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Fertiliser use: one of the keys to attaining and sustaining higher crop yields

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Abstract

The fertility of Uganda soils is on the whole, declining. This is due to poor farming practices characterised by low inputs use, among other factors, and a generally poor farmers' response to soil conservation practices. Decrease in arable land means that farmers can no longer afford long fallow periods to restore/maintain soil fertility. With the majority of Ugandan farming population predominantly rural and practicing subsistence farming, there is need to modernise agriculture in order to feed the rising population. Studies in Uganda and elsewhere have shown that soil fertility and productivity can be maintained through use of inorganic fertilisers supplemented by organic materials. A good fertiliser management programme is preceded by an appropriately conducted soil test complemented with plant tissue analysis and correlated with field crop response data to generate fertiliser recommendations. While a fertiliser recommendation depends on the level of soil fertility, the crop to be grown and the yield goal, fertiliser efficiency depends on the characteristics of the fertiliser material, the timing and mode of application. Attaining and sustaining higher crop yields are a collective challenge to farmers and scientists in the 21st century.

Key words: Declining fertility; productivity; fertilizer use.

Introduction

Declining soil fertility leading to low soil productivity is a serious problem in view of the rising Uganda's population. Fertiliser use combined with soil and water conservation measures, may go a long way in alleviating this situation.

The soil fertility status of Uganda soils

Soils in Africa are among the world's oldest and most intensely weathered, and having sustained agricultural production for a long time they are among the most exhausted. The decline in native fertility is worsened by other factors such as soil erosion and deforestation on top of low input continuous cultivation that characterises much of subsistence farming in Sub-Saharan Africa. Improving the productivity of such soils to a high sustainable level in light of increasing population presents a big challenge to agricultural scientists. The Reconnaissance Soil Survey of Uganda (Chenery et al., 1959) identified a) soils with higher than moderate productivity and b) soils with low or nil productivity. The distribution of these is detailed in Stephens (1970). Table 1 presents ranges for soil analytical data for some Uganda soils as observed from early soil fertility work

Based on earlier soil analytical work (Table 1), one could expect soil acidity, low organic carbon content, N, P and exchangeable Ca as factors likely to limit soil productivity. This was indeed confirmed by soil fertility research work at the time (Webb, 1954; Dept. of Agric., 1955). Foster (1970) reported yield response to lime and potassium fertiliser for several crops in Uganda. Aluminium and Manganese toxicities were also observed in some soils (Foster, 1970; Stephens, 1970). Mughogho and Wortmann (1988) observed that most nutritional disorders in many African soils were linked to low soil pH, including aluminium and manganese toxicity, low plant available P and P fixation, low CEC and low availability of bases. Mukasa Kiggundu (1975) observed that bean performance in Uganda was most affected by soil acidity. Foster (1970) related bean response to lime on the pH and exchangeable Ca level of continuously cultivated Uganda soils. Zake (unpubl.) obtained greater response in bean yield from ash incorporation than when soil was amended with $CaCO_3$ or $CaCO_3$ + K. He attributed this to additional nutrients such as K in the ash. Hitherto, the problems outlined above still exist and in some cases have worsened. Data from recent soil tests at Kawanda soil analytical laboratories (Table 1) show pH values as low as 3.3, and exchangeable Ca, Mg and K values of 4.0, 0.5 and 0.2, respectively, on soils from Kabale district. Organic C levels as low as 0.2 % have also been observed on soils from Kyengera, Mpigi district; organic matter is associated with many other soil characteristics. Total soil nitrogen values as low as 0.02 % have for example, been observed on soils from Adjuman in West Nile. It is clear therefore that the present fertility status of Uganda soils may not be as good as earlier portrayed by Chenery, et al. (1959).

Rationale for using fertilisers

Uganda's population stood at 18.5 million by 1995. With an annual growth rate of 3 %, population is estimated to reach 22 million by the year 2000 (The World Bank, 1996).

