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Determination of Physical and Chemical Properties of the Soils Under Different Land Managements

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This study aimed to determine the effects of different land management systems on the physical and chemical properties of soil. The study was conducted on a cultivated land, forest land and orchard adjacent to each other on the same topographic position at Tokat Rural Research Institute. With this aim, 10 soil samples were taken randomly from 0-30 and 30-60 cm depths of each land management area. The physical (field capacity, wilting point water content, soil texture, hydraulic conductivity, bulk density) and chemical (organic matter, $CaCO_3$ content, pH, EC, cation exchange capacity, nitrogen, phosphorus, exchangeable sodium, potassium, calcium, magnesium) properties of the soil samples were examined and the spatial variability of the soil properties were mapped by using geographic information systems (GIS). The statistical evaluation indicated that all topsoil (0-30 cm) properties except phosphorus, silt and exchangeable sodium showed statistically significant differences ($p < 0.05$) at three land management systems. Whereas, all subsoil (30-60 cm) properties but silt, exchangeable sodium and hydraulic conductivity revealed statistically significant differences ($p < 0.05$) at three land management systems. The study concluded that the properties of soil change through land management and they should be done based on the physical and chemical properties of the lands following their classification for soil quality and environmental protection.

Key Words: Land management types, Soil properties, Soil quality, Environmental protection.

INTRODUCTION

The aim of the agricultural production is to obtain the optimum yield from unit area. Meanwhile, the soil should be preserved in its original location. If the multi-faceted balance and stability in the soil is to be preserved, in addition to being able to harvest crops from the soil for years, it is also possible to increase the productivity by eliminating the undesired properties. For this reason, the protection and sustainability of soil fertility are two of the most important requisites of agriculture. In order to

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provide productivity in sustainable farming, such issues as preserving the organic matter content of the soil, economical fertilizing, minimum soil cultivation and proper sowing turns all have importance in a strategically suitable and effective land management[1].

In a study examining the sustainability in agricultural lands, it was found out that different land management designs were important indicators with respect to ecological sustainability[2]. Soil properties vary through land management. In order to make this variation positive and provide productivity, suitable plants should be grown through a successful land management. It is not so easy to apply a successful land management for an optimum agricultural production. For a successful land management, it is necessary to be aware of soil properties, climate, soil erosion, salinization, alkalizing, soil moisture, growth necessities of plants and the positive and negative effects of the agricultural activities on the environment[1]. Saltali *et al.*[3] reported in their study conducted on adjacent lands-one a pasture and the other a cultivated land converted from pastoral land-in Kazova region of Tokat province that organic and inorganic phosphorus fractions (except for H_2O-P and Olsen P) decreased significantly in cultivated land compared with that of natural pasture. Durak *et al.*[4] reported in their study conducted to determine trace metal concentrations in soil under different growing systems and farming techniques that land management systems significantly influenced the iron, copper, manganese and zinc uptake of the plants due to the change in pH and organic matter contents of soils. Because of the issues mentioned above, the study intended to determine the physical and chemical changes in the soils of a cultivated land, forest land and orchard adjacent to each other on the same topographic position at Tokat Rural Research Institute. The management of the study area has not changed for about 40 years. The aim of the study is to compare the positive and negative changes in the physical and chemical properties of soils on the same topographic position resulting from different land management.

EXPERIMENTAL

Site description: The research area is located on the 10th km of Tokat-Turhal main road in Kazova region (40º19'20"N-40º19'30"N and 36º26'50"E-36º27'10"E). The mean elevation is 580 m. The mean annual precipitation and mean annual temperature are 436 mm and 13 ºC, respectively. The soil moisture regime of the research area is ustic and soil temperature regime is mesic. The topography of the site is foot-slope.

The study was conducted on the soils of a cultivated land, forest land and orchard adjacent to each other on the same topographic position under the same management for about 40 years. The research area has 6-8 % slopes. The cultivated land has been used to grow wheat and beans in turns for 40 years and sunflowers for some years. Commercial fertilizers have been applied to the land in proper amounts every year following soil analysis and the land has been manured once a decade.

