growing AFRICA

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PRECISION NUTRIENT MANAGEMENT

A CALL FOR ACTION: IMPLEMENTING THE AFRICAN PROFESSIONAL CERTIFIED AGRONOMY ADVISORY PROGRAM

COMPARING LABORATORY AND REMOTE SENSING METHODS FOR SOIL NUTRIENT ANALYSIS

ADVANCING AGRICULTURAL SUSTAINABILITY THROUGH COLLABORATIVE DATA GROWTH

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ACTIONABLE SCIENTIFIC INFORMATION ON PLANT NUTRITION

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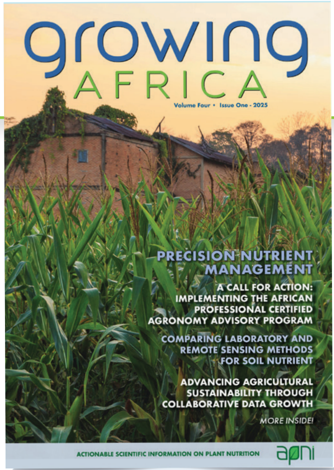

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Inside this Issue

Welcome to our first issue of 2025! Inside you will find a collection of articles dedicated to the topic of precision nutrient management (PNM), one of APNI's strategic R&D themes. Of course this is a broad topic, so our approach has been to examine PNM through a few different lenses. We've highlighted a range of recent examples of key progress …as well as some areas of need that are currently being addressed. As always, I'd like to express our appreciation to each of our contributors for the insights they have given us.

We begin with an overview of the state of precision agriculture in Africa whose authors provide an interesting review of current constraints, needs and opportunities. This is followed by a renewed call for action for the ongoing initiative to develop a **Professional Certified Agronomy Advisory Program for Africa (PCAAP)**. As the authors describe, this is a cornerstone initiative designed to create new capacity for professional agronomic training.

We also have an expanded call for researchers to contribute data to a growing and collaborative agronomic database called the **Open Data Crop Nutrition Platform.** This open access initiative is creating an increasingly diverse dataset. This effort is meant to unlock a previously untapped ability to query a shared data resource, and generate hypotheses, conduct analyses, and uncover insights from a large global depository.

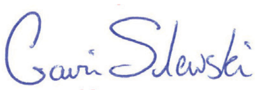
From the field, a study from Uganda provides some key lessons gained from on-farm experimentation (OFE), where farmers work through the discovery of local solutions to climate-smart management in upland rice fields. Another OFE study features a group of maize farmers in Kenya who have been 'triggered' with a new motivation to test technologies previously thought to be out of reach. Lastly from northern Nigeria, researchers present a comparative study examining the advantages, and trade-offs, for soil nutrient assessment conducted by remote sensing versus traditional lab methods.

Our newest infographic forum, **GrowthCharts**, highlights crop diversity in Africa as a unique strength to explore. We also want to use this opportunity to offer your participation in our open forums. Submit a question to be answered by of staff via the **Ask an APNI Expert** forum.

On the news front, our **Annual Photo Contest** is open to submissions once again. Make sure to upload your images of crop nutrient deficiency or R&D in action before this year's deadline of September 30. You can also always share any of your photos destined for social media through use of the hashtag **#ShareGrowingAfrica** …we feature one interesting image in each issue of the magazine. Curious about our schedule for research proposal calls? Be sure to consult our **EXCEL Africa** calendar to stay up to date on important dates for the remainder of the year.

We appreciate the opportunity to amplify research and outreach results with our audience of end-users of agronomic knowledge. Initial questions about making a submission can be answered by our guide for authors found at https://growingafrica.pub/about. More information about the publication process can be obtained by contacting our staff directly.

