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Detailed soil mapping and classification study for sustainable agricultural land management; Samsun-Vezirköprü example

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Abstract

This study aims to determine basic physico-chemical soil properties, make a classification, create a soil database, and generate a digital soil map for agricultural areas that cover about 111 km^2 ha and includes 18 villages located in Vezirköprü district in the Samsun province. The average annual temperature is 12.52 °C and the annual average rainfall is 518 mm. According to the Newhall simulation model, soil temperature and moisture regimes are *Mesic* and *Typic Xeric*, respectively. Field observations and investigation of topographical, geological, and geomorphological maps, 16 soil pedons were described. Soil samples were taken from each pedon based on the genetic horizon and laboratory analyzes were performed. The detailed field study was carried out by considering the grid method and auger examination. The determination and description of 16 soil series were made by evaluating the findings of analyses and field research. Due to their quick pedological processes, six of them were classified as Entisol, six as Inceptisol, three as Verisol, and one as Alfisol. Vertisols cover about 35.63% of the total area followed by Inceptisols at 22.3%, Entisols at 22.3%, and Alfisol at 13.58%. As for FAO-WRB classification system, soils were classified as Vertisol, Cambisol, Leptosol, and Luvisol. In addition, whereas the Bakçekonak series has the largest area (15.02%), the Yürükçal series was determined as the smallest land (1.65%) in the study area.

Introduction

Throughout history, the production of nutrients for human nutrition, the creation of raw materials for industry, and the fact that it is a large employment area have made agriculture important in every period. The land, which is an indispensable element of agriculture, has been divided for centuries as a result of human intervention, loses its productivity due to its misuse, and is exploited as a continuous production material to feed the existing population. Rapid population growth restricts access to basic food products and complicates access to safe food, paving the way for global food crises.

It is of great importance to prepare soil maps that combine physical and chemical properties in a database to ensure the sustainability of the soil, which takes centuries to form in its natural state. Misuses of irrigation, fertilizer, and other agricultural practices are brought on by failing to take into account the physical and chemical characteristics of soils (Arslan et al., 2018). It has a negative effect on the productivity of soils by creating erosion, barrenness, salinization, and ultimately soil pollution.

With the effect of the increasing population, the division of agricultural lands by inheritance, the fragmentation of agricultural lands, and the intensive use of chemicals to meet the needs of the population in existing lands and to obtain high efficiency from the unit area, soil fatigue, and pollution occur. As a result of unconscious agricultural practices (fertilization, irrigation, etc.), wrong soil management, erosion, barrenness, unintended land use, and soil pollution, the borders of our agricultural lands are narrowing day by day, and their physical, chemical, and biological properties are destroyed. and their quality decreases accordingly. Finding out the soil's physical, chemical, and biological characteristics will make it easier to choose the production models to use and to cultivate the chosen goods.

Digital soil maps are based on very detailed and good coverage of point-based soil profile data together with large-scale data with appropriate resolution (Stoorvogel et al., 2017). The use of morphometric approaches in soils sampled based on the genetic horizon makes it possible to determine the distribution areas in terms of managing the soils following their characteristics. For this reason, with the help of mapping units created for soil survey and mapping purposes, drawing the boundaries of soils that differ in terms of physical and chemical properties provides convenience in the management of soils.

Formerly during the Ministry of Agriculture and Rural Affairs, 30 large agricultural basins were determined, and in the next process under the name of the Ministry of Food, Agriculture and Livestock. Finally, the Ministry of Agriculture and Forestry of the Republic of Turkey, these basins were reduced to the district level and included in the scope of support for the basin-based production model in terms of agricultural products. For the yield and quality of the products supported within the basin borders to be at the desired level, the information to be produced for the soil should be up-to-date and detailed. Agricultural efficiency and productivity are concepts that are often confused. Plant nutrients, which are a reflection of the physical, chemical, and biological values of the soil, are the most basic element that creates productivity and loses their current properties to a certain extent with their exploitation by plants. However, in addition to the physical and chemical properties of the soil, the depth, stoniness, and erosion tendencies, as well as the geological and topographic structure also have a significant effect on the productivity of the soil. According to Heidari et al. (2022), it is possible to have detailed information about the physical, chemical, and weathering properties of soils by classifying them at different taxonomic levels.

In addition to the climate, soil, and plant existence for any basin, revealing the hydrological characteristics is also important in terms of determining the needs of the people in terms of socio-economic terms and the management of natural resources (Dengiz et al., 2015; Coşkun and Dengiz, 2016). Soil maps have the most important place for the sustainable management of soils and the implementation of correct management plans. Produced soil maps and accompanying reports are the most basic material that decision-makers can refer to, with the feature of creating a database in terms of agriculture, forest, and pasture uses, as well as different engineering applications and protection of natural resources (Dengiz and Sarıoğlu, 2011). Soil maps are an important material in terms of the use and management of existing resources by their purpose (Coşkun and Dengiz, 2016). Soil survey and mapping studies carried out in detail not only provide convenience in determining the problems related to soils and propose solutions but also provide an opportunity for sustainable soil management.

The land protection and land use law numbered 5403 adopted in 2005, was enacted by taking it under protection developing protect and develop to protect and develop soil resources and classifying agricultural lands. The lack of a classification of land and soil resources within the scope of the same law by scientific principles in field conditions creates problems in terms of proper use and management of soils. According to Bayramin et al. (2013), one of the most fundamental issues is the lack of adequate soil surveys and mapping studies with detailed information across our nation. According to Kurşun and Dengiz (2018), the information and data on land resources could not be recorded systematically, and the problems experienced during the evaluation and transformation of the recorded data into information were seen as a major deficiency in the country.

Soil maps produced as a result of detailed soil surveys and mapping studies and related reports constitute an important soil database for users. With this study, in the light of detailed numerical and spatial data and information obtained from the area, ensuring the sustainability of the lands and soils in the future, infrastructure, and scientific studies (land consolidation, watershed improvement, erosion, irrigation-drainage planning, land use planning, etc.) constitute an important resource. The study includes determining the basic soil properties, creating a soil database, mapping and classifying the lands covering 111 km^2 of 16 villages within the borders of the Vezirköprü district of Samsun province with the help of Geographical Information Systems.

Material and Method

General characteristics of the study area

The study area is located within the borders of the Vezirköprü district of Samsun province, which is located in the Central Black Sea Region, between 41º 00' - 41º 19' north latitudes and 35º 01'-35º 48' east longitudes. Vezirköprü district, with an area of 1713 km², is 115 km away from Samsun province (Figure 1). The district is surrounded by Boyabat and Osmancık in the west, Havza in the east, Gümüşhacıköy and Merzifon districts in the south, while Alaçam and Bafra districts are located in the north (Anonymous, 2023a). The study area, which is on the southeastern border of the district, includes Ağcaalan, Aydoğdu, Bahçekonak, Bayramköy, Boğazkoru, Çakırtaş, Çalköy, Çekmeden, Esenyurt, Güder, Kızılcaören, Kületek, Meşeli, Pazarcı, Tekekıranı, Yağcı, Yeniçelik, Yürükçal neighborhoods.

