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SUSTAINABLE SOIL FERTILITY MANAGEMENT FOR OPTIMUM CROP PRODUCTION.

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Abstract

Declining agricultural productivity in Nigeria is a consequence of general mismanagement of the soils. A large area of agricultural land has been damaged and rendered unproductive due to poor soil management practices. Sustenance of soil management in the country therefore entails wise use and maximization of soil resources for optimum soil and crop productivity. Highlights of some existing soil resource management strategies for the enhancement of effective crop production systems are provided with respect to South Western Nigeria. Soil fertility improvement is sustained by effective soil characterization and testing, use of improved fallows, planting of legumes and covercrops, efficient fertilizer use and management, adoption of low input technology involving use of organic fertilizer and supplementation with inorganic fertilizer, use of agro-minerals, alley farming, bio-fertilization, e.t.c. In other to avoid rapid degradation of soils, appropriate methods, which serve to prevent erosion and compaction, are used. These methods include surface mulching, use of minimum tillage for mechanically cultivated land and incorporating appropriate cover and fallow crops in the farming system. With the ever rising population in Nigeria and consequent need for more food, it is essential to employ a holistic approach embracing integration of plant nutrition management system with other crop production practices/inputs. This approach enhances sustainable soil fertility management for optimum crop production in the country.

INTRODUCTION

Major soils found in Sub-Sahara Africa have inherent low levels of fertility. Low productivity of the soil is attributed to low organic matter content, the easily leaching ability of the soils and the low activity clay (e.g. kaolinite). Coarse textured surface horizons, high bulk density and aggregate stability characterize the soils when mechanically cultivated and are easily prone to degradation when improperly managed. The fertility status of these soils deteriorates fast due to high temperature regime and heavy rainfall, which encourage rapid decomposition of organic matter and soil/nutrient loss. In addition, Chiezey and Yayock (1989) opined that the decline in the natural fertility of the soils is acçelerated by pressure on the land caused by urbanization, population growth and industrialization.

Declining productivity of agricultural soils can also be caused by indiscriminate burning of vegetation, inappropriate fertilizer use, exposure of soils to hazardous conditions such as erosion and sun, employing poor soil conservation practices and farming systems, e.t.c. Furthermore, the sole use of fertilizer deficient in micronutrients may cause widespread of micronutrient deficiencies. Inadequate supply of plant nutrients to the soil often causes nutrient imbalance and low crop yield. There is therefore the need to wisely use land and inputs required for sustenance of soil fertility and maximization of soil resources for optimum soil/crop productivity.

A large population of farmers in Nigeria and in Africa in recent times practice multi-cropping, and intensive cropping systems. With these practices, a large amount of nutrients are removed, causing low soil fertility. Shifting cultivation is a common practice among farmers (Agboola & Unamma, 1994). After a short period of continuous cropping, the declining productivity of the soil is the main factor responsible for farmers shifting from poor to a bush fallowed land. Therefore, alternative shifting cultivation and bush fallow serve as a major soil fertility programme embarked upon by most resource-poor farmers in the region.

For the past three decades, agricultural extension services in Nigeria have been laying emphasis on the use of mineral fertilizers for soil fertility improvement. However, the existing economic and technical infrastructures have not been able to meet the needs of resource-poor farmers with respect to regular and adequate supply of chemical fertilizers. Most of the farmers therefore use little or no fertilizer on their crops due to either poverty, or ignorance. A number of farming communities are aware of the rapid results that can be obtained from using mineral fertilizers (Ogunfowora, 1989). As the population increases and more mouths to feed, an approach to integrate farming systems with soil management practices is required for optimum crop production. This paper therefore discusses soil researches and resource management strategies with respect to South Western Nigeria.

