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Original Research Article

Properties and Classification of Soils Developed Under *Shalla* Mango Orchard in Malikawa Village, Kware Local Government Area, Sokoto State, Nigeria

Hayatu NG[1], Nabayi A[2], Sharu MB[3*], Buji IB[4], MahmudAT[2], Abdulwahab MO[1], Girei AH[2], Yusif SA[2], Saadu I[5], Abubakar SD[5], Dangaladima W[3], Sani. I[6] and Samim S[7]

[1]Department of Soil Science and Agricultural Engineering, Usmanu Danfodiyo University, Sokoto, Nigeria PMB 2346 Sokoto State
[2]Department of Soil Science, Federal University Dutse, Jigawa state Nigeria Ibrahim Aliyu bye-pass PMB 7156 Dutse, Jigawa State
[3]Department of Agricultural Science, Shehu Shagari College of Education, Sokoto, Sokoto State
[4]Department of Soil Science, Faculty of Agriculture, University of Maiduguri P.M.B. 1069 Maiduguri, Borno State
[5]Department of Geography, Faculty of Social Science, Usmanu Danfodiyo University, Sokoto, Nigeria PMB 2346 Sokoto State
[6]Department of Chemistry, Zamfara State College of Agriculture, Maru
[7]Department of Agricultural Economics & Extension, Takhar University, Afghanistan

***Corresponding Author**
Sharu MB

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Abstract: A reconnaissance soil survey and image analysis of Kware town Fringes was conducted to determine the effect of orchard cultivation on some soil properties. Two profile pits were dug and described in line with FAO guidelines for soil description. The data obtained were subjected to both descriptive and inferential statistics. Soils for orchard cultivation were clay loam in texture. The soil units were rated low in OC (1.20 – 10.80 g kg^{-1}), EC (0.01 dSm^{-1}) and bulk density (1.0-1.6 gcm^{-3}). Similarly, all the soil units were also rated high in exchangeable Na (1.47 – 1.54 cmol kg^{-1}) and PBS (95.54-98.74 %). The soil units were classified using USDA and WRB systems. Soils of the study site were high in CEC (15.55 cmol kg^{-1}) and OC (6.70 g kg^{-1}) as such incorporation of organic residues and reduced tillage was recommended to improve their fertility status. Soils of orchard cultivation were slightly alkaline (7.29), as such the soils are suitable for mango cultivation as it falls within optimum range.

Keywords: Orchard, cultivation, physical and chemical properties.

INTRODUCTION

Soil is a complex mixture of mineral nutrients, organic matter, water, air, and living organisms determined by various environmental factors such as climate, parent materials, relief, microorganisms, and time factors [1]. As the interface between the atmosphere, biosphere, and lithosphere, soil undergoes an intense vertical exchange of materials resulting in steep chemical and physical gradients from the surface to bedrock [2].

Agriculture is a major use of land, and the share of land used for agriculture has been slowly increasing across most of the world’s regions over the past few decades as population increases [3]. Increasing population growth will continue to exert very high pressure on land resources. And for this reason, over the decades in both agriculturally advanced and small-scale crop production, nutrient replenishment through fertilizers and manures will continue to remain far below crop removal, thus causing the depletion of nutrient reserves [4]. Furthermore, these problems will continue to aggravate due to unsustainable land resource management strategies coupled with population pressure [5-7].

Nigeria has an estimated land area of 904,000 km^2 with a population of over 120 million in which about 65% of the land area is under various forms of food (crop and animal) production and forest plantation [8]. The continuous conversion of tropical cropland to grassland or forest causes variation in soil parameters [9] as well as the overall natural environment [10]. Some soil properties such as nutrient contents (N, P, K, Ca, Mg, S, etc.), pH, organic matter, CEC, structure etc. differs with changes in land use [11]. Again, the physico-chemical characteristic entails the potential status of nutrients distribution in soils of different land uses [12, 13]. Recent studies are validating the justification that land-use changes can have effects on soil fertility [14]. The results of physical and chemical properties provide information about the supplying capacity of soil mineral nutrients [15].

