

Characteristics, genesis and classification of a basin peat soil under negative human impact in Turkey

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Abstract The objective of this research was to investigate the morphology, genesis and classification of organic soils formed on depression and flat land around Lake Yenicaga, west-central Turkey. Formation of the area has been influenced by tectonic and karst processes. This peatland is important in this area due to its extensive use as a horticultural plant growth medium resulting from positive physical and chemical properties. Organic soils in the study area were formed in nutrient-rich conditions and it is classified as typical basin peat. Four representative pedons were excavated in the study area based on extensive observations performed with random grid method using an auger. Samples were taken from horizons in each profile for laboratory analyses. Organic matter contents ranged from 12.5 to 91.5% across all four pedons. Fiber contents were between 4.3 and 91.5%, and *N* ranged from 0.56 to 2.19%. Cation exchange capacity ranged from 37 to 222 cmol kg⁻¹, bulk density from 0.09 to 0.78 g cm⁻³, lime from 0.15 to 2.62%. The pH and EC_e values ranged from 5.38 to 7.92 and 0.50 to 3.80 dS m⁻¹, respectively. Sand, silt and clay contents of the organic soils ranged between 0.75–3.92, 40.70–74.77 and 24.15–57.30%, respectively. Differences in organic soils were found to

depend on the environment, botanical origins, decomposition degrees, and groundwater composition. The organic soils of the research area were classified in the typic, hemic and hydric subgroups of Medifibrists (Soil Taxonomy 1999).

Keywords Peat · Organic soils · Genesis · Classification · Turkey

Introduction

Organic soils cover approximately 240 km² area in Turkey. The Yenicaga, Bolu peatland is considered as one of the best organic soils in Turkey due to the excellent physical and chemical properties for plant growth medium (Cayci et al. 1989). These characteristics allow the production of many vegetables and field crops. The Yenicaga, Bolu peatland began to be used as a peat mine from the beginning of the 1980s; unfortunately, this area was degraded relatively in short time because of lack of mining legislation for peat extraction at that time in Turkey. Factors that cause peat to accumulate are similar all over the world, but different types of peatlands develop because of differences in climate, soil type and plant species. Peat formations in Turkey are known as basin peat (Dinç 1974). These formations occur at low elevations influenced by topography and hydrologic processes in distinct depressions of natural basins that flood and develop into lakes. Lacustrine mud generally consisting of calcareous and detrital gyttja for several meters thick often occur under peat layer. Plants grow around lake edges and eventually extend over most of the surface, often with the only area of open water at the center or deepest part of the basin. Basin peat formations are fertile compared to peat formed under cool and wet

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climatic conditions, which have high acidity, low nutrient status, and low microbiological activity.

Organic soils can be classified by topography, chemical and physical properties, botanical origin, and genetic processes (Andriess 1988). Soil Taxonomy (Soil Survey Staff 1999) has been developed to serve as an international system and there is interest in Turkey to apply criteria of this classification system to our soils. Increasing interest in the use of peat in agriculture and industry in Turkey has resulted in the need for more information about chemical and physical differences in peatlands and how new management approaches can be applied. Their behavior, properties and land use have drawn more attention in the last decade due to above mentioned reasons.

The objective of this research was to characterize the physical, chemical and morphological properties of the Yenicaga, Bolu peatland displaying typical characteristics of Turkish basin peat soils and classify it according to Soil Taxonomy (1999) with regard to formation.

Material and methods

Site description

The peatland around the Lake Yenicaga is located in between $40^{\circ} 46' N$ and $31^{\circ} 59' E$ (Fig. 1). Lake Yenicaga which is near the Yenicaga district of the Bolu province, occupies 230.2 ha in depression area between Bolu Plain and Gerede fault. The study area is situated at an altitude of 991 m above mean sea level. Climate is cold and rainy with the average annual precipitation and temperature of 538 mm and $10.2^{\circ} C$, respectively.

Lake Yenicaga is a basin formed by tectonic activity and limestone dissolution (karst) processes. This basin is mainly fed by the Caga stream, surface and ground waters.

