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Effects of Different Topographic Positions on Soil Properties and Soil Enzymes Activities

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The main objectives of this study were (i) to determine physical and chemical properties of six different soils (ii) to measure the range and degree of three soil enzyme activities, (iii) to evaluate the influence of soil properties on soil enzyme activities in the both sides of the Çankiri-Aciçay river associated with specific landforms and different slope gradient. While right side soils of the Aciçay river are formed on quaternary alluvial deposits that find on terrace and floodplain, left side soils formed from quaternary alluvium, alluvial-collivial material and oligomiocene gypsum and salt strata located on floodplain, terrace and steep lands, respectively. Soil properties data of both sides of Aciçay river soils indicated significantly differences each other in terms of pedogenic processes which have been shaped by landscape position and parent material. According to soil taxonomy, 6 different soils were determined and classified as entisol, inceptisol and mollisol along transect. In addition, it was found that changes of landscape positions associated with erosion and organic matter content can alter the soil enzyme activities within the soil profile and along different slope.

Key Words: Soil genesis, Soil landscape, Soil enzyme activity.

INTRODUCTION

Soils are essential natural resources with a board range of environmental functions. The degree of soil development depends on the different soil forming factors[1]. These soil forming factors determine soil properties by governing the type and intensity of the pedological processes involved. Because the variable of climate, parent material, relief and time also govern geomorphic processes, landscape evaluation is intimately related to soil development[2]. Therefore, the characteristics of soils change from region to region or from place to place[3]. However, this changing is not coincidence in nature.

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Several soil studies in arid and semi-arid areas indicate that soils show wide spatial variability resulting from differences in parent material, age of land surface, topography, water distribution, amount and intensity of rainfall and living organisms' heterogeneity[4,5].

Soil is a complex system wherein chemical, physical and biochemical factors are held in dynamic equilibrium. Studies of enzyme activities provide information on the biochemical processes occurring in soil. There is growing evidence that soil biological parameters may be potential and sensitive indicators of soil ecological stress or restoration[6] and management-induced changes in soil quality[7]. Measurements of several enzymatic activities have been used to establish indices soil biological fertility[8]. The urease (UA) is involved in the hydrolysis of urea to carbon dioxide and ammonia, which can be assimilated by microbes and plants. It acts on carbon-nitrogen (C-N) bonds other than the peptide linkage[9]. The alkaline phosphatase (APA) hydroxy compounds of organic phosphorus and transforms them into different forms of inorganic phosphorus, which are assimilable by plants[10]. The arylsulphatase (ASA) is the enzyme involved in the hydrolysis of arylsulphate esters by fission of the oxygen-sulphur (O-S) bond. This enzyme is believed to be involved in the mineralisation of ester sulphate in soils[11].

The study area has specific properties in terms of different topographical positions and parent material that influence distribution of plant patterns on both sides of Aciçay river. These cases are the main principal reasons for selection of this area. Therefore, the objectives of this study were (i) to determine physical and chemical properties of six different soils (ii) to measure the range and degree of three soil enzyme activities (iii) to evaluate the influence of soil properties on soil enzyme activities in the both sides of the Çankiri-Aciçay river associated with specific landforms and different slope gradient.

EXPERIMENTAL

Description of the study area: The study was carried out transect along both sides of the Çankiri-Aciçay river which is a prominent land form, parent material and vegetation. The study area is located between 557733E-4497924N, 557751E-4497889N and situated in vicinity of Çankiri province. It ranges in relief from 740 to 800 m and four landscape positions (floodplain, terrace, backslope, shoulder), representing changes in geomorphology, topographic gradients and soil characteristics, were selected. The underlying bedrocks within the study area consist of primarily deposits while right side soils of the Aciçay river are formed on quaternary alluvial deposits that find on floodplain and terrace, left side soils are formed on quaternary alluvium, alluvial-collivial material spotted on floodplain and terrace oligomiocene gypsum and rock salt strata located on mid-slope and steep lands. Gypsum were commonly encountered with crystals, foliated (laminae) and mixing (not pure) forms. Vegetation cover varies through transect. Right side lands have been generally used for agriculture crops, while left side lands have covered three major plant community types (herb, shrub-grass and grass) and upper lands are generally barren due to overgrazing. According to meteorological data, the mean annual temperature and rainfall are 11.1ºC and 417.7 mm, respectively. In addition, the study site has mesic soil temperature regime and xeric moisture regime[12].

