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Reclamation and sustainability of the overmined soybean field at Badeggi, Nigeria

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Long-term cultivation of crops in the North central zone of Nigeria, belonging to guinea savanna agro-ecology, has resulted to soil quality degradation that could affect economic development in the region if sustainable production practices are not identified. Over fifteen years, soybean field of the National Cereals Research Institute (NCRI) Badeggi, Niger State, Nigeria have been put into continuous research activities with regular use of inorganic fertilizers to sustain the production. This have led to massive depletion of both soil nutrients particularly the major nutrients including nitrogen(N) and potassium (K) , along with high loss of organic matter and cation exchangeable capacity(CEC) thereby, leading to high reduction in the grain yield per hectare of soybeans. From the result of the analyzed soil samples collected, the presence of N and K were generally very low. The soil pH was at neutral level between the ranges of 6.0-7.8 which was very suitable for soybean production. The organic matter and cation exchange capacity were very low. The general textural class of the soil of the experimental field was sandy loam. From profile dug, the A horizon was very fragile with thickness of 14.0cm, horizon B was 23.5cm and it was a transition between horizon A and C. The C horizon has thickness of 62.5cm and it was made up of 100% laterite soil. This soil of soybean field in NCRI Badeggi is to be reclaimed through the use of organic manure particularly cattle dung which is bulky and can improve the organic matter content of soil, and also thereby, increasing the CEC of the soil. Freshly decomposed organic matter should be used mostly as a fertilizer because it contributes more to CEC content than older organic matter. Zero or minimum tillage should be adopted to enable the maintenance of the soil structure. Farming systems such as crop rotation, bush fallowing, organic farming (using organic materials that are rich particularly in phosphate and nitrogen) and agro-forestry involving the use of trees or shrubs such as acacia (*Acacia spp.)* shear butter (*Buttyrospermum paradoxi*), locust bean (*Parkia clappertonia*), mango *(Mangifera indica,)*, guava *(Psidium guajava)*, tamarind (*Tamarindus indica)* should be practiced to enable the achievement of soil sustainability.

Key words: Over mined soil, soybean field, reclaims, organic fertilizers, minimum or zero tillage.

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Introduction

Soil is the most valuable of all the possessions that have been handed on to us by our ancestors and it is the layer upon which the entire plant and animal worlds still depend for food to sustain life (Gana, 2010). The value of the any region of the earth therefore is measured by its ability to grow the plants that we need as raw material and as food (Deliparthy, 1994).

Nutrient budget for African soils especially of the Sub-Saharan area shows a net annual depletion of N, P and K as a result of long term cropping with little or no external nutrient inputs. Phosphorus (P) is one of the most important elements for soybean production as this element facilitates energy exchange within biological organisms (Wood, 1989). Therefore, being one of the major elemental fertilizer nutrients has a striking effect on root and shoot development. It occurs in the nucleus of living cells and it controls most cell activities (Gana, 2010).

The supply of nutrients has been reported to be the important limiting factor in successful soybean production in Nigeria, especially the Savannah soils of Nigeria where soybean is mostly grown, has little native nitrogen and at the same time the land has been put into use over years with the same recommended rate of inorganic fertilizer.

Soils vary; the differences may range from very striking texture variations to more subtle minor variations of color. Soil differences dictate that the soils must be managed differently and will behave differently when used for agriculture, forestry, sewage disposal, foundations, pavements, and other things.

In sandy soils, especially the upland ecologies where the soils have been over mined, loss of mineral nutrients, water and herbicides through leaching is very high thereby making the soil unproductive (Gana, 2010). Gana (2008) obtained poor growth performance and yielded only 60ton/ha of chewing sugarcane alone at the recommended rate of 120N - $60P_2O_5$ - $90K_2O$kg/ha applied to chewing sugarcane at the upland sugarcane experimental field of NCRI Badeggi. The use of chemical fertilizers decreased the recycling of crop residues and losses of crop nutrient due to leaching and erosion (Singh *et al*., 2001). In this condition of soil, the need for soil sampling and profile excavation to determine the physico-chemical properties of the soil for the adoption of appropriate soil management practices for higher yield and the sustainability of both the yield and soil is very important.

