Chapter 7
Assessment of Soil Fertility Status and Integrated Soil Fertility Management in Ghana

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Abstract The total land area of Ghana is 23,853,900 ha of which 57.1% (13,628,179 ha) is suitable for agriculture but most of the soils are of low inherent fertility. The coarse nature of the soils has an impact on their physical properties and water stress is common during the growing season. Extensive areas of country's land area particularly the Interior savannah zone have suffered from severe soil erosion and land degradation in various forms. The soil nutrient depletion rates in Ghana is projected as 35 kg N, 4 kg P and 20 kg K ha^{-1}. The extent of nutrient depletion is widespread in all the agro-ecological zones with nitrogen and phosphorus being the most deficient nutrients. Nutrients removed from the soils by crop harvest have not been replaced through the use of corresponding amounts of plant nutrients in the form of organic and inorganic fertilizers. There is therefore a steady decline in crop yield levels and increased food production is presently due mostly to extension in the area under cultivation. Overall percentage increase in cultivated area between 2000 and 2008 is about 17.3% (SRID 2008). The average yields of most of the crops are 20–60% below their achievable yields, indicating that there is significant potential for improvement While Ghana has one of the highest soil nutrient depletion rates in SSA, it has one of the lowest rates of annual inorganic fertilizer application – only 8 kg per hectare.

An increase in food security requires increased productivity strategies that will raise yields for most crops toward their achievable levels, mostly by the adoption of intensive and improved technologies, including the use of fertilizers, improved seeds and best management practices. While African policy makers and International donors recognize the urgency of raising fertilizer use by small holder farmers, for achieving both agricultural growth and poverty alleviation objectives, there is little consensus on the most appropriate policy and programmatic course of action. Most efforts to raise fertilizer use in SSA over the past decade have focused on fertilizer subsidies and targeted credit programmes with hopes that these programmes could later be withdrawn once the profitability of fertilizer use has

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been made clear to newly adopted farmers and once they have become sufficiently capitalized to be able to afford fertilizer with their own working capital. Relatively little emphasis has been given to improving the profitability of fertilizer use through understanding the most productive levels and combinations of nutrient input for various agro ecological areas, management practices and market options. Inorganic fertilizer does not improve agricultural productivity in isolation. Information on the fertility status and agricultural potential of the soils are also required. Complementary inputs such investment in soil and water conservation for efficient end optimal nutrient uptake is also important. Improved soil fertility management through increased levels of fertilizer use, increased use of available organic soil amendments, and improved farm management practices, together with the use of improved seed, can result in positive gains in farm productivity. This increase in productivity is demonstrated by the SAWA technology in rice production where yield on farmers' fields increased from 1 ton/ha to 5 tons/ha (Buri et al. 2007). There is lack of information on the profitability of the different soil-crop-fertilizer combinations that could be employed in the different parts of the country. The lack of such information on crop-fertilizer profitability across the country means that farmers cannot tell how much they stand to gain or lose by applying a particular type of fertilizer on a particular crop. This increases their risk and creates a disincentive for use of fertilizer. Information about profitability levels can serve as an incentive for inorganic fertilizer use. Most simply, expected Value Cost Ratios (VCR) from fertilizer use can guide farmers' decisions. Knowledge of soil characteristics and processes regulating nutrient availability and supply to crops is essential to raise productivity per unit of fertilizer nutrient applied. The recommendation of the African Fertilizer Summit (2006) to increase fertilizer use from 8 to 50 Kg/ha nutrients by 2015 reinforces the importance of fertilizer for increasing crop productivity and attaining food security and rural wellbeing in Ghana. The impact of this target will however vary depending upon the agronomic efficiency of applied fertilizer. This efficiency varies across ecological zones, farms and fields within farms and greatly affects the returns to the recommended 50 Kg/ha. The application of insufficient fertilizers and inappropriate nutrient conservation practices by farmers contribute to accelerating the rapid decline in soil fertility. The efficient uses of both inorganic and organic fertilizers, through Integrated Nutrient Management approach, will form an important element of a holistic approach for sustainably increasing crop production in Ghana.

Contents

7.1 Introduction

The agricultural sector of Ghana contributes about 40% to the country's gross domestic product (GDP), employs over half of the labour force and also provides raw materials for industrial growth and development (GoG 2010). The GDP growth rate was 4.4%, while that of the agricultural growth rate was 4.2% in the year 2000–2003. In 2003–2007, the GDP growth rate increased to 5.8%, while that of the agricultural growth increased to 5.2% (The State of the Ghanaian Economy in 2008). From 2006 until 2014 the GDP averaged 2.14%, while the agricultural sector contracted for the first time by 2.9% (GSS 2014).

Consequently various policies and programs have been put in place to drive this growth process. For example the Ghana Poverty Reduction Strategy (GPRS 1 2003) and Growth and poverty Reduction Strategy (GPRS II 2008) documents which identified agriculture as the most important driver for poverty reduction in Ghana. Other programmes that were formulated to improve agricultural production included the Food and Agricultural Sector Development Policy (FASDEP I & II 2003–2008, 2011–2015), implemented through the Medium term Agriculture Sector Investment Plan (METASIP) and the Accelerated Agricultural Growth and Development Strategy (AAGS). The METASIP targets 9.6% agricultural growth rate and halving poverty by 2015 through the allocation of 10% of the national budget to Agriculture.

Agricultural production in a region can increase through two ways: through higher production per unit of land, or by increasing the area cultivated. The dramatic increases in agricultural production in Asia known as the Green Revolution were mostly through higher yields. But Africa's far lower increases have mostly been through expansion of the cultivated land.

The fact that fertilizer use per unit area in Africa is less than 10% of that in Asia explains much of the contrasting trends in these regions. African countries including Ghana today face not only the challenge of increasing agricultural production with scarce overall resources but must raise productivity in a way that conserves the natural resource base and prevents further degradation that has characterized African soils for generations. Soil nutrient mining, the result of overexploitation of agricultural land, is in fact consumption of a key component of the soil's natural capital. The propensity for nutrient mining of Africa's agricultural land and the severity of its consequences are the highest in the world. Soil nutrient mining is usually associated with low agricultural production and land productivity under severe constraints of poverty in terms of physical capital (infrastructure) and human capital (health and education). Continued nutrient mining of soils with no or low external inputs would mean a future of even increased poverty, food insecurity, environmental damage, and social and political instability.

It is evident that, in order to maintain and increase food production, efforts to prevent soil degradation must become a top priority of our global society. Current population models predict a global population of between 8 and 10 billion in the next 50 years (Bongaarts 2009; Lutz et al. 2001) and a two-fold increase in food demand (Alexandratos 1999; Tilman et al. 2002). If mismanagement of soil resources continues to diminish the fertility of the soil and the amount of productive arable land (Pimentel 1995), then we will have lost a precious and essential pillar of sustainable agriculture (Tilman 1999). Sustainable agriculture is an approach to farming that focuses on production of food in a manner that can be maintained with minimal degradation of ecosystems and natural resources. This sustainable approach to agriculture strives to protect environmental resources, including soil, and provide economic profitability while maintaining social equity (Brodt 2011).

Ghana has a relatively large amount of cultivated land per capita; however, most of these lands are characterized by poor fertility and are subject to degradation. To reverse the declining trend in land productivity (crop yield) and ensure food security, soil management is crucial. One way to address the twin problem of low agricultural productivity on one hand and environmental degradation on the other is fertilizer use – both organic and inorganic, especially in low income countries where fertilizer use is lowest (Smaling et al. 2006). Inorganic fertilizer use in grain production, for example, can increase output by 40–60% (Roberts 2009). Application of organic fertilizer from animal and/or plant residues on the other hand provide some nutrients besides playing a crucial role in improving soil moisture conservation, especially when combined with conservation tillage practices that protect soil structure, reduce erosion and runoff, and promote soil biological functions important for soil productivity (Agwe et al. 2007). Nonetheless, a combination of organic and inorganic fertilizer for integrated soil fertility management is the most ideal in increasing yield in the short term, while maintaining long term soil fertility (Alley and Vanlauwe 2009). Indirectly, use of fertilizers lead to higher economic growth and poverty reduction through increased agricultural productivity and output (Dethier and Effenberger 2011). This is particularly more evident in Sub-Saharan Africa (SSA) countries where agriculture is the primary sector and source of livelihood to the majority of the population (World Bank 2007). Nevertheless, if not well managed, long-term use of fertilizer – whether organic or inorganic, results in inefficiencies of input use, leading to soil degradation, lower productivity and potential damage to the environment (FAO 1994).

The use of fertilizer in crop production in Ghana remains low; at about 8 Kg/ha (Fuentes et al. 2012), despite the fact that nutrient depletion is among the highest in Africa (Henao and Baanante 2006). Although Ghana is among countries in SSA that signed the Abuja declaration of increasing fertilizer use from the continent average of 8 kg per hectare to at least 50 kg per hectare per annum by 2015 (African Union 2006), there is little indication that the country is about to attain fertilizer use intensity of at least 15 kg of per hectare per annum. According to Smaling et al. (2006), unless radical interventions occur, projected inorganic fertilizer consumption growth in SSA until 2030 will remain at 1.9% per annum.

While there has been considerable research and policy analysis on fertilizer use in Ghana, there remain knowledge gaps, on the state of fertility of Ghanaian soils; the yield response to fertilizer for major crops, the profitability of fertilizer use, and the likely effects of changing climatic conditions on the profitability of fertilizer use. This report therefore presents an overview of the soil fertility status and integrated soil fertility management in Ghana.

7.2 The Soils Resource Base of Ghana

The soils of Ghana are formed on very old landscapes and highly weathered except in areas over recent alluvium or where erosion has exposed the basement rocks. They are therefore inherently low in fertility especially in weatherable mineral reserves. The topsoils are predominantly loamy sands and sandy loams especially where the soils developed over granites and sandstones. On other geological materials, selective erosion also results in similar topsoil textures. The subsoils, on the other hand, have relatively heavier textures varying from gritty sandy clay loams/sandy clays to clays due to clay migration down the profile or selective erosion in surface horizons. Clay textured soils are normally common in the valley bottoms, which are ideal for rice cultivation.

Sedentary soils that developed from pegmatitic rocks (that is presence of large quartz veins) may contain abundant coarse material either as gravels or stones especially in the subsurface horizons. The subsoils also often show features of accumulation or concentrations in the form of iron and manganese concretions and nodules (FAO/WBCP 1991).

On the basis of the length of the growing period developed by FAO, the country is covered by six agroecological zones. The major soils in each zone classified according to the World Reference Base for Soil Resources (WRB) (IUSS Working Group WRB 2006) are outlined in Table 7.1 below.

Aluvial soils (Fluvisols) and eroded shallow soils (Leptosols) occur in limited extent in all the ecological zones and were not indicated in the table above. Table 7.2 shows key attributes about the major soils since Table 7.2 does not give clear appreciation of the nature of soils to readers.

The main constraints of the soils and their suitability for crop production are provided in Table 7.3.

Table 7.1 Major soils in the six agroecological zones in Ghana

Item	Agroecological Zone	Major soil types (Reference Soil Groups (WRB)
1	Forest-Savanna Transition	Lixisols, Nitisols, Plinthosols and Cambisols
2	Guinea Savanna	Plinthosols Lixisols, Planosols, Luvisols and Gleysols
3	Sudan Savanna	Lixisols, Plinthosols, Luvisols and Gleysol
4	Coastal Savanna	Vertisols, Solonchacks, Luvisols, Cambisols, Gleysols, Solonetz and intergrades
5	High Rainforest	Ferralsols, Acrisols, Nitisols and Gleysols
6	Semi-Deciduous Forest	Acrisols, Lixisols, Nitisols and Gleysols

Table 7.2 Simplified guide to Reference Soil Groups that commonly occur in Ghana

Item	RSG	Key attribute
1	Acrisol	Soils with clay-enriched subsoil having low cation exchange capacity and low base status (BS $< 50\%$)
2	Lixisols	Soils with clay-enriched subsoil having low cation exchange capacity but high base status (BS $> 50\%$)
3	Alisols	Soils with clay-enriched subsoil having high cation exchange capacity but low base status (BS $< 50\%$)
4	Luvisols	Soils with clay-enriched subsoil having low cation exchange capacity and low base status (BS $> 50\%$)
5	Cambisols	Moderately developed soils soil profiles
6	Vertisols	Soils with limitations to root growth due high clay content and shrink swell phenomenon under alternating wetting and drying condition
7	Leptosols	to thin soils or abundant gravels and stones
8	Solonetz	Soils with limitations to root growth due to high content of exchangeable Na
9	Solonchack	Soils with limitations to root growth due to high concentration of soluble salts
10	Plinthosol	Occurrence of plinthite (accumulation and redistribution of iron) within 50 cm from the soil surface and usually cemented or pisolithic
11	Ferralsols	Soils distinguished by dominance of kaolinite and iron and aluminium oxides
12	Nitisols	Low activity clay, P-fixation, stronly structured withmany iron oxides
13	Planosol	Stagnating water, with more than doubling of clay content in underling layers
14	Gleysols	Groundwater affected soils

Source: Modified After (IUSS Working Group, WRB 2014)

7.2.1 *Fertility Status of Ghanaian Soils*

Most of the soils are developed on thoroughly weathered parent materials. They are old and have been leached over a long period of time especially in the humid (High rain forest and Semi-deciduous) zones (Benneh et al. 1990). Organic matter content is generally low due to high mineralization under warm and humid climate and continuous cropping especially in the Sudan savanna zone. In general the soils have low buffering capacity due to the low mineral reserves, low organic matter content and coarse-textured topsoils. Nutrient retention is also low since the predominant clay mineral is kaolinite (cation exchange capacity is less than 10 $\text{cmol}_{(+)}\ \text{kg}^{-1}$ clay). The soils are consequently of low inherent fertility.

