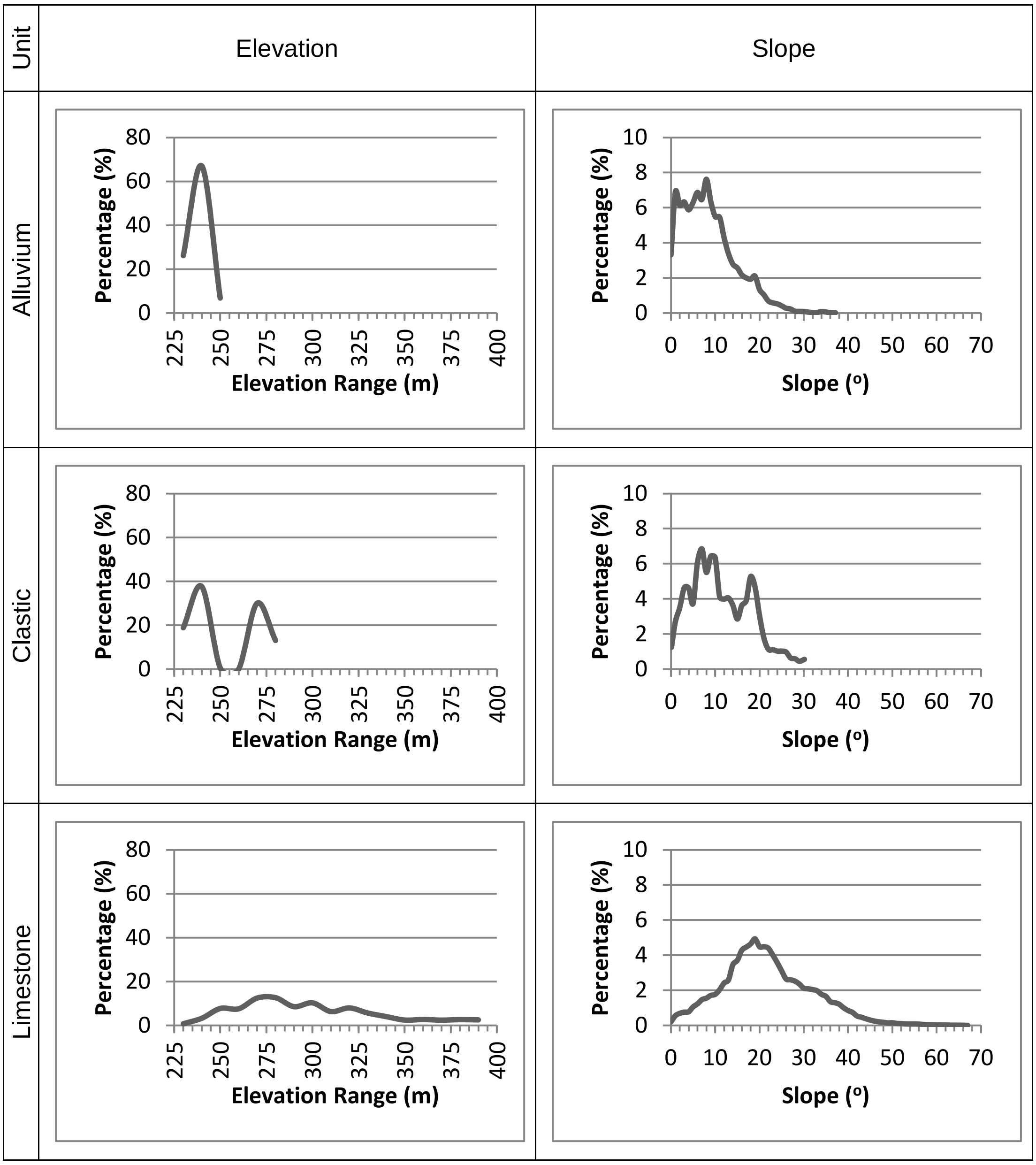


Figure 4.20: Histograms of slope and elevation for rock units in Kızılköy region

The difference histograms for the terraces in relation to slope and elevation are given in Figure 4.21. The elevation difference histogram is generated by subtracting “elevation values of terrace” from “elevation values of all area”. The histogram clearly indicates a positive interval between 230 and 250 meters and a negative interval greater than 250 meters. Therefore, terraces in this region are preferred to be constructed in low elevation values.

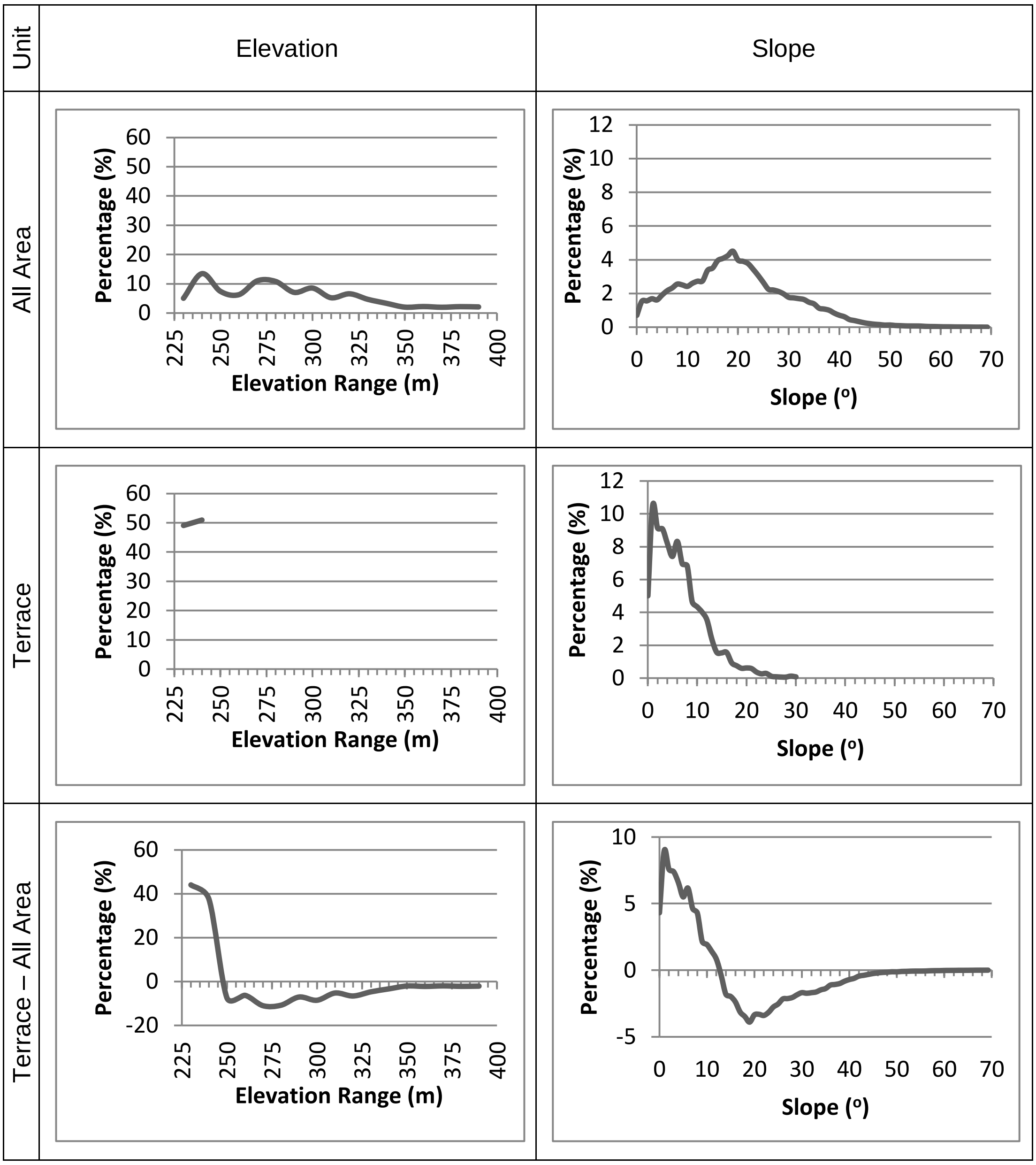


Figure 4.21: Difference histograms of terraces for elevation and slope in Kızılköy region.

The difference histogram for elevation clearly indicates that the lowest elevation values the most preferred elevation where terraces have been built in this region.

The slope difference histogram has a similar pattern to that of the elevation histogram. According to the histogram terraces are preferred to be constructed at the range of 0 to 12 degrees. The difference histogram makes a peak at 2 degrees, indicating the favorite slope values chosen for terrace locations in this region.

4.6 Kızılyer Region Analysis

The region is located 2.7 km southeast of Bozburun center, west of Bahçeli region. The region is the western part of Söğütköy village and was named according to the western district Kızılyer (Figure 4.22).

Figure 4.22: 3-D Google Earth view of Kızılyer region with 2x elevation exaggeration.

Kızılyer region is one of the characteristic regions having shoreline in Bozburun. There are non-terraced resistant limestone unit at higher elevations, soft and easy to excavate clastic unit at moderate height. Steep terraces in clastic unit and alluvial unit at lowest elevation with wide agricultural terraces were observed during fieldtrip to the region.

Access is available through Yeşilova region by a moderate asphalt road. Elevation of this region ranges from 0 to 206.25 meters (Figure 4.23a) where the highest elevation is indicated by white and the lowest elevation by blue color. Sudden change in color indicates high slope values. High slope values can be seen at the outer margin of the region except the western part where there is a gentle slope.

Distribution of the rock units in the area is shown in Figure 4.23b. Areas and percentages of the units are given in Table 4.11. Clastic unit is exposed to all the region except the western parts and covers 80.07 percentage of the area. Limestone crops out as a belt at the north and partially non-geometric shapes in the middle of the region. Limestone covers 8.77 percent of the area. Quaternary alluvium is confined to a relatively small area in the west central coastal part of the region and covers 11.16 percentage of the region. Agricultural terraces are almost all located in clastic soft unit or in alluvial unit (Figure 4.23c). It is noticeable that terraces were not constructed in limestone units.

Table 4.11: *Area percentages of units in Kızılyer Region.*

Lithology	Area (m²)	Percentage (%)
Alluvium	251994	11.16
Clastic	1807323	80.07
Limestone	197998	8.77
All	2257498	100.00

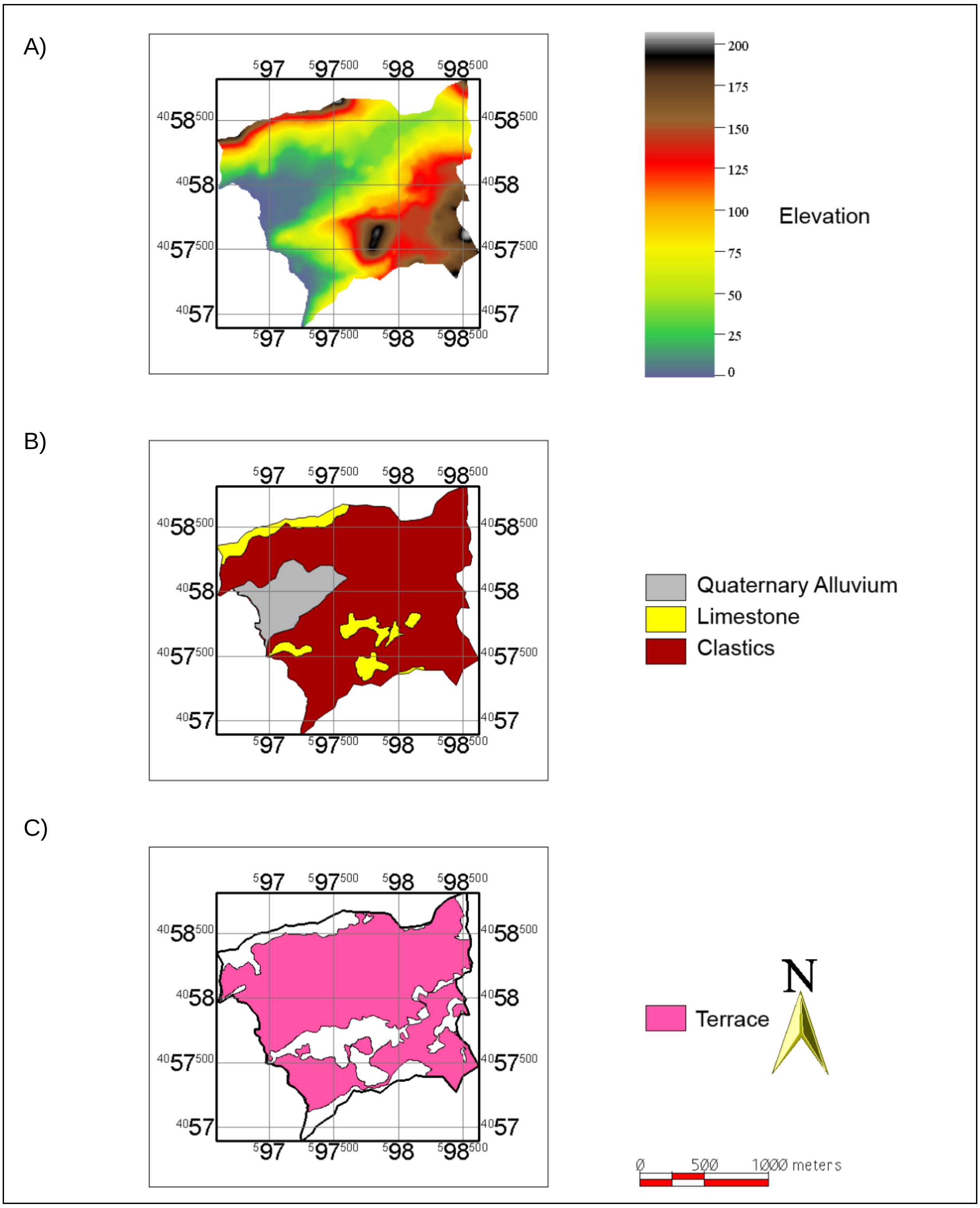


Figure 4.23: Kızılyer Region Maps. Elevation map (A), Lithological map (B) and Terrace map (C).

The relationship between rock units and topographic attributes are shown in histograms in Figure 4.24 and Table 4.12. Elevation values of 3 rock units show distinct differences.

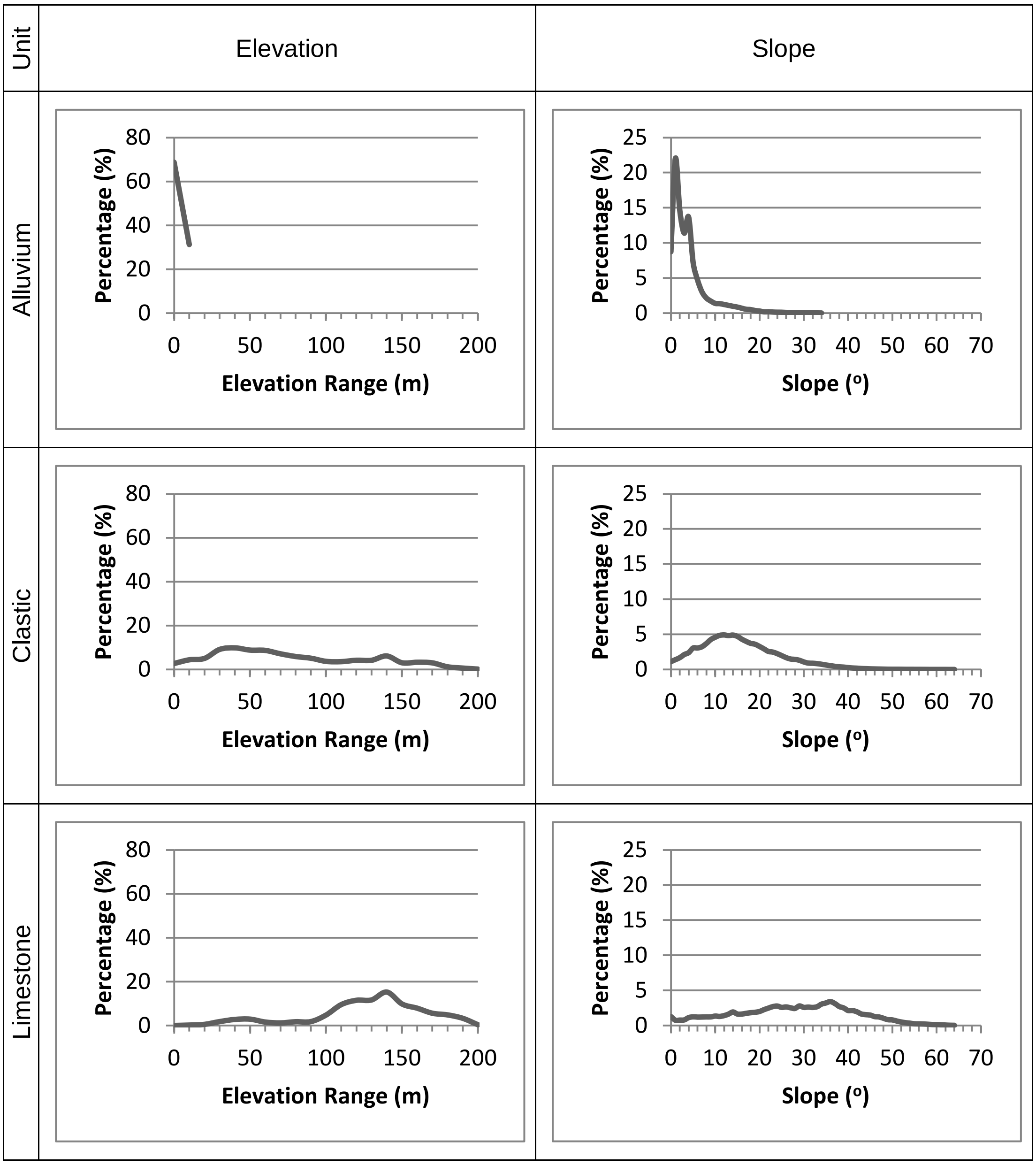


Figure 4.24: Histograms of slope and elevation for rock units in Kızılyer region.

