Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences
Volume 1 Number 3: 271-274, 2002

Effect of Time on Soil Formation in Selected Alluvial Soil Series of Pakistan

S. M. Mehdi, [1]A. M. Ranjha, M. Sarfraz, G. Hassan and M. Sadiq
Soil Salinity Research Institute, Pindi Bhattian, Pakistan
[1]Department of Soil Science, University of Agriculture, Faisalabad, Pakistan

Abstract: The physical, chemical, morphological and mineralogical properties of three soil series viz. Shahdara, the Sultanpur and the Lyallpur, forming a chrono-sequence, were determined to quantify the effect of time on soil formation. The data showed that the relative particle-size differentiation in various horizons of the profiles increased with age and an illuviated clay profile developed progressively. There was no consistent increase in organic matter content with age. This trend was, most probably, due to high temperature and low rainfall, which resulted in little accumulation of organic matter in all the cases. The amount of $CaCO_3$ decreased with soil age, while no definite trend of the cation exchange capacity and NH_4OAc extractable bases was observed. Both the EC_e & pH_s, decreased with soil age. The mineralogical variation of these alluvial soils was not found to be related to pedogenic processes but parent material. The illite content was the same through out the profile in all the series. Smectite was more in Shahdara and decreased with age. Vermiculite was absent while chlorite and kaolinites were present, though in minor amounts, in all the three series.

Key words: Soil formation, time and soil series

Introduction

The nature and the intensity of changes occurring in the soil with the passage of time have been studied by many investigators (Brewer and walker, 1969; Campbell, 1971; Alexander, 1974). Such studies involve a comparison of certain characteristics of soils having different ages, but formed from a similar type of parent material under the similar environment. The studies related to chronosequence revealed that, with time, organic matter content increased, soluble salts, bases and carbonates were leached whereas pH was decreased (Wright *et al.*, 1959; Foss and Rust, 1962; Mehdi *et al.*, 2000). Parsons *et al.* (1962) and Campbell (1971) found that after initial accumulation of organic matter there was a distinct trend of decreasing values with further passage of time. Campbell (1971) showed a decrease in cation exchange capacity with increase in age, while Brewer and Walker (1969) reported that in an age sequence, with degree of weathering illuviated clay profile was progressively developed. As weathering proceeds, the clay content increases as a result of physical and chemical alteration of primary minerals. With further chemical changes, the transformations may takes place within the clay fraction of soil. The type of clay minerals formed depends on the climatic conditions and the chemical environment within the soil. Brady (1984) and Jackson (1968) described progressive modifications of the clay minerals with increasing weathering under various environments given as under:

Feldspar	--------------------illite-----------------	Vermiculite-montmorillonite Kaolinite-Oxides of Fe & Al.
Mica	------------------chlorite------------	Degree of weathering increase →

The chlorite and illite apparently represents the younger, the montmorillonite and vermiculite, the intermediate and the oxides, the oldest state of weathering. Franzmeier and Whiteside (1963) observed illite and chlorite during the initial stages of development and these two intergrade to vermiculite and montmorillonite with soil development. Bajwa (1989) Akhtar and Jenkins (1999) and Mehdi *et al.* (2000) also reported similar results. Keeping all this in view present study was undertaken to see the effect of age on soil formation in three soil series of Pakistan.

Materials and Methods

Profiles of three soil series i.e., the Shahdara (recent, 100 year old), the Sultanpur (Subrecent, 600-1000 years of age) and the Lyallpur (the pleistocene, 10^4 to 2×10^4 years old) were exposed at the selected locations and were described with the technical help of the soil survey staff, Lahore. Their classification is given in Table 1. Bulk soil samples were collected from Ap, B and C-horizons for physical, chemical and mineralogical analysis. These samples were air dried, ground and passed through a 2 mm sieve and were analyzed for texture, EC_e (dSm^{-1}) pH_s, O.M (%), CEC (me 100 g^{-1}), NH_4OAc extractable bases, soluble ions and mineralogical composition.
All the analyses were done according to the methods given in Hand Book No.60 (U. S. Salinity Lab. Staff, 1954) except texture by Moodie *et al.* (1959).

