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The Changes in Biological and Physical C Fractions after Conversion of Native Forest to Grassland and Cultivated land in the Northern Turkey

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ABSTRACT

Soil management systems have greater effect on soil chemical, physical and biological properties. Conversion of forest to grassland and cultivated land can alter carbon and nitrogen dynamics. The objective of this study was to evaluate the changes in biological and physical carbon and nitrogen fractions after conversion of native forest to grassland and cultivated land in the northern Turkey. Some soil physical, chemical, and biological properties were measured. Soil texture ranged from sandy clay loam through clay loam. The highest bulk density was observed in the grassland (1.41 g cm^{-3}) and the lowest one was in the cultivated land (1.14 g cm^{-3}). Soil pH was the similar (pH = 7) in the three land uses. Microbial biomass C and total organic carbon were almost two times greater in the forest than forest cleared grassland and four times greater than cultivated land. The greater portion of organic carbon was stored in macro aggregates (>250 micron) in the three land uses. Physically unprotected organic carbon (light fraction) comprises smaller portion of soil organic carbon in the three land uses. Therefore, this study indicated that microbial biomass C, mineralizable C, and protected organic C decrease in forest cleared grassland and cultivated lands.

Key words: Carbon Fractions, native forest, cultivation, microbial biomass, grassland.

INTRODUCTION

Soil physical, chemical, and biological properties have greater variability even in a smaller distance. The variability of soil properties generally attributed to changes in environmental factors. Soil organic carbon is the largest and dynamic C pool in terrestrial ecosystem. The changes in organic carbon pool have a greater effect on atmospheric CO_2 content. The factors controlling soil organic C contents are soil temperature, precipitation, and soil management systems (Plante et al., 2006). Soil organic C cycle can reach a steady state condition when the changes in these environmental factors are minimized. The time of reaching steady state condition can also controlled by the character of soil organic carbon pools. Soil organic C pools are determined as physically, chemically, and biologically.

Soil physical C pools are fractioned as light fraction (unprotected organic C) and aggregate (micro and macro aggregates) associated (protected) organic carbon. The fractions of soil physical C pools are more sensitive to the changes of soil management systems. Cultivation breaks down soil aggregate and release organic matter as unprotected. The unprotected organic matter can be easily decomposed by soil organisms. Therefore, cultivated soils generally have lower protected organic carbon compared to uncultivated and native ecosystems. Some studies indicated that aggregate associated organic C accounts for %42-74 of total organic C and this ratio is generally greater in uncultivated and pasture ecosystems, and decrease with cultivation (Chan, 2001). The intensive cultivation and drying and wetting decrease aggregation and result reduction of soil organic C content (Chenu et al., 1999). Short-term cultivation (1-4 years) changes aggregate protected organic C and microbial biomass C with no effects on total organic C (Chenu et al., 1999). Conversion of a cultivated land to pasture increased aggregate stability and physically protected organic C after second year of pasture with no effects on total soil organic C (Robertson et al., 1991). Some researchers reported that aggregate stability under long-term cultivation (5-8 years) mostly depends on microbial biomass C other than total soil organic C (Sparling and Shepherd, 1986; Hart et al., 1988; Sparling et al., 1992). Long-term crop production reduced total organic C %70 and 60% compared to pasture and wood land, respectively (Saviozzi et al., 2001). Therefore, the management of forest ecosystem is important for the terrestrial C management. However, the ecology of forest also plays important role for carbon storage. Forest in cold climates stores more C than warm climate (Post et al., 1982). However, forest clearing with cultivation decreases %30-35 soil organic C in A and B profiles (Ellert and Gregorich, 1996). The changes in the cover vegetation and soil management systems either improve or retardate soil biological properties.

Microbial biomass C, total organic C tided up to soil organisms, compromise smaller and most active portion of soil organic C. This fraction plays critical role the distribution of C fraction and is a good soil quality indicator. Soil organisms produce exracellular enzyme and hyphea which hold soil particles and create aggregates. Soil microbial biomass is more sensitive to agricultural management than other fractions. Therefore, the short-term effect of soil management on soil properties can be determined by looking at the soil microbial biomass (Churchman and Tate, 1987; Haynes, 1993). Generally, soil microbial biomass is more dynamic fraction of soil organic C. Microbial biomass can be a store and source for plant nutrients. Therefore, microbial biomass controls C and N cycle in biosphere (McGill et al., 1986). Soil fauna (for example earthworms) not only controls nutrient cycling but also increases macro aggregation.