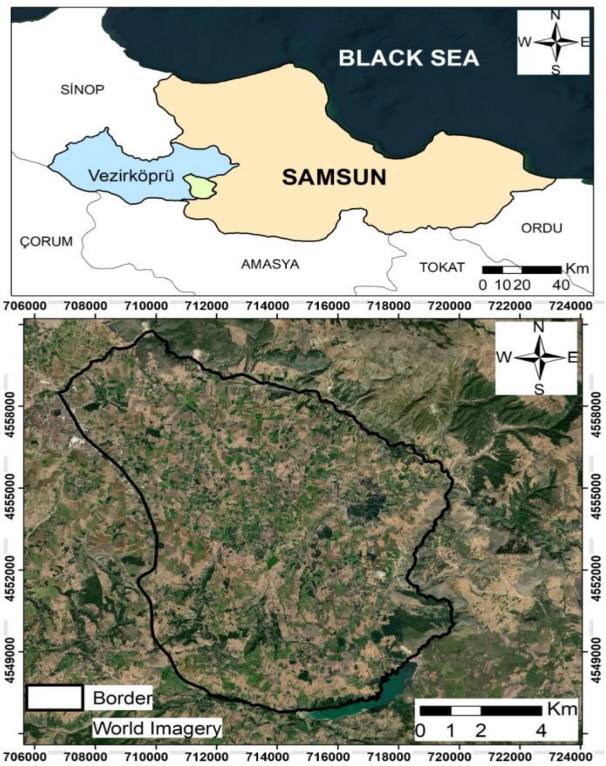

Figure 1. Study area location map

The study area is approximately 111 km^2, and its altitude varies between 240-750 m above sea level. The elevation, slope, and digital elevation model maps of the study area are shown in Figure 2, respectively. Although there are areas with steep slopes of more than 30% in the area's northeastern and southern parts, the majority of them are nearly flat, light, and medium slopes (0-12%) suitable for cultivated agriculture. Also, the majority of the area has north, northeast, and southwest aspects.

Vezirköprü is distinguished between the humid temperate climate type of the coastal zone and the continental climate type of the interior parts in terms of climatic conditions, with the unique thermal and humidity characteristics of the transition zone; winters are colder than the coast and hotter in summers (August monthly average temperature is 22.3ºC). According to long annual averages, the annual temperature is 12.5 °C and, the annual precipitation amount is 518 mm, and it is seen that precipitation in the form of snow is also effective with the increase in precipitation in the surrounding high parts. The distribution of precipitation according to the seasons throughout the year shows a distinctive spring feature (35.5%); summer precipitation reaches 18.6%, and summer drought is effective as a result of increased evaporation (Anonymous, 2023b). In addition, soil and moisture regimes were determined with the help of the Newhall simulation model (Van Wambeke, 2000) of the soils distributed within the boundaries of the Vezirköprü district. The long-term average temperature and precipitation data of Vezirköprü station were taken into account. The soil temperature regime in the determined area was Mesic and the soil moisture regime was Typic Xeric in the Xeric subgroup.

Agricultural lands, which have a share of 72.43% with an area of 8149 ha in the total area, cover the largest area. Agricultural areas are followed by forests with a share of 1353 ha and 12.03%. Non-agricultural lands defined as rocky, bare land, roads, settlements, grasslands and forests within the area cover an area of 591 hectares. The share of non-agricultural lands in the total area is 5.25%.

