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ORIGINAL PAPER

Evaluation of physical and ground engineering properties of soils in agricultural lands located in stream beds*

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Abstract

Global climate change, improper and unintended land use, rapid and unplanned urbanization are very important factors that exert significant pressure on water and soil resources. The aim of this study is to determine and evaluate the physical and ground engineering properties of soils in agricultural lands located in stream beds. The research includes a detailed analysis of the physical and ground engineering properties of the soils in stream valleys in the Şebinkarahisar region, which is under the influence of transitional climate conditions in Türkiye. Soil sampling was carried out in the autumn season. Topsoils and subsoils are mostly in the clay loam, sandy loam and sandy clay loam texture classes. The results of particle density, bulk density and total porosity analyses were found to represent well the samples taken from stream beds. Hydraulic conductivity varies from very slow to fast across all soils. It was determined that the differences in the hydraulic conductivity values of the grounds were due to the sampling from different stream beds and the variation in texture classes. According to the classification based on the values of the plasticity index, the majority of the soils have been found to have high and medium plasticity. The clay activities of the grounds, most of which are classified as having high and medium plasticity, were categorized as non-active and normal. For agricultural activities in the study area, it would be beneficial to map the land characteristics and analyze the waters in the streams. It is thought that analyses of the physical and detailed engineering properties of grounds in stream valleys and determination of different ground types will provide an important contribution to soil-water conservation studies.

Keywords: stream beds, Atterberg limits, hydraulic conductivity

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INTRODUCTION

Global climate change, desertification, improper and unintended land use, earthquakes, forest fires, erosion, landslides, floods, pollution, overgrazing, intensive agricultural activities, rapid and unplanned urbanization, and excessive plastic consumption are factors that exert significant pressure on water and soil resources, threatening their sustainability.

The valleys of rivers with high altitudes and steep slopes form an area where intensive agricultural activity and rural development take place (Jazouli et al. 2020). Increasing demands for food and bioenergy production will place intense pressure on soil and water resources in a changing climate, necessitating fundamental scientific advances, appropriate land management and innovative agricultural practices (Shang et al. 2018). The soil's load-bearing capacity as a foundation, its water retention capacity, aeration, and drainage conditions, the resistance the soil provides to the development of plant roots, and the retention and availability of plant nutrients in the soil are all related to the soil's physical properties (Aydın, Kılıç 2013). The variation in behavior of soils depending on their water content was experimentally described by Atterberg in 1911. The boundary water contents defined by Atterberg are known as the Atterberg limits or consistency limits (Yılmaz et al. 2014). The liquid limit, one of the consistency limits, represents the minimum water content at which the soil can flow under its own weight, while the plastic limit is the water content that separates the plastic state from the semi-solid state (Atterberg 1911*a*,*b*, Uzuner 2007).

The Nile Delta represents a unique case among river deltas; its fertile and ancient soil is extensively used for agriculture with a fully controlled irrigation system that regulates all the water flow from the Nile and the discharge of water into the sea (Alfiky et al. 2012). Durak and Aydın (2014) examined soils formed on the Yeşilırmak river terraces, which have alluvial parent material, using four different profiles. As a result of this research, they revealed that alluvial parent material, texture, topography and time affect the formation of defined soils to different degrees. Kalala et al. (2017) investigated some typical alluvial soils in the Kilombero District of Tanzania. Depending on the landform features and soil physico-chemical properties, the soils represented by the three studied profiles were recommended for paddy production.

Borek and Bogdał (2018) investigated the soil water retention of alluvial soils of the Odra River in Poland. They reported that specific alluvial soil conditions influence the high water content in the soil, which is reflected in the water content available for plants. Essoka and Esu (2003) determined the physical properties of inland valley soils of central Cross River State in Nigeria by studying 6 profiles. They analyzed texture, bulk density, particle density, porosity in surface and subsoil horizons. Jonczak et al.

(2022) investigated the soil formation processes and specific characteristics of soils developed from alluvial deposits in the valley of the Kamienna stream in northern Poland by describing its seven soil profiles. They noted that soils show a wide spatial heterogeneity, emphasizing the importance of local-scale factors in their formation.

Şebinkarahisar District (Giresun/Türkiye) has significant potential for plant and animal production owing to its transitional climate conditions, hosting various stream sources, richness in natural resources, and the presence of different soil types. Considering the fact that agricultural lands are being rapidly lost due to intensive construction work, especially in city centers, it is of great importance to investigate the possibilities of agricultural activities in rural areas. This work was conducted to determine the physical and ground properties of the soils in agricultural lands located in stream beds, and to evaluate their suitability for agriculture.

MATERIALS AND METHODS

Study area and soil sampling

The district of Şebinkarahisar, located within the Eastern Black Sea Region of Türkiye's Black Sea Region, consists of a highly rugged and mountainous terrain, where mountains, valleys, and plateaus cover a large area. The center of the district, located within the administrative boundaries of Giresun province, is situated on the southern foothills of the Giresun Mountains and the northern slopes of the Avutmuş Creek Valley (Yürüdür 1998, Sezer 2017). The research was carried out in Şebinkarahisar District (Giresun-Türkiye), which is under the influence of transitional climate conditions and where stream beds are located at altitudes of 848-1714 meters. The map showing the location of Şebinkarahisar District was created using the World Geodetic System (WGS) 1984 Datum with the ArcGIS-ArcMap 10.3 program (Figure 1).

