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Utjecaj nagiba i dubine na kemijska svojstva tipičnog alfisola

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EFFECT OF SLOPE AND DEPTH ON SOIL CHEMICAL PROPERTIES OF A TYPICAL ALFISOL

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SUMMARY

Management options proffered with respect to the chemical properties along a toposequence are a key to sustainable crop and soil productivity since nutrient status and soil properties are related to topography of the land area. A study was conducted to evaluate the effect of slope and depth on selected soil chemical properties at the University of Ilorin Teaching and Research Farm in 2013. Three points: upper, middle and bottom slope, along a toposequence with an average distance of 200 m apart were delineated and sampled for soil analysis at depths of 0–30 cm, 30–60 cm and 60–90 cm using core sampler and auger. Soil chemical properties which included pH in water, pH in KCl, electrical conductivity, organic matter, total nitrogen, available phosphorus, exchangeable bases (Ca, Mg, K, Na), exchangeable acidity, effective cation exchange capacity, base saturation, exchangeable sodium percentage and sodium adsorption ratio were determined in the laboratory/ computed afterwards. Data from the analysis were subjected to ANOVA using 2x3 factorial combinations of factors slope and depth - in randomized complete block design (RCBD) with five replicates. Results on the effects of slope and soil depth on soil chemical properties showed that soil depth affected all the measured soil chemical properties except exchangeable sodium. The pH (both in water and KCl), electrical conductivity, available phosphorus and exchangeable potassium were not affected by slope. Also, pH, exchangeable magnesium and sodium were not affected by the interaction between the effect of slope and soil depth.

Key-words: slope, depth, chemical properties, Alfisol

INTRODUCTION

Topography is a major factor which controls most surface processes taking place on earth, i.e. soil formation and soil development. Topography influences soil chemical and physical properties and also pattern of soil distribution over landscape (Kalivas et al., 2002; Esu et al., 2008). For instance, the negative impact of rainfall is higher where landscape is sloppy with regards to erosion and deposition. Soils on hill slopes differ from those at summits or valleys in terms of moisture distribution, soil depth, cations distribution, and organic matter contents (Asadu et al., 2012). Ogban et al. (1999) reported that nutrient status and soil properties are related to topography of the land area. A wide variation in phosphorus (P) distribution along a toposequence in south-eastern Nigeria; where total P was found to be highest at the upper slope and lowest at the middle slope was observed by Osodeke and Osondu (2006).

Organic matter varies with landscape position (Bhatti et al., 1991). In addition to the soil organic matter which varies with landscape, landscape influences soil texture, penetration resistance (Bruand et al., 2004), root development (Busscher et al., 2001), exchangeable basic and acidic cations (Shutten et al., 2004), soil exchangeable chemistry (Clien et al., 1997), and nutrient budget (Mallarino, 1996). Hence, landscape is important in fertilizer management (Paz-Gonxalez et al., 2000).

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Soil depth, however, does not have a direct effect on chemical properties and is equally important in fertilizer management because it impacts the rooting depth, which in turn affects plant growth. With emphasis being shifted to precision farming in Nigeria to meet up food requirements of a rapidly growing population, examination of soil properties in different landscape positions is necessary. Potentials of soil can readily be optimized when information on its physical, chemical and biological properties are available (Lawal et al., 2013). However, information on the effect of slope and depth on physical and chemical properties of the soil in the study area is scarce. Consequently, the objective of this study was to study the effects of slope and soil depth on chemical properties of a typical Alfisol.

MATERIAL AND METHODS

Description of the Study Area

The study was carried out along a toposequence of soil: upper (N 08 27´ 08.6" E004 39´42.2", 323 m), middle (N 08 27´ 18.7" E004 39´ 49.8", 335 m) and bottom (N 08 27´ 19.8" E004 39´ 51.5", 336 m) slope at University of Ilorin Teaching and Research Farm, Ilorin, Kwara State, Nigeria. The vegetation of the area is a forest savanna mosaic with the soils formed over the basement complex (Olaniyan, 2003). Gravelly *Alfisols* dominate the landscape. The study area had been altered by cultivation though fallowed at the time of sampling. It is located in the Southern Guinea Savanna ecological zone of Nigeria approximately by longitudes 4^{0} 35' E and latitude 9^{0} 29' N of Nigeria, 307 m above sea level within a tropical climate characterized by a bimodal rainfall pattern with peaks in June and September and a dry spell between mid-July and August. Annual rainfall ranges from 1000 mm - 1240 mm. The daily temperature range is 20 ^{0}C - 35 ^{0}C (Kolo et al., 2012).