The two most deficient nutrients are nitrogen and phosphorus particularly because of the very low organic matter content. The build-up of any amount of organic matter is further constrained by the regular burning of crop residue and/or competitive use of these residues for fuel, animal feed or building purposes. The low vegetative cover during the long dry season also renders most of the soils in the

Table 7.3 Main constraints of the soils and their suitability for crop production

Agroecological Zone	Major soil type	Main constraints	Major crops/use
Forest-Savanna Transition	Lixisols, Plinthosols	Low nutrient status, high P-fixation potential	Cashew, maize, cowpea, cassava, yam
		Poor natural soil fertility caused by strong weathering, waterlogging in bottomlands and droughtiness on petroplinthite,or pisoliths (ironstone gravels)	---------------do---------------
Guinea Savanna	Lixisols, Plinthosols, Planosols,	Same as above	Maize, sorghum, cowpea, cotton, yam
		Same as above	
		Low nutrient status and temporal waterlogging	Groundnuts, cowpea
			Rough grazing
Sudan Savanna	Lixisols, Plinthosols, Luvisols	Same as above	Maize, sorghum, millet, cowpea
		Same as above	
		Droughtiness of topsoil	Groundnut and cowpea
Coastal Savanna	Vertisols, Solonchacks, Solonetz	Workability limitations, Low phosphorus availability, susceptibility to alkalinization and salinization, high potential of nitrogen losses	Rice, sugar cane
		Accummulation of salts	Grazing
		Presence of clay pan, high alkalinity	
High Rainforest	Ferralsols, Acrisols,	Low nutrient supply and retention capacity, low exchangeable basic cations, fixation of phosphorus, aluminium toxicity at pH < 5.0, molybdenum is often deficient for BNF by legumes	Oil palm, para rubber, and cassava
Semi-Deciduous Forest	Acrisols, Lixisols, Nitisols	High leaching, high potential to fix phosphorus, boron deficiency, poor internal drainage, poor rootability of the subsoil, high potential of erosion in weakly structured surface horizons	Cocoa, oil palm, plantain, cocoyam, cassava, maize cowpea, yam
		Same as above	---------------do---------------
		High potential for P-fixation	---------------do---------------
	Fluvisol and Gleysols	Poor drainage, high potential of Aluminium and iron toxicity	Rice and occasionally sugar cane in southern Ghana

Table 7.4 Soil fertility status of the high rainforest agro-ecological zones

Agro-ecological zones	Soil parameter	Value	Remarks	Major crops				
				Cereals	Starchy crops	Legume	Vegetables	Tree crops
High Rainforest	Soil pH	3.8–4.5	Extremely acid to strongly acid	Maize, rice	Cassava, coco-yam, plantain	–	Pepper, okra, eggplant	Citrus, coconut, oilpalm, rubber
	Organic C	1.52–4.24	Medium to high					
	Total N	0.12–0.38	Low to medium					
	Available P	0.12–5.42	Low					
	Available K	63.57–150.41						

Table 7.5 Soil fertility status of the forest-transition agro-ecological zones

Agro-ecological zones	Soil parameter	Value	Remarks	Major crops				
				Cereals	Starchy crops	Legume	Vegetables	Tree crops
Forest-Transition	Soil pH	5.1–6.4	Moderately acid to slightly acid	Maize, rice	Cassava, cocoyam, plantain	Cowpea	Pepper, okra, eggplant, tomato	Citrus, coffee, oilpalm, cashew
	Organic C	0.59–0.99	Low					
	Total N	0.04–0.16	Very low to low					
	Available P	0.30–4.68	Low					
	Available K	58.29–72.53						

Table 7.6 Soil fertility status of the semi-deciduous forest agro-ecological zones

Agro-ecological zones	Soil parameter	Value	Remarks	Major crops				
				Cereals	Starchy crops	Legume	Vegetables	Tree crops
Semi-Deciduous Forest	Soil pH	5.5–6.2	Moderately acid to slightly acid	Maize, rice, sorghum	Yam, cocoyam, plantain, cassava	Cowpea, groundnut	Tomato, pepper, okra, eggplant	Citrus, coffee, cashew
	Organic C	1.59–4.80	Medium to high					
	Total N	0.15–0.42	Low to medium					
	Available P	0.36–5.22	Low					
	Available K	62.01–84.82						

Table 7.7 Soil fertility status of the Coastal Savanna agro-ecological zones

Agro-ecological zones	Soil parameter	Value	Remarks	Major crops				
				Cereals	Starchy crops	Legume	Vegetables	Tree crops
Coastal Savanna	Soil pH	5.6–6.4	Moderately acid to slightly acid	Maize, rice, sorghum, millet	Yam, cassava	Cowpea, groundnut, bambara	Tomato, pepper	Sheanuts, cashew
	Organic C	0.61–1.24	Low to high					
	Total N	0.05–1.16	Very low to very high					
	Available P	0.18–3.60	Low					
	Available K	48.02–58.71						

Table 7.8 Soil fertility status of the Guinea Savanna agro-ecological zones

Agro-ecological zones	Soil parameter	Value	Remarks	Major crops				
				Cereals	Starchy crops	Legume	Vegetables	Tree crops
Guinea Savanna	Soil pH	6.2–6.6	Slightly acid	Maize, rice, sorghum, millet	Sweet potato	Cowpea, groundnut, bambara	Tomato, onion	Sheanuts
	Organic C	0.51–0.99	Low					
	Total N	0.05–0.12	Very low to low					
	Available P	0.18–3.60	Low					
	Available K	46.23–55.27						

Table 7.9 Soil fertility status of the Sudan Savanna agro-ecological zones

				Major crops				
Agro-ecological zones	Soil parameter	Value	Remarks	Cereals	Starchy crops	Legume	Vegetables	Tree crops
Sudan Savanna	Soil pH	6.4–6.7	Slightly acid	Maize, rice	Cassava	Cowpea	Tomato, shallot	Coconut
	Organic C	0.48–0.98	Low					
	Total N	0.06–0.14	Very low to low					
	Available P	0.06–1.80	Low					
	Available K	36.96–44.51						

Source: Adapted from 2005 Annual Report, CSIR-SRI and Fening et al. (2005a, b) and Gerken et al. (2001)

Nothing on the availability of major nutrients. Can we have uniform information for all zones. We can then even summarize the information in a table.

7.2.1.3 Semi-Deciduous Forest

The dominant soils in this zone are the Acrisols and Lixisols with Lithosols (Leptosols), Luvisols and Gleysols occurring in limited areas as marginal soils. The pH ranges from about 5.5 to 6.2 in the A horizon and declines with soil depth to about 4.8. The average soil organic carbon content is more than 1.0% (i.e. 1.6–4.8%) in the A horizon which falls below 1.0% in lower horizons. Total nitrogen is associated with soil organic carbon. Total nitrogen levels range from 0.15 to 0.24% in the A horizons. Available P levels are also low and concentrated in the A horizon and ranging from 0.4 to 5.2 mg/kg soil.

Available potassium values range from 62.0 to 100.0 mg/kg soil and declines to lower values in the subsoil. Some of the suitable crops for the soils in this zone are: Cocoa, coconut, oil palm, rice, sugar cane, cassava, cocoyam, yam, plantain, citrus, maize, banana, vegetables, mango and avocado. Are there crops unsuitable for this area?

7.2.1.4 Coastal Savannah

The major soils encountered in the coastal savanna zone include Lixisols, Vertisols and Solonetz and Vleisols. They have generally low organic matter contents (0.6–1.2%) in the A horizon. The soil reaction is near-neutral or moderately acidic to acidic (5.6–6.4) in the topsoil and become increasing alkaline with depth because of the accumulation of calcium carbonate concretions. Organic carbon content is less than 1.0% with a range of about 0.6 to 1.2%. Total nitrogen is less than 0.1% with a range of 0.05 to 0.16%. Available phosphorus values are low ranging from 0.3 to 4.1 mg/kg due to low apatite content of soil and partly due to fixation on Fe-Mn concretion surfaces. Potassium availability is low due to the presence of vermiculite in some of the soils causing K-fixation. Available potassium values range from 48.0 to 58.7 mg/kg. The following crops are normally grown on the soils in this zone. Rice, cotton, sugar cane, cowpea, vegetables, maize, cassava, shallots, and coconut. Are they suitable?

All of this is merely repeating what is in the table.

Instead, unusually high or low ranges can be identified in the table itself.

And explain why top and subsoil differences in nutrient content matter. Does it have anything to do with suitability of crops or suggest degradation?

7.2.1.5 Guinea Savannah

The dominant soils encountered in the Guinea savannah zone include Ferric Acrisols, Lixisols, Nitisols, and Plinthosols. These are shallow to very shallow reddish brown to brown, concretionary, and medium to light textured soils susceptible to erosion. We didn't see anything about the depth of soils in other zones. The organic carbon content is low ranging from about 0.5 to 1.0% in the topsoil. Total nitrogen content is generally less than 0.1% (0.05–0.12%). Available phosphorus values are low (0.2–3.6 mg/kg) and available potassium values are also low (46.2–55.3 mg/kg). Rice, cotton, sugar cane, cowpea, vegetables, maize, cassava, vegetables, groundnuts, soybean, yam, mango, sorghum, millet, usually grown or suitable?

7.2.1.6 Sudan Savannah

The soils encountered include Ferric Lixisols, Luvisols, Eutricalcicgleysols. They have generally low organic carbon content (0.5–1.0%) due to insufficient accumulation of biomass under savannah conditions. Soil reaction ranges from near neutral (6.4–7.0) in the A horizon to moderately acidic with depth (in the subsoil). Available phosphorus values are low (0.1–1.8 mg/kg) due to low soil apatite content and fixation on iron concretions. Available potassium content is also low (37.0–44.5 mg/kg). The nature of the soils make it suitable for the cultivation of these crops; Rice, cotton, sugar cane, cowpea, vegetables, maize, cassava, vegetables, groundnuts, soybean, yam, mango, sorghum, millet.

Please expand table two by adding two columns: one for key characteristics of the soil (such as, "shallow soils prone to erosion") and the other for suitable crops.

Indicate unusually low levels by shading the squares.

Discuss the major differences between zones in one or two paragraphs. Explain why top and sub soil differences mater and how they vary among zones.

7.2.2 Soil Degradation and Nutrient Depletion

Sustainable agricultural production depends primarily on productive soils, however the soil resources of the country are being degraded as a result of the interaction of both natural and anthropogenic factors. In order to meet the future food needs of Ghana, while reducing poverty and protecting the environment would require halting and reversing soil degradation through restorative measures of soil, water, nutrient and crop management.

The major processes or types of soil degradation in Ghana are physical (erosion, compaction, crusting and iron pan formation), chemical (depletion of nutrients, salinity and acidification) and biological (loss of organic matter).

Table 7.10 Erosion on Bare Farm Plots within the agro-ecological zones of Ghana

Agro-ecological zone	Soil series	Slope (%)	Soil loss (t/ha)	Runoff % of rainfall
Semi-Decíduous	Asuansi (Ferric Acrisol)	7.5	186.9	47.0
Forest-Savanna Transition	Bediesi (RhodicNitisol)	3.0	12.8	38.0
Guinea Savanna	Nyankpala (Ferric Lixisol)	2.0	0.9	11.5
Coastal Savanna	Toje (RhodicNitisol)	2.5	0.6	18.0

Source: Adapted from Bonsu (1979)

7.2.2.1 Soil Erosion

Soil erosion is one of the most potent degradation processes affecting soil productivity. (Oldeman et al. 1991). The causative agents of erosion are water and wind. Although wind erosion is presently of no major consequence, it can be serious as bare land increases due to the removal due to the removal of vegetation in the compound farming areas in the Sudan savannah zone.

On the other hand, large tracts of land have been destroyed by water erosion (Quansah et al. 1991). Studies by Asiamah (1984) on the extent of erosion reveal the land area susceptible to the various forms of erosion as 70,441 km^2 to slight to moderate sheet erosion, 103,248 km^2 to severe sheet and gully erosion and 54,712 km^2 to very severe sheet and gully erosion. These forms of erosion are common and severe where the vegetation has been disturbed in the savannah and forest zones, hilly areas and steep slopes. However, the most vulnerable zone is the northern savannah (Guinea and Sudan Savannah zones) which covers nearly 50% of Ghana with the Upper East Region being the most degraded area of the country. In this region, Adu (1973) reported a loss of 90 cm of soil by sheet and rill erosion. Some severely eroded lands had lost all the 120 cm thick solum above the un-weathered parent rock.

What is the nature of investments that need to be made to reduce erosion here?

Runoff plot studies on bare plots in the various ecological zones of Ghana (Table 7.10) show soil losses ranging from 187 t ha^{-1} in the semi-deciduous forest zone to 0.6 t ha^{-1} in the Coastal Savanna Zone (Bonsu 1979). The corresponding values of runoff of water? as a percentage of rainfall are 47 and 18. Climate change may also contribute to accelerated coastal erosion, to which Ghana is particularly vulnerable (ISSER/DFID/WB 2005).