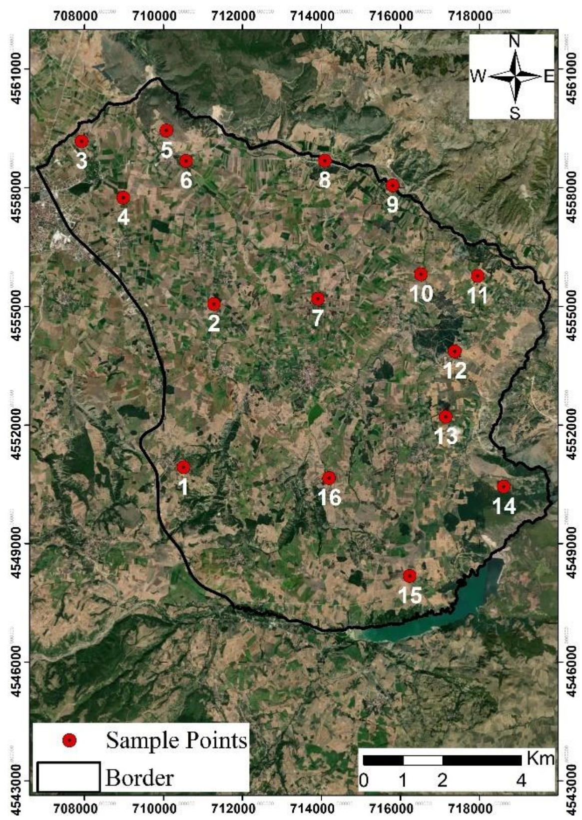

Figure 3. Profile locations showing distribution in the area

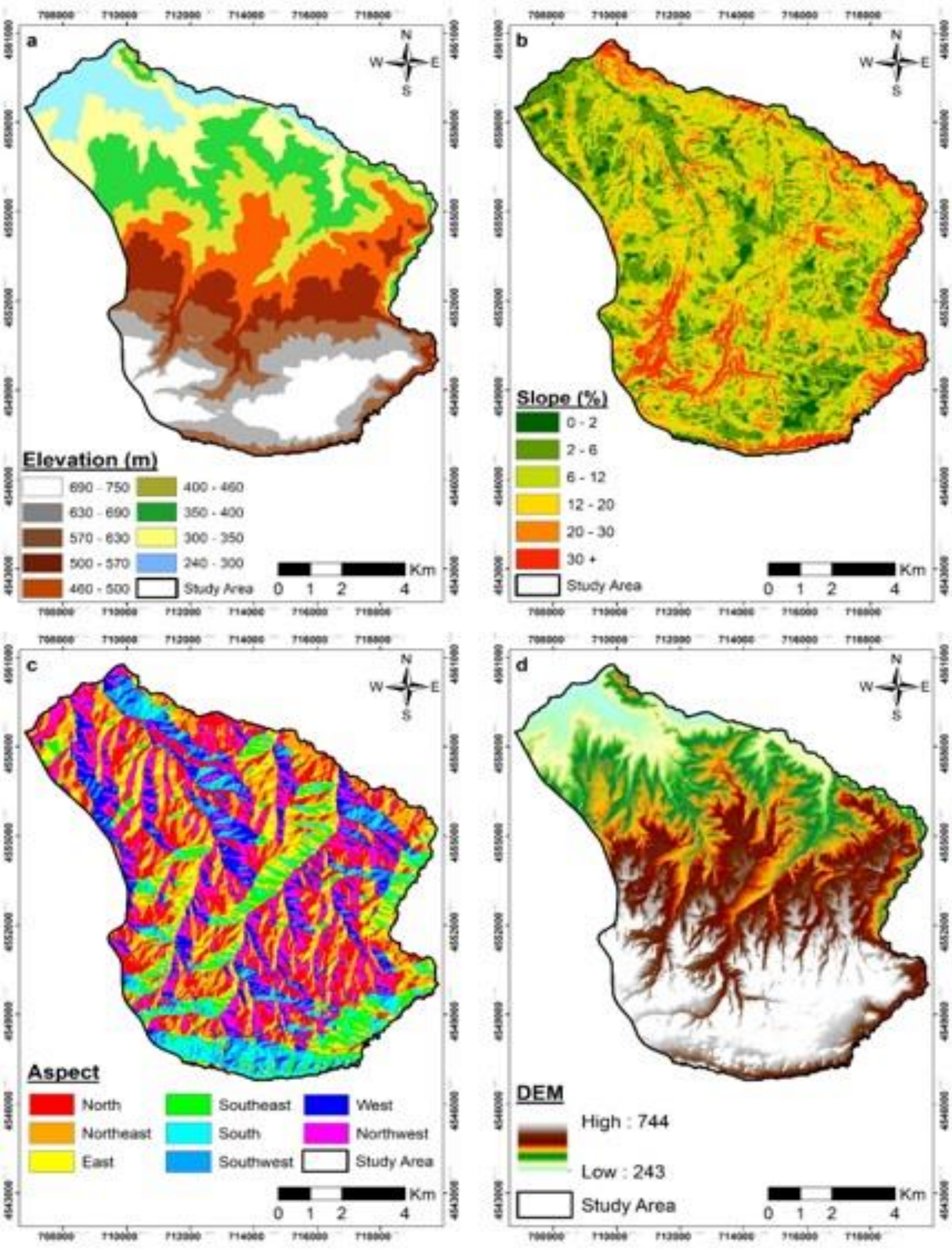

Figure 2. Study area elevation (a), slope (b) aspect (c) and DEM (d) maps

Method

In addition to the determination of the basic soil properties of the soils in the study area and the new soil classification system, their definitions according to the WRB classification system were carried out using 1/25.000 scale topographic maps and satellite images. Thanks to the soil database created by determining the series (physical, chemical, productivity, and morphological) properties of the soils of the study area and classifying them according to soil taxonomy, maps showing the distribution area and spatial status of the soils with different characters distributed in the area were obtained. This process; office, field, laboratory, and reporting studies were carried out in four stages. In this context, first of all, besides determining the vegetation pattern and land use in the area, different slope groups, physiographic units, relief, aspect, and landforms spreading in the area were determined by using DEM.

By combining the determined landform and land cover with numerical geology data, the soil series formed on different parent materials and different physiography were determined, and a draft soil map was created. In the field study, which is the second stage, the coordinates of the soil profile locations were recorded on the draft soil series with different characteristics determined as a result of the previous office work, the location of the profile pits was determined using the GPS device and profile pits were dug in the field.

Soil samples were taken from 16 different soil profiles based on the genetic horizon since 2 of 18 different soil profiles found in the study area showed similar characteristics. Soil Survey Staff (1993 and 1999) were used for the criteria, sampling, and classification to be considered to examine the morphological characteristics of the soils in the field. In the soil samples taken; body Bouyoucous (1962), field capacity, wilting point and available water content Richards (1954), bulk weight Blake and Hartge (1986), exchangeable cations Rhoades (1982), lime content Çağlar (1958), soil reaction (pH), electrical conductivity, salt content, organic matter were analyzed within the framework of the principles reported by Jackson (1958). In the last stage of the study, necessary corrections were made by taking into account the analysis results of soils with different characteristics, and a 1:25,000 scale basic soil map of the basin was prepared. In the study, probing was carried out every 400 m by using the grid system, especially in the finalization of the soil boundaries. Soil series and their phases were used as the mapping unit in the detailed soil survey and mapping studies. The Soil Survey Staff 1993 was also used for the factors such as slope, drainage, stoniness, rockiness, depth, and erosion observed in the separation of the soils into phases. ArcMap 10.8.2, a Geographical Information System Software, was used for digitizing 1:25,000 scale topographic maps, drawing new maps, and preparing soil databases.

Results and Discussion

Some physical, chemical, and morphological properties of soil series

The physical and chemical analysis results of the soil series in the study area are given in Table 1 and Table 2. The Ağcaalan series, covering an area of 8.71% of the total area, the series soils are in the south of the basin and their heights relative to sea level are between 460-630 m. Soils with shallow depth are formed on a mixture of marl and andesite parent material. The texture of the surface soils is clayey and their natural drainage is moderate. While their organic matter content is at a moderate level of 1.62%, their pH is slightly acidic at 6.13. Although they have a clay structure due to their compaction in the surface soils due to field traffic, their bulk density is 1.53 gr/cm^3.

The soils belonging to the Aydoğdu aşağısı series are located in the north of Aydoğdu village and their heights vary between 350-460 m above sea level. It has been determined that the surface soils of this soil series at medium depth are clayey in heavy texture class (61% clay content), while the clay content in the subsurface horizons decreases to 29%. The organic matter content of the series soils is quite low (0.66%), and this rate decreases further towards the depths. While the lime content is 21.81% on the surface, it decreases to 10.91% in the sub-surface horizon, then increases to 15.35% again, exhibiting a wavy appearance. This situation also causes color changes, especially in the horizons formed in the profile, and the color which is 10YR 4/3 on the surface turns into 5 Y 4/2. The pH of the soil varies a little between 8.02 and 8.46, and it is moderately alkaline. In addition, the soils do not have any problems in terms of salinity.

Aydoğdu üzeri series is located in the south of Aydoğdu village, and the soils of this series vary between 400-500 m above sea level. These soils, formed on marl parent material, have medium depth. In soils dominated by clayey texture throughout the profile, the organic matter content is 4.03% at the surface, while it drops to 1.11% under the surface. In addition, the lime content is 13.09% in the surface soils and 48.63% below the surface. No problems were determined in terms of the salinity of the soils in this series soils.

The Boğazkoru series are soils within the steep lands in the southeastern part of the basin and their heights vary between 500-750 m. They are deep soils with clayey textures throughout the profile. The pH of this series of soils varies between 7.33 and 8.13. While the organic matter content is 2.28% on the surface, it decreases by 0.82% towards the deep. In addition, while the surface soils are slightly calcareous in terms of lime content, lime increases with deep washing and turns into a calcareous structure.

Bayramköy series are deep soils with clayey texture, distributed in the southern part of the study area. The clay content increases towards the depths and reaches over 60%. Accordingly, the amount of available water decreases along the profile. While the organic matter on the surface is very rich at 4.46%, this rate decreases towards the depths and becomes very poor at 0.29%. In these soils formed on the marl parent material, while the lime content is 0.81% on the surface without lime, it increases under the surface with the effect of the parent material and becomes very calcareous.

Soils belonging to the Güder aşağısı series are located on topography varying from steep lands with steep slopes to lands with a slight slope of 2-6%. They are deep soils with clayey textures throughout the profile. While the organic matter content is 1.59% on the surface, it decreases to 0.02% under the surface. The lime content of these soils, whose surface is less calcareous, increases towards the depths and becomes very calcareous. The soil reactions of this series of soils range from slightly alkaline to moderately alkaline, and their pH values are between 7.97-8.23.

