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Geotechnical Properties of Termite-Reworked Lateritic Soil from Ibadan, Southwestern Nigeria

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Abstract: *Important geotechnical parameters such as grain size distribution characteristics, plasticity index, linear shrinkage, compaction parameters, unconfined compressive strengths and California bearing ratio of samples of termite reworked soils from Ibadan, Southwestern Nigeria were determined and compared with those of neighbouring, 'parent' lateritic soils. This was with a view to assessing the effect of reworking by termites on the geotechnical characteristics of the soils. The amount of fines is lower in termite-reworked soil samples than in the nearby soils and thus possess better engineering properties. There is a significant influence of reworking by termites on the compaction parameters of the studied soil. The specific gravity of grains, the Unconfined Compressive Strength and the California Bearing Ratio (CBR) of the termite-reworked soils were higher than those of the nearby soils. However, the plasticity indices and linear shrinkages of the termite-reworked soils were significantly lower than those of the adjacent soils. Findings from this research work indicate that reworking by termites has significantly improved the engineering properties of the studied soils.*

Keywords*-Compaction, Lateritic soil, migmatite-gneiss, termite-reworked soil*

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I. Introduction

Lateritic soils abound in most parts of the tropical world including Nigeria. Such soils have over the years found wide applications not only as foundations for structures but more importantly as construction materials for structures such as building, roads, highways, dams and embankments. Prominent among their uses is in road construction where they are utilized not only as fill materials but also as materials on which the flexible highway pavements are built. It has been discovered that lateritic soils possess physical, mineralogical and geotechnical characteristics that make them good engineering soils, their properties may need to be improved upon when the need arises. The process used to modify the properties of a soil in order to make it useful for a given purpose is referred to as soil stabilization. This has over the years been adopted among the users of soils. Quite unknown to many people, some social insects and burrowing animals do modify the structure and hence some geotechnical properties of soils (Adeyemi et al. 2004).

Earthworms, for instance, rework alluvial deposits and make them at times more porous and permeable while termites (social insects) rework soils and make them appear stronger.

Termites are recognized as one of the major ecosystem engineers in tropical soils. Their effects on soil are caused mostly by their major construction activities of which the mounds (Termitaria) are the most complex type. Termitaria which are edifices built by tropical termites of the order isoptera abound virtually in all parts of the tropics. The caste workers of the genius Macrotermes are the most important in the building of termitarium. A termitarium is usually built from a mineral matrix mixed with faeces or saliva, depending upon the termite species. The construction of these mounds causes both, physical changes (in water-holding capacity, bulk density, porosity, permeability and structural stability) and chemical changes (in cation-exchange capacity and organic matter content) of the soil. The effects of termites on soil is closely linked to their feeding habits and the type of constructions they build. Of the six feeding groups Cubitermesniokoloensis is the only group to build mounds from a fine mixture of soil and faeces containing a dense and specific microbial community (Fall, S. et al. 2007)

Soil feeding termite mounds (such as those of C. niokoloensis) have very specific properties arising from the combination of materials of two distinct origins i.e. soil and faeces. This creates an increased richness in clay (5 times more), minerals (2 to 3 times more) with respect to neighbouring soil.

Construction of termite mounds involves escavation in the soil and mass shifting of escavated to the surface. The soils (mostly of clay and silt-size fraction) are then mixed with saliva and faecal materials from the termites and at times some other debris is added to form a tough material referred to as carton with variable compositions. A termitarium which may be up to 6m or 7m high may weigh up to two and a half tons (Atkins, 1980) cited in (Adeyemiet al. 2004).

In tropical ecosystems termite-reworked soils constitute an important soil compartment covering around 10% of African soils (Fall et al., 2007).Owolabiet al.(2008) pointed out that termite-reworked soils are in abundance in Nigeria and other African countries, at an average volume of $1.15 \times 10^6\ m^3$ per square kilometre which is fairly large enough for application and huge volumes running into several tonnes are being reworked by termites.

II. Study Area

Ibadan is underlain by rocks of the Crystalline Basement Complex (Fig. 1). The location is situated within the Deeper Life Bible Church Camp Ground, via Moniya, Ibadan.

