AGNES
African Group of Negotiators Experts Support

Improved Nutrient use and Manure Management in Africa

KEY MESSAGES

1. **Nutrient inputs are currently low in Africa, improved agricultural production will require increase in fertilizer input.**
2. **Scaling up agronomic technologies and practices for nutrient use and management developed for African farming systems have the potential to benefit low-input systems in becoming more productive while reducing emissions intensity.**
3. **Sound manure use and management is important for improved agricultural yields, restoration of degraded agricultural land and promoting soil carbon sequestration.**
4. **Strengthening technical capacity of extension and coordinated research on soil information systems should be prioritized.**

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Rurinda, J., C. Costa Jr., E. Omollo, L. Motaroki, J.L. Osumba, A. Karim, and G. Wamukoya

Introduction

Achieving food security is one of the main agenda of African governments given that about 230 million people are currently facing severe food shortages. Agriculture, the main source of livelihoods in Africa, is limited primarily by declining soil organic carbon and nutrient stocks. Farmers have continuously cultivated their fields with little or no fertilizer inputs resulting in soil nutrient mining and negative nutrient balances. The soil nutrient depletion leads to low nutrient use efficiency and land degradation.

Global warming is currently increasing at 0.2°C, on average, per decade due to past and ongoing anthropogenic greenhouse gas (GHG) emissions (IPCC, 2018). However, solutions for enhanced food security in Africa will, to large extent, come from improved management of agricultural soils. Healthy soils not only sustain agricultural productivity and nutritional quality for human health, but are potentially large carbon sinks. The importance of managing soils for delivering ecosystem services for human wellbeing and nature has been recognized by the United Nations through its declarations of the Year of Soils (2015) and the International Decade of Soils (2015-2024).

Nutrient use for soil health and climate resilient cropping systems

Nutrient use for improved crop yield and resilience to climate change

To improve and sustain productivity of African soils and agroecosystems, the use of fertilizer is necessary. Nutrients, especially nitrogen (N), phosphorus (P), and potassium (K), are essential building blocks of plant growth and livestock production. Yet, N and P are deficient in large proportions of agricultural land in Africa, due to continued cropping with no fertilizer inputs (Rurinda *et al.*, 2020). Many studies have demonstrated that use of mineral fertilizer supports increased crop yields and profits of farmers in Africa (e.g. Kihara *et al.*, 2016). For example, a study conducted in different climatic and soil fertility conditions across five countries in Africa showed that grain yield of maize and sorghum increased drastically when mineral fertilizer was applied, compared to no fertilized control plots (Figure 1).

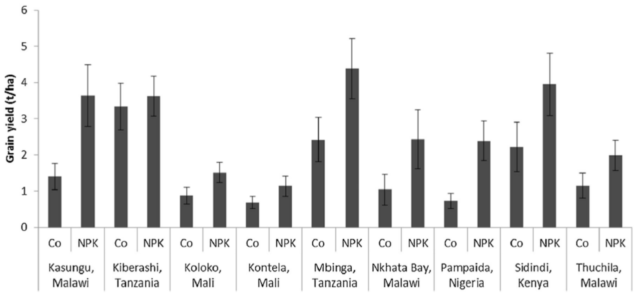

Figure 1: Grain yield obtained for control plots (Co - no fertilizer applied) compared with yield obtained when mineral fertilizer (NPK) was applied across many areas in five countries in Africa. Sorghum was the crop in Koloko and Kontela, while maize was in all the other areas. Error bars are standard deviations (from Kihara et al., 2016).

Cassava yield increased three-fold when fertilizer was applied under good agronomic management, compared with farmers' current yield, in eastern Africa (Fermont *et al.*, 2009). Even legumes that have the capacity to fix nitrogen from the atmosphere require phosphorus fertilizer for increased crop productivity (Mtambanengwe and Mapfumo, 2009). Nutrient use is also important to stabilize crop yield under both current and projected climatic conditions (Rurinda *et al.*, 2015).

In Sudano-Sahelian zone of West Africa, fertilizer use buffered losses in maize and millet yield by up to 50% of the baseline yield under a changing climate (Figure 2).