The orchard has been used to grow apples for 40 years. Apple trees are semi-dwarf and they have been replaced as their life span has lasted. As is the case in the cultivated land, the commercial fertilizers have been applied to the orchard in proper amounts following soil analysis. The forest land has also been under management for 40 years and there are pine trees in the area.

Sampling: Soil samples were collected from lands studied in detail earlier. The research areas were under three different management systems. They included a cultivated land, a forest land and an orchard. Located on a sloping topography and formed on calcareous parent material, these lands were classified as Deneme and Akis series (in Entisol order Orthent and sub-order Ustorthent Great Group) as they did not have descriptive horizons. The forest land did not have a taxonomic classification. Ten soil samples were randomly collected from 0-30 and 30-60 cm depths of each management areas based on soil depth principle. Therefore, a total of 60 soil samples were collected (Fig. 1).

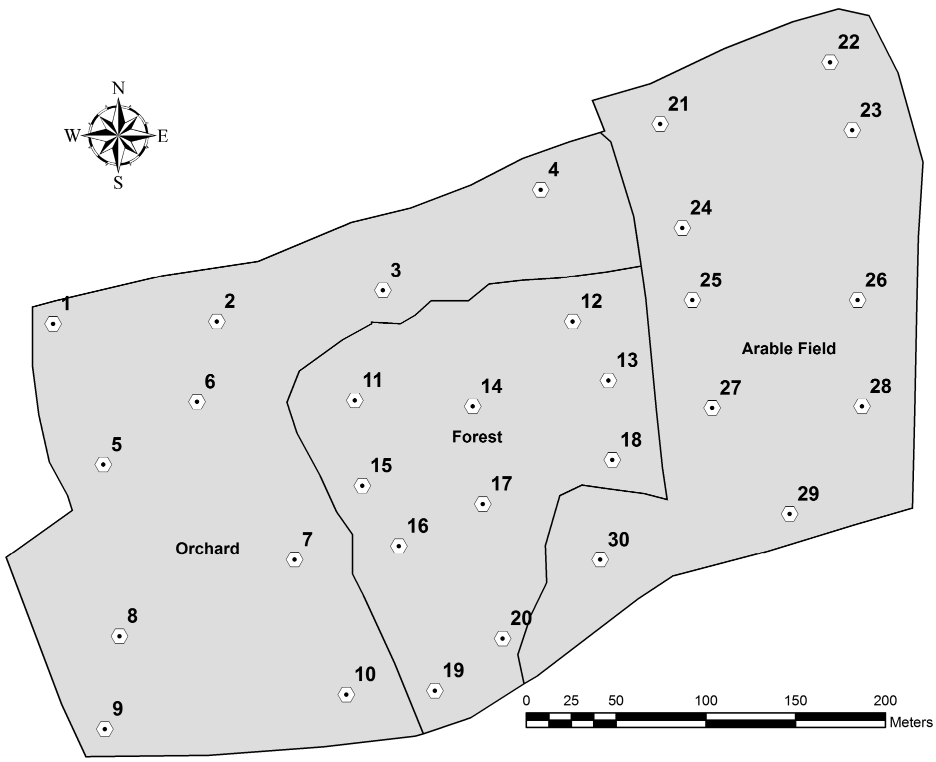

Fig. 1. Sampling locations

Soil analyses: The soil samples collected from the research area were first dried at room temperature, they were passed through a 2 mm sieve after they were ground and then they were made ready for analysis.

The hydrometer method was used to determine the soil texture. Soil reaction (pH) was determined in 1.0:2.5 soil-water suspension[5]. Cation exchange capacity (CEC) was determined by saturating the samples with sodium acetate; exchangeable cations (Na, K, Ca and Mg) with ammonium acetate; electrical conductivity (EC) in 1.0:2.5 soil-water saturation and organic matter using Walkley-Black method[4].