Soil macro aggregates are more sensitive to agricultural practices compared to micro aggregates (Janzen et al., 1992; Cambardella and Elliott, 1992). Cultivation practices decreases protected organic C and increases light fraction (unprotected C) compared to native ecosystems (Jastrow ve Miller, 1997). However, the effect of different management systems on soil organic carbon fractions varies based on the climate and location on the world. In this study, three different land management (native forest, pasture, and cultivated land) have been evaluated based on soil organic C and physical and biological C fractions in the northern Turkey, Tokat.

MATERIAL and METHODS

This experiment was conducted on the three different land management (forest, pasture, and cultivated lands) of the northern Turkey, Tokat. The history of the study site was previously native forest for more than 10 years. Some parts of the forest were cleared and converted to cultivated land and pasture. The cultivated land has been under dry land continuous wheat production with plowing and disking before planting. Since, the forest cleared pasture has been used as grazing land with sheep without any chemical fertilizer application. Four sampling locations were randomly chosen from each site. Total 12 composite samples were taken from 0-5, 5-15, and 15-30 cm depth of each land management. Soil samples were passed through 4-mm sieve and stored at 4 ^{o}C until analysis. Before analysis, soil water content was determined gravimetrically and The all results were expressed based on oven dry weight. Soil bulk density was measured by taking undisturbed soil samples at spring.

Some physical and chemical properties of soils were determined. Soil texture was performed based on Bouyocous hydrometer method (Bouyocous, 1951). Soil pH was also determined based on 1:2.5 (w:v) dilution method. Organic matter content and N contents were determined using wet oxidation method. Soil inorganic N was extracted using 2 M 100 mL KCL solution and analyzed total inorganic N using distillation procedure. Total organic N content was determined by subtracting inorganic N from total N.

Biological C and N fractions (mineralizable C and N, microbial biomass C and N pools) were determined under laboratory conditions. Mineralizable C and N contents were analyzed after short-term incubation at 23 ^{o}C for 28 days (Russell et al., 2004). Soil samples (20 g) were placed in 100 mL flacks and soil water contents were adjusted to %50 of water holding capacity. These flacks were placed inside of mason jars with 10 mL of NaOH solution. These alkaline traps were replaced weakly and CO_2 contents were determined diluted HCl solution. Mineralizable N was extracted at the end of incubation and analyzed for N content.

Microbial biomass C was determined using fumigation incubation method (Horwath and Paul, 1994). The CO_2 produced during incubation was trapped inside alkaline solution and titrated with diluted HCl solution. Microbial biomass N was determined using extraction and distillation method at the end of incubation.

Soil organic C was fractioned as light fraction (unprotected) and protected (micro and macro aggregates) organic C. Light fraction of soil organic carbon was removed from soil using 1.8 g cm^{-3} NaI solution (Eliot and Cambardella, 1991). Macro (>250 µm) and micro (between 250 and 52 µm) aggregates were separated using wet sieving and analyzed for soil organic C (Le Bissonnais, 1996). After separation of soil aggregates, macro and micro aggregates were dried at 50 ^{o}C and organic C were determined.

The experimental design was completely randomized design with four replications. Analysis of variance and separation of means by least significant differences test ($p<0.05$) were performed for soil data using SAS procedures (SAS Institute Inc., 1996).

RESULTS and DISCUSSIONS

The clay content was significantly greater in the forest and cultivated lands compared to the pasture at the all depths ($p<0.001$) (Table 1). Soil texture from surface through profile was the similar in the each land use. Thus, soil depth was not significant on soil texture at the three managements ($p>0.05$). The interaction between soil management and soil depth was not significant, as well.