Soil sampling: On the basis of hypothesis that topography and parent material and also vegetation cover might be the main controlling factor in soil development. Soils have been studied on along transect (crosswise from East to West direction) with representative six profiles. Morphological properties of these six profiles in the field were identified and sampled by genetic horizons and classified according to soil survey staff[12,13]. 25 Soil samples were taken to investigate for their physical and chemical properties at the laboratory. The soil samples were then air-dried and passed through a 2 mm sieve to prepare for laboratory analysis.

Soil physico-chemical analysis: Soil samples were then air-dried and passed through a 2 mm sieve, particle size distribution was determined by the hydrometer method[14]. Coarse fragments from 2 to 60 mm were separated by passing from 2 mm sieve and mass coarse fraction ration (CFm) was calculated.

Organic matter was determined in air-dried samples using the Walkley-Black wet digestion method[15]. pH, electrical conductivity (EC) were determined according to soil survey laboratory[16]. Lime content by Scheibler calsimeter[16]. Total gypsum by precipitation with $BaCl_2$[17]. Cation exchange capacities (CEC) was measured using a 1 N NH_4OAc (pH 7) method[16].

Soil enzyme activities: Urease (EC 3.5.1.5) activity (UA) was measured by the method of Hoffmann and Teicher[18]. 0.25 mL toluene, 0.75 mL citrate buffer (pH 6.7) and 1 mL of 10 % urea substrate solution were added to the 1 g sample and the samples were incubated for 3 h at 37ºC. The formation of ammonium was determined spectrophotometrically at 578 nm and results were expressed as μg N g^{-1} dry sample.

Alkaline phosphatase (EC 3.1.3.1) activity (APA) was determined according to Tabatabai and Bremner[19]. 0.25 mL toluene, 4 mL phosphate buffer (pH, 8.0) and 1 mL of 0.115 M *p*-nitrophenyl phosphate (disodium salt hexahydrate) solution were added to the 1 g sample and the samples were incubated for 1 h at 37ºC. The formation of *p*-nitrophenol (*p*-NP) was determined spectrophotometrically at 410 nm and results were expressed as μg *p*-NP g^{-1} dry sample.

Arylsulphatase (EC 3.1.6.1) activity (ASA) was measured according to Tabatabai and Bremner[20]. 0.25 mL toluene, 4 mL acetate buffer (pH, 5.5) and 1 mL of 0.115 M *p*-nitrophenyl sulphate (potassium salt) solution were added to the 1 g sample and the samples were incubated for 1 h at 37ºC. The formation of *p*-nitrophenol (*p*-NP) was determined spectrophotometrically 410 nm and results were expressed as µg *p*-NP g^{-1} dry sample.

Statistical analysis: All results are reported as the mean value of three replicate determinations calculated on an oven-dry basis. Moisture was determined by weight loss after drying the soil at 105ºC for 48 h. Statistical analyses were performed by using the statistical package for social science (SPSS 10.0) program. The asterisks, * and ** indicate significance at $p < 0.05$ and $p < 0.01$, respectively.

