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Long Term Cultivation Effects on Soil Properties in Pastures

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Four soil profiles were examined to determine and compare the effect of soil management practices on various soil physical, chemical and morphological features. Soils were developed in an alluvium over lacustrine materials. The locations of pits studied were selected based on the distance from river and profiles were excavated two from native pasture (never been cultivated) and the other two from cultivated field (15 years of cultivation). Soil moisture contents of cultivated lands were higher than that of pasture field. Organic matter content of surface horizons were decreased almost 50% in cultivated fields due to the increasing decomposition rate of organic matter in tilled fields. Soluble salt content was increased at about 90 cm depth in cultivated land while in pastures high soluble salt contents were observed closer to the surface (about 50 cm depth). Calcium carbonate nodules and masses were described at around 60 cm of the soil surface in cultivated field. Results indicated that long-term management practices resulted in changes in soils, both in physical and chemical properties.

Key Words: Cultivation, Soil properties, Pasture, Bulk density, Organic matter.

INTRODUCTION

Soils are formed from the interaction of parent material, climate, topography and living organisms over time[1]. The living organisms cover vegetation, fauna and different human management practices. Human effect on soil formation is either direct such as through tilling, manuring, liming, fertilizing or indirect through changing natural soil forming factors such as leveling, irrigation, drainage and erosion[2].

Tillage has been an integral component of crop production for centuries[3]. Long term cultivation, irrigation, addition of mineral fertilizers and such human activities cause changes in soil characteristics and in the classification of soils. Surface water logging associated with long continued irrigation of soils results in changes of Typic Kanhapludults to Antraquic Kandiudults. Similarly, in arid environments Cambids become Salids as a result of unconscious irrigation[2].

Soil tillage moves subsurface material to the surface where it is then exposed to wetting-drying and freezing-thawing cycles and subjected to raindrop impact[4], thereby increasing the susceptibility of aggregates to disruption. Plowing also changes the soil conditions (*e.g.*, temperature, moisture and aeration) and increases the decomposition rates of organic material[5]. In no tillage, due to drier conditions and reduced contact between soil microorganisms and litter, decomposition rate of plant residues is slow as compared to conventional tillage[6].

Generally, cultivation leads to a substantial loss of organic matter associated with size fractions > 50 μm, resulting in a relative shift of soil organic matter from coarser to finer fractions[7]. Cultivation both reduces soil carbon content and changes the distribution and stability of soil aggregates[8]. Studies on carbon losses of soils due to the long and continuous cultivation and sequestration of atmospheric CO_2 back to the soils are plenty[9–11]. Because of accelerated decomposition with cultivation and erosive forces, which preferentially remove the lower density components of soils (*i.e.*, organic matter), extreme losses of soil organic carbon have commonly been reported from the studies.

Soil loss is accelerated by soil degradation, especially soil compaction that induces organic matter losses and soil structure disruption[12]. The use of heavy tillage disturbs the structure of soils. Sites that had been under long-term pasture have a greater aggregate stability than that of cultivated sites[13]. The concerned area in this study is located between arid and humid climate. Therefore, long-term cultivation or continued grazing with inadequate management promotes accelerated erosion.

Since soil formation and the horizon differentiation of soils take a very long time, changes in soil genesis of soils such as clay alluviation and calcium carbonate accumulation after long-term cultivation have not been given enough consideration in literature. Majority of the studies regarding long-term cultivation were concentrated on the losses of organic carbon and nitrogen losses of soils and erosion effect of cultivation.

This research was conducted in Kazova plain with a combination of native grassland, land that had never been cultivated and land under approximately 15 years continuous cultivation. In this study, the changes in the properties of soils is investigated after cultivation. The changes include organic matter content, bulk density, clay alluviation, calcium carbonate accumulation and oxidation-reduction of soils.