The average elevation values of Quaternary alluvium, Clastic rocks and limestone are 7.54, 82.63 and 131.94 meters, respectively. For all three rock units, minimum elevation and slope values are no indicators whereas maximum values are significant indicators. In this region it can be seen that no Quaternary alluvium unit exceeds the elevation of 20.67 meters. Among three rock units only clastic rock units can be seen above 202.01 meters elevation. Slope values also have differences.

The average slope value of Quaternary alluvium is 4.72 degrees which is the minimum slope among all others. Clastic rocks and limestone have average values of 16.24 and 28.36 degrees, respectively. Slope range values are close to each other.

Table 4.12: Elevation and Slope Statistics of Kızılyer Region.

	Elevation(m)			Slope(^{0})		
	Min	Max	Mean	Min	Max	Mean
All Area	0	206.25	78.58	0	75.69	16.06
Alluvium	0	20.67	7.54	0	52.29	4.72
Clastic	0	206.25	82.63	0	75.69	16.24
Limestone	5.388	202.01	131.94	0	73.36	28.36

The difference histograms for the terraces in relation to slope and elevation are given in Figure 4.25. The elevation difference histogram is generated by subtracting "elevation values of terrace" from "elevation values of all area". The histogram clearly indicates a positive interval between 0 and 80 meters and a negative interval with a elevation value greater than 80 meters. Therefore, terraces in this region are preferred to be constructed in low elevation values.

The difference histogram for elevation clearly indicates that the elevation close to 0 is the most preferred elevation where terraces have been built in this region.

The slope difference histogram has a similar pattern to that of the elevation histogram. According to the histogram terraces are preferred to be constructed at the range of 0 to 20-22 degrees. The difference histogram makes a peak at 1 degrees, indicating the favorite slope values chosen for terrace locations in this region.

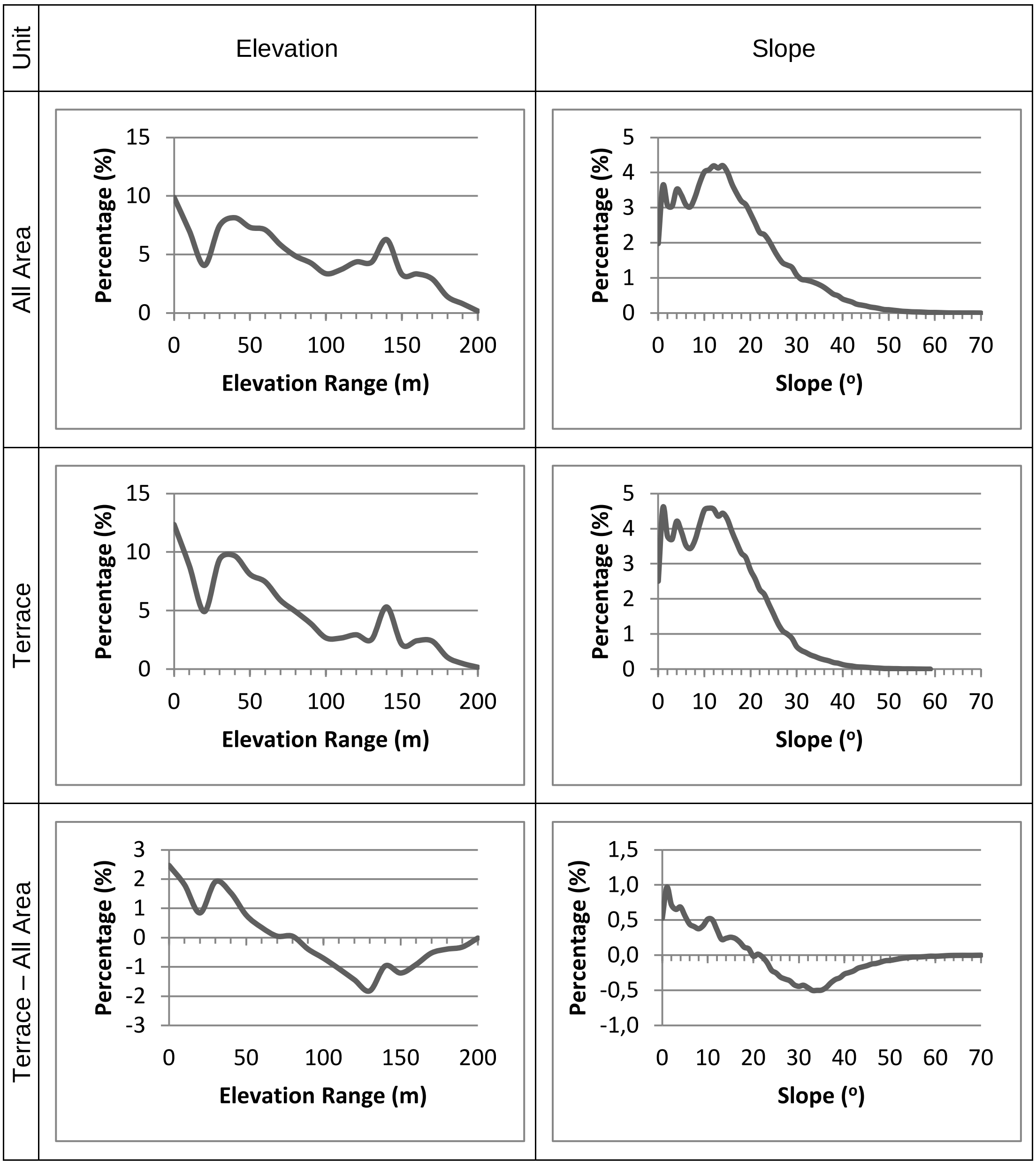


Figure 4.25: Difference histograms of terraces for elevation and slope in Kızılyer region.

4.7 Bahçeli Region Analysis

The region is located 7.7 km south-west of Bozburun center, east of Kızılyer and north of Taşlıca region. The region is the eastern part of Söğütköy village and was named according to the eastern district Kızılyer.

Bahçeli region like Örteren-1 region has no shoreline border but has a connection to another region (Kızılyer) through a neck. The neck is not as small as the neck connecting Örteren-1 and Örteren-2. Though similarities can be seen as non-terraced resistant limestone unit at higher elevations, soft and easy to excavate clastic unit at moderate (Figure 4.26).

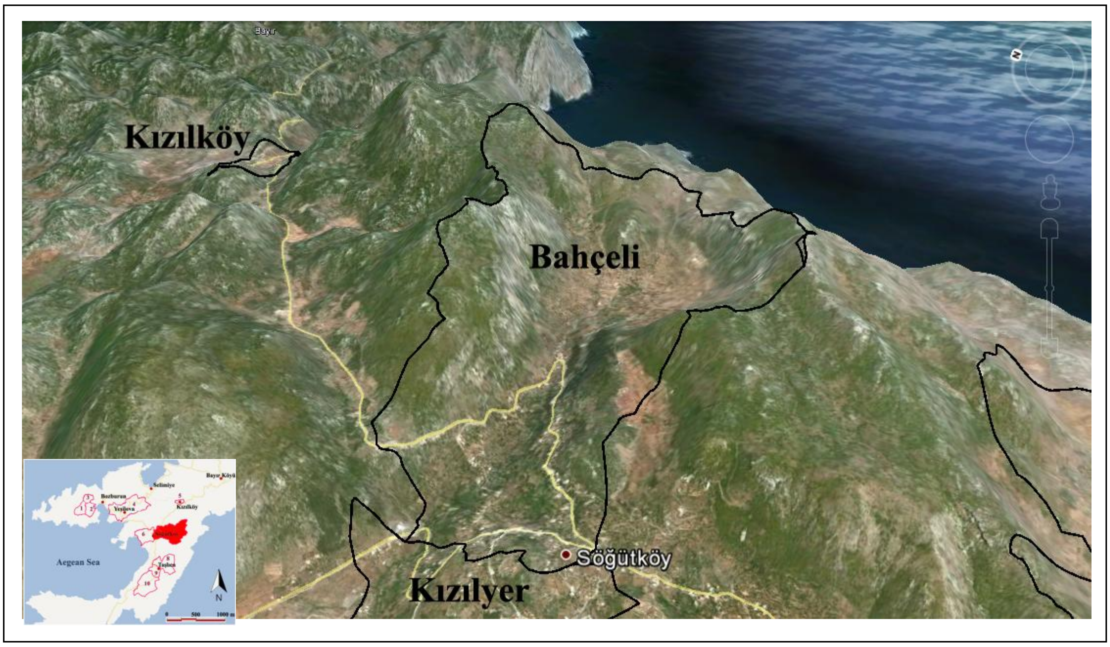


Figure 4.26: 3-D Google Earth view of Bahçeli region with 2x elevation exaggeration.

Access is available through Kızılyer and Kızılköy by an aspahlt road. Elevation of this region ranges from 68.91 to 594.00 m (Figure 4.27a) where the highest elevation is indicated by white and the lowest elevation by blue color. Sudden change in color indicates high slope values.

High slope values can be seen at the northeastern and southeastern part of the region whereas areas with gentle slope are located at inner and western parts of the region.

Distribution of the rock units in the area is shown in Figure 4.27b. Areas and percentages of the units are given in Table 4.13.

Clastic unit is exposed especially at southern and western parts and covers 59.11 percentage of the area. Limestone crops out at the outer margins except western parts and covers 31.08 percent of the area and is exposed as a ring surrounding the region. Quaternary alluvium is confined to a small area in the west central part of the region and covers 29.84 percentage of the region. Agricultural terraces are almost all located in clastic soft unit or in alluvial unit (Figure 4.27c). It is noticeable that terraces were not constructed in limestone units.

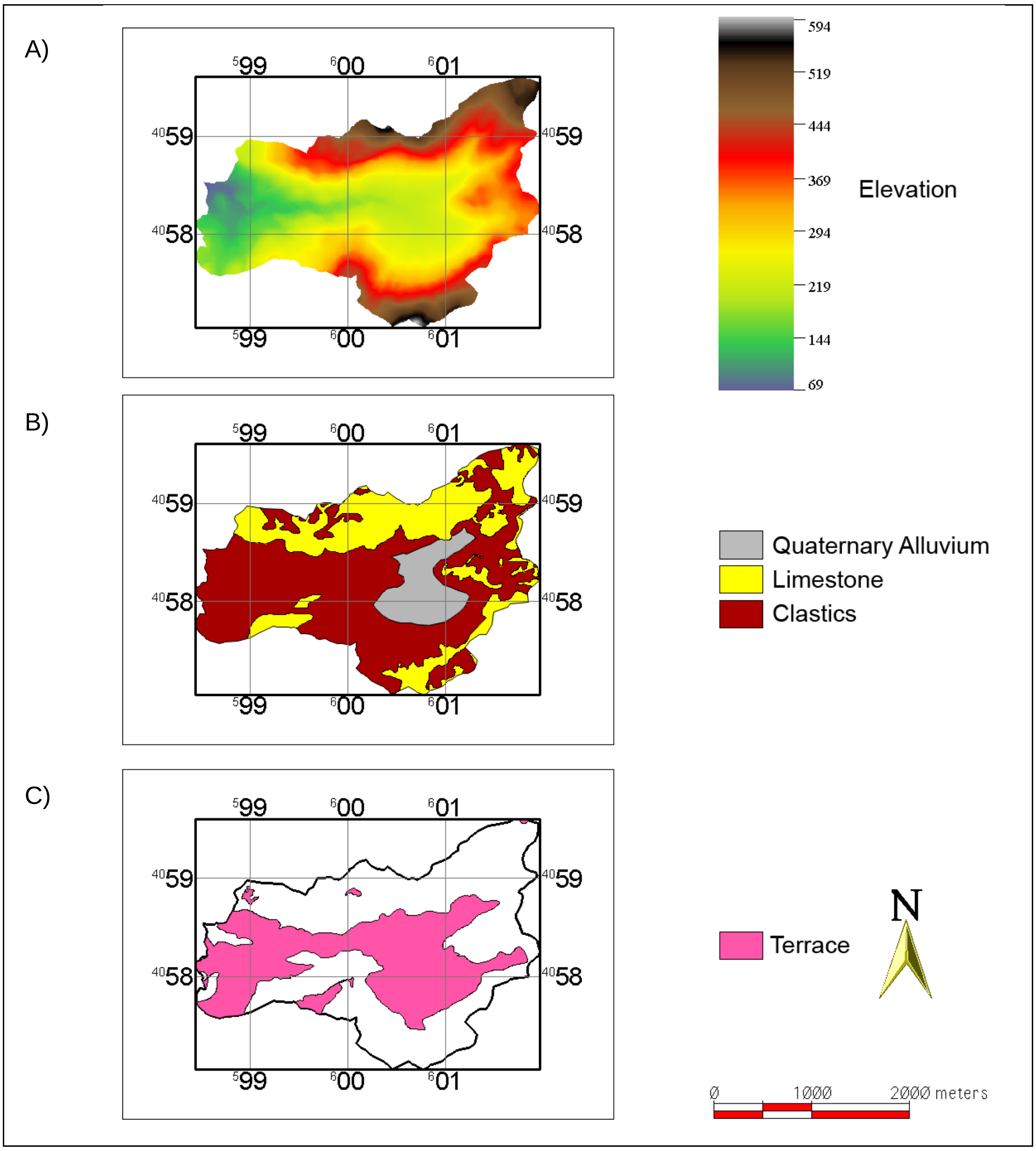


Figure 4.27: Bahçeli Region Maps. Elevation map (A), Lithological map (B) and Terrace map (C).

Table 4.13: Area percentages of units in Bahçeli Region.

Lithology	Area (m²)	Percentage (%)
Alluvium	516139	9.81
Clastic	3112543	59.11
Limestone	1636778	31.08
All	5265738	100.00

The relationship between rock units and topographic attributes are shown in histograms in Figure 4.28 and Table 4.14. Elevation values of 3 rock units show distinct differences.

Table 4.14: Elevation and Slope Statistics of Bahçeli Region.