Sincerely yours,



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Precision Agriculture in Africa: Challenges and Opportunities

By Samuel Njoroge, Esther Mugi-Ngenga, Bernice M. Limo, and Oluwatobi Fakoya

Precision agriculture (PA) in Africa, though still emerging, holds great promise for transforming smallholder farming. *It enhances productivity through site-specific input use, digital tools, and data-driven decisions. However, adoption is limited by high costs, low digital literacy, poor infrastructure, and environmental challenges. Opportunities lie in falling tech costs, supportive policies, and growing digital platforms. Scaling PA requires better internet access, training, partnerships, and affordable, context-specific technologies.*

A brief history of precision agriculture in Africa

Precision Agriculture (PA) has a relatively recent history in Africa, with research efforts beginning in the early 2000s, decades later than in the global North. In its early stages, PA research in Africa was received with some skepticism on its feasibility particularly in sub-Saharan Africa (SSA), given the anticipated implementation challenges (Shibusawa, 2001). While research and application have increased, adoption remains low. Research and implementation are also concentrated within a few countries, namely, South Africa, Nigeria, Kenya, and Niger (Nyaga et al., 2021), where most PA-related startups are also based.

PA is defined as a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production (ISPA, 2019). PA implementation in Africa contrasts significantly to that in the global North, where adoption is more widespread and technologically advanced. In the global North, PA commonly involves high-resolution data from satellites and drones, variable-rate fertilizer application, yield monitors, and sensor-based weed management systems. These tools support fine-tuned management practices that optimize input use and improve productivity. In contrast, application of advanced PA technologies in Africa is generally rare and mainly limited to countries with stronger socio-economic and technological infrastructure. However, there are some notable adoptions of PA technologies in Africa. These include yield monitoring, variable-rate lime application, and auto-guidance systems in South Africa; improved irrigation efficiency in fruit farming in parts of Southern and Eastern Africa; weather and pest forecasting; digital agronomic advisories; and micro-dosing of fertilizer and manure in the Sahel. These cases highlight the potential of PA to support improved productivity and resource use efficiency in Africa, despite broader constraints to widespread adoption.

The need for precision agriculture in Africa

PA is essential for achieving significant improvements in crop productivity within Africa's predominantly smallholder, rainfed farming systems. Crop production in these systems is often characterized by suboptimal yields, and large gaps between actual and attainable yields (www.yieldgap.org). These yield gaps are driven by poor soil fertility, nutrient mining, inadequate crop management, and unbalanced fertilizer recommendations, all compounded by high variability in crop responses to inputs. Addressing these constraints is a prerequisite for achieving sustainable crop productivity intensification. PA offers targeted solutions for intensification, enabling efficient use of inputs through improved agronomic practices, site-specific management, and decision-support tools. Technologies such as yield and soil mapping support the delineation of management zones, while variable rate application ensures nutrients are applied precisely, where, and when needed. Furthermore, PA can enhance extension services by leveraging mobile technologies to provide real-time, localized guidance on planting, input use, pest and disease alerts, and weather forecasting. Given the widespread use of mobile phones in Africa, digital PA tools present an opportunity for scalable dissemination of customized advisories. This can lead to improved input efficiency, higher yields, reduced environmental impact, and enhanced farm profitability, contributing to broader development goals such as poverty reduction and food security. Indeed, the African Union has identified the adoption of PA as vital in realizing the vision of 'the Africa we want-no hunger, no poverty and global peace and harmony' (African Union, 2015).

Relevance of precision agriculture for African farming systems

Agriculture is evolving into a technology-driven sector, often referred to as "Agriculture 4.0". This transformation emphasizes the integration of digital technologies to support sustainable, efficient, and data-informed farming practices. PA aligns closely with this paradigm by enabling site-specific input application, real-time decision-making, and improved resource use efficiency. Through tools such as artificial intelligence, remote sensing, and data-driven support systems, PA enhances productivity while minimizing environmental impacts.