The studied soils are underlain by migmatite-gneiss, which is an important member of the Basement Complex rocks of Southwestern Nigeria. The major minerals in the medium to coarse grained rock include biotite, plagioclase feldspar, muscovite, Alkali feldspar and quartz. Few concordant and discordant pegmatite and quartz veins were noticed on most of the outcrops. Structures such as joints and minor faults were also observed on the outcrops.

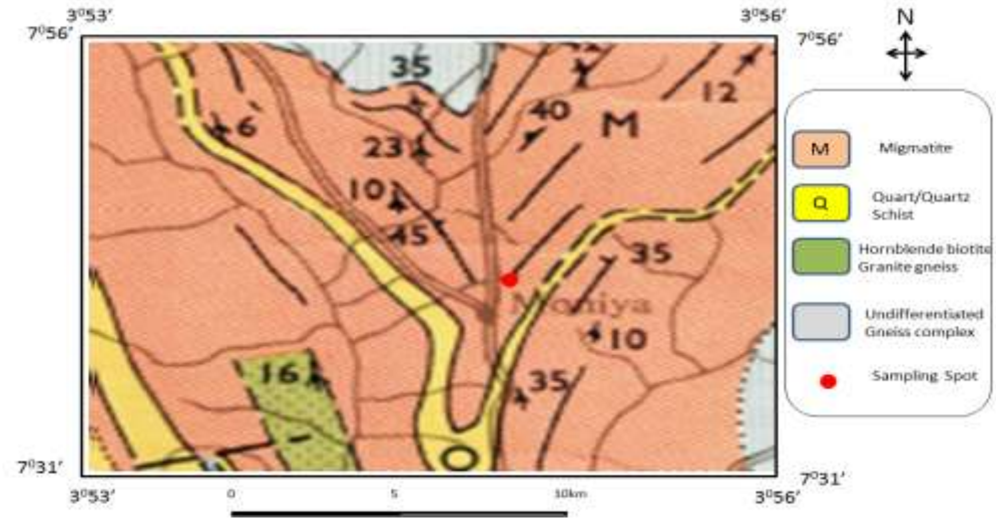


Figure 1: Geological Map of Parts of Southwestern Nigeria showing Ibadan, the Study Area.

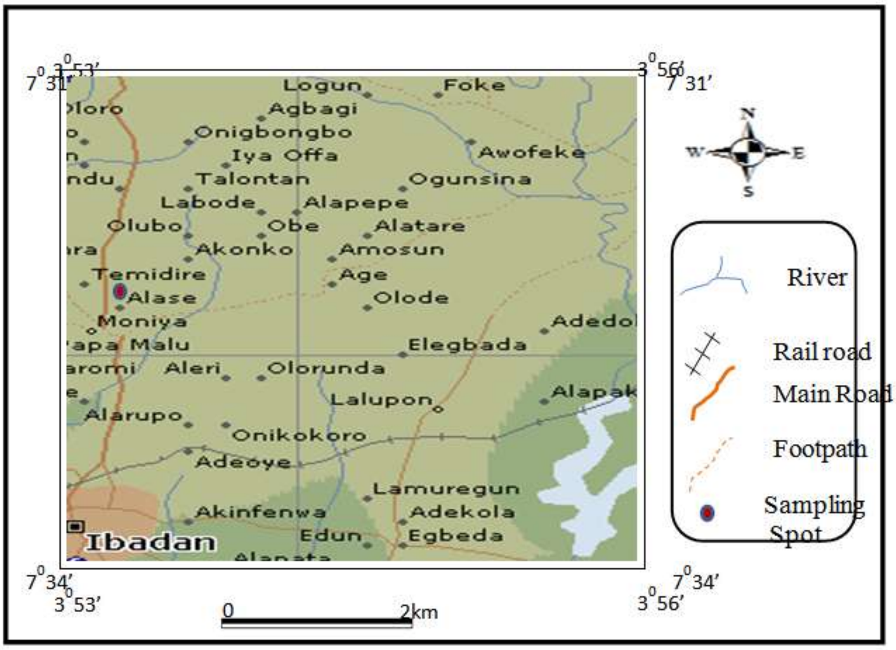


Figure 2: Accessibility Map of Parts of Southwestern Nigeria showing Ibadan, the Study Area**.**

III. Method of Investigation

Six samples were obtained for the purpose of this study. Four samples of termite-reworked soils were taken from tamitarium and two samples of nearby lateritic soils were taken at depths identical with those from which soils reworked by termites were taken. The exposed surface of the termite reworked soils was scraped off before the samples were taken.