	Elevation(m)			Slope(^{0})		
	Min	Max	Mean	Min	Max	Mean
All Area	68.91	594.00	303.66	0	84.21	20.11
Alluvium	198.88	278.58	231.56	0	58.72	8.63
Clastic	68.91	576.02	274.79	0	84.21	19.04
Limestone	138.35	594.00	381.27	0	77.83	25.76

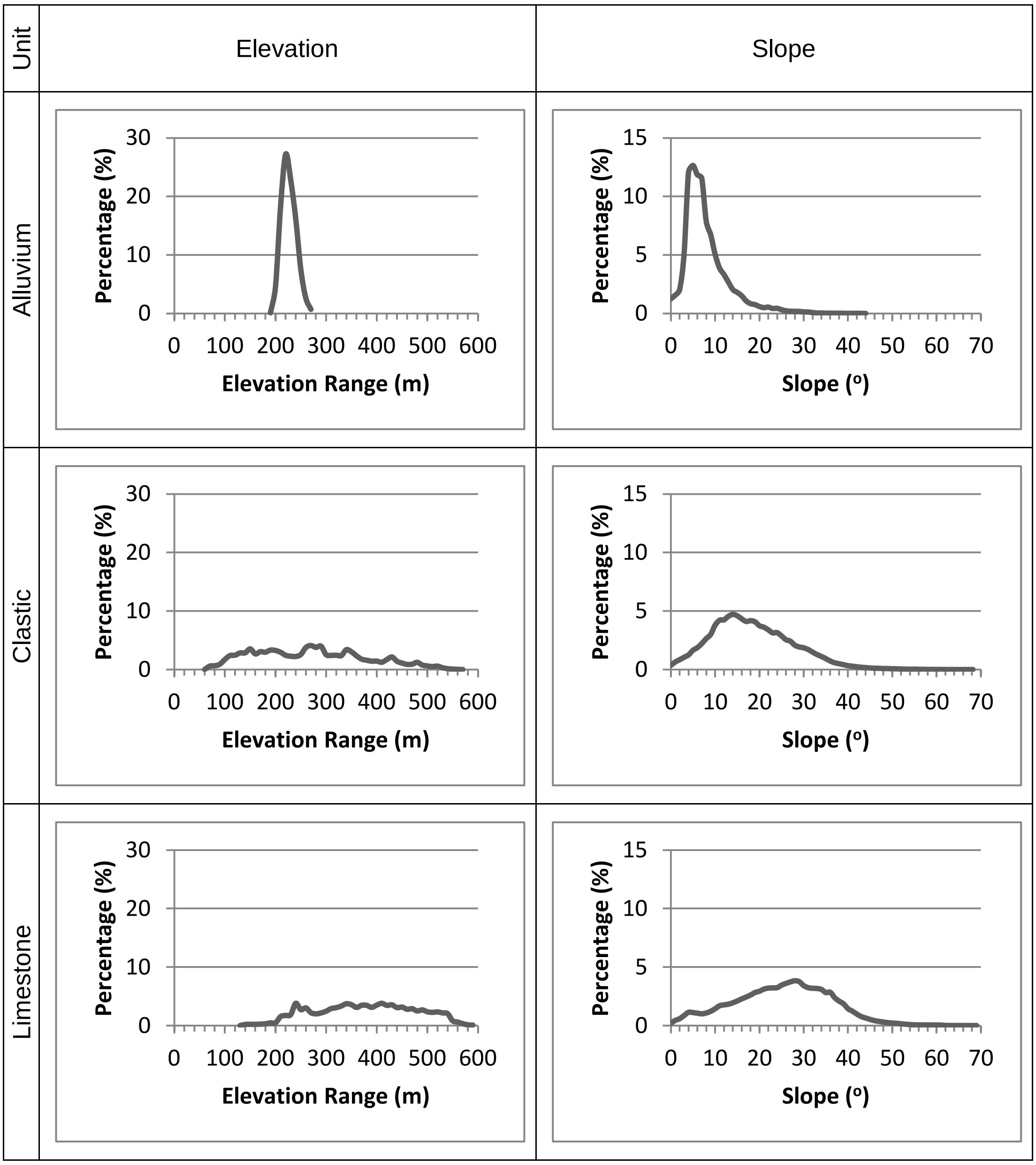


Figure 4.28: Histograms of slope and elevation for rock units in Bahçeli region

The average elevation values of Quaternary alluvium, clastic rocks and limestone are 231.56, 274.79 and 381.27 meters, respectively. In this region it can be seen that no Quaternary alluvium unit exceeds the elevation of 278.58 meters. Among three rock units only limestone units can be seen above 576.02 meters elevation.

Slope values also have differences. The average slope value of Quaternary alluvium is 8.63 degrees which is the minimum slope among all others. Clastic rocks and limestone have average values of 19.04 and 25.76 degrees, respectively. Slope range values are close to each other and only maximum values can be used as indicators of rock units.

The difference histograms for the terraces are given in Figure 4.29.

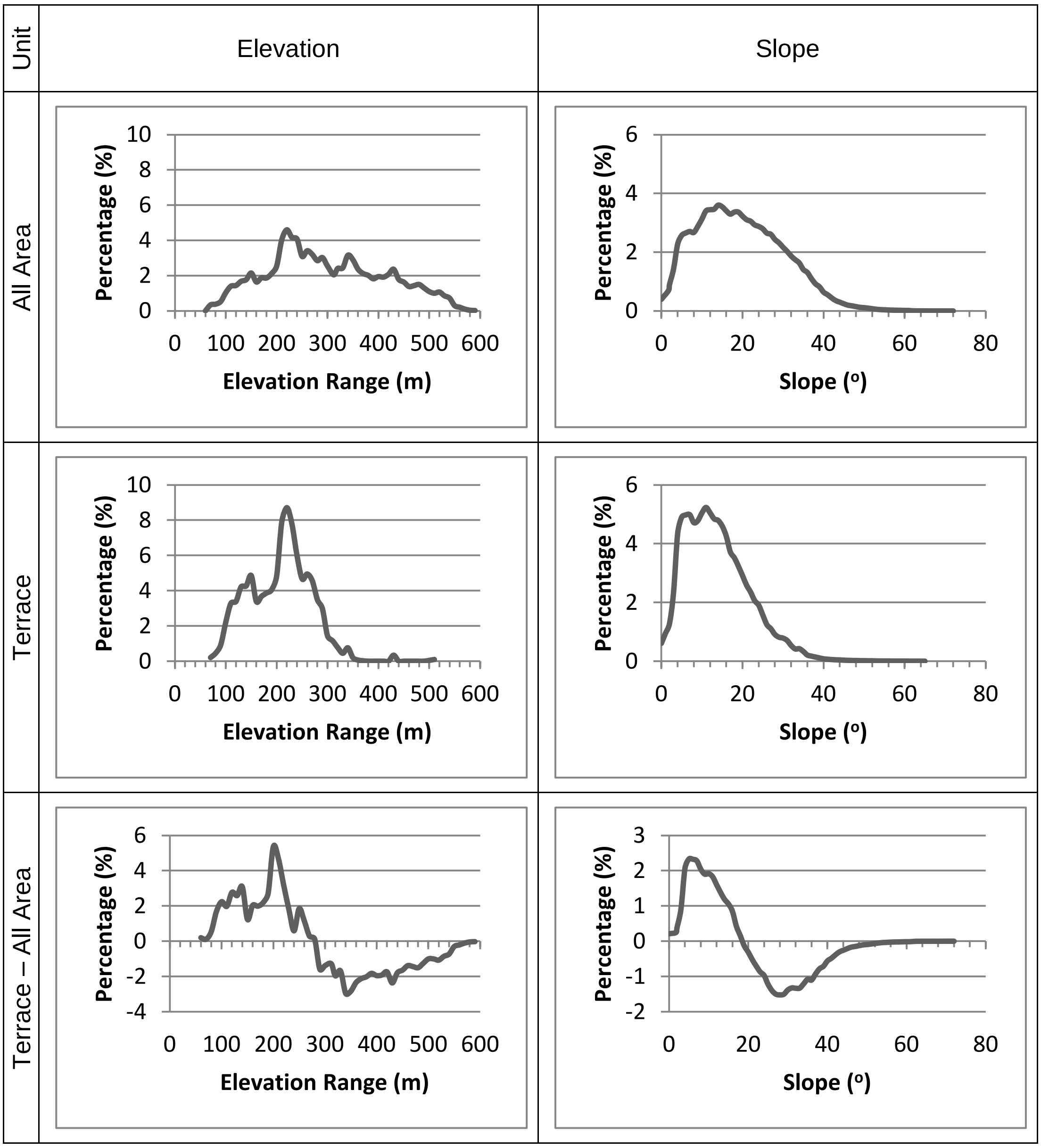


Figure 4.29: Difference histograms of terraces for elevation and slope in Bahçeli region.

The elevation difference histogram is generated by subtracting “elevation values of terrace” from “elevation values of all area”.

The histogram clearly indicates a positive interval between 60 and 290 meters and a negative interval with a elevation value greater than 290 meters. Therefore, terraces in this region are preferred to be constructed in low elevation values. The difference histogram for elevation clearly indicates that the elevation value about 200 meters is the most preferred elevation where terraces have been built in this region.

The slope difference histogram has a similar pattern to that of the elevation histogram. According to the histogram terraces are preferred to be constructed at the range of 0 to 19 degrees. The difference histogram makes a peak at 7 degrees, indicating the favorite slope values chosen for terrace locations in this region.

4.8 Taşlıca-1 Region Analysis

The region is located 9.2 km south-east of Bozburun center, north of Taşlıca-2 and south of Bahçeli region. Taşlıca-1 region was named according to the local region’s name Taşlıca. Taşlıca region was divided into three parts according to their different geo-morphological features. Taşlıca-2 and Taşlıca-3 region will be discussed in the next two section (3.9 and 3.10).
Taşlıca-1 region like Örteren-1 and Bahçeli is one of the most characteristic regions having terraces in Bozburun. Having no shoreline border and connected to another region through a neck, non-terraced resistant limestone unit at higher elevations, soft and easy to excavate clastic unit at moderate height, steep terraces in clastic unit and alluvial unit at low elevations with wide agricultural terraces are the characteristic features of Taşlıca-1 (Figure 4.30).

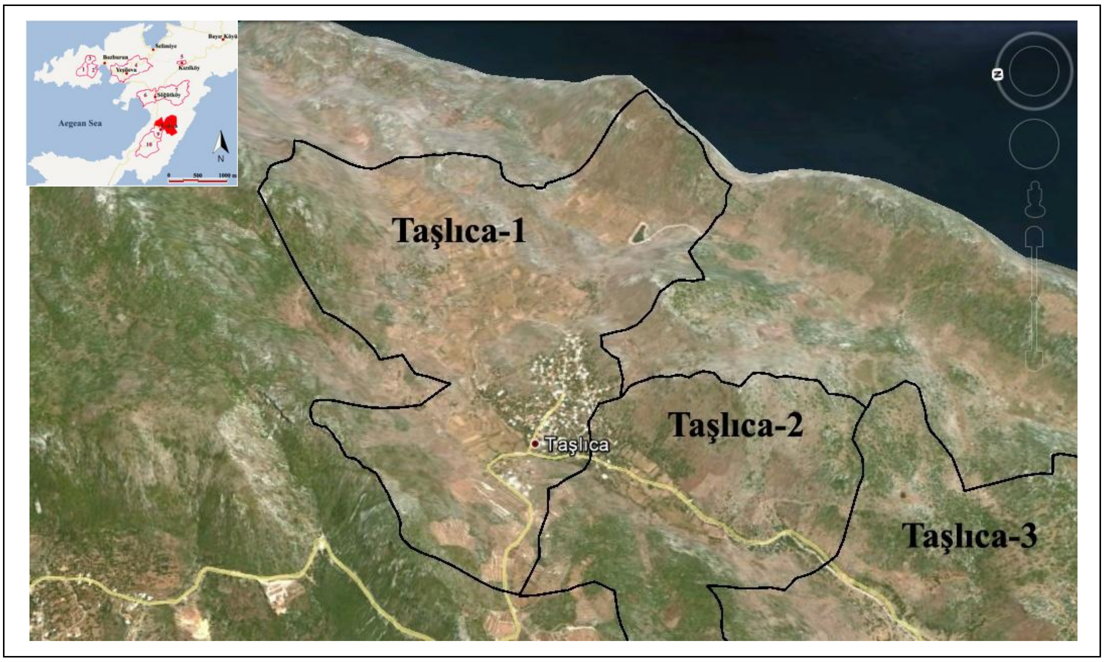


Figure 4.30: 3-D Google Earth view of Taşlıca-1 region with 2x elevation exaggeration.

Access is available only through Bahçeli region by an asphalt road. Elevation of this region ranges from 207.72 to 462.31 m (Figure 4.31a) where the highest elevation is indicated by white and the lowest elevation by blue color. Sudden change in color indicates high slope values. High slope values can be seen at the northeastern and southern parts of the region whereas areas with gentle slope are located at inner and western parts of the region.

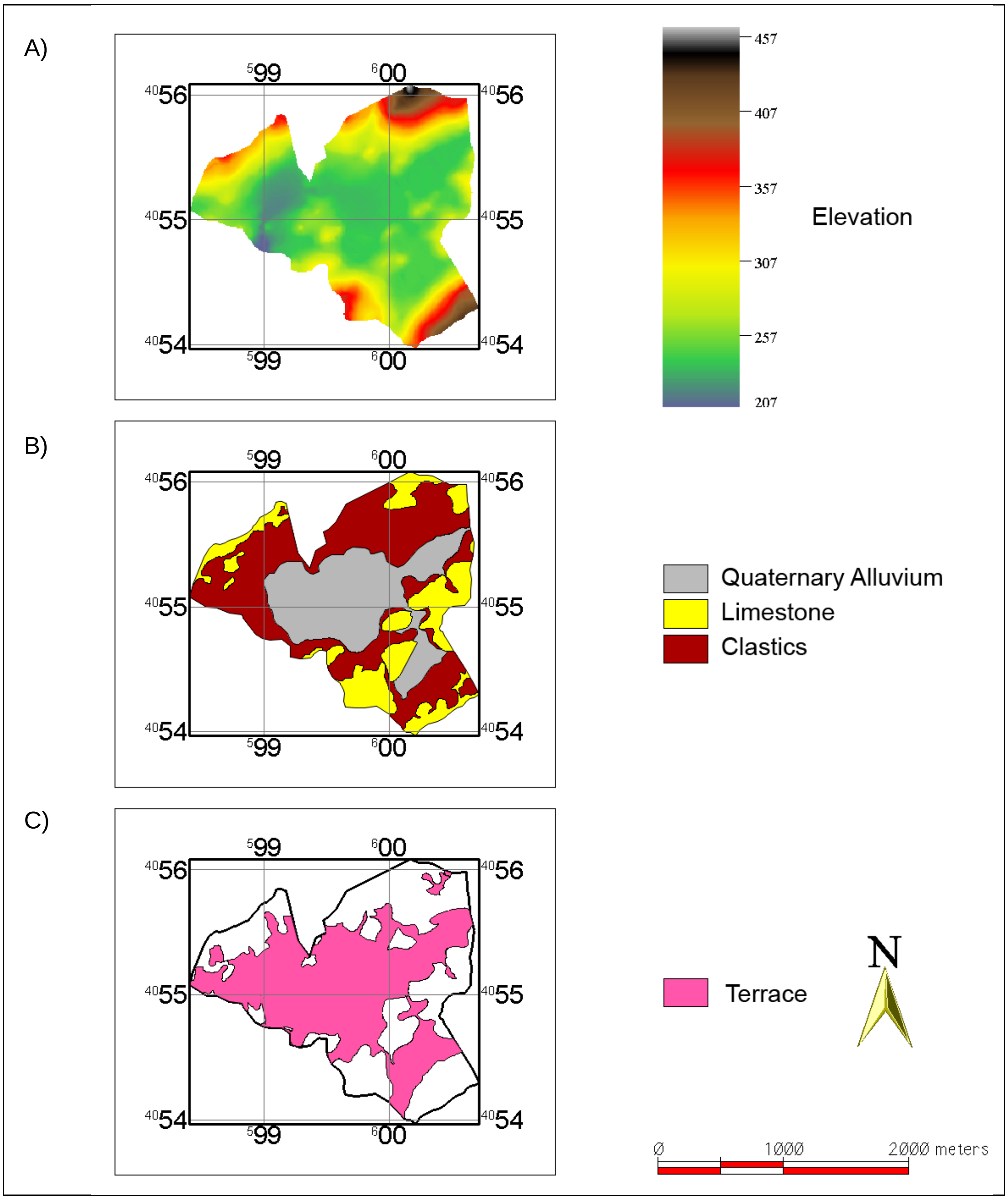


Figure 4.31: Taşlıca-1 Region Maps. Elevation map (A), Lithological map (B) and Terrace map (C).

Distribution of the rock units in the area is shown in Figure 4.31b. Areas and percentages of the units are given in Table 4.15. Clastic unit is exposed as a ring surrounding the Quaternary alluvium unit and covers 45.92 percentage of the area. Quaternary alluvium is confined to a small area in the central part of the region and covers 31.40 percentage of the region. Limestone in this region crops out irregularly and covers 22.86 percentage of the region.

Agricultural terraces are almost all located in Clastic soft unit or in alluvial unit (Figure 4.31c). It is noticeable that terraces were not constructed in limestone units.

Table 4.15: Area percentages of units in Taşlıca-1 Region.

Lithology	Area (m^2)	Percentage (%)
Alluvium	869710	31.40
Clastic	1271729	45.92
Limestone	627849	22.68
All	2769446	100.00

The relationship between rock units and topographic attributes are shown in histograms in Figure 4.32 and Table 4.16. Elevation values of 3 rock units show distinct differences. The average elevation values of Quaternary alluvium, clastic rocks and limestone are 241.02, 281.46 and 311.68 meters, respectively. In this region it can be seen that no Quaternary alluvium unit exceeds the elevation of 291.61 meters. Among three rock units only limestone units can be seen above 429.75 meters and only clastic rocks can be seen below 218.28 meters elevation. Slope values also have differences. The average slope value of Quaternary alluvium is 6.69 degrees which is the minimum slope among all others. Clastic rocks and limestone have close average values of 17.86 and 18.57 degrees, respectively. Slope range values are close to each other and only maximum values can be used as indicators of rock units.

Table 4.16: Elevation and Slope Statistics of Taşlıca-1 Region.