On bare plots, it is related to slope?

A model of land degradation assessment in Ghana predicts that land degradation reduces agricultural income in Ghana by a total of US$4.2 billion over the period 2006—2015, which is approximately five percent of total agricultural GDP in these 10 years (Diao and Sarpong 2007).

Apart from soil erosion, most of the soils in the Forest-Savannah Transition, Guinea and Sudan Savannah Zones have predominantly clay loam textured surface horizons with clay pans appearing at shallow depths. How do they matter? Inappropriate tractorization in the early 1960s, without proper site selection with regard to soil characteristics resulted in topsoil physical degradation. Is the current tractorization okay?

An additional threat to the productivity of the soil resources of the country is the insidious formation of iron-pan (petroplinthite) within the soils. Over 96.000 km^2 of land in Ghana have been found to contain iron-pan, most of it covering the Guinea and Sudan Savannah and Transition Zones (FAO 1976). Iron-pan is the result of an irreversible hardening of plinthite which is a soft subsoil material.

7.2.2.2 Nutrient Depletion

Loss of nutrients, including organic matter, is the key contributor to chemical soil degradation. Nutrient depletion occurs primarily through crop removal in harvested products and residues, leaching, erosion and N volatilization. Stoorvogel and Smaling (1990) showed that nutrient losses through these depletion pathways are only partially compensated for by crop residues left on the field, manure and fertilizer application besides atmospheric inputs. Consequently the annual NPK balance for sub-Saharan Africa were negative with minus 22–26 kg N, 5.83–6.87 kg P_2O_5, and 18–23 kg K_2O ha^{-1} from 1983–2000.

In Ghana, annual depletion rate of 30 kg N, 3 kg P and 17 kg K h^{-1} were recorded for the period 1982–1984. The projected figures for year 2000 were 35 kg N, 4 kg P and 20 kg K ha^{-1}. The extent of nutrient depletion in Ghana is widespread in all the agro-ecological zones with nitrogen and phosphorus being the most deficient nutrients. These deficiencies are, however, more pronounced in the coastal, Guinea and sudanSavanna zones where organic matter content is low and the annual burning and removal of crop residues further prevent the build-up of organic matter. It has also been generally observed that the eroded sediments contain higher concentrations of organic matter and plant nutrients in available forms than the soil from which these were lost (Quansah et al. 2000).

The high losses of organic matter are of particular concern since nutrients applied to the soil in the form of mineral fertilizers are far less effective on soils with low organic matter content (Swift 1997). Moreover, organic matter is the main source of nitrogen, phosphorus and sulphur for plants in no-fertilizer peasant agriculture (Acquaye 1990). The loss of soil organic matter and soil fertility replenishment could therefore contribute significantly to marked increases in crop yield, food security and mitigate the effects of water stress.

7.2.2.3 Salinity

Salinity is a problem with most soils along the coast due to salt intrusion. These soils occur mostly within the coastal savannah zone. Acid sulphate clay soils and salt affected soils also occur oddly along the cost in the west where annual rainfall is about 2000 mm. Over 10,000 km^2 of these degraded soils have been mapped and classified as Arenosols, Solonetz and Solonchaks (Asiamah 1995). Apart from their high salt content and high acidity, most of these soils are heavy-textured, poorly grained with columnar structures (Asiamah 1999). What are the implications though?

7.2.2.4 Water Logging

In the Guinea and Sudan Savannah zones localized water logging is experienced every rainy season. This is mainly due to shallow soils, high rainfall intensities and poor surface drainage resulting from the general low relief of the terrain. Peak season floods are major cause of recurrent crop failures and food shortages. In the Coastal Savannah Zone, the low infiltration of Vertisols, the subdued relief and high rainfall intensities are responsible for periodic water logging which causes crop failure.

7.2.2.5 Land Tenure Arrangement

A key factor that determine the extent of nutrient mining in many areas of Ghana are prevailing land tenure arrangements and the lack of plant nutrients as mineral or organic fertilizers. The type of land tenure arrangements more often than not make farmers indifferent to the loss of future economic returns to land. For instance, the estimated technical efficiency for farms under sharecropping in the Guinea Sudan savannah zone is approximately 45.17% (Donkor and Owusu 2014). Sharecroppers have put enormous pressure on soil fertility to realize immediate high yields in order to pay land rents (Benneh 1997). Farmers in such situations discount the future at very high rates, thereby reducing the incentive for long-term investments in improved soil fertility.

Demographic pressures and land availability constraints have also contributed to the decline in soil fertility. With increasing populations, the traditional techniques for renewing soil fertility, such as slash-and-burn and long-term fallowing, are not as feasible as they once were. The need for subsistence production and income are such that land can no longer be taken out of production for substantial periods to allow for natural nutrient replenishment. Nor are animal manures and crop residues usually sufficient for replacing lost nutrients. In addition, particularly in the savannah zones, the promotion of rural non-agricultural development has increased the demand for crop residues as a source of fodder, fuel, and raw materials for artisanal activities, thereby limiting their availability as soil amendments.

Other traditional soil fertility management techniques also generally fall short of the nutrient requirements of today's intensive agricultural practices. Majority of farmers in Ghana generally do not have the resources to produce sufficient organic fertilizers to replace all the nutrients removed at harvest time. For example, in order to provide 150 kg of plant nutrients to fertilize one hectare of land, a farmer could apply either 200 kg of inorganic NPK fertilizer, or 10 to 15 metric tons of crop residue grown on 5–10 ha of land, or 18 metric tons of animal manure generated from crop residue grown on 10–15 ha of land (CSIR-SRI 2005).

7.2.2.6 Climatic Conditions

Harsh climatic conditions common to the Guinea and Interior savannahs also contribute to declining soil fertility conditions. Rapid water evaporation and inadequate and highly variable rainfall, for instance, deprive plants of the water necessary for growth. High atmospheric temperatures, strong light, and heat-retentive, sandy soils combine to make the local environment too hot for proper plant growth. Powerful, dry winds occasionally damage plants through both lodging (which causes plants to fall over and die before harvest) and evaporation.

Furthermore communal rights to graze land has led to serious overgrazing, which is reported to be the main cause of human induced degradation in the Guinea and Interior savannah zones.

7.2.2.7 Change in Forest Cover

Between 1990 and 2000, Ghana lost an average of 135,400 ha of forest per year. This amounts to an average annual deforestation rate of 1.82%. Between 2000 and 2005, the rate of forest change increased by 4.2% to 1.89% per annum. In total, between 1990 and 2005, Ghana lost 25.9% of its forest cover, or around 1,931,000 ha. Measuring the total rate of habitat conversion (defined as change in forest area plus change in woodland area minus net plantation expansion) for the 1990–2005 interval, Ghana lost 27.6% of its forest and woodland habitat. Deforestation exposes the land to all forms of degradation.

7.2.2.8 Indiscriminate Mining

Although information on land use statistics in Ghana does not clearly indicate the extent to which indiscriminate mining has degraded agricultural lands, reports indicate that more than 50% of agricultural lands in mining areas have been taken over by mining activities. For example in Tarkwa in the Western region, surface mining concessions have currently taken over 70% of the total land area. Studies by

Schueler et al. (2011), showed that surface mining has resulted in deforestation (58%), a substantial loss of farmland (45%) within mining concessions in the Western region, and widespread spill-over effects as relocated farmers expand farmland into forests.

7.3 Major Crops Grown in the Various Agro-ecological Zones

7.3.1 *Crop Yield Gaps*

Evidence suggests that considerably more plant nutrients are being removed and lost from cultivated fields than are being applied, with a consequent progressive impoverishment of the soils. Traditional, soil exhausting cultivation practices are still used extensively in all the ecological zones (Gerner et al. 1995). The difference between the quantities of plant nutrients applied and the quantities removed or lost show nutrient deficits for almost all the crops (FAO 2004). This represents a loss of potential yield and progressive soil impoverishment. According to the estimates, cassava and yams account for almost 20% of the cropped area but 37% of the nitrogen deficit. These crops remove large quantities of nutrients and their soils are prone to erosion during harvest.

The average yields of most of the crops are 20–60% below their achievable yields (Table 7.11), indicating that there is significant potential for improvement.

The average per hectare maize yields in Ghana for example are lower than the average for Africa, less than one-half of the world average, and less than one-third of the average for Southeast Asia (Fig. 7.1).

A major contributing factor to the low yields is poor soil fertility resulting from nutrient depletion and low input use. As a result of population increase, pressure on land has reduced to 8–15 years natural fallow period that is required to regenerate soil fertility after 1–3 years of cropping to only 2–3 years, further reducing soil fertility (FAO 2004a, b). Soils are not adequately protected by cover crops as crop rotation is hardly practiced, resulting in easily fragile soils that are easily eroded, a problem exacerbated by over farming.

Almost all the nutrient balances in Ghana show a deficit as more nutrients are removed by harvesting or lost to erosion than are applied as fertilizers (FAO 2004). This represents a loss of potential yield and progressive soil impoverishment. According to FAO estimates, cassava and yams account for almost 20% of the cropped area, but 37% of the nitrogen deficit. The highest depletion rates are in the southeast and the central west parts of Ghana, which correspond to the cassava area (FAO 2005).

Overall, Ghana is estimated to have annual nutrient losses around 60 kg/ha NPK, which is considered the highest in SSA (Henao and Baanante 1999; Stoorvogel et al. 1993). Several studies have suggested that large increases in fertilizer usage

Table 7.11 Average yields of some selected crops and potentials yields gaps

Crop	Average yeilds (mt/ha)	Potential yeilds (mt/ha)	Yield gap (mt/ha)	Yield gap (% achievable)	Expected increase to meet target (%)
Maize	1.5	2.5	1	40	67
Cassava	12.7	28	15.3	55	120
Rice (paddy)	2	3.5	1.5	43	75
Yams	12.4	20	7.6	38	61
Cowpeas	0.9	1.3	0.4	31	44
Millet	0.8	1.5	0.7	47	88
Sorghum	0.9	1.5	0.6	40	67
Cocoyams	6.5	8	1.5	19	23
Plantains	8.1	10	1.9	19	23
Sweet potatoes	8	18	10	56	125
Groundnuts	0.8	1	0.2	20	25
Soybeans	0.8	1	0.2	20	25
Cocoa	0.4	1	0.6	60	150
Pawpaw	26	40	14	35	54
Pineapple	65	100	35	35	54
Tomato (rainfed)	25	35	10	29	40
Tomato (irrigated)	30	65	35	54	117
Garden eggs	8	15	7	47	88
Pepper	10.3	15	4.7	31	46

Source: SRID, METASIP (September 2010) and Breisinger et al.

are necessary to correct the massive nutrient losses of much of the arable land in SSA (Morris et al. 2007; Heisey and Mwangi 1997; Wallace and Knausenberger 1997). Ironically as of 2010, fertilizer use in Ghana was 8 kg/ha, well below the average in SSA (FAOstat 2014).

7.3.2 Fertilizer Use in Ghana

Numerous studies show that substantial agricultural productivity gains can be achieved in SSA in increasing the use of fertilizer and the efficiency of its utilization (Eicher 1994; Ersado et al. 2004; Tomich et al. 1995; Maiangwa et al. 2007). Experiences outside Africa also highlight fertilizer's key role in boosting agricultural productivity. Fertilizer was an integral part of the technological trinity – improved seed, irrigation, and fertilizer – responsible for bringing about the Green