Land use changes and managements practices brings about changes in soil physical, chemical, morphological chemical and biological properties the effect to which is well reflected in the soil productivity [16]. Knowledge on how soils respond to management practices overtime is the key to maintaining soil quality. Nowadays, the increase in awareness that soil is an important component of the earth biosphere which not only functions in the production of food and fiber, but also in the maintenance of local, regional and worldwide environmental quality has trigger the interest in evaluating the quality of our soil resources [17]. Furthermore, feeding of the ever-increasing population is an important challenge looking at the degradation rate of our soils. For instance, in Sub-Saharan African countries, soil fertility depletion is the fundamental biophysical cause for declining per capita food production [18]. Land use has affected significantly the basic processes of erosion, soil structure and aggregate stability, nutrient cycling, leaching, carbon sequestration, and other similar physical and biochemical processes [19]. This challenge will continue as population increases and degradation of soil resources is aggravated.

The need to generate adequate knowledge of soil is by the exploration of soil properties at different depths, which would provide relevant information on patterns of nutrients accumulation and redistribution of both surface and deep layers of the soil for proper utilization of land resources [20]. The study and understanding of the effect of orchard cultivation on the soil will be useful for the development of a soil management plan for the efficient utilization of limited land resources. Hence, the objective of the research is to investigate the effect of physical and chemical characteristics of the soils and agricultural potentials and constraints for sustainable yield as well as crop production.

MATERIALS AND METHODS

Description of the Study Area

This research was conducted at Malikawa village, Kware Local Government area, Sokoto state. Malikawa is located between latitude 13^0 13` 22.27`` to $13^0$ 13` 21.39`` N and longitude 5^0 16` 34.74`` to $5^0$ 16` 35.83`` E. The climate of the area is characterized by Tropical climate with an average rainfall of 565 mm/year [21]. The minimum temperature is 27 ^{0}C while the maximum temperature is 40 ^{0}C [21]. The relative humidity during dry season is about 15-20% and reaches up to 70-75% during the rainy season. Agriculture is one of the dominant activities engaged by the people of Malikawa villages. The dominant underlying geology of the study area is Cretaceous and Tertiary sediments [22]. The vegetation is largely that of the Sudan zone, which contains savannah woodland on the better soils and tree and shrub savannah on the poorer ones. The major land use types in the study were arable crop production both at upland and lowland areas and non-agricultural uses such as residential, quarry and mining, roads construction etc.

Field Work

Two (2) farmers plot located at Malikawa village were purposely selected for the study. The farms were cultivated for over 20 years with Millet-Cowpea-Sorghum intercrop under the mango orchard. The general site description such as climate, vegetation, land use, slope gradient, drainage type and condition, type and degree of erosion and depth to ground water table were recorded. Two profile pits (2 x 1.5 x 2 m) were dug and described morphologically following FAO [23] guidelines. For each profile, depth, colour, texture, structure, consistence, roots, pores, inclusions, as well as boundary characteristics were recorded. Garmin eTrex 10 global positioning system (GPS) device was used in recording the coordinates.

Sample Collection and Preparation

Soil samples were collected from each genetic horizon of the two profile pits dug. Similarly, undisturbed soil samples for bulk density determination were taken using core samplers of known volume, whereas disturbed samples for other physical and chemical parameters determination were taken in nylons, labelled accordingly and transported to the laboratory. The samples for bulk density determination were oven dried at 105 ^{0}C for 48 hours. Disturbed soil samples on the other hand, were air-dried for 24 hours, crushed gently using pestle and mortar and pass through 2 mm sieve. Particles < 2 mm were used in the laboratory analyses.

Laboratory Analyses

Soil samples were subjected to series of analyses; particle size analysis was determined following Bouyoucos Hydrometer [24] method, bulk density was by core sampler method as described by Blake and Hartge [25]. Particle density was determined by the use of Pycnometer bottle method [26]. Total porosity was calculated from particle and bulk density values using the following relationship:

$$P = 100\,(1 - \frac{Bd}{Pd})$$

Where P is porosity, Bd is bulk density, Pd is particle density

Soil pH was determined both in water and 0.01M $CaCl_2$ with a glass electrode pH meter at 1:2.5 soil to liquid ratio [27]. Organic carbon was determined by wet oxidation method as described by Nelson and Sommers [28]. Total nitrogen (N) was determined using the Micro-Kjeldahl digestion and distillation method [29]. Available phosphorus was extracted following Bray No. 1 method and determined using molybdenum blue method [30]. Cation exchange capacity (CEC) was determined by the neutral ammonium acetate saturation method buffered at pH 7 [24]. Exchangeable bases (Ca, Mg, K and Na) were determined by extraction with neutral 1*N* NH_4OAC saturation method. Ca and Mg were read using atomic absorption spectrophotometer (AAS), whereas K and Na were read using Flame Photometer [24]. Percentage base saturation (PBS) of the soils was calculated using the following relationship:

$$\text{PBS} = \frac{\sum(\text{Exchangeable Bases})}{\text{CEC}} \times 100$$

Where; PBS is percent base saturation, and CEC is cation exchange capacity

DATA ANALYSIS

The data collected and generated were analyzed statistically for descriptive statistics such as means, ranges, and percentages and Pearson's (r) correlation analysis using SPSS statistical package version 20.

RESULTS AND DISCUSSION

Description of the Soils of Orchard Lands

Soils of the orchard plantation are mainly dominated by mango trees (*Mangifera indica*). The farmers cultivate the orchard with arable crops such as sorghum, millet, cowpea and groundnut in the rainy season. During the dry season, they also cultivate vegetable crops such as onions and okra by irrigation.

Morphological properties of the soils of orchard lands

The morphological properties of Pedons Orc P1 and P2 are presented in Table 1. Both pedons in the orchard land were shallow (70 cm) to moderately (114 cm) deep profiles. Pedon Orc-P1 had three generic soil horizons (Ap-Bw-AB), while Pedon Orc-P2 had four horizons (Ap-Bw1-AB-Bw2). The Pedons were similar in terms of horizonation and horizons thickness. The pedons had slight discernable variations in relation to surface and subsoil colour patterns. The colours varied from yellowish brown (10YR5/4) to dark yellowish brown (10YR4/6) dry in Pedon Orc P1 and P2 surface layers respectively (Table 1) depicting the influence of topography, location, weathering, parent material and organic matter content. The colour of the subsurface horizons ranged from reddish yellow (7.5YR6/6) to dark brown (10YR4/3) in the Bw and AB of Pedon Orc-P1 respectively to yellow (10YR 7/6) in the deepest subsurface horizon of Pedon Orc-P2 (i.e. Bw2).

The soils of orchard lands (Table 1) had similar soil texture. The surface horizons of Pedon Orc P1 and P2 were sandy loam in texture, whereas, the subsurface horizons were sand to sandy loam in texture. These types of soil texture (clay loam and/or sandy loam) according to Masabni and Strang [31] are better-suited for fruit trees than very sandy or heavy clay soils. Soil structure of the surface Pedons were sub-angular blocky, except for Bw2 of Pedon Orc-P2 which was single grain. The poor or weak soil structure observed could be attributed to the effect of cultivation, owing to the fact that, traces of arable crops (evident by stumps) cultivation was observed within the orchard. This further shows that, what the farmers are practicing is no longer a single land use, but rather, a multiple land use. Differences were also observed in terms of consistency, with majority of the horizons being hard when dry. This could also be attributed to the water content and type of mineral that make up the soils. For instance, Bw2 horizon is sandy in texture, single grain in structure and loose (dry) in consistence, depicting the presence of primary minerals (such as kaolinite, quartz etc).

Another striking feature of the soils as shown in Table 1 is the possession of shallow water-table corroborating the previous findings of Anonymous [32] who observed that water table is generally deeper beneath hills and shallower beneath valleys. The water-table of Pedon Orc-P1 is shallower (around 70 cm deep) than that of Pedon Orc-P2 (around 114 cm deep), indicating differences in elevation and position of the profiles as well as their relative closeness to the nearby water stream (also known as *Shalla*) that supplies the orchard with water all year round. This result has contradicted the findings of Masabni and Strang [31] who opined that, areas with high water-table are not well-suited for orchard plantation.