EXPERIMENTAL

The study area is located in a flood plain called Kazova, 15 km northwest of Tokat province, Turkey. Four soil profiles (Cerci soil series): two from native grass (never before cultivated) and two from adjacent cultivated fields (the first one has been cultivated since 1992 and the other one since 1989) were selected for this study. The locations of pits studied were decided, based on the distances from the Yesilrmak River and profiles 3 and 4 (P3, P4) were closer to the river. The region is under the effect of both Black Sea region climate and terrestrial climate of the Central Anatolian region. Average annual precipitation is 600 mm and the temperature is 11–12°C. The first two profiles (P1 in the cultivated field and P2 in pasture) were located closer to the ancient lake and parallel to each other. The third (P3) and the fourth (P4) profiles were also parallel to each other but further from the ancient lake coast. Conventional tillage was performed at maximum tillage depth of 20 cm with tillage operations totalling 5 or 6 per year in continuously cropped fields. Soils were classified as fine, smectitic, mesic Fluvaquentic Haplustolls (P2, P3, and P4) and fine, smectitic, mesic Aquic

Argiustolls (P1) order according to soil taxonomy[14] consequently. A pit *ca.* 2 m deep was dug for each site. The detailed morphological descriptions of soil profiles were made according to field book for describing and sampling soils[15], and horizons were identified on site. Bulk samples for physical and chemical analyses and 100 cm^3 core samples for bulk density determination were taken from all horizons. Oven-dry bulk densities were determined for each sampled horizon.

Samples were air dried, manually ground and sieved to remove coarse fragments > 2 mm. Particle size distribution was made by the hydrometer method[16]; soil pH was measured from a 1 : 1 soil/water suspension[17]; exchangeable cations were extracted with 1 M NH_4OAc at pH 7; cation exchange capacity was determined by the summation of cations; calcium carbonate content was determined by the pressure-calcimeter method[18].

The following data were recorded in the field: upper and lower boundaries of horizons, moist and dry colour (Munsell colour chart), reaction to 10% HCl and the presence of carbonate accumulation.

RESULTS AND DISCUSSION

Soils investigated were very deep, poorly drained and formed in alluvium over clayey lacustrine deposits. Kazova, a flood plain, was initially a swamp area and after the 1970's the government started to establish drainage systems in the plain. A small portion of the plain has never been cultivated and is used as pasture. Since the pastures belong to the government, the villagers who benefit from the pasture do not manage the pastures properly. Due to the intensive grazing, grass production of the pasture is not very good. Therefore, organic matter addition to the soil surface is not as high as expected.

Selected physical and chemical characteristics of profiles studied are presented in Table-1 and morphological descriptions in Table-2. Profiles 1 and 2 were located in cultivated fields and profile 3 and 4 in pastures. The upper 50 cm of the soil profiles in cultivated fields was slightly higher in clay than the profiles in pastures. Interpretation of the data (Table-1) and field observations (Table-2) of clay films in Bt horizons demonstrates that Profile 1 has an argillic horizon as a result of clay movement from the Ap horizon downward to the Bt horizon. However, the formation of argillic horizon probably started long before the cultivation practices started, because the formation of clay skins is a time dependant process related to soil forming factors[19]. Since clay movement is a mechanical process, it could be relatively fast if the conditions are suitable. Even in this case, Breeman and Buurman[19] observed clay films in the glacial deposits that were less than 200 years old. In the studied soils, clay movement started before the tillage started. Since the parent material of the soils is clayey in nature, it is ready to be transported. Therefore, it can be concluded that tillage may fasten the alluviation process and argillic horizon formation in P1. In the other 3 profiles, higher clay content in B horizons than surface soil was detected but the amount of clay content does not meet the criteria of argillic horizon.