Yenicaga Lake is a part of Bolu Yeniçaga segment of north Anatolian fault zone. The lake is located in north block of North Anatolian fault zone. This block contains Devonian and Cretaceous-aged limestone, Bazaltic tuff, lava and Olistolites. These formations also contain granites, limestone blocks and same age volcanic rocks. The uppermost layer consists of Tertiary and Quaternary formations of sand, gravel, silt and clay.

Soil sampling

The study area covers approximately 192.6 ha. In addition, the peatland is surrounded by alluvial and hydromorphic alluvial soils.

Initially, organic soils around the lake were surveyed using the random grid method and auger sampling based on land observations and a topographic map (Fig. 2). Four representative soil profiles were selected based on these results. Soil morphological properties of soil profiles were described (Soil Survey Div. Staff 1993). Soil samples taken from each horizon were air-dried in the laboratory and sieved to <2 mm. In addition, undisturbed soil samples were taken from the each horizon to determine bulk density and water content.

Laboratory study

Analyses performed were fiber content and color of the extract with sodium pyrophosphate (Soil Survey Staff 1999), bulk density, calcium carbonate and cation exchange capacity (CEC) (U.S.Salinity Lab. 1954), total nitrogen (Bremner 1982), organic matter (DIN 1978), and pH and the electrical conductivity (EC_e) in saturated medium extract (Kirven 1986). Particle size distribution

Fig. 1 Location of the study area

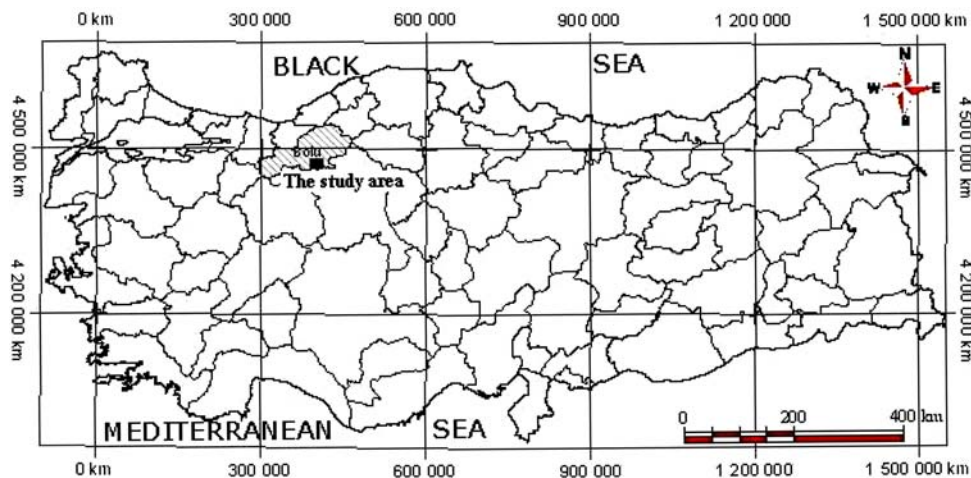
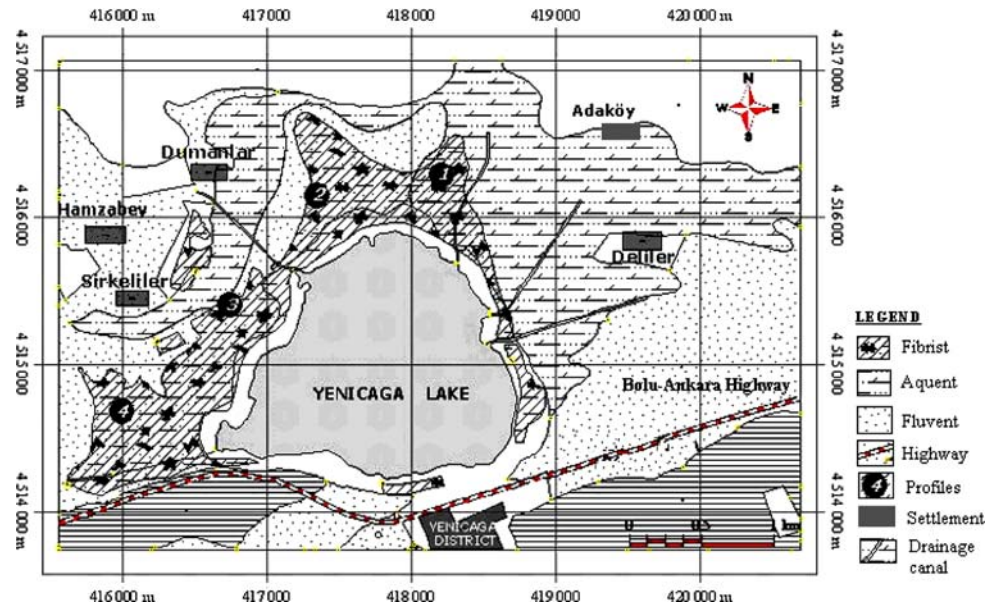