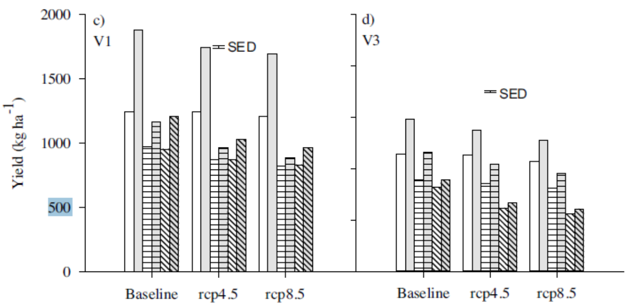

Figure 2: Average simulated grain yield of the long (V1) and short (V3) duration varieties of millet under the baseline climate and under the two future climate scenarios (rcp4.5 and 8.5) for the mid-century (2040-69) period. For millet F1 = no N applied as farmer practice, F2 = application of 40 kg N ha-1 as recommended practice. D1, D2 and D3 correspond respectively to early (June), medium (July) and late (August) planting. SED: Standard error of the difference between means (from Traoré et al., 2017).

Use of fertilizer replenishes nutrients removed through losses (i.e. volatilization, leaching, runoff or erosion), harvested produce and exported crop residues, a common practice in African smallholder farming systems.

Photo 1: An on-farm experiment demonstrating the importance of fertilizer use for increased maize growth in Ethiopia in 2015.

Manure use for improved soil health and restoration of degraded land

Manure plays an important role in nutrient cycling in mixed crop-livestock systems in Africa. Repeated applications of manure contribute to build up of soil organic matter, which leads to soil carbon sequestration (Table 1).

Table 1: Impact of previous manure management on soil properties in western Kenya (Adapted from Njoroge et al., 2019)

Nutrient management history	Soil properties		
	pH in water	*SOC (g kg^{-1})	Av. P (mg kg^{-1})
Fields with history of manure application	5.8 (5.3-6.4)	18.5 (14.6-26.8)	8.5 (2.0-27.3)
Fields with no history of manure application	5.7 (5.1-6.1)	16.4 (9.3-22.7)	4.7 (1.2-9.4)

*av. P – available phosphorus; OC – organic carbon; Available phosphorus (P) and organic carbon (OC) were analysed using the modified Olsen and Walkley-Black methods, respectively.

By increasing soil organic matter, manure improves soil structure, soils aeration, cationic exchange capacity, available phosphorus, activity of soil microorganisms, plant-available water holding capacity and recovery efficiencies of nutrients (Zingore *et al.*, 2008). Long-term field experiments demonstrated that use of manure at a rate between 5 and 10 t ha-1 year-1 are sufficient to enhance soil nutrients and maintain soil organic carbon close to the contents of the soil under undisturbed savanna vegetation in West Africa (Mando *et al.*, 2005). Therefore, manure is the main input of carbon into the soil as crop residues are removed from farmer's fields for use as fodder, housing or palisades (Mtambanengwe and Mapfumo, 2005).

The use of manure also plays a central role in restoration of non-responsive or degraded soils. Application of about 17 t manure ha-1 year-1 over three consecutive cropping seasons can restore productivity of degraded soils (Figure 3). Use of mineral fertilizer alone even at optimum rates could not restore productivity of the degraded soils. This demonstrates that the role of manure cannot be substituted with use of mineral fertilizers in restoring productivity of degraded soils. Non-responsive degraded soils are estimated at about 20% of arable land in Africa (Kihara *et al.*, 2016).