Soil Sampling and Laboratory Analysis

Soil Samples from the layers of 0-30 cm, 30-60 cm and 60-90 cm were collected from fifteen mini pits dug along the toposequence, five on each of the toposequence. A total of 90 samples (45 disturbed and 45 undisturbed) were collected along the toposequence. From each soil depth, undisturbed samples were collected with metal cylinders of 8.3 cm height and 5.5 cm internal diameter. The soil was secured with a piece of calico tied round the cylinder and held firmly with a rubber band. Disturbed samples were also collected with soil auger from each depth. The samples were placed in well labelled polythene bags. The samples (disturbed and undisturbed) were transported to the laboratory for soil physical properties determination using standard laboratory methods and/or computed using established procedures.

Disturbed samples were air-dried, crushed and made to pass through a 2 mm sieve and used for analysis.

Soil pH was measured with a glass electrode; samples were diluted in water and KCl (the ratio of soil to water and KCl was 1:2.5).

Electrical conductivity was measured with electrical conductivity meter in saturated paste extract as described by Okalebo et al. (2002).

Soil organic carbon was determined using the Wet Oxidation Method of Walkley and Black described by Nelson and Sommers (1982). The percent of organic carbon was multiplied by a factor of 1.724, following the standard practice that organic matter is composed of 58% carbon (Brady and Weil, 1999).

Total nitrogen was determined using the micro Kjeldahl method/procedure as described by Bremmer and Mulvaney (1982).

Available phosphorus was determined by the Bray 1 method of Bray and Kurtz (1945) and as described by Murphy and Riley (1962).

Exchangeable bases (Ca, Mg, K, and Na) were extracted in 1N NH_4OAC (ammonium acetate), at pH 7. K and Na were determined by flame photometer. Ca and Mg were determined by the EDTA titration method described by Simard (1993).

Exchangeable acidity of the soil was determined by titration method using 1N KCl extract as described by Rhoades (1982).

Effective Cation Exchange Capacity (ECEC) was the summation of exchangeable bases (Ca, Mg, K, Na) and exchangeable acidity.

Percent base saturation was expressed as:

$$\text{Percent base saturation} = \frac{TEB}{ECEC} \times 100\% \quad (1)$$

Where: TEB = Total Exchangeable Bases; ECEC = Effective Cation Exchange Capacity

Exchangeable sodium percentage was expressed as:

$$\text{Exchangeable sodium Percentage} = \frac{Exchangeable\ Na}{TEB} \times 100\% \quad (2)$$

Sodium adsorption ratio was expressed as:

$$\text{Sodium adsorption ratio} = \frac{Na^{t}}{\sqrt{\frac{1}{2}[Ca^{2t} + Mg^{2t}]}} \quad (3)$$

Where: Na^{+} = exchangeable sodium, Ca^{2+} = exchangeable calcium, Mg^{2+} = exchangeable magnesium

Statistical Analysis

Soil data collected from the experimental site are in normal distribution and in linear model, thus subjected to Analysis of Variance using SPSS 16.0 edition. The statistical design adopted for the study involving two factors (slope x depth) at three levels each was the 2x3 factorial combinations in a randomized complete block design (RCBD) with five replicates (r). The 3 levels of each factors: Depth ($D_{0\text{-}30\ cm}$, $D_{30\text{-}60\ cm}$ and $D_{60\text{-}90\ cm}$), and Slopes (Upper, Middle and Bottom) serve as blocks.

