Chapter 12
Fertilizer Recommendation for Maize, Sorghum, Millet, Cowpea, Soybean and Cotton in Nigeria

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Abstract Nigeria, like most sub-Sahara Africa countries, is an agrarian country its heavy reliance on petroleum as a major source of income notwithstanding. Fertilizer is one of the most important inputs needed for increased and sustained crop and soil productivity. This is because most of the soils are inherently poorly endowed with many of the essential nutrients required by crops grown in Nigeria. Due to the fact that fertilizers must be used judiciously to ensure good economic returns and minimize any deleterious environmental consequence, there is the need to determine the right source, right rate, right placement method and time of application (4Rs). This is further necessitated by the high spatial variability of Nigerian soils occasioned by diverse rocks from where they are formed, the climate, vegetation and other soil forming factors. Efforts have been made by Agronomists and Soil Scientists since 1937, when inorganic fertilizers were introduced into Nigeria, to ensure that the four Rs of best fertilizer management practices (BFMPs) are put in place. This paper reviews the development in fertilizer recommendations for some selected crops in Nigeria. It ascertained that before a recommendation is made necessary steps such as correlation and calibration studies, and the establishment of critical soil test levels are carried out; such trials result in average recommendations for a crop within an area which are normally put out by approved extension agencies for adoption by farmers. Most of these efforts were aimed at maximizing crop yields while a few studies included information on maximizing profits and providing options for different economic categories of farmers to use this input. The paper posits that to ensure site-specific recommendation, efforts should be geared towards the employment of decision support tools such as Nutrient Expert and Rice

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Advisor, among others and soil tests with innovative tools such as the SoilDoc and other soil test kits.

Keywords Fertilizer recommendation • Site-specific • Soil test

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12.1 Introduction

Agriculture is strategic to the Nigerian economy and plays the key roles of supplying food for the population, raw materials for industries, earning high foreign exchange which is next only to that from crude oil, providing market for the industrial sector and a key contributor to wealth creation and poverty alleviation. About 70% of the population derive their living from agriculture and agro-allied activities, with the sector contributing about 41% of the Gross Domestic Product (GDP) and accounting for 5% of total export.

It is estimated that about 800,000 square km (80 million hectares) of the total land area of Nigeria of 923,000 square km are cultivable but only about 40% is currently under cultivation. Similarly, of the estimated 3.14 million hectares of irrigable land area only about 220,000 hectares (7%) is utilized. Small-scale farm holdings predominate in Nigeria, accounting for 81% of the total area under cultivation and about 94% of agricultural output, with commercial farms producing the remaining balance.

It is generally accepted that the soils are of poor inherent fertility due largely to the fact that soils in Nigeria have formed from the residues of deeply weathered, complex base rocks and alluvial materials under humid to dry tropical conditions. Most of the soils are therefore highly leached resulting in medium to high acidity, moderate to low cation exchange capacity and base saturation, and low organic matter content. The concentration of available levels of nitrogen, phosphorus and potassium are correspondingly low. Many of the soils are susceptible to erosion due to their relatively low nutrient status and organic matter content, and fragile structure. Soil degradation and attendant depressed yields due to nutrient mining, and inadequate soil and moisture conservation practices, has already reached severe proportions in parts of the country. Soil nutrient replenishment from organic and mineral sources is therefore a prerequisite for continuous cultivation of such soils particularly under intensive production. Additionally, Nigerian soils, like most other tropical soils are inherently micro-variable within short distances. This is complicated by geographical location, climatic factors, vegetation, and land use. The implication is that the native soil fertility is not uniform; therefore, any amendment of such soil with exogenous material like fertilizer must be applied with caution after appropriate soil testing and precise calculation to ensure nutrient balancing and cater for environmental concerns. Therefore, there is no scientific basis for extrapolative application of fertilizer, except if the climate and soil grouping is found to be the same across the same region.

The afore-stated facts point to enormous potentials that are yet to be exploited in agriculture. For the potentials to be realized several current Government policies such as deregulation of seed and fertilizer sectors, marketing reforms to structure markets, innovative financing for agriculture, new agricultural investment framework could help propel the action. These however need efficient utilization of inputs such as improved germplasm, fertilizer and water to succeed. Efficient fertilizer use can be achieved when the four Rs of best fertilizer management practices (BFMPs): Right source, Right rate, Right place, Right time of application are adopted. This requires that good fertilizer recommendations that are crop and soil specific be formulated.

This paper is an attempt to review fertilizer recommendation of some crops, their usefulness and shortcomings and way forward for more appropriate proposals that should improve nutrient use, crop and soil productivity.

12.2 History of Fertilizer Use in Nigeria

As in most parts of tropical Africa, the traditional method of maintaining soil fertility and productivity in Nigeria has been the bush-fallow system whereby arable land is allowed to revert to fallow after 3–4 years of continuous cultivation. The growing human population and other socio-economic pressures on available land has made this practice difficult to sustain. Attempts to improve soil fertility by planting legumes and grass fallows have not been popular and are inadequate for higher yielding and nutrient demanding crops and production systems. The use of manures, particularly where there were large numbers of animals, replaced the fallow system and brought into eminence the agricultural value of farm yard manure (FYM), household refuse, and other organic materials. The first recorded indication of the potential values of inorganic fertilizers in Nigeria was in 1937 when it was shown that response of cereal crops to small applications of FYM was matched by the use of single super-phosphate (SSP) containing equivalent quantities of phosphate. The need to apply fertilizer to depleted soils to resuscitate plant productivity heralded fertilizer use experimentation on the response of crops to applied nutrients such as N, P, and K. The combined application of inorganic and organic fertilizers, especially farmyard manure (FYM) has been advocated by Nigerian agronomist; predating the current ISFM paradigm. This is predicated on research results which established that combined application gave significantly higher yields than either the inorganic or farmyard manure alone. The consensus among the scientist is that the FYM be applied once in two to three years of continuous cropping supplemented with small amounts of inorganic fertilizers. The main constraints associated with use of organic fertilizers include the fact that dung production is constrained by the prevalent semi-nomadic husbandry practices. Additionally, the material is often of low quality because very little attempt is paid to the storage and handling.