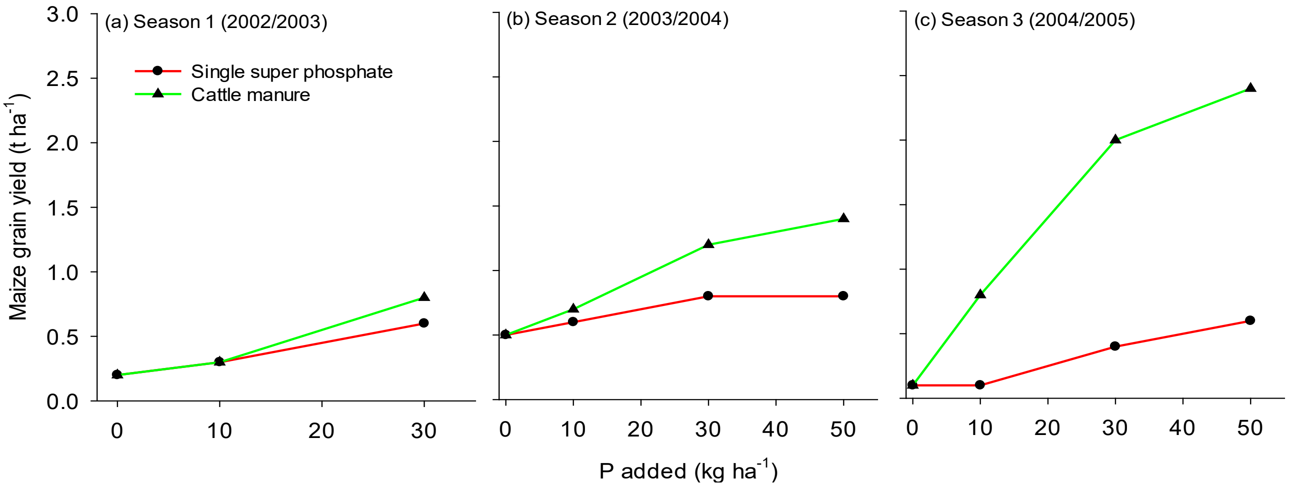

Figure 3: Maize yield response to soil amended with 100 kg N ha-1, and phosphous (P) added as mineral fertilizer or cattle manure, in Zimbabwe (Adapted from Zingore et al., 2008).

Nutrient and manure availability, and nutrient use efficiency

In Africa, both mineral and organic fertilizers including manure are insufficient to provide optimum nutrients for plant uptake. Mineral fertilizers are expensive beyond the means of many farmers that only small amounts of fertilizers are being used. Current fertilizer application rates in Sub-Saharan Africa (SSA) average only about 16 kg ha-1 year-1, compared with over 100 kg ha-1 in Europe and North America, and over 150 kg ha-1 in China in Asia (IFASTAT, 2019). It is on this basis that the African Heads of State and Governments, through the Abuja Fertilizer Summit Declaration, have committed to increase fertilizer use in the region to about 50 kg ha-1 (Africa fertilizer summit, 2006).

The quantity and quality of manure are generally poor on African smallholder farms (Table 2). Cattle, the main source of manure, commonly graze in the rangelands and a large proportion of animal manure is not directly usable as it is deposited in the grazing areas. Feed resources have also decreased through loss of communal grazing areas and increased pressure on arable land for food production. The quantity and quality of manure are also affected by collection and storage of manure, stabilizing period, amount of organic residues added as bedding and efficiency of collection of the manure. Mass losses, from manure stored in heaps, of between 15 and 50% depending on the conditions and duration of storage, were reported for African smallholder systems (Tittonell *et al.*, 2010). Nutrients and carbon from manure are also lost during manure handling and storage, through gaseous losses, leaching, runoff or erosion.

Table 2: Nutrient composition of manure (on a dry matter basis) collected from different farms across sub-Saharan Africa

Region	N	P	K	Ca	Mg	Total Zn	Organic C	References
	g kg^{-1}	g kg^{-1}	g kg^{-1}	cmol$_c$ kg^{-1}	cmol$_c$ kg^{-1}	mg kg^{-1}	g kg^{-1}	
East Africa	16.2 (2.0-22.0)	5.0 (2.0-16.0)	13.0 (5.0-27.0)	2.6	2.6	-	350 (399)	Lekasi et al., 2001; Njoroge et al., 2019
Southern Africa	8.0 (1.0 - 27.6)	2.0 (0.4-2.6)	0.85 (0.33-1.59)	5.0 (1.8-11.9)	1.3 (0.4-2.9)	22.5	131 (54-367)	Nhamo, 2002; Mugwira et al., 2002; Manzeke et al., 2019
West Africa	0.3-2.2	0.04-0.92	0.4-1.2	-	-	-	-	Harris, 2002

On the other hand, values of recovery and agronomic efficiencies of nutrients remain low in Africa potentially a source of GHG emissions from increased fertilizer use (ten Berge *et al.*, 2019). For instance, the agronomic use efficiency of nitrogen fertilizer ranges between 15 and 23 kg additional grain yield kg-1 N applied, on average, for hybrid maize (see Figure 4). Farmers in Africa use blanket fertilizer recommendations that are developed based on general soil and climate information.