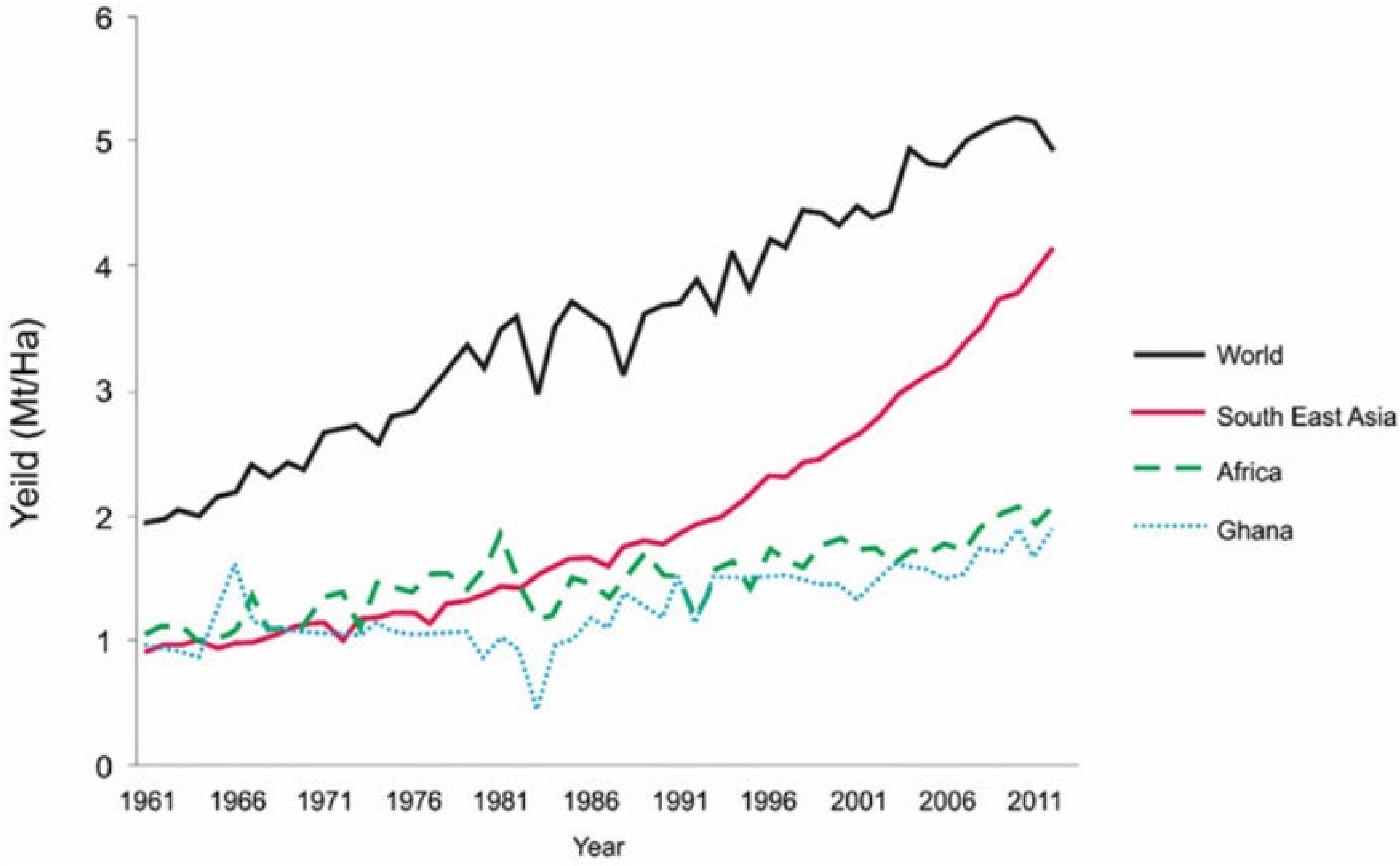


Fig. 7.1 Average maize yields (Source FAOStat 2014)

Revolution in Latin America and Asia, and it contributed as much as 50% of crop yield growth in the regions (Bumb and Baanante 1996; Dufluo et al. 2003; Kikuchi and Aluwihare 1990; Mujeri et al. 2012; Viyas 1983).

Fertilizer consumption in SSA is the lowest in the world, making up only 2% of the 2002 world supply and expected to rise to only 3% by 2011/12 (Camara and Heinemann 2006). In recent years SSA's fertilizer consumption has fluctuated and ultimately decreased to 1,041,000 MT of nutrients in 2007, as compared with 1,113,000 MT in 2002 (Fig. 7.3). Nitrogen has accounted for more than half of the total consumption in the region. From 2002 to 2007, nitrogen accounted for 53% of the almost 7 million MT of nutrients consumed in SSA, phosphate accounted for 29%, and potash accounted for the remaining 18% (Hernandez and Torero 2011). Despite the relatively dismal aggregate trends in fertilizer use in SSA, great variability in fertilizer use has been observed within the region.

Historically, Ghana has seen some fluctuations in fertilizer usage, but the rates have always remained relatively low (FAO 2005). The average Nitrogen and Phosphate fertilizer application rates per hectare in Africa and Ghana indicates that, while the gap between the rates has decreased in recent years, the average fertilizer application rates in Ghana are still well below the average of Africa overall (Fig. 7.2).

Although the importance of inorganic fertilizers is clearly emphasized in national development plans, its adoption in Ghana is very low. The average application rate is less than 8 kg/ha, which is considerably lower than in other countries like Malawi and Kenya, where application rates are 22 and 32 kg/ha, respectively (Fuentes et al. 2012). Fertilizer application rates are highest for cash crops such as cocoa, cotton, palm oil and vegetables. Application rates for maize

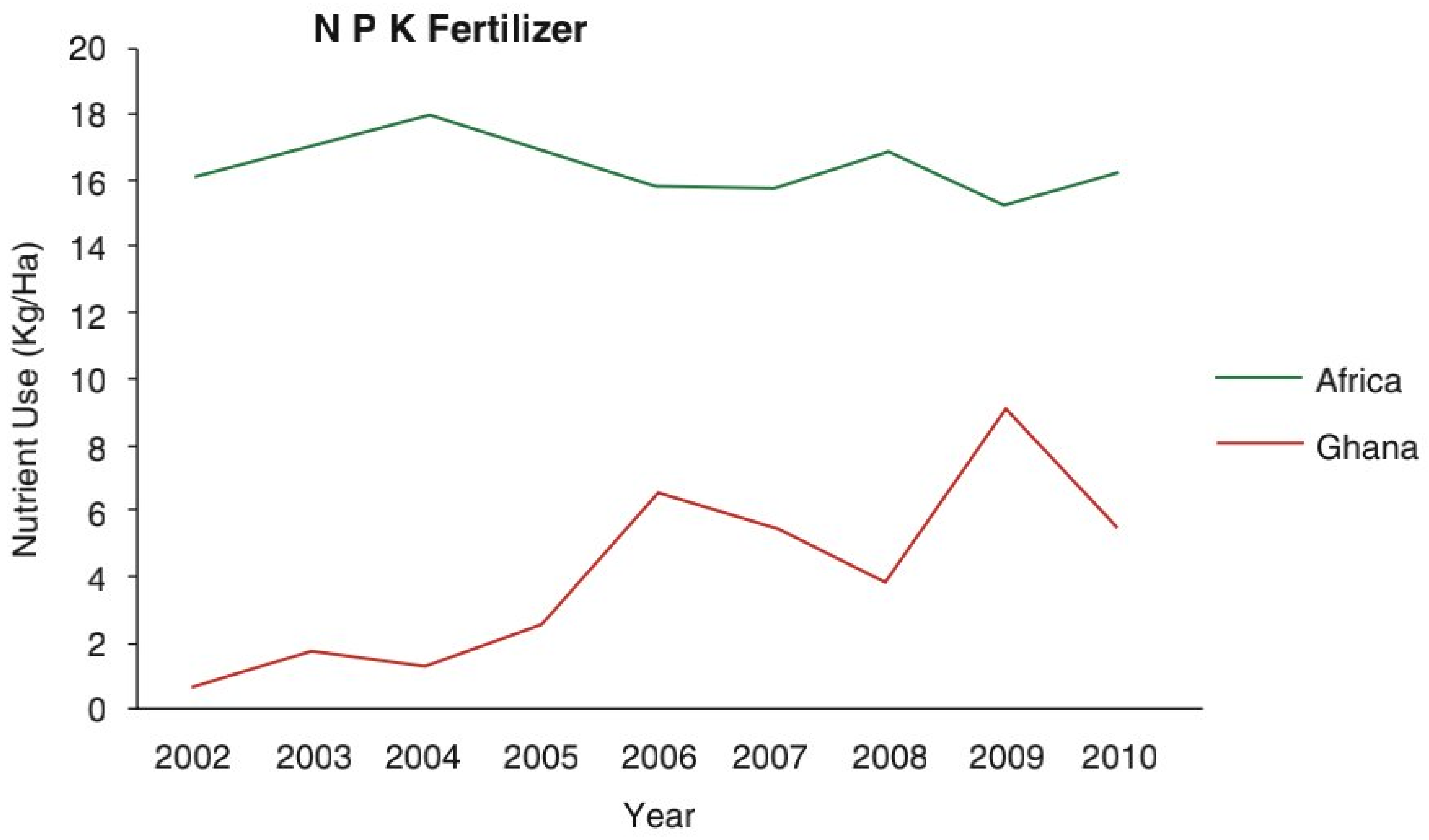


Fig. 7.2 Average fertilizer nutrient application (Source: FAOStat 2014)

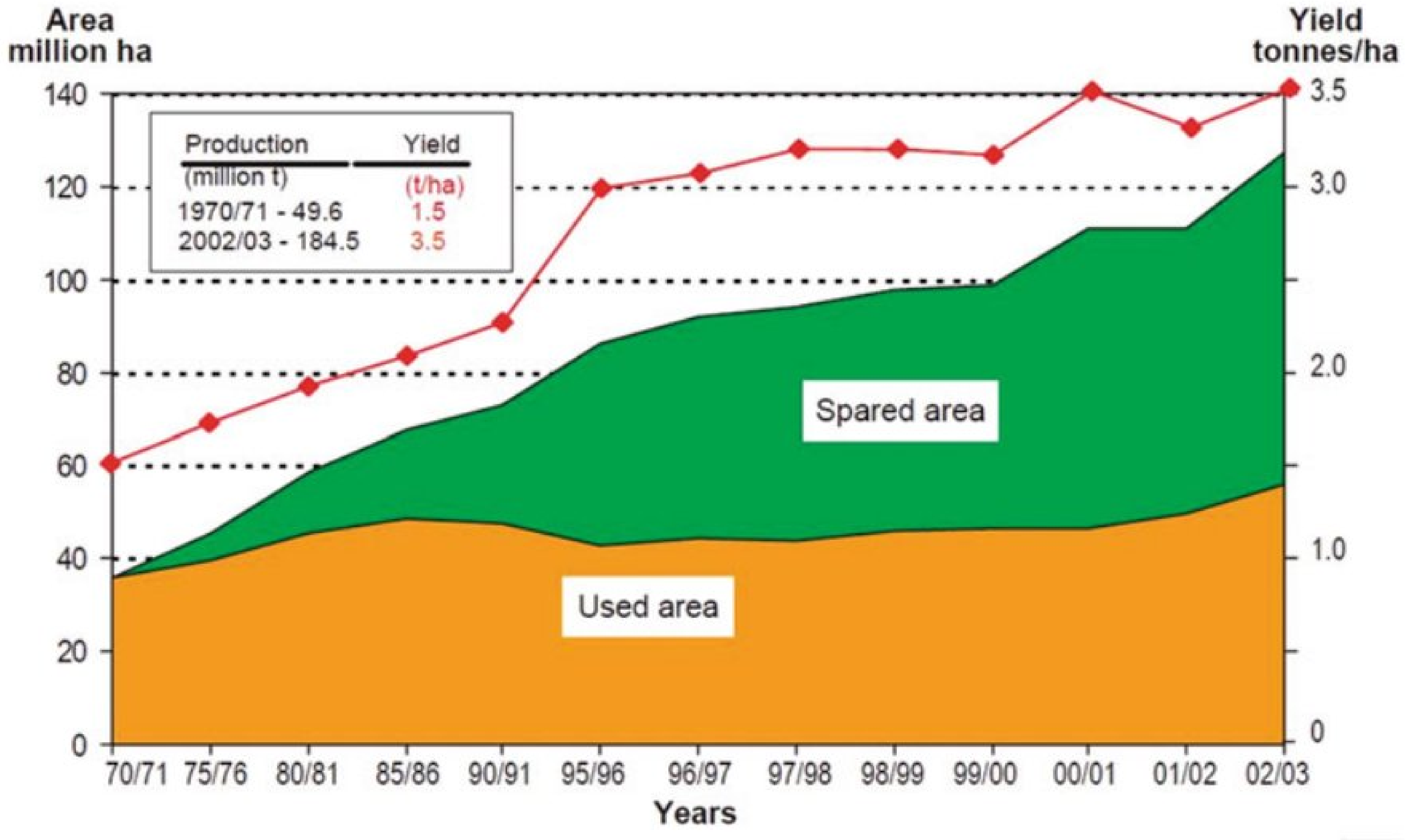


Fig. 7.3 Crop production, yields and land spared from deforestation, Brazil, 1970–2002 (Source: FAO Fertilizer and Plant Nutrition Bulletin 17, 2006)

are in the intermediate range, while application rates for crops such as cassava, millet, sorghum and yams are negligible (FAO 2005). The number of households using fertilizer by 2011 was 31% on average, although there is some variation across the country (Quiñones and Diao 2011). Approximately 10% of smallholders

Table 7.12 Observed yield paramaters of Obaatampa Maize grown at Kpalesawgu in Guinea Savanna zone of Ghana

Treatments (kg/ha N-P_2O_5-K_2O)	Yield (kg/ha)
0-0-0	231
40-60-60	1208
80-60-60	2503
120-6060	3789
150-60-60	3522
120-0-60	1258
120-45-60	3239
120-90-60	3831
120-60-0	3314
120-60-45	3772
120-60-90	3578
Probability Function	<0.01
Least Significant Difference	99.3
Coefficient of Variation	0.5

Adapted from Atakora et al. (2014)

with less than 1.0 ha use fertilizer, compared with over 20% of those with more than 5.0 ha (GoG 2010). Thus agricultural growth in Ghana has been mainly due to land area expansion as opposed to yield increases.