$CaCO_3$ content was determined using calcimeter[6] and bulk density in unspoiled 100 cm^3 soil samples[7]. Saturated hydraulic conductivity was determined by measuring the bulk of water passing through the soil samples collected with cylinders at a time[8]. Field capacity and wilting point water content were determined on pressure plates[9].

Total nitrogen was determined using Kjheldal method and available phosphorus using sodium bicarbonate method[5]. In addition, soil properties belonging to different management areas based on soil analysis results were statistically evaluated for each depth.

GIS Applications: All processed data were entered into a database (dbf) file containing the geographic reference coordinates along with the sampling locations and the soil attributes of these coordinates (X, Y and Z). Using created (XYZ) database file, all tabular informaton were transformed into a point map layer and saved as a shape file (shp) in ArcGIS 9.1. software[10,11]. In this transformation, we used geographic (WGS84) output coordinate system as a spatial reference for input coordinates. Created point map were utilized to develop a series of raster maps (1 m × 1 m resolution) for surface and subsurface soils by applying Kriking method with spherical variogram model in ARC/GIS 9.1.

RESULTS AND DISCUSSION

The findings regarding soil properties of surface soil (0-30) samples belonging to different management areas are presented in Table-1. The mean values concerning the analysis results were statistically evaluated and compared using t-test on SPSS Software Version 12.

Organic matter content was found to be high in forest samples than those of other management systems due to the addition of plant wastes and therefore an excess of nitrogen content was also found depending on this (Table-1 and Fig. 2). The existence of nitrogen in small amounts in other management areas was due to less organic matter addition and its removal through soil cultivation. Studies reported that organic matter content decreased in the soils of lands opened to agriculture in comparison with those of forest lands[12,13].

In the management areas, phosphorus like nitrogen, indicated a change due to the effects of fertilization and organic wastes (Table-1 and Fig. 2). The high phosphorus content in forest area might be attributed to organic wastes adding organic phosphorus to the soil through decomposition. Saltali *et al.*[3] reported that they determined organic and inorganic phosphorus fractions in a land converted to farming field decreased significantly in comparison with those of natural pastoral land.

TABLE-1
CHANGES OF TOPSOIL (0-30 cm) PROPERTIES UNDER DIFFERENT AGRICULTURAL MANAGEMENTS (EC: ELECTIRICAL CONDUCTIVITY, CEC: CATION EXCHANGE CAPACITY, K: POTASSIUM, CA: CALCIUM, NA: SODIUM, MG: MAGNESIUM)

Soil variables	Average values		
	Forest	Field	Orchard
Nitrogen (gk g^{-1})	0.23^a	0.13^b	0.11^b
Phosforus (gk g^{-1})	26.37^a	19.86^a	24.59^a
Organic matter (%)	6.36^a	2.72^b	2.24^b
$CaCO_3$ (%)	20.16^a	14.09^b	24.11^c
pH (1:2.5)	7.45^a	7.66^b	7.59^b
EC (dS cm^{-1})	0.21^a	0.15^b	0.21^a
Clay (%)	31.70^a	32.45^a	41.70^b
Silt (%)	25.00^a	27.13^a	24.88^a
Sand (%)	43.30^a	40.43^a	33.43^b
Bulk density (g cm^{-3})	1.27^a	1.54^b	1.59^b
CEC (cmol kg^{-1})	43.14^a	27.38^b	32.55^b
Exchangeable K (cmol kg^{-1})	1.11^a	0.52^b	0.81^c
Exchangeable Ca (cmol kg^{-1})	23.14^a	19.34^b	22.03^c
Exchangeable Na (cmol kg^{-1})	0.05^a	0.06^a	0.06^a
Exchangeable Mg (cmol kg^{-1})	18.84^a	7.46^b	9.66^b
Hydraulic conductivity (cm h^{-1})	15.97^a	9.67^a	5.32^{ba}
Wilting point (%)	31.66^a	22.29^b	29.61^a
Field capacity (%)	45.23^a	37.16^b	46.71^a

$CaCO_3$ content was determined to decrease in orchard, forest and cultivated land respectively (orchard > forest > cultivated land) (Table-1 and Fig. 2). This might be attributed to the depth of calcareous parent material. The order regarding soil reaction was forest, orchard and cultivated land, respectively (forest < orchard < cultivated land) (Table-1 and Fig. 2). This was thought to result from carbon dioxide produced by organic matter content and emitted by the respiration of plant roots. Grerup *et al.*[14] reported that soil pH increased in cultivated land in comparison with that of oak forest.