In case of mineralogical composition determination all steps were performed for clay samples preparation for X-ray diffraction by Jackson (1979) including:
Destruction of carbonates and removal of divalent cations, Decomposition of organic matter and dissolution of MnO_2, Removal of free iron oxide, Dispersion and separation of less than two-micron fraction, Pretreatment and sample preparation for X-ray analyses.
Clay samples were X-rayed by using a Norelco X-ray diffractometer, equipped with a flow counter and Bristol Dynamaster recorder. Copper K or iron K radiation were employed with A, 1.5418 and 1.9373 A^0, respectively. Each of the sample was scanned through the range of 0-30^0 at a speed of 20/2θ/minute (Jackson, 1979).

Table 1: Classification of the soils series

Name of the series	Order	Family
Shahdara	Entisols	Coarse-silty calcareous hyperthermic Typic Torrifluvent
Sultanpur	Aridisols	Coarse silty, mixed calcareous hyperthermic Fluventic Camtorthid
Lyallpur	Aridisols	Fine silty, mixed, hyperthermic ustalfic Haplargid

Results and Discussion

The data for the physical, chemical, morphological and mineralogical analyses of three soil series i.e., the Shahdara, the Sultanpur and the Lyallpur were considered to determine the effect of time on soil formation. These soil series varied in age forming a chronosequence.

Physical analysis: The distribution of soil particles i.e. sand, silt and clay (Table 2) was haphazard in the various horizons of the Shahdara soil series. Profile indicating a kind of stratification of the alluvial material. In the sub recent Sultanpur soil series, the clay content increased from 21 to 24 percent from surface to subsoil (up to 66 cm). In case of the Lyallpur soil series, the older one, there was a continuous increase in the clay content from surface to subsoil up to the depth of 90 cm and then it decreased. The particle size distribution showed sharp changes in the various size fractions in the relatively un-altered part of the profile i.e. the C-horizon. The relative particle-size differentiation increased with soil age and an illuviated clay profile was progressively developed. Brewer and Walker (1969), Ruhe (1956) and Campbell (1971) reported an increase in the clay content of the B-horizon with increasing soil age. Wright *et al.* (1959) found clay illuviation only in the relatively older members of some soil chronosequences. Ahmad *et al.* (1977) also has reported similar findings.

Chemical properties: The organic carbon content was low (0.50%) in Ap of the Shahdara series than that in the Sultanpur (1.0%) and the Lyallpur (0.62%) soil (Table 3). Depth wise distribution of organic carbon was irregular in the recent, Shahdara, while a consistent decrease in the sub recent, Sultanpur, and the old Lyallpur series. Organic mater accumulates in the soil

Table 2: Physical characteristics of the three soil series forming a Chronosequence

Soil Series	Horizon	Depth (cm)	Clay	Silt	Sand
Shahdara	Ap	0-17	17	61	22
	C1	17-26	8	70	22
	C2	26-60	5	60	35
	C3	60-67	15	70	15
	C4	67-92	5	61	34
	C5	92-102	20	70	10
Sultanpur	Ap	0-10	21	52	29
	BW1	10-29	22	53	25
	BW2	29-66	24	61	15
	2C1	66-84	7	50	43
	2C2	84-110	7	70	23
	2C3	110-118	21	70	9
Lyallpur	Ap	0-13	20	53	27
	BAT	13-28	22	56	22
	BT1	28-58	26	53	21
	BT2	58-90	30	51	19
	2BCK 1	90-110	26	53	21
	2BCK 2	110-145	14	62	24