RESULTS AND DISCUSSION

Effect of Selected Soil Chemical Properties

Data on selected soil chemical properties along a toposequence are presented in Table 1. There were no significant differences on pH in water and KCl along slope, though pH decreased across slope. However, the pH values were statistically different with depths. It was generally observed that pH increased with depth both in water and KCl, with the trend: 6.2<6.8<7.2 from 0-30 to 60-90 cm depth and 6.0<6.6<7.0 in water and KCl, respectively (Table 1). This could be attributed to the moisture content (Rigg, 1993) as well as eluviation of basic cations down the soil profile (Brady and Weil, 2010). Decomposition of organic matter in form of leaf droppings is a common phenomenon in the 0-30 cm layer which acidifies the soil as ammonium nitrogen is converted to nitrate (Tisdale et al., 2003). Brady and Weil (2010) had established pH range of 5.5-7.0 as optimal for overall satisfactory availability of plant nutrients. Hence, pH values obtained are within ideal range for optimum growth and nutrient availability to plants. Esu (1991) attributed the pH values to the nature of the parent materials on which the soil is developed.

Main effect in Table 1 for electrical conductivity indicated no injury to plant as accumulation of water soluble salts mainly sodium is negligible (<2 dS m^{-1}) (Richards, 1954). There was no significant difference with respect to slope but depth effects were not statistically the same at $p \leq 0.05$ (Table 1). Salinity, though not significant increased with depth: 0.14<0.22<0.25 dS m^{-1} from 0-30 to 60-90 cm, respectively. Interaction was significant at $p \leq 0.01$ (Table 2) with the 60-90 cm of the upper slope and 30-60 cm depth of the middle slope recording the highest value of 0.27 dS m^{-1}.

Total nitrogen contents decreased with depth with the trend 1.25>0.82>0.57 g kg^{-1} which were statistically different at $p \leq 0.05$ (Table 1). Similarly, effect of slope was significant on nitrogen contents in the soil with the upper slope having the highest (1.03 g kg^{-1}) which was statistically different from the middle and lower slopes that were statistically the same (Table 1). This remarkable difference at the upper slope might be attributed to percolating water which tends to move laterally across profile instead of vertically (Esu, 2010). It has been established that water movement in landscapes is the major process responsible for soil development (Gobin et al., 2001). Also, the nitrogen contents were lower than the critical level of 1.5 g kg^{-1} (Enwenzor et al., 1979). Thus, appropriate management practices such as green manuring, fertilizer application etc. are pertinent for soil sustainability. However, interaction of slope and depth was not significant (Table 2).

Soil Organic Matter content (g kg^{-1}) as presented in Tables 1 and 2 indicate that slope, soil depth and the interaction between the effect of slope and soil depth were significant at 5% probability level. The values obtained showed that it increased across slope and decreased with depth with the following trend: 10.21<13.77<15.63 g kg^{-1} and 20.92>12.94>5.50 g kg^{-1} for slope and depth 1, 2 and 3, respectively. Okusami and Oyediran (1985) observed similar distributions with depth in soils of Ife area in Nigeria. This result implied that the terrain has a steep slope which enhanced accumulation of soil organic matter at the lower slope. Also, cultural practices are more pronounced at the 0-30 and 30-60 cm. Consequently, the higher organic matter contents at these depths which were statistically different from each other and the 60-90 cm depth. OC decreased with increasing soil depth, probably due to decreased faunal activities in the underlying horizons as suggested by Browaldh (1995). Total N was also relatively low in the studied soils and its contents ranged from 0.6 to 1.25 g kg^{-1}. Organic matter content of soil supplies about 85 to 90% of soil nitrogen in unfertilized soils (Amalu, 1997). Although N is associated with organic matter, its distribution in surface horizon was not in tandem with the OC along the slope sequence.

Available phosphorus (AP) decreased across slope and depth, although slope difference was not significant ($p<0.05$) (Table 1). Organic matter was identified as principal source of soil phosphorus for many soils (Evans, 1999). However, irrespective of soil depth, P levels were higher in upper slope position than the middle and lower slopes probably due to solubilisation of P. This finding does not conform to earlier submission of weathering of P-rich parent rock releasing phosphorus into the soil (Lawal et al., 2014).

Exchangeable calcium increased significantly ($p<0.05$) with depth (Table 1). This to an extent may show the influence of parent materials on distribution of Ca^{2+} within the soil profile (Brady and Weil, 2010). Increased Ca^{2+} values in the sub-surface horizon could be attributed to leaching or extraction by roots down the capillary fringes. High Ca^{2+} values may also be an indication that the soils have a high affinity for calcium, and also that Ca^{2+} is more strongly bound to the exchange sites than other cations. Ca^{2+} was rated medium to high. Interaction of slope and depth was also significant with the 60-90 cm depth of the middle slope recording the highest content (7.86 cmol kg^{-1}) (Table 2).