The Meşeli series spreads in the steep lands in the southwestern part of the basin and areas with heights varying between 450 and 750 m. The soils of this series, which were formed on calcareous parent material, are deep and clayey texture is dominant throughout the profile. Although the soils are formed on the calcareous parent material, the surface soils are lime-free, especially due to leaching. While the soils have a slightly

Table 1. Some chemical analysis results of soil series

Horizon	Depth (cm)	pH	EC (dS.m-1)	Lime Content (%)	OM (%)	KDK (cmol kg-1)	Exchangeable Cations, cmol kg-1			
							Na^+	K^+	Ca^{++}	Mg^{++}
Ağcaalan										
A	0-30	6.13	1.16	0.81	1.62	47.3	0.33	0.24	27.20	3.85
Aydoğdu aşağısı										
Ap	0-20	8.19	0.23	21.81	0.66	46.2	0.30	0.42	60.30	3.15
Bw	20-58	8.02	0.40	10.91	0.67	49.5	0.34	0.50	57.85	7.25
Ck	58+	8.46	0.21	15.35	0.20	25.6	0.33	0.22	43.90	8.05
Aydoğdu üzeri										
A1	0-20	7.85	0.50	13.09	4.03	73.7	0.33	1.05	64.50	6.70
A2	20-41	7.96	0.29	25.29	1.93	58.0	0.16	0.35	66.85	4.15
AC	41-60	7.63	1.67	48.63	1.11	39.6	0.23	0.29	66.45	4.55
Bahçekonak										
Ap	0-20	8.02	0.28	11.15	1.68	68.9	0.21	0.92	67.30	3.65
A2	20-41	8.06	0.27	12.20	1.12	72.3	0.23	0.59	70.25	4.40
Bt	41-77	8.10	0.31	15.27	0.50	65.8	0.20	0.64	68.80	3.65
Bk	77-136	8.30	0.31	17.13	0.18	71.0	0.95	0.40	62.90	15.75
Ck	136+	8.21	0.35	10.26	0.12	58.5	0.42	0.42	56.80	16.45
Bayramköy										
A	0-30	7.06	0.45	0.81	4.46	62.5	0.23	0.93	37.50	9.15
Bt1	30-54	7.75	0.35	0.81	1.34	62.6	0.23	0.38	45.65	8.75
Bt2	54-95	7.90	0.43	8.00	0.90	58.7	0.30	0.39	57.90	10.95
Ck	95+	8.17	1.99	23.18	0.29	39.2	0.54	0.16	61.75	4.30
Boğazkoru										
Ap	0-17	7.33	0.42	0.89	2.28	74.2	0.22	0.83	48.95	6.20
A2	17-43	7.61	0.33	0.73	0.82	60.7	0.20	0.63	45.10	10.65
Bss1	43-75	7.92	0.31	1.86	1.36	62.9	0.24	0.53	54.20	15.60
Bss2	75-106	8.13	0.27	8.64	1.21	58.0	0.30	0.49	63.80	6.15
Çakırtaş										
Ap	0-24	7.89	0.28	16.32	2.34	54.7	0.26	0.76	28.40	34.75
Bw1	24-58	7.96	0.29	6.62	1.81	56.4	0.20	1.31	33.15	27.45
Bk	58-91	8.21	0.25	25.53	0.59	52.2	0.36	0.32	32.85	34.05
BC	91-127	8.27	0.26	33.93	0.87	50.5	0.28	0.26	32.85	35.65
Ck	127+	8.35	0.26	45.72	0.14	42.9	0.40	0.21	28.40	34.45
Çalköy										
Ap	0-25	8.15	0.26	10.83	1.21	34.0	0.37	0.91	21.60	30.45
Ad	25-55	8.15	0.29	12.84	1.27	43.6	0.68	0.57	23.75	26.25
C1	55-90	8.03	0.73	14.54	0.79	58.1	1.10	0.49	25.45	40.30
C2k	90-123	7.99	1.46	15.35	0.26	44.5	1.96	0.39	31.95	34.90
2C	123+	8.14	1.18	14.22	0.24	31.3	1.79	0.26	43.45	11.20
Çalköy aşağısı										
A	0-20	8.23	0.24	27.47	1.29	37.1	0.39	0.24	30.10	29.85
C	20-56	8.58	0.30	14.14	0.50	37.9	0.41	0.19	24.20	38.80
Çekmeden										
Ap	0-17	7.95	0.28	2.75	2.23	68.1	0.34	1.38	35.45	18.15
A2	17-40	7.97	0.03	3.15	1.59	68.8	0.36	0.56	31.95	28.10
Bk1	40-83	8.09	0.30	3.42	1.04	74.6	0.25	0.53	34.35	24.75
Bk2	83-137	8.17	0.32	7.19	1.18	69.3	0.38	0.45	44.15	25.55
Ck	137+	7.95	0.31	10.02	0.59	75.1	0.53	0.39	46.80	24.55
Güder aşağısı										
Ap	0-20	7.97	0.23	3.64	1.59	67.1	0.36	0.72	56.10	6.80
Bw	20-75	7.98	0.31	5.57	1.03	72.3	0.35	0.53	66.45	5.40
C1k	75-132	8.23	0.28	16.08	0.50	53.9	0.27	0.22	67.35	11.20
C2k	132+	8.05	0.31	17.69	0.02	52.0	0.29	0.35	59.00	2.00
Kületek										
A	0-20	8.05	0.21	9.29	0.29	16.0	0.35	0.37	34.00	0.95
C1	20-40	8.24	0.24	8.89	0.07	11.0	0.30	0.17	27.15	1.85
Meşeli										
Ap	0-27	6.30	0.14	0.89	2.80	80.4	0.23	0.51	30.35	11.30
Bss1	27-72	7.43	0.34	0.73	0.98	65.7	0.36	0.28	39.10	3.90

Bss2	72-116	7.89	0.25	1.86	0.68	66.3	0.27	0.38	56.45	7.75
Ck	116+	8.17	0.29	41.85	0.76	66.2	0.20	0.22	52.75	8.80
Tekekıranı										
Ap	0-16	7.92	0.33	15.43	1.74	53.8	0.27	0.46	61.00	4.75
Bk	16-52	8.11	0.29	21.08	0.39	42.5	0.29	0.28	57.20	3.70
C1k	52-80	8.07	0.31	17.13	0.45	36.7	0.38	0.35	56.70	6.50
C2k	80-105	8.27	0.28	23.59	0.49	51.4	0.33	0.27	65.15	3.90
C3k	105+	8.02	0.38	9.61	0.19	45.4	0.30	0.62	60.10	2.80
Yeşilada										
Ap	0-24	7.95	0.26	13.25	2.22	24.6	0.33	1.09	17.35	31.50
Bw	24-52	8.20	0.24	13.65	1.17	32.6	0.25	0.43	24.20	24.05
Bw2	52-70	8.26	0.26	13.98	1.31	27.4	0.33	0.42	23.30	28.05
Ck	70+	8.30	0.26	14.95	0.30	19.0	0.58	0.26	29.50	24.65
Yürükçal										
A	0-29	7.72	0.35	11.71	3.32	41.2	0.27	0.80	49.65	4.20
C1	29-70	8.20	0.25	12.12	1.27	32.6	0.18	0.58	45.55	11.65
C2	70+	8.21	0.30	12.60	1.74	41.8	0.52	0.47	48.00	15.30

acid reaction on the surface, they turn slightly alkaline, especially with the increase of basic cations and lime towards the deep, therefore pH values show that they vary between 6.30 and 8.17. While the organic matter is 2.80% on the surface, this value decreases towards the depths and decreases to 0.68%. Soils are problem-free in terms of salinity and there is no erosion problem.