	Elevation(m)			Slope(^{0})		
	Min	Max	Mean	Min	Max	Mean
All Area	207.72	462.31	275.61	0	78.26	14.51
Alluvium	218.28	291.61	241.02	0	78.26	6.69
Clastic	207.72	429.75	281.46	0	72.48	17.86
Limestone	239.15	462.31	311.68	0	69.33	18.57

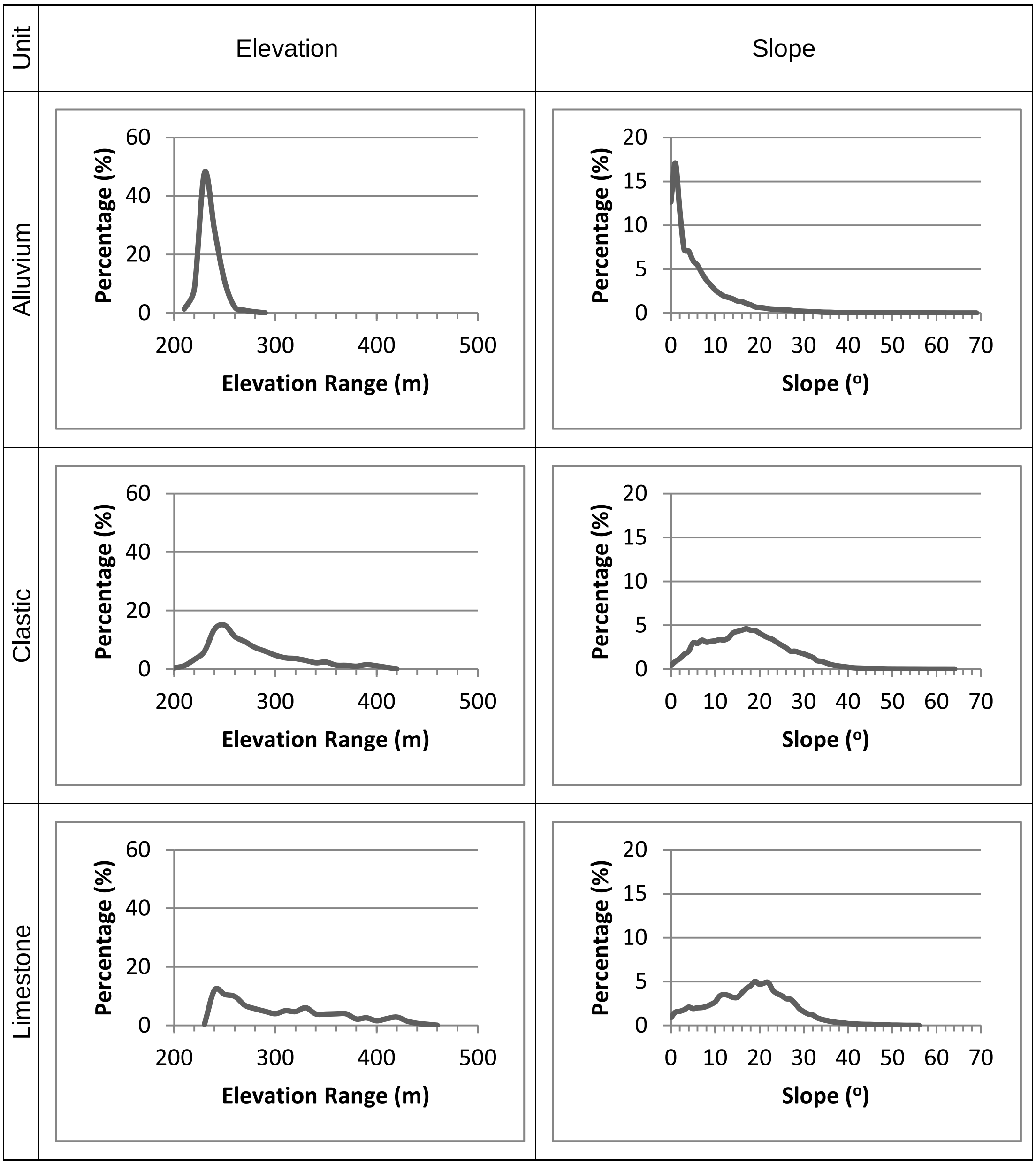


Figure 4.32: Histograms of slope and elevation for rock units in Taşlıca-1 region

The difference histograms for the terraces in relation to slope and elevation are given in Figure 4.33. The elevation difference histogram is generated by subtracting “elevation values of terrace” from “elevation values of all area”. The histogram clearly indicates a positive interval between 200 and 260 meters and a negative interval with an elevation value greater than 260 meters. Therefore, terraces in this region are preferred to be constructed in low elevation values. The difference histogram for elevation clearly indicates that the elevation value about 235 meters is the most preferred elevation where terraces have been built in this region.

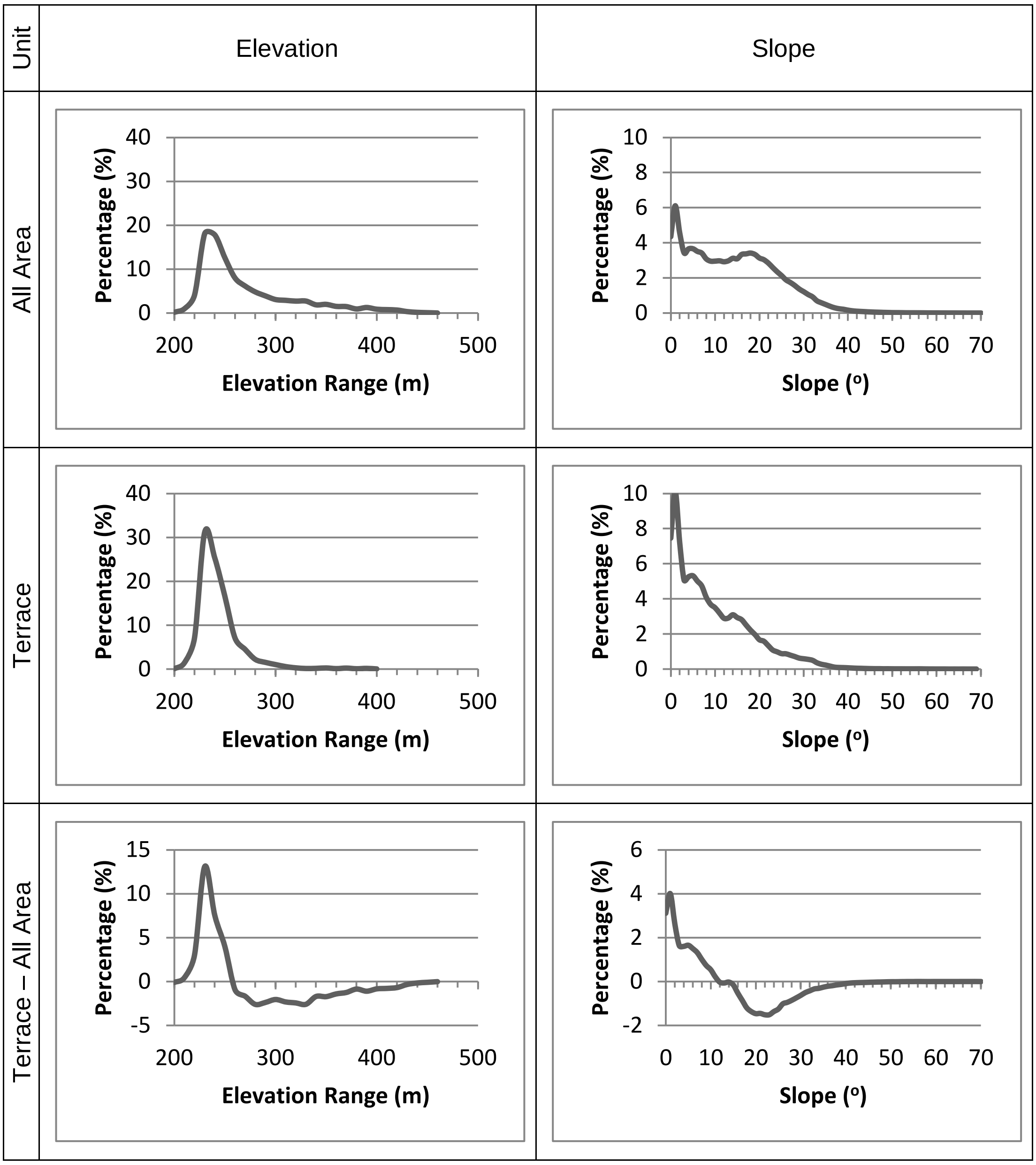


Figure 4.33: Difference histograms of terraces for elevation and slope in Taşlıca-1 region.

The slope difference histogram has a similar pattern to that of the elevation histogram. According to the histogram terraces are preferred to be constructed at the range of 0 to 11 degrees. The difference histogram makes a peak at 2 degrees, indicating the favorite slope values chosen for terrace locations in this region.

4.9 Taşlıca-2 Region Analysis

The region is located 9 km south-east of Bozburun center, north of Taşlıca-3 and south of Taşlıca-1 region (Figure 4.34). Taşlıca-2 region was named according to the local region's name Taşlıca. Taşlıca region was divided into three parts according to their different geo-morphological features and this region is the second one studied.

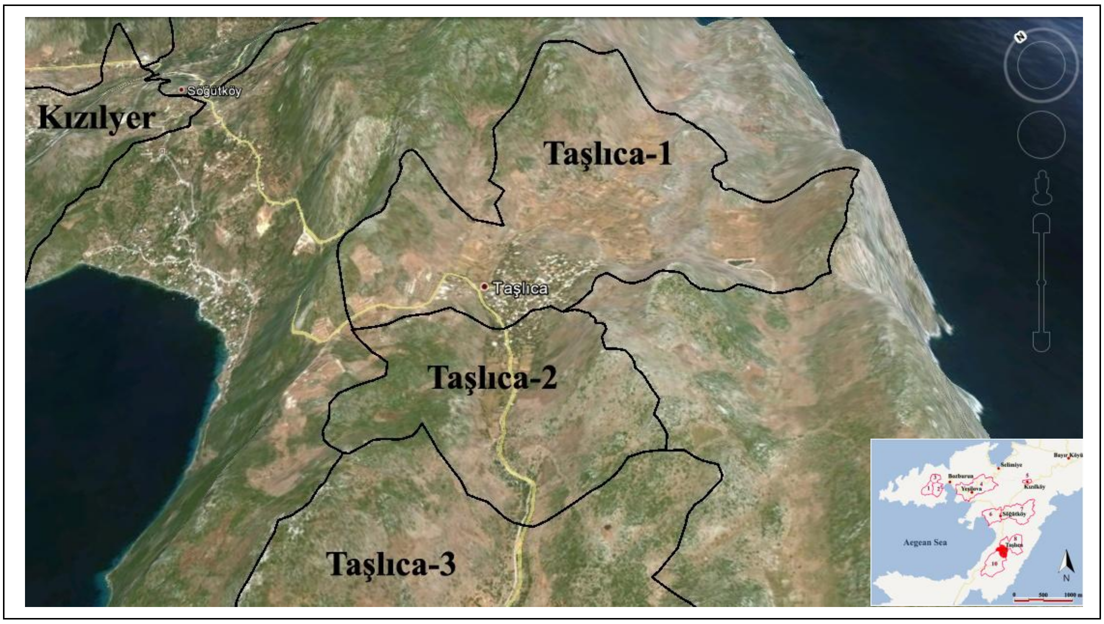


Figure 4.34: 3-D Google Earth view of Taşlıca-2 region with 2x elevation exaggeration.

Taşlıca-2 region is a special region having terraces in Bozburun. It has some similarities with Üçören region. The Region has two necks connected to other regions one for income flow of the drainage system from Taşlıca-1 and one for discharge at south to Taşlıca-3. Non-terraced resistant limestone unit at higher elevations, soft and easy to excavate clastic unit at moderate height, steep terraces in clastic unit and alluvial unit at low elevation with wide agricultural terraces are the characteristic features of Taşlıca-2.

Access is available only through Bahçeli and Taşlıca-1 region by a moderate asphalt road. Elevation of this region ranges from 157.42 to 395.87 meters (Figure 4.35a) where the highest elevation is indicated by white and the lowest elevation by blue color. Sudden change in color indicates high slope values. High slope values can be seen at the eastern parts of the region whereas areas with gentle slope are located at inner and western parts of the region.

Distribution of the rock units in the area is shown in Figure 4.35b. Areas and percentages of the units are given in Table 4.17. Clastic unit is exposed as a ring surrounding the Quaternary alluvium unit and covers 49.39 percentage of the area. Quaternary alluvium is confined to a small area in the central part of the region and covers 8.58 percentage of the region. Limestone in this region crops out irregularly and covers 42.03 percentage of the region. Agricultural terraces are almost all located in clastic soft unit or in alluvial unit (Figure 4.35c). It is noticeable that terraces were not constructed in limestone units.

Table 4.17: Area percentages of units in Taşlıca-2 Region.

Lithology	Area (m²)	Percentage (%)
Alluvium	85577	8.58
Clastic	492909	49.39
Limestone	419398	42.03
All	998044	100.00

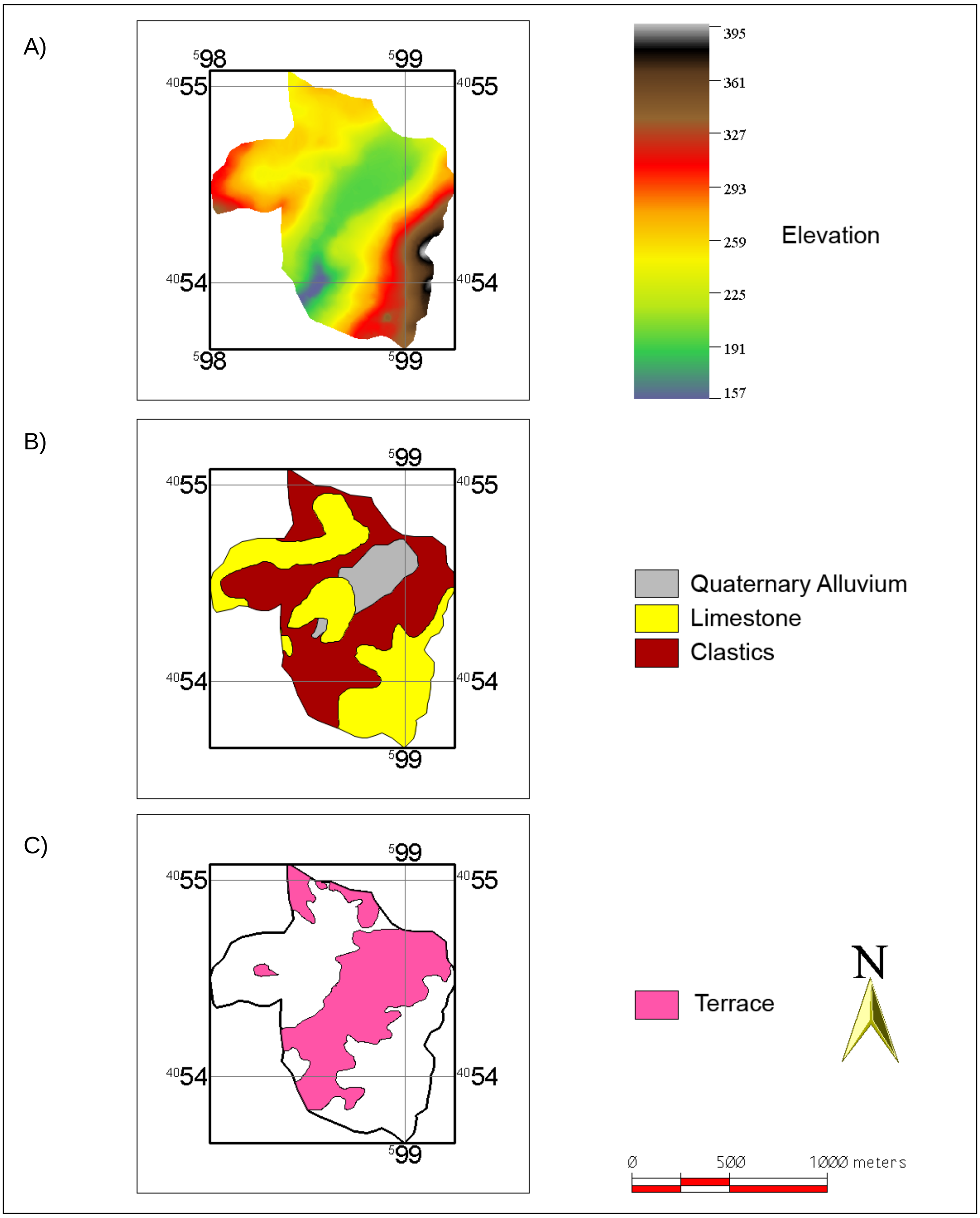


Figure 4.35: Taşlıca-2 Region Maps. Elevation map (A), Lithological map (B) and Terrace map (C).