For Africa, the relevance of PA is reinforced by its potential to support agricultural transformation goals. Continental frameworks such as the 2014 Malabo Declaration recognize the adoption of PA as vital for accelerating agricultural transformation (African Union, 2015). Recent pledges by African leaders to deliver crop- and site-specific agronomic recommendations to the majority of smallholder farmers by 2034 (Africa Union, 2024) provide opportunities for using PA to achieve these targets. In particular, the 4R Nutrient Stewardship framework offers a structured approach to optimize nutrient use through PA technologies capable of strengthening resilience, productivity, and livelihoods across the continent.

Constraints to precision agriculture adoption in Africa

The adoption and implementation of PA in Africa is constrained by a range of interrelated socio-economic, environmental, educational, and technical factors. These constraints have previously been categorized into five distinct categories, namely, (i) farmer-demographic characteristics, (ii) environmental, (iii), educational, (iv) economic, and (v) technical constraints (Bosompem, 2021).

Demographically, the majority of smallholder farmers are often older (i.e., >60 years) and have limited formal education or exposure to digital tools, which reduces their capacity and willingness to adopt complex technologies. Low digital literacy, compounded by minimal farm incomes, further limits the feasibility of investing in PA innovations.

Economically, the high cost of acquiring and maintaining PA equipment, including hardware, software, and training, presents a major barrier. Most farming households in Africa operate on small farms with limited resources and face restricted access to credit or institutional financial support. The lack of economies of scale typical of smallholder systems also undermines the cost-effectiveness of PA technologies.

Environmental factors further challenge implementation. Many farming systems in Africa are in topographically complex regions, such as the East African highlands, where steep and uneven terrain impairs mechanization. Farming systems in Africa also commonly feature trees interspersed within and between fields, with approximately one-third of smallholder farmers in SSA integrating trees into annually cropped areas. Although these trees contribute directly and indirectly to rural livelihoods, they can impede the use of PA technologies by obstructing the movement of machinery such as tractors, harvesters and planters.

Globally, the adoption of PA has been hindered by educational and training challenges, including limited local expertise, low awareness among farmers and professionals, weak PA education systems, and insufficient development of PA-specific software and hardware. These barriers are more acute in Africa due to shortages in trained personnel, underfunded research, and inadequately resourced extension services. These constraints limit both the development of context-appropriate PA technologies and the dissemination of existing tools. Further compounding the issue are declining enrollments in agricultural programs, a lack of skilled faculty, especially in resource-constrained institutions, and curricula that insufficiently integrates PA, all of which hinder the advancement and adoption of PA across African farming systems.

From a technical aspect, the lack of digital infrastructure presents a significant constraint to the adoption of PA in Africa. Internet connectivity is low in many rural areas, and access to smartphones, computers, sensors, and remote sensing services remains limited. Since many PA systems depend on reliable data transfer and connectivity, these gaps hinder the functionality and scalability of PA technologies across the continent.

In sum, demographic, economic, environmental, educational, and technical barriers collectively limit the adoption of PA in Africa. Addressing these constraints through tailored, inclusive strategies is essential to unlock the potential of PA in supporting sustainable intensification and productivity gains in smallholder farming systems.

Opportunities for enhancing precision agriculture in Africa

Despite persistent barriers, the outlook for PA adoption in Africa is increasingly optimistic. Rapid advancements in digital technologies, paired with falling costs, are expanding the feasibility of PA for smallholder farmers. Successful trials in Africa have demonstrated the value of soil and plant sensors, satellite imagery, and GIS-linked crop models for supporting site-specific management, e.g., Onyango et al., (2021). These tools can improve the precision of input use and boost productivity. The growing availability of open-access agricultural monitoring systems also presents an opportunity to fill critical data gaps. Platforms at global, continental, regional and national scales now provide land cover, cropland extent, and high-resolution imagery to support research and decision-making for PA implementation.