Table 1. Ranges of soil analytical data for Uganda soils as observed from early soil fertility work.

	pH	Organic C, %	Total N, %	Truog P, ppm	Organic P, ppm	Exchangeable cations, mg/100g Ca	Mg	K	Mn	H
High	6.0	6.4	0.42	475	680	420	97	109	3.9	15.8
Low	4.5	1.0	0.07	5	170	32	9.6	3.9	0.8	2.4
Critical value	4.5	1.0	0.10	5	—	40	6.0	7.8	3.6	—
Recent low[1]	3.3	0.2	0.02	—	—	4.0	0.5	0.2	—	—

— No data available

[1] Recently observed low values obtained at Kawanda soil analytical laboratory, 1997-98.

Adopted from Stephens, 1970.

Although agriculture contributes about 70 % of GNP, agriculture output for 1985-95 rose by 2.7 % compared to a population growth of 3 %, implying that food production failed to keep pace with the population growth rate. Available data (World Bank, 1996) shows that inspite of the increase in population, per capita food production for Uganda for the period 1970-94 did not increase. There is therefore, an eminent need for increasing food production to feed the rising population.

Secondly, agriculture contributes about 75 % of Uganda's export earnings, and forms the basis of livelihood for the majority of the rural population who make up about 90 % of Uganda's population. Mostly, this is low input subsistence type. In order to achieve increased agricultural output, adoption of improved technology through use of fertilisers, improved seeds and better farming techniques is an absolute necessity. Table 2 shows that use of improved technology in food production would nearly double a farmer's yield and net income. Fertiliser use in crop production is one aspect of this improved technology. Present technology implies local / indigeneous varieties grown without any soil amendments / fertilizer input.

From the agronomic perspective, use of fertilisers has been associated with an improvement in water utilisation by the crop and consequently, yield. Data from ICRISAT showed a 2 to 3 times increase water use, water use efficiency and resulting yield nf pearl millet following fertiliser use compared to the unfertilised fields at three different sites in Niger (ICRISAT, 1985).

Table 2. Yield and income from maize crop at present and improved technology compared.

	Present technology		Improved technology	
Income	Yield, kg/ha	Value, Shs.	Yield, kg/ha	Value, Shs.
Gross	1,500	174,000	2,800	324,800
Net		78,406		145,870

Adopted from Ministry of Agriculture, 1990, Annex B.

Thirdly, with Uganda's agriculture predominantly characterised by low use of inputs, there is a continuous removal of soil nutrients over time through crop harvesting especially where residues are not recycled. This is aggravated by unfavourable farming practices such as slash and burn, leading to a progressive decline in soil nutrient status, hence soil productivity. Stephens (1969) observed a 13 – 20 % decline in the yield of several crops at different sites in Uganda due to continuous cropping. Jones (1972) reported declines in crop yields and soil (0-15 cm) organic matter, total N, total P, pH, and exchangeable Ca, K and Mg after 2.5 years of cropping a newly opened field at Namulonge. Some of the decline in soil characteristics above were regained during the 2.5 year fallow period, with a corresponding increase in yield. With land availability increasingly limiting, resting periods have become shorter and cropping periods longer. In many areas farmers have resorted to continuous cropping, hence a progressive decline in soil fertility and a corresponding decrease in yields. Table 3 presents data for the variation in nutrient status of soils after different years under coffee. There is a clear decline in soil pH, exchangeable Ca, Mg and CEC, although the K status varied irregularly, while P tended to increase possibly due to replenishment from the decomposing litter. The trend for decreasing pH, Ca and Mg was reversed following the application of dolomitic limestone two years prior to sampling. Le Mare (1968a) reported significant response to P in a range of crops in both pot and field experiments on an acid, low organic

Table 3. Changes in nutrients status in a coffee plantation over a thirty-year period.