Tillage is used for planting and also to loosen the surface and sub-surface soil

TABLE-1
SELECTED PHYSICAL AND CHEMICAL PROPERTIES OF SOIL PROFILES

Horizon	Depth (cm)	Total Sand	Silt	Clay	Bulk density ($g\ cm^{-3}$)	Org. matter (%)	pH 1 : 2 H_2O	EC (mmho/cm)	$CaCO_3$ (%)	CEC ($cmol_c\ kg^{-1}$)	Exchangeable Ca + Mg	Na	K
		%									($cmol_c\ kg^{-1}$)		
Profile 1 (cultivated field)													
Ap	0–22	23.9	30.3	45.8	1.53	4.25	7.93	678	14.9	36.71	35.82	0.31	0.58
Bt_1	22–52	20.6	17.8	61.6	1.79	2.10	7.95	589	18.0	37.61	36.96	0.37	0.28
Bt_2	52–74	17.3	27.8	54.9	1.60	2.04	8.18	719.5	20.2	31.50	30.70	0.68	0.12
Bg_1	74–86	25.5	34.2	40.4	1.73	1.76	8.25	988.5	17.7	33.19	31.86	1.21	0.12
Bg_2	86–103	15.6	44.5	39.9	1.73	1.05	8.20	1522.5	12.9	29.04	27.13	1.81	0.10
Cg_1	103–123	19.8	26.1	54.1	1.61	2.09	7.95	2155	11.9	35.81	33.47	2.22	0.12
Cg_2	123–139	19.8	17.0	63.3	1.61	1.19	7.82	2725	11.1	39.46	37.16	2.15	0.15
2Cg	139–156	16.3	41.7	42.0	1.36	3.30	7.58	2930	6.0	45.23	43.27	1.75	0.21
3C	156–165	—	—	—	1.01	12.35	6.59	3640	2.0	67.22	65.45	1.56	0.21
4Cg	165–210	32.3	17.8	49.9	1.30	8.05	6.78	2780	7.1	42.30	41.50	0.56	0.24
Profile 2 (pasture)													
A	0–16	35.8	26.4	37.9	1.44	3.99	7.41	545	18.5	37.61	37.06	0.31	0.24
Bw_1	16–36	22.4	29.9	44.4	1.61	1.73	7.66	475	18.5	33.19	32.57	0.44	0.18
Bw_2	36–51	20.8	41.5	37.7	1.76	1.54	7.68	2006	16.4	30.67	29.28	1.32	0.07
C_1	51–68	16.6	54.9	28.6	1.53	0.85	7.63	2395	13.3	25.90	24.37	1.38	0.15
C_2	68–97	17.4	28.3	54.2	1.63	1.25	7.62	2080	7.7	34.93	33.95	0.86	0.12
$2Cg_1$	97–114	27.4	17.5	55.1	1.35	2.53	7.55	2520	15.1	44.24	43.54	0.52	0.18
$2Cg_2$	114–139	18.3	21.7	50.1	1.46	2.38	7.58	1925.5	8.7	41.34	40.82	0.37	0.15
3C	139–148	—	—	—	1.23	11.45	6.04	3865	1.9	40.39	39.97	0.27	0.15
4Cg	148–160	41.5	43.3	25.4	1.36	7.14	6.10	3770	5.8	34.93	34.54	0.21	0.18

