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SOIL LANDSCAPE RELATIONSHIPS BETWEEN DIFFERENT PHYSIOGRAPHIC UNITS IN TEJAN CATCHMENT (NORTHERN IRAN)

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ABSTRACT

There is a paucity of research on soil-landscape relationship in the Tejan catchment (northern Iran). Soil-landscape relationships were studied in two physiographic units; a mountainous and hilly terrain with mesic-xeric climate and limestone parent material and a hilly area with thermic-udic climate and conglomerate parent material. With the exception of some parts of southern slope of mountainous area which are covered by field crops and pasture, the whole area is covered with forest vegetation. Pedons in each unit were described at summit position and in shoulder, backslope, and footslope positions on the north and south sides. In the mountainous and hilly physiographic units, the northern slope with a lower evapotranspiration, lower temperature and high humidity, the climate is favorable for clay migration and formation of argillic horizon. The organic carbon content is high (up to 3.8%) and the $CaCO_3$ content is lower than 15%. The soils are Typic Haploxeralfs. The type of clay minerals in the order of their abundance were montmorillonite, vermiculite, kaolinite, illite, chlorite and hydroxy inter-layer vermiculite, respectively. But in the southern slope with higher evapotranspiration, higher temperature and lower humidity, the soils are

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Typic Calcixerepts at the summit, shoulder and backslope, and Fluventic Haploxerolls in the footslope area. Organic carbon content was lower and $CaCO_3$ content was higher than those of northern slope, respectively. The type of clay minerals in the order of abundance were illite montmorillonite, vermiculite, kaolinite, chlorite and hydroxy inter-layer vermiculite, respectively. In the hilly physiographic unit, due to udic moisture regime and forest vegetation cover, the soil conditions are favorable for the formation of argillic horizon. Soil type, clay minerals, organic carbon and $CaCO_3$ contents of the southern slope were almost identical to the northern slopes of the same unit and also those of northern slopes of mountainous area. Organic carbon content of the surface horizons ranges between 2.32 to 3.05% and $CaCO_3$ varies from zero up to a maximum 5.75% in the upper horizons. The soils of the southern as well as northern sites are mostly Mollic to Typic Hapludalfs.

Key words: Moisture and temperature regime, Physiographic units, Profile development, Soil-landscape relationships, vegetation covers.

تحقیقات کشاورزی ایران

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ارتباط بین فرم های مختلف زمین و خصوصیات خاک واحد های فیزیوگرافی مختلف در حوزه تجن در شمال ایران

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چکیده

تحقیقات اندکی در باره ارتباط فرم های مختلف زمین و خصوصیات خاک در حوزه تجن (شمال ایران) صورت گرفته است. ارتباط بین فرم زمین و خصوصیات خاک در دو واحد فیزیوگرافی مطالعه شد: زمین کوهستانی و تپه ای با رژیم آب و هوایی ترمیک-زریک و ماده مادری سنگ آهک و منطقه تپه ای با رژیم ترمیک-یردیک و ماده مادری کنگلومرا. به استثنای بعضی از نواحی شیب جنوبی منطقه کوهستانی که بوسیله گیاهان زراعی و مرتعی پوشیده شده است تمامی دارای درختان

جنگلی است. پروفیل هائی برروی قله، شانه شیب، دامنه پرشیب و شیب دامنه جهات شمالی و جنوبی مورد مطالعه قرار گرفت. در فیزیوگرافی کوه و تپه ای، در شیب های شمالی با تبخیرکم، دمای کـم و رطوبت نسبی زیاد اقلیم برای حرکت رس و تشکیل افـق آرجیلیـک مناسـب اسـت. کربـن آلـی تـا ۳/۸ درصد و کربنات کلسیم کمتر از ۱۵ درصد می باشد. خاکها به صورت تیپیک هایلوزرالف هستند. نوع کانی های رس به ترتیب درجه فراوانی شامل مونت موریلونیت، ورمیکولیت، کائولینیت، ایلیت، کـلریت و هیدروکسیدهای بین لایه ای ورمیکولیت هستند. اما در شیب های جنوبی که تبخیر و تعرق بیشـتر، دما بالاتر و رطوبت کمتر است، خاک ها از نوع تیپیک کلسی زرپت در قله، شانه شیب و دامنه پرشیب بوده و در نواحی شیب دامنه فلوونتیک هاپلو زرول می باشد. کربن آلی کمتر و آهک به ترتیب بیشتر از مقادیر شیب هـای شـمالی بـوده اسـت. نـوع کـانی هـای رسـی بـه ترتیـب فراوانـی ایلیـت، مونـت موریلونیت، ورمیکولیت، کائولینیت، کلریت و هیـدرو کسـیدهای بیـن لایـه ای ورمیکولیـت هسـتند. در واحد فیزیوگرافی تپه ای به دلیل رژیم رطوبتی یودیک و پوشش جنگلی، شـرایط خـاک بـرای تشـکیل افق آرجیلیک مناسب هستند. نوع خاک و کانی های رسی و مقدار کربن آلی و آهک شیب های جنوبی کم و بیش شبیه شیب های شمالی همین واحد و همچنین شیب های شمالی منـاطق کوهسـتانی اسـت. کربن آلی خاک سطحی حدود ۲/۳۲ تا ۳/۰۵ درصد و کربنات کلسیم از صفر تا ماکزیمم ۵/۷۵ درصد در افق های بالایی بود. خاک های جنوبی و شمالی غالباً مالیک تا تیپیک هاپل یودالف است.