The relationship between rock units and topographic attributes are shown in histograms in Figure 4.36 and Table 4.18. Elevation values of 3 rock units show distinct differences. The average elevation values of Quaternary alluvium, Clastic rocks and limestone are 199.34, 240.63 and 280.94 meters, respectively. In this region it can be seen that no Quaternary alluvium unit exceeds the elevation of 212.44 meters.

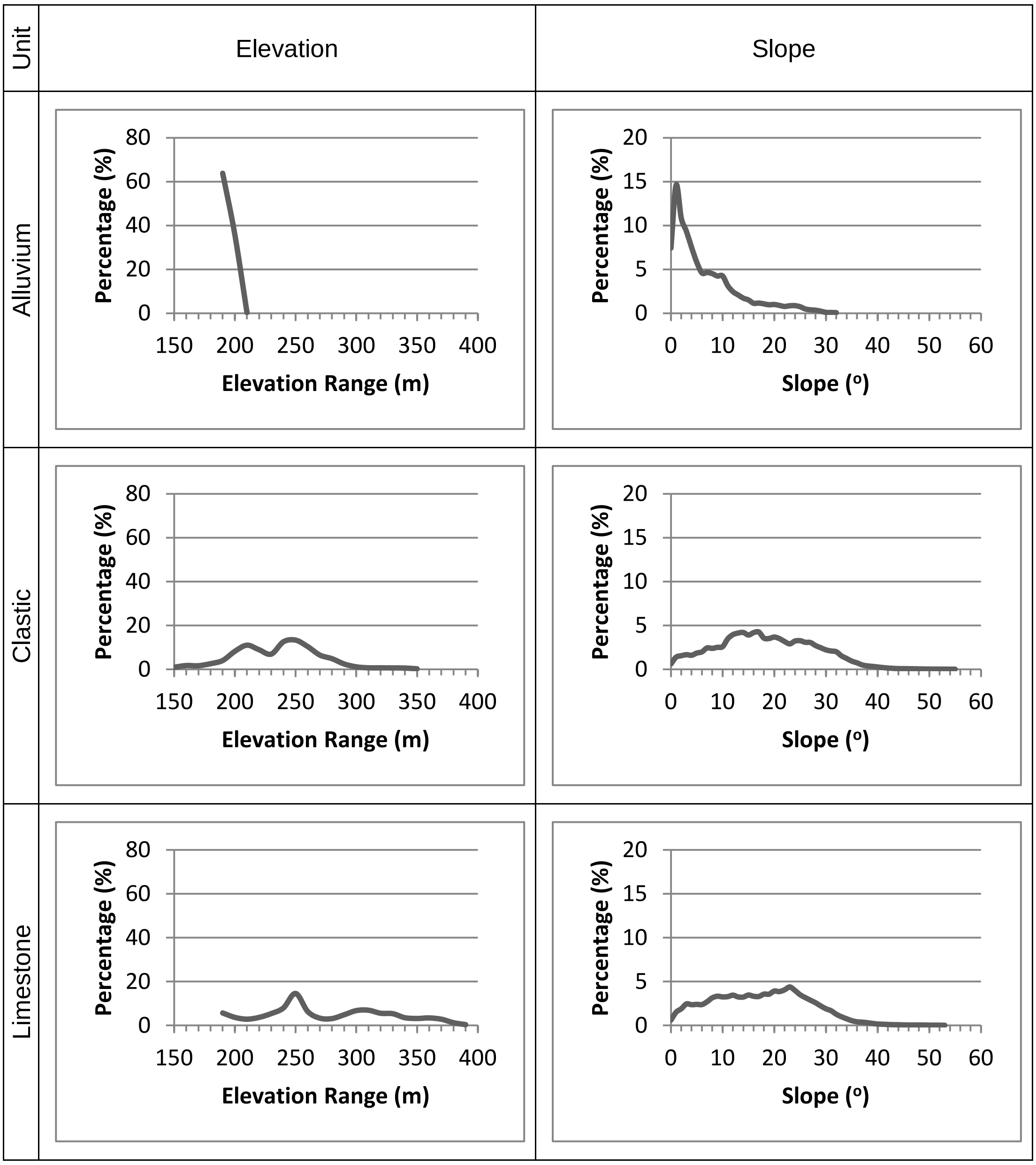


Figure 4.36: Histograms of slope and elevation for rock units in Taşlıca-2 region

Table 4.18: Elevation and Slope Statistics of Taşlıca-2 Region.

	Elevation(m)			Slope(^{0})		
	Min	Max	Mean	Min	Max	Mean
All Area	157.42	395.87	254.04	0	74.54	17.59
Alluvium	193.76	212.44	199.34	0	47.80	7.39
Clastic	157.42	360.22	240.63	0	64.51	19.00
Limestone	193.03	395.87	280.94	0	74.54	18.01

Among three rock units only limestone units can be seen above 360.22 meters and only clastic rocks can be seen below 193.76 meters elevation. Slope values also have differences and in this region. The average slope value of Quaternary alluvium is about 7.39 degrees which is the minimum slope among all others. Clastic rocks and limestone have average values of 19.00 and 18.01 degrees, respectively.

This region is the only region together with Taşlıca-3 where the average slope value of clastic unit exceeds the average slope value of limestone unit. Still high slope values over 64.51 degree can only be seen in limestone unit.

The difference histograms for the terraces in relation to slope and elevation are given in Figure 4.37. The elevation difference histogram is generated by subtracting "elevation values of terrace" from "elevation values of all area". The histogram clearly indicates a positive interval between 150 and 250 meters and a negative interval with a elevation value greater than 250 meters. Therefore, terraces in this region are preferred to be constructed in low elevation values.

The difference histogram for elevation clearly indicates that the elevation value about 195 meters is the most preferred elevation where terraces have been built in this region.

The slope difference histogram has a similar pattern to that of the elevation histogram. According to the histogram terraces are preferred to be constructed at the range of 0 to 11 degrees. The difference histogram makes a peak at 2 degrees, indicating the favorite slope values chosen for terrace locations in this region.

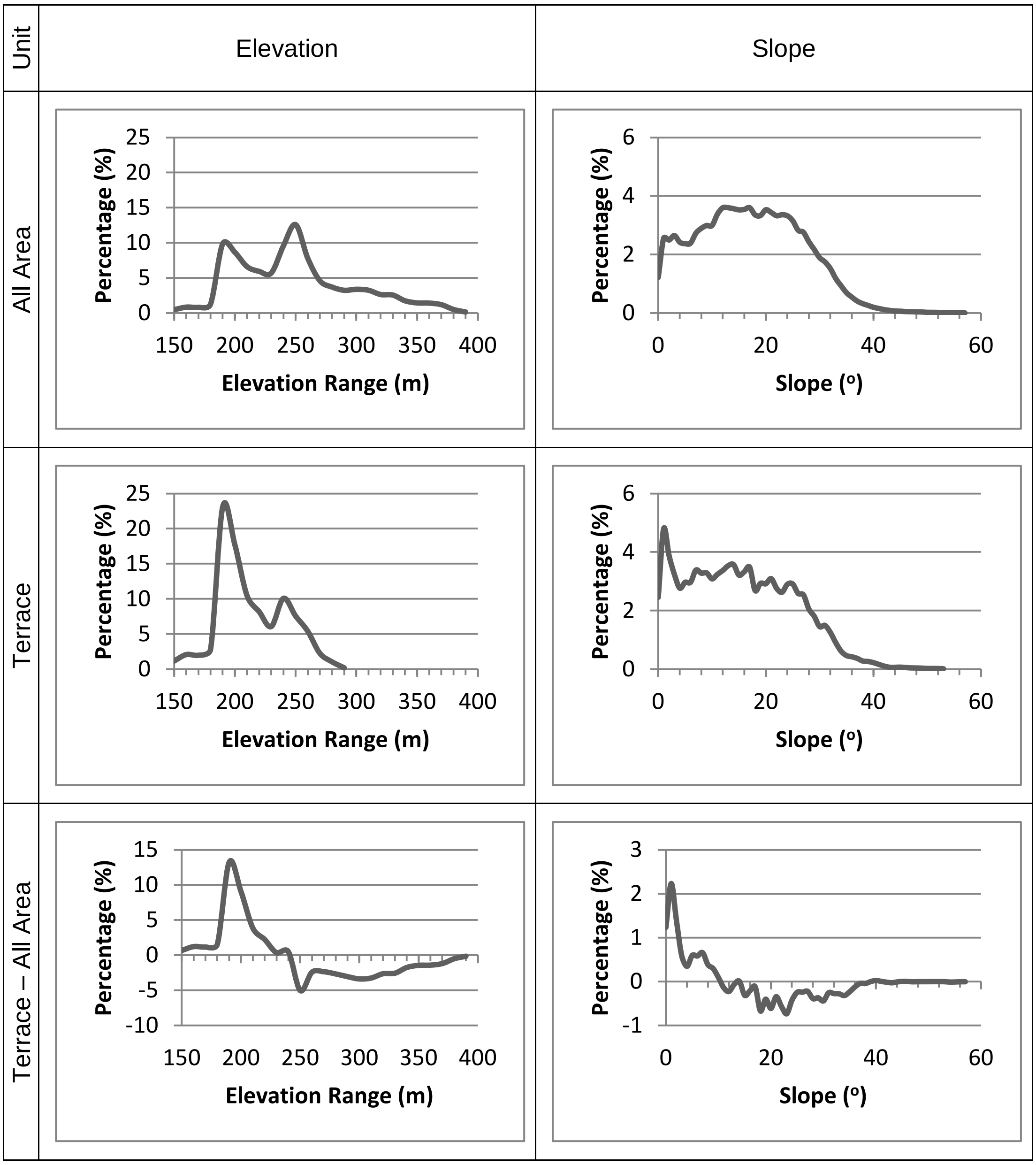


Figure 4.37: Difference histograms of terraces for elevation and slope in Taşlıca-2 region.

4.10 Taşlıca-3 Region Analysis

The region is located 10 km south southeast of Bozburun center, south of Taşlıca-2. Taşlıca-3 region was named according to the local region's name Taşlıca. Taşlıca region was divided into three parts according to their different geo-morphological features. Taşlıca-3 is the third part studied of Taşlıca.

Taşlıca-3 is unique region among all other studied regions having terraces in Bozburun. The region is connected to Taşlıca-2 by a tight neck. Through the neck there is an income of drainage water but the region has no discharge neck or shoreline border. Similarities such as: Non-terraced resistant limestone unit at higher elevations, soft and easy to excavate clastic unit at moderate height, steep terraces in clastic unit and alluvial unit at lowest elevation with wide agricultural terraces can be seen at Taşlıca-3 (Figure 4.38).

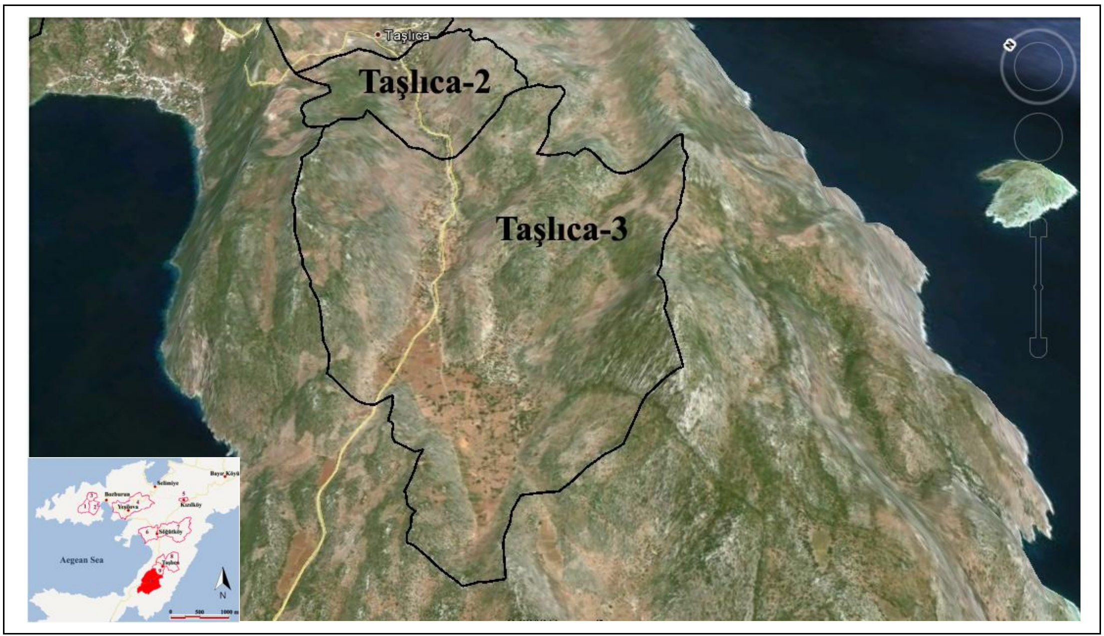


Figure 4.38: 3-D Google Earth view of Taşlıca-3 region with 2x elevation exaggeration.

Access is available only through Bahçeli, Taşlıca-1 and Taşlıca-2 region by an asphalt road. Elevation of this region ranges from 120.17 to 535.18 m (Figure 4.39a) where the highest elevation is indicated by white and the lowest elevation by blue color. Sudden change in color indicates high slope values. High slope values can be seen at the southern parts of the region whereas areas with gentle slope are located at inner and western parts of the region.

Distribution of the rock units in the area is shown in Figure 4.39b. Areas and percentages of the units are given in Table 4.19. Clastic unit is exposed randomly at the area and covers 35.16 percentage of the area. Quaternary alluvium is confined to a small NE-SW elongated area in the central part of the region and covers 9.57 percentage of the region. Limestone in this region crops out irregularly and covers 55.27 percentage of the region. Agricultural terraces are almost all located in clastic soft unit or in alluvial unit (Figure 4.39c). It is noticeable that terraces were not constructed in limestone units.

Table 4.19: Area percentages of units in Taşlıca-3 Region.

Lithology	Area (m^2)	Percentage (%)
Alluvium	365820	9.57
Clastic	1344517	35.16
Limestone	2112922	55.27
All	3823558	100.00

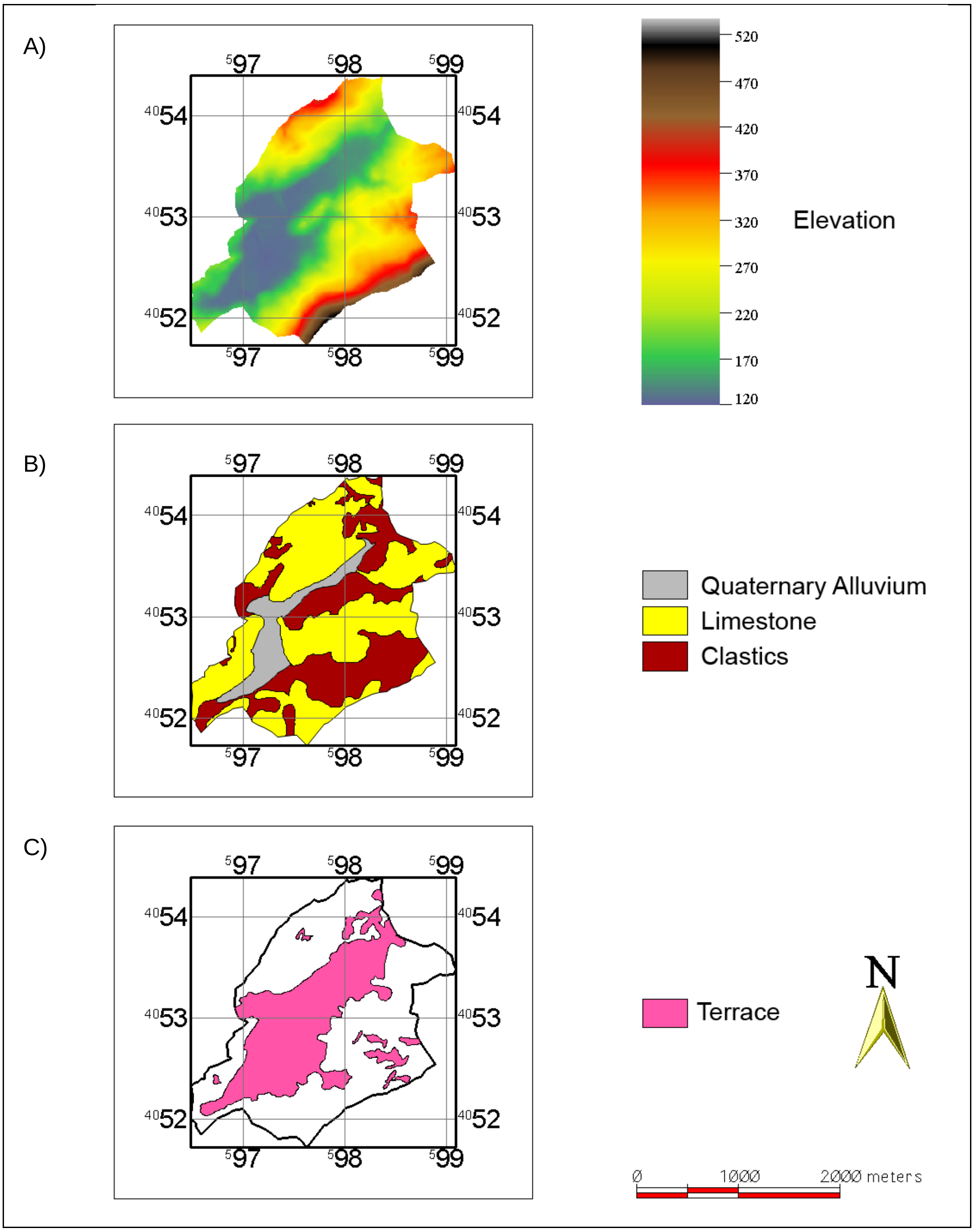


Figure 4.39: Taşlıca-3 Region Maps. Elevation map (A), Lithological map (B) and Terrace map (C).