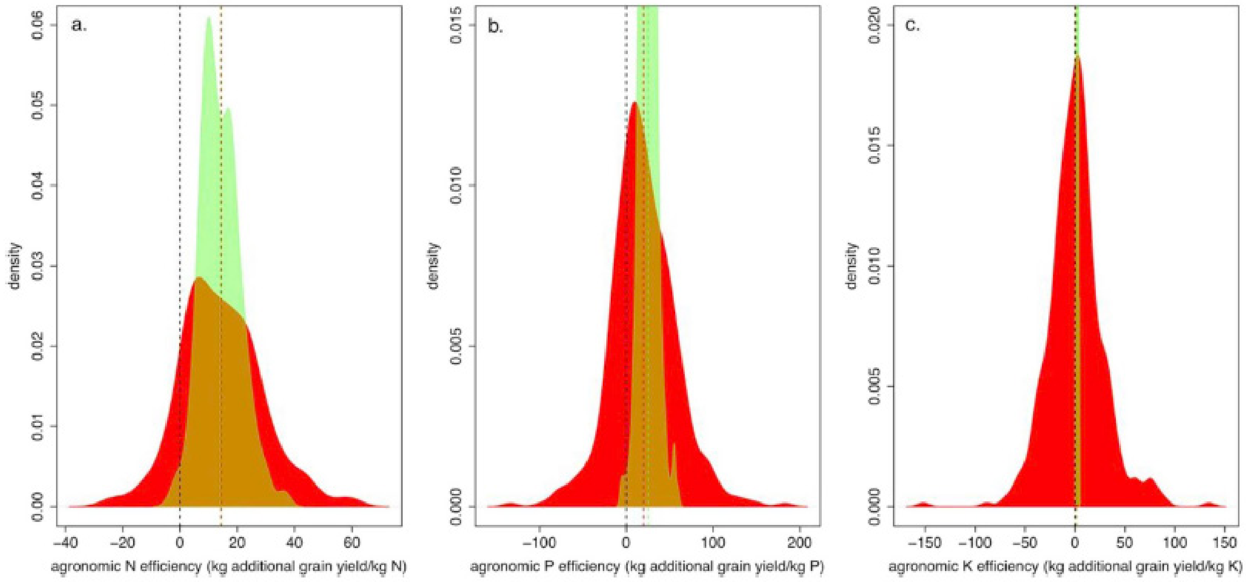

Figure 4: Frequency distributions of observed (red) and predicted (BLUPs, green/orange) field level responses to the three crop macro-nutrients N, P and K. Black, red and green vertical lines mark 0, the observed means and the marginal model means (best linear unbiased estimates, BLUEs). TAMASA nutrient omission trials (NOTs) in Ethiopia (n=82), Tanzania (n=202), and Nigeria (n=167) (from ten Berge et al., 2019).

Yet crop yield response to applied fertilizers and nutrient use efficiencies vary within short distances due to varying rainfall and soil fertility conditions, management and germplasm (Figure 5). To supply balanced nutrients and increase nutrient use efficiencies for specific locations and crops, farm or area specific nutrient management is important. This can be achieved through understanding of soil nutrient contents in arable land at finer spatial resolution.

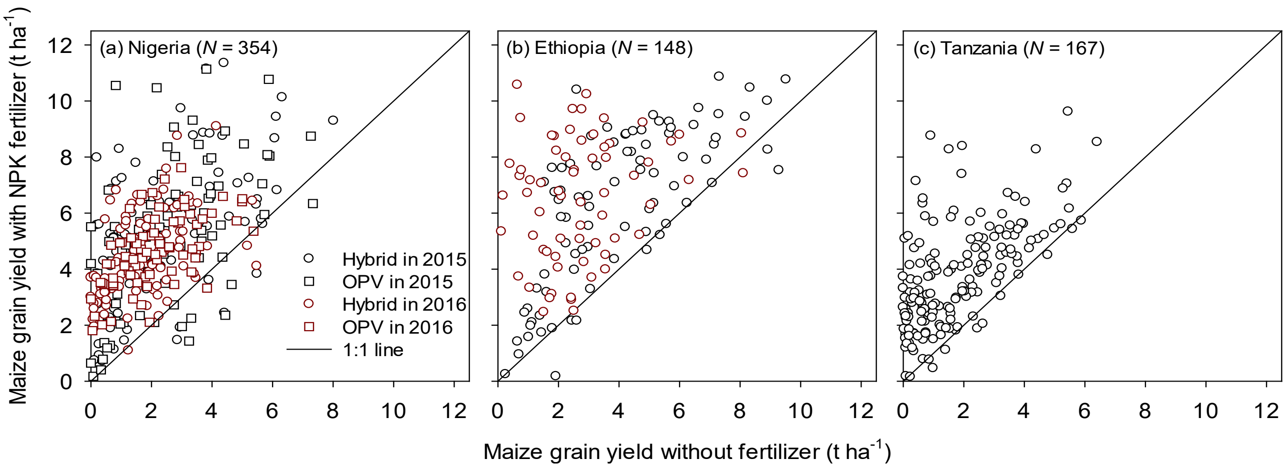

Figure 5: Maize yield for the control plots (no fertilizer applied) compared with maize yield obtained when mineral fertilizer was applied in Ethiopia, Nigeria and Tanzania (Rurinda et al., 2020).