INTRODUCTION

The distinctive characteristics of the landscape are commonly a complex response to variations in rock type (lithology). Weathering represents the response of minerals which were in equilibrium at different depths within the lithosphere to conditions at or near the earth-atmosphere interface (11). Soils form a three-dimensional continuum on the landscape and hence do not exist in isolation, but are organized within the landscape. Geomorphic processes play a major role indicating the distribution of soils on the landscape. In geomorphology, the landscape is viewed as an assemblage of landforms that are individually transformed during the process of landscape evolution. Because soils are an integral part of the land surface, any change in the geomorphic processes influences the pedogenic processes (14, 15).

For some studies of soil genesis, the hillslope model and the use of geomorphology have improved the framework for evaluating the interaction of pedogenic and geomorphic processes (12, 22, 23). In recent years greater attention has been focused on soils variability to further quality the pedogenic concepts and to better understand the causal factors for soil - distribution patterns and landscape evolution (31).

Little research has been conducted on soil-landscape relationships in northern Iran. For this reason representative landscape segments were selected with the following objectives: (i) the effect of topography on soil development, and (ii) to investigate the relationships between soil, microclimate and vegetation in differing slope facing aspects.

MATERIALS AND METHODS

Study Area

The study area is located in northern Iran (Lat. 36° 50′ to 36° 55′, Long. 53°,80′ to 53°, 25′, Tejan catchment) (Fig. 1). The area is composed of two major physiographic units: mountainous and hilly regions (Fig. 2). The climate of Tejan catchment is temperate and humid with an average annual precipitation of about 810 mm. The average annual air temperature is about 13.2°C and elevation ranges from 300 m at the footslope of the hilly region to 1500 m above mean sea level at the summit of the mountains. Two major climatic zone were distinguished for the two different physiographic units of the study area: mountainous and hilly terrain have mesic-xeric soil temperature and moisture regime in the control section (Fig. 3), while hilly regions contains thermic-udic regimes (Fig. 4).

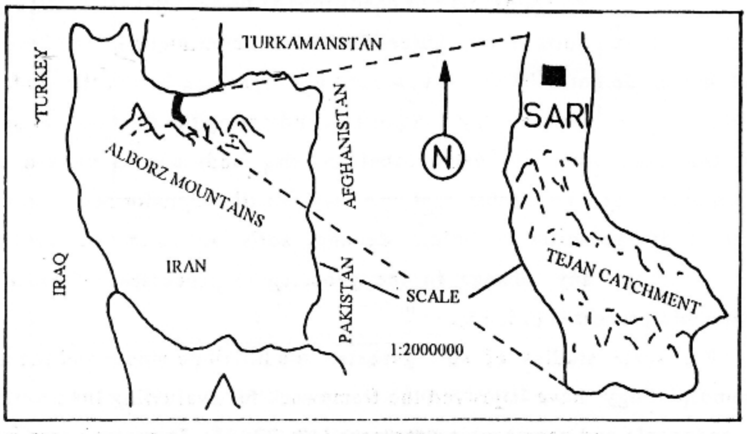

Fig. 1. Location of the study area (Tejan catchment).