The relationship between rock units and topographic attributes are shown in histograms in Figure 4.40 and Table 4.20.

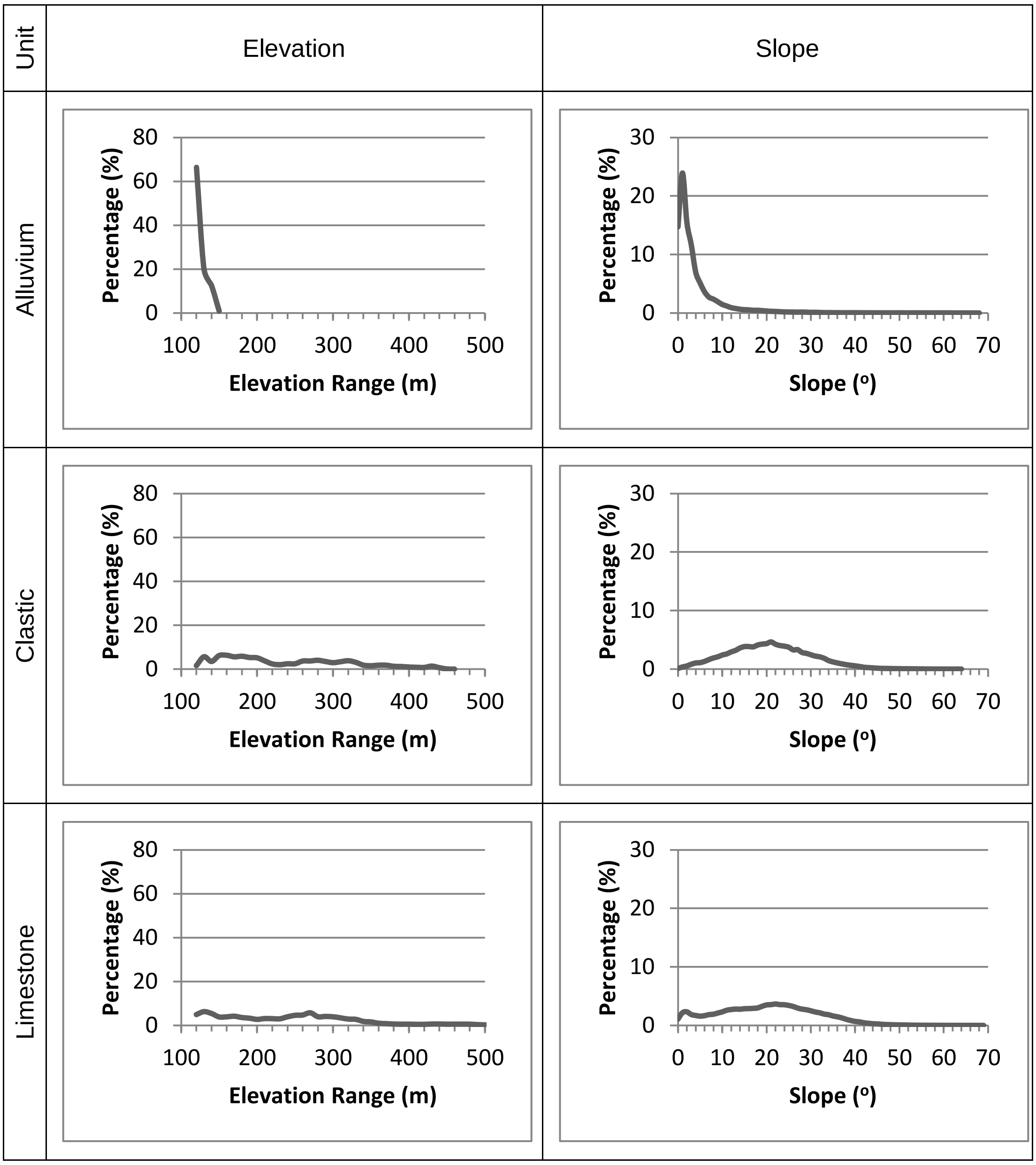


Figure 4.40: Histograms of slope and elevation for rock units in Taşlıca-3 region

The average elevation values of Quaternary alluvium, clastic rocks and limestone are 131.38, 244.10 and 246.70 meters, respectively. In this region it can be seen that no Quaternary alluvium unit exceeds the elevation of 156.39 meters. Among three rock units only limestone units can be seen above 463.49 meters elevation. Slope values also have differences. The average slope value of Quaternary alluvium is 5.04 degrees which is the minimum slope among all others. Clastic rocks and limestone have close average values of 21.34 and 20.81 degrees, respectively.

Table 4.20: Elevation and Slope Statistics of Taşlıca-3 Region.

	Elevation (m)			Slope (^{o})		
	Min	Max	Mean	Min	Max	Mean
All Area	120.17	535.18	234.75	0	78.78	19.49
Alluvium	120.17	156.39	131.38	0	78.78	5.04
Clastic	125.24	463.49	244.10	0	72.46	21.34
Limestone	124.27	535.18	246.70	0	74.37	20.81

The difference histograms for the terraces in relation to slope and elevation are given in Figure 4.41. The elevation difference histogram is generated by subtracting “elevation values of terrace” from “elevation values of all area”. The histogram clearly indicates a positive interval between 120 and 210 meters and a negative interval with a elevation value greater than 210 meters. Therefore, terraces in this region are preferred to be constructed in low elevation values. The difference histogram for elevation clearly indicates that the elevation value about 135 meters is the most preferred elevation where terraces have been built in this region.

The slope difference histogram has a similar pattern to that of the elevation histogram. According to the histogram terraces are preferred to be constructed at the range of 0 to 11 degrees. The difference histogram makes a peak at 2 degrees, indicating the favorite slope values chosen for terrace locations in this region.

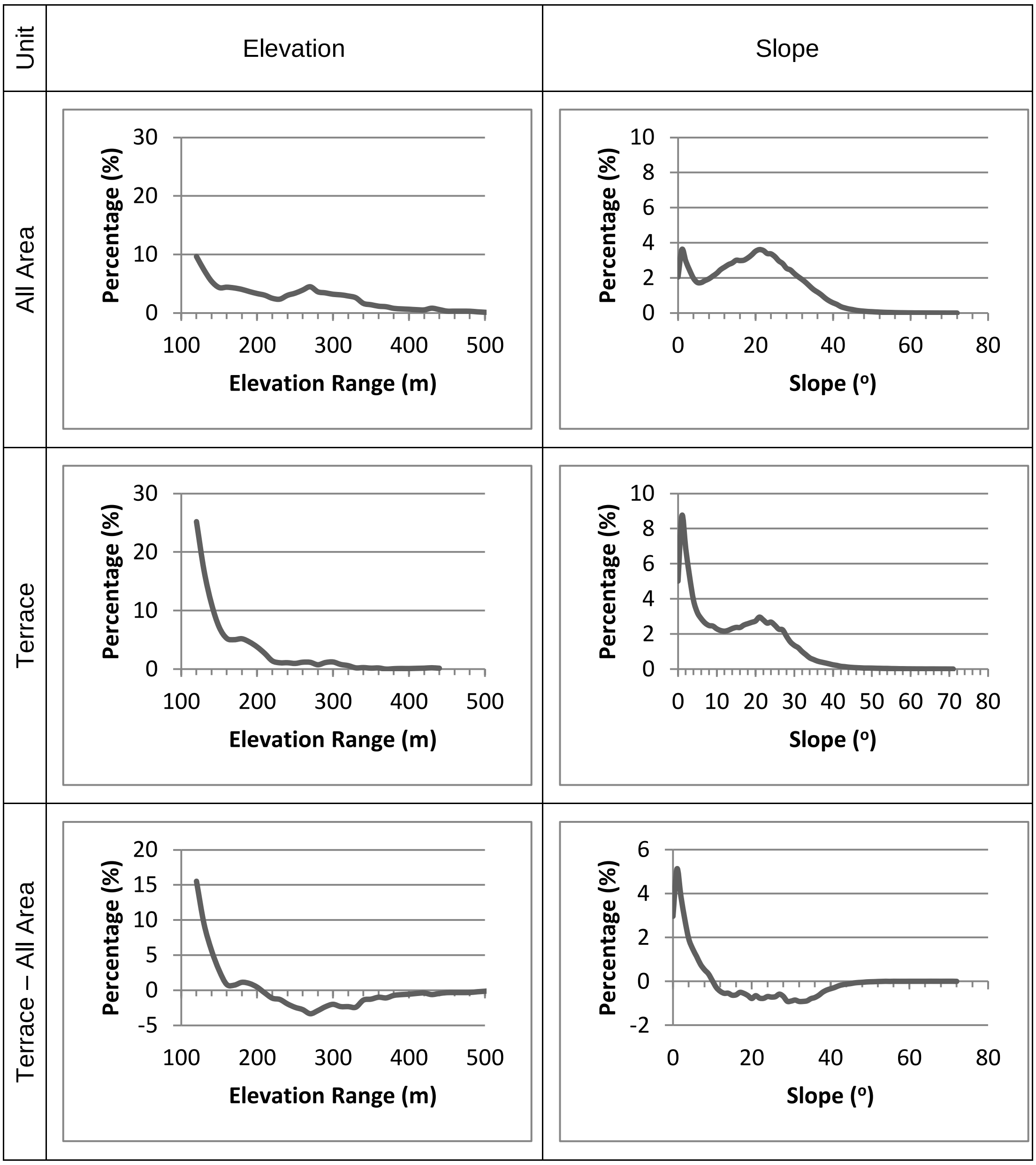


Figure 4.41: Difference histograms of terraces for elevation and slope in Taşlıca-3 region.

CHAPTER 5

DISCUSSION

This chapter consists of discussion on the quality of data used in this study and the relationship between topography, lithology and agricultural terraces.

5.1 Quality of data

In this study scanned 1/25000 topographic maps, digital 10 m elevation contours and analogue 1/5000 scaled topographic maps were combined to create a complete Digital Elevation Model (DEM) having 1 meter pixel size. This pixel size was satisfactory for detailed topographic data such as slope and elevation, even in very small and local studies. However, for both elevation and slope values, it must be considered that the average values are given for the general trend.

Analogue 1/5000 scaled maps were also scanned and georeferenced and were used to draw catchment areas for selected regions to be studied. Accuracy of the catchment areas were also very reliable since they were created from registered 1/5000 scaled maps combination.

1/500000 geologic maps prepared by MTA (given in the section 1.3.1) were very coarse and could not be used for the very local study of the selected regions of Bozburun. The map was modified using field data and satellite images. Satellite Images of Digital Globe (can be WORLDVIEW-2 or QUICKBIRD satellite) and GEOEYE have 0.5 meter pixel size. Three different dated satellite images of the same area were used to clarify any confusion during the drawings of the three main lithological units. This data was also very satisfying for discrimination of the lithologic units and terraced areas. However there may be minor differences in the three main lithologic units and other lithologic units which were ignored due to very low coverage.

In addition to the data used in this study, some other data sets could also be included in order to increase the accuracy of results. Examples of these data can be digital soil map, landuse maps, water data (wells and cisterns), aerial photographs, archaeological data and detailed fault data. These data are excluded in this study either due to being very coarse or they are not available or being out of the scope of the study.

Additionally gathered data of well coordinates could be used for deriving relationship between wells and three main datasets (lithologic units, topographic properties and terraces). However this comparison would be out of scope of the study.

5.2 Interpretation of results

This section is composed of four parts; 1) Relationship between topography and lithology, 2) Relationship between topography and agricultural terraces, 3) Relationship between lithology and agricultural terraces and 4) Integration of all parameters.

5.2.1 Topography and Lithology

Slope for any topography can only range from 0 to 90 degrees whereas the range for elevation can differ for each region. Due to the need of interpretation of elevation, each elevation range has been converted linearly to a 0 to 100 meters range. Minimum value of elevation for each region has been considered as 0 and the maximum value of elevation has been considered as 100 meters. The real values of elevation were given in the previous chapter (Chapter 4). This calculated new elevation value will be referred to as “rescaled elevation”. The formula used for this conversion is in Figure 5.1. Value "h" represents the corresponding mean elevation value of the lithologic unit rescaled. The interpretation of topography and lithology differs from terrace interpretation because both lithology and topography are results of natural processes and are not artificial.

$$h = \frac{mean(elev) - \min(elev)}{\max(elev) - \min(elev)} * 100$$

Figure 5.1: Formula used for mean elevation conversion to 100 scale.

A table providing converted mean elevation values for each lithologic unit in all studied regions is given in Table 5.1 and a graph of the units mean elevation values is given in Figure 5.2.

The mean elevation value of alluvium is 9.06 meters, although the accumulation of alluvium in Bahçeli region was at a high point (compare Figure 4.27a and 4.27b). Similarities can be noticed between other regions. The table clearly indicates that, alluvium was confined at low elevation values and has a smaller range of distribution. Almost at all regions clastic rocks' mean elevation value has a slightly lower value than the full areas mean value. Table 5.1 points that clastic rocks are exposed to an average elevation height about 29.59 meters. Limestone, for all regions crops out at high elevation values about 46.36 meters. According to this table for each region, three lithological units can be seen as follows; in low elevation alluvium, moderate elevation clastic rocks and at high elevation limestone.

Table 5.1: Rescaled mean elevation values of lithologic units and full areas.

Region Name	Alluvium (m)	Clastic (m)	Limestone (m)	Area (m^2)
1) Örteren-1	5.38	26.43	48.81	33.27
2) Örteren-2	2.14	31.03	47.13	38.63
3) Üçören	6.76	26.96	38.53	29.84
4) Yeşilova	4.61	26.06	42.32	25.45
5) Kızılköy	3.76	12.44	40.19	34.11
6) Kızılyer	3.66	40.06	63.97	38.10
7) Bahçeli	30.98	39.21	59.49	44.71
8) Taşlıca-1	13.08	28.96	40.83	26.67
9) Taşlıca-2	17.58	34.90	51.80	40.52
10) Taşlıca-3	2.70	29.86	30.49	27.61
Mean	9.06	29.59	46.36	33.89

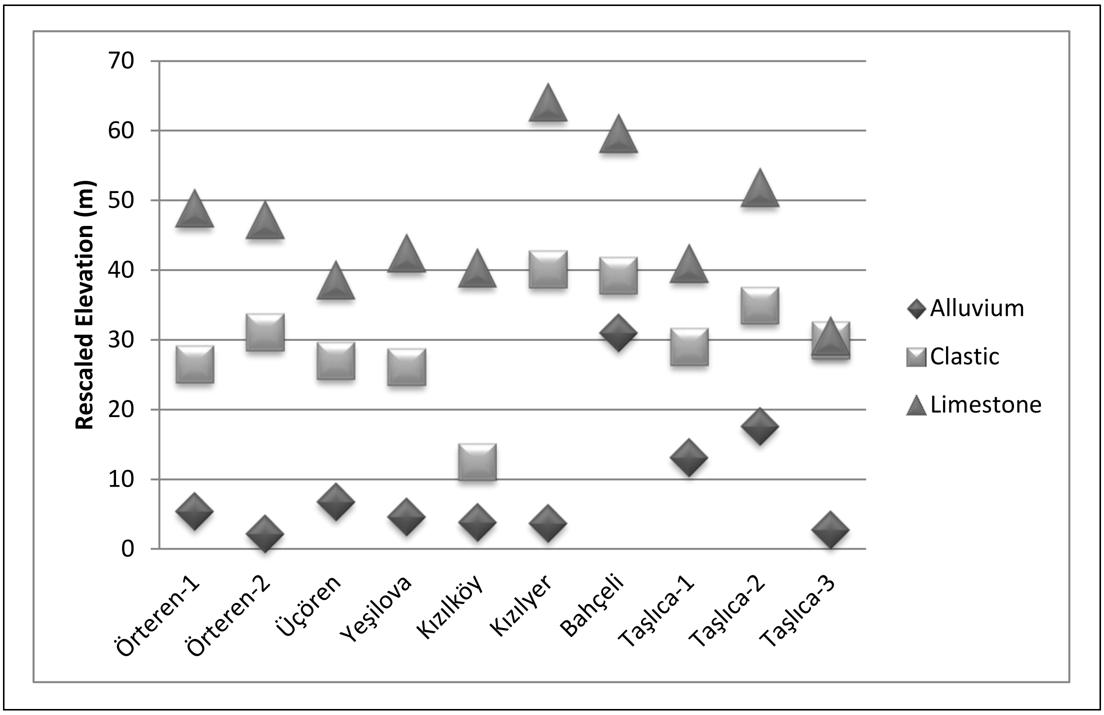


Figure 5.2: Graph of rescaled mean elevation values of lithologic units.