Widespread adoption of fertilizer began in the late 1970s with the proliferation of Agricultural Development Projects (ADPs), but overall levels of fertilizer use have been too low to compensate for soil nutrient removal. Today, Nigerian farmers have recognized the importance of fertilizers as a n indispensable input in their crop production ventures, albeit numerous problems militating against their desire to use this important input. The current national average NPK use hovers at 18 kg/ha of arable land (World Bank 2016). This situation persists in spite of the numerous efforts such as involvement of private sector to establish manufacturing and bulk blending plants, institution of subsidy and other agricultural programmes aimed at boosting fertilizer use and crop productivity. Agronomists and Soil Scientist have put in tremendous efforts in providing needed information with respect to appropriate fertilizer recommendation for the crops grown in the country. The current fertilizer recommendation in Nigeria are reported in a manual titled Fertilizer Use and Management Practices for Crops in Nigeria, compiled by the National Fertilizer Use Committee under the auspices by the Federal Fertilizer Department of the Federal Ministry Of Agriculture and Rural Development; It is edited by Chude et al. (2012).

While inorganic fertilizer use has boosted soil fertility and crop production, use of wrong types, rates, placements and timing has created challenges. For example, the continuous application of sulfate of ammonium resulted in the gradual acidification of the soils, so its use was stopped in 1969. Low fertilizer use efficiencies are due to inability or unwillingness of farmers to follow the 4Rs of best fertilizer management practices of applying right fertilizer types at the right rate and time to the right place. This, coupled with use of poor germplasm and non adoption of good husbandry practices has created wide yield gaps between breeders' on-station potential yield predictions and realities from farmers' fields.

12.3 How Fertilizer Recommendations Are Derived

Current fertilizer recommendations for sole crops in Nigeria come from extensive laboratory and/or field trials over time and space. After correlation and calibration studies, and the establishment of critical soil test levels, such trials result in average recommendations for a crop within an area which are normally put out by approved extension agencies for adoption by farmers. However, where an approved fertilizer practice is considered inadequate or where no formal recommendation is available, the Fertilizer Use Committee puts forward suggested practices on the basis of existing information, individual or common knowledge and experience. Details of current recommendations have been documented in a monograph titled, *Fertilizer Use and Management Practices for Crops Nigeria* authored by Chude et al. (2012).

The fertilizer recommendations are accompanied by some salient husbandry practices such as appropriate varieties for each agro-ecology, seed rate, time of planting, disease and weed control, fertilizer rate, fertilizer application time and methods. Commonly yields obtainable and yields under good management are also indicated.

Some of the fertilizer recommendations for the crops are further disaggregated based on soil test levels and agro-ecologies. The criteria for soil fertility classes are as defined below:

Low – The value below critical level
Medium – The range above critical level where variable response to fertilizer is expected
High – The range where response is unlikely and fertilization may not be necessary

Categorization of soil test levels of some nutrients used in fertilizer recommendations are as follows:

	Rating for soil fertility classes			
Nutrient	Very low	Low	Moderate	High
Nitrogen (Total N, g kg^{-1})	0.3–0.5	0.6–1.0	1.1–2.0	2.1–2.4
Phosphorus (Bray – 1-P, mg Kg^{-1})	<3	3–7	7–20	>20
Exchangeable. K, (cmol kg^{-1})	0.12 – 0.2	0.21–0.3	0.31–0.6	0.61–0.73
Zinc (DTPA) mg kg^{-1}		<1.0	1.0–5.0	>5.0
Boron (Hot H_2O soluble) mg kg^{-1}	<0.35	<0.35–0.5	0.5–2.0	<2.0

The following Tables are the fertilizer recommendations for the selected crops. All are sourced from *Fertilizer Use and Management Practices for Crops in Nigeria* authored by Chude et al. (2012) (Tables 12.1, 12.2, 12.3, 12.4, 12.5, 12.6, 12.7, 12.8, 12.9, 12.10, 12.11, 12.12, 12.13, 12.14, 12.15 and 12.16).

Fertilizer recommendation to farmers in Nigeria often appears as straight N, P, or K e.g. urea, SSP and muriate of potash. However to make it more convenient for the farmers to apply fertilizer-nutrient needs in one single formulation, the use of compound fertilizer 15-15-15 has been very widely adopted by farmers. In fact over 70% of all fertilizer used in Nigeria today is in the form of 15-15-15. The problem with too much reliance on 15-15-15 is that this fertilizer has low N and P content, and it lacks sulphur or zinc. Yet supplementary sulphur and zinc appear to be necessary for optimum crop performance in many parts of the country, particularly, the savanna grasslands. There is indication that B may also be needed in some parts. The under listed crop and soil fertilizer formulations were developed from Soil Fertility Maps of Nigeria:

The authors of the monograph realize that, whichever of these is produced, there is need to conduct field studies to determine the optimum rates for different crops under different soil fertility conditions. Certain parts of the country may have

Table 12.1 Recommended maize varieties for different agro-ecological zones

Agro-ecological zone		Recommended maize variety
Sahel	Open pollinated Hybrid:	TZSR – Y , TZSR – W, 8644 – 27, 8341 – 58322 – 13, 8425 – 8
Sudan	Open pollinated Hybrid:	As in Sahel + DMRSR – Y, DMRSR – N DMRsR – N
		8341 – 6 8341 – 5, 8322 – 13, 8425 – 8 8644 – 27
Northern Guinea Savanna	Open pollinated Hybrid:	As in Sudan
		As in Sudan
Southern Guinea	Early season	TZSR – Y, TZSR – W, TZB, TZPB, FARZ34, FARZ227
	Open pollinated	FARZ7 WESTERN YELLOW. NCA, NCB
Savanna and Forest	Hybrid:	8329 – 15, 8329 – 22, 8329 – 19, 8425 – 18
		8236 – 17, 8339 – 17, 8428 – 19, 8321 – 18, 8322 – 13
	Late season	DMR-SR-Y, DMR-SR-W, EV8443-SR-W, EV8423-SR-Y
	Open pollinated Hybrid:	8341 – 6, 8341 – 5

