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Research Paper

Soil Quality and Soil Degradation as Influenced by Agricultural Land Use Types in the Humid Environment

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Abstract: This study investigated the influence of land use types on soil quality and soil degradation. Four profile pits representing varying agricultural land use types were studied. The texture of the soils ranged from sand, loamy sand to sandy loam, with sand dominating the particle fractions of the soil. Bulk density of the soils increased with depth, varying from 1.27 – 1.50g/cm^3, with continuously cultivated land having the highest value. Soils were acidic, with pH values ranging from 4.27-5.56. The least organic matter content was recorded in continuously cultivated soils (10.68g/kg). The total nitrogen contents of the soils were generally low (0.70 -1.4g/kg). Exchangeable sodium percent (ESP) was very low ranging from 1.60 to 4.27%. The CEC of the soil was dominated by Ca^{2+} and Mg^{2+} and ranged from 3.13 to 5.98 cmol/kg. From the study, it was ascertained that forest, oil palm plantation and fallow soils posses superior quality than those of continuously cultivated soil.

Keywords: land use type, soil quality, soil degradation

Introduction

In Nigeria, non sustainable use of land has resulted in massive land degradation and soil infertility (Udoh et al, 2002). Assessing land use-induced changes in soil is essential for addressing agro-ecosystem transformation and sustainable soil productivity issues. Variations in soil quality could be consequent of the nature of parent material (Ibanga, 2006), land use types, topography and soil erosion. In the tropics, the selection of suitable land use type is of paramount importance for sustainable agriculture. Because soil attribute is important for the overall performance of land and play a preponderant role in checking land quality, it has been used extensively by several authors to monitor land degradation (Senjobi , 2007; Senjobi and Ogunkunle, 2001).

In most parts of Nigeria, there is noticeable evidence of land degradation, which varies from place to place in terms of the types, duration, severity and socio-economic impact (Aruleba, 2004). A survey in 1990 by the United Nations suggested that a quarter of the world's total crop land is affected by degradation severely enough to restrict its productivity, 15.6% of this compromised agricultural land is strongly degraded land whose original quality is largely destroyed (Senjobi, 2007), resulting to production loss of about 17% on degraded lands. In spite of rapid human population growth, concomitant intensification of land use contributed tremendously to soil degradation and poor soil quality. However, the extent to which a given soil degrades depends on its relative sensitivity to degradation (Stocking and Murnaghan, 2001). The soil sensitivity and resilience are thus related to a combination of soil inherent properties and the management history. In view of the soil degradation processes in Southeastern Nigeria due to human interference on the natural ecosystem, it then becomes pertinent to study the impact of these degradation on soil quality and their implications on soil productivity.

Materials and Methods

Study Area

Owerri West in Imo State of Southeastern Nigeria is located between the Latitude 5^0 53^1N and Longitude $7^0$54E and has an altitude between 30 to 150 meter above sea level (Ofomata 1975). Soils are derived from coastal plain sand . It is a humid tropical environment with an average annual rainfall of about 2250 mm and mean monthly temperature varying between 28^{o}C to 30^{o}C (Ofomata 1975). Farming is a major socio-economic activity in the area. Land clearing is by slash-and-burn technique while soil fertility regeneration is by bush fallowing whose length has decreased due to anthropogenic activities.

Field Studies

Four land use types (forest, fallow land, continuously cultivated land and oil palm plantation) were selected for the study. One profile pit was dug in each of the land use types, the profile pits were described using (FAO, 1998) guidelines and samples were collected according to horizons. Core samples were collected for bulk density determination. The soil samples were air dried, crushed and sieved through a 2 mm sieve.

Laboratory Analysis

Particle size distribution was determined by hydrometer method (Gee and Or, 2002). Bulk density was determined using core method (Grossman and Reinch, 2002). Soil pH was determined using 1:2.5 soil – liquid (water) ratio (Thomas, 1996). Organic carbon was measured by wet digestion method (Nelson and Sommers, 1996). Available P was determined using Bray-P 2 method (Olsen and Sommer, 1992). The soil exchangeable bases were determined by the neutral ammonium acetate procedure. Exchangeable acidity was measured in lN KCl (Mclean, 1965). Total nitrogen was determined by Kjeldah digestion method (Bremner and Mulvaney, 1982). Soil color was determined with munsell color chart. Total porosity was calculated using $TP = 1 - \ell_b / \ell_s \times 100$ where ℓ_b = bulk density (g/cm^3), ℓ_s = particle density (2.65g/cm^3). Exchangeable sodium percentage (ESP) was used as an index of sodium concentration and was calculated as follows: Na/CEC x 100. Alsat (%) was calculated thus Al/ECEC x 100.