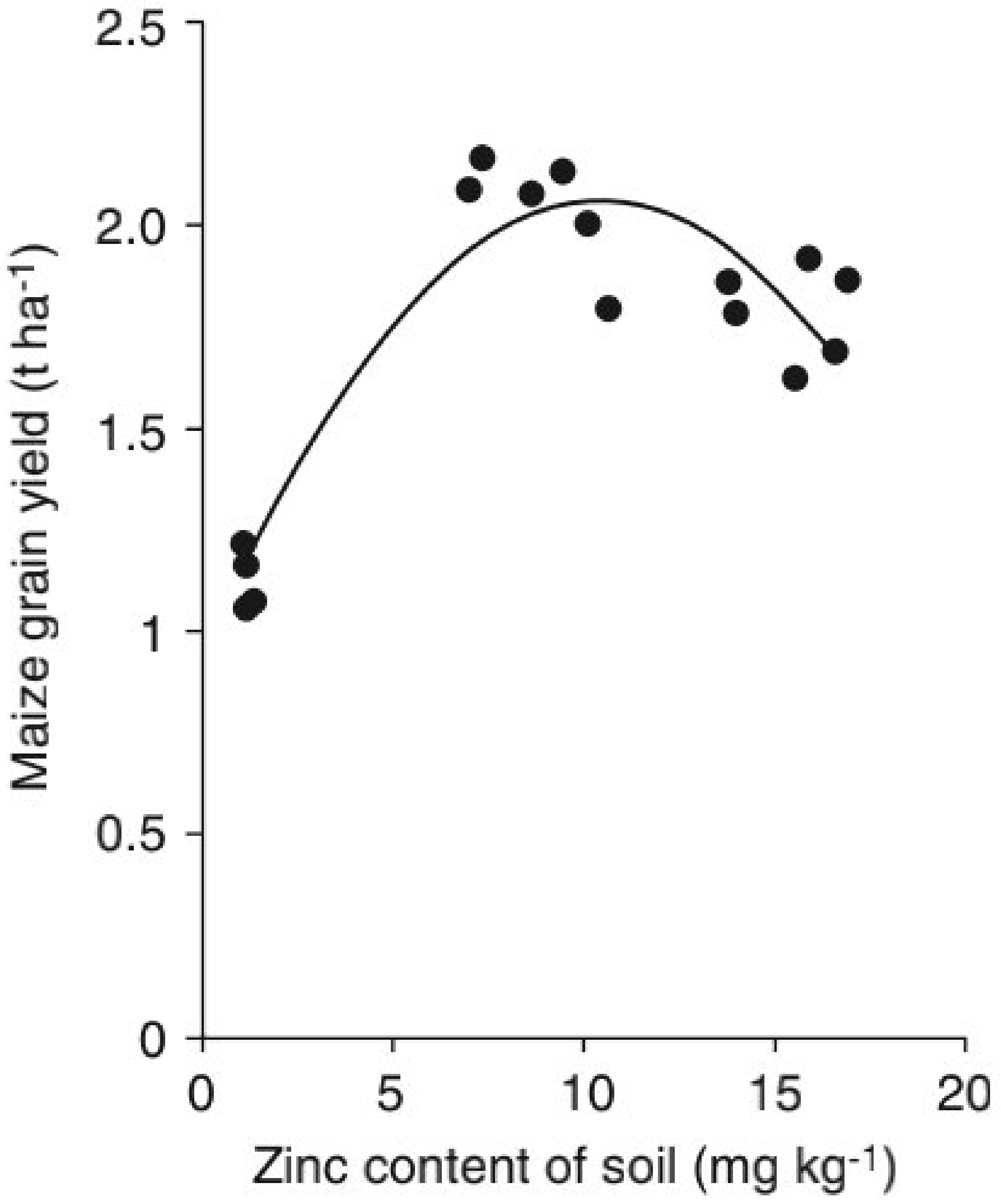
Similar to Ghana, Brazil is characterized by a large diversity of soil types, however the increased use of mineral fertilizers in Brazil has played an important role in the development of agricultural productivity and environmental preservation in the past 30 years in Brazil (Fig. 7.3). An additional cropped area equivalent to 77 million ha of cleared forest would have been necessary if the current total production were to be obtained with the yield average of 1970.

7.3.3 Response to Fertilizer Application

Varied results on crop response to fertilizer application are found in the literature. This is to be expected due to lack of uniformity over a wide range of ecological conditions, especially soil types, under which the various crops are cultivated. Generally on responsive soils, where applied fertilizer nutrients overcome crop nutrient limitations, substantial responses to fertilizers can be expected. For instance maize yield increase over the control due to NPK fertilizer application from 6 sites in the forest and transition zones and average over 3 years was 130%, when the soil was amended with poultry manure (SRI 2008).The response of hybrid maize O *baatanp*to NPK application in the Guinea Savanna (Kpalesawgu) zone of Ghana is presented in Table 7.12.

The highest grain yield was obtained when 120-90-60 Kg/ha N-P_2O_5-K_2O was applied.

Fig. 7.4 Influence of soil Zn content on Maize Grain Yield (Source: Adapted from Abunyewa and Mercer-Quarshie 2004)



The degree of insignificance difference between 40-60-60 and 1200-60 NPK Kg/ha applied indicates that P is a limiting nutrient. There was also no significant difference between grain yield when 120-45-6- and 120-60-0 NPK was applied.

Despite these positive improvement to fertilizer application studies have shown that there are great on farm soil fertility gradients and yields are bound to vary greatly even on the same production unit.

The inorganic fertilizer available to farmers contains mainly N and P with/without K. Though farmers grow various genetically improved crop varieties with high yield potentials, yields have been observed to be low. For instance in maize yields in the Guinea and Interior savannahs of Ghana, have been found to rarely exceed 1 t ha^{-1} in farmer's field. The observed low maize grain yield in spite of the application of NPK compound fertilizer indicates possible deficiencies of other important nutrients.

The highly weathered and sandy-textured soils of these zones tend to be limiting in micronutrients. Thus the application of Zn improved maize grain yield by 100% (Fig. 7.4.) stressing the need for balanced fertilization.

The response of sweet potato to fertilizer application in the Forest Transition and Savanna Zones is given shown in Fig. 7.5. Compared with the control, sweet potato responded positively to fertilizer application in two the locations. The yield of sweet potato is significantly depressed if potassium is missing. However, eliminating phosphorus does not affect the yield.

The yield is also depressed slightly when nitrogen is missing. Balanced fertilization gives large tubers while the number of tubers harvested decreases (Table 7.13) (Fig. 7.6).

Phosphorus deficiency is acute in the majority of soils in Ghana. Local farmers on the other hand use very low P fertilizers partly because of the high cost. The use of locally available phosphate rock (PR) could be an alternative to imported P

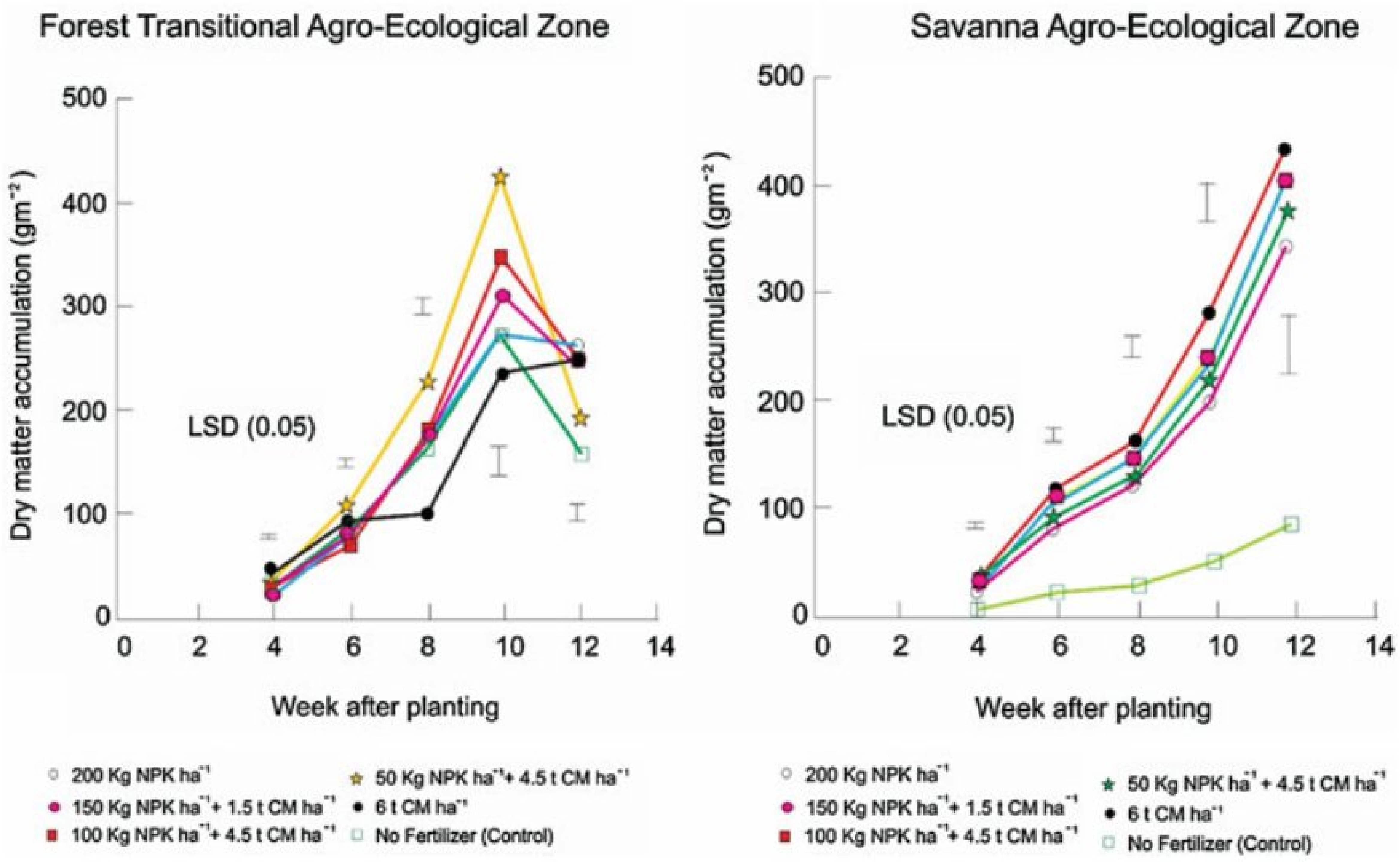


Fig. 7.5 Response of sweet potato to fertilizer application in two Agro-ecological Zones (Source: Adapted from Yeng et al. 2012)

Table 7.13 Sweet potato: response to nutrient balances

Treatment N-P-K (kg/ha)	Yield of Tubers (t/ha)	Average weight per tuber (g)	Tuber per ha (thousands)
0-30-30	11.00	136.00	83.50
30-0-30	12.60	130.80	96.00
30-30-0	8.75	132.70	68.00
30-30-30	12.30	163.70	76.00

Source: Adapted from 2003 Annual Report, CSIR-SRI

fertilizers. For example, Bationo et al. (1987) showed that direct application of local PR may be more economical than imported water-soluble P fertilizers. While all crops need an adequate supply of Phosphorus, legumes are particularly responsive and large inputs from nitrogen fixation are only possible when P deficiencies are corrected. Large increases in cowpea and other legumes yield are observed in most soils when P fertilizer is applied. The response to P fertilization is insignificant when the initial fertility status of the soil is low (Fig. 7.7).

The deficiency of P is found to be as important as or more important than that of N for crops such as upland rice grown in the humid forest or savanna zones in West Africa (Sahrawat et al. 2000, 2001). The direct application of PR to acidic pH soils (Ultisols and Oxisols) in the humid forest zone of SSA holds greater potential for boosting production of upland rice cultivars compared to production of rice in the dry regions (Sahrawat et al. 2001).