Table 12.2 Fertilizer recommendations for maize (open pollinated) (based on soil test/soil fertility map)

Nutrient	Fertility class	Nutrient rates ha^{-1}	Fertilizer rate and source/ha^{-1}
Nitrogen	Low	120 kg N	Urea (260 kg or 5 bags) or CAN (462 kg or 9 bags or 20-10-10) (600 kg or 12 bags). Apply half the rate of N at planting or 2 – 3 WAP and the remaining half at 5 – 6 WAP.
	Medium	60 kg N	Urea (133 kg or 2½ bags) or CAN (231 kg or 4½ bags) or 20-10-10 300 kg or 6 bags)
	High	30 kg N	Urea 63 kg or 1½ bags or CAN 115 kg or 2¼ bags 150 kg 20-10-10 or 3 bags
Phosphorus	Low	60 kg P_20_5	SSP (333 kg or 7 bags) or SSP 3 bags at planting or 2 – 3 WAP
	Medium	30 kg P_20_5	SSP (167 kg or 3 bags) at planting or 2 – 3 WAP
	High	Nil	-
Potassium	Low	60 kg K_20	MOP (100 kg or 2 bags) at planting or 2 – 3 WAP
	Medium	30 kg K_20	MOP (50 kg or 1 bag) at planting or 2 – 3 WAP
	High	NIL	NIL

specific needs that are different from the recommended formulations. Specific formulations may be recommended for such areas.

Most fertilizer recommendations, including those contained in the monograph currently in use in Nigeria were made for maximizing yield and little consideration for maximizing profits. Moreover, current recommendations guiding fertilizer use

Table 12.3 Fertilizer recommendations for Guinea corn (Sorghum) (based on soil test/soil fertility map)

Nutrient	Fertility class	Nutrient rates ha^{-1}	Fertilizer rate and source ha^{-1}
Nitrogen	Low	64 kg N	Urea (142 kg or 3 bags) or CAN (246 kg or 5 bags) or 20-10-10 (320 kg or 6¼ bags)
	Medium	32 kg N	Urea (71 kg or 1½ bags) or CAN (123 kg or 2½ bags) or 20-10-10 or (160 kg or 3¼ bags)
	High	16 kg N	Urea (35 kg or ¾ bag) or CAN (61 kg or 1¼ bags) or 20-10-(10 180 kg or 1¾ bags)
Phosphorus	Low	32 kg P_20_5	SSP (178 kg or 4 bags) or (71 kg or 1½ bags
	Medium	16 kg P_20_5	SSP (89 kg or 2 bags) (36 kg or 1 bag)
	High	NIL	NIL
Potassium	Low	30 kg K_20	MOP (50 kg or 1 bag)
	Medium	15 kg K_20	MOP (25 kg or ½ bag)
	High	NIL	NIL

Table 12.4 Generalized fertilizer recommendations for guinea corn (sorghum) (based on agro-ecological zones)

Agro-ecological zone	Recommendation (nutrient ha^{-1})	Material ha^{-1}
Sahel	**64 kg N**	Urea (142 kg or 3 bags) or CAN (246 kg or 5 bags) 20-10-10 (220 kg or 6½ bags)
Sudan	**32 kg P_20_5**	SSP (178 kg or 4 bags)
Northern Guinea	**30 kg K_20**	MOP (50 kg or 1 bag)
Savanna		
Southern Guinea	**32 kg N**	Urea (71 kg or 1½ bags) or CAN (123 kg or 2½ bags) or 20-10-10 (160 kg or 3¼ bags)
	16 kg P_20_5	SSP (89 kg or 2 bags)
Savanna and Forest	**15 kg K_20**	MOP (50 kg or 1 bag)

in Nigeria were developed over 30 years ago and many are out dated and do not reflect current soil, crop and weather situations. Additionally, these recommendations were formulated from results of soil samples collected from non-geo-referenced sites and, therefore, do not account for the indigenous potential supply of soils, climatic potential of the various AEZs, economic considerations, and fertilizer availability.

While all farmers can profit from fertilizer use, only those with adequate finance may strive to maximize net returns per hectare resulting from fertilizer use. Others need to maximize return on their limited investment. For example by increasing the use and correct application of fertilizer, poor farmers surveyed in Nigeria were able to improve their yields by approximately 30–55%. In turn, they benefited by

Table 12.5 Fertilizer recommendations for millet (based on soil test/soil fertility map)

Nutrient	Fertility class	Nutrient rates ha^{-1}	Fertilizer sources and rate ha^{-1}
Nitrogen	Low	60 kg N	Urea (131 kg or 3 bags) or CAN (231 kg or 5 bags) or 20-10-10 (300 kg or 6 bags)
	Medium	30 kg N	Urea (65 kg or 1½ bags) or CAN (115 kg or 2½ bags) or 20-10-10 or (150 kg or 3 bags)
	High	15 kg N	Urea (32 kg or ¾ bag or (CAN 57 kg or 1 bag) or 20-10-10 (75 kg or 1½ bags)
Phosphorus	Low	30 kg P_20_5	SSP (167 kg or 3 bags) or TSP (67 kg or 1 bag)
	Medium	15 kg P_20_5	SSP (83 kg or 1½ bags) or TSP (33 kg or ½ bag)
	High	NIL	NIL
Potassium	Low	30 kg K_20	MOP (50 kg or 1 bag)
	Medium	15 kg K_20	MOP (25 kg or ½ bag)
	High	NIL	NIL