Data Analysis.

Data generated were subjected to mean and coefficient of variation. The coefficient of variation was ranked according to the procedure of (Aweto, 1982) where $Cv \leq 25\%$ = low variation, $Cv \geq 25 \leq 50\%$ = moderate variation, $Cv \geq 50 \leq 100\%$ = high variation.

Results and Discussion

Results of soil morphological properties as shown in Table 1varied from one land use type to another in all the land use types especially as regards to color and texture. Soils under forest were browner at the surface horizons but reddish to brownish at the argillic horizons revealing the significant influence of organic matter on soil color. Soils of the oil palm plantation and fallow land were more reddish to brownish irrespective of the horizons. Except the surface horizon, soils under cultivation were orange in color indicating variations in soil color which may be a consequent of drainage and soil water table. This is in agreement with the findings of (Senjobi, 2007) and (Onweremadu et al, 2007). The soils were very friable, firm and well drained in all the land use types indicating the preponderance of macro pores. According to (Baker et al, 2004), good drainage is a result of abundance of macro pores in soils. There were presence of roots in the soils except in the last horizons of the pedons in fallow, oil palm plantation and cultivated land. However, the argillic horizons of forest soils had abundance of tap roots which may be due to the presence of perennial plants, an important attribute of forest. The oil palm plantation consisted more of oil palm roots which is peculiar to the land use type. Generally, the variability could be due to landscape position and land use type. This is in confirmation with the report of Ndukwu et al, 2009 and Akamigbo, 1999 that land use types alter soil properties which influence the overall performance of soil.

The texture of the soils ranged from sand, loamy sand to sandy loam (Table 2). The soil texture reflected the nature of the parent material from which the soils where developed and the drainage pattern of the area. Sandiness of the soils suggest low CEC, high infiltration rate and observable low moisture content of the soils which may result to moisture stress. In addition to the above, this scenario encourages rapid leaching of nutrient from the soils beyond the rooting zones of the planted crops - a critical situation that threatens food security. However, the coarse nature of the studied soils can in turn encourage soil erodibility on exposure to high rainfall through reduced fallow period and the conversion of forest to cultivated land, leading to soil degradation. Soil degradation as a result of erosion can be checked to the barest minimal level through appropriate land use practices which are not only environmental friendly and acceptable by the land users, but which also ensure the maintenance and continuous vegetative cover over the soil surface. The clay fraction of the soils increased with depth in all the soils. Low clay content of the surface horizons could be due to sorting of soil materials by biological and /or agricultural activities, clay migration or surface erosion by runoff or combination of these (Malgwi, 2000; Ojanuga, 1975). Chikezie et al, 2009 and Idoga and Azagaku, 2005 reviewed that increased in clay content of soil with depth may be the consequence of eluviations - illuviation processes as well as contributions of the underlying geology through weathering. The silt-clay ratio (Table 2) reflects the weathering stage of parent material (Mbagwu, 1985). Continuously cultivated land had the least silt-clay ratio (0.29%) indicating the advanced stage of weathering. On the other hand, soils under fallow had high silt-clay ratio followed by those of the forest indicating that these soils are still undergoing some weathering processes. The high silt-clay ratio observed in the surface horizons of forest and fallow land may be attributed to the deposition of plant materials (litter) which are still undergoing decomposition. Sand had little variations (cv $\leq$ 25%) in all the soils. The variations in physical properties of soils showed that silt-clay ratio had moderate variations (cv $\geq$ 50%) in the four land use types studied. Clay fractions varied moderately in the soils while silt showed little variation in forest, oil palm and fallow land compared to continuously cultivated land that had moderate variation. This could be as a result of topography, deposition of high volume of silt-clay as a result of high rainfall (Onweremadu et al, 2009) and land use types. The results obtained from the fractionation of soil particles revealed that cultivation of forested land alters soil properties.