Being a criterion for saline, EC was found to be lower in cultivated land than it was in the orchard and forest (Table-1 and Fig. 2). This might be due to the leaching of saline from soil surface through profile dept because of the irrigation in the land. Another study reported that saline content decreased in the soils of dry regions following irrigation[15].

Clay content of the orchard was determined to be higher than those of the forest and cultivated land. This was related to the properties of the main material and it depended on the level of decomposition. Silt content was found to be lower in the forest and orchard than it was in the cultivated land. The forest and cultivated land had a higher sand content than the orchard did (Table-1 and Fig. 2). The forest soil had a high pore volume due to the activities of soil insects and other organisms, the excess amount of organic matter and roots and the unspoiled natural structure. A high pore volume caused the bulk density to decrease (Table-1 and Fig. 2). Yuksek and Kalay[16] reported that the bulk density increased as one got closer from forest lands through cultivated lands.

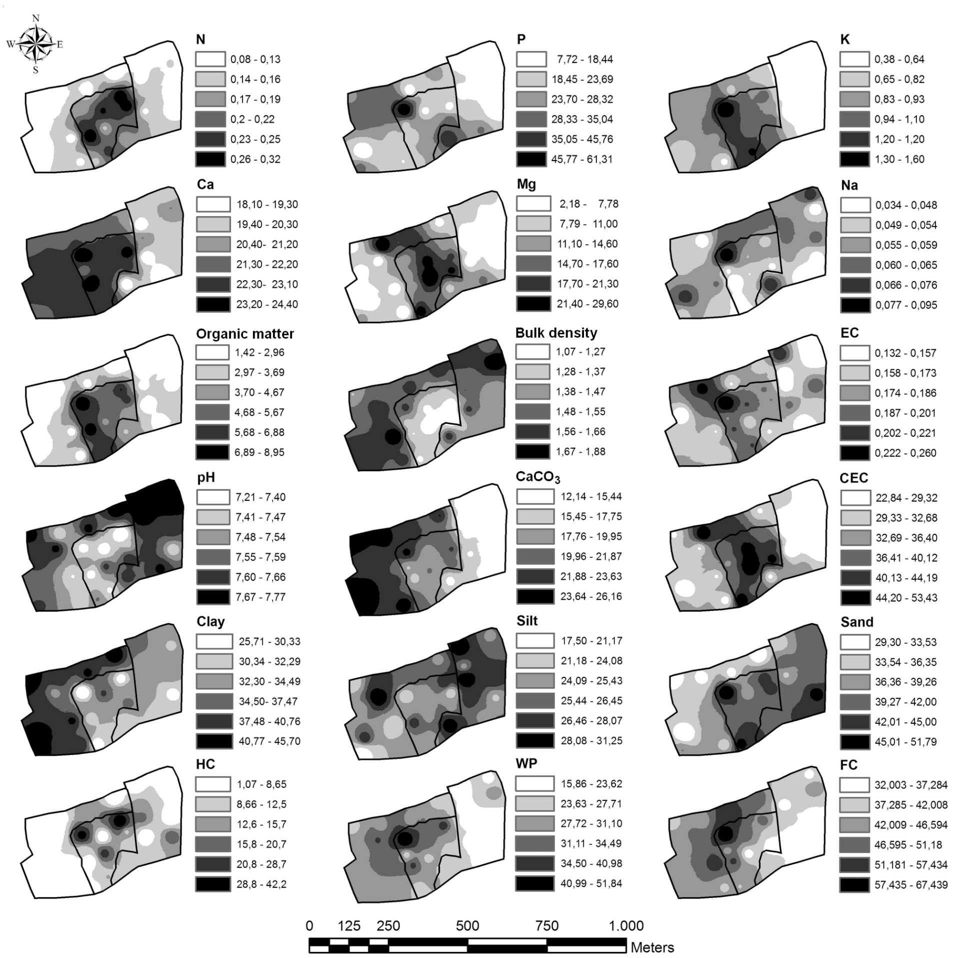

Fig. 2. Spatial variability of topsoil properties at 0-30 cm depth

Cation exchange capacity (CEC) showed a variation in management areas depending on the clay and organic matter content (Table-1 and Fig. 2). Higher rates of cation exchange capacity in the forest in comparison with those of cultivated land and orchard might be attributed to the higher rate of organic content in the forest land. Its higher rates in the orchard compared with the cultivated land resulted from the higher clay content in the orchard. Aydinalp and Cresser[17] reported in a study conducted on vertisol soils that cation exchange capacity was high due to clay content.