Policy development at the continental level further reinforces the momentum. The African Union's Digital Transformation Strategy (2020–2030) calls for the integration of PA and data-driven tools into agricultural systems (African Union, 2020). Key objectives within this strategy include (i) adoption of precision agriculture techniques, (ii) the use of data analytics to improve decision-making and the development of digital platforms to connect farmers with markets and financial services, and (iii) development of digital infrastructures including broadband networks and digital payment systems, to support the growth of digital agriculture. Additionally, commitments made during the 2024 Africa Fertilizer and Soil Health Summit that aim to provide location-specific agronomic recommendations to a majority of smallholder farmers by 2034, align closely with the potential of PA to support tailored nutrient management. These policy frameworks offer essential political support to mainstream PA.

Institutionally, the creation of the African Association for Precision Agriculture (AAPA) marks a key milestone. AAPA provides a coordinated platform to promote research, training, advocacy, and policy engagement related to PA across the continent. Its mandate includes capacity development, dissemination of tailored innovations, and facilitation of international collaboration, critical enablers for scaling PA in Africa. Collectively, these technological, policy, and institutional developments offer a strong foundation for expanding PA adoption in support of sustainable agricultural transformation.

Requirements for enhanced adoption of precision agriculture in Africa

Scaling up the adoption of PA in Africa necessitates coordinated efforts from governments, the private sector, research institutions, and farming communities to address persistent socio-economic and technological challenges. A critical prerequisite is improved internet infrastructure, as limited connectivity currently hinders access to digital farming innovations. Encouragingly, the expansion of 4G networks and data centers across the continent presents opportunities to support digital agriculture. These infrastructure improvements must be complemented by targeted training and capacity building to equip farmers and extension agents with the skills needed to use PA technologies effectively.

Public-private partnerships are also vital for


Examples of drone use in olive (Morocco) and maize (Kenya) fields.

mobilizing investments and facilitating hands-on farmer training. Increased access to consistent, reliable and locally relevant agricultural data is also essential, as nearly half of African countries currently lack the baseline data needed for PA implementation. To address data challenges, supportive policies on data ownership, privacy, and cybersecurity must be developed. Additionally, user-friendly and affordable PA solutions that bridge the skill gap among farmers are needed to catalyze uptake, especially within smallholder systems.

Enhancing PA adoption in Africa additionally requires a nuanced context-specific approach that integrates "soft" (e.g., observational tools and intuitive decision-making) and "hard" (e.g., GPS, remote sensing, and variable rate applicators) technologies. Simple, cost-effective tools such as small machine-based variable rate technology can serve as entry points for individual smallholders, paving the way for more advanced applications such as those that integrate GIS, GPS, variable rate technology, and related tools. Such tiered, context-specific strategies increase the likelihood of successful adoption and can significantly enhance productivity, resilience, and food security across Africa's diverse agricultural systems. ■

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REFERENCES

African Union. 2024. Nairobi Declaration. Africa Fertilizer and Soil Health and Summit, Nairobi, Kenya, May 7-9, 2024. Retrieved from https://au.int/en/documents/20240509/nairobi-declaration-2024-africa-fertilizer-and-soil-health-summit

African Union. 2020. The Digital Transformation Strategy for Africa (2020-30). https://au.int/sites/default/files/documents/38507-doc-DTS_for_Africa_2020-2030_English.pdf

African Union. 2015. Agenda 2063: The Africa we want. African Union Commission. https://au.int/en/agenda2063/overview

Bosompem, M. 2021. Potential challenges to precision agriculture technologies development in Ghana: Scientists' and cocoa extension agents' perspectives. Precision Agriculture 22(5): 1578-1600.

Global Yield Gap Atlas (GYGA), https://www.yieldgap.org. Accessed June 2025

ISPA 2019. https://link.springer.com/journal/11119/updates/17240272 Accessed June 2025

Nyaga, J.M., et al. 2021. Precision agriculture research in sub-Saharan Africa countries: A systematic map. Precision Agriculture 22: 1217-1236.

Onyango, C.M., et al. 2021. Precision agriculture for resource use efficiency in smallholder farming systems in sub-saharan africa: A systematic review. Sustainability 13(3): 1158.

Shibusawa, S. 2001. Precision farming approaches to small-farm agriculture. IFAC Proceedings Volumes, Vol. 34(11): 22-27.