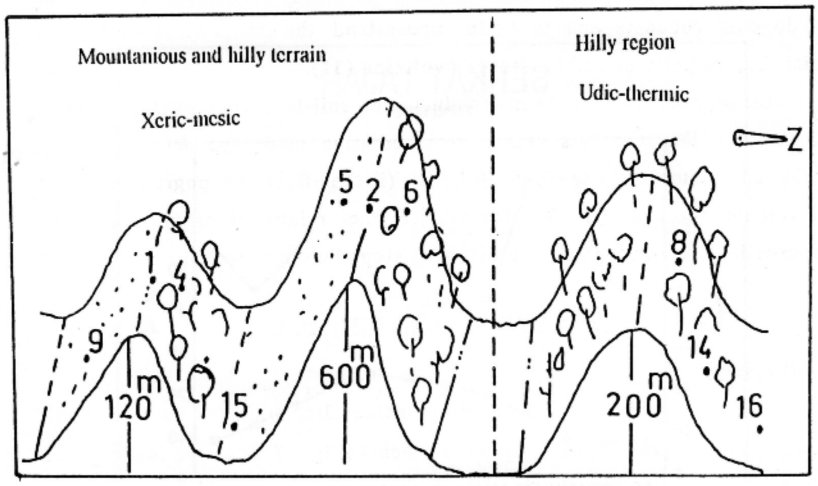

Fig. 2. Cross Section of the landscape showing location of the soil profiles

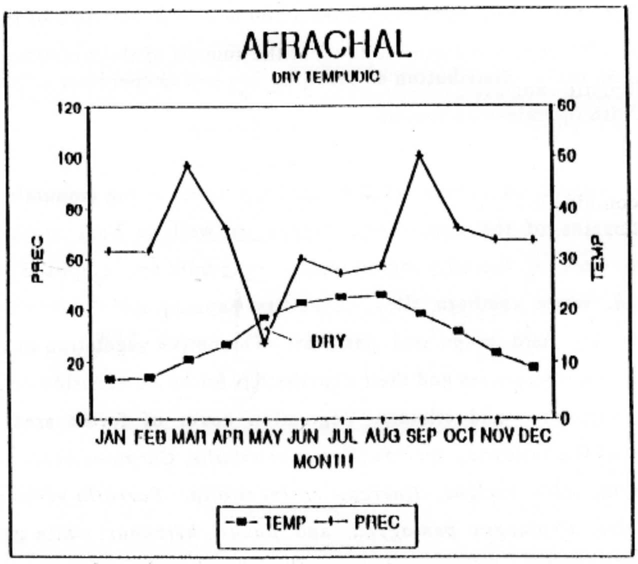

Fig. 3. Monthly distribution of precipitation and temperature of mountainous area with mesic-xeric regime.

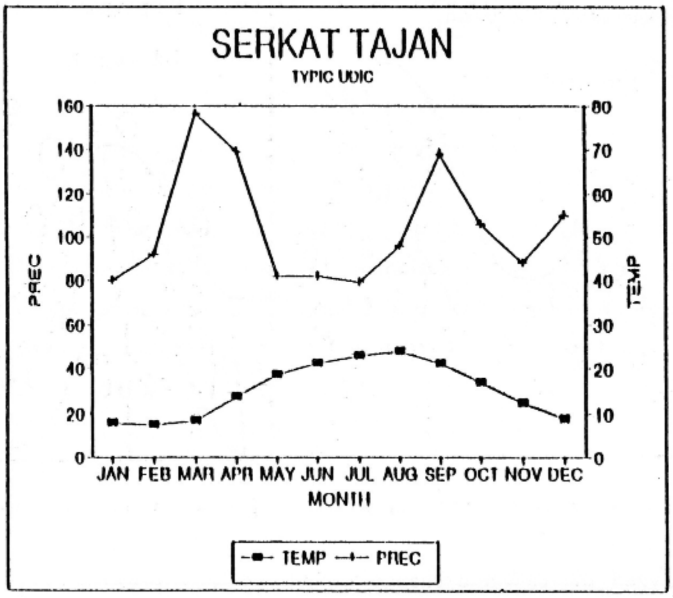

Fig. 4. Monthly distribution of precipitation and temperature of hilly area with thermic-udic regime.

The vegetation covers of the northern sites of the mountainous and hilly terrains of the mesic-xeric regime as well as both northern and southern sites of the hilly region with thermic-udic are composed of forest woodland, while southern sites of the first physiographic units are mostly covered with field crops and pastures. The native vegetation of the area consists of many species and their distribution follows a zonation controlled by physiography and climate. Vegetation cover of forest area mainly consists of the following species: *Fagus orientalis, Carpinus betulus, Alnus subcordata, Acer insigne, Quercus castaneifolia, Parrotia persica, Tilia begonifolia, Crataegus pentagyna,* and *Buxus hyrcanus*; while crops and pastures are of the following species: *Cynodon dactylon, Centurea cyanus, Cynara arvensis, Convolvulus arvensis, Avena fatua, Graminea,* and *Legominus*. The bedrock of the mountainous areas are mainly limestone while in the hilly areas they are conglomerate facies, mainly of marls and silty marls lithology (Bakhtiari Formation).