The Çekmeden series, the soils of this series, most of which have mild to moderate sloping lands, are deep soils formed on colluvial parent material. The pH values of the soils with clayey texture throughout the profile vary between 7.95 and 8.17. While the organic matter is 2.23% on the surface, it decreases to 1.59%, 1.04%, 1.18% in the sub-surface horizons, and 0.59% in the parent material, respectively. While the surface soil was calcareous with 2.75%, it was determined to be moderately calcareous with 10.02% in the subsurface horizon. Soils are problem-free in terms of salinity and there is no erosion problem.

Yeşilada series is located in the north of the study area and they are medium-depth soils formed on colluvial parent material as in the Çekmeden series. The soils of this series are flat and nearly flat inclined, varying between 240 and 300 m above sea level. The body is clay loam throughout the profile. The pH of the soils varies between 7.95 and 8.30. While the organic matter is 2.22% on the surface, it decreases towards the depths and this value decreases to 0.30%. Lime content varies between 13.25% and 14.95%, and it has a medium calcareous structure. In surface and subsurface genetic horizons, the bulk density does not show much variation but varies between 1.41 and 1.51 gr/cm^3. Soils are problem-free in terms of salinity and there is no erosion problem.

Çakırtaş series are deep soils with a slight slope, formed on calcareous parent material. It is seen that clay dominates the body throughout the profile. The pH values of the soils increase towards the depths and are seen to vary between 7.89 and 8.35. While the organic matter is 2.34% on the surface, this value decreases towards the depths and decreases to 0.14%. There is no salinity problem in the profile. As a result of agricultural activities, the surface soils have a somewhat high bulk density (1.36 gr/cm^3) and this value decreases towards the depths (1.23 gr/cm^3).

Soils belonging to the Çalköy series are deep soils formed on alluvial land. While the soil texture is loamy on the surface, clay is the dominant texture towards the depths. The pH of the soils varies between 8.15 and 7.99. While the organic matter is 1.21% at the surface, it decreases to 0.24% at the depths. Lime content varies between 10.83% and 15.35%, and it is in the medium lime class. On the other hand, Çalköy Lower series, these soils formed on steep lands have a slope of more than 30%. The land cover is mostly in the structure of maquis and covered with forest cover, these soils have a depth of 0-20 cm and show shallow characteristics. While the soil reaction varies between 8.23 and 8.58, it is seen that the organic matter is 1.29% on the surface and down to 0.50% on the C horizon.

Bahçekonak series consists of mostly flat and nearly flat lands in the middle part of the study area and medium-sloping lands with 6-12% slope. The pH contents of the soils dominated by clay throughout the profile show moderate alkalinity with 8.02 to 8.30. Their organic matter varies between 1.68% and 0.12%. Lime content ranges from 11.15% on the surface to the moderately calcareous class, up to 17.13% in the profile, and the highly calcareous class.

The Yürükçal series soils are located in the northern part of the study area and have medium-depth soils dominated by clay throughout the profile. The organic matter content of the soils, whose altitudes vary between 300-350 m above sea level, is rich with 3.32% at the surface, while it decreases to 1.27% under the surface. The lime content of the soils varies between 11.71% and 12.60%. Soil reaction is between 7.72 and 8.21.

These soils formed on the Kületek series alluvial gravel deposits are of medium depth. Organic matter content is very low. The lime content of these soils, which do not have salinity problems, is defined as

Table 2. Some physical analysis results of soil series

Horizon	Depth (cm)	Colour Dry, Moist	Texture (%)				Bulk Density gr/cm^3	Field Capacity (%)	Wilting Point (%)	Useful Water (%)
			Clay	Silt	Sand	Class				
Ağcaalan										
A	0-30	10 YR 3/3, 10 YR 3/3	41.07	41.93	17.00	C	1.53	32.94	21.02	11.92
Aydoğdu aşağısı										
Ap	0-20	10 YR 4/3, 10 YR 3/3	61.29	24.78	13.93	C	1.58	33.30	21.56	11.74
Bw	20-58	10 YR 4/2, 10 YR 4/2	28.94	19.61	51.45	SiCL	1.47	35.80	24.23	11.57
Ck	58+	5 Y 4/2, 5 Y 5/2	52.46	38.75	8.79	C	1.41	20.35	13.58	6.78
Aydoğdu üzeri										
A1	0-20	10 YR 3/3, 10 YR 3/4	44.73	31.15	24.12	C	1.34	39.74	32.37	7.38
A2	20-41	10 YR 3/3, 10 YR 3/4	55.69	15.64	28.68	C	1.26	36.58	28.20	8.38
AC	41-60	10 YR 4/3, 10 YR 4/3	42.57	15.16	42.26	C	1.34	27.45	19.43	8.02
Bahçekonak										
Ap	0-20	10 YR 3/3, 10 YR 3/3	53.98	18.10	27.92	C	1.28	47.14	29.96	17.18
Bss1	20-41	10 YR 3/3, 10 YR 3/3	63.52	8.15	28.33	C	1.24	43.03	29.91	13.12
Bss2	41-77	10 YR 3/3, 10 YR 3/4	60.26	18.72	21.02	C	1.25	47.99	30.79	17.20
Bssk	77-136	10 YR 3/3, 10 YR 3/4	69.72	9.03	21.25	C	1.20	41.02	27.49	13.53
Ck	136+	10 YR 4/4, 10 YR 3/3	60.59	13.95	25.46	C	1.22	43.13	27.86	15.27
Bayramköy										
A	0-30	10 YR 3/2, 10 YR 3/2	51.20	22.89	25.91	C	1.29	42.43	31.17	11.26
Bt1	30-54	10 YR 3/2, 10 YR 3/2	57.91	18.39	23.70	C	1.26	43.88	29.40	14.48
Bt2	54-95	10 YR 3/2, 10 YR 3/2	63.93	18.72	17.35	C	1.27	40.75	26.36	14.39
Ck	95+	10 YR 4/3, 10 YR 4/4	62.73	15.92	21.35	C	1.25	35.52	25.03	10.49
Boğazkoru										
Ap	0-17	10 YR 3/3, 10 YR 3/4	55.58	29.85	14.57	C	1.34	42.72	31.60	11.12
A2	17-43	10 YR 3/3, 10 YR 3/3	67.03	15.90	17.07	C	1.27	44.90	31.04	13.86
Bss1	43-75	10 YR 3/2, 10 YR 3/2	69.55	17.59	12.87	C	1.27	47.64	29.36	18.27
Bss2	75-106	10 YR 3/3, 10 YR 3/4	67.17	15.09	17.75	C	1.26	41.86	28.32	13.54
Çakırtaş										
Ap	0-24	10 YR 3/3, 10 YR 3/4	47.17	28.03	24.80	C	1.36	35.28	22.84	12.44
Bw1	24-58	10 YR 3/3, 10 YR 3/4	50.03	27.33	22.64	C	1.35	41.31	26.16	15.16
Bk	58-91	10 YR 3/3, 10 YR 3/4	60.27	21.55	18.18	C	1.27	33.04	21.98	11.06
Bc	91-127	10 YR 4/4, 10 YR 4/5	63.67	17.95	18.38	C	1.25	31.99	21.18	10.81
Ck	127+	10 YR 5/4, 10 YR 5/5	69.35	14.70	15.95	C	1.23	29.23	19.14	10.09