Horizon	Depth (cm)	Total			Bulk density ($g\ cm^{-3}$)	Org. matter (%)	pH 1 : 2 H_2O	EC (mmho/cm)	$CaCO_3$ (%)	CEC ($cmol_c\ kg^{-1}$)	Exchangeable		
		Sand	Silt	Clay							Ca + Mg	Na	K
		%									($cmol_c\ kg^{-1}$)		
Profile 3 (cultivated field)													
Ap	0–30	31.7	21.5	46.8	1.43	2.82	7.71	603.0	18.5	45.23	44.74	0.21	0.28
Bt	30–60	20.5	26.5	53.1	1.68	0.95	7.79	483.0	18.5	44.24	43.79	0.27	0.18
Bk	60–77	20.5	34.0	45.6	1.64	0.90	7.84	406.0	16.4	39.46	39.13	0.21	0.12
BC	77–99	16.7	31.5	51.8	1.73	0.74	7.80	622.5	13.3	37.61	37.16	0.24	0.21
C_1	99–126	19.2	30.2	50.6	1.49	0.42	7.66	2300.0	7.7	40.39	39.70	0.41	0.28
C_2	126–143	20.5	29.0	50.6	1.50	1.11	7.59	2165.0	15.1	40.39	39.84	0.34	0.21
2C	143–162	26.7	27.7	45.6	1.35	2.02	7.27	2285.0	8.7	40.39	39.81	0.34	0.24
3Cg	162–195	28.0	31.5	40.6	1.42	1.10	7.21	2490.0	1.9	37.61	37.06	0.31	0.24
Profile 4 (pasture)													
A	0–16	52.2	19.8	28.1	1.33	7.35	7.78	443.0	20.4	43.26	42.20	0.31	0.75
Bw_1	16–34	40.9	23.5	35.6	1.56	2.04	7.87	423.0	16.3	46.23	45.71	0.34	0.18
Bw_2	34–43	35.9	21.0	43.1	1.60	1.60	7.87	519.5	10.6	47.24	46.69	0.37	0.18
Bw_3	43–62	19.7	32.3	48.1	1.69	0.70	7.79	952.5	7.2	38.53	37.86	0.52	0.15
Bk	62–77	18.4	36.0	45.6	1.76	0.56	7.61	1520.0	8.4	34.93	34.10	0.68	0.15
C_1	77–97	19.4	30.2	50.4	1.70	7.81	7.61	1863.5	12.7	36.71	35.91	0.68	0.12
C_2	97–119	20.7	27.5	51.8	1.44	0.33	7.55	1484.5	3.5	41.34	40.72	0.44	0.18
$2Cg_1$	119–129	19.2	30.2	50.6	1.39	0.95	7.57	2003.5	6.9	38.53	37.86	0.52	0.15
$2Cg_2$	129–138	18.2	27.5	54.3	1.48	0.73	7.63	1311.0	2.2	43.26	42.77	0.34	0.15
$2Cg_3$	138–149	15.2	33.0	51.8	1.28	0.70	7.72	980.5	4.1	36.71	36.25	0.31	0.15
$3Cg_4$	149–170	24.0	22.5	53.5	1.31	0.66	7.66	1157.0	5.4.	28.24	27.69	0.31	0.24

TABLE-2
MORPHOLOGICAL DESCRIPTION AND CLASSIFICATION OF SOIL PROFILES

Horizon	Depth (cm)	Matrix color	Texture	Structure	Consistence	Boundary	Special features
Profile 1 (cultivated field): fine, smectitic, mesic Aquic Argiustolls							
Ap	0–22	10YR3/2		1m gr[a]	(m) vfr	CW	Common fine roots
Bt_1	22–52	10YR3/6		2m pr 2m sbk	(m) fr	CW	Discontinuous clay films on vertical faces of peds (10YR4/6); moderately few fine roots
Bt_2	52–74	10YR4/3		2m pr 2m sbk	(m) fi	CW	Common discontinuous clay films on vertical faces of peds (10YR4/6); Many redox concentrations as masses of iron
Bg_1	74–86	10YR4/4		2m sbk	(m) fr	CW	Few medium $CaCO_3$ masses
Bg_2	86–103	10YR3/4		1m sbk	(m) vfr	CW	Gleyic matrix; common medium $CaCO_3$ masses
Cg_1	103–123	10YR3/4		massive	(m) vfi	CW	Common redox concentrations as masses of iron (10YR5/8)
Cg_2	123–139	2.5Y5/1		massive	(m) vfi	CW	Many redox concentrations as masses of iron (10YR4/6) and manganese
2Cg	139–156	2.5Y4/1		massive	(m) vfi	CS	Many redox concentrations as masses of manganese; many diatoms
3C	156–165			massive		CS	Free water, very little decomposed litter
4Cg	165–210	2.5 Y5/1		assive	(m) vfi		Common iron concentrations as masses (10 YR 4/6)
Profile 2 (pasture): fine, smectitic, mesic Fluvaquentic Haplustolls							
A	0–16	10YR4/2		2m gr[a]		CW	0.5 to 1 cm thick crack, goes into 1 m depth; common fine roots
Bw_1	16–36	7.5YR4/2		2m sbk		CW	Common fine roots
Bw_2	36–51	7.5YR4/2		1m sbk		CI	Few fine roots; common redox concentrations as masses of iron
C_1	51–68	10YR4/2		2co abk		CW	Common redox concentrations as masses of iron
C_2	68–97	10YR5/4		massive		CS	Many redox concentrations as masses of iron (7.5YR4/6) and few Mn (10YR4/2)
$2Cg_1$	97–114	2.5Y5/2		massive		CS	Many redox concentrations as masses of iron (7.5YR4/6) common Mn (2.5Y3/1)
$2Cg_2$	114–139	10YR4/3		massive		CS	Common redox concentrations as masses of iron (7.5YR4/4)
3C	139–148	5Y3/1		massive		CS	Moderately decomposed litter
4Cg	148–160	5Y4/1		massive			Gleyic matrix