Table 3: Chemical characteristics of three soil series forming a chronosequence

Soil series	Horizon	Depth(cm)	$CaCO_3$ (%)	O.M. (%)	CEC me	pHs	ECe dsm^{-1}	HCO_3 (me L^{-1})	Cl^{-2} (me L^{-1})	SO_4 (me L^{-1})	Ca^{++} Mg^{++} (me L^{-1})	Na^+ (me L^{-1})	K^+(me L^{-1})	NH_4OAC Extractable bases (mg kg^{-1})
Shahdara	Ap	0-17	13.0	0.50	10.4	8.1	0.86	2.0	3.7	3.2	3.0	6.2	0.13	9.5
	C1	17-26	11.0	0.20	6.0	8.1	0.90	1.5	4.9	3.2	6.0	4.1	0.12	5.2
	C2	26-60	11.0	0.16	4.1	8.1	1.10	1.5	4.2	5.2	5.6	6.0	0.30	3.7
	C3	60-67	14.0	0.23	9.0	8.2	1.30	1.8	5.1	6.7	5.0	9.5	0.31	8.0
	C4	67-92	11.0	0.16	4.1	8.1	7.20	1.0	14.2	58.6	35.0	36.0	0.31	4.0
	C5	92-102	14.0	0.23	9.2	8.0	9.50	1.0	18.2	70.6	44.1	51.0	0.30	8.7
Sultanpur	Ap	0-10	10.0	1.00	11.4	7.9	0.84	5.2	1.2	1.5	5.7	3.2	0.22	11.2
	BW1	10-29	10.0	0.60	11.0	8.0	0.82	3.6	1.6	2.4	4.6	3.9	0.20	11.0
	BW2	29-66	10.0	0.30	11.1	8.1	0.94	2.4	2.0	4.2	3.0	6.6	0.11	10.9
	2C1	66-84	11.0	0.20	6.0	8.0	0.70	2.4	1.2	2.4	1.5	5.0	0.11	5.8
	2C2	84-110	11.0	0.20	6.0	7.9	1.12	1.6	3.0	5.1	3.5	7.2	0.10	6.0
	2C3	110-118	14.0	0.31	10.0	8.0	1.10	1.4	5.4	9.0	6.5	10.5	0.10	9.8
Lyallpur	Ap	0-13	1.1	0.62	10.0	7.8	0.74	6.0	0.3	1.2	7.0	0.6	0.30	9.5
	BAT	13-28	1.1	0.42	8.4	7.9	0.34	1.4	1.0	1.1	2.0	1.5	0.10	8.2
	BT1	28-58	1.1	0.31	10.0	7.9	0.90	3.5	2.5	3.1	6.1	2.8	0.20	9.7
	BT2	58-90	3.2	0.26	9.0	8.0	0.85	3.2	1.0	5.8	7.5	2.0	0.11	8.8
	2BCK1	90-110	10.0	0.22	7.0	8.0	0.75	2.0	1.1	4.0	6.2	2.1	0.13	6.7
	2BCK2	110-145	10.0	0.20	5.0	8.1	0.40	1.1	1.0	2.1	3.1	1.2	0.14	4.5

O.M. = Organic matter ECe = Electrical conductivity of saturation extract CEC = Cation exchange capacity

Table 4: Main morphological features of the selected soil series.

Series	Parent Material	Physiography	Age	Climate	Drainage	Micro relief	Main morphological features
Shahdara is	-do-	-do-	Recent (Late Holo cene)	Semiarid and sub-humid subtropical continental	Well drained	Level land	Moderately deep to deep well drained, medium textured, calcareous soils without B horizon, subsoil stratified.
Sultanpur	Alluvium mixed material from the Himalayas	Terrace in River valley	Subre cent	Semiarid subtropical continental	Well drained	Level or smooth	Brown/dark brown silt loam, massive moderately calcareous . Ap horizon underlain by a brown to dark brown silt loam, very weak coarse subangular blocky, moderately calcareous B horizon underlain by a brown, very fine sandy loam and silt loam, massive, moderately calcareous C horizon which is usually stratified.
Lyallpur	-do-	-do-	Late Pleisto-cene	Semiarid subtropical continental	-do-	Level or Smooth	Brown, silt loam, with weak subsoil structure very deep with distinct kankars in lower subsoil, well drained strongly calcareous subsoil.

Table 5: Clay mineralogy of < 2μm fraction

Soil series	Horizon	Illite	Smectite	Chlorite	Vermiculite	Kaolinite
Shahdara	Ap	3	3	1	-	2
	C1	3	2	1	-	1
	C2	3	2	2	-	1
Sultanpur	Ap	3	1	2	-	2
	B	3	2	2	-	2
	C	3	2	2	-	2
Lyallpur	Ap	3	1	2	-	1
	B	3	1	2	-	1
	C	3	3	2	-	1

4 = Dominant 3 = Major 2 = Minor 1 = Traces.

with increasing development (Franzmeier and Whiteside, 1963) and after reaching a stable equilibrium in mature soils; it declines (Campbell, 1971). In the present study there was no consistent increase in organic matter with age but Syers *et al.* (1970) observed that organic matter continued to increase even after 10,000 years of soil development. However, these findings pertain to the possible reason, for low organic matter in the soils, may be high temperature, which promoted its rapid oxidation.