Hence, the objective of this project was to determine the physicochemical properties of soybean field of the National Cereals Research Institute Badeggi for the recommendation of agronomic and soil management practices that could be adopted to reclaim the over mined soybean field of NCRI Badeggi for higher productivity of soybean and the sustainability of the soil over a long period of time.

Materials and methods

The soybean experimental field of the National Cereals Research Institute(NCRI) Badeggi is located within latitude 9°45 |N, longitude 0.6°07 |E; and is 70.5 meters above sea level in the Southern Guinea Savannah ecological zone of Nigeria. The soil of the experimental site had been classified as ultisol and sandy loam in texture with a bulk density of 1.459 per meter (Ayotade and Fagade, 1993). The area has an average annual rainfall of 1124mm and mean temperature of 23°- 33°C. The soybean field was divided into five segments or portions. The division was based on the topography of the field. Segment 1 was the area for the advanced yield trial for early and medium varieties of soybean and germplasm. Segment 2 was the portion where TGX1440-4E and TGX1019-2EN varieties of soybeans were evaluated. Segment 3 contained TGX1987-62F,TGX1987-10F evaluation, and an experiment on TGX1448-2E(Depressed portion), Segment 4 is the portion from the ant hill to the bush containing the following varieties of soybean:-TGX1941-4F, TGX1405-17E,TGX1878-7E,Cameroun late,TGX1804-1F, TGX1956-1F, NCRISOY8, TGX1848-4F,TGX19371F,NCRISOY2, TGX1430-20E, NCRISOY17, TGX1908-1F,TGX1019-2E. Segment 5, was multiplication of TGX448-2E variety. Soil samples were collected from soil depths of 0-15 and 15-30cm respectively from each segment using soil auger. The samples collected from each depth and location were placed into a polythene bag and labeled neatly. The colour of each fresh soil sample collected was identified on the spot using Soil Colour Chart Mussel from China (Hue 7.5YR).The collected samples were dried, processes and analyzed at the NCRI laboratory. One profile pit was excavated at 1.0 m^2. The profile was dug using digger, shovel and cutlass. Metre tape was used to determine the horizon thickness. Soil sample was collected at each horizon and the colour of each sample collected was identified immediately using the soil colour chart Mussel from China (Hue 7.5YR)**.** Each soil sample collected was kept inside polythene bag and labeled using pencil with a masking tape. The samples were dried, processed and analyzed at NCRI Badeggi laboratory.

The analytical characteristics of the soil samples were determined in the following manner

Determination of soil nutrient status

Particle size analysis

Particle size distribution was analyzed for by using the hydrometer method and the textural class was determined by the soil textural triangle (IITA, 1979).

Soil pH

Soil pH was determined in water by using a soil solution ratio of 1:2.5 by means of a Philip analogue pH meter (McLean, 1982, IITA, 1979).

Total nitrogen

The nitrogen content of the soil was determined using Macro Kjeldahl procedure (Bremner, 1965).

Available phosphorus

Available phosphorus was determined using Trough method. The extracted phosphorus was determined by the molybdate blue colour method (Nelson and Sommers, 1982).

Exchangeable bases

The exchangeable bases, calcium (Ca) magmesium (Mg) potassium (K) and sodium (Na) were extracted using IN acetate (pH 7.0) (IITA, 1979).

Soil organic carbon

This was determined using Walkley - Black method (Nelson and Sommers, 1982).

Soil organic matter

This was determined by multiplying product of organic carbon with a factor of 1.724 (IITA, 1979).

Cation exchange capacity (CEC)

Cation exchange was determined by ammonium saturation method using IN ammonium acetate (pH 7.0) saturation followed by the displacement of the absorbed ammonia (Rhoades, 1982).