RESULTS AND DISCUSSION

Soil physical properties that have been taken into consideration in this study showed variability as a result of dynamic interactions among natural environmental factors such as climate, parent material, land cover-land use and topography. Especially, slope has been regarded as one of the most important abiotic factors that control the pedogenic process on a local scale[21,22]. Steeper slope contributes to greater runoff, as well as to greater translocation of surface materials down slope through surface erosion and movement of soil mass[23]. In left side soils, clay percentage of surface soils in low slope sides is more than on higher slope except floodplain top soil that is almost coarse recently alluvial deposits and the sand content for slopes with high gradient is higher than for low slopes. The same conclusion is supported by Rezaei and Gilkes[24]. A logical reason of this event is that in low slope (2-4 %) accumulation processes and in upper slope (> 30 %) runoff processes are dominant. This case is similar to the coarse fragment ratio (CFr). While the lowest value (0.44 %) of CFr is for slopes ranging from 0 to 2 %, the highest values of CFr that are steadily increased with increasing slope gradient are 34.52 %. While right side floodplain of Aciçay river finer-textured soils, sand and coarser textured soils occupied the opposite bank (Table-1).

Effect of topography on soil thickness has been reported by many researchers[24-27] soils along transect of left side of Aciçay river display variation in terms of principal distribution and depth in surface horizon. These variables are responsible for the effect of eroding forces. Therefore, surface soils were carried and accumulated from uplands to low lands leading to progressively redder, deeper and finer texture soils with decreasing elevation. While the deepest soil formed on low slope class (2-4 %) or terraces, shallow soils cover on steep slope.

TABLE-1
SELECTED PHYSICAL, CHEMICAL PROPERTIES FOR THE SIX TYPICAL SOIL PROFILES

Horizon	Depth (cm)	Particle size				CFm > 2 mm (%)	pH	EC (ds m^{-1})	Organic matter (%)	$CaCO_3$ (%)	Gypsum (%)	CEC (cmol kg^{-1})
		C (%)	Si (%)	S (%)	Class							
Right side floodplain (PI) Aquic Xerofluvent												
Ap	0-14	31	44	25	CL	1.1	7.52	1.90	1.92	12.23	0.18	16.70
C1	14-40	18	46	35	L	23.1	7.53	1.13	0.78	11.53	0.21	15.43
2C2g	40-69	11	9	80	LS	64.6	7.66	1.80	0.33	7.78	0.21	10.75
2C3g	69+	15	24	61	SL	20.3	7.52	2.92	0.65	8.84	0.25	12.45
Right side old river terrace (PII) Typic Calsixeroll												
Ap	0-22	41	37	22	C	1.41	7.28	1.79	2.44	10.61	0.10	15.61
A2	22-53	32	44	24	CL	1.05	7.52	1.70	1.21	12.37	0.13	15.74
Bw	53-113	38	38	24	CL	0.96	7.47	2.61	1.11	13.14	0.24	22.08
Bk	113-149	43	39	18	SiC	0.54	7.80	3.22	1.05	17.34	0.74	25.08
BC	149-185	36	49	15	SiCL	0.13	7.83	3.85	0.98	12.08	0.66	19.45
C1	185-229	48	37	15	C	0.21	7.78	4.50	0.72	11.64	0.50	22.74
C2	229+	45	43	12	C	0.74	7.48	2.80	0.70	12.14	0.34	18.70
Left side floodplain (PI) Typic Xerofluvent												
A	0-6	5	22	73	LS	0.44	7.53	3.50	0.98	15.73	0.53	9.04
C1	6-15	9	53	38	SiL	1.33	7.77	4.71	0.72	15.19	0.62	9.35
C2z	15-26	9	43	48	L	2.16	7.93	9.32	0.78	14.66	1.33	11.65
C3z	26+	8	39	54	SL	5.31	7.82	8.71	0.59	14.66	1.44	10.62