Field Method

Field work based on profile observation of the summit, shoulder, backslope and footslope at the northern and southern slope of mountainous as well as hilly areas was made in each physiographical units. Detailed soil profile description was compiled and the soils were classified in accordance with the guidelines and regulations of the National Cooperative Soil Survey (29). In this study, 110 soil profiles were digged in various physiographic units (4) of which only 10 representative profiles were selected for the present study. Pedons representing the overall properties of the various soils were sampled by genetic horizon for laboratory analysis (Fig. 2).

Laboratory Method

The soil samples were air-dried, ground to pass through a 2 mm sieve. and analyzed for cation exchange capacity (CEC), organic carbon, pH, texture, $CaCO_3$ and clay minerals. The CEC was determined by the sodium-saturation method (10). Organic carbon was measured by the Walkley and Black method (2). The pH value of the saturated paste was measured by a glass electrode (25). Particle size analysis of the soil samples were determined by the pipette and hydrometer methods (13). Carbonate was determined by the acid neutralization method (3). Removal of chemical cements and separation of different size fraction, for mineralogical analysis were done according to the methods of Kittrick and Hope (20) and Jackson (17). Free iron oxides were removed from clay sample by the citrate-dithionite method (26). Clay samples were saturated with Ca^{2+} and K^{+}, using $CaCl_2$ and KCl, respectively. Ca-saturated clay was also solvated by ethylene glycol and K-saturated clays heated at 550°C for five hours. The clay minerals were then identified by X-ray diffraction analysis (17). Since no feldspars were found in the clay fraction, the percentage of illite was obtained from total K_2O content of the clay (17). Vermiculite in the clay fraction was determined quantitatively by the method of Alexiades and Jackson (1). Quantity of other minerals was estimated from their relative peak intensities using ethylene glycol-treated samples (18). Thin section of the soil profiles were studied for recognition of argillic horizons according to Brewer's methods (7).

RESULTS AND DISCUSSION

Morphological Properties

The two pedons studied on the summit have a matrix color of chroma ≥ 3.5 in A horizons and weak, and fine granular structure (Table 1). The B horizons also have weak, medium to fine, angular blocky structure and accumulation of soft powdery lime. The C horizons have weak and fine angular blocky structure and accumulation of soft powdery lime.

Soils on the shoulder position in southern slope occur under pasture and field crops have calcic horizons. Solum thickness is about 95 cm. Soil structure is weak, medium to fine and angular blocky. In the northern slope under woodland, no accumulation of soft powdery lime was observed in the solum. In spite of steep slopes in the northern and southern parts, elluviation and illuviation of clay occurred in the woodland area. The solum is very deep, and structure is medium to coarse, angular blocky. Soils on the backslope also have a solum of about 105 cm thick, and an accumulation of soft powdery lime in B horizon. In both the northern and southern slopes under woodland, the solum is very deep and the observed clay coating on ped faces in the field suggests that clay illuviation has occurred. Structure is moderate to weak, coarse to medium and angular blocky.

At the footslope two pedons were selected. In the southern slope the mountainous areas have a matrix color of chroma ≥ 2.5 in A horizon and medium and moderate granular structure. Elluviation and illuviation of clay did not occur. In the northern slope of the hilly area, the accumulation of clay occurred in B horizon (>18 cm). In this area the structure is moderate, coarse to medium, and angular structure (Table 1).

Physico-chemical Characteristics and Clay Mineralogy

The texture of surface horizons in summit position was silty clay loam to silty clay. The shoulder position was either silty clay loam to silty clay in both aspect faces. Backslope under field crops have a texture of clay loam in the southern face. Clay texture is the predomineat textural class in the

Table 1. Morphology and classification of the soil profiles in different physiographic units†