Table 1. Morphological Properties of Soils of Dissimilar Agricultural Land Utilization Types.

Land use types	Depth (cm)	Horizons	Color	Texture	Roots	Consistency	Drainage
	0-4	Oa	10R2/3	LS	Fibrous roots	Very friable	Wd
	4-17	A	10R2/3	LS	Fibrous roots	Very friable	Wd
Forest	17- 40	AB	10R4/3	LS	Secondary roots	Friable	Wd
	40 – 92	Bt_1	10R4/3	SL	Tap roots	Firm	Wd
	92 – 160	Bt_2	10R6/8	SL	Tap roots	Firm	Wd
	0 – 18	A	2.5YR3/4	LS	Fibrous roots	Friable	Wd
	18 – 35	AB	10R2/1	Sand	Secondary roots	Very friable	Wd
Fallow land	35 – 53	Bt_1	2.5YR3/4	LS	Tap roots	Very friable	Wd
	53 – 83	Bt_2	7.5R5/3	LS	Tap root	Firm	Wd
	83 – 150	Bt_3	10R5/4	LS	Nil	Very Firm	Wd
	0 – 6	AP	10R4/3	LS	Fibrous roots	Very friable	Wd
Continuously cultivated land	6 – 27	AB	10R4/3	LS	Fibrous roots	Very friable	Wd
	27 – 83	Bt_1	2.5YR7/3	SL	Nil	Firm	Wd
	83 – 120	Bt_2	2.5YR7/3	SL	Nil	Firm	Wd
	120-170	Bt_3	2.5YR7/8	SL	Nil	Very firm	Wd
	0 – 4	A	10R2/1	Sand	Fibrous roots	Loose	Vwd
Oil palm plantation	4 – 15	AB	10R4/3	SL	Fibrous roots	Very friable	Wd
	15 – 45	Bt_1	2.5YR3/4	SCL	Oil palm roots	Friable	Wd
	45 – 80	Bt_2	7.5R5/3	SCL	Tap roots	Firm	Wd
	80 – 150	Bt_3	10R5/4	SCL	Nil	Firm	Wd

Wd = well drained, vwd = very well drained, SL = sandy loam, LS = loamy sand, SCL = sandy clay loam

Bulk density of the soils increased with soil depth primarily because of less organic matter. Highest bulk density value was recorded in continuously cultivated land (1.42%) which may be a reflection of frequent cultivation of land that results to soil compaction. The least bulk density values were found in oil palm plantation, forest and fallow land with corresponding high organic matter. Several authors have reported the significant influence of cultivation and organic matter on soil bulk density (Akamigbo, 1999, Onweremadu et al, 2009). Results on bulk density were less than the critical limits for root restriction (1.75 – 1.85 g/cm^3) (Soil survey staff, 1996).

Generally, soil pH was acidic (4.27 – 5.56) and did not follow definite sequence in its distribution within the profile. The total nitrogen contents in all the soils were generally low (0.70 -1.4g/kg) compared with the critical value of 1.5g/kg (Agboola and Corey, 1973; Senjobi and Ogunkunle, 2011). The least total N value recorded in continuously cultivated soils may be attributed to the intense cultivation of the soils which normally increase the rate of mineralization of the organic matter. The N content of the soils of the different land use types had little to high variation. High amount of N recorded in the surface horizon of the forest soils was a reflection of its high organic matter content (Table 3). The organic matter content of the soils ranged between 10.68 to 17.80 g/kg and fluctuates irregularly with depth in all the pedons. High organic matter contents of the surface horizons is acceptable. This may be due to the fact that most of the organic residues in both cultivated and virgin soils are deposited on the surface. Higher organic matter contents were recorded in forest, oil palm plantation and fallow soils compared to the continuously cultivated soil. This may be because soils under those land use systems were always covered and had not been subjected to intense cultivation and use as in continuously cultivated land. Organic matter is one of the important parameters used in judging soil quality and degradation. It has been reported to have significant positive influence on soil pH, cation exchange capacity, color, buffering capacity, base saturation and water holding capacity (Akamigbo, 1999) and effective cation exchange capacity (Onasanya, 1992).