The relevant sheets of the 1:25000 scale standard topographic maps obtained from Anonymous (2019) were used to determine the soil sampling points in the stream beds located in Şebinkarahisar District. In addition, the points for soil sampling were finally chosen based on observations and examinations conducted during field visits. The soil samples were taken from uncultivated lands, orchards, and agricultural fields in September, October and November 2019. The coordinates and elevations above sea level of the sampling points were determined using a handheld GPS device, a Magellan Explorist 610, with an accuracy of 1-3 meters. Soil samples were collected from 24 various points in 11 different stream beds as topsoil (0-30 cm) and subsoil (30-60/61/62/65 cm), 21 of which were taken from active stream beds and 3 from dry stream beds. There are 2 different stream beds named the Derin stream in different locations. One is active and the other is an inter-

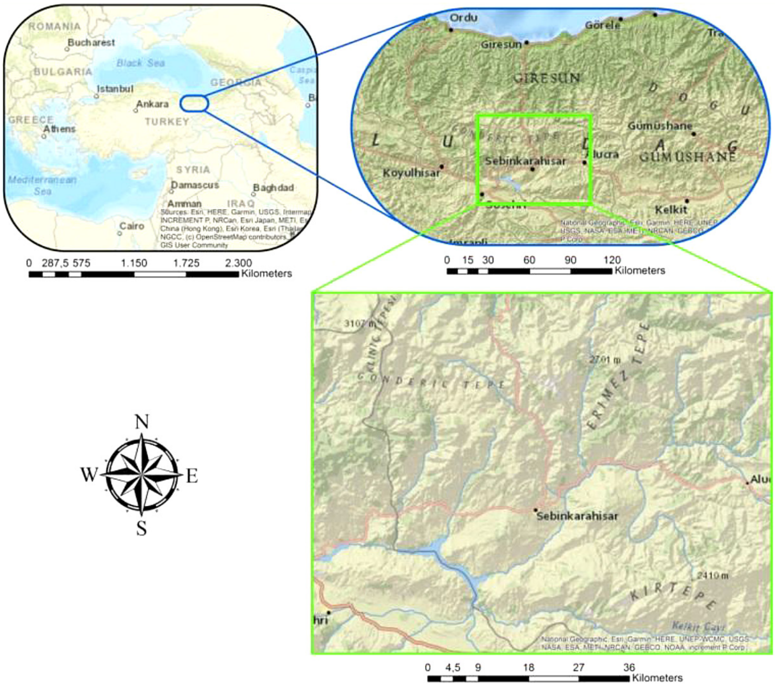


Fig. 1. Map showing the location of research area (Şebinkarahisar/Türkiye)

mittent stream bed. The map showing the soil sampling points and stream beds in the study area is presented in Figure 2. GPS data were used in this map prepared with Google Earth Pro program version 7.3.6.9796 (64-bit). In order to correctly name the streams and locations, information obtained from landowners was used together with Anonymous (2019) and Anonymous (2021*b*). The information regarding the soil sampling points and the streams/ stream beds is shown in Table 1.

Şebinkarahisar District is located in the southern zone of the eastern belt of the Pontides tectonic unit (Ketin 1966). Coordinate data, stream and stream bed information, elevation data, land use information of the research area were reported in a previous study by Atmaca (2023). In the current study, elevation data and land use information are given together with sample points.

The district has a transitional climate between the semi-arid climate and the Black Sea climate (Sezer, 2017). Atmaca (2023) classified the climate of the Şebinkarahisar district using various methods based on the averages of 48 years of climate data between 1965 and 2012. Using the Thornthwaite (1948) method, Atmaca (2023) determined the climate indices of the district as C2 B'1 s2 b'3 (Moist subhumid) and the climate characteristic as first mesothermal, large summer water deficiency, summer concentration 54.57%. According to the De Martonne-Gottman method (De Martonne

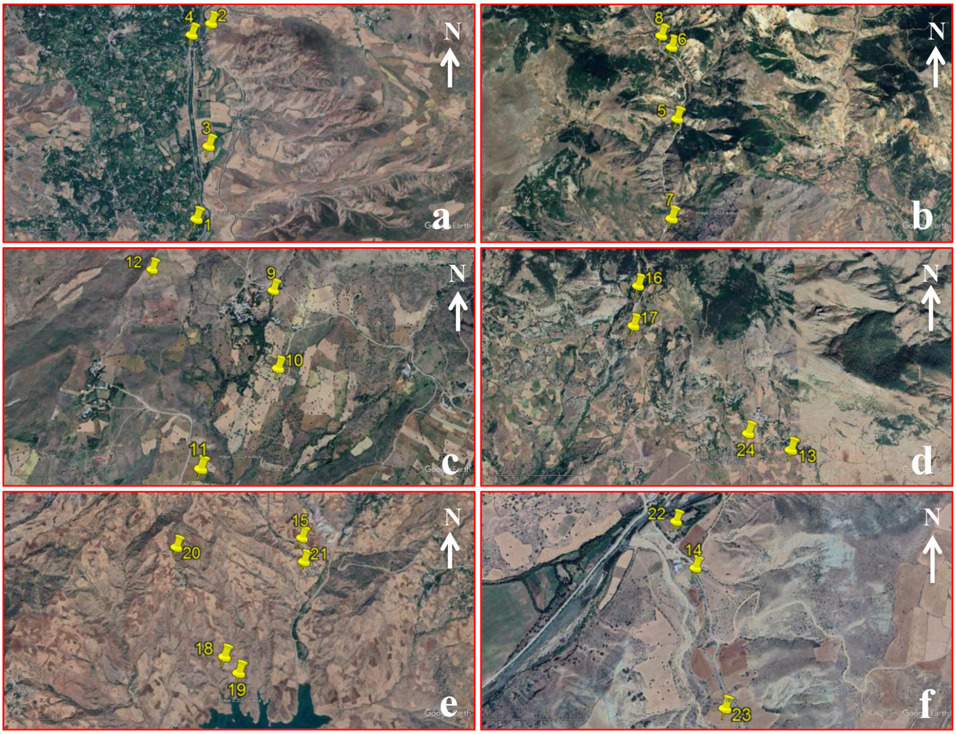


Fig. 2. Google Earth Pro image of soil sampling points and stream beds in the study area

1942, Baltas 2007), Atmaca (2023) identified the aridity index as 17.74, and the climate characteristic as semi arid - humid. Atmaca (2023) determined the precipitation efficiency index as 39.32, and the climate classification as semi humid according to the Erinç method (Erinç 1965, 1984).