Exchangeable potassium content was determined to be lower in the orchard and cultivated land than that of the forest land (Table-1 and Fig. 2). This was thought to result from lower organic matter content in the cultivated land and orchard compared with the forest land and lack of sufficient application of fertilizers with potassium content as these lands lose a considerable amount of potassium as a result of agricultural production.

TABLE-2
CHANGES OF SUBSOIL (30-60 cm) PROPERTIES UNDER DIFFERENT AGRICULTURAL MANAGEMENTS (EC: ELECTIRICAL CONDUCTIVITY, CEC: CATION EXCHANGE CAPACITY, K: POTASSIUM, CA: CALCIUM, NA: SODIUM, MG: MAGNESIUM)

Soil variables	Average values		
	Forest	Field	Orchard
Nitrogen (gk g^{-1})	0.22^{a}	0.13^{b}	0.10^{c}
Phosforus (gk g^{-1})	15.13^{a}	16.07^{a}	20.32^{b}
Organic matter (%)	4.24^{a}	2.62^{b}	1.93^{c}
$CaCO_3$ (%)	22.35^{a}	14.18^{b}	24.73^{c}
pH (1:2.5)	7.62^{a}	7.67^{ab}	7.70^{b}
EC (dS cm^{-1})	0.20^{a}	0.16^{b}	0.17^{ab}
Clay (%)	38.45^{a}	33.33^{b}	43.70^{c}
Silt (%)	25.50^{a}	25.63^{a}	23.63^{a}
Sand (%)	36.05^{a}	41.05^{b}	32.68^{c}
Bulk density (g cm^{-3})	1.28^{a}	1.69^{b}	1.59^{c}
CEC (cmol kg^{-1})	36.90^{a}	25.55^{b}	30.05^{c}
Exchangeable K (cmol kg^{-1})	0.81^{a}	0.41^{b}	0.64^{c}
Exchangeable Ca (cmol kg^{-1})	23.29^{a}	19.34^{b}	22.03^{c}
Exchangeable Na (cmol kg^{-1})	0.06^{a}	0.06^{a}	0.06^{a}
Exchangeable Mg (cmol kg^{-1})	12.74^{a}	5.74^{b}	7.31^{b}
Hydraulic conductivity (cm h^{-1})	8.37^{a}	5.81^{a}	4.00^{a}
Wilting point (%)	27.42^{a}	26.22^{a}	30.61^{b}
Field capacity (%)	40.94^{a}	42.66^{a}	48.97^{b}

Escobar *et al.*[18] reported that exchangeable potassium content was found to be higher in poplar grove than it was in pasture. The lower rates of potassium in the cultivated land in comparison with that of the orchard might have resulted from more agricultural activities in the cultivated land contrasted with the orchard and lower clay content in the cultivated land. Another study reported that exchangeable potassium content was higher in deserted lands than it was in cultivated lands[19].