According to FAO (1978), the decrease in organic matter status of the soil when the biomass or the crop residues are insufficient to replace the humus could be attributed to the rapid biological degradation of the soil. For most low activity clay of the tropical soils, the organic matter is the major exchange site for the basic nutrient cations in the soil. In view of this, steps should be taken to increase the organic matter content of the soil, so as to improve soil quality and reduce soil degradation. This can be achieved through appropriate land use type and use of organic residues to conserve, maintain favorable soil temperature and encourage biological activities of soil organisms. The available P was higher in forest, fallow and continuously cultivated soils compared to the soil of oil palm plantation. Soil of the fallow, forest and continuously cultivated land had P values higher than the critical value (15 mg/kg) as reviewed by (Enwezor et al, 1990) for soils of southeastern Nigeria. The average P content of the soils showed little variation in all the land use types (Table 3) with Cv values of 2.19, 4.97, 14.86 and 41.7% respectively.

Table 2. Physical Properties of Soils of Dissimilar Agricultural Land Utilization Types.

Land use types	Dept (cm)	Horizon	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	BD (g/cm^3)	% Total Porosity	Moisture (%)	SCR
	0-4	Oa	858.00	94.00	48.00	1.20	54.70	5.00	2.00
	4-17	A	858.00	64.00	78.00	1.30	50.90	5.00	0.82
Forest	17-40	AB	818.00	74.00	108.00	1.40	47.10	5.00	0.69
	40-92	Bt1	778.00	54.00	168.00	1.40	47.10	6.00	0.32
	92-150	Bt2	758.00	64.00	188.00	1.40	47.10	5.00	0.34
		Mean	**814.00**	**68.00**	**118.00**	**1.34**	**49.38**	**5.80**	**0.83**
		Cv (%)	5.60	24.61	50.14	6.67	6.88	8.60	82.79
	0-18	A	878.00	64.00	48.00	1.20	54.70	9.00	1.33
Fallow land	18-35	AB	898.00	54.00	48.00	1.30	50.90	7.00	1.13
	35-53	Bt1	855.00	94.00	48.00	1.40	47.10	7.00	2.00
	53-83	Bt2	835.00	64.00	98.00	1.40	47.10	9.00	0.65
	83-120	Bt3	818.00	54.00	128.00	1.40	47.10	6.00	0.42
		Mean	**858.00**	**66.00**	**75.40**	**1.34**	**49.38**	**7.60**	**1.11**
		Cv (%)	3.70	24.89	47.96	6.68	6.88	6.51	55.69
Continuously cultivated land	0-6	AP	858.00	54.00	88.00	1.20	54.70	6.00	0.61
	6-27	AB	858.00	34.00	108.00	1.40	47.40	7.00	0.32
	27-83	Bt1	778.00	34.00	188.00	1.50	43.40	8.00	0.18
	83-120	Bt2	778.00	24.00	198.00	1.50	43.40	7.00	0.12
	120-170	Bt3	758.00	44.00	198.00	1.50	43.40	8.00	0.22
		Mean	**806.00**	**38.00**	**156.00**	**1.42**	**50.76**	**7.20**	**0.29**
		Cv (%)	5.97	30.00	34.34	9.18	10.24	11.62	66.59
Oil palm plantation	0-4	AP	892.40	50.00	57.60	1.20	54.72	3.31	0.87
	4-15	AB	752.40	50.00	197.60	1.22	53.96	5.87	0.25
	15-45	Bt1	752.40	30.00	217.60	1.30	50.94	5.13	0.13
	45-80	Bt2	752.40	30.00	217.60	1.30	50.94	5.12	0.13
	80-150	Bt3	742.40	30.00	227.60	1.33	49.81	5.09	0.13
		Mean	**778.40**	**38.00**	**183.60**	**1.27**	**52.07**	**4.90**	**0.30**
		Cv (%)	8.20	28.83	38.82	4.45	4.10	18.60	50.12

Cv = Coefficient of variation, cv $\leq$ 25% = low variation, cv $\geq$25 $\leq$ 50% = moderate variation, cv $\geq$50 $\leq$100% = high variation. BD = Bulk density, SCR = Silt-clay ratio.