Exchangeable magnesium decreased across slope as follows: 1.65<1.52<1.23 cmol kg^{-1} (Table 1) which was statistically different from one another. Similarly, magnesium decreased with depth and was also significantly different from one another. Interaction of slope and depth was not significant. Magnesium was rated medium to high. In terms of plant nutrition, Mg may not be a constraint in the studied soils, but its accumulation in soil may have negative impact on soil structure, lower water intake rates and may affect the chemical and biological properties of soil (Donstova and Norton, 2001).

There was no significant difference in exchangeable potassium concentration with slope (Table 1). However, exchangeable potassium (K) content was significantly different with depth ($p<0.05$). Exchangeable K decreased from 0-30 cm (0.28 cmol kg^{-1}) to 30-60 cm (0.14 cmol kg^{-1}) which was not statistically the same (Table 1). There was, however, no significant difference in the exchangeable K of the 30-60 cm and 60-90 cm depth (0.15 cmol kg^{-1}). Interaction between the effect of slope and soil depth was significant at 5% probability level (Table 2).

Exchangeable sodium in the upper and bottom slopes recorded the highest (0.15 cmol kg^{-1}) concentration which was statistically different from the middle slope (0.11 cmol kg^{-1}). Effect of depth and interaction was not significant at 5% level of probability (Tables 1 and 2).

Total Exchangeable Bases (cmol/kg) presented in Tables 1 and 2 indicate that slope and interaction between the effect of slope and soil depth were significant at 5% probability level. Slopes at various levels were statistically different from one another with the trend: $7.41<8.09>4.99$ cmol kg^{-1} from the upper to lower slope, respectively (Table 1). Similarly, the 60-90 cm depth of the upper slope has the highest TEB (9.07 cmol kg^{-1}) value which was statistically different from others (Table 2).

Values of exchangeable acidity in the middle slope recorded the highest (0.93 cmol kg^{-1}) which was statistically different from the bottom slope (0.62 cmol kg^{-1}) and upper slope (0.56 cmol kg^{-1}) which are statistically at par (Table 1). Low total acidity values are associated with high pH values and indicate low acid weathering in the soils. Interaction of slope and depth was significant.

Effective cation exchange capacity in the middle slope recorded the highest (9.02 cmol kg^{-1}) followed by those in the upper slope (7.97 cmol kg^{-1}) and lastly the bottom slope (5.61 cmol kg^{-1}) (Table 1). The effective cation exchange capacity values obtained were low which implied that the soil would acidify quickly. Effective cation exchange capacity in both upper and middle slope levels showed an increase in values with depth but in the case of the bottom slope, a decrease was recorded as depth increases. Slope, soil depth and interaction between the effect of slope and soil depth were significant at 5% probability level with slope and soil depth at various levels statistically different from one another (Tables 1 and 2).

Table 1. Main effects of slope and depth on selected chemical properties of Unilorin Teaching and Research Farm, Ilorin, Nigeria

Tablica 1. Glavni učinci nagiba i dubine na odabrana kemijska svojstva na Unilorin Teaching and Research Farm, Ilorin, Nigerija