The samples were air-dried for few weeks prior to the tests. The tests carried out included determination of the specific gravity grains, grain size distribution, plasticity, linear shrinkage, and compaction at different energy levels. The California Bearing Ratio (CBR) and unconfined compression tests were carried out on samples compacted at the optimum moisture content of the West African Level. T-test statistical analysis was employed to determine the nature of the difference between the magnitudes of geotechnical parameters of termite-reworked and those of the neighbouring lateritic soils.

IV. Results and discussion

4.1 Specific Gravity of Grains

The specific gravity of soil particles is an important engineering index property often employed in estimating the degree of laterization of lateritic soil (Lohnes and Demirel, 1973; Truncer and Lohnes, 1977). It is an important property in identifying and evaluating aggregates for construction purpose (Gidigasu, 1976).
Table 1 shows that the termite reworked soil samples possess significantly higher specific gravity than the nearby soils. Therefore, the termite reworked soil samples are more lateritised (Lohnes and Demirel, 1973: Truncer and Lohnes, 1977) and are thus likely to possess higher strengths than the adjacent soils. The significant difference in the value of specific gravity can only be attributed to reworking by termites (in termite-reworked soils).

Table 1: Result of Specific Gravity of the studied soil samples at depth 2m

Sample	ADT1	ADT2	ADT3	ADT4	ADL1	ADL2
Specific Gravity	2.75	2.74	2.76	2.75	2.52	2.54

ADT1= Termite reworked soil sample 1
ADT2= Termite reworked soil sample 2
ADT3= Termite reworked soil sample 3
ADT4= Termite reworked soil sample 4
ADL1= Lateritic soil sample 1
ADL2= Lateritic soil sample 2

4.2 Grain size distribution

This test is important in the estimation of relative proportion of various size grades in the samples. The physical and engineering properties of lateritic soils have been found to depend on their textural characteristics. Although grading characteristic has little relevance in the characterization of fined-grained soils, most of the engineering properties of coarse-grained soils are closely associated with the predominant particle size.

The grading curves of the studied soils are presented in Figs. 3 and 4. The summary of the grain size distribution characteristics of the studied soils are shown in the Table 2 below. The termite-reworked soil samples on the average contain 2% gravel-size grains, 50.5 % sand-size grains and 47.5% fines. All the termite-reworked soils are silty sands.

The residual lateritic soil samples on the average contain 3.75% gravel-size grains, 36.1% sand-size grains and 60% fines. All the residual lateritic soil samples are sandy silt. It can be seen that termite-reworked soils have a much lower percentage of fines (clay and silt-sized particles) than the nearby residual lateritic soil indicating better geotechnical characteristics. The reworking by termites on the termite-reworked soil has some remarkable influence on the grain size distribution.

Therefore the termite-reworked samples have a better grading characteristic than the nearby residual lateritic soil. The lower amount of fines in termite-reworked soil is caused by reworking of termites. The lower the amount of fines in a soil sample, the better the engineering properties of the soil. The lower the clay size fraction, the higher the degree of the laterization and consequently the higher the crushing strength (Adeyemiet al. 1990). The termite-reworked soils have higher percentage of sand-sized particles than the residual lateritic soils. The higher the percentage of sand-sized particles in the soil the better the load bearing capacity of the soil. From the data obtained, the high percentage of sand particles in the studied soils could be attributed to the mineralogical composition of the parent rocks. The rock sample taken from the parent rock is composed of high percentage of quartz. The sand size fraction is also contributing to the mechanical strength of any soil. It is apparent based on the grain size distribution that the termite-reworked soils possess better engineering properties than the residual lateritic soils. Topographic condition and the position of soil in the profile also affect the grain size distribution.

Both sets of samples (termite-reworked samples and residual lateritic samples) would be classified as well graded but the results of the grain-size analyses clearly reflect the mineralogical and textural characteristics of the parent rock.

Daniel (1993b) recommended amount of fines of at least 20% for landfill seals i.e. for soil that can be good for base of landfill. Therefore the studied soils meet this standard specification and can be used for base of landfill.