SOIL FERTILITY MANAGEMENT PRACTICES

Soil Characterization and Testing:

Agricultural practices have significant impacts on the status and nutrient reserve of the soil. During harvesting of every crop some plant nutrients are removed. During land preparation involving clearing and removal of bushes/thrashes or burning, loss of nutrients is usually high. Such nutrients that are removed should be replaced to obtain maximum crop production. Such replacement is done through fertilizer application with good soil management practices. In most cases, the farmer is faced with the problem of the type and quantity of fertilizer, when and how to apply them. Fertilizers are expensive, and farmers have to be guided on its use to maximize profit per unit of fertilizer input. The solution to these problems is to test the soil before cropping (Adediran and Banjoko, 1995; Adetunji, 1976; Agboola and Corey, 1972). In soil testing, inventory of the plant nutrient reserve is taken. The type of crop that will grow better on a particular soil and appropriate fertilizer practices meant for such soil are recommended. Without carrying out a soil test, the farmer may end up using more or less fertilizer than the soil/crop really needs. This will negatively affect the economic returns of the farmer. Generally, soil testing on farmers' field before cropping/fertilizer application will reduce abuse of fertilizer inputs, boost agricultural production, save money for the farmers and reduce environmental pollution.

Traditional Systems

Shifting Cultivation:

The traditional system of keeping soil fertile through bush fallowing and shifting cultivation is an old agricultural practice. It is an effective and stable method of soil management when land availability is not limiting. The cumulative effect of traditional bush fallow method is the improvement in the physical, chemical and biological properties of soil during the fallow period. Recently, research into the improvement of bush fallow system has provided opportunity in the shortening of bush fallow period by 4 – 6 years or more. This is achieved by planting of legumes/cover crops (Agboola and Unamma, 1994; Adediran et al., 2001).

Green Manuring:

Green manuring is another way of solving soil fertility problem. Legumes like mucuna, centrosema, e.t.c. are worked under the soil while still young. This practice has been found to improve soil fertility when the crops are well incorporated into the soil. But, its demerit has been attributed to the crops inability to give cash returns to the farmers after allocating land, time, and input to the cultivation of such crops.

Cropping system:

Majority of peasant farmers practice mixed cropping, relay cropping and intercropping using legumes and cover crops. In these systems, the economic interest overrides other factors in the choice of crops to combine. Case of incompatibility of the crops to enhance soil fertility are usually recorded after few years of cropping. The usual practice of combining compatible crops such as cereal/legumes involving cereal/cowpea, cereal/soybean, cereal/pigeon pea under intercropping system or in a relay or under sowing have been found to be effective in improving soil fertility (Kang et al., 1984; Adediran et al., 2001).

Agro-forestry:

The effectiveness of trees in restoring soil fertility is highly emphasized in agro-forestry and multi-storied cropping system. The scattered trees growing inside the cropped land have the ability to absorb the leached plant nutrients from the deep layers of soil. The nutrients are later made available to crop plant through decomposition of leaf litter (Kang et al., 1984; Adediran et al., 1999). Planting of shrubs in alley farm has also been regarded as a source of nutrient regeneration for crop production. The leaf litter of these tree and shrub when decomposed, improve the organic matter content, physical and biological properties of soil. The use of *Gliricidia sepium*, *Leucaena lecocephella* in agro-forestry has been well emphasized in south western Nigeria. Application of the plant biomass gave increase in crop yield (Fig. 1).

Use of cover crops and planted fallows:

The use of planted fallows and cover crops (live mulches) can lead to conservation and restoration of soil physical and chemical properties and build-up of soil organic matter. Several works in the tropics have shown the beneficial effect of planted fallows and cover crops in conserving the soil (Lal et al., 1979; Salako and Hauser, 2001). Among the species that can be used for planted fallows and cover crops are *Centrosema pubescence Psophocarpus palustris, Mucuna utilis, Cajanus cajan* and *Leucaena leucocephala.* Using mulches as surface soil covers have been shown to reduce soil erosion drastically (Lal 1976: Cogo et al., 1983; Idowu et al., 2001). Surface mulches, which are usually gathered dried and burnt by the local farmers can prevent direct contact between erosive agents and the soil surface, and dissipate the effects erosive agents where erosion is intensive. This practice also helps in soil moisture conservation, improves soil temperature and aeration.

Other traditional methods of improving soil fertility include, crop rotation, intercropping, slash and burn at land preparation, application of farmyard manure on the farms, e.t.c. All these are carried out by majority of African peasant farmers with low level technology. There is the need to assist farmers in improving the technologies they are familiar with.