Horizon	Depth (cm)	Matrix color	Texture	Structure	Consistence	Boundary	Special features
Profile 3 (cultivated field): fine. smectitic, mesic Fluvaquentic Haplustolls							
Ap	0–30	7.5YR3/2		2m gr[a]	(m) vfr	CS	Common fine roots; crack goes into 2C horizon few discontinuous
Bt	30–60	10YR4/2		3m sbk-3f sbk	(m) fi	CI	Clay films on vertical faces of peeds; common redox concentrations along root channels (5YR4/6)
Bk	60–77	10YR4/3		2mpr-2fpr	(m) fi	CW	Common 0.5–1.0 cm diameter calcium carbonate masses; common redox concentrations along root channels (7.5YR4/6)
BC	77–99	10YR4/3		1m pr	(m) fi	CS	Very common redox concentrations both along root channels and on the faces of peds 7.5YR/6(Fe) and 10YR6/1(Mn)
C_1	99–126	2.5Y5/2		1m pr	(m) fr	CW	
C_2	126–143	10YR5/3		massive	(m) fr	CS	Very common redox concentrations 10YR6/8 (Fe) and few 5YR4/6 (Mn) concentrations
2C	143–162	2.5Y4/2		massive	(m) vfr	CS	Very little decomposed plant tissue; redox concentrations 2.5Y5/1 (Mn) concentrations and 2.5Y5/1 (Mn) gleyic matix
3Cg	162–195			massive	(m) vfr		
Profile 4 (pasture): fine, smectitic, mesic Fluvaquentic Haplustolls							
A	0–16	10YR3/2		2m gr[a]	(m) vfr	CW	Common fine roots; 0.5 to 1 cm thick crack, goes into 110 cm depth
Bw_1	16–34	2.5Y4/2		3m sbk	(m) fi	CW	
Bw_2	34–43	2.5Y4/2		3m sbk	(m) vfr	CW	Very common redox concentrations 7.5YR4/6 iron
Bw_3	43–62	10YR4/3		3m pr	(m) fi	CW	
Bk	62–77	2.5Y5/3		3m pr	(m) fi	CW	Few 1.5–2.0 cm diameter carbonate masses
C_1	77–97	10YR4/3		2m sbk	(m) vfi	CI	
C_2	97–119	2.5Y5/3		massive	(m) vfr	CS	Very common redox concentrations 2.5Y56/6 iron
$2Cg_1$	119–129	2.5Y5/2		massive	(m) vfr	CW	Common redox concentrations 7.5YR3/1 iron
$2Cg_2$	129–138	5Y4/1		massive	(m) vfr	CS	
$2Cg_3$	138–149	5Y4/1		massive	(m) vfr	CW	
$2Cg_4$	149–170	5Y4/1		massive	(m) vfr		