Mean slope values for each lithologic unit in all studied regions are given in Table 5.2 and a graph of the units mean slope values is given in Figure 5.3.

Table 5.2: Mean slope values of lithologic units and full areas.

Region Name	Alluvium (°)	Clastic (°)	Limestone (°)	Area (°)
1) Örteren-1	5.90	17.92	20.11	17.12
2) Örteren-2	4.32	23.29	19.47	19.76
3) Üçören	7.01	14.83	21.77	17.08
4) Yeşilova	5.40	20.29	26.37	18.35
5) Kızılköy	9.23	12.10	22.37	20.17
6) Kızılyer	4.72	16.24	28.36	16.06
7) Bahçeli	8.63	19.04	25.76	20.11
8) Taşlıca-1	6.69	17.86	18.57	14.51
9) Taşlıca-2	7.39	19.00	18.01	17.59
10) Taşlıca-3	5.04	21.34	20.81	19.49
Mean	6.43	18.19	22.16	18.02

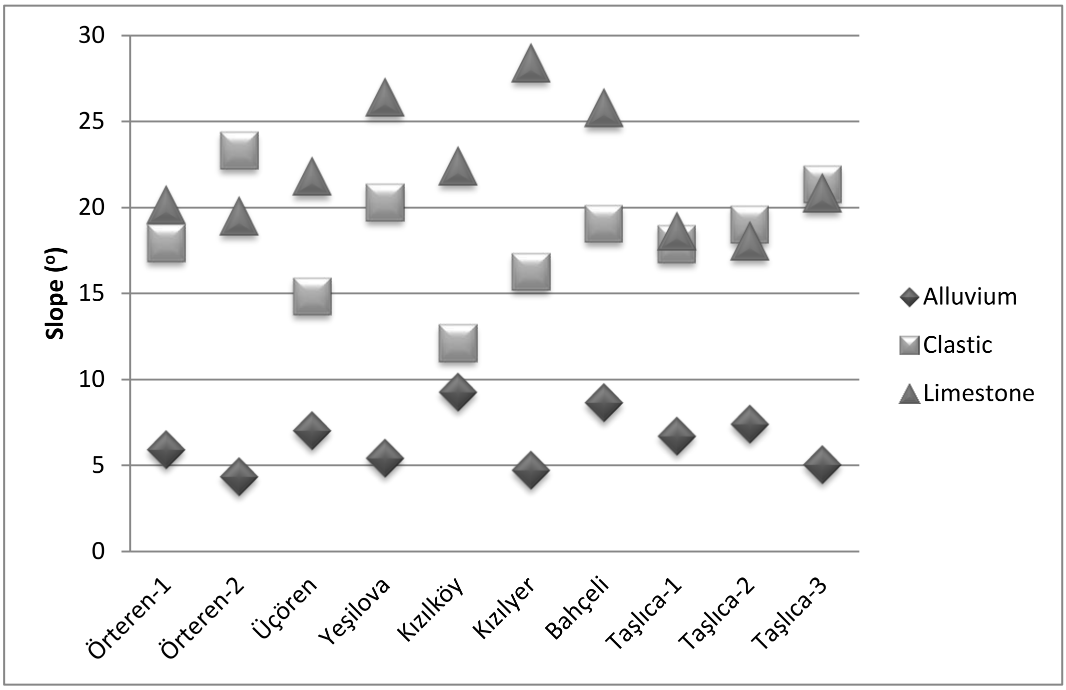


Figure 5.3: Rescaled mean slope values of lithologic units.

As expected, the mean of the slope values of alluvium is 6.43. So the table clearly indicates that alluvium was confined at very low slope values. Clastic rocks and Limestone units have an average slope value of 18.19 and 22.16 degrees, respectively. According to the table, alluvium cannot be seen above 9.23 degrees. All slope values are, therefore, consistent with their geologic nature.

5.2.2 Topography and Terraces

This section shows how agricultural terraces are affected by the topographic properties. Due to the need of interpretation of elevation, each elevation range has been converted linearly to a 0 to 100 meters range. Minimum value of elevation for terraces has been considered as 0 and the maximum value for terraces elevation has been considered as 100 meters. The real values of elevation were given in the previous chapter (Chapter 4). Agricultural terraces are artificial structures and there is a preferred range of elevation for each region. Table 5.3 gives the ranges and the “most preferred values of elevation” for agricultural rescaled.
The formula used for this conversion has been given in Figure 5.4. Value "h" represents the corresponding most preferred elevation value, where terraces were built.

$$h = \frac{most(elev) - \min(elev)}{\max(elev) - \min(elev)} * 100$$

Figure 5.4: Formula used for most preferred elevation conversion to 1 to 100 scale. The variable "$most(elev)$" here represents the real elevation value at which terraces where preferred to be built at most.

Table 5.3: Rescaled preferred mean elevations for agricultural terraces.

Region Name	Preferred Min Elev. (m)	Preferred Max Elev. (m)	Most Preferred Elev. (m)
1) Örteren-1	0	28.06	3.74
2) Örteren-2	0	41.44	6.22
3) Üçören	0	27.30	14.15
4) Yeşilova	0	26.56	3.32
5) Kızılköy	0	7.76	1.65
6) Kızılyer	0	38.79	0.49
7) Bahçeli	0	42.11	26.87
8) Taşlıca-1	0	16.61	10.72
9) Taşlıca-2	0	38.83	15.76
10) Taşlıca-3	0	20.86	2.61
Mean	0	28.83	8.55

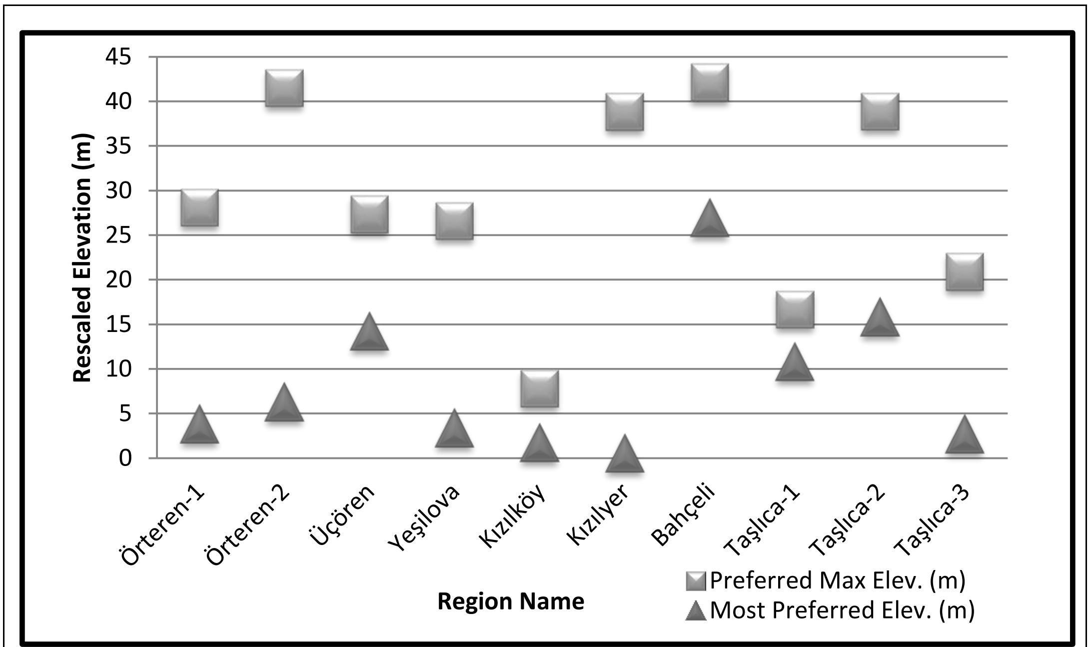


Figure 5.5: Rescaled mean elevation graph for all regions.

Elevations preferred for terraces to be constructed are random. It can be observed that elevation has no effect on terraces. Although there is no exact most preferred elevation, comparison of the preferred maximum elevation numbers clearly indicates that low elevation values were preferred for agricultural terraces. In rescaled values, above 41.44 meters were avoided for terrace construction.

Mean slope values for terraces are given in Table 5.4 and a graph of the terraces mean slope values is given in Figure 5.6. Calculations indicate that agricultural terraces were seen in Bozburun about 40 m rescaled elevation.

Table 5.4: Rescaled preferred mean slopes for agricultural terraces.

Region Name	Preferred Min Slope (°)	Preferred Max Slope (°)	Most Preferred Slope (°)
1) Örteren-1	0	10	7.5
2) Örteren-2	4	15	5
3) Üçören	0	17	5
4) Yeşilova	0	20	4
5) Kızılköy	0	12	2
6) Kızılyer	0	22	1
7) Bahçeli	0	19	7
8) Taşlıca-1	0	11	2
9) Taşlıca-2	0	11	2
10) Taşlıca-3	0	11	2
Mean	0	14.8	3.75

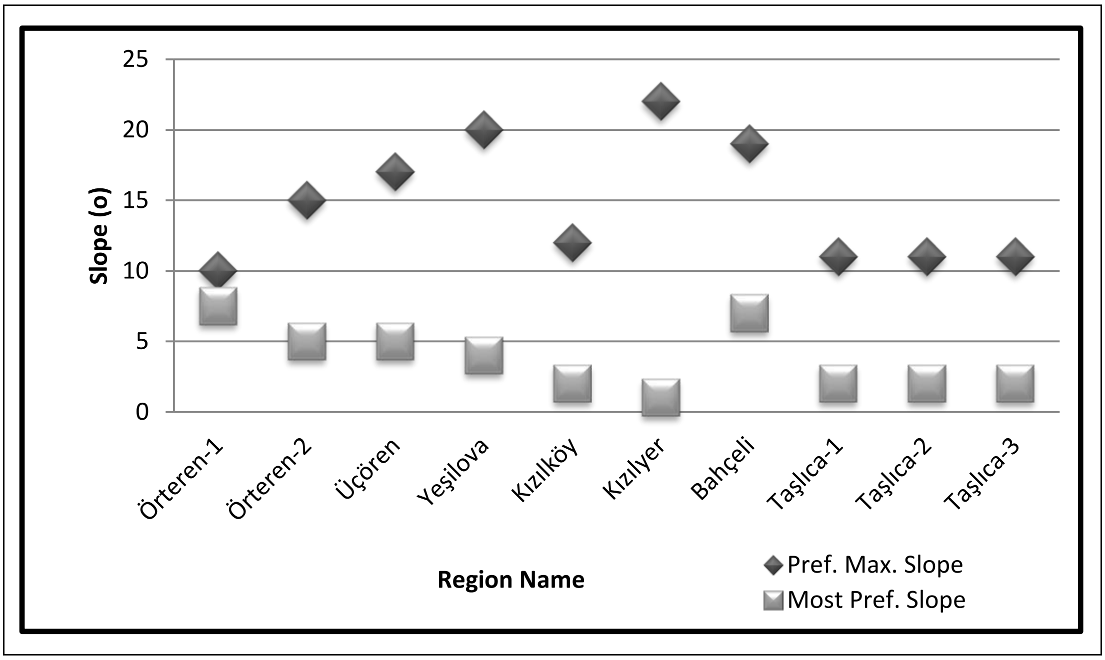


Figure 5.6: Mean slope graph for all regions.

Slopes, preferred for terraces to be constructed are close to each other. It can be observed that various slope values up to 22 degrees were observed at the selected regions. Although the variety of slopes, terraces were mainly built at low slope values. The mean value for the most preferred slope is 3.75 degrees. Values above 22 degrees were avoided for terrace construction. Therefore, terraces were decided to be built at lower elevations and gentle sloped regions of Bozburun.

5.2.3 Lithology and Terraces

In this section the relationship between lithological units and agricultural terraces is interpreted. Iit was observed that agricultural terraces were preferred to be constructed in alluvium and clastic rocks at the field. This is because alluvium and clastic rocks are easy to excavate, whereas limestone is a resistant unit. Table 5.4 provides percentage of areas for each rock unit and terraces in an order from low to high percentages of terraces.

Table 5.4: Percentage of all units and the agricultural terraces in studied regions of Bozburun in an increasing order of agricultural terrace percentage.

Region Name	Alluvium (%)	Clastic (%)	Limestone (%)	Terrace (%)
5) Kızılköy	14.89	2.37	82.74	4.99
2) Örteren-2	6.70	34.09	59.21	21.26
10) Taşlıca-3	9.57	35.16	55.27	38.17
7) Bahçeli	9.81	59.11	31.08	39.29
3) Üçören	12.39	41.09	46.52	40.70
9) Taşlıca-2	8.58	49.39	42.03	41.17
1) Örteren-1	14.70	40.95	44.35	49.14
8) Taşlıca-1	31.40	45.92	22.68	55.83
4) Yeşilova	24.71	46.29	28.92	60.00
6) Kızılyer	11.16	80.07	8.77	75.98
Mean	14.39	43.44	42.16	42.65

The results indicate that the averages of the mean values for ten areas for alluvium, clastic rocks, limestone and terraces are 14.39, 43.44, 42.16 and 42.65, respectively. The data given in Table 5.4 is plotted in Figure 5.7. Following observations can be made based on this table and figure :

- Alluvium has the lowest values almost at all regions. The percentage ranges from 6.70 to 31.40 with a maximum concentration at 10 percentage.
- Clastic rock differs from region to region. Except Kızılköy and Kızılyer regions where it has the lowest and the highest percentages, respectively it has percentage between 30 and 60.
- Limestone is one of the most varying unit, ranging from 8.77 to 82.74 percentage.

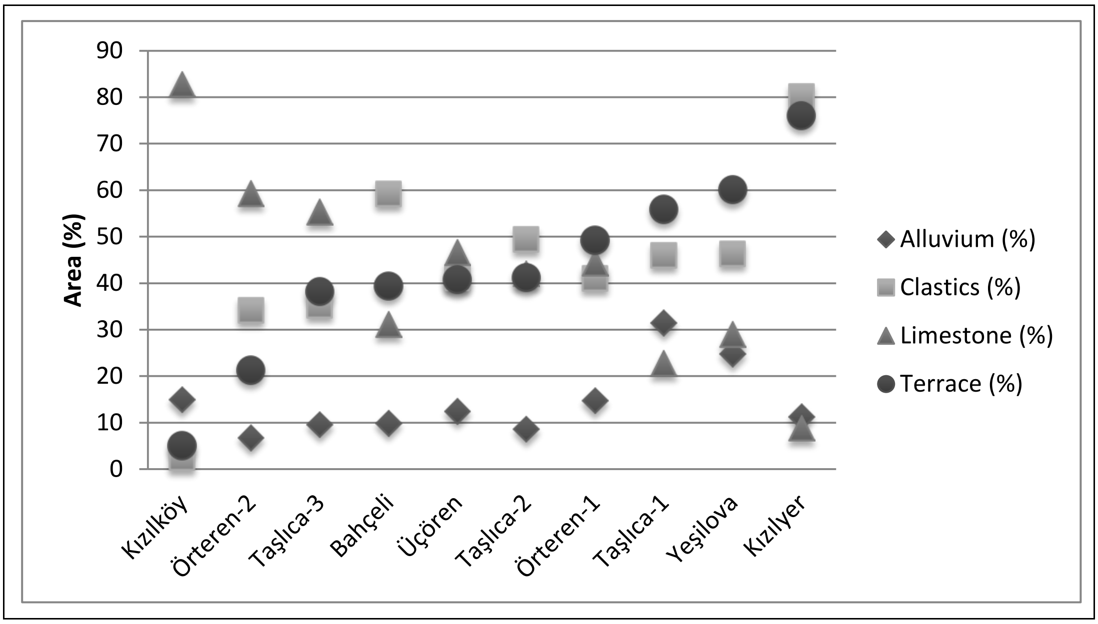


Figure 5.7: Graph of percentages of lithologic units and agricultural terraces. Note the inverse attribute of limestone and terrace percentages.

The relationship between terraces and rock units are plotted separately for detailed interpretation in Figure 5.8. The regions are arranged according to the increasing order of terraces percentages. For each parameter a trend line is added to simplify the interpretation of the graphics.