Table-1: Morphological Properties of the Soils of Malikawa Series Pedons Orc P1 and P2

Horizon	Depth (cm)	Colour	Texture[1]	Structure[2]	Consistence[3]	Boundary[4]	Other Features[5]
Malikawa Series- Pedon Orc P1 (Aquic Ustipsamments/Rubic Arenosols (Eutric)							
Ap	0-8	10YR5/4	SL	sab	h	gs	mfmlr, ffp, fmwc
Bw	8-12	7.5YR6/6	SL	sab	h	cs	mfmlr, ffp,
AB	12-70	10YR4/3	SL	sab	h	ds	fmlr, mfp
-	>70	Water table					
Malikawa Series- Pedon Orc P2 (Aquic Ustipsamments/Rubic Arenosols (Eutric)							
Ap	0-10	10YR4/6	SL	sab	h	gw	fmr, mmp
Bw1	10-41	10YR5/8	S	sab	s	dw	ffr, fmp
AB	41-63	10YR3/6	S	sab	s	dw	flr
Bw2	63-114	10YR7/6	S	sg	l	dw	fmr
-	>114	Water table					

[1]SL= sandy loam, S= sand
[2]sab= sub-angular blocky, sg=single grain
[3]h= hard, s= soft, l= loose
[4]gs= gradual smooth, cs= clear smooth, ds= diffuse smooth, gw= gradual wavy, dw= diffuse wavy
[5]mfmlr= many fine medium and large roots, fmlr= few medium and large roots, fmr= few medium roots, ffr= few fine roots, flr= few large roots, ffp= few fine pores, mfp= medium fine pores, mmp= many medium pores, fmwc= few medium widely spaced cracks Physical properties of the soils of orchard plantation lands

The soils of orchard plantation land were generally sandy loam in texture in the surface horizons. The subsurface horizons of Pedons Orc P1 and P2 were sandy loam and sand in texture respectively. In the surface horizons of Pedons Orc P1 and P2, the sand contents ranged from 68.0 to 70.0% (69%) and was rated high. The silt and clay content of the soils ranged from 15.7 to 17.7% (16.7%) and 14.3 to 14.3% (14.3%) and were rated low respectively. For the underlying horizons, the sand, silt and clay contents varied from 68.0 to 89.6% (78.8%), 7.9 to 17.7% (12.8%) and 2.5 to 14.3% (8.4%) respectively (Table 3). In both pedons, the percent sand was observed to have increased with increasing depth, whereas the percent silt and clay were found to have decreased with increasing depth in an irregular pattern. The high silt and clay contents observed in the surface than the subsurface horizons could be attributed to seasonal fluxes of silt and clay (sedimentation process) via alluvial deposition. The high sand content observed could be attributed to the effect of cultivation and crop removal, because the farmers are not practicing sole orchard cultivation but rather a kind of *Tungia* system.

The bulk density values in the surface horizons of Pedons Orc P1 and P2 ranged from 1.0 to 1.3 gcm^{-3} (1.2 gcm^{-3}) and was rated low. For the underlying horizons, bulk density values varied from 1.0 to 1.6 gcm^{-3} (1.3 gcm^{-3} mean) and was also rated low (Table 2). the bulk density varied irregularly with depth in the subsurface horizons of both pedons Orc P1 and P2. Similar results were reported by Salazar [33] who worked on agroforestry combined with water harvesting in the central zone of Chile and obtained a lower bulk density value of 1.1 g cm^{-3}. This low bulk density can be attributed to increased soil organic matter, root activity of perennial trees, and increased soil biological activity by soil macrofauna [34, 35, 33].

In the surface horizons of Pedons Orc P1 and P2, the total porosity varied from 47 to 65% (56%) and was rated high. For underlying horizons, total porosity ranged from 37 to 71% (54%) and was also rated high. The total porosity of the soils varied irregularly with increasing soil depth (Table 2), which could be attributed to the bulk density of the soils. This result indicated an inverse relationship between bulk density and porosity. The bulk density had negatively but significantly correlated with total porosity ($r = -0.988$, $p<0.01$) (Table 4).