Fig. 2 Profile places and peat area of the study area



in the mineral part was determined by the hydrometer (Bouyoucos 1951) and pipette methods (U.S.Salinity Lab. 1954) after removal of organic material.

Results and discussions

Formation and properties of the soils

The organic soils in the study area formed on the low-lying shallow fresh water lake under the influence of topography, climate and hydrologic processes. Their formation resulted from the accumulation of partly or completely decomposed plant residues such as carex, phragmites and brush wood formed under anaerobic conditions and all profiles mainly consisted of *Phragmites communis* remains as a parent material. Surface and ground waters contain large amounts of calcium carbonate and other nutrients due to limestone parent material of the study area. Therefore, they are classified as eutrophic based on flooding with nutrient rich water.

Study of morphological properties (Table 1) found that granular structures pedogenically formed in surface horizons from the high degree of organic matter decomposition. Below the surface, other horizons are structureless, massive in all profiles. Rubbed colors of each horizon of profiles were generally brownish black (5YR 2/4, 2/2, 7.5YR 3/2, 2/2), indicating a high degree of chemical decomposition in the soil surface. The dark brown and dark reddish brown (10YR 3/3, 7.5YR 2/3, 5YR 2/3, 2/4, 3/4) color is dominant in subsurface horizons of profiles. In addition, Oi₂ fibric horizon color of profile III was brown (10YR 4/4), indicating a lower degree of decomposition and higher fiber content

relative to surface horizons. On the other hand, mineral horizons of profile I were gray (5Y 5/1), while the Cg horizon, under control section of the profile IV was grayish olive (5Y 5/3) due to gleization.

Most of the organic horizons were non-plastic and non-sticky however, some organic horizons were weakly plastic and sticky. Contrary to organic horizons, mineral horizons were very plastic and very sticky. Seasonal ground water flocculation has a substantial effect on changing of morphological properties of organic soils in the study area.

These substantial differences among the organic horizons result from eutrophic processes, differences in botanical origins, decomposition degrees, ground water composition, and depth and land use management in the study area (Baran 1994; Cayci et al. 2000). Ground water level flocculation has the most important role in the differentiation of the profiles. Tables 2 and 4 show the differences among the profiles in terms of physical, chemical and morphological properties. It is found that the fiber content of the profiles (Table 4) increases with depth through the subsurface tiers. Fiber contents were always low on top of the soils because of declining of water table level in evaporative periods and severe oxidation conditions. There was a relationship between CEC, organic matter, and decomposition degree as well. While the decomposition degree decreases, the organic matter and consequently, the CEC increase.