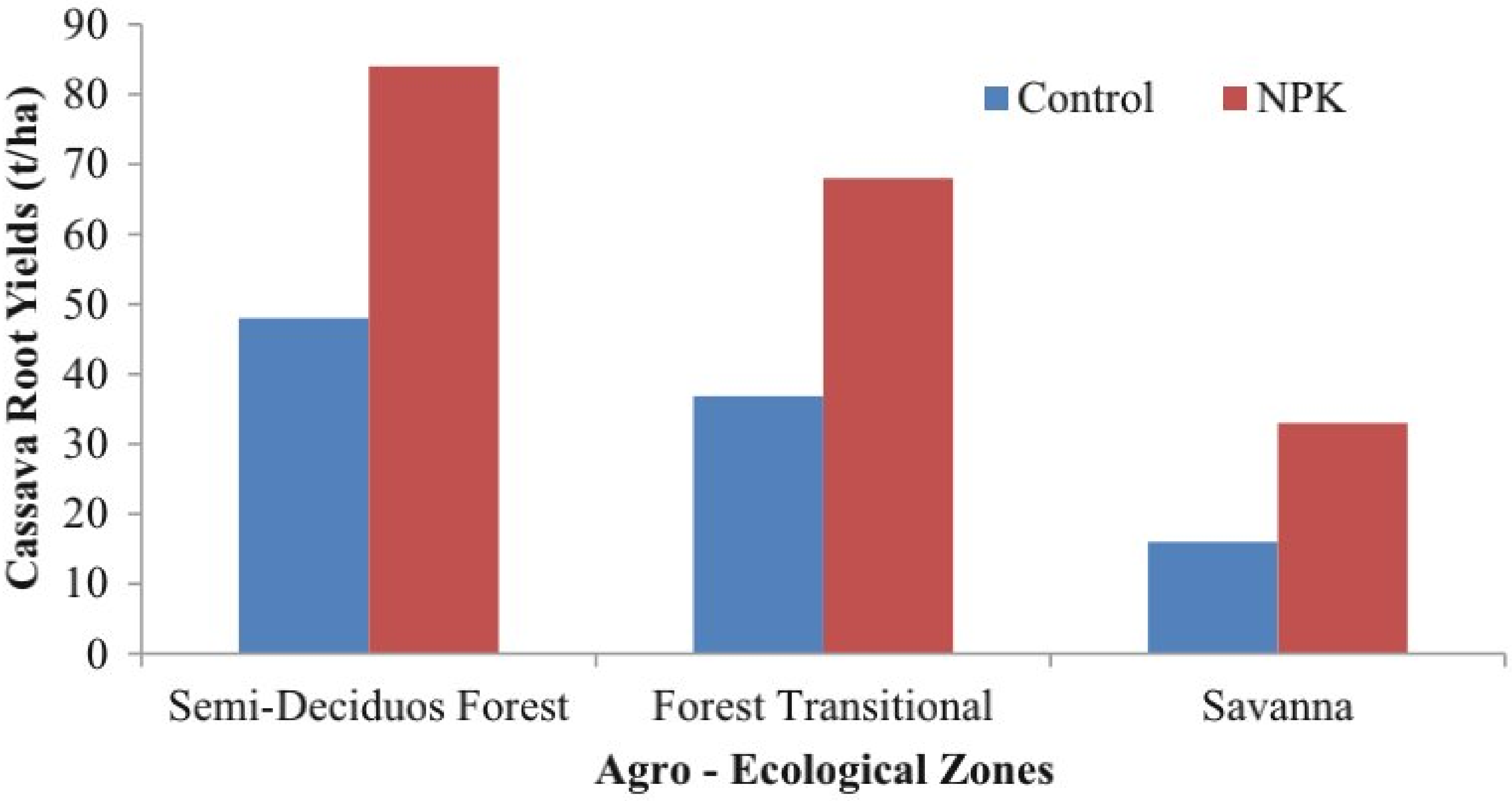
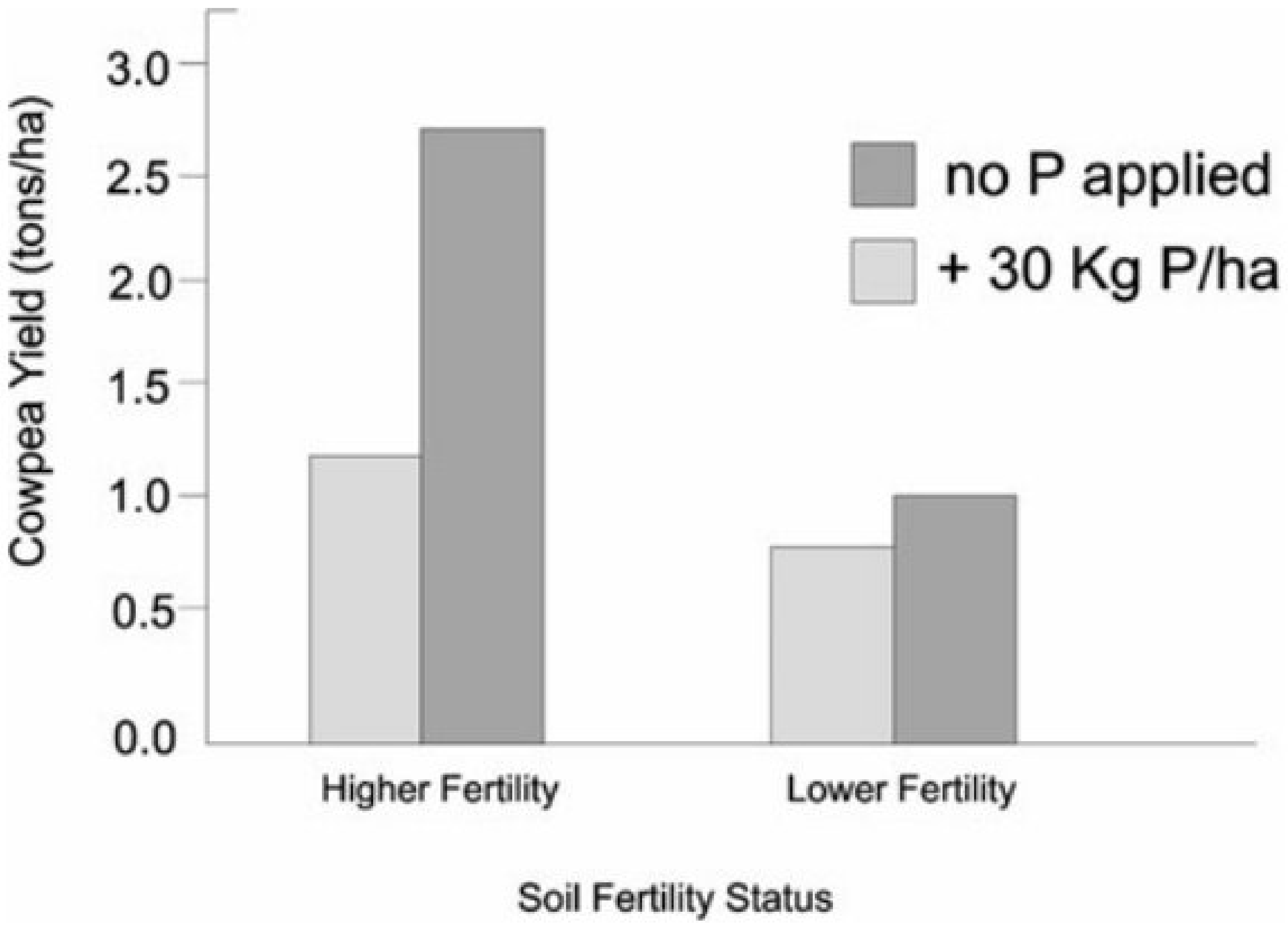


Fig. 7.6 Root Yield of Cassava to NPK (60-40-40) application (Source: Adapted from 2007 Annual Report, CSIR-SRI)

Fig. 7.7 Response of Cowpea to P Application (Adapted from 2010 Annual Report, CSIR-SRI)



There continues to be low crop response to fertilizer application in farmers' fields mainly because of poor fertilizer management by farmers; fertilizer unavailability at the time it is needed; lack of complementary inputs, such as improved seeds and irrigation (Bationo et al. 2006). There has also been low profitability from fertilizer use mainly due to the low response, high fertilizer prices and low and unstable product prices.

More fertilizer yield response and profitability studies are therefore needed for a range of crops in Ghana. Profitability ratios under a range of input and output cost scenarios should be determined across the country so that farmers can know beforehand what levels of fertilizer application will be profitable for them to use on a particular type of crop.

7.3.4 Profitability of Fertilizer Usage

The demand for a particular variety/brand of fertilizer (like nitrogen) is derived demand, price elastic and influenced by the price of other varieties/brands of fertilizer (Acheampong and Dicks 2012). The price and/or availability of other inputs that complement and enhance fertilizer productivity – for example, hybrid seed and irrigation, also play an important role in farmer's decision to use fertilizer. Similarly, the price and/or availability of other inputs that substitute a variety of fertilizer as well influence its use (Acheampong and Dicks 2012).

Langyintuo and Mekuria (2005) categorized factors that influence farmers' decisions to use agricultural improved inputs as: farmer characteristics, institutional factors and characteristics of the input. Farmer characteristics among others include; sex, age, education, and household size while institutional factors include farm size, membership to association, access to information, access to credit, and access to infrastructure such as roads or storage. Characteristics of the factor input relate to the subjective attributes of the input as perceived by the farmer (Adesina and Zinnah 1993).

The wedge between the high price of fertilizer on the one hand and low price of crops on the other, especially for farmers in landlocked countries in SSA is one of the major factors that make them reluctant to use the input. Morris et al. (2007) observe that demand for fertilizer is often weak in Africa because incentives to use fertilizer are undermined by the low level and high variability of crop yields on the one hand and the high level of fertilizer prices relative to crop prices on the other. Smaling et al. (2006) indicate for example that farmers in Africa require 6–11 kg of grain to purchase one kg of nitrogenous fertilizer compared with about 2–3 kg of grain in Asia. High fertilizer prices in SSA are mostly attributed to high transaction costs of fertilizer trade arising from high transportation costs, high interest rates and low volume of purchases (Gregory and Bumb 2006). Lack of market Lack of market information about the availability and cost of fertilizer and the inability of many farmers to raise the resources needed to purchase fertilizer in bulk is cited among other factors that make farmers pay more for fertilizer (Morris et al. 2007). Low farm-gate prices for crops on the other hand is mainly influenced by poor road infrastructure and lack of storage facilities as well as lack of market information (Torero and Chowdhury 2004; Morris et al. 2007).

According to Morris et al. (2007), even if farmers believe that fertilizer is profitable, they may be unable to purchase it if lack cash and/or cannot obtain credit. In agricultural households, the main sources of cash include earnings from salary/wage employment, sell of livestock, and trade. Besides, farm-household size and composition – which has close links with labour supply as well as the income status of the household head, has both positive and negative implications on adoption of inputs. In case of labour intensive inputs such as production and use of organic fertilizer, availability of labour with minimum knowledge can encourage its use even in poor households. On the other hand, if large households are disproportionately poor, then lower use of relatively expensive inputs such inorganic fertilizer is expected in households with large families. Information about the

Table 7.14 Partial budget for eight fertilizer treatments on maize in 2011

	Treatment for 2011 – Across locations							
Treatment	1	2	3	4	5	6	7	8
Mean yield of maize (kg ha^{-1})	2397	3772	4114	4203	4311	4277	4761	4894
Adjusted yield (kg/ha^{-1})	2157.3	3394.8	3702.6	3782.7	3879.9	3849.3	4284.9	4404.6
Gross field benefits (GH ¢/ha)	1078.6	1697.4	1851.3	1891.9	1939.95	1924.6	2142.4	2202.3
Cost of NPK (15-15-15)	–	51	51	51	–	–	–	–
Cost of sulphate of ammonia	–	35	–	–	–	–	–	–
Cost of Sulfan fertilizer	–	–	35	–	–	–	–	–
Cost of Urea fertilizer	–	–	–	46	–	–	–	–
Cost of Actyva fertilizer	–	–	–	–	51	51	51	51
Cost of Winner fertilizer	–	–	–	–	–	–	–	52
Cost of fertilizer application	–	50	50	50	50	75	75	75
Total cost that vary (GH ¢/ha)	–	136	136	147	101	126	126	178
Net benefits (GH ¢/ha)	1078.6	1561.4	1715.3	1744.35	1838.95	1798.6	2016.4	2024.3

availability and cost of fertilizer and the inability of many farmers to raise the resources needed to purchase fertilizer in bulk is cited among other factors that make farmers pay more for fertilizer (Morris et al. 2007).

The appropriate dosages for application of inorganic fertilizer formulations on maize yield and profitability was assessed in the semi deciduous and transition zones of Ghana. According to Berchie et al. 2013, the application of Actyva (125 kg/ha) at planting plus Winner (125 kg/ha) at 2 WAP plus Actyva (250 kg/ha) at 4 WAP out-yielded the recommended fertilizer rate by 30% and the control by 104% in 2011 and also produced the highest grain yield across locations in both 2011 and 2012. The partial budget for the various treatments (Tables 7.14 and 7.15) showed that the net benefit for no fertilizer application (GH ¢ 1078.6) was lower than all the treatments.

7.3.5 Importance of Agronomic Efficiency

Returns can be increased with effective use. Nutrient recoveries of applied fertilizer by crops under farmers' practices are distressingly low. Only about 10–15% of the P

Table 7.15 Partial budget for eight fertilizer treatments on maize in 2012

	Treatment for 2012-Across locations							
Treatment	1	2	3	4	5	6	7	8
Mean yield of maize (kg ha^{-1})	4027	3978	3761	4230	4415	4588	4113	4769
Adjusted yield (kg/ha $^{-1}$)	3624.3	3580.2	3384.9	3807	3973.5	4129.3	3701.7	4292.1
Gross field benefits (GH ¢/ha)	2174.58	2150.94	2030.9	2284.2	2384.1	2477.58	2221.02	2575.26
Cost of NPK (15-15-15)	–	51	51	–	–	–	–	51
Cost of sulphate of ammonia	–	–	–	–	–	–	–	35
Cost of Sulfan fertilizer	–	35	–	–	–	–	–	–
Cost of Urea fertilizer	–	–	46	–	–	–	–	–
Cost of Actyva fertilizer	–	–	–	51	51	51	51	–
Cost of Winner fertilizer	–	–	–	–	–	–	52	–
Cost of fertilizer	–	50	50	25	25	25	50	50
Total Cost that vary (GH ¢/ha)	–	136	147	76	76	76	153	136
Net benefits (GH ¢/ha)	2174.58	2014.94	1883.9	2208.2	2308.1	2401.58	2068.02	2439.26

Adapted from Berchie et al. (2013)

and 10–20% of the N and K applied through fertilizer is assimilated by crops. This ineffective use of fertilizer in effect discourages investment in fertilizer by poor African farmers (Africa Fertilizer Summit 2006). Low assimilation efficiencies are common as a result of several factors. Crops require nutrients in different quantities and proportions. According to the Law of Minimum (Russel 1973), deficiency in one nutrient results in reduced plant growth and less ability to make use of all other nutrients. Most fertilizers only address the primary nutrient requirements of crops (N, P, K). In this regard soil reserves of non-limiting nutrients decline with intensifying cultivation, limiting the use of efficiency of these fertilizers that do not contain them (Giller et al. 1998; Vanlauwe et al. 2006). However applying the Law of Optimum, evidence suggests that the lack of one nutrient influences the

Table 7.16 Nitrogen Use Efficiency (NUE), grain yield, and yield components of Sorghum as affected by N, P, and K Fertilizer levels

Treatment	100 kernel Weight (grams)	Kernel m^{-2}	Grain Yield (kg ha^{-1})	NUE (kg grain kg N^{-1})
P_2O_5 level (kg ha^{-1})				
0	2.05a	6517a	1930a	11.3a
40	2.13a	7018a	2092b	11.9a
K_2O level (kg ha^{-1})				
0	2.08a	6765a	1992a	11.4a
40	2.10a	6830a	2029a	11.8a
N level (kg ha^{-1})				
0	2.18	4342	1397	
40	2.06	6928	2048	16.3
80	2.07	7833	2242	10.6
120	2.07	8088	2356	7.9
N linear	NS	–	–	–
N quadratic	NS	–	–	NS
CV (%)	11	22	14	35

Adapted from Buah et al. (2012)

efficiency of uptake of another one at even non limiting levels. In this way stressed crops are limited in their ability to make efficient use of applied nutrients. Drought stress leads to impaired root development. Soil characteristics such as soil crusting, impermeable soil layers, extreme pH levels and Al toxicity negatively affect plant root development and nutrient uptake. Ineffective management of inputs leads to nutrients losses and inefficient utilization by crops. Fertilizer application needs to be applied and timed at appropriate rates in accordance with crop nutrient requirements and tailored to environmental conditions.