Exchangeable calcium content was determined to be lower in the orchard and cultivated land than it was in the forest land (Table-1 and Fig. 2). This was due to higher content of organic matter in the forest land compared with others. Escobar *et al.*[18] reported that exchangeable calcium content was higher in the poplar grove than it was in the pastoral land. Its higher content in the orchard compared with the cultivated land might be attributed to the higher clay and lime content in the orchard in comparison with that of the cultivated land. This is because calcium carbonates are particularly dominant in limy soils and clay surface holds calcium. Exchangeable sodium content did not yield a significant variation in the cultivated land, orchard and forest land (Table-1 and Fig. 2).

Exchangeable magnesium content was determined to be lower in the cultivated land and orchard regarding the forest land (Table-1 and Fig. 2). Its higher content in the forest land was due to higher organic matter content in the forest in comparison with other lands. Its lower content in the orchard and cultivated land was due to the agricultural production in these lands. It was reported in a study that exchangeable magnesium content was higher in deserted lands in comparison with cultivated lands[19].

Hydraulic conductivity is an indicator of permeability and it is a property of texture class. As sand content increases hydraulic conductivity increases, too and it decreases as clay content increases. For this reason, hydraulic conductivity was determined to decrease in the lands in forest > cultivated land > orchard order (Table-1 and Fig. 2). In addition, higher organic content in the forest land decreased the bulk density and increased the hydraulic conductivity.

The compact structure of the soil in the orchard and cultivated land caused by agricultural activities also affected the decrease in hydraulic conductivity. Gol *et al.*[20] reported that hydraulic conductivity was higher in forest lands than it was in pastoral and cultivated lands.

Wilting point water content increased depending on organic matter and clay content. Its higher content in the forest land in comparison with the cultivated land resulted from higher organic matter content in the forest.

Field capacity water content, like the wilting point water content, varies depending on organic matter and clay content. Its higher content in the forest compared with the cultivated land might have been attributed to higher organic matter content in the forest. Karagul[21] reported that field capacity water content was higher in forest and pastoral lands compared with cultivated lands (Table-1 and Fig. 2).

Organic matter contents in subsurface soil, as it was in the surface soil, was determined to be higher in the forest than it was in the cultivated land and orchard. In addition, organic matter content was found to be lower in the subsurface soils of all management areas than it was in the surface soils of the areas. Nitrogen content in the subsurface soils, as it was in the surface soils, was higher in the forest land compared with the cultivated land and orchard (Table-2 and Fig. 3).

Phosphorus contents in the subsurface soils was determined to be lower than it was in surface soils in all management areas. Lime content in the subsurface soils, as it was in the surface soils, was found to decrease in orchard > forest > cultivated land order. In addition, it yielded an increase in the subsurface soils of all management areas compared with the surface soils of the areas. This was related to getting closer to the main material (Table-2 and Fig. 3).

Soil pH in the subsurface soils increased in all management areas compared with the surface soils of the areas. This increase was due to decrease in organic matter content and plant roots in subsurface soils. The decrease was in forest < orchard < cultivated land order (Table-2 and Fig. 3).