The annual average temperature values in Şebinkarahisar District were found as 10.64°C in 2020, 10.39°C in 2021 and 10.01°C in 2022. The annual total rainfall averages were determined as 479.5 mm (2020), 542.2 mm (2021) and 439 mm (2022). The annual average relative humidity values were found to be 58.55% in 2020, 57.42% in 2021, and 61.17% in 2022. (Anonymous 2021*a*, Anonymous 2022, Anonymous 2023).

Large soil groups covering the most area in Şebinkarahisar region are brown soils and non-calcic brown forest soils. However, there are also high mountain meadow soils, brown forest soils, colluvial soils, gray-brown podzolic soils and alluvial soils (Atmaca and Cüce 2023) – Table 2.

Methods

In the study, a total of 48 disturbed soil samples were collected from 24 different points in the designated stream beds, with topsoil samples (0-30 cm) and subsoil samples (30-60/61/62/65 cm). A shovel and an earth

Table 1

Information on soil sampling points and stream beds

Soil smple No.	Coordinates	Stream name (stream bed) (active/ ıntermittent)	Elevation (m)
1	40°17’10”N 38°28’15”E	Avutmuş Creek (active)	944
2	40°18’22”N 38°28’22”E	Avutmuş Creek (active)	976
3	40°17’36”N 38°28’21”E	Avutmuş Creek (active)	947
4	40°18’18”N 38°28’12”E	Avutmuş Creek (active)	967
5	40°21’22”N 38°26’43”E	Asarcık Stream (active)	1378
6	40°22’17”N 38°26’37”E	Asarcık Stream (active)	1398
7	40°20’09”N 38°26’39”E	Asarcık Stream (active)	1274
8	40°22’26”N 38°26’27”E	Asarcık Stream (active)	1402
9	40°18’19”N 38°22’47”E	Bayhasan Stream (active)	1464
10	40°18’04”N 38°22’47”E	Bayhasan Stream (active)	1434
11	40°17’47”N 38°22’30”E	Bayhasan Stream (active)	1405
12	40°18’24”N 38°22’16”E	Kepçeli Stream (active)	1522
13	40°21’42”N 38°35’38”E	Derin Stream (active)	1517
14	40°14’13”N 38°25’59”E	Soğulcuk Stream (active)	882
15	40°17’13”N 38°17’06”E	Acı Stream (active)	955
16	40°22’42”N 38°34’25”E	Püsküllü Stream (active)	1714
17	40°22’26”N 38°34’23”E	Püsküllü Stream (active)	1690
18	40°15’55”N 38°16’01”E	Çatalkaya Stream (intermittent)	864
19	40°15’46”N 38°16’12”E	Çatalkaya Stream (intermittent)	848
20	40°17’06”N 38°15’20”E	Derin Stream (intermittent)	1192
21	40°16’56”N 38°17’07”E	Yedikardeş Stream (active)	942
22	40°14’19”N 38°25’56”E	Avutmuş Creek (active)	870
23	40°13’57”N 38°26’04”E	Soğulcuk Stream (active)	902
24	40°21’47”N 38°35’18”E	Derin Stream (active)	1566

Table 2

Large soil groups in Şebinkarahisar and the proportional distributions of the areas they cover

Great Soil Groups	Ratio (%)
Brown soils	30.828
Non calcic brown forest soils	30.568
High mountain meadow soils	14.295
Brown forest soils	12.539
Colluvial soils	0.590
Gray-brown podzolic soils	0.289
Alluvial soils	0.136
Other (river floodplains, bare rock and rubble, rivers and streams, residential area, pond, lake)	10.754

Source: Atmaca and Cüce (2023)

auger were used to take soil samples. After the soil samples were dried, they were prepared for physical and ground engineering properties analyses using the necessary materials.

The textures of the soils were determined by the hydrometer method (Bouyoucos 1951). The texture triangle was used to determine texture classes (Anonymous 1993). The moisture contents (%) of the soils were determined in soil samples dried at 105°C, as reported by Kacar (2016). The bulk density was found in disturbed soil samples using the compaction method according to Tüzüner (1990). The particle density of the soils was analyzed using the volumetric flask method described by Kacar (2016), and the results were calculated as specified by Estefan et al. (2013). The hydraulic conductivity values (cm h^{-1}) in disturbed soil samples were determined according to Klute (1986), and their classification was performed based on the values reported by Tüzüner (1990). The total porosity (%) values of the soils were calculated using the formula specified by Kacar (2016). The liquid limit (LL %), plastic limit (PL %), and plasticity index (PI) values from ground analyses were determined using the methods and principles reported by Orhan et al. (2013) and Uzuner (2007). The liquid limit values were determined using the Casagrande liquid limit device (Casagrande 1932, 1958), and the plastic limit values were found using a plastic limit test set. The plasticity index was calculated as the difference between the liquid limit and the plastic limit of the soil. Grounds with no plasticity were classified as non-plastic (NP) grounds. The determination and classification of the clay activity values of the research soils were performed as reported by Uzuner (2007). Accordingly, samples with clay activity (A) values defined as the ratio of the plasticity index to the clay percentage less than 0.75 were classified as non-active; samples in the range of 0.75-1.25 were classified as normal and samples greater than 1.25 were classified as active. Correlation analyses of the physical and ground engineering analysis results of the soils were performed using the IBM SPSS Statistics 22 program.