Results and discussions

From the result of the analyzed soil samples as shown in Tables 1 and 3, the soil colour across the five segments, within the soybean field where soil samples were collected from the soil depths of 0-15 and 15-30cm and samples from the soil profile, ranges from brown to light brown to strongly orange brown. The colour was an indicator of the colour of the type of parent material that formed the soil. The prominence of the brownish colour was as a result of the laterite soil found in horizon B and C. The soil profile dug (Table 3), showed that the horizon B was a transition between horizon A&C which was made up of sand and laterite soil with a fragile thickness of 23.5cm.While horizon C having a thickness of 62.2cm with 100% late rite soil (Table 3).

The productivity of this soil could be very low because the horizon A had a very thin thickness of only 14.0cm which was made up of sand, organic matter and nutrients. The depth of this horizon was low or small to enable the optimum supply of the needed nutrients and support to soybean plant. The sub soil was made up of purely sand and laterite which could not give any nutritional support to the crop. According to Bennet, (1994) lateritic soils are characterized by their low soil fertility. Due to the high rate of weathering, low charge minerals and having high iron and aluminum oxide contents, the soil is unable to retain the nutrients needed for plant growth. Continuous mechanization under this condition of fragile horizons A and B, and C purely laterite lead to soil compaction. Sooner, the soil will become hard pan which is nuisance to agriculture particularly in crop production.

The soil pH was close to the neutral level with value ranges between 6.0-6.7 (Tables 1 and 3). This is very good for soybean and other arable crop production. According to Gana (2010) soil pH ranges from 5.9-7.0 are favourable for arable crop production particularly leguminous crops. However, the level of nitrogen, potassium, cat ions, organic matter and CEC from both the samples analyzed from the profile and samples collected from various segments within the soybean field (Tables 1, 2, 3 and 4) were low. The low levels of the major nutrients such as N and K could be as a result of low level of organic matter in the over mined soil (Tables 2 and 4) thereby making the soil highly porous thus led to serious leaching of the added inorganic fertilizer. According to Gana (2010), sand soils especially in the upland ecologies where the soils have been over mined, loss of mineral nutrients and water as well as herbicide leaching is very high thereby making the soil unproductive. Gana (2011a) in his experiment on the use of cattle manure in reclaiming an over mined soil of sugarcane field observed that due to decades of indiscriminate use of chemical fertilizers the organic matter content of soils has gone down. The use of chemical fertilizers is a major cause of concern for the safety of food and sustainable production. It is believed that organic farming, by reverting to the use of manures, green manures, urban waste, and rural wastes, can bring eco-friendly and sustainable agriculture. To the maximum extent feasible, organic farming systems rely upon crop rotation, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral bearing rocks and aspects of biological pest control to maintain soil productivity and to supply plant nutrients as well as to control insects, weeds and other pests (Kanchikerimath and Singh ,2001).

The presence of exchangeable cat ions (CEC), which could empower the soil to absorb the applied nutrients, was generally low in the soil (Tables 2 and 4). The use of organic fertilizer is highly advised to be adopted in this ecology to enable the reclaimation of the soil and its sustainability thereby, increasing productivity.

In recent years, a growing consensus has emerged on the need for both organic and inorganic fertilizer to reverse the nutrient imbalances in cropping systems in agriculture in Sub-Saharan Africa (ASS) as continuous sole application of either of these inputs tend to create soil related constraints to crop production (Van Lauwe *et al*., 2001). The application of cow dung is needed not only to replenish lost nutrient but also to improve the physical, chemical and biological properties of sandy upland ecologies. This will also enhance the performance of the other applied inputs. According to Giller (2002), manure increases organic matter content, water holding capacity and plant nutrients. It also increases the efficiency of mineral fertilizer by improving the physical properties of the soil. Freshly decomposed organic matter should be used as a fertilizer because it contributes more to CEC content than older organic matter (Gana, 2011b). Soil incorporated with cow dung contains enough suitable phosphoric acid, potash and lime (Deliparthy *et al*., 1994). Soil organic matter is affected by the type of land use adopted. This in turn, determines the organic matter turnover and nutrient cycling. In order to minimize chemical fertilizer input, sustainable agricultural systems often use animal wastes and crop residues such as N and P sources for plants. Kanchikerimath and Sighn (2001) found significant correlations between management practices and soil organic carbon as well as microbial biomass carbon content in the soil of a 26-year-old fertilization experiment. In addition to its direct contribution to N and P supply, the incorporation of C-rich manure and crop residue to soils has been shown to increase the amount of soluble organic matter in soil that may affect the bioavailability of soil P (Zsolnay and Gorlitz, 1994).