Exchangeable sodium percent (ESP) which identifies the degree to which the exchange complex is saturated with Na was very low ranging between 1.60 to 4.27%. Low ESP obtained from the study may be a consequent of the acidic conditions of the soils and high rainfall intensity. As rain water percolates, it dissolves and leaches away Na cations which may accumulate in ground water, implying that the amount of sodium in ground water may be proportional to the amount of soluble Na cations leached out of top and sub-soils. This is consistent with the report of Dupriez and Deleener (1992) that rain water falling on the surface of a field causes soils to hardly be associated with any saltiness. ESP levels of 15% is associated with pH values of 8.5 and above. Al-saturation of the soils is directly related to the acidity of the soils. Al (aluminum) toxicity is recognized as one of the dominant chemical constraints affecting plant growth in acid soils. Meriga et al (2003) stated that among phytotoxic species, Al^{+3} is the most potent and inhibits root growth and uptake of nutrients, which ultimately reduce crop yield. The CEC of the soil was dominated by Ca^{2+} and Mg^{2+} and ranged between 3.13 to 5.98 cmol/kg. Except the soils of oil palm plantation, soils of the forest, fallow and continuously cultivated lands had Ca and Mg values above the critical levels of 2.00 and 1.2 cmol/kg respectively. However, the cation exchange capacity of the soils were generally low indicating the inability of the soils to retain nutrient and water. This may be attributed to the parent material and coarse nature of the soils. In view of this, steps should be taken to boost the organic matter contents of the soils through appropriate management practices to ensure optimum soil productivity. The continuous cultivation of forest and fallow land is associated with reduced organic matter content of the topsoil (Ross, 1993; Singh and Singh, 1996) and subsequent decline in productivity (Singh and Singh, 1996). Such changes in soil properties expose the soil to soil erosion, a major causative agent for soil degradation.

Conclusion

Continuous cultivation of land led to changes in soil properties. The decline of these soil qualities is attributed to intensive cultivation of crops, use of inorganic fertilizers, poor water and soil conservation measures employed by farmers. Another imperative factor contributing to this change is lack of agricultural extension information on soil fertility management by majority of farmers. Land management practices such as conservation tillage and agro-forestry practices that boost soil quality should be up-scaled to cover wider area to promote sustainability of soil productivity. Farming without adequate soil conservation measures should be discouraged.

Table 3 Chemical Properties of Soils of Dissimilar Agricultural Land Utilization Types.