Pedon no	Horizon	Dept cm	Munsell color (moist)	Structure	Consistence	Clay film	Boundry	Text
PHYSIOGRAPHIC UNITS								
SUMMIT								
Fine, mixed (calcareous), mesic, Typic Calcixerepts (Hill, pasture, crop)								
1	A_p	0-20	10YR 4.0/4	flgr	ml	-	cs	sicl
	B_k1	20-40	10YR 5.0/4	m2abk	mfr	-	cs	c
	B_k2	40-75	10YR 4.5/4	m2abk-f2abk	mfi	-	cs	socl
	C_k	75-130	10YR 5.0/4	m-flabk	mfi	-	-	sicl
Fine, mixed (calcareous), mesic, Typic Calcixerepts (Mountain, pasture)								
2	A_p	0-28	10YR 3.3/5	f1gr	ml	-	cs	sicl-sic
	B_k1	28-42	10YR 4.5/4	m2abk-f2abk	mfr	-	cs	sic
	B_k2	42-80	10YR 5.0/4	m1abk-f1abk	mfi	-	cs	sic
	C_k	80-125	10YR 5/6	m-f1gr	ml	-	-	sicl
SHOULDER								
Fine, mixed, mesic, Typic Haploxeralfs (Hill, north facing, woodland)								
4	A	0-9	10YR 3/3	gr	mfr	-	cs	sil
	Bt	9-40	10YR 4/4	m2abk-f2abk	mfi	fdcp	cs	sic-c
	BC	40-100	10YR 5/4	f1abk	mfi	-	-	sic-c
Fine, mixed (calcareous), mesic, Typic Calcixerepts (Mountain, south facing, crop)								
5	A_p	0-20	10YR 3.5/3.5	gr	mfr	-	cs	sicl
	B_k1	20-48	10YR 4/3	f1abk-gr	mfi	-	cs	sicl
	B_k2	48-95	10YR 5/4	m1abk-f1abk	mfi	-	cs	sicl
	C_k	95-130	10YR 5/5	m	ml	-	-	sicl
Fine, mixed, mesic, Typic Haploxeralfs (Mountain, north facing, woodland)								
6	A_1	0-13	10YR 3.5/3	f2abk-gr	mfr	-	cs	c
	B_w	13-36	10YR 4/3.5	f2abk-$f_1$abk	mfr	-	cs	c
	B_t1	36-70	10YR 4/4	m1abk-$f_1$abk	mfi	cdcp	cs	c
	C_t2	70-95	10YR 4.5/4	m1abk	mfi	cdcp	cs	c
	BC	95-130	10YR 3/4	1fabk	mfi	-	-	c
Fine, mixed, thermic, Typic Hapludalfs (Hill, north facing, woodland)								
8	A_1	0-7	10YR 3/2.5	f1abk-m2gr	mfr	-	cs	sicl
	B_t1	7-35	10YR 4/4	c2abk-m2abk	mfi	mdcp	cs	c
	B_t2	35-70	10YR 3/3	m2abk-f2abk	mvfi	mdcp	cs	c
	B_t3	70-120	10YR 4/4	c2abk-m2abk	mvfi	mdcp	-	c
BACKSLOPE								
Fine, mixed, mesic (Calcareous), Typic Calcixerepts (Hill, south facing, crops)								
9	A_p	0-17	10YR 4.5/4	m2gr	ml	-	cs	cl
	B_k1	17-55	10YR 5/4	m2abk-f1abk	mfr	-	cs	c
	B_k2	55-105	10YR 5/6	m2abk-f1abk	mfi	-	cs	sic
	C_k	105-130	10YR 6/6	m-f1abk	mfi	-	-	sic
Fine, mixed, thermic, Typic Hapludslfs (Hill, north facing, woodland)								
14	A1	0-6	7.5YR 3.2	f1abk-f1gr	mfr	-	cs	sicl
	B_t1	6-26	7.5YR 4/4	m1abk-f1abk	mfi	mdcp	cs	c
	B_t2	26-58	5YR 3/3	c2abk-m2abk	mvfi	adcp	cs	c
	B_t3	58-90	5YR 3/3	m2abk-f2abk	mvfi	mdcp	cs	c
	BC	90-130	10YR 4.5/4	flabk	mfi		-	c
FOOTSLOPE								
Fine, mixed, mesic (calcareous), Fluventic Haploxerolls (Mountain, south facing, crops)								
15	A_p	0-22	10YR 3.5/2.5	m2gr	mvfr	-	cs	sicl-sic
	B_w1	22-50	10YR 4/3.5	m2abk-f2abk	mfr	-	cs	sic
	B_w2	50-75	10YR 4/4	f2abk-gr	mfi	-	cs	sic
	BC	75-115	10YR 4/5	f2abk-gr	mfi	-	-	c
Fine, mixed, thermic, Mollic Hapludalfs (Hill, north facing, woodland)								
16	A1	0-18	10YR 3/2.5	f2abk-gr	mfr	-	cs	sicl
	B_t1	18-48	10YR 3.5/4	m2abk-f2abk	mfi	cdcp	cs	sic
	B_t2	48-73	10YR 4/3.5	c2abk-m3abk	mvfi	mdcp	cs	sicl
	B_t3	73-120	10YR 4/4	f2abk-f1abk	mfi	mdcp	-	c