The $CaCO_3$ content, which indicates the intensity of leaching of a soil profile is an important index of the degree of soil formation. The distribution of $CaCO_3$ in the profile of the Shahdara soil series was inconsistent, in the Sultanpur a total amount was slightly less but there was a little increase with depth wile in the Lyallpur series, the percent $CaCO_3$ was low and it also increased with depth. Under climatic conditions permitting net downward movement of water at some time of the year, the amount of lime in soil decreased with greater soil age (Wright *et al.*, 1959). A definite trend of the cation exchange capacity of the soils of different series was observed. Actually the CEC of a soil is a function of colloidal particles in its mineral and organic fractions. Soil with low organic matter content, as was in the present

Plate I: The shahdara profile (*Typic torrifluvent*) prominent depositional stratification and lamination.

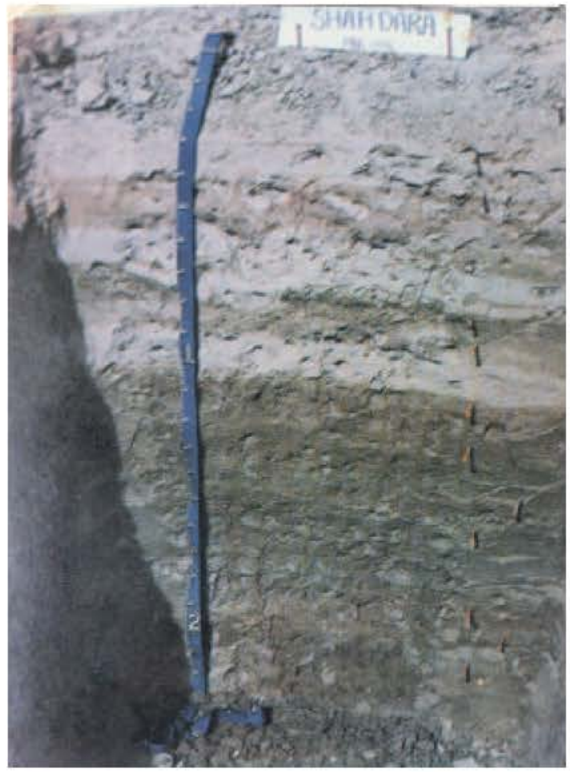

Plate III: The Lyallpur profile (*Ustalfic haplargid*) very distinct color horizon. Zone of secondarylime accumulation occurred below about 90 cm depth.

Plate II: The Sultanpur profile (*Fluventic camborthid*) because of relatively younger age, profile development is only to limited depth and horizon not much conspicuous. The substratum comprises unaltered parent material exhibiting depositional stratification.

case, the CEC is generally controlled by the mineral colloids. There was slightly high increase in the CEC of the surface soil of the Sultanpur series probably due to more organic matter oldest, the Lyallpur soil series. The ammonium acetate extractable base also did not exhibit any relation with soil age.

Morphological features: The main morphological features of the profiles are presented in Table 4. Plates 1,11 and 111 also shows some morphological features of the Shahdara, Sultanpur and Lyallpur soil series, respectively. The topsoil color was uniform throughout the soil sequence but the subsoil color varied. The top soil structure was essentially the same in all the soils, however, the subsoil structure ranged from depositional stratifications in the youngest soil (the Shahdarab series) to well developed structural aggregates in the oldest soil (the Lyallpur series). Both the electrical conductivity and pH of the surface soil had comparatively higher values in the youngest soil than that in the others. Solum depth, horizon thickness, and structural development increased and clay illuviation became pronounced with time. Similar conclusions were drawn by Ruhe (1956), Gile (1966), Brinkman and Rafiq (1971) and Ahmad *et al.* (1977).