Soil properties varied widely depending on the pedon (Table 2). Sand, silt and clay contents of the organic soils ranged between 0.75–3.92, 40.70–74.77 and 24.15–57.30%, respectively. Fiber contents were between 4.3 and 91.5%, varying due to degree of organic matter decomposition. Highly decomposed sapric (Oa) horizons were

Table 1 Some morphological properties of soil profiles

Pedon	Altitude	Level of ground water table	Horizon	Depth (cm)	Color (Rubbed)	Structure	Stickiness/plasticity	Boundaries properties
I	996	132	Oa	0–11	7.5YR 2/2	Mo–Co–Gr	Non St–Non Pl	Abrupt-smooth
			Oi ₁	11–42	7.5YR 2/2	Massive	Non St–Non Pl	Clear-smooth
			Oe	42–67	5YR 2/1	Massive	Non St–Non Pl	Abrupt-smooth
			Oi' ₁	67–94	7.5YR 3/3	Massive	Sl St–Sl Pl	Abrupt-smooth
			C	94–108	5Y 5/1	Massive	Mo St–V Pl	Clear-wavy
			Oi ₂	108–136	7.5YR 3/3	Massive	Non St–Non Pl	Clear-wavy
			C'	+136	5Y 4/1	Massive	V St–V Pl	–
II	993	120	Oa	0–20	7.5YR 3/3	Mo–Co–Gr	Sl St–Non Pl	Clear-smooth
			Oi ₁	20–31	5YR 3/4	Massive	Non St–Non Pl	Abrupt-smooth
			Oe	31–51	7.5YR 3/2	Massive	Non St–Non Pl	Abrupt-smooth
			Oi' ₁	51–64	5YR 2/2	Massive	Sl St–Mo Pl	Abrupt-smooth
			Oi ₂	64–91	7.5YR 3/2	Massive	Mo St–Mo Pl	Abrupt-smooth
			Oi ₃	91–130	7.5YR 3/4	Massive	Mo St–Mo Pl	–
III	990	75	Oa	0–15	10YR 3/3	St–Co–Gr	Mo St–Mo Pl	Clear-smooth
			Oe	15–31	7.5YR 3/2	Massive	Non St–Sl Pl	Abrupt-smooth
			Oi ₁	31–63	7.5YR 2/3	Massive	Sl St–Non Pl	Clear-wavy
			Oi ₂	+63	10YR 4/4	Massive	Non St–Non Pl	–
IV	992	65	Oa	0–16	7.5YR 2/3	Mo–F–Gr	Mo St–Mo Pl	Gradual-smooth
			Oe	16–28	5YR 2/2	St–Me–Gr	Sl St–Mo Pl	Clear-smooth
			Oi	28–71	5Y 5/2	Massive	Non St–Non Pl	Abrupt-smooth
			Cg	71–85	10YR 3/3	Massive	V St–V Pl	Clear-smooth
			Oi'	85–108	7.5YR 2/2	Massive	Sl St–Non Pl	Clear-smooth
			Cg'	108–160	5Y 5/3	Massive	V St–V Pl	–

St Strong, Mo moderate, Me Medium, F Fine, Co Coarse, Gr Granular, Pl plastic, St Sticky, Sl Slightly, V Very

present on all profile surfaces and had <10% fiber due to rapid decomposition and mineralization of organic matter.

Slightly decomposed fibric (Oi) horizons were present in the subsoil and had higher fiber contents (48–91.5%). This was more evident in profile III located close to the lake in which relatively high water table prevented decomposition of organic matter and led to higher fiber content.

Organic matter ranged from 12.5 to 91.5% across all four pedons. Higher organic matter contents were found in fibric horizons of profiles III and IV. However, organic matter contents in fibric horizons of profiles I and II were lower due to high chemical decomposition.

Distribution of organic matter was irregular in all pedons. The amount and type of organic materials influenced water-holding capacity of each horizon. For example, water-holding capacities were as low as 140–330% in sapric horizons of the four pedons, while fibric horizons had higher water-holding capacities (730–1,200%).

A fibric layer was found under the Cq mineral horizon in profiles I and IV. This horizon sequence can be explained by occurrence of different sedimentation periods from severe floods. This case resulted in a variety and density of

the plant growth across the study area, resulting in large differences in N% and C% contents among horizons of all profiles.