Horizon	Depth (cm)	Particle size				CFm > 2 mm (%)	pH	EC (ds m^{-1})	Organic matter (%)	$CaCO_3$ (%)	Gypsum (%)	CEC (cmol kg^{-1})
		C (%)	Si (%)	S (%)	Class							
Right side old river terrace (PII) Typic Calsixeroll												
Ap	0-22	41	37	22	C	1.41	7.28	1.79	2.44	10.61	0.10	15.61
A2	22-53	32	44	24	CL	1.05	7.52	1.70	1.21	12.37	0.13	15.74
Bw	53-113	38	38	24	CL	0.96	7.47	2.61	1.11	13.14	0.24	22.08
Bk	113-149	43	39	18	SiC	0.54	7.80	3.22	1.05	17.34	0.74	25.08
BC	149-185	36	49	15	SiCL	0.13	7.83	3.85	0.98	12.08	0.66	19.45
C1	185-229	48	37	15	C	0.21	7.78	4.50	0.72	11.64	0.50	22.74
C2	229+	45	43	12	C	0.74	7.48	2.80	0.70	12.14	0.34	18.70
Left side back slope (PIII) Typic Xerorthent												
A	0-20	28	39	41	L	26.90	7.45	7.52	0.78	11.31	1.76	18.16
Cy	20-44	26	33	51	SCL	15.30	7.56	5.11	0.52	13.29	13.43	16.11
2Cy	44-120	23	42	36	L	10.25	7.75	16.62	0.33	10.61	21.71	16.30
R	120+	-	-	-	-	-	-	-	-	-	-	-
Left side shoulder (PIV) Lithic Xerorthent												
A	0-18	14	24	62	SL	34.52	7.42	9.79	0.46	6.36	20.13	18.09
R	18+	-	-	-	-	-	-	-	-	-	-	-

Topsoil textural classes that were affected by slope gradient have the following distribution with decreasing elevation: Coarse sandy loam, clay loam, clay. This result to some extent is concurrence with the result of Kreznor *et al.*[28]. Rezaei and Gilkes[24] showed dependency of particle size on landscape attributes, including slope gradients. However, there is an abrupt textural transition from old river terrace soils to floodplain soils that contain loamy sand texture. There are common pebbles and cobbles within profiles of floodplain of both sides. Phillips *et al.*[29] indicated that the soil on the terrace shows greater soil development and better drainage compared to the soil on the floodplain. The same results were also observed in the study area. This is because of the higher position of this soil on the landscape. Moreover, the effect of parent material on structure and solum depth of the left side soils is more than the effect of landscape position. Soil profile thickness and soil clay content are important parameters for water retention. Benny and Stephens[25] reported that soil profile thickness was considered an effective element in determining soil quality, especially considering storage of plant available water and nutrients. Rezaei and Gilkes[24] also indicate that this case is a very important soil physical property especially for rangelands, which usually receive no artificial fertilizer.

Soil chemical properties on different slope position and parent material were significantly affected by the degree of soil development and leaching processing. In addition, Gerrard[30] also indicated that the movement and distribution of water on slopes is one of the primary reasons for differences of soil properties on landscapes. Soil pH and EC are generally greater at depth than at the soil surface. This case was particularly observed in left side terrace soil that has significantly high pH values (7.80-8.75), whereas pH value of right side terrace soil varies between 7.28-7.83. It seems that this situation has significantly effect on distribution of land uses and plant pattern of both sides of Aciçay river.

Many studies have made correlations between soil properties and landscape positions-slope and parent material. In their study, Brubaker *et al.*[31] found 13 soil properties that differed with landscape position on four fields in eastern Nebraska. According to their results, sand, silt, pH, EC, calcium carbonate generally increased down slope. Clay content, organic matter and CEC generally decreased down slope. On the other hand, in this study it was found that clay content, organic matter and CEC generally increased from upper slope to low slope lands. Soil organic matter content depends on the complex interaction of several factors including the quantity and quality of litter fall, climatic factor, soil properties (especially the amount and type of clay) and erosion[32]. Soils of the both sides of Aciçay river have consistently low organic matter ranging from 0.46 to 2.61 % (Table-1).