Table-2: Physical Properties of the Soils of Malikawa Series Pedons Orc P1 and P2

Horizon	Depth (cm)	Particle Size Distribution (%)			Textural Class	Bulk Density	Particle Density	Porosity
		Sand	Silt	Clay		gcm^{-3}		(%)
Malikawa Series- Pedon Orc P1 (Aquic Ustipsamments/Rubic Arenosols (Eutric)								
Ap	0-8	68.0	17.7	14.3	SL	1.0	2.5	65
Bw	8-12	73.9	13.7	12.4	SL	1.0	2.5	71
AB	12-70	68.0	17.7	14.3	SL	1.4	2.5	44
-	>70	Water table						
Malikawa Series- Pedon Orc P2 (Aquic Ustipsamments/Rubic Arenosols (Eutric)								
Ap	0-10	70.0	15.7	14.3	SL	1.3	2.5	47
Bw1	10-41	87.6	9.9	2.5	S	1.1	2.7	58
AB	41-63	87.6	9.9	2.5	S	1.4	2.6	46
Bw2	63-114	89.6	7.9	2.5	S	1.6	2.6	37
-	>114	Water table						
Mean		77.5	13.2	8.96	SL	1.3	2.56	49
SE		2.51	1.29	2.05	-	0.07	0.04	2.89

SE= standard error, SL= sandy loam, S=sand

Chemical properties of the soils of orchard plantation lands

The pH values in the surface horizons of Pedons Orc P1 and P2 ranged from 7.23 to 7.34 (7.29) and was rated slightly alkaline. For the underlying horizons, pH values varied from 6.65 to 7.99 (7.32) and was also rated slightly alkaline (Table 3). The pH values appeared similar between the Pedons Orc P1 and P2, and did not show much variability with depth. pH values of 6.5 to 8.0 are indications of high base saturation in soils [36]. According to Bally [37] mangoes are tolerant of a range of soils from alkaline, calcareous soils to heavy clay soils. The optimum pH range is 5.5 to 7.5, but the tree will grow outside this range, with low pH (acid) being the most deleterious to growth. This shows that the pH (Table 3) of the soils is suitable for mango cultivation as it falls within optimum range.

The organic carbon content of the soils is generally low and ranged in the surface horizons of Pedons Orc P1 and P2 from 10.80 to 2.60 g kg^{-1} (6.70 g kg^{-1}). For the subsurface horizons, organic carbon content varied from 1.20 to 7.00 g kg^{-1} (4.10 g kg^{-1}) (Table 3). The lower levels of organic carbon in these soils could be attributed to low soil organic matter content. Correlation analysis showed significant negative relationship of organic carbon ($r = -0.828$, $p<0.05$) with sand (Table 4).

The total nitrogen content in the surface horizons of Pedons Orc P1 and P2 ranged from 0.94 to 0.99 g kg^{-1} (0.97 g kg^{-1}) and was rated high. For the subsurface horizons, total nitrogen varied from 0.35 to 2.11 g kg^{-1} (1.23 g kg^{-1}) and was also rated high (Table 3). The result is contrary to the findings of Akinola [38] and Skujins [31] who reported that most of the Nigerian soils to be low in nitrogen. The high nitrogen (Table 3) may be due to low leaching and volatilization of nitrogen as influenced by the tree canopy cover and to nitrogen supplied by the symbiotic bacteria (rhizobia) of the leguminous species cultivated alongside the orchard trees. In this study, positive but significant relationship of total nitrogen ($r = 0.686$, $p<0.05$) with pH was observed (Table 4).

The available phosphorus content in the surface horizons of Pedons Orc P1 and P2 ranged from 33.19 to 34.31 mg kg^{-1} (33.75 mg kg^{-1}) and was rated high. For the underlying horizons, available phosphorus content varied from 10.94 to 44.88 mg kg^{-1} (27.91 mg kg^{-1}) and was also rated high (Table 3). The high phosphorus values may be due to appreciable quantity of clay content (Table 2), high cation exchange capacity values and slightly alkaline pH (Table 3) of the soils. This result is in line with that of Murthy [40] and Bopathi and Sharma [41-43] who reported red sandy soils of India to be low in phosphorus due to low cation exchange capacity values, clay content and soil reaction. Output of correlation matrix showed insignificant but positive relationship of available phosphorus with clay ($r = 0.441$, $p>0.05$) and cation exchange capacity ($r = 0.347$, $p>0.05$). It also indicated negative but insignificant relationship between available phosphorus and pH ($r = -0.195$, $p>0.05$).