The average uniformity coefficient of termite-reworked samples (SDT^A, SDT^B, SDT^C, SDT^D)is 32.5, while that of the $SD1^A$ is 30.5 These values are greater than one, which is indicative of a well graded soil and hence a good highway sub-base and sub-grade materials. The residual lateritic soil samples ($SD1^B$, $SD2^A$, $SD2^B$, $SD3^A$ and $SD3^B$) have no uniformity coefficient because of the absence of D_{10}.

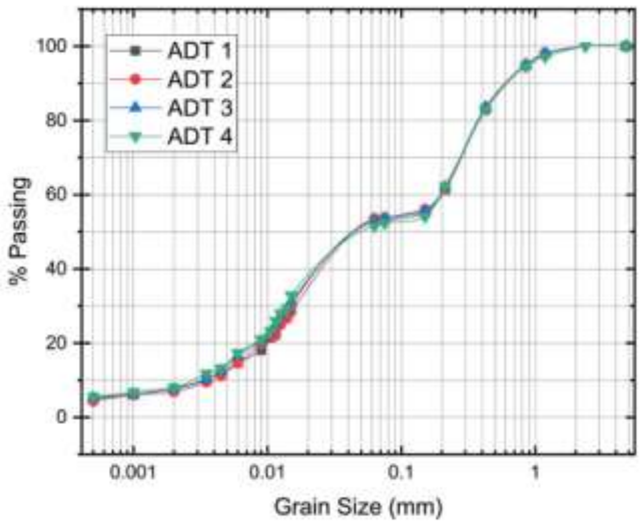
The permeability coefficient values obtained from this study are in the range of 10^{-6}mm/sec recommended by Clayton and Huie (1973) for the base of a landfill. Hence, soils here could be used in the construction of landfill.

The amount of fines is lower in termite reworked soil samples than in the nearby soil as shown in Fig. 3 and Table 2 and thus possess better engineering properties.

Table 2: Grain size distribution characteristics of the studied soils

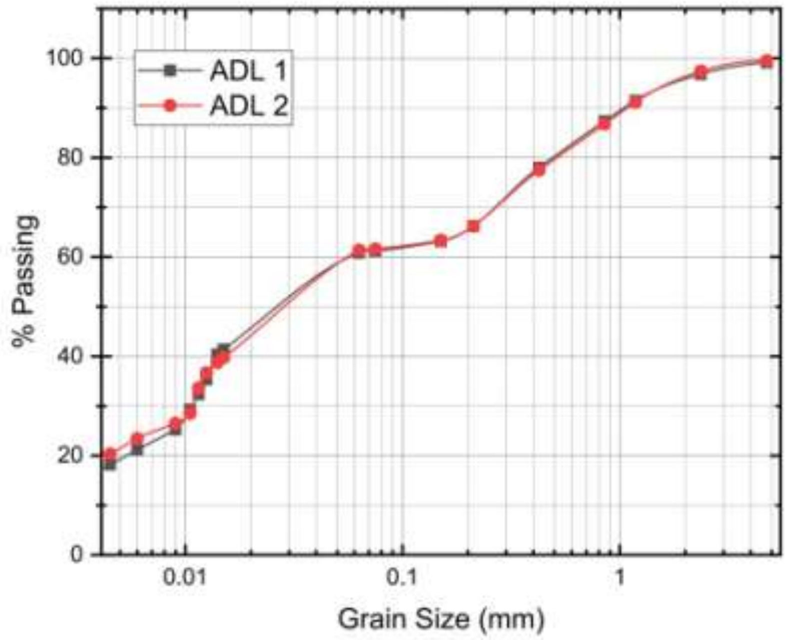
Parameters	**SAMPLES**					
	ADT1	**ADT2**	**ADT3**	**ADT4**	**ADL1**	**ADL2**
% Gravel	**1**	**1**	**1**	**2**	**4**	**3**
% Sand	**47**	**46**	**47**	**47**	**35**	**35**
% Silt	**45**	**47**	**44**	**45**	**50**	**48**
% Clay	**7**	**6**	**8**	**6**	**11**	**14**
Amount of fines %	**52**	**53**	**52**	**51**	**61**	**62**