Çalköy										
Ap	0-25	10 YR 4/4, 10 YR 3/4	25.71	39.36	34.92	L	1.31	26.74	15.97	10.77
Ad	25-55	10 YR 3/3, 10 YR 3/4	54.44	20.77	24.78	C	1.50	35.54	21.30	14.24
C1	55-90	10 YR 3/3, 10 YR 3/4	58.74	18.80	22.45	C	1.26	34.72	23.21	11.51
C2k	90-123	10 YR 3/3, 10 YR 3/4	47.59	27.99	24.42	C	1.39	31.18	21.05	10.13
2C	123+	10 YR 4/3, 10 YR 4/4	33.77	37.93	28.30	CL	1.52	24.90	15.32	9.58
Çalköy aşağısı										
A	0-20	10 YR 5/4, 10 YR 4/4	44.80	20.88	34.32	C	1.35	25.40	15.19	10.21
C	20-56	10 YR 5/4, 10 YR 4/4	46.32	13.25	40.44	SiC	1.58	24.52	13.70	10.81
Çekmeden										
Ap	0-17	10 YR 4/3, 10 YR 3/3	48.70	26.06	25.23	C	1,34	40.40	25.92	14.48
A2	17-40	10 YR 3/3, 10 YR 3/4	56.01	20.80	23.19	C	1,29	44.14	26.55	17.59
Bk1	40-83	10 YR 3/3, 10 YR 3/4	56.03	20.76	23.20	C	1,29	46.22	28.42	17.80
Bk2	83-137	10 YR 3/4, 10 YR 3/3	58.50	20.40	21.10	C	1,27	43.09	26.89	16.20
Ck	137+	10 YR 3/2, 10 YR 3/3	58.19	21.01	20.80	C	1,28	41.53	27.03	14.50
Güder aşağısı										
Ap	0-20	10 YR 3/2, 10 YR 3/3	47.84	27.47	24.69	C	1.36	39.48	31.30	8.18
Bw	20-75	10 YR 3/2, 10 YR 3/3	49.71	21.36	28.93	C	1.33	41.34	30.94	10.40
C1k	75-132	10 YR 3/3, 10 YR 3/4	59.81	20.23	19.96	C	1.25	38.01	27.75	10.26
C2k	132+	10 YR 4/3, 10 YR 4/3	46.28	39.05	14.67	C	1.57	38.69	23.59	15.10
Kületek										
A	0-20	10 YR 4/3, 10 YR 4/3	12.48	74.41	13.11	SL	1.61	13.47	5.85	7.62
C1	20-40	10 YR 4/3, 10 YR 4/3	8.51	86.49	5.00	LS	1.60	8.06	4.09	3.97
Meşeli										
Ap	0-27	10 YR 4/3, 10 YR 3/3	50.36	29.01	20.62	C	1.31	40.27	25.96	14.31
Bss1	27-72	10 YR 3/2, 10 YR 2/2	53.62	27.41	18.97	C	1.29	41.61	23.79	17.82
Bss2	72-116	10 YR 3/2, 10 YR 2/2	57.71	21.18	21.11	C	1.28	47.07	26.30	20.78
Ck	116+	10 YR 6/3, 10 YR 5/3	64.43	16.89	18.68	C	1.27	38.87	22.33	16.54
Tekekıranı										
Ap	0-16	10 YR 3/3, 10 YR 3/4	50.41	27.14	22.45	C	1.35	37.19	24.77	12.42
Bk	16-52	10 YR 5/3, 10 YR 5/4	55.56	25.96	18.48	C	1.32	36.27	24.40	11.87
C1k	52-80	5 Y 5/2, 5 Y 5/2	53.59	27.59	18.82	C	1.34	35.18	24.73	10.45
C2k	80-105	5 Y 5/2, 5 Y 5/3	61.50	20.16	18.33	C	1.30	35.84	24.99	10.85
C3k	105+	5 Y 6/3, 5 Y 6/4	54.05	27.18	18.77	C	1.34	42.44	30.34	12.10

Yeşilada										
Ap	0-24	10 YR 4/3, 10 YR 3/3	31.90	38.02	30.09	CL	1.44	26.39	11.27	13.12
Bw	24-52	10 YR 3/3, 10 YR 3/4	35.98	27.69	36.32	CL	1.43	26.34	13.03	13.31
Bw2	52-70	10 YR 3/3, 10 YR 3/4	36.42	25.49	38.09	CL	1.41	28.59	17.41	11.18
Ck	70+	10 YR 4/4, 10 YR 3/3	30.72	27.16	42.12	CL	1.51	26.90	13.36	13.54
Yürükçal										
A	0-29	5 Y 5/3, 5 Y 4/3	40.46	22.79	36.75	C	1.31	31.18	18.30	12.88
C1	29-70	5 Y 4/3, 5 Y 4/4	44.60	20.84	34.56	C	1.35	29.78	16.64	13.15
C2	70+	5 Y 4/3, 5 Y 4/4	42.61	26.99	30.40	C	1.38	31.12	18.41	12.72

9.29%-8.89% in the low calcareous class. Soil reaction shows moderate alkalinity with 8.05-8.24.

The soils of the Tekekıranı series are found to the east of the study area. These lands, which mostly consist of steep slopes and steep lands, range in elevation from 300 to 500 meters above sea level. These are deep soils with a clayey texture that runs throughout the profile. Organic matter contents vary between 1.74% and 0.19%, Lime contents vary between 23.59%-9.61% and pH values vary between 7.92 and 8.27.

Soil series distribution areas and their phases

The spatial and proportional distributions and maps of the soil series in the study area are given in Table 3 and Figure 4. Bahçekonak series are the dominant soil series in the area of 1664.88 ha (15.02%), Bayramköy series 1506.08 ha (13.58%), and Meşeli series 1259.17 ha (11.36). In addition, with an area of 182.45 ha (1.65%), the Yürükçal series covers the lowest area.

Phases were determined in 58 mapping units belonging to the soil series. The parameters and limit values considered in the separation of soils into phases are given in Table 4. It is the soils expressed by the Bh1.Co1d4t1k4 mapping unit belonging to the Bahçekonak series, which covers the largest area with 983.61 ha (8.47%) in the study area. These soils are deep and have a high lime content. They have a clayey texture and belong to the C slope class. The lowest area is covered with 3.73 ha (0.03%) by the lands expressed by the map unit codded as By1.Ai1d3t1k1 belonging to the Bayramköy series.