RESULTS AND DISCUSSION

Analysis results of soils

The texture classes, chemical properties and plant nutrient contents of soil samples in the current study were determined in a previous study by Atmaca (2023). Accordingly, the investigated topsoils (0-30 cm) were classified as L (3 soil samples), SL (7 soil samples), SCL (4 soil samples), C (1 soil sample), and CL (9 soil samples) in terms of texture. Subsoils (30-60/61/62/65 cm) were classified as L (3 soil samples), as SL (5 soil samples), as LS (1 soil sample), as C (2 soil samples), as CL (8 soil samples) and as SCL (5 soil samples) in terms of texture. The pH values of topsoils range from 5.84 to 7.98, while the pH values of subsoils range from 6.06 to 8.05.

No salinity problem has been detected in the soils. The lime contents of topsoils and subsoils varied from 0.00% to 38.30%. Organic matter was found to range from 0.32% to 4.16% in topsoils and from 0.14% to 2.16% in subsoils. Total nitrogen values varied between 0.01% and 0.21% for topsoils and subsoils. Phosphorus, potassium, calcium and magnesium values of all research soils were found in the ranges of 0.01-80.80 ppm, 57.61-626.92 ppm, 1587.79-9648.03 ppm, 154.29-829.02 ppm, respectively. The value ranges for the content of elements in topsoils and subsoils were determined as iron (1.01-85.50 ppm), copper (1.30-8.41 ppm), zinc (0.04-7.29 ppm), manganese (1.75-58.82 ppm).

The physical analysis results of topsoil (0-30 cm) and subsoil (30-60/61/62/65 cm) samples taken from the research area in Şebinkarahisar are shown in Table 3. The topsoils and subsoils of samples 1, 7, and 24, the subsoils of samples 5 and 10, and the topsoil of sample 13 were classified in the SCL texture class. The topsoils and subsoils of samples 2, 14, 18, 21, and 23, the topsoils of samples 10, 15, 20, and 22, and the subsoils of samples 3, 9, and 13 were classified as texture class CL. The topsoils and subsoils of samples numbered 4, 6, and 16, the topsoils of samples numbered 3, 5, 8, and 17, and the subsoils of samples numbered 12 and 22 fall into the texture class SL. The topsoils and subsoils of sample no. 19, the topsoils of samples nos. 9 and 12, and the subsoils of samples nos. 15 and 17 were found to be in the L texture class. Topsoils and subsoils of sample 11 and subsoil of sample 20 were determined to be in C texture class. The subsoil of sample 8 is also in the LS texture class (Anonymous 1993).

The sand amounts of the soils analyzed in the research were determined to be between 30.76% and 77.048% in the topsoil, and between 27.552% and 83.912% under the topsoil. The silt amounts of the topsoils were found to be between 13.728% and 38.144%; and the silt amounts of the subsoils were found to be between 8.360% and 40.648%. The clay amounts of the topsoils were determined to be between 7.512% and 40.360%, and the clay amounts of the subsoils were found to be between 7.728% and 46.432%.

The soil moisture content varied between 1.61% and 7.03% in topsoils and between 1.55% and 7.30% in subsoils. The lowest moisture contents were determined in the top and subsoils of sample 8 and the highest moisture contents were found in the top and subsoils of sample 11. Three of the soil samples were taken from intermittent stream beds. Some soil sampling points were close to the streams, while others were located a little further away. The distance to the streams is thought to affect the moisture content of the soils. In addition, the water levels of some of the streams in the study area have decreased over the years due to climate change, which may have affected the irrigation of the lands and reduced the moisture content of the soils.

The particle density values of the soils varied between 2.46 g cm^{-3} - 2.74 g cm^{-3} in topsoils; and between 2.47 g cm^{-3} - 2.76 g cm^{-3} in subsoils. The bulk density values of the soil samples were found to range between 1.07 g cm^{-3} and 1.50 g cm^{-3} in topsoils, and between 1.18 g cm^{-3} and 1.55 g cm^{-3} in sub-