For all soils, the organic matter is the highest in the surface horizon and decreases sharply to its lowest level in the subsoil. In the study area, the reasons of the low level organic matter are attributable to rapid decomposition and mineralization of organic matter (especially, due to intensive agricultural activities for right side), to overgrazing and to soil erosion (due to high slope for left side). Cation exchange capacity in the soils ranged from 9.04 to 27.18 cmol kg^{-1}. CEC values generally tended to be more related to the clay content (r = 0.901**), because organic mater content is generally low particularly in subsurface horizons. On the other hand, it was found statistically relation between organic matter and CEC (r = 0.596*). The gypsum content, which is relatively high in the fresh parent material (from 13.43 to 21.71%) is low relatively low from 0.10 to 1.76 % in most surface horizons.

Soil enzyme activities: The enzyme activities are presented in Fig. 1 for each landscape position and profiles. There were significant differences in extracellular enzyme activities among landscape positions and soil depth. Close observation suggests that there is a tendency for greater values in enzyme activities at the old river terrace for both sides of river. Moreover, enzyme activities on shoulder and backslope position in left side were significantly lower than the old river terrace in footslope position, which was in good agreement with the work of Askin and Kizilkaya[33]. This situation may be based on erosion and soil organic carbon deposition in footslope position. Gregorich *et al.*[34] and Fu *et al.*[35] reported that backslope and shoulder soils were the most affected by erosion and footslope soils showed the higher clay and organic matter content. Because of the high in organic matter contents, it was assumed that organic matter and clay content might be affecting the enzyme activities of soils.

For all landscape positions, enzyme activities showed similar trend in all profiles. In all positions and each sides, enzyme activities in soils decreased from the surface soil downwards indicating that the major part of the location is existed to the A horizon. On the contrary, the minority of extracellular enzymes has generally remained in the C horizon of the all profiles. Additionally, all enzymes exhibited similar pattern on all profiles. The same results were found by Bergstrom *et al.*[36] they suggested that higher proportion of organic matter and enzyme activities such as urease, phosphatase, arylsulphatase, β-glucosidase and dehydrogenase in A horizon in a Grey Brown Luvisol (Hapludalf) at all landscape position. Shukla *et al.*[37] assumed that higher organic matter and enzyme (urease, phosphatase and dehydrogenase) activities higher 0-10 deep soil and decreased with soil depth. Enrichment of organic matter and enzyme activities in surface soil is also reported by Zaman *et al.*[38]. Speir and Ross[39] suggested that the distribution of APA and ASA correspond with the distribution of microorganisms in the profiles. Definite positive relationships between enzyme activities and organic matter content in soil profiles have also been found[40]. The decrease in enzyme activities with depth can be mainly attributed to the diminution of biological activity down the profile. Inactivation of enzymes by clay minerals in the deeper horizons may be partly responsible for the different distribution patterns of the enzymes with depth[39].