Research Area Classification of Soils According to Soil Taxonomy and FAO/WRB

Both physico-chemical and morphological characteristics of soils gain character under ecological

Table 3. Spatial and proportional distributions of soil series in the study area

Series Name	Symbol	Area (ha)	Ratio (%)
Ağcaalan	Ac	965.17	8.71
Aydoğdu aşağısı	Aa	406.42	3.67
Aydoğdu üzeri	Au	451.12	4.07
Bahçekonak	Bh	1664.88	15.02
Bayramköy	By	1506.08	13.58
Boğazkoru	Bk	1025.81	9.25
Çakırtaş	Ct	922.58	8.32
Çalköy	Ck	389.28	3.51
Çalköy aşağısı	Ca	215.45	1.94
Çekmeden	Cd	884.67	7.98
Güder aşağısı	Gd	361.25	3.26
Kületek	Kt	268.82	2.42
Meşeli	Ms	1259.17	11.36
Tekekıranı	Tk	367.39	3.31
Yeşilada	Ya	216.14	1.95
Yürükçal	Yc	182.45	1.65
TOPLAM		11086.68	100.00

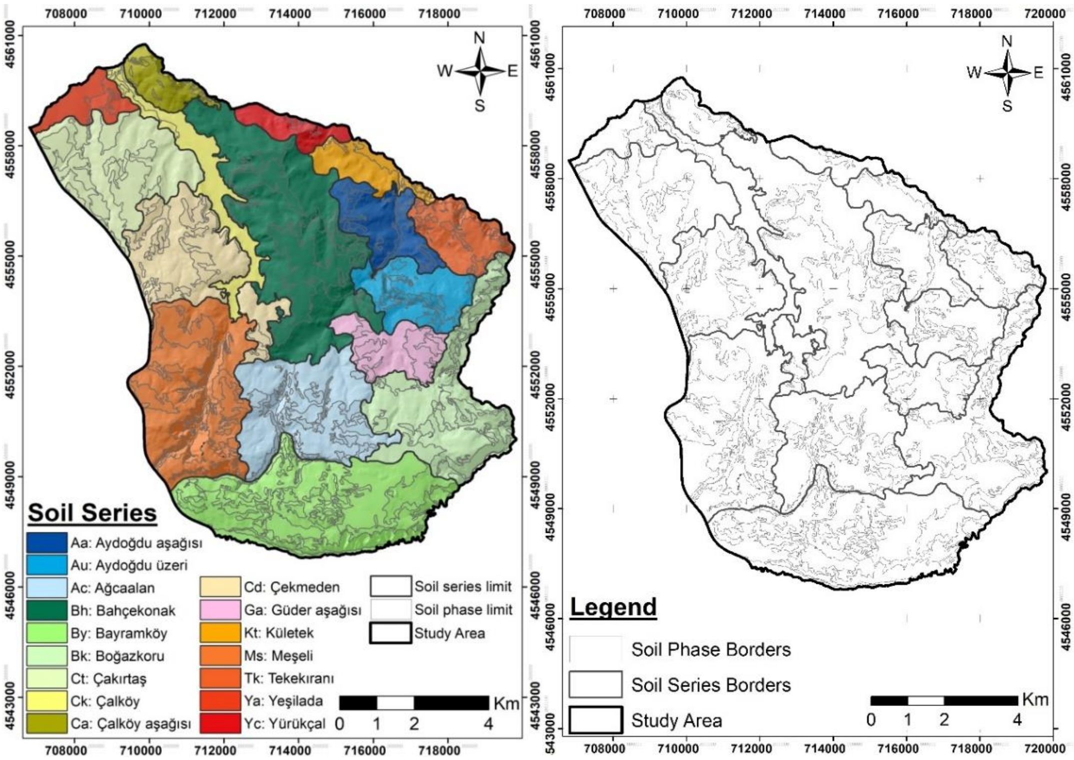

Figure 4. Soil series and phases distributed in the study area

conditions. They are in soil properties, which gain their character according to the contribution and degree of impact of environmental factors and play an important role in the management and productivity of the soil. Veenstra and Burras (2012) stated that soil pH, color, cation exchange capacity, base saturation, and changes in carbonate content are just a few of the soil properties that can cause changes in soil classification and soil fertility. Dengiz et al. (2010), to determine the distribution of the soils formed on the alluvial lands where rice cultivation is carried out in Çorum-Osmancık and to classify the different soils, 12 soil profiles were opened in the study area of approximately 1663 ha and 9 different soil series were defined as a result of the analyzes and field observations. They classified 2 of them in Entisol, 4 of them in Ineptisol, and 3 of tare them in Vertisol order. In addition, Darvishi-Foshtomi et al. (2010), qualitative and economic land suitability assessments were carried out for the Tea plant (*Camellia sinensis* L.) in Guilan province in the north of Iran. The digital elevation model was analyzed by interpreting the outputs obtained from GIS and determining 16 profiles in the study area. They stated 8 soil series with different properties formed on granite and phyllite as the main material. They defined 3 of them in Alisol, 3 in Cambisol, 1 in Umbrisol and 1 in Regosol class. These case studies show that many different soil types can be found in agricultural areas where agricultural activities are located and it turns out that each soil type must take into account its specific management request to make sustainable planning without losing productivity functions of the soils.

The classification of soils in the study area according to soil taxonomy (Soil Survey Staff, 1999) and (WRB, 2014) is given in Table 5. Taking into account the observations made in the field and laboratory results, in the classification of soil series distributed within the study area according to soil taxonomy, their pedogenetic features and upper diagnostic horizons (Epiphone), sub-surface diagnostic horizons and their characteristics should be taken into account. and they are placed in 4 orders, 5 sub-orders, 6 large groups and 7 subgroups (Soil Survey Staff, 2014). Some surface (ocric. vertic) and subsurface (clacic. cambic. clay deposition. slip surfaces) diagnostic horizons formed after the formation process of the soils were determined and placed in Entisol. Inceptisol and Vertisol orders. Among these orders, Vertisol covers the most area with 35.63% followed by Inceptisols at 28.49% Entisols at 22.3% and Alfisol soils at 13.58% respectively. According to FAO-WRB (2014), Leptosol is classified as Cambisol and Vertisol and Luvisol.

Entisol soils consisting of Ağcaalan, Aydoğdu üzeri, Çalköy aşağısı, Yürükçal, Kületek, and Çalköy series do not have any subsurface soils since they have an A/C horizon sequence with the effect of erosion, both because they have not been under the influence of sufficient pedological processes and because they are distributed on slopes that adversely affect this process. It does not have a diagnostic horizon. These series of soils, which are described as young soils, are classified in the Xerorthent large group due to the Xeric moisture regime, in the Orthent suborder due to their location on the slopes, and in the Typic Xerentent subgroup because

Table 4. Parameters and limit values considered in the separation of soils into series and phases

Topsoil Texture (UTT Classes)				
Symbol	General Classes	Secondary Classes	Texture fraction	Texture Class
1	Clays Lands (Heavy)	Fine textured	Clay	C
			Silty clay	SiC
			Sandy clay	SC
2	Loamy Soils (Middle)	Medium fine texture	Clay loam	CL
			Sandy clay loam	SCL
			Silty clay loam	SiCL
3		Medium texture	Silty	Si
			Silty loam	SiL
			Loam	L
			Very fine sandy loam	VFSL
4	Sandy Soils (Light)	Medium rough texture	Sandy loam	SL
			Fine sandy loam	FSL
5		Ruugh texture	Loamy sand	LS
			Sandy	S