Table 12.6 General fertilizer recommendations for millet (based on agro-ecological zones)

Agro-ecological zone	Recommendation (nutrient ha^{-1})	Material ha^{-1}
Sahel	60 kg N	Urea (131 kg or 3 bags) or CAN (231 kg or 5 bags) 20-10-10 (300 kg or 6 bags)
Sudan	30 kg P_20_5	SSP (167 kg or 3 bags)
Northern Guinea	30 kg K_20	MOP (50 kg or 1 bag)
Savanna		
Southern Guinea	30 kg N	Urea (65 kg or 1½ bags) or CAN (115 kg or 2½ bags) or 20-10-10 (150 kg or 3 bags)
	15 kg P_20_5	SSP (82 kg or 1½ bags)
Savanna and forest	15 kg K_20	MOP (25 kg or ½ bag)

Table 12.7 Fertilizer recommendations for upland and lowland rice (based on soil test/soil fertility map)

Nutrient	Fertility class	Upland rice	Lowland rice
N	Low	80 kg N	100 kg N
	Medium	60 kg N	80 kg N
	High	40 kg N	40 kg N
P	Low	30 – 40 kg P_20_5	40 – 50 kg P_20_5 "b"
	Medium	30 kg P_20_5	40 kg P_20_5
	High	NIL	NIL
K	Low	30 – 40 kg K_20	30 – 40 kg K_20
	Medium	30 kg K_20	30 kg K_20
	High	NIL	NIL

Table 12.8 Recommended upland rice varieties for the different agro-ecological zones

Agro-ecological zone	Recommended upland rice variety
Sahel	FARO 45, FARO 46 EX-China, FARO 55 (NERICA 1)
Sudan	FARO 45, FARO 46, EX-China, FARO 38, FARO 39 FARO 55 (NERICA 1)
Northern Guinea Savanna	FARO 46, FARO 39, FARO 38, FARO 11, FARO 45 FARO 55 (NERICA 1), FARO 56 (NERICA 2) FARO 58 (NERICA 7), FARO 59 (NERICA 8), FARO 62 (OFADA 1), FARO 63 (OFADA 2)
Southern Guinea Savanna	FARO 46, FARO 48, FARO 49, FARO 43, FARO 41 FARO 55 (NERICA 1), FARO 56 (NERICA 2) FARO 58 (NERICA 7), FARO 59 (NERICA 8), FARO 62 (OFADA 1), FARO 63 (OFADA 2)
Forest	FARO 46, FARO 48, FARO 49, FARO 43, FARO 41 FARO 55 (NERICA 1), FARO 56 (NERICA 2) FARO 58 (NERICA 7), FARO 59 (NERICA 8), FARO 62 (OFADA 1), FARO 63 (OFADA 2)

Table 12.9 Recommended lowland rice varieties for different agro-ecological zones

Agro-ecological zone	Recommended lowland rice variety
Hydromorphic and inland valley swamp	FARO 44, FARO 52, FARO 31, FARO 15, FARO 28, FARO 51 FARO 62 (OFADA 1), FARO 63 (OFADA 2), FARO 60 (NERICA L19), FARO 61 (NERICA L34)
Shallow swamp and irrigated swamp	FARO 44, FARO 52, FARO 51, FARO 27, FARO 29, FARO 37, FARO 60 (NERICA L19), FARO 61 (NERICA L34)
Deep water and floating	FARO 15, CK 73, DA 29, BKN 6986 – 17, ROK 5, IR 54
Mengrove	FARO 15, ROK 5, WAR 77-3-2-2, FARO 28, IR 54

Table 12.10 Fertilizer recommendations for groundnut in different agro-ecological zones

Agro-ecological zones	Recommendation (nutrient ha^{-1})	Material ha^{-1}
All Zones	**54 kg P_20_5**	SPP (300 kg or 6 bags) or TSP (120 kg or 2½ bags)
	25 kg K_20	Muriate of potash (42 kg or 1 bag)
		As above

Table 12.11 Groundnut varieties suitable for different agro-ecological zones

Agro-ecological zone	Recommended groundnut variety
Sahel	Spanish 205, T.47 – 56
	Natal common.
Sudan	Spanish 205, T.47 – 56, 55 – 437 (ex – Dakar) Red Bulk
	Nata common, 55 – 437, 48 – 115B (IAR Cross-breed)
Northern Guinea	Samaru 38, MSS 39, MS 358, DS 5418, RMP 12, M554 – 76
Savanna	MK 374, MS 539, Samaru 61, G.153
Southern Guinea	M.25 – 68*, T.37 – 47
Savanna and Forest	

Table 12.12 Fertilizer recommendations for cowpea and soybean (based on soil test/soil fertility map)

Nutrient	Fertility class	Nutrient rates ha^{-1}	Fertilizer rate and source ha^{-1}
Nitrogen	Low	20 kg N	Urea (44 kg or 1 bag) or CAN (74 kg or 1½ bags) or 20-10-10 (100 kg or 2 bags)
	Medium	10 kg N	Urea (22 kg or ½ bag) or CAN (37 kg or ½ bags) 20-10-10 (50 kg or 1 bag)
	High	NIL	NIL
Phosphorus	Low	40 kg P_20_5	SSP (222 kg or 4½ bags) or TSP (89 kg or 2 bags)
	Medium	20 kg P_20_5	SSP (111 kg or 2 bags) or TSP (44 kg or1 bag)
	High	NIL	NIL
Potassium	Low	20 kg K_20	MOP (33 kg or 1 bag)
	Medium	10 kg K_20	MOP (16 kg or ½ bag)
	High	NIL	NIL

Table 12.13 Fertilizer recommendations for cowpea and soybean (based on agro-ecological zone)