Mineralogical composition of the clay: The results of X-ray diffraction analysis of $< 2\mu$ clay fraction from surface and subsoil horizons from all the three soils are presented in Table 5. The illite content was the same throughout the profile in all the series. Smectite was more in the Shahdara and it decreased with soil age. In the case of the Lyallpur series, smectite content increased in the C material. Vermiculite was absent while chlorite and kaolinites were present, though in minor amounts, in all the three series. Minerals in the clay fraction are subjected to weathering and transformation with soil development (Brewer and Walker, 1969) The chlorite and illite apparently represent the younger, the smectite and vermiculite, the intermediate; and the oxides, the oldest state of weathering (Jackson, 1968; Campbell, 1971; Franzmeier and Whiteside, 1963; Brady, 1984). But, in this study, the mineralogical variation of alluvial soils reflected the differences of their original material rather than that of pedogenic processes, so, the loessial materials (alleviated) carry principally hydrated mica (illite) and smectite in association with chlorite and kaolinite. Bajwa (1989); Akhtar and Jenkins (1999) and Mehdi *et al.* (2000) also reported similar results.

References

Ahmad, M., J. Ryan and R.C. Paeth, 1977. Soil development as a function of time in the Punjab River Plains of Pakistan. Soil Sci. Soc. Am. J., 41: 1162-1166.

Akhtar, M.S. and D.A. Jenkins, 1999. Mineralogical characterization of the glauconitic sandstone from Chickali formation of sorghan range. Pak. J. Sci. & Ind. Res., 42: 215-219.

Alexander, E. B., 1974. Extractable iron in relation to soil age on terraces along the Truckee River, Nevada. Soil Sci. Soc. Am. Proc., 38: 121-124.

Bajwa, M.F., 1989. Potassium mineralogy of Pakistani soils and its effect on potassium response. Pp. 203-216. In NFDC bulletin, 4-89.

Brady, N.C., 1984. The Nature and properties of Soils. The MacMillan Co. New York, U.S.A. pp: 140-188.

Brewer, R. and P.H. Walker, 1969. Weathering and soil development on a sequence of river terraces. Aust. J. Soil Res., 20: 293-305.

Brinkman, R. and M. Rafiq, 1971. Landform and soil parent materials in West Pakistan. Soils Bull. No.2. Soil Survey Project of Pakistan, Lahore, pp: 1-28.

Campbell, I. B., 1971. A weathering sequence of basaltic soils near Dunedin, New Zealand. New Zealand J. Soil Sci., 14: 907-924.

Foss, J. E. and R.H. Rust, 1962. Soil development in relation to loessial deposition in Southeastern Minnesota. Soil Sci. Soc. Am. Proc., 26: 270-274.

Franzmeier, D. P. and E. P. Whiteside, 1963. A chronosequence of podzols in northern Michigan: II. Physical and chemical properties. Michigan Quarterly Bull., 46: 21-56.

Gile, L. H., 1966. Cambic and certain noncambic horizons in desert soils of southern New Maxico. Soil Sci. Soc. Am. Proc., 30: 773-781.

Jackson, M. L., 1968. Weathering of primary and secondary minerals in soils. 9th Int. Cong. Soil Sci. Trans., 4: 281-292.

Jackson, M. L., 1979. Soil Chemical Analysis. Advanced Course. 2nd Ed. 11th Printing Madison, WI.

Mehdi, S. M., A. M. Ranjha, S. Akhtar, M. K. Tanvir and G. Hassan, 2000. Morphological, chemical and mineralogical Characteristics of a Chronosequence of soils on alluvial deposits in Pakistan. Int. J. Agric. Boil., 2: 364-368.

Moodie, C. D., H. W. Smith and P. R. Mc Creery, 1959. Laboratory Manual of Soil Fertility. State College of Washington, Mimeograph, Pullman, Washington, 1. pp: 175.

Parsons, R. B., W. H. Scholtes and F. F. Riechen, 1962. Soils of Indian mounds in Northeastern Iowa as benchmark for studies of soil genesis. Soil Sci. Soc. Am. Proc., 26: 491-496.

Ruhe, R. V., 1956. Geomorphic surfaces and the nature of soils. Soil Sci., 82: 441-445.

Syers, J. K., J.A. Adams and T.W. Walker, 1970. Accumulation of organic matter in a chronosequence of soils developed on wind blown sand in New Zealand. J. Soil Sci., 21: 146-153.

U.S. Salinity Lab. Staff, 1954. Diagnosis and Improvement of Saline and Alkali Soils. USDA Hand Book No.60 Washington, D.C. pp: 160.

Wright, J. R., A. Leachey and H.M. Rice, 1959. Chemical morphological and mineralogical characteristics of a chronosequence of soils on alluvial deposits in the Northern Territories. Can. J. Soil Sci., 39: 32-43.