The effect of soil management on soil pH was not significant in this study ($p>0.05$) (Table 2). Soil pH changed from 6.97 to 7.18. The similar pH in the managements could be result of lack of chemical fertilizer application to the cultivated land. Grerup et al. (2006) reported that cultivation of forest soil increases soil pH. In this study, soil pH tends to be increase in pasture and cultivated land, but the increases were not significant. The changes in the soil pH could be the result of leaching of nutrients and fertilizer application. Soil bulk density significantly increased at the surface of pasture compared to the other managements ($p<0.05$). The increase of soil bulk density in the pasture is the result of compaction of soil surface due to animal grazing. Soil organic matter content significantly decreased in the cultivated and pasture fields ($p<0.001$). The highest soil organic matter content was absorbed at the surface of forest, pasture, and cultivated fields, respectively. Organic matter content significantly changed from surface through deeper depths. The changes in organic matter content through the soil depth were greater in the forest and pasture. This can be attributed to the larger amount of soil organic matter addition and undisturbance of pasture and forest. Soil organic mater content generally controlled by climate, soil texture, topography, drainage, and cover vegetation. Cultivated soils generally have low organic matter content compared to native ecosystems, since cultivation increases aeration of soil, which enhances decomposition of soil organic matter. In addition, most of the soil organic matter produced in the cultivated lands was removed with harvest. Conversion of forest to cultivated land significantly decreased soil organic matter content (Riezebos and Loerts, 1998; Jaiyeoba, 2003)

Table 1. Soil texture of forest, cultivated land, and pasture at 0-5, 5-15, and 15-30 cm depths.

Soil management	Depth cm	% Sand	% Silt	% Clay
Pasture	0-5	50,09 (1,44)	27,19 (0,80)	22,73 (1,95)
	5-15	48,34 (3,20)	27,38 (1,73)	24,29 (2,16)
	15-30	50,84 (2,19)	25,31 (1,07)	23,85 (1,98)
Forest	0-5	43,96 (1,18)	24,38 (0,36)	31,66 (1,39)
	5-15	41,46 (1,56)	24,25 (0,44)	34,29 (1,85)
	15-30	43,96 (2,07)	27,19 (2,12)	28,85 (3,85)
Cultivated	0-5	40,71 (0,99)	23,13 (0,49)	35,98 (0,51)
	5-15	40,53 (1,20)	23,31 (0,67)	36,16 (0,99)
	15-30	39,59 (0,60)	23,19 (0,51)	37,23 (0,38)

( ) Standard error (n = 4).

Microbial biomass C significantly changed with soil managements (Table3). The greatest microbial biomass C was observed in forest (0.505 mg C g^{-1}). Cultivation resulted the lowest microbial biomass C compared the other managements (0.120 mg C g^{-1}). Some studies indicated that microbial biomass C significantly decreases with cultivation, but conversion from cultivated land to pasture significantly increases soil microbial biomass (Haynes and Swift, 1990; Haynes et al., 1991).

Table 2. Some soil chemical and physical properties of pasture, cultivated, and pasture lands at 0-5, 5-15, and 15-30 cm.

Soil management	Depth cm	pH	Bulk density (g cm^{-3})	Soil organic matter (%)	Lime (%)
Pasture	0-5	7,13 (0,05) a*	1,41 (0,03) a	2,96 (0,50) a	1,31 (0,24) a
	5-15	7,17 (0,06) a	1,41 (0,09) a	2,22 (0,21) a	2,24 (0,85) a
	15-30	7,13 (0,11) a	--------------	1,31 (0,18) a	1,72 (0,73) a
Forest	0-5	7,01 (0,07) b	1,21 (0,06) b	4,73 (0,22) b	0,88 (0,34) a
	5-15	6,99 (0,08) a	1,32 (0,04) a	2,49 (0,19) a	1,01 (0,06) a
	15-30	6,96 (0,11) a	--------------	1,89 (0,11) b	1,10 (0,30) a
Cultivated	0-5	7,18 (0,05) a	1,14 (0,07) b	1,65 (0,04) bc	0,82 (0,07) a
	5-15	6,97 (0,09) a	1,26 (0,11) a	1,62 (0,06) b	0,93 (0,08) a
	15-30	7,02 (0,11) a	--------------	1,72 (0,07) a	0,80 (0,21) a
Soil management		ns	0,03	0,0001	0,03
Depth		ns	ns	0,0001	ns
Soil Management* Depth		ns	ns	0,0001	ns

( ) Standard error (n = 4).