The agronomic and economic benefits of applying nitrogen (N), phosphorus (P), and potassium (K) fertilizers to sorghum in the Guinea savannah zone of Ghana has indicated that fertilizer N, P, and K did not show significant inter- actions for any parameter. Across years, added K did not influence grain yield and yield components. However, P increased yield by 14%, and N affected yield in a quadratic manner. The application of 40, 80, and 120 kg N ha^{-1} resulted in yield increases of 47%, 60% and 69% over farmers' practice (0 kg N ha^{-1}), respectively. Economic analysis revealed that two N and P combinations, i.e., 40:0 and 40:17.2 kg ha^{-1}, were economically superior and stable within a price variability range of 20%. Thus, farmers in the Guinea savanna agro-ecology in Ghana can get better returns on the money invested in fertilizer for producing improved sorghum than with their traditional practice of no fertilizer input. (Buah et al. 2012)

Nitrogen-Use Efficiency (NUE) calculated as a ratio of grain yield to amount of N applied was not affected by added P and K when averaged across N levels (Table 7.16). However, NUE decreased as a linear function of N rate when averaged across P and K levels. Sorghum had highest NUE (16.3 kg grain kg^{-1} N)

Table 7.17 Nutrient content of cattle and poultry manure

Source of Manure	Agro-Ecological Zone	Nutrient content (mg/g) N	P_2O_5	K_2O
Cattle	Sudan Savannah	18.5	10.5	3.0
	Guinea Savannah	13.2	7.3	6.1
	Coastal	14.2	7.2	8.5
Poultry	Forest	29.58	20.87	7.02

Source: Adapted from Fening et al. (2005a, b)

at 40 kg N ha^{-1}. The use of 80 kg N ha^{-1}or 120 kg N ha^{-1}, however, did not result in a corresponding increase in NUE across years. On average, the 120 kg N ha^{-1} treatment resulted in the lowest NUE value of 7.9 kg grain kg^{-1} N. Economic analysis (partial budgets) for fertilizer N and P levels showed that all the treatments had positive gross benefits when averaged across years and K levels. The net benefits ranged from US$366 to US$542. Fertilizer application gave gross benefits and net benefits that were greater than those of no fertilizer treatment (farmers' practice) (Buah et al. 2012).

7.3.6 Response of Crops to Organic Manure

The two most important types of manure being used by farmers in Ghana are cattle and poultry. Cattle manure is popularly used in the savannah ecosystems where cattle production is predominant. Poultry manure on the other hand is commonly used in the forest zones where there are large commercial poultry farms. Cattle manure are usually obtained either from kraals where the animals are housed or from the animal droppings in the field. Table 7.17 gives the nutrient qualities of some sampled cattle and poultry manure.

In the Interior, Sudan Savannah and Forest transitional zones, cattle manure is commonly applied to crops, including maize, millet, sorghum, cowpea, cassava. The use of poultry manure is more common to the Coastal savannah and Forest zones.

7.3.7 Response to Inorganic and Organic Manure Combination

The need for the application of both organic and inorganic fertilizer to reserve the declining trend in soil fertility has emerged in recent years. While fertilizers supply plant nutrients, organic manure is a precursor of soil organic matter, which

Table 7.18 Cassava root yield and partial budget analysis in response to combined application of organic and inorganic fertilizer

	Root weight t/ha		Partial budget analyses (000 Cedis)		
Treatment	2002	2003	Gross farm gate benefits	Total variable input cost	Net benefit
Control	55b	43b	4400	2130	2270
$N_{30}P_{20}K_{20}$	87a	74a	6960	2900	3950
$N_{60}P_{40}K_{40}$	89a	92a	7120	3590	3530
PM 2.5 t/ha	89a	77a	7120	2610	4510
PM 5.0 t/ha	96a	85a	7680	2890	4790
$N_{30}P_{20}K_{20}$ + PM 2.5 t/ha	113a	96a	9040	3340	5700
LSD ($P = 0.05$)	31	24			

At the time of this work US$1 = 8200 Cedis. Source: Fening et al. (2005a, b)

maintains the physical and physic-chemical components contributing to soil fertility such as cation exchange capacity (CEC) and soil structure. The major reason for advocating the use of organic manure and inorganic fertilizer in combination is that either one of them may not be available or affordable in sufficient quantities. One other salient aspect of simultaneous application of the two nutrient sources is the potential for positive interactions between both inputs leading to added benefits in the form of extra grain yield or improved soil fertility and reduced losses of nutrients. Table 7.18 demonstrates the benefits of combined application of organic and inorganic fertilization for sustainable cassava production.

7.4 Soil Fertility Management Practices

A range of soil management technologies that have been adopted by farmers across the agro- ecological zones has been documented (Table 7.19). Differences that occur between zones can be explained from differences in farm type and farming intensity as well as from the cropping system and its biophysical conditions. There are differences in farm structure and land ownership, historical development of agricultural production, protection of the environment and landscape, and main recommendations by agricultural extension services that may cause differences between zones and management practices. Available evidence shows that these technologies increase agricultural productivity in the environments in which they have been adopted and provided farmers with some significant yields. But it is also known that what may work in one site, may not work in another due to differences in soil types, acidity levels, organic matter content, chemical composition of soils, rainfall, slope of land and other factors.

Table 7.19 Soil fertility management practices in Ghana

Agro-ecological zone	Soil management practices
Coastal savanna	Strip cropping, Crop rotation, Organic and Inorganic Fertilization
High rainforest	Closed Canopy cropping, Mixed cropping, Liming, Soil erosion measures, Drainage control and Organic and Inorganic Fertilization
Semi-deciduous forest	Mixed cropping, Agroforestry, Organic and Inorganic Fertilization, Contour cultivation, Cover cropping, Flood and Drainage control, Mulching, Strip cropping
Forest savanna transition	Mixed cropping, Agroforestry, Organic and Inorganic Fertilization, Cover cropping, Mulching, Strip cropping rotation
Guinea savanna	Mulching, Stone terracing, Strip cropping, Crop rotation, Organic and Inorganic Fertilization, Contour ploughing, Residue retaining, Drainage control, Liming

Source: Adapted from Ghana National Soil Fertility Management Action Plan 1998

7.4.1 Proven Soil Fertility Technologies That Can Be Scaled Up

Small holder farming systems in Ghana occur within diverse biophysical and socio – economic environment. The farmers therefore develop different livelihood strategies driven by opportunities and constraints encountered in such environments. Within ecological zones, and localities within the zones farmers differ in resource endowment, production orientation education, past experience, objectives of production and management skills and attitudes towards risks. Studies on farm typologies have shown the fundamental differences between farm categories, with about 3 typologies that often represent the differences in resource endowment. (1) - Resource-endowed farmers who are usually large scale farmers have ready access to large quantities of manure and mineral fertilizers, which contribute to higher soil fertility and crop productivity on their farms. (2) Resource-constrained farmers who use little or no manure and mineral fertilizers, and have limited capacity to invest in labour-demanding soil fertility management technologies. (3) Sharecrop holders who discount the future fertility of the soil, thereby reducing the incentive for long-term investments in improved soil fertility management. Recognition of these variables is the first step with regard to the adoption of new technologies. An array of nutrient management strategies tailored to specific agro-ecological zones rather than blanket recommendations across diverse zones that have been developed for sustainable crop production intensification include the following:

7.4.1.1 Cassava – Cowpea Strip Intercropping/Rotation

The technology involves simultaneous growing of cassava and cowpea in strips wide enough to allow independent cultivation but, at the same time, sufficiently narrow to induce crop interactions.

Advantages

- Improves yield of component crops
- Increases farmers monetary returns
- Improves soil fertility
- Facilitates independent crop management
- Offers greater yield stability
- Reduces risk of total crop loss
- Offers better land use efficiency

Studies conducted in the transitional and forest ecological zones using this technology improved yields of component crops by over 50% (Fening et al. 2009).

7.4.1.2 Conservation Agriculture

Water is a key constraint to crop production in the Sudan and Guinea Savanna zones of Ghana. Large areas within the region receive less than 800 mm rain annually in a normal year and are prone to drought periods within the cropping season. Conservation agriculture offers possibilities for better water management and yield enhancement. Conservation agriculture involves a number of approaches for reducing tillage, which results in higher retention of soil organic matter and improved physical properties of soil, such as water holding capacity, aggregation and infiltration. In addition to minimum or zero tillage, conservation agriculture involves early land preparation and timely planting, legume rotations, micro-water basins, point seeding and fertilizer application, and covering the soil with biomass (crop and farm residues).

Although the practice is not yet widespread in SSA and many of its technologies are not available or well-suited to small-scale farmers, incorporation of many of the principles fundamental to Conservation Agriculture can assist in ISFM. Currently CA is practice to a lesser extent in Ghana mainly in the Guinea and Sudan savannah zones (Derpsch 2008).

7.4.1.3 SAWA Technology

The concept and the term "Sawa" refers to man-made improved rice fields with demarcated, levelled, bunded and puddle rice fields with water inlets and outlets which can be connected to various irrigation facilities such as irrigation canals, ponds, springs and pumps. The SAWA system of rice production ensures proper management of the rice environment and improves the fertility status of the soil, resulting in efficient and higher grain production with higher returns. Under the SAWA technology rice yield increased from less than 1 t/ha to over 6 t/ha under farmers' conditions in the inland valleys of Ashanti and Brong Ahafo regions of Ghana (Buri et al. 2007). Increase in rice production under the traditional system has mainly been due to increased area put to rice as against SAWA which increase yield per unit area.

7.4.1.4 Combined NPK and Manure

The benefits of the combined application of manure and NPK has been demonstrated extensively in maize, yam and cassava. In cassava for instance a monetary return of over 50% has been achieved with half the rate of NPK and poultry manure in the forest transition zone. (Fening et al. 2005a, b).

7.4.1.5 Green Manures

The use of cattle is very limiting in the semi-deciduous zone where livestock is not fully integrated in the farming system. Other organic resources such as high biomass producing plants could therefore be used as alternatives to address declining soil fertility. The use of plant biomass for soil fertility replenishment requires the identification of species found in the farm vicinity to reduce labour cost. Such plant species should have the ability to increase P availability and produce a large pool of mineral N before the period of rapid N uptake by a crop. The use of *Chromolaena odorata*, *Crotalaria juncea* and *Panicum maximum* and their combination with NPK for improving soil fertility and maize yield has been investigated in the semi-deciduous zone of Ghana. The plant materials plus $N_{45}P_{30}K_{60}$ provided nutrients that were sufficient to increase maize yields by over 85% relative to the control for two consecutive seasons. Maize grain yield was not influenced by the quantity of plant materials applied. (Fening et al. 2009).

7.5 Potential of BNF for Improving Soil Fertility

Nitrogen is the most limiting nutrient element to crop production in Ghana. Nitrogen deficiency results from its continual removal from the soil pool by processes such as volatilization, leaching and most importantly, removal from harvested crops and residues from the soil. The nitrogen reserve of agricultural soils must therefore be replaced regularly in order to maintain an adequate level of production. The replacement of nitrogen is generally accomplished by the addition of inorganic fertilizers or by biological nitrogen fixation (BNF). While there is a wide range of organisms and microbial–plant associations that are capable of fixing atmospheric nitrogen, the symbiotic relationship between rhizobia and legumes is responsible for contributing the largest amounts of fixed nitrogen to agriculture. In contrast to expensive chemical N fertilizers, BNF is often a more attractive and practicable alternative. Maximal rates of BNF recorded in the tropics reach an astonishing 5 Kg N/ha/day (Giller 2001). More than 250 Kg N/ha of fixed N has been measured in soybean in southern Africa with associated grain yield of 4 t/ha. Thus when effective BNF can meet the goals of the Abuja Summit in the fields where legumes are grown.