Age of coffee	pH	P		K	Ca		Mg	CEC	Percent of CEC
(years)		ug/ml	---	mg/100g	---	cmol/kg	K	Ca	Mg
1	5.9	12	26.1	130	25.9	24	2.8	27	9.1
11	5.0	16	35.9	156	37.2	20	4.5	38	15.0
30	4.0	21	20.3	10	2.4	16	3.3	3	1.3
30*	4.6	16	15.6	36	15.6	15	2.6	11	8.5

* Three tonnes of dolomitic limestone applied during two years prior to sampling.
Adopted from Willson, 1985.

matter, Buganda red clay loam soil at Namulonge particularly after years of continuous cultivation. The response to P was reflected in plant tissue P content of a number of crops rather than yield. Table 4 summarises data for estimated nutrient removal for some common crops at the stated yield levels.

Clearly, crop harvesting is associated with huge nutrient removal and if these are not replenished there will be a continuous decline in soil fertility and productivity. Catani and de Moraes (1958) reported soil nutrient removal by five year old arabica coffee as 277, 36.7, 28.2, 180 and 55 kg/ha for N, P_2O_5, K_2O, CaO and MgO, respectively. Further soil nutrient losses occur through erosion and leaching,

Table 4. Nutrient removal for common crops at stated yield levels.

Crop	Yield level	Nutrient removal (kg/ha/growing cycle)		
		N	P_2O_5	K_2O
Banana	25 ton/ha	17-28	6-7	56-78
Dry beans	1 ton/ha	31.0	3.5	6.6
Maize	6 ton/ha	165	55	135
Robusta coffee		135	35	145
Cassava (cultivar 53101)*	7.4 ton/ha	27.1	16.0	85.2

Source: Sys, et al., 1993.
* Source: IITA. 1990. Yields for cassava represent tuber dry matter yield.

depleting the soil nutrient reserve. There is therefore need the replace nutrients so lost or removed, through use of fertilisers in order to sustain crop production. This could be in form of inorganic or organic fertilisers, supplemented with other practices such as mulching or crop residue recycling.

Fertiliser use in Uganda

From studies on the fertility of Uganda soils, Jones (1972) attributed the failure of inorganic fertilisers to raise yields of arable crops, or to maintain soil fertility, to the use of non balanced fertiliser materials, among other factors. Stephens (1969) observed that yields of several crops in Uganda were maintained by N, P and K fertilisers as well as farmyard manure. Nitrogen was most limiting and K the least, with P intermediate. However, response to K increased with continued cropping. Kraal manure or a period of rest was more effective in restoring soil fertility than any inorganic fertiliser treatment. With the majority of Uganda soils intensely weathered and exhausted, however, the main source of nutrients is closely associated with organic matter which, being derived from vegetation, could potentially supply all nutrients (Jones, 1972). Foster (1980) observed that groundnut performance on ferallitic soils in Uganda were largely dependent on organic matter mineralisation to release soil phosphate. Response to applied P was related to mean organic matter levels and to factors which affect its mineralisation. Leguminous green manure crops have been tried for improvement in soil fertility and consequently, crop yields. Wortmann et al. (1994) reported 180 and 240 % increase in maize grain yields following crotalaria (*C. ochroleuca*) in sole crop compared to maize followed by maize in on-station and on-farm trials, respectively. Kaizzi and Wortmann (1998) observed a 41

%, 60 % and 50 % increase in maize yields following a one season fallow with crotalaria, mucuna (*M. pruriens*) and lablab (*Dolichos lablab*), respectively. Together with canavalia (Canavalia ensiformis), these crops have also been associated with improvement in soil moisture, improved soil tilth and suppression of weeds. Thus, where costs limit use of inorganic fertilisers, organic fertilisers can be used. The amounts of organic material required for equivalent effectiveness as inorganic fertilisers are however, high. As a general guide for farmyard manure, for example, 2.5 tonnes of farmyard mauure is equivalent to 500 kg of 10:7.5:15 fertiliser (Simpson, 1986). In addition, some nutrients in manures are not immediately available for crop use but become available slowly over time. It is apparent therefore that use of organic materials could go a long way in maintaining Uganda's soil productivity. Despite the many known benefits associated with fertilisers, fertiliser use in Uganda is very low. Socio-economic reasons and lack of information on part of farmers (weak agricultural extension services)
are partly responsible for this, among other factors.