* Different letter in the same colon and depth indicate difference.

Mineralizable C was significant affected by soil management and depth (Table 3). Mineralizable C content was greater in the forest and pasture due to greater amount of organic matter addition annually. However, proportional distribution of mineralizable C was greater in the cultivated land. Cultivation increased labile fraction of soil organic C while decreasing resistant fraction of soil organic C. Thus, cultivation disturbs soil aggregates and releases soil organic C to the soil, which increases proportionally mineralizable organic C. Similarly, total organic C content was lower in the cultivated field and increased in the pasture and forest.

Total N, mineralizable N, and microbial biomass N were significantly decreased after conversion from forest to pasture and cultivated fields (Table 4). Soil managements, depth was significant on mineralizable N and microbial biomass N. Cultivation of forest decreased almost two times total organic N, mineralizable N, and microbial biomass N, and the decreases in the pasture was smaller compared to cultivated land. Mineralizable N is an important source of nitrogen in native ecosystems. The higher mineralizable N in the forest and pasture could be the result of higher organic matter at the surface of soil.

Table 3. Total organic C, mineralizable C, and microbial biomass C of pasture, forest, and cultivated lands at 0-5, 5-15, and 15-30 cm.

Soil management	Depth cm	Microbial biomass C mg C g^{-1}	Minerelizable C mg C g^{-1}	Total soil organic C %
Pasture	0-5	0,295 (0,019) a*	0,280 (0,12) a	1,506 (0,24) a
	5-15	0,286 (0,011) a	0,384 (0,16) a	0,997 (0,10) a
	15-30	0,276 (0,025) a	0,705 (0,31) a	0,588 (0,08) a
Forest	0-5	0,505 (0,074) b	0,328 (0,12) a	2,351 (0,23) b
	5-15	0,409 (0,059) a	0,475 (0,16) b	1,122 (0,09) a
	15-30	0,264 (0,030) a	0,871 (0,34) a	0,851 (0,05) b
Cultivated	0-5	0,120 (0,021) a	0,253 (0,10) ab	0,741 (0,02) bc
	5-15	0,171 (0,033) b	0,343 (0,13) a	0,730 (0,03) b
	15-30	0,187 (0,047) ba	0,433 (0,16) a	0,775 (0,03) ab
Soil management		0,0001	0,0001	0,0001
Depth		0,0001	ns	0,0001
Soil management*Depth		0,0001	ns	0,0001

( ) Standard error (n = 4).

* Different letter in the same colon and depth indicate difference.

Table 4. Soil organic N, inorganic N, mineralizable N, and microbial biomass N of pasture, forest, and cultivated lands at 0-5, 5-15, and 15-30 cm.

Soil management	Depth cm	Organic N mg N g^{-1}	Inorganic N mg N g^{-1}	Mineralizable N mg N g^{-1}	Microbial biomass N mg N g^{-1}
Pasture	0-5	0,079 (0,014) a*	0,0112 (0,0007) a	0,0178 (0,0018) a	0,135 (0,015) a
	5-15	0,050 (0,012) a	0,0047 (0,0003) a	0,0107 (0,0002) a	0,081 (0,011) a
	15-30	0,049 (0,009) a	0,0027 (0,0008) a	0,0064 (0,0006) a	0,038 (0,003) a
Forest	0-5	0,105 (0,009) a	0,0138 (0,0012) a	0,0229 (0,0013) b	0,271 (0,009) b
	5-15	0,065 (0,013) a	0,0062 (0,0010) a	0,0128 (0,0014) a	0,115 (0,020) a
	15-30	0,040 (0,011) a	0,0058 (0,0011) b	0,0094 (0,0012) b	0,067 (0,007) b
Cultivated	0-5	0,045 (0,017) ab	0,0043 (0,0017) b	0,0122 (0,0005) c	0,057 (0,012) c
	5-15	0,028 (0,002) ab	0,0035 (0,0005)ab	0,0089 (0,0005) ab	0,039 (0,007)ab
	15-30	0,025 (0,002) ba	0,0027 (0,0006) a	0,0065 (0,0002) a	0,026 (0,006) a
Soil management		0,002	0,0001	0,0001	0,0001
Depth		0,002	0,0001	0,0001	0,0001
Soil management*Depth		ns	0,003	0,006	0,0001

( ) Standard error (n = 4).