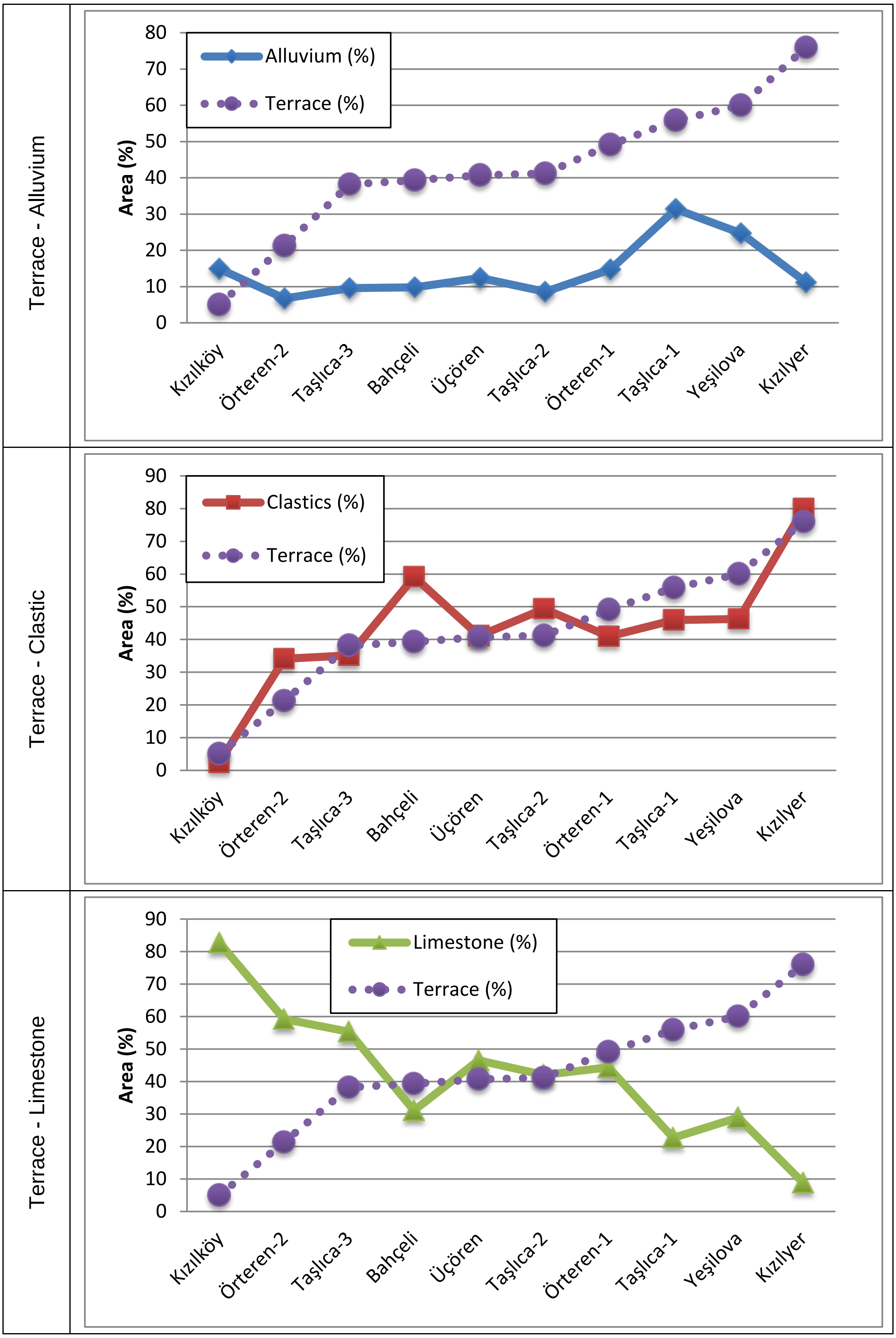


Figure 5.8: Terrace percentage attributes corresponding to lithologic units.

Terrace vs. Alluvium: Both parameters are slightly relational. Except Kızılköy region the percentage of terraces are higher than alluvium. This indicates that terraces are built on alluvium plus other units.

Terrace vs. Clastics: The trend line indicates that they have similar and consistent percentages. This means clastic rocks play an important role on terrace construction. However one cannot claim that terraces are built only ever the clastic rocks.

Terrace vs. Limestone: The chard clearly shows an inversely proportional relationship between limestone and terrace percentages. The percentage of terrace is minimum where the percentage of limestone is maximum vice versa the percentage of terrace is maximum where limestone has a minimum value.

Figure 5.8 clearly indicates that agricultural terraces were highly and inversely influenced by limestone among all lithologic units. That means the limestone is the most avoided rock type for terrace construction.

5.2.4 Integration of All Parameters

In this section all available parameters (elevation, slope, rock units and terrace) are integrated for a final interpretation. Two graphs are created one for elevation and one for slope (Figure 5.9). Since these two graphs have very similar patterns they will be explained together. In both graphs, the units are ordered as alluvium, terrace, clastics and limestone from low to high values. According to this, the limestone has the highest elevation and slope values whereas; alluvium has the lowest elevation and slope values. Clastic rocks are between limestone and alluvium with values closer to that of limestone.

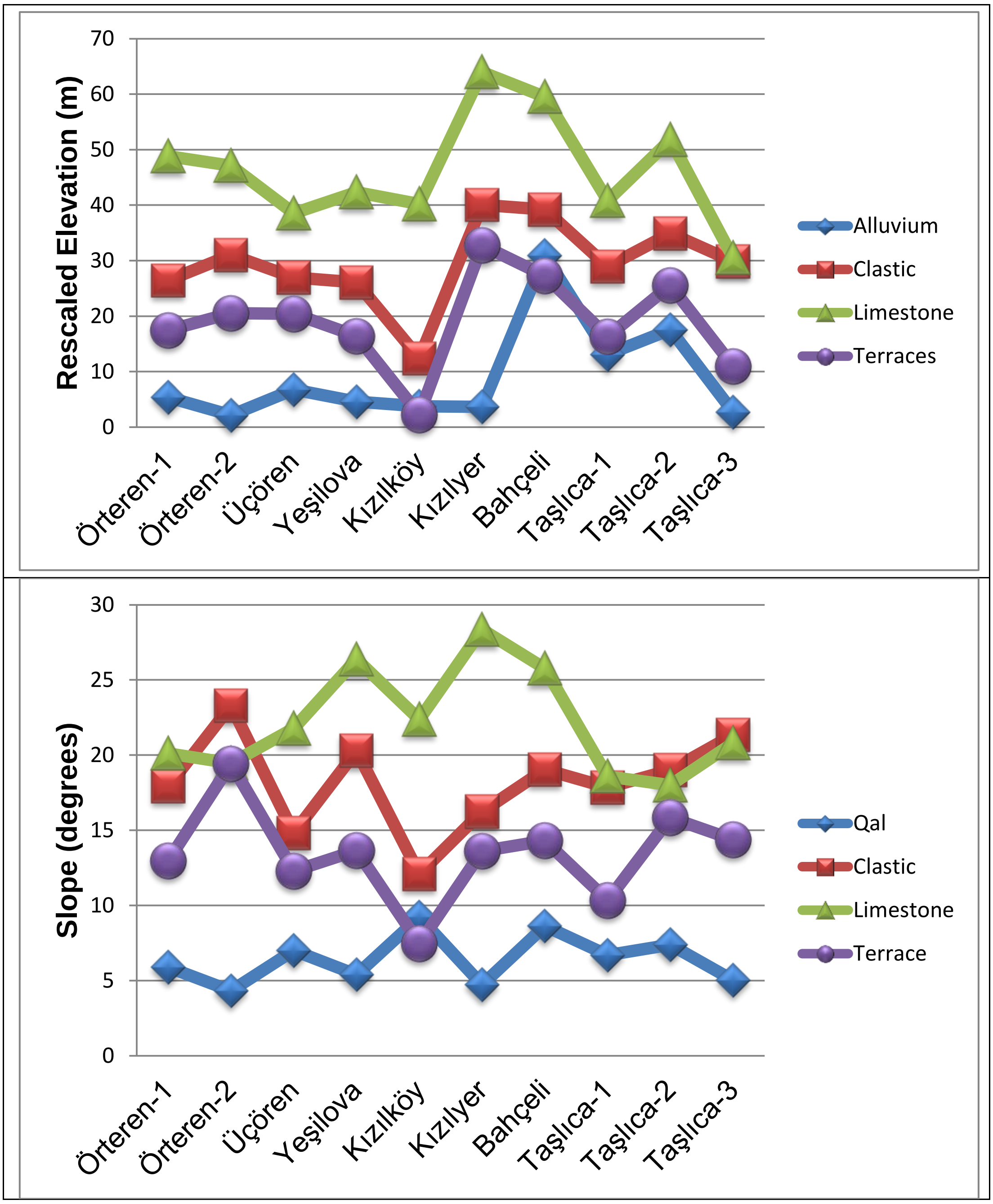


Figure 5.9: Rock types and terraces plotted against topographic values.

Position of terraces in the graphs is between alluvium and clastics indicating a genetic relationship between terraces and them. To quantify the elevation and slope values of terraces it can be concluded that the terraces are built one-fifth of elevation (rescaled to 100) and 7 to 20 degrees (with maximum concentration at 13) of slope.

5.2.5 Effect of Landform

As it is mentioned previously (Chapter 2), three different landforms are proposed for Bozburun area in relation to terrace construction. These landforms were defined as “coastal”,” valley” and “karstic”. Coastal regions are Örteren-2, Yeşilova and Kızılyer. Valley type regions are represented by Üçören and Kızılköy. Examples of karstic type are Örteren-1, Taşlıca-1 and Taşlıca-3. Two of the selected regions (Bahçeli, Taşlıca-2), on the other hand, represent a mixed type between valley and karstic. For this reason all ten regions are not analyzed for their landform type; instead, three typical regions were selected representing each type. These are Kızılyer for coastal, Kızılköy for valley and Taşlıca-3 for karstic type.

Topographic, rock unit and terrace values for each landform are illustrated in Figure 5.10. The figures depict a clear difference in the values for three landform types:

- For coastal landform, all units are distributed in a relatively high range for both rescaled elevation and slope. For example, limestone is above 60 m, whereas, alluvium is lower than 10 m. Clastics and terraces are located in the middle part of the range, clastics having slightly higher values than terraces.
- For valley landform, all units are closer in slope and elevation than in coastal type. Clastics instead of being in the middle, appears closer to alluvium having low values. Terrace has the lowest values among all other landform types both for slope and elevation.
- For Karstic landform, the range between units is minimum. Clastics almost show equal values to limestone for both elevation and slope. Alluvium has lowest, terrace has intermediate values.
- Comparison of the rock unit values in different landform types indicates that : 1) limestone values decrease from coastal to valley to karstic; 2) Clastic rocks have minimum values in valley type; 3) terrace and alluvium have lowest values in both elevation and slope varying in different landforms. Alluvium has constant low elevation values in all landform types.

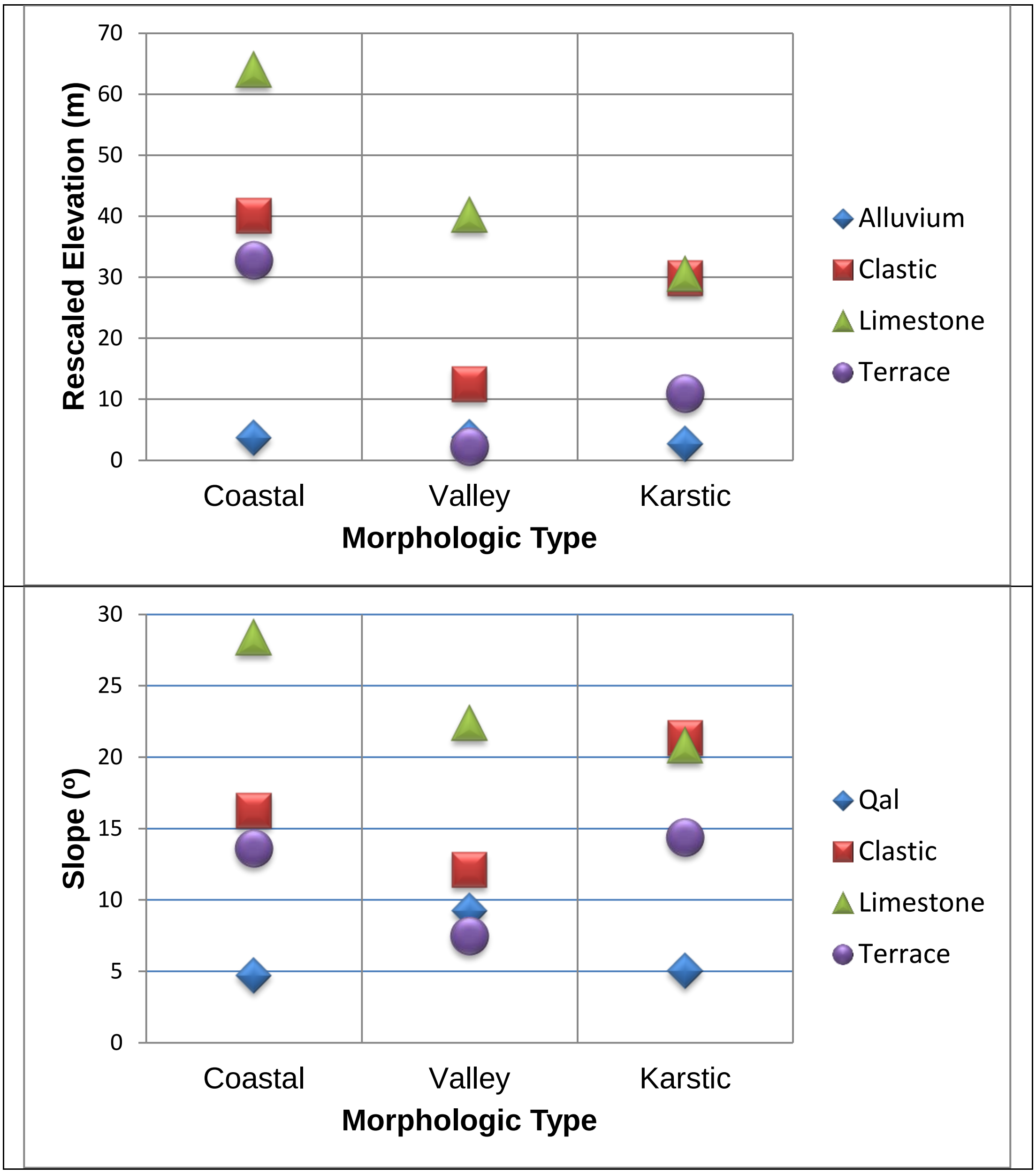


Figure 5.10: Results of the analysis for three landform types.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATION

6.1 Conclusions

This study has been carried out on Bozburun peninsula in ten selected regions. For each region, topographic parameters (slope and elevation), rock units (alluvium, clastics, limestone) and agricultural terraces are quantified to seek a relationship between them. Considering morphologic properties of the regions three landform types were defined.

The main conclusions reached in this study are as follows:

- As far as the elevation and slope parameters are considered, the units are ordered from lowest to highest values as alluvium, terraces, clastics and limestone.
- Agricultural terraces were highly and inversely influenced by limestone among all rock units.
- Terraces are mostly built in alluvium and clastics. Limestone is generally avoided for terrace construction.
- Low elevation and low slope values are preferred for agricultural terracing. The maximum values are calculated as 40 meters of rescaled elevation and 22 degrees for slope. The most preferred slopes value is 3.75 degree.
- Three landform types have different patterns in elevation and slope values of rock types as well as terraces. 1) limestone values decrease from coastal to valley to karstic; 2) Clastic rocks have minimum values in valley type; 3) terrace and alluvium have lowest values in both elevation and slope varying in different landforms. Alluvium has constant low elevation values in all landform types.

6.2 Recommendation

1. The methodology in this study considers investigation of the area in some selected regions. Instead of selecting certain representative regions, another approach (eg. full area) could be applied.

2. Slope value percentages are calculated by the covering area. It should seriously be considered that in a map or satellite image or aerial photo, areas having high slope values will cover much more than it appears in maps or images. Only areas with slope of 0 degree will represent real area and areas having slope value of 90 degree will have no area at maps and images. The low values of slopes even at rough mountains is because of this reason.

3. A study about the typology of terraces could be added to the study.

4. Gathering more detailed data of well coordinates could be used for deriving relationship between wells and three main dataset (lithologic units, topographic properties and terraces).

5. Since terraces were constructed for agricultural purposes, availability of water plays a main role for terraces locations. During the field study, many wells in geologically

suitable places and cisterns at higher elevations were observed. Water need was supplied by these wells and cisterns. Although, the function of the cistern is totally different than the well they can also be considered in analysis.

6. This study should be considered as a first step from earth science perspective. A multidisciplinary approach, supported by various disciplines, can contribute more to the evaluation of the terrace distribution.

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