Slope			Depth (cm)		
Slope class	Slope degree (%)	Description	Symbol	class	Description
A	0-2	Flat- close to flat	d1	0-20	Too shallow
B	2-6	Slightly sloping	d2	20-50	Shallow deep
C	6-12	Medium slope	d3	50-90	Medium deep
D	12-20	Steep slope	d4	90+	Deep
E	20-30	Very steep slope			
F	30+	Steep			

Drainage		Stoniness		
Symbol	Description	Symbol	Description	Degree (%)
i	Good	t1	Without stones- with few stones	2-10
o	Middle	t2	Medium stony	10-50
f	Bad	t3	Too stony	50-90

Erosion			Lime		
Symbol	Classes	Degree (%)	Symbol	Classes	Degree (%)
1	Light or no	0-25 (A horizon)	k1	Lime free	0-5
2	Middle	25-75 (A horizon)	k2	Less chalky	5-10
3	Severe	75-100 (A horizon)	k3	Medium chalky	10-15
4	Very severe	25-75 (B horizon)	k4	Too much chalky	15-30
			k5	Marn	30+

they contain all the characteristics of the large group. According to the FAO/WRB (2014) classification system; Ağcaalan, Aydoğdu üzeri, Çalköy aşağısı, Yürükçal series are classified as Leptosol. while Kületek and Çalköy series are classified as Fluvisol.

Aydoğdu aşağısı, Yeşilada, Çakırtaş, Çekmeden, Güder aşağısı and Tekekıranı series. with the diagnostic horizon, they contain (cambic) because they show a soil formation more advanced than the Entisols, and because of the Xeric soil moisture regime, secondary calcium carbonate accumulation in 100 cm depth It is classified as Vertic Calcicxerept at the subgroup level due to its vertical characteristics in the surface horizons. According to the FAO/WRB (2014) classification system; It is classified as caloric vertical Cambisol.

Soils belonging to the Meşeli, Boğazkoru and Bahçekonak series were placed in the Vertisol ordo because of the high amount of swelling clays (40% or more along the profile), the cracks extending from the surface to the deep in the dry seasons and the slip surfaces in the profile from time to time. Because the soil moisture regime is Xeric, it is classified in the Xerert lower ordo and Bahçekonak series soils are classified in the Calcixererert large group due to the development of a Calcic horizon as a result of calcification. At the subgroup level, it is classified as Typic Calcixerert because it has all the characteristics of the larger group. Meşeli and Boğazkoru series were classified as Haplxererts at the large group level and as Typic Haplxererts at the subgroup level. These series were classified as Calcic Vertisol and Haplic Vertisol according to the FAO/WRB (2014) classification system. Finally, the Bayramköy series was classified as Mollic Haploxeral, as a subsurface diagnostic horizon and as Calcic Luvisol, according to the FAO/WRB (2014) classification system, due to the development of the argillic horizon and the determination of metallic properties on the surface.

Table 5. Soil classification and FAO-WRB classification of soil series

Series Name	Soil Taxonomy –(2014)				FAO-WRB-(2014)
	Ordo	Subordo	Large Group	Subgroup	
Ağcaalan	Entisol	Orthent	Xerothent	Lithic Xerorthent	Lithic Leptosol
Aydoğdu üzeri	Entisol	Orthent	Xerothent	Typic Xerorthent	Clayic Leptosol
Çalköy aşağısı	Entisol	Orthent	Xerothent	Lithic Xerorthent	Lithic Leptosol
Yürükçal	Entisol	Orthent	Xerothent	Typic Xerorthent	Clayic Leptosol
Kületek	Entisol	Fluvent	Xerofluvent	Typic Xerofluvent	Skeletic Fluvisol
Çalköy	Entisol	Fluvent	Xerofluvent	Typic Xerofluvent	Densic Fluvisol
Aydoğdu aşağısı	Inceptisol	Xerept	Calcixerepts	Vertic Calcixerept	Calcaric vertic Cambisol
Yeşilada	Inceptisol	Xerept	Calcixerepts	Vertic Calcixerept	Calcaric vertic Cambisol
Çakırtaş	Inceptisol	Xerept	Calcixerepts	Vertic Calcixerept	Calcaric Cambisol
Çekmeden	Inceptisol	Xerept	Calcixerepts	Vertic Calcixerept	Calcaric vertic Cambisol
Güder aşağısı	Inceptisol	Xerept	Calcixerepts	Vertic Calcixerept	Calcaric vertic Cambisol
Tekekıranı	Inceptisol	Xerept	Calcixerepts	Vertic Calcixerept	Calcaric vertic Cambisol
Meşeli	Vertisol	Xerert	Haplxererts	Typic Haplxerert	Haplic Vertisol
Boğazkoru	Vertisol	Xerert	Haplxererts	Typic Haplxerert	Haplic Vertisol
Bahçekonak	Vertisol	Xerert	Calcixererts	Typic Calcixerert	Calcic Vertisol
Bayramköy	Alfisol	Xeralf	Haploxeralf	Mollic Haploxeralf	Calcic Luvisol

Conclusion

Sustainable agricultural production is only possible with the effective and efficient use of agricultural inputs. Soil, which is the most important of these agricultural inputs, is subject to deterioration in each production period, that is during the period from planting to harvest. This event, which is defined as soil degradation, defined as the intensive use of agricultural lands, pollution of water resources, and as a result, causing some political and social problems. With the selection of the best soil plant and land management, it is possible to improve many characteristics of the soils, together with ensuring sustainability in agriculture. For this reason, to develop planning strategies that will ensure the sustainable use of agricultural lands and to make models on environmental issues, detailed soil surveys and mapping studies, which will include basic information such as soil, physiography, climate, vegetation and land use, and monitoring, evaluation and updating in the process, a soil database is needed. Most of the soils in the study area consist of deep soils with clayey textures. The establishment of pressurized irrigation systems in the region has a wide product potential in terms of agricultural diversity, and is important for agricultural productivity. Determining the unique physical and chemical properties of soils is the most basic factor that increases productivity and quality in production. For this purpose, the determination of the exact boundaries and distribution areas of the soils after the soil survey carried out in the 11086.68 ha study area in total is a guide that can be taken into account in terms of crop cultivation. The main identified problems of the soils of the study area are tillage, slope, soil depth, erosion, base stone and poor drainage. For example, in the Çalköy and Aydoğdu series the subsurface layer (base stone), which is compressed as a result of continuous plowing at the same depth, needs to be broken with deep plowing. In addition, airless conditions may occur as a result of very slow drainage of water in vertisol soils with dense clay content. For this reason, it is important to take this property of the soil into consideration, both irrigation periods and methods and plant water consumption. Another issue is that in agricultural areas where soils are classified as typic or lithic xerorthent, which are distributed on sloped lands are used, soil cultivation should be carried out perpendicular to the slope to prevent erosion and soil transport. In addition, since organic matter is low in most surface soils distributed within the study area, this ratio should be increased with good agricultural practices.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that might apper to influence the work reported in this paper.

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Author Contributions

FS: Conceptualization, investigation, methodology, validation, software, validation, formal analysis, investigation, resources, data curation, writing-original draft preparation, writing-review and editing, visualization, supervision, statistical analysis, project administration; **OD:** Conceptualization, investigation, methodology, validation, software, validation, formal analysis, investigation, resources, data curation, writing-original draft preparation, writing-review and editing, visualization, supervision, statistical analysis, project administration.

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