ADT1= Termite reworked soil sample 1
ADT2= Termite reworked soil sample 2
ADT3= Termite reworked soil sample 3
ADT4= Termite reworked soil sample 4
AD1= Lateritic soil sample 1
AD2= Lateritic soil sample 2



Clay	**Silt**	**Sand**	**Grav el**

Figure 3: Grading curves of termite-reworked soil samples



Clay	Silt	Sand	Gravel

Figure 4: Grading curves of residual lateritic soil samples

4.3 Plasticity characteristics of the studied soils

Table 3 shows that the termite-reworked soil are of lower plasticity compared to that of the nearby soils. Casagrande chart classification shows that the plasticity of the nearby soil is high while that of the termite reworked soils is medium (Fig. 3).

Table 3: Plasticity characteristics of the studied soils

Samples	LIQUID LIMIT(%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	LINEAR SHRINKAGE
ADT1	34.25	23.01	11.24	7
ADT2	33.02	21.11	11.91	6.5
ADT3	32.50	23.23	9.27	6.2
ADT4	32.31	23.72	8.59	6.8
ADL1	49.60	28.78	17.31	11.80
ADL2	48.00	29.64	18.36	9.25

ADT1= Termite reworked soil sample 1
ADT2= Termite reworked soil sample 2
ADT3= Termite reworked soil sample 3
ADT4= Termite reworked soil sample 4
ADL1= Lateritic soil sample 1
ADL2= Lateritic soil sample 2

4.4 Compaction Parameter

In any engineering construction work, compaction of soils is done to achieve soils with improved engineering properties. The process of compaction results in a soil mass that is free of large continuous inter-clods voids, increases its density and strength, and reduces its hydraulic conductivity (Benson and Daniels, 1990).

Water content and dry density values can greatly affect a soil's ability to resist the transmission of fluid flow and other physical properties of the soil (permeability, strength and shrinkage potential) that control the performance of a soil as mineral seal (Das, 1998; Taha and Kabir, 2006).

Table 4 and 5 show the compaction parameters of soil samples compacted at the Standard Proctor level and modified proctor level. The tables indicate that reworking by termites has improved the compaction parameters of the soil. Therefore, there is a significant influence of reworking by termites on the compaction parameters of the studied soil.

Table 4: The maximum dry density (MDD) and optimum moisture content (OMC) of termite-reworked soil sample and the residual lateritic soil compacted at Standard Proctor Level

	LEVEL OF COMPACTION	
	STANDARD PROCTOR LEVEL	
	MDD	OMC
Termite –reworked soil (ADT1)	1720.20	17.60
Termite –reworked soil (ADT2)	1710.10	17.80
Termite –reworked soil (ADT3)	1720.30	17.90
Termite –reworked soil (ADT4)	1718.50	17.50
Residual lateritic soil (ADL1)	1650.30	18.20
Residual lateritic soil (ADL2)	1660.00	18.50

Table 5: The maximum dry density (MDD) and optimum moisture content (OMC) of termite-reworked soil sample and the residual lateritic soil compacted at Modified Proctor Level

	LEVEL OF COMPACTION	
	MODIFIED PROCTOR LEVEL	
	MDD	OMC
Termite –reworked soil (ADT1)	1840.15	16.00
Termite –reworked soil (ADT2)	1850.10	15.60
Termite –reworked soil (ADT3)	1820.10	15.00
Termite –reworked soil (ADT4)	1860.16	15.20
Residual lateritic soil (ADL1)	1790.25	18.20
Residual lateritic soil (ADL2)	1730.50	18.20

4.5 Unconfined Compressive Strength

Unconfined compressive strengths and CBR of soils are often used to evaluate highway sub-grade and sub-base soils (Simeon et al 1973). They are often used to estimate the shear strength of engineering soils. Generally for clayey soils, the shear strength is about half of the unconfined compressive strength (Krynine and Judd, 1957). Table 6 presents a summary of the strength characteristics (uncured and suncured) of the studied soil samples.Table 6 also shows that both the uncured and cured unconfined compressive strengths of the termite-reworked soils compacted at the optimum moisture content of the West African level are significantly higher than those of the surrounding lateritic soils.