Agro-ecological zones	Recommendation (nutrient ha^{-1})	Material ha^{-1}
Sahel and Sudan	**20 kg N**	Urea (44 kg or 1 bag) CAN (74 kg or 1 ½ bags)
	40 kg P_20_5	20-10-10 (100 kg or 2 bags)
	25 kg K_20	SSP (222 kg or 4½ bags), TSP (89 kg or 2 bags)
		Muriate of potash (33 kg or _ bag)
Guinea Savanna and Forest	**10 kg N**	Urea (22 kg or ½ bag) CAN (37 kg or ¾ bag)
	36 kg P_20_5	SSP (200 kg or 4 bags), TSP (80 kg or 1½ bags)
	20 kg K_20	Muriate of potash (33 kg or _ bag)

making an additional 30–40% profit through greater commodity sales (ProOpCom 2011). Deliberate efforts must therefore be made in ensuring that fertilizer investments give high returns with little risk. This necessitates employment of ingenious techniques for optimizing fertilizer use. Fertilizer use optimization refers to maximizing profit from fertilizer use, including profit per hectare for farmers with adequate finance and profit on the small investment in fertilizer use by the financially constrained farmers. Results from the AGRA funded trial in Nigeria known as Optimizing Fertilizer Recommendations in Africa (OFRA) showed that maximizing net return requires understanding crop response to applied nutrients. The project made use of results of past research (legacy data) which were compiled and analyzed, and additional field research was conducted to improve the information for fertilizer use decisions in the Savanna agro-ecological zones (AEZs) of Nigeria. The food crops addressed were cassava, maize, sorghum, pearl millet, lowland and

Table 12.14 Recommend cowpea and soybean varieties for different agro-ecological zones

Agro-ecological zone	Cowpea variety	Soyabean variety
Southern Sudan	ACCS. 341, 339 – 1, 1768 and 593; IT60, IT84E – 108	TGX 844 – 29D
	ACCS. 355 & 335, ITS4E – 124	
Northern Guinea Savanna	ACCS. 341, 1768, 3391 – 1, 1696	TGX 536 – 02D, SAM Soy – 1, SAM Soy – 2, TGX 855 – 29D
	588/2; IT84E – 108, TVX3236	
	ACCS. 335, 355 and 353	
	Ife Brown, IT84E – 124	
Southern Guinea Savanna	ACCS. 339 – 1 and 341; IT84e – 108 TVX 3236	TGX 536 – 02D, SAM Soy – 1, SAM Soy – 2, TGX 855 – 29D
	ACCS. 335 and 353; Ife Brown IT 84E – 124	
Forest	KANO 1696, Vita 5. Modupe, Ife-Bimpe,	TGM 579, M312, TGX 306 – 036C
	Ife Brown	

Table 12.15 Fertilizer recommendations for cotton

Agro-ecological zones	(Nutrient/ ha^{-1})	Material/ha^{-1}
Sahel, Sudan and Northern Guinea Early Crop	60 kg N	Urea (125 kg or 2½ bags) CAN (125 kg or 4 ½ bags) B SPP, 140 kg (3 bags) KCl, 33 kg (1 bag) or 20-10-10 (6 bags) in Boronated SSP
	25 kg P_20_5	
	20 kg K_20	
	0.75 kg Bo	
Late crop	40 kg N	Urea (87 kg or 1¾ bags) CAN (96 kg or 2 bags)
	20 kg P_20_5	
	0.35 B	Boronated SSP (61 kg or (1 bag)
	20 kg K_20	
		KCl (1 bag)
Forest	35 kg N	CAN, 135 kg (3 bags) or SA, 175 kg (3½ bags) or compound (20-10-10) 175 kg (3½ bags)

upland rice, groundnut and soybean. The crop yield responses to applied nutrients were captured in curvilinear to plateau yield response functions as shown in Fig. 12.1 for maize response (vertical axis or y-axis) to applied N (horizontal axis or x-axis) in the Mid-altitude zone. Maize grain yield response to increasing N rates, as exemplified in the Nigerian Mid-altitude AEZ has a steep response at low N rates and a reduced rate of increase at higher N rates until the yield plateau is reached, after which further increase in N rate has little or no effect to increase

Table 12.16 Soil/crop specific fertilizer formulations

States	Fertilizer formulations
Anambra	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Abia	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Adamawa	(i) NPK: 20-10-10 + 1S + 1Zn for cereals
	(ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Akwa-Ibom	(i) NPK: 20-5-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-5-10 + 1Zn + 2MgO + 2Ca for roots, tubers and tree crops
Abuja	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Bauchi	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Benue	(i) NPK: 20-10-5 + 1ca + 15 + 1Zn for cereals, cotton and vegetables
	(ii) NPK: 10-20-10 + 1S + 1Zn for legumes
	(iii) NPK: 15-10-10 + 1Ca + 2MgO + 1Zn for roots, tubers and tree crops
Borno	(i) NPK: 20-10-10 + 1S + 1Zn for cereals
	(ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Ebonyi	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Edo	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Ekiti	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Enugu	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Cross River	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Delta	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Bayelsa	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes

(continued)

Table 12.16 (continued)