Land use	Horizon	Depth	pH	AvP (mg/kg)	OM (g/kg)	Ca	Mg	K	Na	CEC cmol/kg	H^+	Al^{+3}	EA	ECEC	ESP (%)	Al sat (%)	% BS	TN (g/kg)
	Oa	0-4	4.78	26.8	40.30	4.80	2.40	0.27	0.16	7.63	0.12	0.96	2.08	9.71	2.10	9.89	78.00	1.96
Forest	A	4-17	4.35	20.00	15.70	2.80	1.60	0.06	0.09	4.55	0.24	1.51	1.76	6.31	1.98	23.93	72.00	0.98
	AB	17-40	4.20	16.10	14.30	2.40	2.00	0.10	0.09	4.58	0.32	1.04	1.36	5.94	1.97	17.51	77.00	0.84
	Bt_1	40-92	4.20	20.00	7.40	2.80	1.60	0.12	0.11	4.64	0.64	0.96	1.61	6.25	2.37	15.36	74.00	0.46
	Bt_2	92-150	4.80	17.80	1.40	2.80	1.20	0.08	0.13	4.21	0.40	0.88	1.28	5.49	3.09	16.03	77.00	0.78
	Mean		**4.27**	**20.14**	**15.82**	**3.12**	**1.76**	**0.13**	**0.12**	**5.12**	**0.54**	**1.07**	**1.62**	**6.74**	**2.30**	**13.37**	**75.6**	**0.10**
	CV (%)		15.25	2.19	93.80	30.54	25.51	64.36	25.00	2.56	54.33	23.59	19.89	25.09	20.40	46.07	3.32	56.51
Fallow Land	A	0-18	4.17	18.10	18.80	3.60	2.00	0.13	0.11	5.84	0.72	1.70	1.92	7.76	1.88	21.91	75.00	1.26
	AB	18-35	4.45	17.80	26.00	3.60	2.40	0.10	0.07	6.17	0.03	1.76	1.79	7.95	1.13	22.14	77.00	1.40
	Bt_1	35-53	6.03	16.10	15.70	4.00	2.80	0.14	0.13	7.07	0.77	1.20	1.97	9.04	1.84	13.27	78.00	0.84
	Bt_2	53-83	5.30	17.10	10.30	2.40	2.00	0.12	0.10	4.61	0.80	0.24	1.04	5.65	2.17	4.25	81.00	0.13
	Bt_3	83-120	5.02	17.50	11.70	3.60	2.40	0.12	0.06	6.18	1.44	0.40	1.84	8.02	0.97	5.00	77.00	0.20
	Mean		**4.99**	**17.32**	**16.50**	**3.44**	**2.32**	**0.12**	**0.09**	**5.98**	**0.75**	**1.06**	**1.71**	**7.68**	**1.60**	**13.31**	**77.60**	**1.12**
	CV (%)		14.65	4.97	38.05	17.79	14.43	12.5	32.39	14.87	66.61	67.15	22.32	16.15	32.45	65.40	2.82	20.71
Continuously Cultivated Land	AP	0-6	5.50	27.70	19.50	2.40	2.00	0.08	0.10	4.59	Trace	0.56	0.56	5.15	2.18	10.87	89.00	1.12
	AB	6-27	5.13	17.10	7.80	5.20	1.60	0.10	0.10	4.99	0.48	0.64	1.12	6.11	2.00	10.48	81.00	0.42
	Bt_1	27-83	4.67	15.90	7.80	4.00	1.20	0.10	0.19	5.48	0.16	1.20	1.36	6.84	3.47	17.54	80.00	0.78
	Bt_2	83-120	4.46	17.50	6.60	4.00	2.80	0.11	0.17	7.08	0.88	0.32	1.20	8.28	2.40	3.87	85.00	0.54
	Bt_3	120-170	4.40	20.40	11.70	3.20	2.00	0.10	0.06	5.36	0.64	0.40	1.04	6.40	1.12	6.25	83.00	0.70
	Mean		**5.03**	**19.72**	**10.68**	**3.76**	**1.92**	**0.10**	**0.12**	**5.50**	**0.43**	**0.62**	**1.06**	**6.56**	**2.23**	**9.80**	**83.60**	**0.70**
	CV (%)		6.58	41.77	51.45	27.74	29.87	11.18	51.71	23.50	76.19	55.80	34.55	18.33	37.88	53.34	9.41	3.76
Oil palm Plantation	A	0-4	5.93	11.20	19.50	2.03	2.03	0.10	0.02	4.18	0.08	0.03	0.11	4.29	0.48	0.70	97.43	1.40
	AB	4-15	5.58	9.99	19.00	3.07	2.07	0.16	0.03	5.29	0.12	0.21	0.33	5.62	0.57	3.74	94.13	1.40
	Bt_1	15-45	5.52	9.01	18.30	3.10	2.10	0.16	0.03	5.39	0.16	0.21	0.37	5.76	0.56	3.65	93.56	1.40
	Bt_2	45-80	5.54	8.35	16.30	0.12	0.03	0.22	0.04	0.41	0.20	0.32	0.52	0.93	9.76	34.40	44.09	1.30
	Bt_3	80-120	5.53	7.72	16.00	0.10	0.03	0.23	0.04	0.40	0.18	0.30	0.48	0.88	10.00	34.s09	45.46	1.30
	Mean		**5.56**	**9.25**	**17.80**	**1.68**	**1.25**	**0.17**	**0.03**	**3.13**	**0.15**	**0.21**	**0.36**	**3.50**	**4.27**	**15.31**	**74.93**	**1.40**
	CV (%)		0.81	14.86	8.91	2.56	8.51	31.13	28.87	29.23	32.15	15.10	44.68	34.14	119.87	113.15	7.47	5.05

ESP= Exchangeable Sodium Percentage, OM=Organic Matter AvP= Available P, CEC= Cation Exchange Capacity, AlSat= Aluminum Saturation EA= Exchangeable Acidity BS= Base Saturation, Cv = Coefficient of variation, cv ≤ 25% = low variation, cv ≥25 ≤ 50% = moderate variation, cv ≥50 ≤100% = high variation. TN= Total Nitrogen, ECEC= Effective Cation Exchange Capacity

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