Appropriate tillage practices

In order to avoid rapid deterioration of soil, the need for appropriate tillage methods become imperative. Under mechanized tillage, reduction in the number of tractor passes and tillage operations (minimum tillage) on the farm land checks soil erosion. The normal practice of harrow-based tillage in sub-Saharan Africa should be reviewed because of the accompanying soil loss and runoffs resulting from such practice. Conventional tillage (ploughing followed by harrowing) creates a surface condition that is relatively smooth, which offers less storage during the process of runoff. Thus, runoff can build up rapidly, leading to excessive soil loss. Therefore, there is the need to move from harrow-based tillage to a less pulverizing tillage practice. Several authors have shown that increasing the tillage-induced roughness can significantly reduce soil losses and runoff (Cogo et al., 1983; Edwards et al. 1994; Idowu et al., 2001). This implies that ploughing the soil alone should be preferred to ploughing and harrowing. Ploughing alone creates a lot of micro-depressions, which temporarily store water during the rain. These depressions are very strategic to the control of runoffs and soil loss. Currently a study is being carried out at the Institute of Agricultural Research and Training, Ibadan, to access the potentials of ploughing alone tillage practice in raising arable crops compared to ploughing and harrowing. Preliminary results have shown that there is no significant difference in the grain yield of cowpea and maize under ploughing and harrowing treatments (I.A.R.&T. In-house Review Report, 2002).

Efficient Fertilizer Use and Management

Experience with the traditional methods of soil fertility improvement, has shown that the level of production achieved by peasant farmers is very low. These practices have many limiting factors preventing the attainment of maximum crop production. The use of fertilizer has therefore been regarded as a fast approach to increase agricultural productivity in the short run by providing the required plant nutrients and improving soil fertility (Ogunfowora, 1989).

For the past four decades emphasis has been laid on the use of mineral fertilizers to achieve increase in crop production. The use of mineral fertilizers in Nigeria most especially in the South West started with testing of some imported fertilizers on some cash crops grown for export in the 60s. A decade later, testing of the fertilizer materials was extended to some food crops like maize, sorghum, millet, cassava, etc. In the 80s and 90s, there was increasing demand for production of cereals for industrial use. This led to genetic improvement of food crops, which

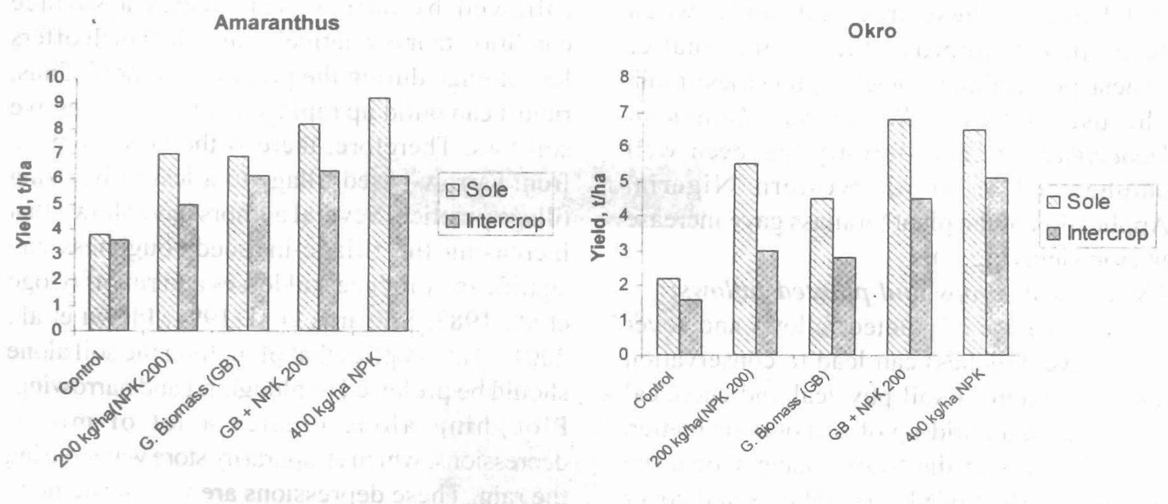

Fig. 1: Effect of gliricidia biomass and mineral fertilizer on the yield of vegetable crops planted as sole and intercrops. (Source: Adediran *et al.* 1999).