Parameters	pH water	pH KCl	EC	OM	TN	AP	Ex. Ca	Ex. Mg	Ex. K	Ex. Na	TEB	EA	ECEC	BS	ESP	SAR
Slope (S)																
Upper	6.71	6.53	0.20	10.21c	1.03a	11.07	5.22b	1.65a	0.19	0.15a	7.41b	0.56b	7.97b	93.25a	2.16b	0.09a
Middle	6.77	6.56	0.21	13.77b	0.74b	10.44	6.25a	1.52a	0.19	0.11b	8.09a	0.93a	9.02a	90.02b	1.5c	0.06b
Lower	6.74	6.50	0.20	15.63a	0.85b	10.32	3.43c	1.23b	0.18	0.15a	4.99c	0.62b	5.61c	87.67c	3.13a	0.10a
SE±	0.44	0.06	0.01	0.58	0.06	0.28	0.14	0.09	0.01	0.01	0.14	0.03	0.13	0.42	0.14	0.00
Depth (D)																
0-30 cm	6.18c	5.97c	0.14c	20.92a	1.25a	13.66a	3.87c	1.98a	0.28a	0.15	6.27	0.41c	6.68c	93.92a	2.40a	0.088a
30-60 cm	6.83b	6.58b	0.22b	12.94b	0.82b	9.79b	5.25b	1.42b	0.14b	0.13	6.94	0.61b	7.55b	91.90b	1.98b	0.070b
60-90 cm	7.21a	7.03a	0.25a	5.50c	0.57c	8.42c	5.72a	1.00c	0.15b	0.14	7.22	1.08a	8.30a	85.33c	2.46a	0.090ab
SE±	0.44	0.06	0.01	0.58	0.06	0.28	0.14	0.09	0.01	0.01	0.14	0.03	0.13	0.42	0.14	0.00
Interaction																
S × D	NS	NS	**	**	NS	*	***	NS	**	NS	***	*	***	***	***	NS

Means with different letters along the same row are statistically different from each other at $p\leq0.05$. NS = Not significant, *, ** and *** = significant at the 5%, 1% and 0.01% level of probability. EC = electrical conductivity in dS m^{-1}, OM = organic matter in g kg^{-1}, AP = available phosphorus in meq kg^{-1}, Ex. Ca = exchangeable calcium in cmol kg^{-1}, Ex. Mg = exchangeable magnesium in cmol kg^{-1}, Ex. Na = exchangeable sodium in cmol kg^{-1}, Ex. K = exchangeable potassium in cmol kg^{-1}, EA = exchangeable acidity in cmol kg^{-1}, ECEC = effective cation exchange capacity in cmol kg^{-1}, BS = base saturation in %, ESP = exchangeable sodium percentage in %, SAR = sodium adsorption ratio

Table 2. Interaction of slope and soil depth on selected chemical properties along a toposequence of Unilorin Teaching and Research Farm

Tablica 2. Interakcija nagiba i dubine na odabrana kemijska svojstva duž toposekvence na Ilorin Teaching and Research Farm

Slope	Depth	EC	OM	AP	Ex.Ca	Ex.K	TEB	ECEC	BS	ESP
Upper	0-30	0.12a	16.39b	14.82	3.56	0.25	6.12	6.45	94.86	2.7
Upper	30-60	0.21d	8.97e	9.28	5.44	0.15	7.29	7.77	93.74	1.99
Upper	60-90	0.27e	4.03g	8.36	7	0.17	9.07	9.99	90.82	1.7
Middle	0-30	0.11a	23.89a	13.74	3.58	0.29	6.21	6.67	93.05	2.02
Middle	30-60	0.27e	15.25c	9.86	6.78	0.14	8.43	9.3	90.6	1.21
Middle	60-90	0.24d	4.20g	8.39	7.86	0.16	9.25	10.62	87.02	1.37
Lower	0-30	0.19c	24.00a	12.22	4.47	0.3	6.51	6.97	93.49	2.35
Lower	30-60	0.18b	14.60d	10.22	3.52	0.12	5.09	5.57	91.37	2.74
Lower	60-90	0.24d	8.28f	8.51	2.3	0.12	3.36	4.3	78.16	4.31
SE±		0.01	0.34	0.16	0.08	0.005	0.0787	0.0767	0.2	0.08

Means with different letters along the same column are statistically different from each other at $p \leq 0.05$. EC = electrical conductivity in dS m^{-1}, OM = organic matter in g kg^{-1}, AP = available phosphorus in meq kg^{-1}, Ex. Ca = exchangeable calcium in cmol kg^{-1}, Ex. K = exchangeable potassium in cmol kg^{-1}, TEB = total exchangeable bases in cmol kg^{-1}, ECEC = effective cation exchange capacity in cmol kg^{-1}, BS = base saturation in %, ESP = exchangeable sodium percentage in %

Base saturation in the upper slope recorded the highest value (93.25%) followed by those in the middle slope (90.02%) and lastly the bottom slope (87.67%). High values obtained for base saturation in this study imply that the soil is nearly saturated with exchangeable cations, which is a characteristic of a typical *Alfisol* (>35% in argilic horizon) which reflects dominance of non-acid cations on the exchange sites of the soil (Lawal et al., 2014). Slope, soil depth and interaction between the effect of slope and soil depth were significant at 5% probability level with slope and soil depth at various levels statistically different from one another (Table 1). Surface horizons have more variable composition being area of active depositional processes. The base saturation decreases concomitantly with increase in exchangeable acidity. However, increase in exchangeable cations (K, Ca, Mg) and base saturation have been reported (Kretzschmar et al., 1991) with addition of organic amendment.