Table 3

Results of analysis of physical properties of grounds

Soil Sample No.	Depth (cm)	Soil texture sand (%)	silt (%)	clay (%)	Soil texture class	SM (%)	PD (g cm^{-3})	BD (g cm^{-3})	TP (%)	HC (cm h^{-1})
1	0-30	54.112	21.584	24.304	SCL	4.42	2.63	1.26	52.09	6.16
	30-60	50.976	21.008	28.016	SCL	4.35	2.65	1.26	52.45	2.51
2	0-30	37.408	23.008	39.584	CL	5.25	2.54	1.27	50.00	4.74
	30-61	35.624	25.008	39.368	CL	5.37	2.63	1.27	51.71	6.18
3	0-30	73.912	18.576	7.512	SL	2.19	2.74	1.50	45.26	7.84
	30-60	38.344	30.288	31.368	CL	3.38	2.66	1.40	47.37	8.57
4	0-30	60.344	20.288	19.368	SL	3.46	2.69	1.31	51.30	3.77
	30-60	68.760	16.952	14.288	SL	2.88	2.75	1.27	53.82	13.22
5	0-30	59.696	24.088	16.216	SL	2.43	2.55	1.24	51.37	7.72
	30-61	55.768	22.016	22.216	SCL	2.93	2.58	1.23	52.33	15.81
6	0-30	56.992	30.720	12.288	SL	1.73	2.50	1.20	52.00	10.00
	30-61	53.208	30.720	16.072	SL	1.76	2.54	1.27	50.00	8.11
7	0-30	51.352	26.720	21.928	SCL	4.22	2.64	1.18	55.30	4.51
	30-61	50.256	20.376	29.368	SCL	3.12	2.73	1.35	50.55	2.49
8	0-30	77.048	13.728	9.224	SL	1.61	2.60	1.33	48.85	5.28
	30-62	83.912	8.360	7.728	LS	1.55	2.76	1.55	43.84	13.05
9	0-30	36.056	38.144	25.800	L	4.23	2.73	1.30	52.38	0.17
	30-61	39.768	30.720	29.512	CL	6.19	2.75	1.33	51.64	0.10
10	0-30	41.912	26.720	31.368	CL	5.37	2.61	1.21	53.64	3.14
	30-62	47.408	22.160	30.432	SCL	5.12	2.66	1.30	51.13	2.55
11	0-30	34.632	25.008	40.360	C	7.03	2.50	1.07	57.20	4.30
	30-60	28.776	24.792	46.432	C	7.30	2.59	1.18	54.44	0.40
12	0-30	42.848	33.080	24.072	L	5.43	2.67	1.28	52.06	7.21
	30-60	52.920	32.936	14.144	SL	5.08	2.71	1.37	49.45	0.66
13	0-30	46.920	26.792	26.288	SCL	4.55	2.55	1.20	52.94	5.43
	30-60	42.472	27.096	30.432	CL	4.51	2.64	1.18	55.30	2.50
14	0-30	36.848	33.368	29.784	CL	3.07	2.57	1.30	49.42	4.31
	30-60	37.048	33.584	29.368	CL	2.99	2.47	1.30	47.37	6.42
15	0-30	35.912	34.792	29.296	CL	4.17	2.61	1.34	48.66	4.29
	30-60	44.200	40.648	15.152	L	3.12	2.62	1.44	45.04	2.59
16	0-30	60.344	24.648	15.008	SL	4.29	2.68	1.23	54.10	6.31
	30-60	61.912	21.296	16.792	SL	4.38	2.68	1.25	53.36	14.55
17	0-30	52.272	31.152	16.576	SL	3.72	2.59	1.23	52.51	8.17
	30-61	39.336	38.520	22.144	L	3.83	2.67	1.27	52.43	8.36
18	0-30	38.416	27.728	33.856	CL	4.67	2.49	1.38	44.58	1.83
	30-60	39.064	25.368	35.568	CL	4.62	2.47	1.35	45.34	0.60
19	0-30	45.424	31.080	23.496	L	4.21	2.65	1.28	51.70	8.83
	30-60	49.568	28.864	21.568	L	4.12	2.69	1.26	53.16	5.45
20	0-30	37.712	22.504	39.784	CL	3.17	2.46	1.20	51.22	6.08
	30-61	27.552	28.592	43.856	C	3.45	2.57	1.37	46.69	0.83
21	0-30	38.920	29.080	32,000	CL	2.92	2.55	1.30	49.02	1.31
	30-61	35.280	35.208	29.512	CL	3.01	2.69	1.31	51.30	1.93
22	0-30	39.912	28.304	31.784	CL	3.36	2.53	1.40	44.66	2.26
	30-65	54.992	25.224	19.784	SL	2.95	2.69	1.45	46.10	5.30
23	0-30	30.760	34.160	35.080	CL	3.19	2.67	1.23	53.93	4.35
	30-60	37.696	29.656	32.648	CL	2.75	2.68	1.36	49.25	3.54
24	0-30	52.776	18.720	28.504	SCL	5.09	2.52	1.25	50.40	2.28
	30-61	63.208	14.144	22.648	SCL	5.20	2.60	1.25	51.92	5.34

C – clay, L – loam, CL – clay loam, SL – sandy loam, LS – loamy sand, SCL – sandy clay loam, SM – soil moisture, PD – particle density, BD – bulk density, TP – total porosity, HC – hydraulic conductivity soils. The total porosity was found to range between 44.58% and 57.20% in top soil samples, and between 43.84% and 55.30% in subsoil samples.

The lowest hydraulic conductivity values of the research soils were found to be 0.17 cm h^{-1} in the topsoil and 0.10 cm h^{-1} in the subsoil (Sample 9). The topsoil of sample 6 with 10.00 cm h^{-1}, and the subsoil of sample 5 with 15.81 cm h^{-1} were determined to have the highest hydraulic conductivity values. Topsoils and subsoils were found to represent the same hydraulic conductivity classes; samples 1, 2, 7, 10, 13, 15, 22, 23, 24 were determined to have medium level hydraulic conductivity; samples 3, 6 and 17 were found to have medium fast level hydraulic conductivity; samples 18 and 21 were determined to have medium slow level hydraulic conductivity. In addition, hydraulic conductivity classes of samples 4 and 8 were determined to be at medium level in topsoils and at fast level in subsoils. The topsoils of samples 5 and 16 were found to have medium fast level hydraulic conductivity and the subsoils were determined to have fast level hydraulic conductivity. The hydraulic conductivity classes of sample 9 were determined as topsoil slow, subsoil very slow; sample 11 as topsoil medium and subsoil slow; sample 12 as topsoil medium fast and subsoil medium slow; sample 14 as topsoil medium and subsoil medium fast; sample 19 as topsoil medium fast and subsoil medium and sample 20 as topsoil medium and subsoil medium slow.

Due to the high sand content in the topsoil of sample number 3 analyzed within the scope of the research, the liquid limit (LL), plastic limit (PL), and plasticity index (PI) values could not be calculated, and the sample was evaluated as NP (non-plastic). The highest LL (60.698%) and PI (26.675%) values for subsoils were determined in the topsoil of sample 11. The topsoil of sample 2 was also found to have the highest PL value (39.921%). The LL values of the subsoils range between 27.369% and 61.694%. In terms of plastic limit, the lowest value in the subsoils was determined as 19.458% in sample 14, and the highest value was found as 36.192% in sample 11. The PI of the subsoil of sample 8 was determined to have the lowest value of 3.675%, and the PI of the subsoil of sample 11 was found to have the highest value of 25.502%. The LL values of the topsoils and subsoils of samples 4, 8, 14, 15, 17 and 21, the topsoils of samples 3 and 16, and the subsoils of samples 5, 6, 7, 19, 22 and 23 were determined to be less than 40%. The LL values of the remaining topsoils and subsoils were found to be more than 40%.