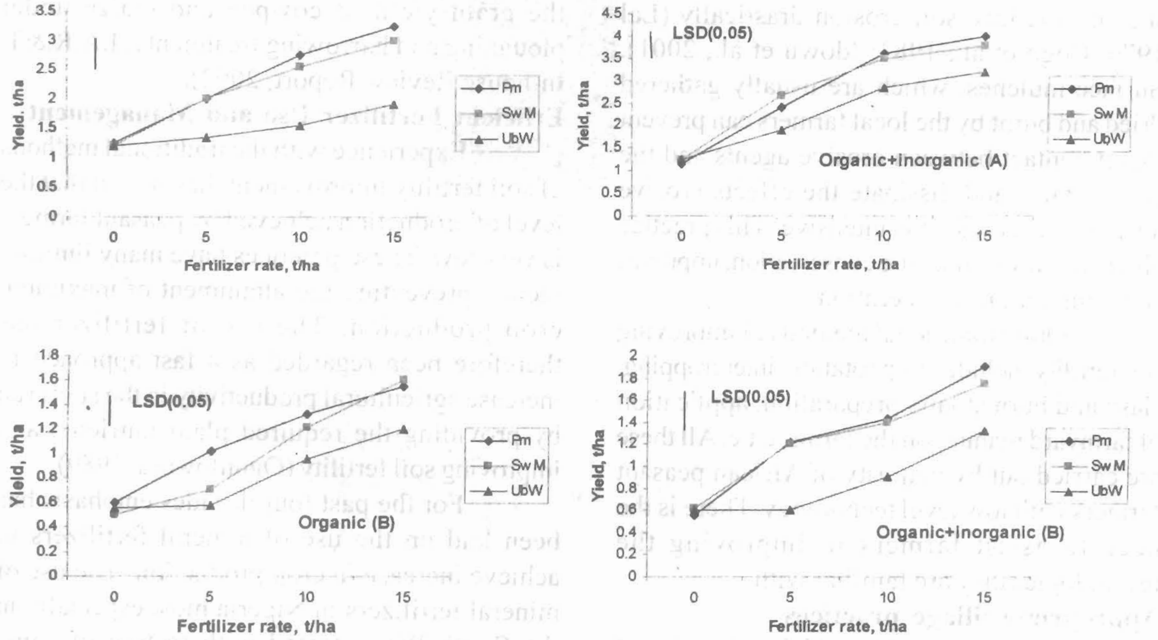

Fig. 2: Effect of organic and complementary use of inorganic fertilizers on maize yield at first (A) and residual (B) croppings. (Source: Adediran *et al.* 1999).

have high fertilizer demand and consequently caused rise in the cost of fertilizers.

Macro-nutrients:

In order to obtain optimum crop production, fertilizer studies were carried out either in long or short-term bases across the country. Such studies involve testing of N, P, and K levels and using different types of fertilizers on various crops. In long-term studies carried out by Amon and Adetunji (1973), optimum fertilizer rates for maize in the savanna was 50kg N/ha, 20-40kg P/ha and 60kg K/ha. Sobulo and Osiname (1985) and Adebusuyi (1986) reported that in the savanna, about 90-100kg N and 40kg P/ha are required for maize under continuous cultivation. However, Kang and Osiname (1979) recommended 90-120kg P/ha on the forest sedimentary sandstone. Sobulo (1980) reported lower N level (30-50kg N/ha) for soils with organic matter between 2 and 3% or more.

Studies reported by Adediran and Banjoko (1985) showed that annual application of the blanket fertilizer recommendation for maize would be effective subject to soil test. This practice prevents accumulation of P and K in the soil over the years. Optimum response of maize to N was 50-100kg/ha, phosphorus 20-40kg/ha and potassium 0-30kg/ha. Results from trials conducted in South Western Nigeria on some nitrogen sources (granular area, prilled area and calcium ammonium nitrate (CAN) showed that granular urea and CAN gave almost similar effect on maize yield. It was established, that CAN leached faster than granular urea and the latter was therefore recommended for production and use in the region (Adediran *et al.,* 1999). However, K problem is more serious on the sandstone sedimentary soils and coastal sands than on basement complex in the forest zone. This is due to low organic matter and potash bearing minerals in the former.