[a] Abbreviations were made according to field book for describing and sampling soils[22]

to decrease soil compaction. When a virgin soil is put under cultivation, the upper horizons become the furrow slice. Cultivation destroys the original layered condition of this portion of the profile and the furrow slice becomes more or less homogenous. Mikhailova *et al.*[10] reported greater bulk density values from 50 years continuous fallow, yearly cut hay field and continuously cropped field when compared to native grassland down to a depth of 33 cm. They concluded that the reason in increase of bulk density is due to the intensity and duration of cultivation. However, Miao *et al.*[20] obtained greater values of bulk density from rangelands. According to Miao *et al.*[20], cattle grazing has several effects on rangeland soil properties. Their trampling damages plant tissue, increases soil bulk density and slows water infiltration. Bulk densities obtained from the upper two horizons of soils in cultivated fields were higher than those of the pasture soils (Table-1). This was due to both tillage effect and the higher clay content of the soils located in cultivated sites.

Lobe *et al.*[3] reported that the organic matter content in soils decreased rapidly in the first few years they were cultivated. In the soils cultivated for 90 years, the C concentrations had been reduced to 34% of the concentrations in the grassland. Profiles from the cultivated land (P1 and 3) had less organic matter content than profiles from pastures had (P2 and 4). In a pasture, residue accumulates at the surface where the litter decomposition rate is slowed due to drier conditions and reduced contact between soil microorganisms and litter[6]. Organic matter content of the Ap horizon in profile 1 was *ca.* 50% less as compared to the A horizon of profile 4 located in a pasture, whereas differences in organic matter content of upper horizons were not obtained between profiles 1 and 2 (Table-1). This was probably because of high clay content of cultivated field (P1). High clay content might cause slow decomposition of organic matter. Kaiser and Guggenberger[21] also reported that sorption to mineral surfaces is a major process in the preservation of organic matter in soils.

Calcium carbonate content in the first 1 m of soil profiles varied from 7.2 to 20.4% and from 3.6 to 20.2%, in pasture and cultivated field, respectively. Surface horizons of cultivated land had lower calcium carbonate content than that of A horizons in pastures (Table-1). Tillage loosens surface and sub-surface soil and water penetrates the soil profile homogenously in cultivated fields. Therefore, calcium carbonate in the upper horizons easily leaches down to the sub-surface horizons. Thus, pedogenic carbonate masses were identified in profiles 1 and 3, located in cultivated land and carbonate masses were concentrated in about 60–70 cm depth of profiles (Table-2). Although pedogenic carbonate features were identified in this portion of horizons of profiles 1 and 3, calcium carbonate content was not sufficient to identify a calcic horizon in any one of the soil profiles investigated.

There are three possible sources of calcium carbonate found in the studied soils. The first source is the lateral leaching of carbonates from steep hills, because the plain is surrounded with steep hills and mountains consisting of limestone. The second source is the addition of calcium carbonate with dust, and the third source is the diatoms that survived before draining the plain. We observed many diatoms throughout the soil profiles investigated.

Soil pH, in general, decreased towards the lower part of the soil profiles and varied from 8.25 to 6.04. In contrast, EC increased towards the lower part of the soil profiles, but it was not too high to be harmful for agricultural production. Exchangeable cations were dominated by Ca and Mg in both cultivated field and pasture (Table-1).

All soils studied exhibited redoximorphic features indicative of seasonal saturation. Soil profiles located closer to the ancient coast had a gleyic horizon nearer (74 cm) to the surfaces as compared to that of further profiles (119 cm) (Table-2).

Fifteen years of continuous cultivation of pastures led to changes in some of the physical, chemical and morphological properties of soils. Soil properties affected by tillage practices are soil organic matter, bulk density, calcium carbonate and clay content. In cultivated area, organic matter, calcium carbonate and clay content of soil surface were decreased. Continuous tillage at the same depth caused compaction of soil between 20–30 cm depths. However, tillage effect became less pronounced with increased profile depth. While deciding pasture areas converting to cultivated areas, controlled management practices must be applied to prevent soil degradation.

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