The PL values of the topsoils of samples 3 and 15, and the subsoils of samples 14, 21, and 23 were found to be below 20%. The PL values of all other samples, except for these, were determined to be above 20%.

Since the topsoil of sample 3 from the research soils was found to be NP (Non-Plastic), the clay activity (A) values of the topsoils range between 0.280% and 1.191%. The A values of the subsoils were determined to be 0.280% and 1.031%. The ground engineering properties of soils are shown in Table 4.

Table 4

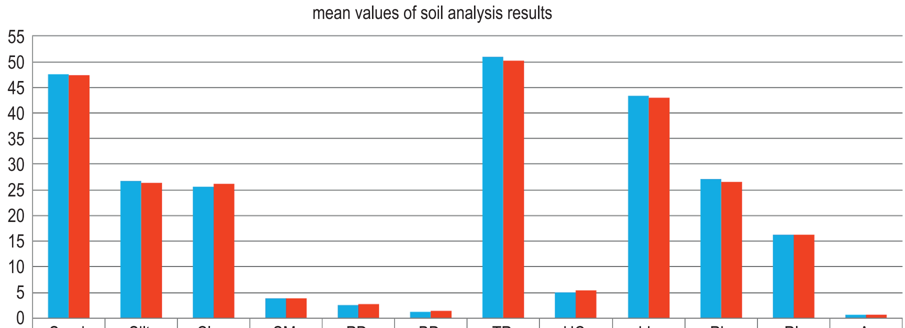
Results of analysis of ground engineering properties of soils

Soil sample No.	Depth (cm)	LL (%)	PL (%)	PI (%)	A (%)
1	0-30	49.683	26.964	22.719	0.935
	30-60	52.295	30.488	21.807	0.778
2	0-30	60.184	39.921	20.263	0.512
	30-61	57.880	35.205	22.675	0.576
3	0-30	NP	NP	NP	-
	30-60	46.942	33.395	13.547	0.432
4	0-30	38.754	30.542	8.212	0.424
	30-60	32.578	26.259	6.319	0.442
5	0-30	46.271	33.210	13.061	0.805
	30-61	36.177	26.711	9.466	0.426
6	0-30	46.762	32.121	14.641	1.191
	30-61	37.220	29.207	8.013	0.499
7	0-30	49.647	37.580	12.067	0.550
	30-61	36.268	28.039	8.229	0.280
8	0-30	30.561	24.637	5.924	0.642
	30-62	27.369	23.694	3.675	0.476
9	0-30	46.974	35.459	11.515	0.446
	30-61	51.913	29.369	22.544	0.764
10	0-30	53.193	32.437	20.756	0.662
	30-62	50.904	29.855	21.049	0.692
11	0-30	60.698	34.023	26.675	0.661
	30-60	61.694	36.192	25.502	0.549
12	0-30	45.940	28.957	16.983	0.706
	30-60	42.847	28.574	14.273	1.009
13	0-30	45.866	26.796	19.070	0.725
	30-60	47.072	27.080	19.992	0.657
14	0-30	39.851	21.615	18.236	0.612
	30-60	36.115	19.458	16.657	0.567
15	0-30	39.428	19.916	19.512	0.666
	30-60	33.723	21.220	12.503	0.825
16	0-30	39.053	25.726	13.327	0.888
	30-60	43.005	25.691	17.314	1.031
17	0-30	39.409	26.357	13.052	0.787
	30-61	39.025	23.823	15.202	0.687
18	0-30	44.538	23.228	21.310	0.629
	30-60	46.933	22.762	24.171	0.680
19	0-30	41.432	25.008	16.424	0.699
	30-60	39.977	24.336	15.641	0.725
20	0-30	40.758	26.066	14.692	0.369
	30-61	47.140	26.089	21.051	0.480
21	0-30	38.965	22.019	16.946	0.530
	30-61	37.481	19.997	17.484	0.592
22	0-30	45.176	25.886	19.290	0.607
	30-65	36.865	21.307	15.558	0.786
23	0-30	42.143	22.009	20.134	0.574
	30-60	35.820	19.880	15.940	0.488
24	0-30	55.357	30.411	24.946	0.875
	30-61	53.240	30.657	22.583	0.997

LL – liquid limit, PL – plastic limit, PI – plasticity index, A – activity

According to the Atterberg limits analysis, the liquid limit values of 28 soils are found to be more than 40%, and the plastic limit values of 43 soils were found to be more than 20%. According to the classification based on the plasticity index values, 22 of the soils were determined to have high plasticity, while 22 others were found to have medium plasticity. The plasticity of 3 samples was determined to be weak. Sample number 3 was classified as non-plastic because the liquid limit and plastic limit values could not be determined for the topsoil.

The mean values of the soil properties analyzed in the research were calculated separately for topsoils and subsoils and are given in graphical form in Figure 3.



	Sand (%)	Silt (%)	Clay (%)	SM (%)	PD (g cm^{-3})	BD (g cm^{-3})	TP (%)	HC (cm h^{-1})	LL (%)	PL (%)	PI (%)	A (%)
topsoils	47,605	26,833	25,562	3,91	2,59	1,27	51,02	5,01	43,36	27,12	16,24	0,646
subsoils	47,419	26,397	26,184	3,92	2,65	1,32	50,25	5,46	42,937	26,637	16,3	0,643

Fig. 3. Mean values of the results of analyses of soil samples

The correlation coefficients and correlation analysis of the topsoils and subsoils properties in the study are presented in Table 5. When evaluating the results of the correlation analysis (Pearson) of soil properties, a positive (+) relationship was determined in all topsoils and subsoils between sand-HC, clay-SM, clay-LL, clay-PI, SM-TP, SM-LL, SM-PL, SM-PI, TP-PL, LL-PL, LL-PI, and PI-A. In contrast, negative (-) relationships were found between sand-silt, sand-clay, sand-LL, sand-PI, clay-HC, SM-BD, BD-TP, BD-LL, and BD-PI. Additionally, for topsoils only, a positive (+) relationship has been determined between TP-LL, LL-A, and PL-A, and a negative (-) relationship has been determined between sand-SM, clay-PD, PD-LL, PD-PI, BD-PL, and BD-A. For subsoils only, a positive (+) relationship was found between sand-PD and SM-A, while a negative (-) relationship was observed between SM-HC, HC-LL, and HC-PI.