Recent analysis of the Ghanaian farming system like others in the sub region indicates that less than 5% of farm lands are often planted to legumes. This is often due to relatively poor market prices for legume grains. However even at the current rates of BNF, which are substantially low a modest increase of the farm are planted with legumes to 105 will automatically double the amount of N input into framing systems. Attention should be given to improving the BNF of useful legumes in Ghana such as cowpea, soybean, common bean, groundnut and pigeon pea.

7.5.1 Use of Inoculants for Improving Soil Fertility

A common approach to improve BNF and legume productivity has been the reliance on superior or very effective exotic rhizobia strains as inoculants. This approach has, however, failed to achieve the desired responses in Ghana. The failure has largely been attributed to the poor nodulation competitiveness of the introduced rhizobia. When introduced, the inoculant rhizobia must adapt to the prevailing soil conditions, multiply in the soil and host rhizosphere and compete with the indigenous often ineffective rhizobia population for infection sites. But unfortunately, the inoculants often fail to occupy a significant proportion of the nodules. A way of improving the success of inoculants can be to use native strains that are effective as well as competitive for nodulation as inoculants. This is currently being investigated under the N2Africa project at CSIR-Savanna Agriculture Research Institute (SARI).

Cowpea (Vigna inguiculata) is an important food legume that features prominently in many farming systems in all the ecological zones of Ghana (Fening and Danso 2002). However, there is great variability in the numbers of bradyrhizobia that nodulate cowpea in Ghanaian soils (Fening and Danso 2002). While no bradyrhizobial were detected in 20% of the soils, at least 60% of the soils contained more than 1×10^3 bradyrhizorbial cells gram per soils. Twenty percent (20%) of the remaining soils contained between 100 and 1000 cells gram per soil (Fig. 7.8).

The effectiveness of the isolates in fixing nitrogen in cowpea is shown in Table 7.20. Generally, distribution of the isolates in the ecozones followed a normal distribution trend with the majority being moderately effective (Fening and Danso 2002).

The relative effectiveness of the 10 most effective isolates against the standard strain TAL 169 indicated that 7 of the isolates possessed symbiotic effectiveness superior to the standard strain, with 4 of these differing significantly from the standard strain (Fig. 7.9).

It is also estimated that in Ghana the benefit of nodulated cowpea to soil nitrogen supply is 60 kg N ha^{-1} when residues from the crop are incorporated into the soil (Dakora et al. 1987).

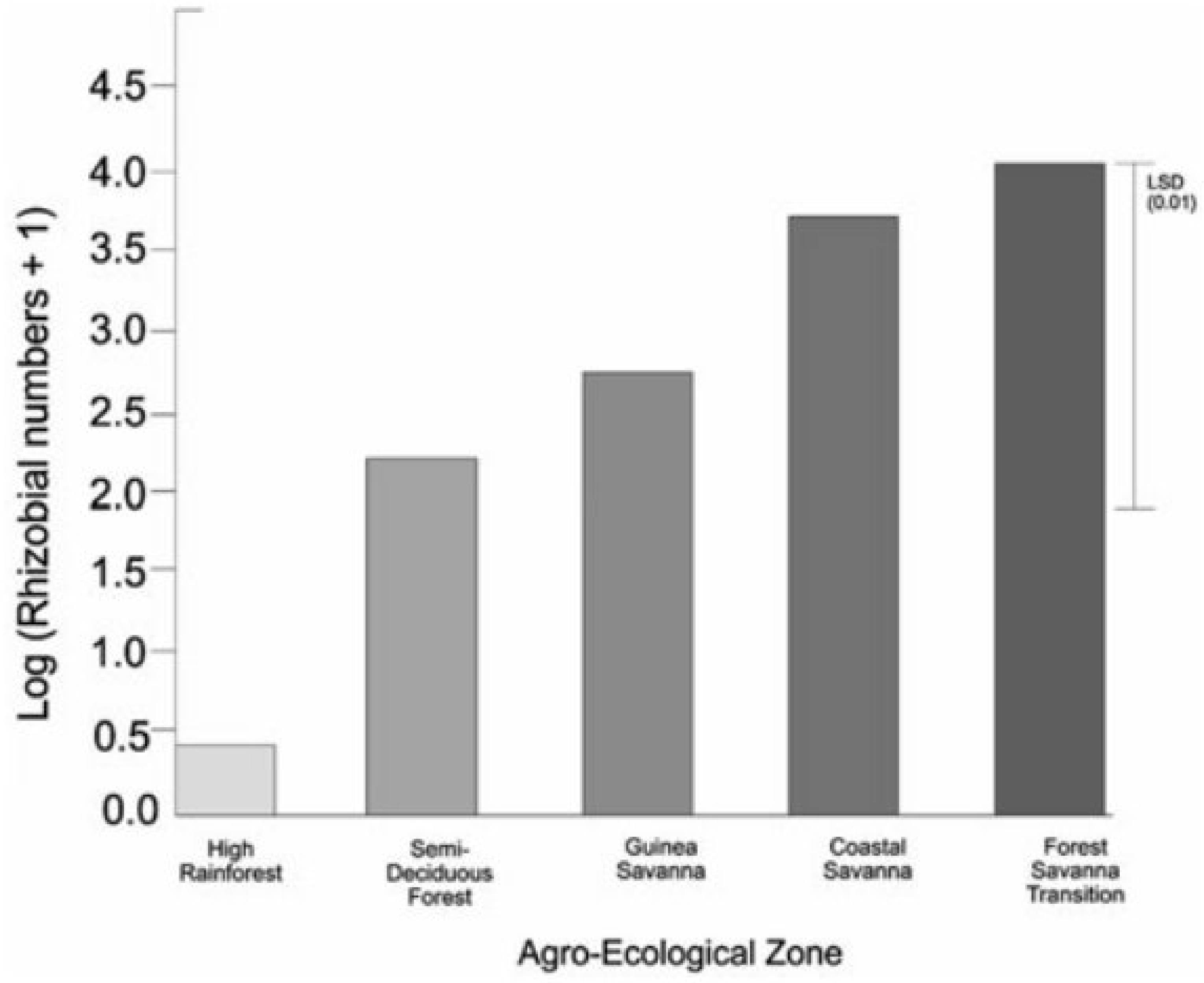


Fig. 7.8 Most Probable Number Estimates of Bradyrhizobia in the Different Agro-ecological Zones. (Source: Fening et al. 2002)

Table 7.20 The effect of agro-ecological zones on the relative effectiveness of Native Cowpea Bradyrhizobia Isolates

	Indices of Effectiveness (%)			
Agro-Ecological Zone	n	Highly effective	Moderately effective	Ineffective
Coastal savanna	20	20.8	75	4.1
High rainforest	20	75	25	0
Semi-deciduous forest	20	33.3	58.3	8.3
Forest savanna transition	20	25	66.7	8.2
Guinea savanna	20	16.7	79.2	4.1

Source: Fening et al. (2002)

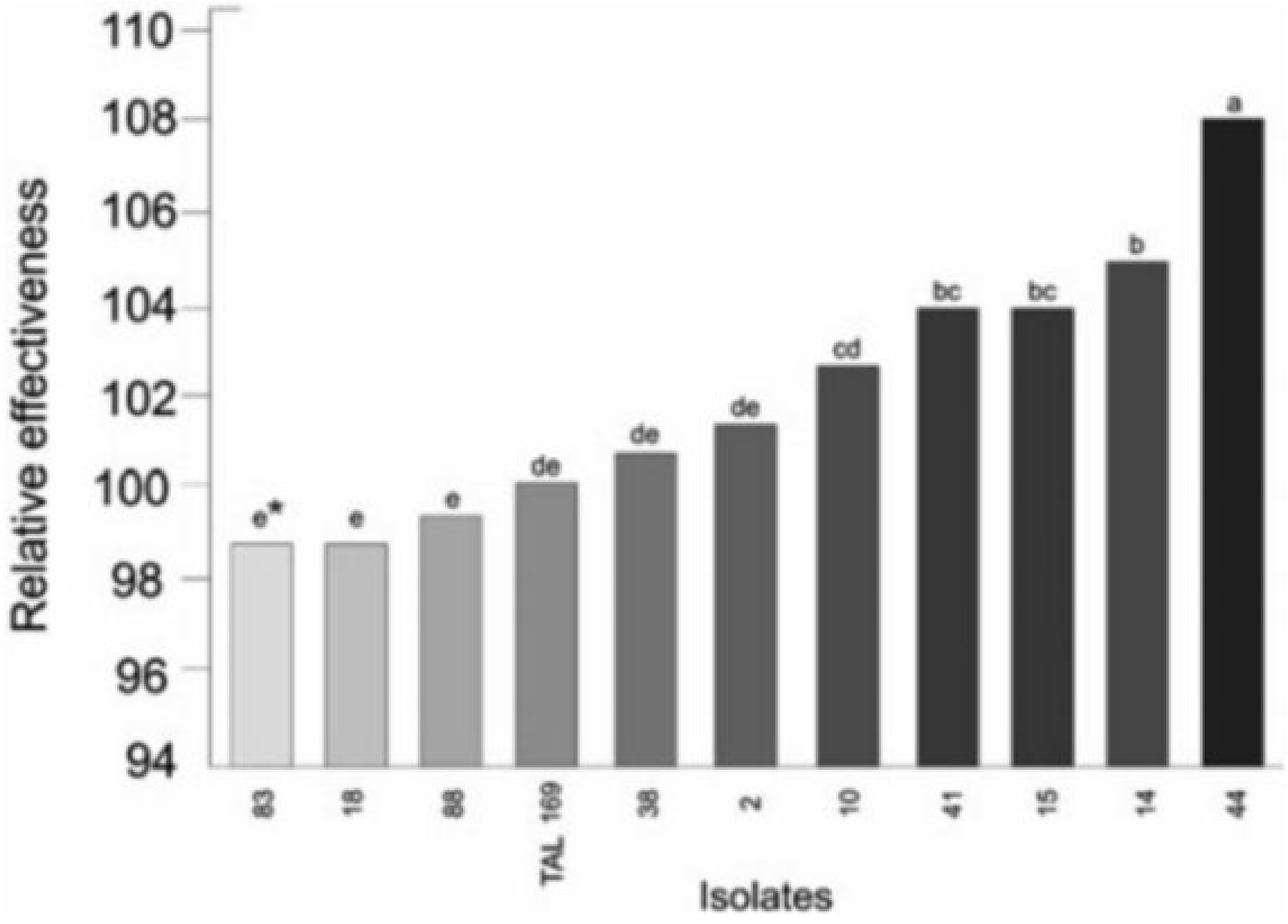


Fig. 7.9 Symbiotic Effectiveness of 10 Cowpea Bradyrhizobia Isolates Relative to an Adopted Standard Strain TAL 169. *: Bars with same letters are not significantly different at 5% level of significance (Source: Fening et al. 2002)

The potential for increasing the yield of cowpea and other legumes as well as improving the soil nitrogen status by using very effective indigenous isolates as inoculants therefore exist. At present there is lack of adequate information on the diversity, symbiotic characteristics, as well as the competitiveness for nodule occupancy of this native population of rhizobia.

Groundnut, an important legume in Ghana in terms of both production and consumption (Ofori 1993), is estimated to receive about 79% of its total nitrogen requirements from symbiotic association with rhizobia (Dakora et al. 1987).

The importance of soybean as a grain legume is gradually growing and gaining popularity in terms of cultivation and consumption in Ghana. Studies have shown that the majority of soybean cultivars cultivated are not readily nodulated by the indigenous rhizobia in most soils where trials have been carried out in Ghana (Abaidoo et al. 2000).

7.6 Conclusions and Recommendations

Recent trends in the agricultural sector indicate that for the first time the growth rate of the sector contracted by 2.9%. Part of the explanation for such a decline in agricultural growth is the decline soil fertility. So long as agriculture in Ghana remains a soil-based industry, there is no way that required yield increases of the major crops can be attained without ensuring that plants have an adequate and balanced supply of nutrients. Future strategies will have to redress this problem of declining soil fertility in order to create synergies with other yield increasing technologies.

The current decline in soil fertility may well lead to irreversible degradation and soil infertility unless steps are taken to improve soil management. The application of targeted, sufficient, and balanced quantities of inorganic fertilizers will be necessary to make nutrients available for high yields. Governments should take the necessary steps to facilitate the widespread and responsible use of chemical fertilizers. At the same time, every effort should be made to improve the availability and use of secondary nutrients and micronutrients, organic fertilizers, and soil-conservation practices.

Fertilizer use, access to credit and use of irrigation are closely linked – yet, in Ghana, farm-household access to these complementary services is low. Therefore, any successful intervention to promote fertilizer use in Ghana will have to be accompanied with complementary inputs and services – as a package.

Given the high variability of soils even at farm level, soil testing and mapping are a prerequisite for informed fertilizer use. Adequate funds should be available for research on fertilizer use to accurately inform fertilizer formulations to meet specific soil needs.

The use of integrated soil fertility management practices, along with other improve crop management technologies, and a conducive policy environment, are key components for attaining increases in agricultural growth.

Research on biological nitrogen-fixation as a low-cost “organic” approach to increasing nitrogen availability and organic matter content in soils should also be promoted.

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