†. Symbols used according to abberviation in Soil Survey Manual, USDA Handbook No. 18, p. 139-140 (1951).

northern face under woodland. All pedons have silty clay to clay texture subsurface horizons, and clay contents increased in the northern face under woodland vegetation. The pH values decreased in shoulder and backslope positions in both physiographies in woodland areas. In summit, shoulder, backslope and footslope soils lime increased with depth in the southern slope sites. Concentrations of $CaCO_3$ were high and accumulated in B and C horizons. In the northern slope and woodland area accumulation of $CaCO_3$ did not occur. Average organic carbon increased from summit to shoulder, backslope and footslope, but the organic carbon contents in woodland area were higher than field crops and decreased sharply from the surface horizon to approximately a depth of 20 cm (Table 2).

Semi-quantitative estimation of clay minerals in hilly area, under woodland, on the northern slope showed a relative occurrence of vermiculite, montmorillonite, illite, kaolinite and hydroxy inter-layer vermiculite. Southern slope soils primarily had vermiculite, illite, montmorillonite, kaolinite and chlorite. Woodland sites on northern slopes of the mountain (with marl parent material) contained montmorillonite, vermiculite, kaolinite, illite, chlorite, hydroxy inter-layer vermiculite. In the southern slope under field crops, illite, montmorillonite, vermiculite, kaolinite, chlorite and hydroxy inter-layer vermiculite are predominant. This suggested that the illite and chlorite are inherited from parent material and under present environment and vegetation conditions it weathered to other minerals but in the southern slope with field crop condition, this weathering process is retarded (Fig. 5).

Genesis and Classification of Soils of the Studied Pedons

The differences between soils of northern and southern slopes are mainly due to difference in microclimates and vegetation covers. In the northern hemisphere of low lattitude, the northern slope with lower radiation, temperature and evapotranspiration, have higher effective precipitation and dense vegetation in contrast to southern slope aspects. As a result, certain evolutionary trends have been taken place in the genesis of soils of different physiographies.

Table 2. Some physico-chemical characteristics of the soils studied

Pedon No.	Horizon	Depth cm	pH paste	O.C	$CaCO_3$	Sand	Silt	Clay	CEC
				%					cmol kg^{-1}
1	A_p	0-20	8.01	0.81	15.0	14	46	38	ND †
	B_k1	20-40	8.21	0.57	21.5	27	32	41	"
	B_k2	40-75	8.34	0.35	28.0	15	47	38	"
	C_k	75-130	8.31	0.02	26.0	12	51	37	"
2	A_p	0-28	7.94	1.85	12.25	14	46	40	"
	B_k1	28-42	7.95	0.66	27.25	12	44	44	"
	B_k2	42-80	8.24	0.40	32.0	18	45	37	"
	C_k	80-125	8.12	0.38	29.25	16	45	39	"
4	A	0-9	7.76	3.86	5.75	7	69	24	"
	B_t	9-40	7.47	2.13	10.75	26	33	41	"
	BC	40-100	7.99	1.17	21.5	13	40	47	"
5	A_p	0-20	7.68	1.93	12.75	11	51	38	"
	B_k1	20-48	7.87	0.99	19.0	14	49	37	"
	B_k2	48-95	8.13	0.52	38.0	16	42	42	"
	C_k	95-130	8.25	0.30	36.0	15	43	42	"
6	A1	0-13	7.67	1.84	10.0	24	35	41	"
	B_w	13-36	8.00	1.25	12.25	15	36	49	"
	B_t1	36-70	8.28	0.65	18.5	12	38	50	"
	B_t2	70-95	7.94	0.40	6.75	11	38	51	"
	BC	95-130	8.25	0.38	15.0	11	41	48	"
8	A1	0-7	7.82	2.32	5.75	18	51	31	"
	B_t1	7-35	6.75	1.66	2.5	6	42	52	"
	B_t2	35-70	6.10	0.60	3.25	6	33	61	"
	B_t3	70-120	6.43	0.33	3.5	10	34	56	"
9	A_p	0-17	7.74	1.88	17.75	28	36	36	23.5
	B_k1	17-55	7.44	1.04	24.75	22	32	46	25.0
	B_k2	55-105	8.00	0.46	29.0	14	44	42	27.5
	C_k	105-130	8.12	0.20	28.5	18	42	40	27.0
14	A1	0-6	6.21	2.62	0.0	10	53	37	44.4
	B_t1	6-26	5.44	0.91	0.0	8	38	54	22.5
	B_t2	26-58	6.38	0.49	3.75	11	33	56	21.0
	B_t3	58-90	6.95	0.39	4.75	6	37	57	32.5
	BC	90-130	7.85	0.32	11.5	10	42	48	25.0
15	A_p	0-22	7.91	1.73	21.5	8	52	40	ND
	B_w1	22-50	7.97	1.22	20.5	6	52	42	"
	B_w2	50-75	8.16	0.45	22.75	10	43	47	"
	BC	75-115	8.07	0.39	21.5	4	36	60	"
16	A1	0-18	7.21	3.05	2.25	10	51	39	"
	B_t1	18-48	7.09	1.37	2.5	11	44	45	"
	B_t2	48-73	7.27	0.71	1.25	9	40	51	"
	B_t3	73-120	7.11	0.56	2.25	9	38	53	"