States	Fertilizer formulations
Gombe	(i) NPK: 20-10-10 + 1S + 1Zn for cereals
	(ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Imo	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Jigawa	(i) NPK: 20-10-10 + 1S + 1Zn for cereals
	(ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Kaduna	(i) NPK: 20-5-10 + 1Zn + 1S for cereals and vegetables
	(ii) NPK: 15-5-10 + 1Zn + 1S for roots, tubers and tree crops
	(iii) NPK: 20-5-10 + 1Zn + 1S + 1B for cotton
	(iv) NPK: 10-20-10 + 1S + 1Zn for legumes
Kebbi	(i) NPK: 20-5-10 + 1Zn + 1S for cereals and vegetables
	(ii) NPK: 15-5-10 + 1Zn + 1S for roots, tubers and tree crops
	(iii) NPK: 20-5-10 + 1Zn + 1S + 1B for cotton
	(iv) NPK: 10 -20-10 + 1S + 1Zn for legumes
Kwara	(i) NPK: 20-10-10 + 1S + 1Zn for cereals
	(ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Kogi	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Kano	(i) NPK: 20-5-10 + 1Zn + 1S for cereals and vegetables
	(ii) NPK: 15-5-10 + 1Zn + 1S for roots, tubers and tree crops
	(iii) NPK: 20-5-10 + 1Zn + 1S + 1B for cotton
	(iv) NPK: 10 -20-10 + 1S + 1Zn for legumes
Katsina	(i) NPK: 20-5-10 + 1Zn + 1S for cereals and vegetables
	(ii) NPK: 15-5-10 + 1Zn + 1S for roots, tubers and tree crops
	(iii) NPK: 20-5-10 + 1Zn + 1S + 1B for cotton
	(iv) NPK: 10 -20-10 + 1S + 1Zn for legumes
Lagos	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Nasarawa	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Niger	(i) NPK: 20-10-10 + 1S + 1Zn for cereals
	(ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Ogun	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Ondo	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes

(continued)

Table 12.16 (continued)

States	Fertilizer formulations
Osun	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Oyo	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Plateau	(i) NPK: 20-10-5 + 1ca + 15 + 1Zn for cereals, cotton and vegetables
	(ii) NPK: 10-20-10 + 1S + 1Zn for legumes
	(iii) NPK: 15-10-10 + 1Ca + 2MgO + 1Zn for roots, tubers and tree crops
Rivers	(i) NPK: 20-10-5 + 1Zn + 2Ca for cereals and vegetables
	(ii) NPK: 15-10-10 + 2Ca + 2MgO + 1Zn for roots, tubers and tree crops
	(iii) NPK: 10-20-10 + 1S + 1Zn + 2 Ca for legumes
Sokoto	(i) NPK: 20-5-10 + 1Zn + 1S for cereals and vegetables
	(ii) NPK: 15-5-10 + 1Zn + 1S for roots, tubers and tree crops
	(iii) NPK: 20-5-10 + 1Zn + 1S + 1B for cotton
	(iv) NPK: 10 -20-10 + 1S + 1Zn for legumes
Yobe	(i) NPK: 20-10-10 + 1S + 1Zn for cereals
	(ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Taraba	(i) NPK: 20-10-10 + 1S + 1Zn for cereals
	(ii) NPK: 10-20-10 + 1S + 1Zn for legumes
Zamfara	(i) NPK: 20-5-10 + 1Zn + 1S for cereals and vegetables
	(ii) NPK: 15-5-10 + 1Zn + 1S for roots, tubers and tree crops
	(iii) NPK: 20-5-10 + 1Zn + 1S + 1B for cotton
	(iv) NPK: 10-20-10 + 1S + 1Zn for legumes

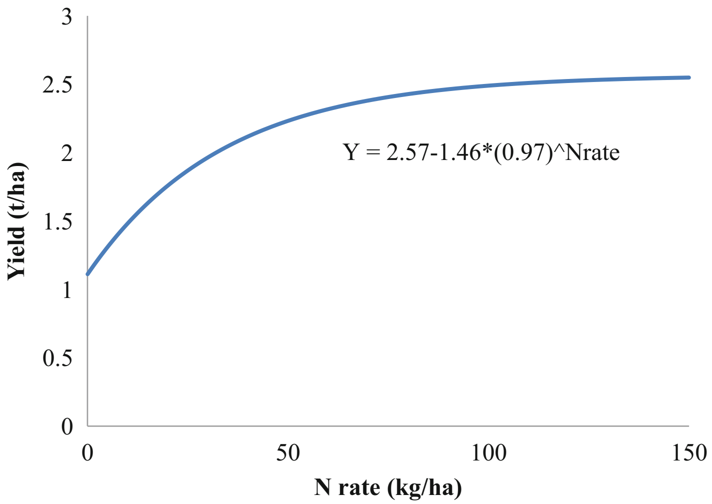

Fig. 12.1 Maize response to nitrogen application in the Nigerian Mid-altitude AEZ

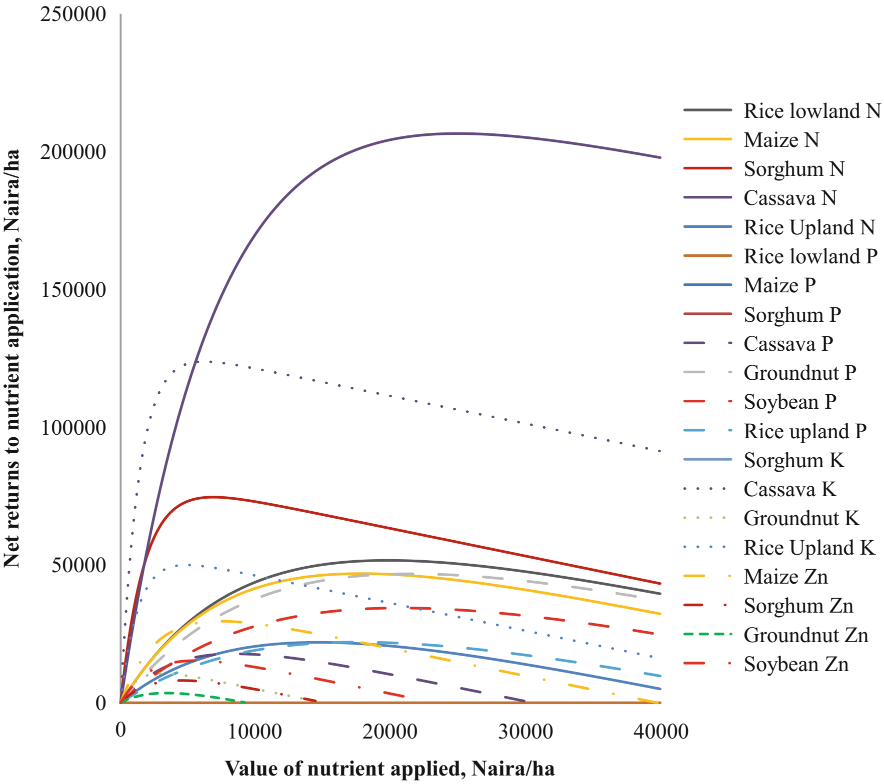

Fig. 12.2 Net returns to investment in nutrients in the Mid-altitude AEZ of Nigeria