Improved nutrient use management for enhanced food security and reduced GHG emissions

Of the total global anthropogenic GHG emissions, agricultural sector contributes about 5.41 Gt CO2 eq yr-1 in 2017. Sources of the emissions are mainly from anaerobic digestion (enteric fermentation) of ruminant animals (especially beef cattle) and their manure left on pastures, production and use of mineral fertilizer, paddy rice cultivation, manure management, and forest- or grass-land conversion to increase agricultural area

(FAOSTAT, 2017). However, emissions from agricultural sector from Africa are lower than that from other regions although improved management of manure and livestock is important for reducing emissions intensity from the sector (Table 3).

Table 3: Greenhouse gas emissions (GHG) from agriculture across different regions of the world in 2017

Region	Agricultural total	Synthetic fertilizers	*Manure	Enteric fermentation
	Gt CO_2-eq year^{-1}			
Africa	0.95	0.03	0.30	0.37
Americas	1.34	0.16	0.38	0.67
Asia	2.34	0.41	0.51	0.77
Europe	0.58	0.10	0.17	0.22
World	5.41	0.70	1.41	2.10

**Manure emissions are generated from manure management, manure applied to soils and manure left on pastures. Source: http://www.fao.org/faostat/en/#data/GE.*

The intensification of crop production with efficient use of fertilizers is projected to moderate the increase in GHG emissions (van Loon et al., 2019). However, improved crop yield and biomass, and its input into the soil may lead to carbon sequestration. The mitigation potential through soil organic carbon (SOC) sequestration induced by an increased fertilizer application – especially organic fertilizers – can be greater than the increased GHG emissions associated with the application of these fertilizers (Richards et al., 2019). This situation, however, is likely to occur only in the short term. A recent study shows that SOC accumulation is able to offset an increase in N2O emissions associated with practices enhancing SOC during the early years of a change in practice. In the long term, N2O emissions will eventually be larger than carbon accumulation, as SOC reaches equilibrium (Lugato et al., 2018). This increase in emissions will need to be further balanced against the food security benefits of potential production increases (Richards et al., 2019).

Many agronomic practices and proven technologies for nutrient management have been developed for African smallholder farming systems for increased nutrient use efficiency and crop productivity, and reduced GHG emissions intensity. Such technologies include use of a combination of organic and mineral fertilizers, climate-smart technologies, legume-cereal rotations; agro-forestry, and 4Rs Stewardship, which is applying the right source of fertilizer at the right amount, and at the right time and in the right place (www.ipni.net/4R). Similarly, there are many practices and technologies designed for improved handling