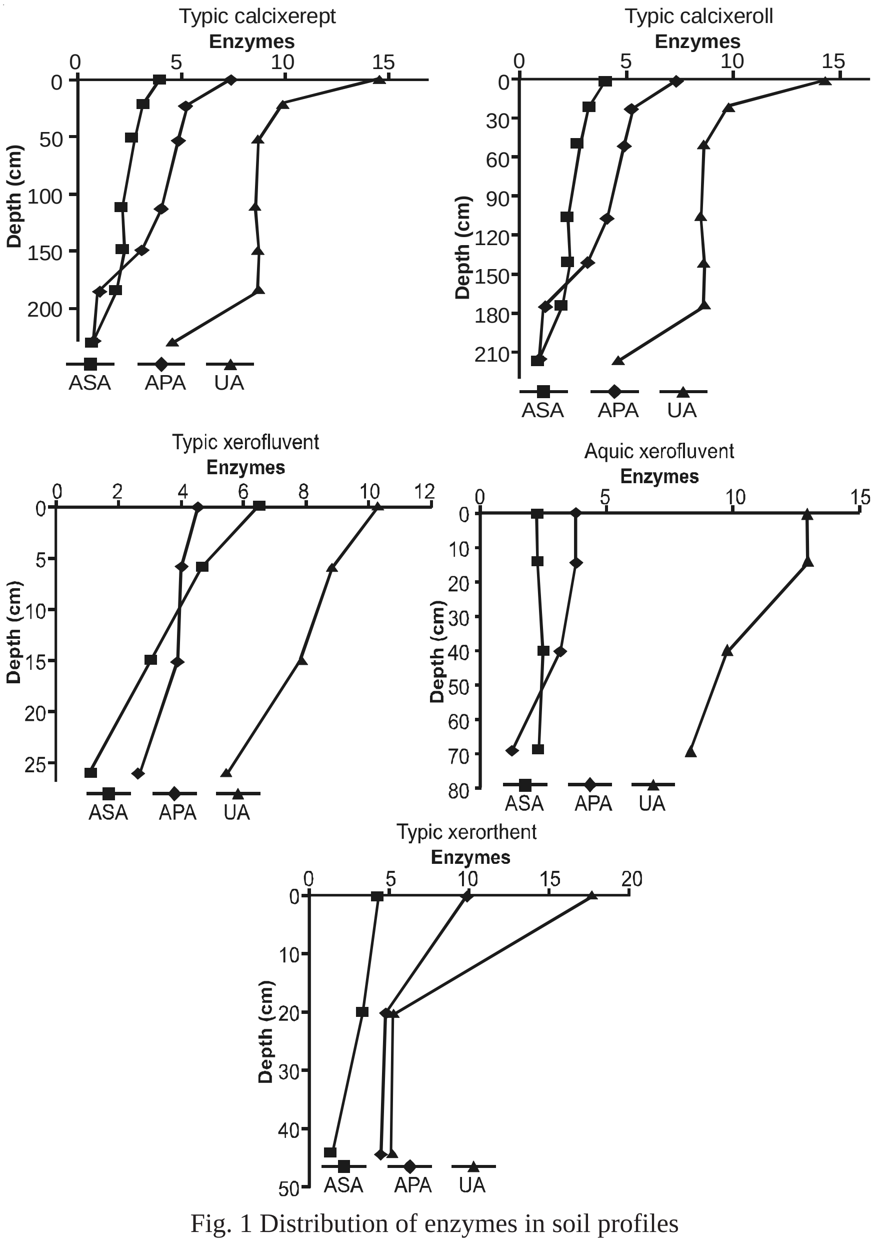

Fig. 1 Distribution of enzymes in soil profiles

The soil organic matter gave the significant correlations with extra cellular enzyme activities such as UA, APA and ASA at $p < 0.01$, but not significantly correlated with the other soil physico-chemical properties. In both sites, the microbial community of the highly skeleton has consumed relatively more organic matter than the other soil physico-chemical properties. Similarly, other studies[41-43] showed that soil organic matter content was significantly correlated with the soil enzymatic activities. The organic matter content, related with soil biological activities, is often used as an index of soil biological activity. Indeed, the microorganisms and their synthesized enzymes such as UA, APA and ASA have been shown to be more sensitive than the total carbon concentration for soil management practices[44].

In conclusion, soil chemical and physical properties data of these both sides of Aciçay river soils indicate significantly differences each other in terms of pedogenic processes which have been shaped by landscape position and parent material. Another way to view this concept that these factors are keys on soil forming processes especially at the local region. In addition, the results also indicated the enzyme activities along a hillslope and soil profile had the great differences in the soils. The old river terrace in footslope position has greater organic matter contents compared the other positions, because the higher levels in the fine particles and organic matter content clearly show erosional depositing at the footslope and denudation of shoulder. The main effects of the organic matter on the enzyme activities may be welded the accumulation or decomposition of organic matter and erosion and deposition. The organic matter strongly correlated with enzyme activities suggests the number and activity of soil microorganisms depend on mainly of mineralizable substrate and enzyme synthesizing. In conclusion, this study demonstrated changes of landscape positions can alter the soil enzyme activities within the soil profile. Landscape position associated with erosion resulted in high variability of enzymes. It is, therefore, a special and interesting area for the performance of an integrated analysis of soil enzymes in relation to landscape position and soil profile.

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