† ND = not determined.

Redistribution and precipitation of carbonates (formation of calcic horizon) and elluviation and illuviation of clay minerals (formation of argillic horizon) are the two main evolutionary processes which occurred in different physiographic units.

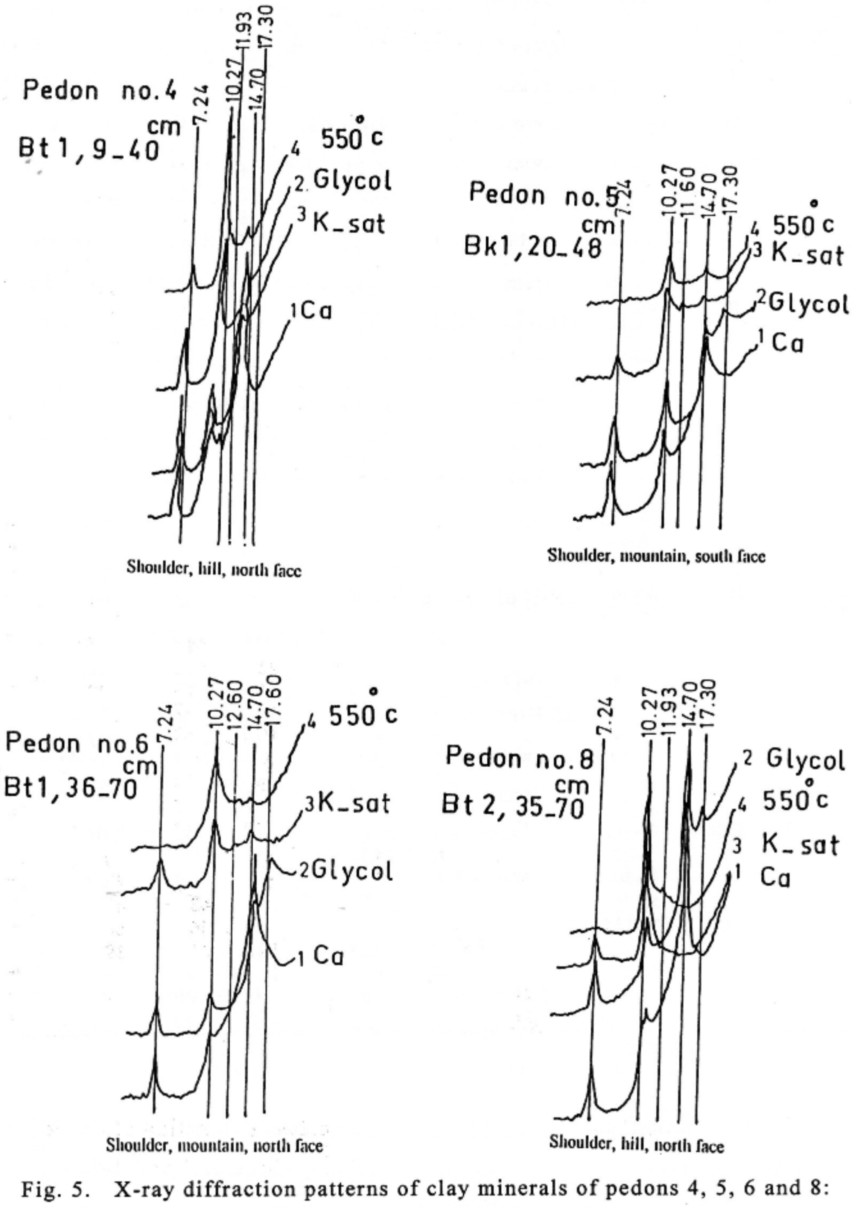

Fig. 5. X-ray diffraction patterns of clay minerals of pedons 4, 5, 6 and 8: 1-Ca saturated, 2-Ethylen Glycol solvated, 3-K saturated, 4-K saturated+550° C.