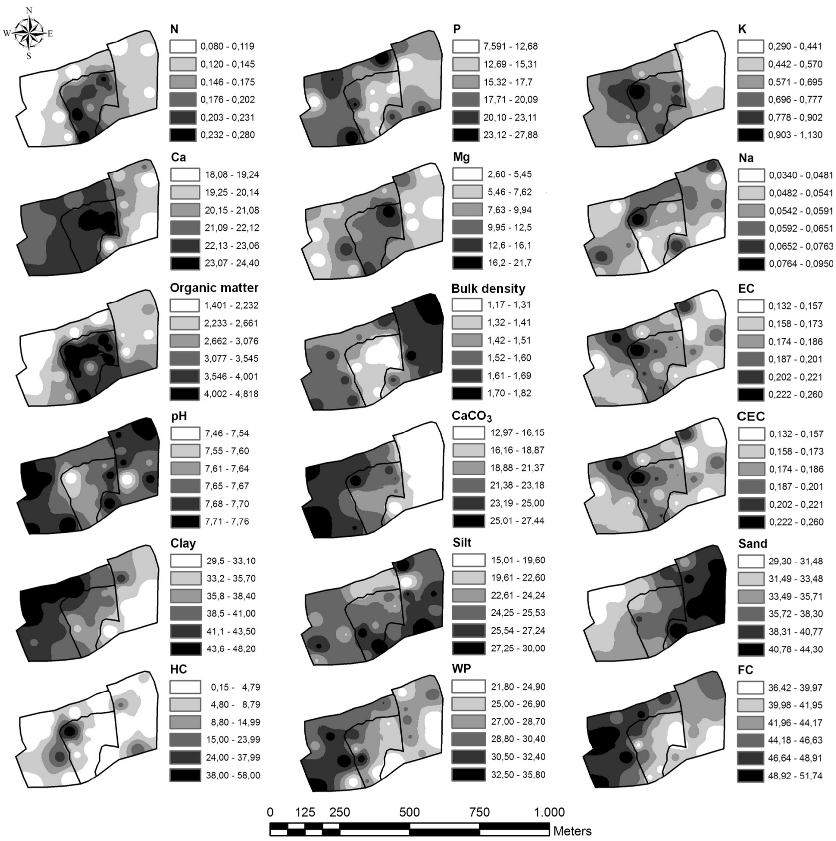

Fig. 3. Spatial variability of soil properties at 30-60 cm depth

EC Values were found to be lower in the subsurface soils of the cultivated land than those of orchard and forest, as it was in the surface soils (Table-2 and Fig. 3).

Clay contents was determined to be lower in the subsurface soils of the forest and cultivated land than that of the orchard, as it was in the surface soils. In addition, it increased in the subsurface soils of all management areas compared with surface soils and this was thought to result from the leaching of clay from the surface through the profile depth. Silt content in the subsurface soils, as it was in the surface soils, was determined to be lower in the forest land and orchard than it was in the cultivated land (Table-2 and Fig. 3). Sand content in the subsurface soils, like its content in the surface soils, was determined to be higher in the forest and cultivated land than it was in the orchard (Table-2 and Fig. 3).

Bulk density was determined to be higher in the subsurface soils, as it was in the surface soils, in the cultivated land and orchard than that of the forest land (Table-2 and Fig. 3). In addition, bulk density increased in the subsurface soils of the cultivated land compared with the surface soils and this was thought to result from the formation of plow pan.

Cation exchange capacity (CEC) was higher in the subsurface soils of the forest, just as in the surface soils, than it was in the cultivated land and orchard. In addition, it indicated a decrease in subsurface soils in all management areas compared with the surface soils and this was related to the decrease in organic matter content in the subsurface soils (Table-2 and Fig. 3).

Exchangeable potassium contents was determined to be lower in both subsurface and surface soils in the orchard and cultivated land compared with that of the forest. Exchangeable calcium content was lower in both subsurface and surface soils in the orchard and cultivated land compared with the forest (Table-2 and Fig. 3). Exchangeable sodium contents did not yield a change in the subsurface soils regarding the surface soils (Table-2 and Fig. 3).

Exchangeable magnesium contents in both subsurface and surface soils was higher in the forest land than it was in the orchard and cultivated land. In addition, it decreased in the subsurface soils of all management areas compared with the figures of surface soils (Table-2 and Fig. 3).

Hydraulic conductivity value decreased in both surface and subsurface soils in forest > cultivated land > orchard order. In addition, it decreased in the subsurface soils of all management areas and this might be due to the increasing clay contents and decreasing organic matter content in the subsurface soils (Table-2 and Fig. 3).

Wilting point water content yielded an increase in the subsurface soils of the orchard and cultivated land compared with the figures of surface soils and this was related to the increasing clay content in subsurface soils. Like the wilting point water content, field capacity water content yielded an increase in the subsurface soils of the orchard and cultivated land compared with the figures of surface soils. This was attributed to the increasing clay content in the subsurface soils. It decreased in the subsurface soils of the forest and this was related to a higher decrease in organic matter in the subsurface soils of the forest compared with the surface soils of other management areas (Table-2 and Fig. 3).