Discussion of soil analysis results

Reza et al. (2016) determined the average values for sand, silt and clay in a total of 85 soil samples (0-25 cm), from the new alluvial plain, old allu-

Table 5

Correlation coefficients (r) and results of the correlation analysis for topsoil and subsoil samples (Pearson)

Topsoils (Depth: 0-30 cm) * $p<0.05$, ** $p<0.01$											
Specification	Sand	Silt	Clay	SM	PD	BD	TP	HC	LL	PL	PI
Silt	-0.682**										
Clay	-0.887**	0.268									
SM	-0.509*	0.140	0.582**								
PD	0.293	0.140	-0.474*	-0.081							
BD	0.272	-0.091	-0.301	-0.435*	0.335						
TP	-0.135	0.150	0.084	0.416*	0.124	-0.893**					
HC	0.459*	-0.109	-0.536**	-0.299	0.059	-0.143	0.192				
LL	-0.547**	0.199	0.595**	0.640**	-0.464*	-0.693**	0.494*	-0.276			
PL	-0.273	0.095	0.300	0.429*	-0.276	-0.668**	0.559**	-0.168	0.878**		
PI	-0.697**	0.259	0.755**	0.675**	-0.535**	-0.467*	0.228	-0.313	0.786**	0.394	
A	0.031	0.140	-0.129	0.097	-0.342	-0.487*	0.339	0.291	0.540**	0.439*	0.469*
Subsoils (Depth: 30-60/61/62/65 cm) * $p<0.05$, ** $p<0.01$											
Specification	Sand	Silt	Clay	SM	PD	BD	TP	HC	LL	PL	PI
Silt	-0.685**										
Clay	-0.827**	0.157									
SM	-0.389	0.017	0.514*								
PD	0.424*	-0.230	-0.396	-0.044							
BD	0.264	-0.026	-0.338	-0.491*	0.277						
TP	-0.060	-0.092	0.152	0.478*	0.198	-0.887**					
HC	0.634**	-0.393	-0.556**	-0.487*	0.133	-0.010	0.080				
LL	-0.477*	-0.050	0.686**	0.879**	-0.226	-0.499*	0.403	-0.470*			
PL	-0.089	-0.291	0.344	0.599**	0.040	-0.393	0.429*	-0.076	0.752**		
PI	-0.620**	0.155	0.721**	0.800**	-0.358	-0.414*	0.246	-0.620**	0.855**	0.301	
A	0.155	0.111	-0.296	0.439*	0.041	-0.087	0.106	-0.165	0.271	-0.030	0.414*

vial plain, meander plain and flood plain areas in Bihar (Katihar-Kadwa) in the northeast of India, as 14.4%, 65.7% and 19.9%, respectively. In the present study carried out in Şebinkarahisar District, the average values of sand, silt and clay were found to be 47.605%, 26.833% and 25.562% respectively in the topsoils. It is seen that these are different results, especially in sand and silt values, compared to the findings from the cited study in India. Horuz and Dengiz (2018) took a total of 64 samples from 0-30 cm depth from paddy soils cultivated in alluvial lands in the Terme region of Samsun Province in Türkiye. They reported that the majority of the soils had a clayey and silty texture. Dengiz et al. (2009) examined the soils formed on alluvial lands, mostly used for paddy cultivation, in Kızılırmak District of Çankırı Province, Türkiye, by opening 8 different profiles. Texture classes were found to be C, L, CL, SL, SiL, SiC, SiCL at different depths (between 0-121 cm) in all profiles. The studies conducted in the provinces Çankırı and Samsun in Türkiye show that silty texture classes were determined differently from the present study.

Chidozie et al. (2019) reported in their research conducted in Imo State located in Nigeria that the bulk density values in 0-20 cm topsoil samples varied 0.93 - 1.76 g cm^{-3}; porosity values varied 30.0 - 65.6% and hydraulic conductivity values varied 0.009 - 0.126 Kg^{-1} S. Tunçay (2019) determined the hydraulic conductivity values of the soil series formed on the side stream alluviums in Konya Province of Türkiye as between 2.60 - 5.43 cm h^{-1} and the bulk density values as between 1.48 - 1.70 g cm^{-3} at different profile depths (between 0-150 cm). Bahrami and Ghahraman (2019) collected 36 soil samples from three alluvial fans located west of Sabzevar in Northeastern Iran. They found the hydraulic conductivity values in samples taken from 0-30 cm depth to be between 1.22 - 3.86 cm h^{-1} in the relict fan, 0.86 - 8.27 cm h^{-1} in the old fan and 0.45 - 10.02 cm h^{-1} in the young fan. Atmaca and Boyraz (2015) determined that the hydraulic conductivity values of top and sub soil samples taken from stream beds in the drainage network located on the coastal strip of the Central District of Tekirdag Province in Türkiye varied 0.10 and 2.35 cm h^{-1}. They classified the hydraulic conductivity of soils as slow, very slow, medium and medium slow. When the bulk density, porosity and hydraulic conductivity results obtained by Chidozie et al. (2019), Tunçay (2019), Bahrami and Ghahraman (2019), Atmaca and Boyraz (2015) and the results of the current study in Şebinkarahisar are examined, it is seen that there are differences.