Exchangeable sodium percentage was also significant at 5% level of probability for slope, soil depth and interaction (Tables 1 and 2). Exchangeable sodium percentage in the bottom slope recorded the highest values followed by those in the upper slope and lastly followed by those in the middle slope which were statistically different from one another.

Data for sodium adsorption ratio calculated implied that the soils studied have no salt problem. Slope, soil depth and interaction between the effect of slope and soil depth were significant at 5% probability level. Values of sodium absorption ratio in the bottom slope level were the highest (0.10) followed by those in the upper slope level (0.09) which are statically at par, but were statistically different from the middle slope level which recorded the lowest value (0.06) (Table 1). In the same manner, soil depth at 0-30 cm and 30-60 cm are statistically different from one another.

CONCLUSION

Results of this study showed the influence of depth on the selected chemical properties, with the three soil depth: 0-30, 30-60 and 60-90 cm levels been important in evaluating soil fertility status of Unilorin Teaching and Research Farm. However, soil organic matter, total Nitrogen, exchangeable bases Ca, Mg, Na and K, exchangeable acid, effective cation exchange capacity, base saturation, exchangeable sodium percentage and sodium absorption ratio were affected by slope, while interaction of slope and depth were significant for electrical conductivity, soil organic matter, total nitrogen, available phosphorus, exchangeable bases, exchangeable acid, effective cation exchange capacity, base saturation, exchangeable sodium percentage and sodium absorption ratio. Thus, management options proffered with respect to the chemical properties along a toposequence with kin interest on depth is panacea for sustainable crop and soil productivity in this area.

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UTJECAJ NAGIBA I DUBINE NA KEMIJSKA SVOJSTVA TIPIČNOG ALFISOLA

SAŽETAK

Mogućnosti gospodarenja koje se nude u pogledu kemijskih svojstava uz toposekvencu ključ su održive produktivnosti usjeva i tla, budući da su nutritivni status i svojstva tla povezani s topografijom površine zemljišta. Provedeno je istraživanje kako bi se procijenio utjecaj nagiba i dubine na odabrana kemijska svojstva tla na znanstveno-nastavnom pokušalištu Sveučilišta Ilorin 2013. Označene su i uzorkovane tri točke: gornja, srednja i donja padina, uz toposekvencu, s prosječnom udaljenošću od 200m, za analizu tla na dubinama 0-30 cm, 30-60 cm i 60-90 cm pomoću sonde za uzorkovanje i svrdla. Kemijska svojstva tla, koja uključuju pH vode, pH KCl, električnu vodljivost, organsku tvar, ukupni dušik, raspoloživi fosfor, izmjenjive baze (Ca, Mg, K, Na), izmjenjivu kiselost, efektivni kapacitet izmjene kationa, zasićenost tla bazama, postotak izmjenjivoga natrija i omjer adsorpcije natrija, utvrđeni su u laboratoriju/izračunati kasnije. Dobiveni podaci podvrgnuti su analizi ANOVA pomoću 2x3 faktorske kombinacije čimbenika - nagib i dubina - u slučajnome bloknome rasporedu (RCBD) s pet replikacija. Rezultati utjecaja nagiba i dubine tla na kemijska svojstva tla pokazali su da je dubina tla utjecala na sva mjerena kemijska svojstva tla, osim izmjenjivoga natrija. Na vrijednost pH (i vode i KCl), električnu vodljivost, raspoloživi fosfor i izmjenjivi kalij nagib nije utjecao. Također, na pH, izmjenjivi magnezij i natrij interakcija između učinka nagiba i dubine tla nije utjecala.

Ključne riječi: nagib, dubina, kemijska svojstva, Alfisol

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