The degree of $CaCO_3$ redistribution and accumulation differred greatly among soils of different physiographies (Table 1). In drier parts of southern slopes, carbonates dissolve and leach from the upper profile during cold rainy winters and precipitate out in lower profile during hot dry summers. The redistribution of carbonates in these profiles is difficult to detect by laboratory calcium carbonate determinations, which do not distinguish between primary and secondary calcites (Table 2); however, carbonate differentiation is quite clear from field morphology (Table 1). The redistribution of carbonates is mainfested by the presence of secondary calcite crystals and nodules in the matrix and by an underlying horizon which contain almost more carbonates than the overlying horizon (Tables 1,2). Most of the proposed pathways for formation of calcic horizon are based on translocation of carbonates from near surface horizons with reprecipitation and accumulation occurring in the zone of effective water penetration (6). It is possible that some of the pedogenic carbonates in the calcic horizon were the result of *in situ* recrystallization of the limestone as explained by West *et al.* (30) or from shallow ground water (19, 21).

According to the literature, due to flocculation effects, carbonate prevents clay migration and illuviation (9, 16). This is the reason why in the drier soils of southern slope of the studied areas, caronate causes the clay to be flocculated and prevents formation of argillic horizon.

The studied pedons on summit position, shoulder and backslope of southern slopes had calcic horizons and were classified as fine, mixed, mesic, Typic Calcixerepts.

From the data given in Tables 1 and 2 it is noted that in the northern slopes with more humid conditions, leaching of carbonate appears to be the major cause of clay dispersion and migration in studied pedons. Dispersion of clay leads to clay migration which is a basic requirement for the formation of argillic horizon. Dispersability of clay probably is affected by the same factors as swelling of clay. Buol and Hole (8) and Rowell and Ahmad (27) listed these as the type of clay, the exchangeable cation on the clay, the free salts present in the soil, the concentration and composition of the electrolyte and the presence of other materials along with clay such as iron oxides, aluminum oxides and organic matter.

Clay migration apparently caused the formation of continuous oriented clay skins observable in the field (Table 1). Continuous clay cutans, strong structure of the B_t horizons of more humid area, show characteristic of argillic horizon (Table 1). Clay accumulation in the B_t horizons could be of different origin. Some workers believe that the clay accumulation of the B_t horizon is mostly due to weathering of primary minerals *in situ* (28) or inherited from parent materials (24). Most of the proposed pathways for the formation of argillic horizon are based on clay migration from the upper horizons with subsequent illuvial accumulation in the argillic horizon. The presence of thick and continuous clay cutans in the argillic horizons prove that the clay accumulation of Alfisols of the Tejan area are mostly of illuvial accumulation trends (Table 1). The same results were also reported earlier (5).

The present day formation of carbonates in soils with argillic horizon probably is of secondary origin; from erosion products surrounding limestone escarpments.

The soils of northern slopes are mostly covered by woodland vegetation and developed an argillic horizon, and are therefore classified as fine, mixed, mesic, Typic Haploxeralfs in xeric-mesic area and fine, mixed, thermic, Typic Hapludalfs in udic-thermic area.

CONCLUSIONS

This study showed that climatic variations and site aspects of physiographies have a major influence on properties and characteristics of soils of Tejan catchment area.

The northern slopes have lower radiation and temperature, higher effective precipitation and dense vegetation in contrast to southern slope aspects. As a result of $CaCO_3$ leaching, clay migration and argillic horizon formation, and humus contents are more pronounced in the northern slope aspects.

Soils formed under mesic-xeric regime, in the northern direction, are covered with forest vegetations, while southern slopes, are covered with crops and pastures. Thus, the soils of southern slopes are classified as Typic Calcixerpts and those of northern slopes are Typic Haploxeralfs. Under thermic-udic regime, both northern and southern sites are covered by forest vegetations, and the soils of both sites are classified as Typic Hapludalfs.

Analysis of clay fractions from each subsurface horizon of the four representative soils of the studied area revealed that more or less similar minerals were present, but they differed in their abundance.

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