Yılmaz et al. (2014) classified the plasticity of soils as follows: If the plasticity index is less than 1%, it is non-plastic; if it is between 1-7%, it is weak plasticity; if it is between 7-17%, it is medium plasticity; if it is between 17-35%, it is high plasticity and if it is greater than 35%, it is extreme plasticity. Accordingly, in Şebinkarahisar district it has been determined that the topsoils and subsoils of samples 1 and 2, samples 10 and 11, sample 13, sample 18, and sample 24 have high plasticity. The topsoils of samples 14, 23, 15, and 22, and the subsoils of samples 9, 16, 20, and 21 have been found to have high plasticity. The plasticity of topsoils and subsoils of samples 5, 6 and 7, sample 12, and samples 17 and 19 were classified as medium. The plasticity of the topsoils of samples 4, 9, 16, 20 and 21 and the subsoils of samples 3, 14, 15, 22 and 23 were determined as medium. The topsoils and subsoils of sample number 8, as well as the subsoil of sample number 4, have been found to have low plasticity. The topsoil of sample number 3 is also classified as non-plastic. Jazouli et al. (2020) reported results of their study area located in the Middle Atlas Mountains, part of the high basin of the Oum Er Rbia River in Khénifra Province of northern Central Morocco. They collected 10 soil samples from the topsoil to a depth of approximately 30 cm in areas at risk of landslides. According to the Atterberg limits analysis results, the plastic limit (PL) values of the soils were determined to be in the range of 43% - 73%, the liquid limit (LL) values were in the range of 28% - 56%, and the plasticity index (PI) values were in the range of 13% - 25%. Adekalu et al. (2007) collected soil samples from the top 15 cm of the soil profile in uncultivated locations in southwestern Nigeria that had been fallow for three years. They determined the liquid limit values in the Ondo, Egbeda, and Iwo series as 18.8%, 20.6%, and 15.8%, respectively. They found the plastic limit values as 13.2% in the Ondo series, 13.8% in the Egbeda series and 11.5% in the Iwo series.

Activity (A) generally reflects the swelling (volume increase) of clays when wetted. Soils with high activity are those with a tendency to swell (Uzuner 2007). The clay activity class of the topsoils and subsoils of samples 1, 16, and 24 has been determined to be normal. The clay activity of the topsoils and subsoils of samples numbered 2, 3, 4, 7, 8, 10, 11, 13, 14, 18, 19, 20, 21, and 23 is classified as non-active. The clay activity of the topsoils in samples 5, 6, and 17 has been found to be normal; the clay activity of the subsoils is also determined to be non-active. The clay activity of the topsoils of samples 9, 12, 15, and 22 has been classified as non-active, while the clay activity of the subsoil has been classified as normal. Clay activities of the soils in the stream beds examined within the scope of the current research in Şebinkarahisar District were classified as non-active and normal, and therefore their swelling tendency was evaluated to be low. Canbolat et al. (1999) determined that in the soil profile formed on calcareous alluvial parent material located in the Daphan Plain of Erzurum, Türkiye, the liquid limit at a depth of 0 - 50 cm is 74.27%, the plastic limit is 31.79%, and the plasticity index is 42.47%. They also found the clay activity to be 0.66. Atmaca and Boyraz (2015) determined values ranging from 28.30% to 68.15% for the liquid limit, from 11.44% to 34.94% for the plastic limit, and from 14.64% to 34.53% for the plasticity index in topsoils and subsoils in stream beds in Tekirdağ. They classified the soils as non-active in terms of clay activity. Ogboin and TrustGod (2021) collected soil samples from a depth of 0.5 - 0.75 meters at five locations distributed along the Niger Floodplain region of the Niger Delta in Southern Nigeria. They found the liquid limit values between 51.0% and 67.9% and the plasticity index values between 31.9% and 42.6%. They determined the activity (A) values of the soils between 1.28% and 1.43%.

It was observed that climatic changes, different soil types and land uses are important for the results obtained from similar studies conducted in different regions/countries, which may have differed from the findings in the present study. According to the results obtained in the study in Şebinkarahisar District, since it is quite difficult to achieve suitable moisture conditions for working with high-plasticity soils, extreme caution is required for any activities conducted on these soils. The lands in the research area and other lands in the stream valleys should not be opened to non-agricultural construction.

CONCLUSIONS

In this study, in terms of water retention in soil and soil cultivation, clay loam and loam textured soils are found to be suitable for agriculture. When evaluating sandy clay loam and sandy loam texture soils for agriculture, their sand content should be taken into consideration. The top and subsoils of sample number 8, and the topsoil of sample number 3 have been found unsuitable for agricultural activities. The results of % particle density, bulk density and total porosity of the soils were found to be represent well the samples taken from the stream beds. It was concluded that the differences in hydraulic conductivity among the soils were due to them being samples from various points in different stream beds and the diversity in texture classes (particularly sand and clay content). The majority of the grounds have been determined to have high and medium plasticity. Since the clay activity classes of all samples were determined as non-active and normal, their swelling tendencies are considered to be low.

It is thought that it would be appropriate to conduct more comprehensive soil analyses in the future for agricultural practices (soil tillage, irrigation, crop rotation, harvesting, and fertilization) and soil-water conservation studies that can be carried out on different soil types in the stream valleys of the Şebinkarahisar region. In addition, it will be useful to map the elevation, slope and aspect characteristics of the region lands and to analyze the waters of the streams. For Şebinkarahisar, land use change from past to present should be determined and modeled. It will also be important to realize the future climate change projections of the region.

Author contributions

BA executed the field research and few laboratory analyses, whereas DBE conceived the idea and supervised the work. All authors have read and agreed to the published version of the manuscript.

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Conflicts of interest

The Authors declare that there is no conflict of interest.

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