Because of thin layer of the top soil including horizon A, zero or minimum tillage is recommended for this ecology to enable the sustainability of the poor soil structure and its improvement. However, the poor texture may not be changed within a short period but under a long time use of organic fertilizers and appropriate farming system such as crop rotation, and agro forestry. Fallowing system using live legumes which are to be incorporated at the tender stage between 6-7weeks after planting is recommended. Legumes used as green manuring crops provide nitrogen as well as organic matter to the soil. Legumes have the ability of acquiring nitrogen from the air with the help of its nodule bacteria. The legumes commonly used as green manuring crops include sannhemp (*Crotalaira juncea*), djainach (*Seshania aculata)* mungbean (*Phaseolus aureus*), cowpea (*Vigna catjung*), lentil (*Lens esculenta*), senji (*Melilotus alba*), berseem (*Phaseolus aureus)* and guar (*Cyamposis tetragonoloba*).

Table 1. Physico-chemical characteristics of the over mined soil of soybean field under continuous cropping for over 15 years at Badeggi, 2012

S/No	Sample and location description	Soil Depth	Soil Colour	Soil pH	Total Nitrogen (N)%	Available Phosphorous (P) ppm	Exchangeable Cations Cmokg^{-1} Na	K	Ca	Mg	EA
1	Advanced yield trial early and medium ,and germplasm	0-15	Hue 7.5YR 4/6 brown	6.45	0.10	41.45	0.13	0.23	2.88	5.90	0.09
		15-30	Hue 7.5YR 6/6 strong orange brown	6.10	0.09	37.50	0.10	0.23	3.13	6.63	0.11
2	TGX1440-4E,TGX1019-2EN, TGX1987-62F,TGX1987-10F	0-15	Hue 7.5YR 4/6brown	6.40	0.10	41.45	0.09	0.18	3.10	6.36	0.06
		15-30	Hue 7.5YR 4/4 brown	6.62	0.08	36.25	0.22	0.18	3.16	6.89	0.10
3	Experiment on TGX1448-2E(Depressed portion)	0-15	Hue 7.5 YR 5/1brownish gray	6.11	0.11	17.25	0.13	0.30	0.45	7.08	0.10
		15-30	Hue 7.5YR 4/3 brown	6.24	0.09	33.25	0.17	0.26	3.29	6.86	0.13

4	Ant hill to the bushTGX1941 -4F, TGX1405-17E,TGX1878 -7E,Cameroun late,TGX1804-1F, TGX1956-1F, NCRISOY8, TGX1848-4F,TGX19371 F,NCRISOY2, TGX1430-20E, NCRISOY17, TGX1908-1F,TGX1019-2E	0-15	Hue 7.5YR 4/6light brown	6.57	0.12	52.56	0.11	0.20	3.14	6.13	0.24
		15-30	Hue 7.5YR 4/4brown	6.64	0.10	56.25	0.14	0.23	2.52	4.47	0.06
5	Multiplication of TGX448-2E field	0-15	Hue 7.5YR4/4 brown	6.01	0.10	25.00	0.09	0.13	2.96	7.99	0.04
		15-30	Hue 7.5YR 5/8 strong orange brown	6.45	0.08	18.75	0.17	0.10	3.56	6.72	0.08

Table 2. Physico-chemical characteristics of the over mined soil of soybean field under continuous cropping for over 15 years at Badeggi