Secondary elements:

Secondary elements such as sulphur (Kang and Osiname, 1976) and magnesium (FPDD, 1994) have been found to be important in crop production. The deficiency of S on maize, rice and soybean is widespread in the savanna. Significant yield response to this element in the derived and southern guinea savanna zones was obtained from applying up to 30kg/ha S. For soybean, application of 10-20kg S is required. Sulphur is better applied using single superphosphate than ammonium sulphate as source of S since the latter has the tendency to cause soil acidity. Agboola and Corey (1976a) observed magnesium deficiency on maize in the savanna. Application of 20-30kg using compound formulation NPK 12-12-17-2MgO would eliminate the deficiency. Magnesium and Ca can be supplied through liming. Amon and Adetunji (1967) suggested the use of lime at 5t/ha. The residual effect of the material was found to last for 3 years. Recently, Oguntoyinbo et al., (1995) showed increased yield of maize using lower rate (2t/ha) of lime. The optimum requirement was based on the equivalence of exchangeable aluminum (Al^{3+}). Application of rate higher than 2t/ha was found to depress both the maize yield and crop uptake of P, K, Mg, Zn, Cu and Mn.

Micro-nutrients:

Lack of micronutrients in most of the compound fertilizers produced in the country has been a limiting factor in crop production. The survey carried out by Agboola and Corey (1976b) was indicative of Zn and Bo deficiency in the savanna. Osiname et al (1973) earlier suggested application of 1-2kg Zn/ha, while on cocoa up to 50kg Zn/ha was recommended. Due to the widespread of S and Zn deficiencies in the savanna region, a fertilizer formulation containing Zn and S provides content as NPK 20-10-10-2S-1Zn is currently being produced by local industries in Nigeria.

Several micronutrient fertilizer formulations are also available in Nigeria. A typical one is Agrolyzer (Adediran, 1991), which is capable of supplying some micro-nutrients. The results of the trials evaluating agrolyzer indicated that vegetable crops derived benefit from the material when mixed with NPK compound fertilizer and this has therefore been recommended to the local industries. Boron (B) as well as iron (Fe) are also important in crop production. Notably, crop like cotton and cocoa respond well to B. Cotton requires about 1kg B/ha while application of B to cocoa has been found to increase yield by up to 40% both in the nursery and field