yield. There was increasing yields with nitrogen rates up to the 100 kg/ha rate beyond which maize grain yields tends to be constant. The maximum expected yield, on average, was 2.57 t/ha. This type of response to applied nutrients is captured by the equation Yield (kg ha^{-1}) = $\boldsymbol{a} - \boldsymbol{b}\boldsymbol{c}^{\boldsymbol{r}}$, where $\boldsymbol{a}$ is near maximum yield for application of that nutrient, $\boldsymbol{b}$ is the maximum yield increase due to applied nutrient, and $\boldsymbol{c}^{\boldsymbol{r}}$ determines the shape of the curvilinear response. The $\boldsymbol{c}$ is the curvature coefficient and $\boldsymbol{r}$ is nutrient rate. This function shows that the benefit relative to cost for N application is expected to be greater with low N levels compared with high N rate.

Profit potential also varies with different nutrients applied to the same or different crops as shown in Fig. 12.2 for the Nigerian Mid-altitude AEZ. Each curve represents the profit potential of a nutrient applied to a crop. Where the curve of the graph is steep, the net returns to investments are very high and where the curve flattens, the point of maximum profit per hectare is reached. When the graph slopes starts declining, the profit is declining. The results show that it is more economical to invest in N and K applied to cassava than in fertilizers for other crops. Application of low rates of N to sorghum and K to upland rice also have good profit potential. Other crop-nutrient options that are shown have profit potential as well as including the application of very low rate of Zn for groundnut. The resource poor farmer needs to take advantage of the most profitable options first and gradually build financial capacity in order to take advantage of the less profitable choices. Poor farmers will benefit according to their financial ability by operating within the steep slope of the curves where there are high returns from investment, while well-resourced farmers will attempt to apply at economic optimum rate (EOR) to maximize profit per hectare.

The results suggest the need to consider the various crop nutrient response functions in light of their other agronomic choices, the current economics of fertilizer use, and their financial ability. Therefore, easy to use decision tools called fertilizer optimization tools (FOT), which use complex mathematics of linear optimization to reiteratively consider the numerous crop nutrient functions in light of the farmer's agronomic and economic situation, are needed to provide recommendations that maximize returns on investment. It also brings to fore the need for farmers' education on the type of fertilizer they need to procure and use on different crops to maximize profit. Choices of single nutrient and double nutrient compound fertilizers are necessary for optimizing profit. The Fertilizer optimization Tool (FOT) was developed by Jansen et al. (2013). It has been adapted to 67 country-AEZs of Africa including the six savanna AEZs of Nigeria. The FOTs are public goods that can be accessed by individuals at https://agronomy.unl.edu/OFRA.

An example of the type of outputs from this approach is presented in Table 12.17 which shows that the response of upland crops in the Sahel Savanna was greater to applied P compared with N, while lowland rice was more responsive to N. Cowpea and groundnut were not found to be responsive to N but had modest response to applied P and K. The field research based EOR were consistently less and generally less than half the recommended rates. Therefore, even for cases of no financial constraint on the amount of fertilizer use, the recommended rates are well above the most profitable rates, and therefore a profit opportunity is lost in applying according to recommendations. For farmers with financial constraints to fertilizer use, the most profitable rates will be less than the EOR as determined through use of FOTs. These results suggest that most of the national fertilizer recommendations for primary fertilizer elements did not consider economic benefits.

This approach is a step ahead of the one in which only yield maximization is considered. It creates opportunities for farmers to take decisions based on his input purchasing power and preferences; giving him the latitude to take sound economic decisions.

Table 12.17 Sahel savanna, Response functions, expected yield increases (t/ha) for crop-nutrients, and OFRA economically optimal rate (EOR) to maximize profit per hectare compared to current or recent (REC) recommendations by AEZs in Nigeria

	Response coefficients, Yield = a – bc^r; r = elemental nutrient rate				Effect of nutrient rate (kg/ha) on grain yield (t/ha)				Recommended nutrient rate	
		A	B	C	0–30	30–60	60–90	90–120	EOR[a]	Rec[b]
Crop	Nutrient	t/ha			t/ha				kg/ha	
Pearl millet	N	0.742	0.223	0.93	0.198	0.022	0.003	0.000	18	60
Sorghum	N	1.098	0.273	0.97	0.164	0.066	0.026	0.011	24	64
Maize	N	1.275	0.687	0.951	0.535	0.118	0.026	0.006	39	120
Rice, lowland	N	4.461	0.564	0.942	0.470	0.078	0.013	0.002	38	100
					0–5	**5–10**	**10–15**	**15–20**		
Pearl millet	P	1.717	0.768	0.940	0.204	0.150	0.110	0.081	14	13
Sorghum	P	0.975	0.548	0.908	0.210	0.129	0.080	0.049	11	14
Groundnut	P	0.254	0.032	0.87	0.016	0.008	0.004	0.002	0	24
Cowpea	P	0.605	0.109	0.93	0.033	0.023	0.016	0.011	2	17
Maize	P	1.275	0.687	0.951	0.153	0.119	0.092	0.072	0	26
Rice lowland	P	5.19	0.189	0.919	0.065	0.043	0.028	0.018	0	22
Groundnut	K	1.093	0.104	0.800	0.070	0.023	0.008	0.002	10	21
Cowpea	K	0.477	0.063	0.650	0.056	0.006	0.001	0.000	6	17
Rice, lowland	K	6.036	0.223	0.750	0.170	0.040	0.010	0.002	9	33