The CEC ranged from 37 and 222 cmol/kg. The high CEC of fibric horizons was due to high organic matter contents. Bulk density ranged from 0.09 to 0.78 g cm⁻³ and related to organic matter content and mineralization rates. The highest bulk density (0.78 g cm⁻³) was found in the sapric (Oa) horizon of profile I. The bulk density values of surface horizons in all profiles were higher than subsurface horizons on account of mineralization.

Nitrogen ranged from 0.56 to 2.19%. Different sedimentation periods, flocculating of ground water table level, vegetation types and their intensities affected decomposition of organic matter which leads to varied distribution of N in the study area

The amount of CaCO₃ was negligible, and ranged from 0.15 to 2.62%. Surface and subsurface horizons of profiles I and II which are quiet far from the center of the basin include lowest amounts of CaCO₃. This can be explained by atmospheric deposition and surface waters rich in dissolved carbonates.

Table 2 Some physical and chemical properties of the organic soils

Pedon	Horizon	Depth (cm)	Organic matter (%)	pH	EC (dS m ⁻¹)	CEC cmol kg ⁻¹	N (%)	C (%)	CaCO ₃ (%)	Texture		
										Sand (%)	Silt (%)	Clay (%)
I	Oa	0–11	36.0	6.35	1.20	104	1.33	20.93	0.15	2.21	58.86	38.93
	Oi ₁	11–42	88.5	6.26	0.80	212	1.58	51.45	0.30	1.15	51.70	47.15
	Oe	42–67	81.0	5.96	1.08	197	1.68	47.09	–	1.03	58.60	40.37
	Oi ₁ '	67–94	71.5	5.38	2.24	201	1.53	41.28	–	0.91	57.10	41.99
	C	94–108	12.5	6.86	2.80	37	0.56	7.27	–	0.78	65.45	33.77
	Oi ₂	108–136	57.0	6.90	3.80	169	1.76	33.14	–	1.17	56.85	41.98
	C'	+136	34.5	7.18	1.70	100	1.22	20.06	–	1.17	61.83	37.00
II	Oa	0–20	42.5	7.19	1.42	97	1.61	24.71	2.24	1.61	55.85	42.54
	Oi ₁	20–31	74.0	7.49	1.00	192	1.79	43.02	2.48	1.52	60.50	37.98
	Oe	31–51	80.5	7.59	0.80	208	1.66	46.80	–	1.86	62.50	35.64
	Oi ₁ '	51–64	75.0	7.64	0.62	201	1.76	43.61	–	1.02	66.53	32.45
	Oi ₂	64–91	57.0	7.10	0.80	147	1.41	33.14	–	1.37	53.44	44.86
	Oi ₃	91–130	56.5	6.82	0.50	141	1.37	32.84	–	0.98	55.14	43.88
III	Oa	0–15	32.0	7.92	0.80	84	1.17	18.60	2.62	0.75	55.15	44.10
	Oe	15–31	78.0	7.04	1.30	210	2.10	45.35	–	0.97	65.96	33.07
	Oi ₁	31–63	91.0	7.02	2.40	222	1.82	52.91	–	0.89	74.25	28.86
	Oi ₂	+63	76.5	6.88	0.60	188	1.69	44.48	–	1.08	74.77	24.15
IV	Oa	0–16	57.5	7.32	1.20	161	2.02	33.43	2.14	2.00	40.70	57.30
	Oe	16–28	55.1	6.96	1.00	144	1.89	32.03	–	3.92	40.78	55.30
	Oi	28–71	85.0	6.50	1.30	195	2.19	49.42	–	3.60	51.06	45.34
	Cg	71–85	22.0	6.37	2.20	44	0.65	16.28	–	1.95	55.10	42.65
	Oi'	85–108	91.5	6.05	3.20	220	1.40	53.19	–	2.20	52.10	45.70
	Cg'	108–160	29.0	6.97	2.20	61	0.71	18.02	–	1.75	58.90	39.35

The pH and EC_e are 5.38–7.92 and 0.50–3.80 dS m⁻¹, respectively. Both pH and EC values had irregular distribution in all pedons. While pH ranged from slightly acid to slightly alkaline, all profiles do not have sufficiently high salts to hinder agricultural use.