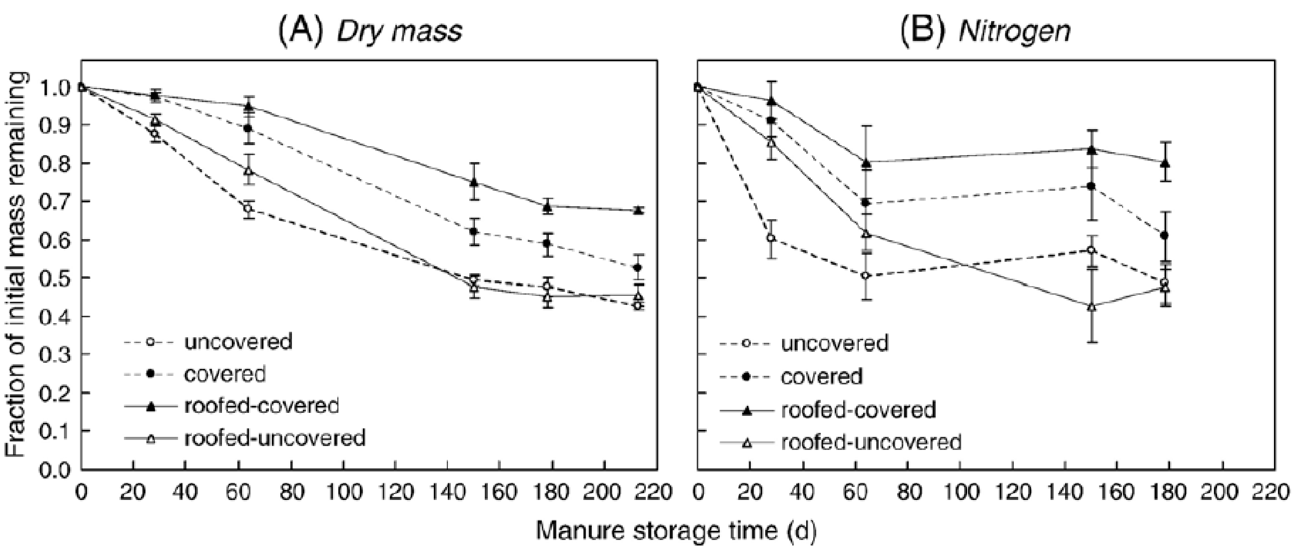

Figure 6: Mass and nitrogen remaining in manure heaps stored for 7 months under roof (roofed, solid lines) and in open air (unroofed, dotted lines), covered (covered, black symbols) or not with a polythene film (uncovered, white symbols), at Kawanda (central Uganda). (A) Fraction of mass remaining in the heap, (B) Fraction of N remaining in the heap, from Rufino et al., 2007).

and storage of manure to minimize carbon and nutrients loses. These technologies include heaps stored under a simple roof, manure pits, improved zero-grazing units with cubicles (a roof and a concrete floor), and covering manure heaps with straw or a polythene film. It has been demonstrated that the efficiencies of nutrient retention during storage can vary between 24% and 38% for total N, 34% and 38% for P and 18% and 34% for K, with the heaps under roof having greater efficiencies of retention of N and K (Tittonell et al., 2010). The study also showed that pit storage of manure could retain more organic matter in the system. Thus, covering manure heaps with a polythene film can reduce mass and N losses considerably (Figure 6).

There are also progressive and transformative options that could improve livestock management and by extension improve the quality of manure and reduce GHG emissions intensity. These include:

1. Improved rangeland management to enhance sequestration of atmospheric carbon into the soils;

2. Improved livestock feed quality through changing land use towards fodder production;

3. Livestock feed additives;

4. Transitioning from extensive rangeland systems to more efficient and productive livestock production;

5. Re-allocation of livestock production to more GHG-efficient systems and regions;

6. Use of methane inhibitors that reduce dairy cow emissions by 30% while increasing body weight without affecting milk yields or composition; and

7. Breeding of cattle that produce less methane.

Although many practices and proven technologies for nutrient and livestock management are available for use, their adoption by farmers has been limited due to lack of connection between science and practice. Deliberate efforts and policy interventions are required to create incentives for adoption of these technologies by farmers. Information and communication technology (ICT) can play a major role in delivering agricultural information to millions of farmers in Africa.

Conclusion

Increased use of both mineral and organic fertilizers may contribute to improved agricultural production and building climate resilient cropping systems in Africa. The agronomic, economic and environmental benefits further increase when mineral fertilizer was used in combination with manure. Use of manure also plays a central role not only in nutrient cycling, but in restoring degraded agricultural land. Manure is the main input of carbon into the soil as crop residues are removed from farmer's fields to feed livestock and for other purposes. The increase in crop production due to nutrient use has the potential to sequester carbon and reduce the demand for agricultural land that could otherwise lead to deforestation and high GHG emissions.

Despite their importance, the current use of both mineral fertilizer and manure is not sufficient to provide optimum nutrients to meet a crop's requirements. Therefore, scaling agronomic practices and technologies for nutrient management developed for African farming systems, such as better application of fertilizer, improved manure management and recycling of nutrients is critical for improved agricultural productivity and food and nutrition security.

Recommendations

1. **Promote access to judicious use of fertilizers** for enhanced food security, and avoiding land degradation and GHG emissions.

2. **Enhance quantity, quality and accessibility of manure,** given its importance for restoration of degraded agricultural land.

3. **Improve adoption of nutrient and manure** management best practices and proven technologies in Africa.

4. **Need for coordinated research** to map soil nutrient contents at finer spatial resolution in African arable land, and development of soil information systems for informed decision making.

5. **Strengthen extension delivery to enhance adoption** of climate smart practices on improved nutrient use and manure management by farmers.

Further Reading

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AGNES
African Group of Negotiators Experts Support

CONTACTS

ICIPE Duduvile Campus, Kasarani
P.O.Box 45801 - 00100
Nairobi, Kenya
+254 759 402 260
info@agnes-africa.org
www.agnes-africa.org

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