The Central Road Research Institute of India (De-Graft-Johnson and Bhatia, 1969) recommended 1034KN/m^2 as the minimum value for the cured strength of road soils. The minimum acceptable value for uncured strength of soils is 103KN/m^2 (Ola, 1977).

Good soils are too sensitive to curing. They have higher percentage increase in strength as a result of curing because they are relatively richer in amount of clay-sized particles than bad soils (Akingbade, 2002). The higher the compressive strength the better the engineering soils.

It was observed from the data obtained that the suncured strengths for all the termite-reworked soil samples are far higher than 1034KN/m^2 recommended by the Central Road Research Institute of India for road soils reported by (De-Graft-Johnson and Bhatia, 1969), whereas the suncured strengths for the adjoining lateritic soils are far lower than the recommended value.

Table 6: Unconfined Compressive Strength in (KN/m^2) of Samples of the Studied Soils

SAMPLE	NATURE OF SAMPLE	UCS (KN/m^2)
ADT 1	UNCURED	137.00
	CURED	1500.86
ADT 2	UNCURED	143.42
	CURED	1604.64
ADT 3	UNCURED	138.6
	CURED	1600.04
ADT 4	UNCURED	138.18
	CURED	1740.92
ADL 1	UNCURED	101.50
	CURED	481.12
ADL 2	UNCURED	98.12
	CURED	484.88

4.6 Carlifornia Bearing Ratio Characteristics

The California Bearing Ratio (CBR) characteristic is a semi-empirical test often used to estimate and evaluate the bearing capacity of highway sub-grade and sub-base soils (Simon et al., 1973; Gidigasu, 1980).

The results of unsoaked and soaked CBR of the soil samples compacted at optimum moisture content of the West African level are presented in Table 7.

The soaked test was meant to assess the extent to which ingress of water would expand and weaken the in-situ soils. Reduction in strengths in terms of CBR brought about by soaking is higher in termite-reworked soil than in the surrounding soil. There is therefore the need to provide adequate drainage facilities if the studied termite-reworked soils are to be used as construction materials for flexible highway pavement

Table 7 shows that the unsoaked CBR of the termite-reworked soil samples are generally higher than those of the surrounding lateritic soil samples. The Asphalt Institute (1962) cited in Adeyemi (1992) recommended an unsoaked CBR value of 0% to 7% for highway sub-grade materials and 7% to 20% for sub-base materials. The Federal Ministry of Works and Housing (1974) specified minimum values of 15% and 10% for unsoaked and soaked samples respectively. The unsoaked and soaked CBR of the studied termite-reworked soils are thus qualified to be used as both sub-grade and sub-base materials because they meet the specifications of both the Institute and Federal Ministry of Works and Housing..

Table 7: Values of Unsoaked and Soaked CBR of the studied soil samples compacted at OMC of West African level

SAMPLE	NATURE OF SAMPLE	TOP	BOTTOM	AVERAGE	% STRENGTH REDUCTION
ADT 1	UNSOAKED	13.38	17.43	15.41	
	SOAKED	5.86	8.57	7.21	53.21
ADT 2	UNSOAKED	22.69	34.27	28.48	
	SOAKED	11.42	21.49	16.46	42.21
ADT 3	UNSOAKED	18.34	35.57	26.96	
	SOAKED	8.27	14.23	11.25	58.27
ADT 4	UNSOAKED	15.21	28.72	21.97	
	SOAKED	10.41	17.75	14.08	35.91
ADL 1	UNSOAKED	11.56	17.22	14.39	
	SOAKED	4.51	5.86	5.19	63.93
ADL 2	UNSOAKED	13.82	23.57	18.69	
	SOAKED	5.86	8.27	7.06	62.23

V. Conclusions

The interpretation and discussion of the determined geotechnical properties of the termite-reworked and adjoining lateritic soils have confirmed the following: The amount of fines is lower in termite-reworked soil samples than in the nearby soils. The specific gravity of grains, the Unconfined Compressive Strength and the California Bearing Ratio (CBR) of the termite-reworked soils were higher than those of the nearby soils. The plasticity indices and linear shrinkages of the termite-reworked soils were significantly lower than those of the surrounding soils. There is also a significant influence of reworking by termites on the compaction parameters of the studied soil. The above findings show that the soils reworked by termites have better engineering characteristics than the nearby soils.

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