Classification of the organic soils in the study area

Histosols are classified at suborder level in Soil Taxonomy according to kinds of soil organic materials of subsurface layer. Thus, morphological properties of the organic soil horizons such as fiber content and degree of decomposition are very important criteria for their classification. Fiber content and degree of decomposition used in the recent (eighth) edition of Soil Taxonomy (Soil Survey Staff 1999) were applied to the soils of the study area. Organic soils are distinguished as fibric, hemic and sapric (Table 3) according to decomposition degree of original plant material. Parameters required for determining these horizons in our study are given in Table 4.

Surface layer of organic soils degrades rapidly under agricultural practices due to the decomposition of the

organic matter. Fibric soil materials transform to hemic and sapric surface horizons. Profile I has a fibric Oi₁ horizon between 11 and 42 cm due to <10% rubbed fiber content. Color and dry bulk density showed some sapric characteristics (Table 4) with a slightly low saturated water content and moderately high dry bulk density. Although the rubbed fiber content tends to be slightly high, the Oe horizon is hemic. Profile II has a fibric Oi₁ horizon due to high rubbed fiber content as diagnostic criterion although the color of the sodium pyrophosphate extract and the dry bulk density show sapric and hemic characteristics. The Oe horizon is between 31 and 51 cm depth has slightly high fiber content but the other properties are suitable to be characterized as a hemic horizon. Even though Oi₂ and Oi₃ horizons have slightly low maximum water content, they display hemic characteristics.

Profile III has a sapric Oa horizon because of a slightly high bulk-density value but all other characteristics showed a hemic character. The Oa, Oi₁ and Oi₂ fulfill all requirements of sapric and fibric soil materials. Profile IV has a sapric Oa horizon between 0 and 16 cm depth since the dry bulk density is high. Nevertheless, all other characteristics indicate hemic character. Moreover, the Oi and Oi₁

Table 3 Soil organic materials properties according to Soil Taxonomy, 1999

Kinds of organic soil materials	Fiber content (after rubbing, by volume)	Color values and chroma	Water content (%)	Bulk density, g cm ⁻³ (general range)
Fibric	3/4 or more 2/5 or more	– 7/1, 7/2, 8/1, 8/2 or 8/3	850–3,000	<0.1
Sapric	Less than 1/6	Right of line down to exclude blocks 5/1, 6/2,7/3	<450	>0.2
Hemic	Medium degree of decomposition between fibric and sapric	–	450–850	0.7–0.18

Table 4 Some properties of organic soils for classification at suborder level

Pedon	Horizon	Depth (cm)	Rubbed fiber (% volume)	Color (Na- Pyrophosphate extract)	Maximum water content (%)	Dry bulk density (g cm ⁻³)
I	Oa	0–11	<10	10YR 6/4	140	0.78
	Oi ₁	11–42	87	10YR 6/4	1,143	0.20
	Oe	42–67	43	10YR 6/2	840	0.17
	Oi ₁ '	67–94	75	10YR 7/2	780	0.19
	C	94–108	–	–	–	–
	Oi ₂	108–136	48	10YR7/2	745	0.13
	C'	+136	–	–	–	–
II	Oa	0–20	<10	10YR 5/6	152	0.54
	Oi ₁	20–31	77.0	10YR 6/4	889	0.16
	Oe	31–51	45.0	10YR 6/4	770	0.17
	Oi ₁ '	51–64	58.0	10YR 8/1	1,250	0.12
	Oi ₂	64–91	75.0	10YR 8/1	790	0.12
	Oi ₃	91–130	70.0	10YR 8/2	730	0.13
III	Oa	0–15	<10	10YR 6/6	140	0.62
	Oe	15–31	39.4	10YR 7/4	580	0.20
	Oi ₁	31–63	83.8	10YR 7/1	1,170	0.12
	Oi ₂	+63	87.5	10YR 7/1	1,200	0.09
IV	Oa	0–16	<10	10YR 6/4	330	0.32
	Oe	16–28	21.3	10YR 7/3	645	0.22
	Oi	28–71	88.1	10YR 7/1	943	0.13
	Cg	71–85	–	–	–	–
	Oi'	85–108	91.5	10YR 8/1	825	0.15
	Cg'	108–160	–	–	–	–

horizons have a hemic character due to the bulk density, but particularly the fiber content and the color of the sodium pyrophosphate extract indicate that those horizons have a fabric character.