Importance of soil and plant testing in soil fertility management

Soil analysis serves as a diagnostic tool in identifying physical and chemical/fertility limitations: deficiencies, toxicities and imbalances in a particular soil. Apart from a proper soil sampling protocol and analysis procedures, a soil test result is characteristic of a particular soil and depends on the past crop and soil management history. Correlation of a soil test result with crop response provides a basis for a sound fertiliser recommendation. A fertiliser recommendation depends on the level of soil fertility, the crop to be grown and the yield goal. Fertiliser efficiency, on the other hand, depends on the type and characteristics of the fertiliser material to be used as well as the timing and mode of application. Frequently, a soil test is complemented with plant tissue analysis as a diagnostic tool. Weil et al. (1990) observed that the fertility requirements of maize growing on soils of different fertility and crop and soil management history were best indicated by plant analyses rather than soil test values. They recommended use of both soil and plant analytical data in making fertiliser recommendations. Numerous fertiliser trials between the 1950s and early 1970s led to the development of soil test procedures and interim fertiliser recommendations for different crops in various parts of Uganda. Table 5 is a summary of the recommendations.

Fertiliser resources of Uganda

Kisitu (1991) identifies two types of rock phosphate: the hard igneous less reactive type (apatite) such as one found at Sukulu Hills, Uganda, and the reactive sedimentary rock phosphate. Butegwa et al. (1996) attributed the ineffectiveness of the raw phosphate rock from Sukulu in

Table 5. Interim fertiliser recommendations for different crops at selected locations in Uganda.

Location	Crop	Fertiliser management
Moyo, Mbarara, Soroti, Gulu, Apac	Cotton	45 kg P_2O_5/ha at planting, 52.5 kg N/ha at 4-5 weeks old.
Masaka, Jinja, Luwero	Cotton	26.3 kg N/ha at 4-5 weeks old.
Soroti, Rakai, Arua, Lira	Ground nuts	22.5 kg P_2O_5/ha at planting.
Mbale, Kapchorwa	Maize	22.5 kg P_2O_5/ha at planting 52.5 kg N/ha at knee high.
Masindi, Hoima, Kibale	Maize	52.5 kg N/ha at knee high **OR**, in 2 split applications: the first at planting the second knee high.
Tororo, Bushenyi, Nebbi, Kitgum, Moyo	Finger millet	22.5 kg P_2O_5/ha at planting 52.6 kg N/ha at planting.
Kapchorwa	Wheat	22.5 kg P_2O_5/ha at planting.
Most parts of Uganda	Beans	22.5 kg P_2O_5/ha at planting 26.3 kg N/ha at planting.
Most parts of Uganda	Robusta coffee	65 kg N/ha per season (130 kg N/ha per year), **OR** 105-147 g N/tree per year.
Mbale, Rukungiri	Arabica coffee	105 kg N/ha per year

Source: Ministry of Agriculture and Forestry. 1985.
However, these recommendations (Table 5) need updating to reflect the decline in soil fertility over the years.

providing plant available P to its high Fe_2O_3 content. Concentrating the phosphate rock by magnetically removing the Fe_2O_3 improved the reactivity of the phosphate rock and increased dry matter yields and P uptake of maize. Phosphate rock has been found to be more effective in acid soils that are extremely deficient in P (Khasaweh and Doll, 1978). According to Kisitu (1991) direct application of phosphate rocks would be cheaper, environmentally safer since they do not produce free acid, and have longer residual effects in soil compared to high analysis chemical phosphate fertilisers. However, due to their low P release, rock phosphates may not supply the P needs for seasonal crops.

Conclusion

In order to improve and sustain crop yields to feed Uganda's expanding population, researchers need to seriously address the problem of declining soil fertility. In addition to promoting the use of chemical fertilisers, there is need to investigate and promote ways of improving soil productivity through better use of soil and water conservation practices as well as use of locally available and sometimes, more affordable fertiliser materials.

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