A Call for Action: Implementing the African Professional Certified Agronomy Advisory Program

By Canon Norris Savala Engoke, Ivan Adolwa, Esther Mugi, Samuel Njoroge, Kwame Frimpong, James Mutegi, Kaushik Majumdar, and Shamie Zingore

The emerging African Professional Certified Agronomy Advisory Program (PCAAP) is an APNI initiative aimed at providing farmers with access to high quality agronomy advisory services. *Its framework encompasses a multi-faceted approach, including the training and certification of agronomy professionals, development of strategic partnerships with private, governmental and non-governmental entities, and the use of innovative communication technologies for information dissemination and sharing. By collaborative promotion of precision nutrient management such as 4R practices and empowering smallholder farmers, PCAAP has the potential to enhance food security, mitigate environmental degradation, and contribute to overall economic development in the region.*

Farmers receive training from a trained agronomist during a farmers' harvest field day in Embu county, Kenya.

Agriculture plays a crucial role in the economies of many African nations, serving as a primary source of livelihood for a significant portion of the population. It contributes substantially to GDP and employment, particularly in rural regions where subsistence farming predominates. Agriculture is also vital for export earnings, with commodities such as cocoa, coffee, and tea forming the cornerstone of international trade (Jayne et al., 2023).

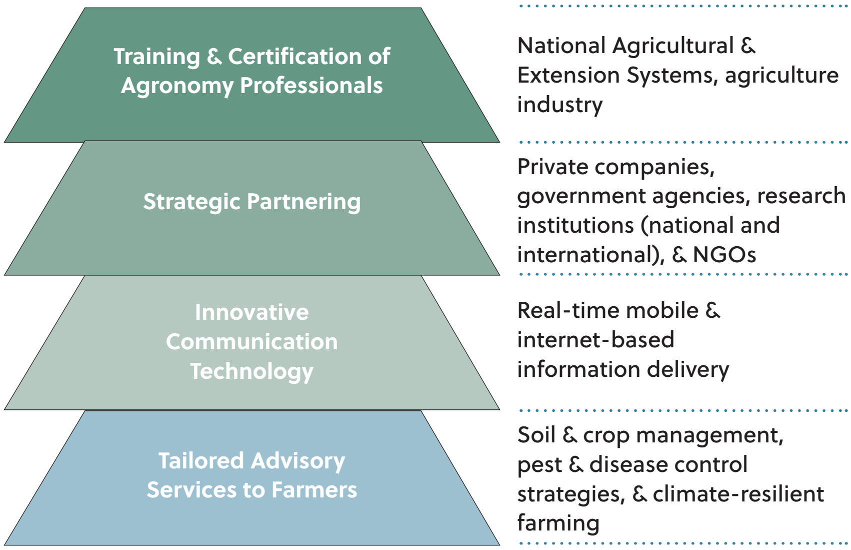

Figure 1. African Professional Certified Agronomy Advisory Program (PCAAP) Framework to deliver high-quality and tailored services to farmers.

Despite this importance, the sector faces a multitude of challenges that limit its full potential. One major challenge is the limited access to modern agronomic practices and advisory services, which deprives farmers of essential resources agents have to take full advantage of high-quality seeds, fertilizer and organic nutrients, and machinery for enhanced efficiency and yields (Masangano and Mthinda, 2017). African agriculture is also highly vulnerable to climate change and variability, with extreme weather events posing significant threats to crop production and livestock rearing. Strengthened advisory services will improve mitigation strategies of smallholder farmers, who are particularly susceptible to climatic shocks that lead to food insecurity and economic losses (Alston et al., 2022). Access to financial services and markets is another significant barrier, impeding farmers' ability to invest in modern inputs and technologies. Policy and regulatory constraints, bureaucratic inefficiencies, and land tenure issues further hinder agricultural development across Africa (Bambio et al., 2022).