S/No	Sample and location description	Soil Depth	Organic Matter (om)%	Ogarnic carbon (OC)%	CEC Cmokg-1	Sand %	Silt%	Clay%
1	Advanced yield trial early and medium and germplasm	0-15	1.18	0.68	9.19	83.24	8.28	8.48
		15-30	1.44	0.83	10.10	89.55	4.50	5.92
2	TGX1440-4E,TGX1019-2EN, TGX1987-62F,TGX1987-10F	0-15	1.19	0.70	10.55	87.52	5.92	5.92
		15-30	1.29	0.69	7.02	88.20	6.28	6.20
3	Experiment on TGX1448-2E(Depressed portion)	0-15	1.41	0.82	11.06	89.52	4.56	5.92
		15-30	1.37	0.72	10.71	81.56	4.42	6.06
4	Ant hill to the bushTGX1941-4F, TGX1405-17E,TGX1878-7E,Cameroun late,TGX1804-1F, TGX1956-1F, NCRISOY8, TGX1848-4F,TGX19371F,NCRISOY2, TGX1430-20E, NCRISOY17,TGX1908-1F,TGX1019-2E	0-15	1.20	0.59	9.82	82.24	9.28	8.48
		15-30	1.50	0.61	7.42	86.96	8.85	4.48
5	Multiplication of TGX448-2E field	0-15	1.30	0.89	11.21	86.20	12.40	1.42
		15-30	1.27	0.74	10.15	89.60	3.64	6.76

Table 3. Profile description and physico-chemical characteristics of the soil of soybean field at Badeggi, 2012

S/No	Sample and location description	Soil Depth (cm)	Soil Colour	Soil pH	Total Nitrogen (N)%	Available Phosphorous (P)ppm	Exchangeable Cations $Cmokg^{-1}$ Na	K	Ca	Mg	E
1	Horizon A	14.	brown	6.30	0.10	13.25	0.22	0.23	3.36	3.46	0.05
2	Horizon B	23.	gray orange	6.40	0.09	21.25	0.30 0.15		0.18	3.72	4.79
3	Horizon C	62.5	Strong orange brown (laterite)	6.7	0.06	23.30	0.30 0.19		0.18	3.72	4.79

Table 4. Profile description and physico-chemical characteristics of the soil of soybean field at Badeggi, 2012

Organic Matter(om)%	Ogarnic carbon(OC)%	CEC $Cmokg^{-1}$	Sand%	Silt%	Clay%
1.67	0.65	7.23	72.52	3.28	24.20
1.42	0.83	9.18	86.20	3.32	10.48
1.00	0.34	3.5	83.20	6.70	11.10

*The soil samples were analyzed at the National Cereals Research Institute Badeggi, Niger State, Nigeria laboratory.

Conclusion

The physicochemical properties of the soybean field at NCRI Badeggi were very poor in major nutrients (N and K), cat ions, organic matter content and CEC. However, the soil pH was within the neutral level. The presence of P was at a moderate level. Therefore, as a result of very poor contents of organic matter and CEC, leaching of the applied inputs was very high thereby affecting the yield of soybean. The low levels of N and K was also one of the reasons for the poor yield per hectare of soybean realized from the field. The only possible way to reclaim this soil is to adopt the use of organic fertilizer of various sources to increase the organic matter content, nutrient contents and to increase the CEC, thereby improving the activities of microorganism in the soil. Zero or minimum tillage should be adopted to enable the maintenance of the soil structure. Farming systems such as crop rotation, bush fallowing, organic farming (using organic materials that are rich particularly in phosphate and nitrogen), and agro forestry involving the use of trees or shrubs such as *acacia*

(Acacia spp,), shear butter (*Buttyrospermum paradoxi*), locust bean (*Parkia clappertonia*), mungo *(Mangifera indica,),* guava *(Psidium guajafa),* tamarind *(Tamarindus indica)* should be practiced to enable the sustainability of the soil.

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