The cation exchange capacity in the surface horizons of Pedons Orc P1 and P2 varied from 12.70 to 18.40 cmol kg^{-1} (15.55 cmol kg^{-1}). For the underlying horizons, cation exchange capacity values ranged from 7.40 to 16.90 cmol kg^{-1} (12.15 cmol kg^{-1}) (Table 3). The percent base saturation of the soils was generally high (Table 3), ranging from 98.04 to 98.74% (98.39%) in the surface horizons of Pedons Orc P1 and P2. For the subsurface horizons, percent base saturation varied from 95.54 to 98.82% (97.18%). The cation exchange capacity and percent base saturation of the soils were both high (Table 3). From the result it could be observed that, there is positive relationship between cation exchange capacity and percent base saturation such that the higher the cations exchange capacity, the higher percent base saturation. Output of correlation matrix showed positive insignificant relationship ($r = 0.864$, $p>0.05$) between cation exchange capacity and percent base saturation. The high cation exchange capacity and percent base saturation values could be attributed to clay type and content, neutral soil reaction and organic matter content of the soils. Similarly, positive insignificant relationship of clay with cation exchange capacity (r =0.927, Pp0.05) and percent base saturation ($r = 0.899$, $p>0.05$) was observed (Table 4).

The calcium, magnesium, potassium and sodium contents in the surface horizons of Pedons Orc P1 and P2 ranged from 9.92 to 14.10 cmol kg^{-1} (12.01 cmol kg^{-1}), 1.43 to 1.82 cmol kg^{-1} (1.63 cmol kg^{-1}), 0.10 to 0.13 cmol kg^{-1} (0.12 cmol kg^{-1}) and 0.70 to 2.38 cmol kg^{-1} (1.54 cmol kg^{-1}) respectively. For the underlying horizons, Ca, Mg, K and Na content varied from 5.44 to 13.20 cmol kg^{-1} (9.32 cmol kg^{-1}), 0.62 to 1.65 cmol kg^{-1} (1.14 cmol kg^{-1}), 0.03 to 0.12 cmol kg^{-1} (0.08 cmol kg^{-1}) and 0.86 to 2.08 cmol kg^{-1} (1.47 cmol kg^{-1}) respectively. The exchangeable bases distribution was in the order Ca>Na>Mg> K (Table 3) contradicting previous findings that the dominant exchangeable bases in tropical soils are calcium and magnesium. Potassium appeared to be lowest and was attributed to effect of cultivation and crop removal. The high sodium values observed could be ascribed to the type and nature of the parent materials (the data not shown here).

Soil classification

The soils were classified according to the guidelines of the United State Department of Agriculture (USDA) Soil Taxonomy System (USDA-NRCS, 2010) and Correlated with World Reference Base (WRB) for Soil Resources (WRB-IUSS Working Group, 2014) as follows:

USDA Classification

These soil units (Orc-P1 and Orc-P2) were classified as *Entisols* at order level, as it does not fit into other soil orders. On the basis of an irregular decrease in organic carbon content with soil depth, these soil units were further classified as *Fluvents* at suborder level. Owing to Ustic moisture regime, the soil units were also classified as *Ustifluvents* at great-group level. At subgroup level they were classified as *Aquic Ustifluvents*, due to Aquic moisture characteristics.

WRB Classification

These soil units were classified at RSG of WRB system as *Arenosols* been predominantly sandy loam in texture. The soil units were further classified at soil unit level as *Rubic Arenosols*, because they possess within 100 cm of the soil surface a sub-surface layer >30 cm thick with a Munsell Hue redder than 10YR. Furthermore, the soils have a base saturation (NH_4OAC buffered at pH 7) above 50 percent, the soil units were further classified as *Rubic Arenosols* (*Eutric*) at supplementary qualifier level.

CONCLUSION

The results indicate that the examined orchard soils were clay loam in texture. Bulk density values of the orchard soils were below the critical value of 1.6 gcm^{-3} that causes poor aeration and hinders root penetration. The soils were generally of high fertility class, with the exception of exchangeable sodium and percent base saturation, which were observed to be high. The soil units studied were low in organic carbon content and were also slightly alkaline. The electrical conductivity of the soils across the orchard soils was generally low. The soils were also found to be high in total N while available P was rated medium across the soil profile.