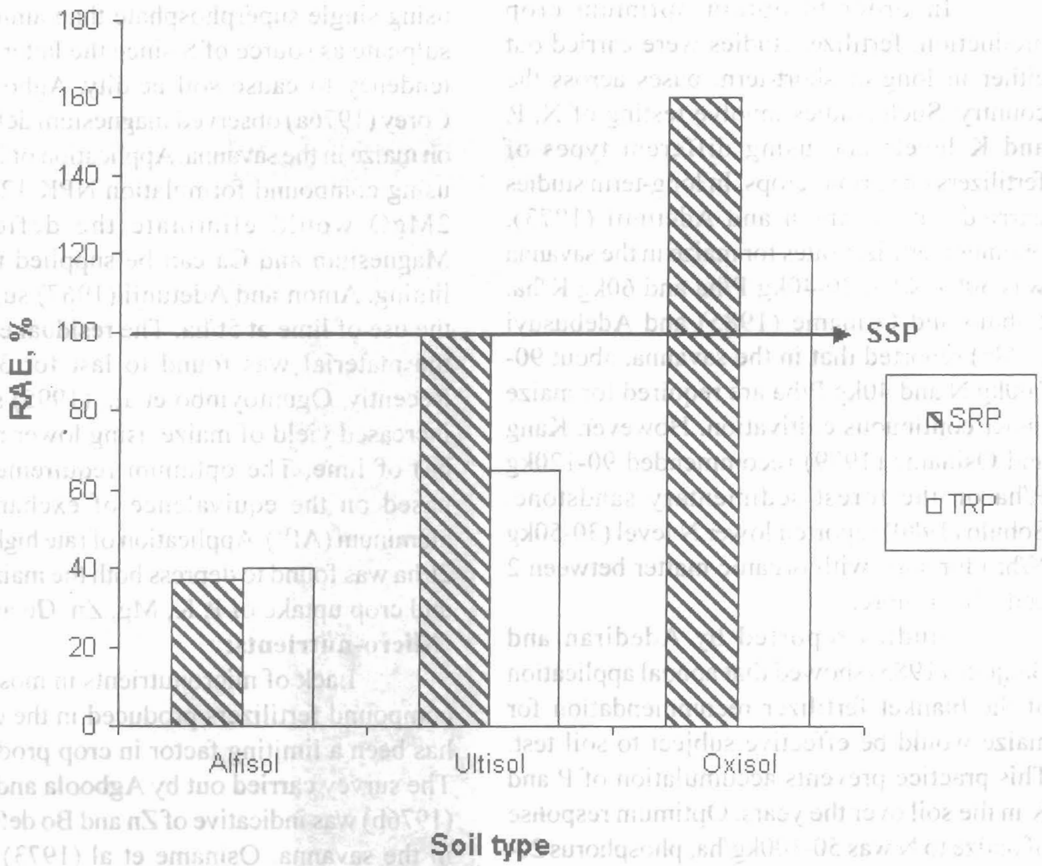

Fig. 3: The relative agronomic effectiveness (RAE) of Togo and Sokoto rock phosphates as compared with SSP applied on three soil types in Nigeria. (Source: Adediran and Sobulo, 1998)

(Omotosho, 1975). Iron problem is localized in few agricultural zones. Kang et al. (1976) in their report indicated some Fe deficiency on upland rice. Chelated Fe, can be used to correct Fe deficiency in crops.

Use of Organic Fertilizers and Agro-Minerals

The belief of most farmers is that the use of inorganic fertilizer is the best solution to soil fertility problems. This makes the input to be widely acceptable among farmers where this can be afforded. However, experience and research findings have shown that continuous cropping on a piece of land with application of inorganic fertilizers reduce both soil physical and chemical properties and consequently crop yield. Application of chemical fertilizers on continuous basis can reduce crop production in soils poor in physical properties. As an alternative, emphasis is now being laid on the use of organic fertilizers such as farmyard manure, green manure, biofertilizer, compost and recycled waste to increase agricultural production. The appropriate use of these materials improves both the physico-chemical and biological properties of soil. They also have the advantage of supplyin[illegible]dditional micronutrients, which are not usu[illegible]ailable in inorganic fertilizers. The organic [illegible]lizer is characterized by slow release of nutrients to crops, but gives improved residual effects on yield of subsequent crops compared to inorganic fertilizers (Fig. 2).

Composting of organic wastes increases the rate of release and enhances crop yield and quality. Recent studies indicated that optimum fertilizer requirement of most arable crops could be met by applying as low as 2.5 – 5.0t/ha and this is more effective when applied in combination with half-recommended dose of inorganic fertilizer (Adediran et al., 1999). Research into the use of agro-minerals as alternative/supplement to mineral fertilizer P was also carried out across the country (Adediran and Sobulo, 1998). Results recommended direct use of Sokoto rock phosphate and several formulations containing the material on mildly acid to acid soils. In order to enhance P availability, the use of partially acidulated form of phosphate rock was recommended. The agronomic effectiveness of phosphate rocks relative to SSP was higher in the acid soils than in mildly acid to neutral soils (Fig. 3).

Biofertilization

The use of microorganism in agriculture is practiced to increase crop production and quality of crops. Rhizobium is one of the soil microorganisms that are used world wide for increasing yield of legumes. Recently, strategies for increasing the efficiency of some of the organisms were identified. As an example, Daramola and Taiwo (1997) suggested optimal level of rhizobial population along with phosphorus in order to ensure effective nodulation and N2 fixation in cowpea. In tropical *Glycine max* (TGX) series of soybean. Taiwo et al. (1999) assessed the importance of rhizobium and phosphorus in their production and suggested adequate inoculation of TGX for optimal yield. Dual use of rhizobium and arbuscular mycorhiza (AM) was similarly assessed on cowpea. Taiwo *et al.* (2000) showed that soybean was found to do well when they were dually inoculated with these microorganisms than when they were inoculated with either of the two organisms or when they were not inoculated at all.

Furthermore, for effective soil fertility management and sustainable crop production, there is the need to formulate soil fertility improvement policy for the whole country based on participatory demand. It is necessary to document soil and fertilizer resources and provide guidelines for soil fertility management, develop integrated plant nutrition management procedures for various crops, and periodically assess the existing strategies put in place for sustainable soil management.

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