The t-test result indicated that phosphorus, $CaCO_3$ contents and exchangeable magnesium (Mg) properties of the forest soil yielded a 5 % statistical significance between the depths (0-30 and 30-60 cm) whereas organic content, pH, clay, sand, cation exchange capacity (CEC) and exchangeable potassium (K) yielded a 1 % statistical significance. The difference in the cultivated land with respect to wilting point water content regarding depths was determined to be at 5 % significance level whereas it was found to be at 1 % significance level with respect to bulk density and field capacity water content. In the orchard, while the difference with respect to pH and electrical conductivity was found to be at 5 % significance level regarding the depths, it was determined to be at 1 % significance level with respect to exchangeable potassium (K). Other properties, though having significance regarding depths with respect to management areas, were not found to be within the levels of statistical significance (Table-3).

TABLE-3
COMPARING SOIL VARIABLES AT DIFFERENT DEPTHS (EC: ELECTIRICAL CONDUCTIVITY, CEC: CATION EXCHANGE CAPACITY, K: POTASSIUM, CA: CALCIUM, NA: SODIUM, MG: MAGNESIUM)

Soil variables	Average values at different soil depths					
	Forest	Field	Orchard	Forest	Field	Orchard
	0-30 cm	30-60 cm	0-30 cm	0-30 cm	30-60 cm	0-30 cm
Nitrogen (gk g^{-1})	0.23	0.22	0.13	0.13	0.11	0.10
Phosforus (gk g^{-1})	26.37*	15.13	19.86	16.07	24.59	20.32
Organic matter (%)	6.36**	4.24	2.72	2.62	2.24	1.93
$CaCO_3$ (%)	20.16*	22.35	14.09	14.18	24.11	24.73
pH (1:2.5)	7.45**	7.62	7.66	7.67	7.59*	7.70
EC (dS cm^{-1})	0.21	0.20	0.15	0.16	0.21*	0.17
Clay (%)	31.70**	38.45	32.45	33.33	41.70	43.70
Silt (%)	25.00	25.50	27.13	25.63	24.88	23.63
Sand (%)	43.30**	36.05	40.43	41.05	33.43	32.68
Bulk density (g cm^{-3})	1.27	1.28	1.54**	1.69	1.59	1.59
CEC (cmol kg^{-1})	43.14**	36.90	27.38	25.55	32.55	30.05
Exchangeable K (cmol kg^{-1})	1.11**	0.81	0.52	0.41	0.81**	0.64
Exchangeable Ca (cmol kg^{-1})	23.14	23.29	19.34	19.34	22.03	22.03
Exchangeable Na (cmol kg^{-1})	0.05	0.06	0.06	0.06	0.06	0.06
Exchangeable Mg (cmol kg^{-1})	18.84*	12.74	7.46	5.74	9.66	7.31
Hydraulic conductivity (cm h^{-1})	15.97	8.37	9.67	5.81	5.32	4.00
Wilting point (%)	31.66	27.42	22.29*	26.22	29.61	30.61

Conclusion

According to the study findings, as a result of the agricultural production in the orchard and cultivated land, there was a decrease in the plant nutrients and a physical decomposition. Depending on the low levels of organic content in these lands, cation exchange capacity was low. A low cation exchange capacity decreased the ability of nutrient elements to hold the soil. For this reason, the physical structure of these lands should be improved by applying organic fertilizers and they must be enriched in plant nutrients. The cultivation of the land should be at minimum levels and different depth tillage should be managed to avoid the formation of plow pan resulting from the increasing density. The periods apart from the soft consistence of soil it should be avoided from the unnecessary soil tillage. In addition, organic fertilizing is needed to improve the physical condition of the soil. Due to the high clay content and low soil depth, the orchard should be watered using sprinkling system or drip irrigation system to avoid surface erosion that might happen as soil particles can flow on the surface because of the surface watering. Finally the soil should be enriched in organic matter. The management systems affected the change of physical and chemical properties of soils. Thus, the change of soil properties under different management systems should be considered to sustainable production.

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