* Different letter in the same colon and depth indicate difference.

Physical fractions of soil organic C were significantly affected by soil management (Table 5). Macro aggregates was greater in the forest, cultivated, and pasture fields, respectively. The lower macro aggregate in the pasture is the result of low clay content and high compaction by grazing animals. Macro aggregate associated organic C was significantly decreased in the cultivated and pastures fields. This indicates that conversion of a forest to agricultural use leads to the loss of soil organic C in the macro aggregates. Some studies reported significantly reduction of macro aggregates in agricultural lands (Janzen et al., 1992; Cambardella and Ellioott, 1992). Micro aggregates tend to be greater in the pasture compared to the other managements. Micro aggregate especially at the surface of forest was lower compared to the other depths. Therefore, macro aggregate plays significant role for C sequestration in forest ecosystem. Light fraction (free soil organic matter) was greater in the pasture than forest soil. This higher amount of light fraction in the pasture can be related to low clay content and macro aggregates.

Table 5. Physical fraction of soil organic C in pasture, forest, and cultivated lands at 0-5, 5-15, and 15-30 cm.

Soil management	Depth cm	Macro Ag. g/100 g soil	Organic C g C kg^{-1} Macro Ag.	Light Organic C >250µm g C/ 100 g Macro Ag.	Light organic C 53-250 µm g C/ 100 g Micro Ag.	Micro Ag. g/100 g soil	Organic C g C kg^{-1} Micro Ag.
Pasture	0-5	35,65 (1,88) a*	71,44 (3,79) a	11,65 (0,95) a	12,71 (1,84) a	14,34 (1,37) a	90,22 (2,27) a
	5-15	40,48 (6,93) a	64,68 (3,29) a	10,71 (1,27) a	10,47 (1,09) a	12,98 (2,75) a	85,84 (1,43) a
	15-30	43,75 (7,18) b	66,69 (1,62) a	9,36 (1,74) a	12,14 (1,33) a	11,70 (2,47) a	94,06 (1,57) a
Forest	0-5	53,25 (3,09) b	73,94 (4,83) a	9,16 (1,78) a	15,12 (0,94) a	6,82 (0,58) b	110,75 (9,94) b
	5-15	53,27 (0,92) a	66,12 (3,21) a	7,08 (0,35) b	10,96 (0,98) a	8,45 (0,76) a	103,90 (5,58) b
	15-30	50,68 (2,36) a	65,31 (2,51) a	6,98 (0,82)a	9,35 (0,89) a	8,86 (0,27) a	88,34 (2,87) a
Cultivated	0-5	55,17 (1,51) b	57,39 (1,80) b	7,96 (1,09) a	9,01 (0,70) ab	8,29 (0,48) b	79,70 (4,10) a
	5-15	49,96 (3,62) a	59,76 (0,89) a	9,49 (0,78) ab	11,94 (0,37) a	7,82 (0,28) a	85,52 (1,06) a
	15-30	42,65 (2,87) a	65,16 (6,38) a	9,99 (1,13) a	10,67 (0,82) a	8,34 (0,57) a	83,83 (1,67) ba
Soil Management		0,002	0,02	0,02	ns	0,0001	0,0001
Depth		ns	ns	ns	ns	ns	ns
Soil management*Depth		ns	ns	ns	0,006	ns	0,02

( ) Standard error (n = 4).

* Different letter in the same colon and depth indicate difference.

Conversion of a native ecosystem to agricultural use decreases soil organic C. However, the changes in soil organic C fractions was greater compared to total organic C. Greater portion of soil organic C is stored in macro aggregates at forest. Therefore, macro aggregates play critical role for C sequestration in native ecosystems and are more sensitive to changes of soil management systems. Conversion of forest to cultivated land and pasture significantly decrease total organic C and N, microbial biomass C and N, mineralizable C and N and the changes was greater in the cultivated lands.

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