Soil temperature in study area is higher than 8°C and difference between mean summer and mean winter temperatures is more than 5°C. Therefore, the soil temperature regime is Mesic. The order of Histosols include soils that consist of more than half of the upper 80 cm of organic material unless rock or rubble are shallower than this depth. All profiles support the requirements of the

Histosols Order as they are saturated for prolonged periods or are artificially drained, have 30% organic matter if the mineral fraction contains 60% or more clay or, minimum 20% organic matter when the mineral fraction has no clay and proportional amounts of organic matter if the clay content of the mineral fraction is intermediate (Soil Survey Staff 1999).

Although the thickness of the horizons in all profiles was different, the fiber material is dominant in the subsurface tiers. Therefore, all profiles classified as Fibrists on the suborder level. On the level of the Great Soil Groups, there

are no humilluvic material and *sphagnum* fibers. Only considering the soil temperature regime, the profiles can be classified as Medifibrist. As for the Subgroup level of the Medifibrist, the first profile was classified as Hemic Medifibrist due to its hemic material that is at least 25 cm thick. Although there was some extent to hemic material in the second profile, thickness is not enough. Therefore, the second profile was classified as Typic Medifibrist. Other two profiles were classified as Hydric Medifibrist because of permanently ground water table in control section.

Conclusions

Accumulation of organic material deposits occurred at the bottom of the surface, and these soils developed as the mineral subsoil at the shores of the lake toward deep water in the study area. Species of reeds have begun to grow especially in north, west and east part of the lake due to shallow water. Decomposed organic materials were moved and deposited to deeper parts of the lake by waves and flows, resulting in the formation of a clayey and organic mud. Subsequent decrease in water depth occurred by mineral sedimentation and heaping of plant residues particularly at the shores of lake. Shore flora narrowed water surface area by moving central part of the lake. Decreasing lake level and surface area resulted in areas in which organic materials raised to the surface and served as organic parent material. Organic materials underwent changes due to chemical and physical decomposition owing to decreasing of water level and this stimulated biological activities. Chemical decomposition was higher in profiles I and II which were far from central area. On the other hand, extreme declining of water level and hindering of capillary water treatments cause rapid oxidation in organic soils.

Conservation of wetlands in arid and semi-arid regions is very important for natural life and environment. Draining of peat swamps for agricultural use or extremely declining of water table level in these areas will result in annihilation of organic soils that serve as natural resources. Peatland ecosystems are highly sensitive to changes in water balance and retaining the natural balance is the key to long-term conservation of individual peatlands sites. There is a strong interrelationship between plants, water and peat. When one component is affected, eventually all components change in peatland ecosystem. Modification of the peatland's hydrology directly affects peatland's flora and fauna. On the longer run changes in the hydrology influence on the hydraulic soil properties. Human being activated oxidation and subsidence processes in the study area by initiating drainage. Intensively drainage following strong pedogenesis severely affected

peatland ecosystem. After oxidation and subsidence started, keeping drainage at suitable levels to match subsidence became a real problem. Restoring peat hydraulic conditions was practically impossible in the study area. Since the compacted peat prevented the water from entering the peat body, the decreased storage of peat caused to larger water level fluctuations, which increased peat decomposition. Our results show that declining the water table level less than 65 cm will cause decomposition of organic materials and transform fibric horizons to hemic and sapric horizons in the study area. In addition, the regional producers, excavating and removing for a growing medium from these organic soils, have also negative effects on Bolu-Yeniçağa peatland that has a unique ecosystem with its natural attractive environments and habitats for biota.

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