$P_2O_5 = P \times 2.29$; $K_2O = K \times 1.2$. Some functions have zero response are because of lack of response or lack of information

[a]EOR was determined with the cost of using 50 kg urea and SSP at ₦ 5500 and 4500, respectively. Commodity values (₦/kg) used were: cassava 20, rice 67; maize 50; Sorghum 60; cowpea 165; groundnut 120; soybean 120; and pearl millet 60

[b]Source: OFRA-Nigeria 2015 country recommendation

12.4 Way Forward

While the efforts made in Nigeria is commendable, there is still need for refinement of the information contained in the Tables presented above. The desire is to reach a point where extension workers or farmers can click to coordinates on a map to get fertilizer recommendation for the crop(s) they intend to grow in a season on their farm plot(s).

Most of current fertilizer recommendations in use are therefore largely outdated and still too general ("blanket recommendations"). Its perils and the need for site-specific recommendations have been elucidated in a study on nutrient rationalization in Nigerian compound fertilizers by Adeoye (2006). Youl (2016) listed the following negative consequences blanket recommendation:

– Output/nutrient ratios often below 10 (for cereals) due to blanket recommendations and inadequate method and time of application of fertilizer;
– High fertilizer cost due to the lack of cost-effective fertilizer blends in the market,
– Soil and environmental degradation due to under- or over-application of fertilizer;
– Lack of farmers' confidence in those providing fertilizer and advice.

This is because the soil, crop and climate data used for deriving the fertilizer recommendations above were not sufficient to provide site-specific recommendations.

Site specific recommendations require sufficient quality crop genotype, climate and soil data. Collaborations need to be sought with various new initiatives such as the current development of Nutrient Expert by IPNI, Rice Advisor by Africa Rice and the IITA-OCP project aimed at developing fertilizer recommendations for maize in the corn-belt of Nigeria need to be exploited with a view to compiling and synthesizing information for developing site-specific recommendations. Similarly, the current efforts being made by the African Soil Information Service (AfSIS) and the collaborating country initiatives such as NiSIS, GhaSIS etc should provide needed soil data required for the present efforts.

Nigeria, indeed ECOWAS/CEDEAO should take advantage of new modern soil analysis method such as NIR spectroscopy to generate soil data for site-specific fertilizer recommendations. An investment in soil testing will radically correct the present nutrient imbalances. The savings that will accrue from not overdosing through soil test and wasting nutrients can be channelled to increasing fertilizer quantity that will provide the nutrients needed. The current drive by the FMARD in introducing soil test kits called Soil Doctor through the Department of Climate Change and Agricultural Land Management Services to farmers across the country is commendable.

There is also the need to address problems of using blends or need to move way from blends due to adulteration, segregation, and difficulty in formulating site specific formulations. One of the draw backs in the current use bulk blends in

Nigeria stems largely from the fact that they are transported over long distances. Moreover, use of existing NPKs blends as basal fertilizers have serious limitations because most of them are low analysis fertilizers. While urea has been generally accepted, the original concept of di-ammonium phosphate (DAP) as a basal has been lost. DAP is a very good basal fertilizer as it contains small amounts of N needed after seeding and the P required. If there is a K deficiency, application of MOP (0:0:60) makes sense economically and allows the flexibility to get the K in the right ratio. Farmers can be trained to apply high analysis fertilizers on their own once they know their soils nutrient requirements through soil test. Need for training of extension workers and augmenting them with practicing farmers in their locality; a success story of the innovative use of farmers as extension agents was established recently (Amapu 2014). Where there is the availability of good soil and crop data, bulk blending plants can established to provide site-specific crop and soil fertilizer formulations. It necessarily means that many bulk blending plants need to be established to carter for farms within radii of 100 kilometres. This could bring about the benefits ingrained in using multi-nutrient fertilizers such as ease of handling, transport and storage, ease of application, even distribution of nutrients in the field; and balanced fertilization, i.e. nitrogen, phosphorus and potassium available together from the start and in accordance with plant requirements.

It should be stressed that fertilizers are good for reducing soil fertility problems. However, adding more fertilizer will bring little or no increase in production when other factors are limiting. Excessive use of fertilizers may even reduce yields because it leads to imbalance in availability of nutrients.

Even if adequate applications of fertilizer were made to highly eroded soils, its efficiency would be much curtailed. It becomes extremely difficult to bring the soil back to full production once the top soil is eroded. Although good agronomic practices including fertilizer use may increase the productive capacity of an erosion affected soil, the same methods would have resulted in such larger yields if the soils had not been impaired in the first place. It becomes imperative therefore that adequate soil management and conservation practices be employed in order to sustain crop production at a reasonably high level.

12.5 Conclusion

Stemming from the fact that validation trials indicate that there is a huge variability in crop responses to application of fertilizers within a small area, depending on slopes, landscape positions, soil fertility gradients and crop types. An investment in soil testing will radically correct the present nutrient imbalances. The savings that will accrue from not overdosing through soil test and wasting nutrients can be channeled to increasing fertilizer quantity that will provide the nutrients needed.

Given the diversity of agro-ecologies and soil types, diverse crop types, and crop production systems, there is a need to further strengthen and refine fertilizer recommendations.

There is the need to synthesize existing but scattered research results at a national level; identify knowledge gaps and missing information for further research; create general understanding on the ongoing efforts and agree upon a common research approach in fine-tuning the fertilizer recommendation at local and regional scales.

Fertilizer recommendations should take into cognizance the purchasing power of the farmer and his interests, and aimed at both maximizing yield and profit and therefore the need to employ DSTs that have such capabilities.

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