Table-3: Chemical Properties of the Soils of Malikawa Series Pedons Orc P1 and P2

Horizon	Depth (cm)	pH (1:2.5)		EC	OC	TN	AP	Ca	Mg	K	Na	CEC	BS
		Water	$CaCl_2$	(dSm^{-1})	g kg^{-1}		mg kg^{-1}	cmol kg^{-1}					(%)
Malikawa Series- Pedon Orc P1 (Aquic Ustipsamments/Rubic Arenosols (Eutric)													
Ap	0-8	7.34	6.84	0.01	10.80	0.99	34.31	14.10	1.43	0.13	2.38	18.40	98.04
Bw	8-12	7.59	6.96	0.01	4.40	0.99	44.88	10.80	1.03	0.07	2.08	14.30	97.76
AB	12-70	7.99	7.19	0.01	7.00	2.11	16.59	13.20	1.65	0.12	1.73	16.90	98.82
-	>70	Water table											
Malikawa Series- Pedon Orc P2 (Aquic Ustipsamments/Rubic Arenosols (Eutric)													
Ap	0-10	7.23	7.52	0.01	2.60	0.94	33.19	9.92	1.82	0.10	0.70	12.70	98.74
Bw1	10-41	7.17	6.48	0.01	1.20	0.60	23.76	6.58	0.85	0.07	0.86	8.60	97.21
AB	41-63	6.65	5.10	0.01	1.20	0.49	26.02	6.34	1.03	0.07	1.02	8.80	96.14
Bw2	63-114	7.58	6.53	0.01	1.60	0.35	10.94	5.44	0.62	0.03	0.98	7.40	95.54
-	>114	Water table											
Mean		7.36	-	0.01	4.11	0.92	27.10	9.48	1.20	0.08	1.39	12.44	97.46
SE		0.17	-	0.02	0.88	0.30	2.94	1.93	0.12	0.03	0.14	2.00	0.87

SE= standard error, pH= soil reaction, EC= electrical conductivity, OC= organic carbon, TN= total nitrogen, AP= available phosphorus, $CaCl_2$= calcium chloride, Ca= calcium, Mg= magnesium, K= potassium, Na= sodium, CEC= cation exchange capacity, Mg= magnesium, BS= base saturation

Table-4: Correlation (r) Analysis of the Soils of Malikawa Series Pedons Orc P1 and P2

	Sand	Silt	Clay	BD	Por	pH	OC	TN	AP	Ca	Mg	K	Na	CEC
Silt	-0.971**													
Clay	-0.995**	0.951**												
BD	0.207	-0.229	-0.299											
Por	-0.056	0.089	0.115	-0.988**										
pH	-0.587	0.508	0.561	0.054	-0.156									
OC	-0.828*	0.838*	0.797	-0.103	-0.018	0.795*								
TN	-0.826*	0.893*	0.777	-0.074	-0.042	0.686*	0.952*							
AP	-0.360	0.310	0.441	-0.807	0.766	-0.195	0.079	-0.012						
Ca	-0.949**	0.963**	0.934**	-0.289	0.153	0.643**	0.938**	0.930**	0.324					
Mg	0.860	0.906**	0.835**	-0.049	-0.077	0.209	0.567**	0.703**	0.230	0.762				
K	-0.801**	0.918	0.761**	-0.208	0.103	0.261**	0.688	0.848**	0.189	0.831	0.911			
Na	-0.470**	0.473**	0.487	-0.379	0.317	0.592**	0.761**	0.570	0.367	0.655	0.048	0.228**		
CEC	-0.940	0.952	0.927	-0.296	0.162**	0.631	0.941	0.922	0.347	0.998	0.741**	0.815	0.690	
PBS	-0.910	0.949	0.899	-0.416	0.286	0.430	0.702	0.795	0.388	0.887	0.878	0.904	0.301	0.864

BD= bulk density, Por= porosity, OC= organic carbon, TN= total nitrogen, AP= available phosphorus, Ca= calcium, Mg= magnesium, K= potassium, Na= sodium, CEC= cation exchange capacity, PBS= percent base saturation

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