There is a strong need for an African Professional Certified Agronomy Advisory Program (PCAAP) to address these challenges by building capacity among agronomy professionals, promoting sustainable agricultural practices, and improving food security and economic resilience in Africa.

In Kenya, extension specialists have worked with smallholder farmers to enhance soil fertility through the adoption of sustainable soil and crop management practices. By promoting practices such as conservation agriculture and organic farming, the program helped farmers increase yields while preserving soil health (Jayne et al., 2023). In Ghana, extension services have supported implementation of integrated pest and disease management strategies to combat common agricultural pests and diseases. Using biological control methods, crop rotation, and resistant crop varieties, reliance on chemical pesticides was reduced while effectively managing pest and disease outbreaks (Masangano and Mthinda, 2017). In Ethiopia, extension agents have introduced climate-resilient farming techniques to help farmers adapt to the challenges posed by climate change. These techniques include the use of drought-tolerant crop varieties, water harvesting and conservation practices, and agroforestry systems, enabling farmers to maintain productivity despite changing climatic conditions (Alston et al., 2022).

PCAAP framework overview

PCAAP is built upon a comprehensive framework that includes the training and certification of agronomy professionals, the development of strategic partnerships, the use of innovative communication technologies, and the provision of tailored advisory services to farmers (**Fig. 1**).

A cornerstone of PCAAP is its provision of a new capacity for rigorous training and certification of agronomy professionals. PCAAP seeks to collaborate with a diverse array of partners, including private companies, government agencies, research institutions (national and international) and non-governmental organizations, to leverage resources and expertise. These partnerships are crucial for comprehensive knowledge development, policy alignment and effective delivery of agronomy advisory services and to ensure the sustainability of PCAAP-linked interventions. Once fully developed, the program will use innovative digital tools and internet-based communication technologies to train agronomists and disseminate agronomic information to farmers. These technologies facilitate real-time communication and information sharing, allowing agronomy advisors and farmers to access timely knowledge, guidance and, in turn, share feedback for improvement (Camillone et al., 2020). A fully deployed PCAAP enables tailored advisory services based on the specific needs and contexts of farmers. These services include practical insights into soil and crop management, pest and disease control strategies, and climate-resilient farming techniques (Bambio et al., 2022).

Empowerment of farmers

PCAAP emphasizes the empowerment of farmers through the effective transfer of the skills and knowledge needed to improve their farming enterprises. The program's implementation can also foster entrepreneurship among farmers, and within rural communities, by supporting the development of connected agribusinesses and value-added enterprises. Through a strengthened agronomic advisory base supported by PCAAP, better economic resilience is secured through it influence on building farmers' awareness on opportunities to diversify their markets and income streams (Camillone et al., 2020). Actively involving local communities in the design and implementation of interventions spurred by PCAAP ensures that they are both culturally appropriate and contextually relevant. Initiatives such as farmer field schools, 'living' labs, and participatory research, tap into the power of community co-learning and co-ownership of agricultural research and education initiatives (Jayne et al., 2023).

Continuous monitoring and evaluation of the effectiveness and impact of PCAAP derived technology and its strengthened advisory interventions will be needed. This process ensures adequate assessment of progress towards program objectives, challenges and bottlenecks, and strategic adjustments needed (Alston et al., 2022). Allowing a pioneering PCAAP to refine and improve its approaches through an iterative process of learning and adaptation ensures responsiveness to the inevitably evolving needs and priorities of smallholder farmers in Africa (Masangano and Mthinda, 2017).

Conclusion

PCAAP represents a comprehensive approach to enhancing agricultural productivity and sustainability in Africa. It is designed to provide farmers with greater access to high-quality agronomy advisory services, promote sustainable farming practices, and foster community engagement. As such, PCAAP has the potential to significantly improve livelihoods and food security across the continent.

Further work is needed to ensure our capacity to assess the long-term impacts of PCAAP interventions and identify areas for improvement. Additionally, studies on the scalability and replicability of PCAAP models across different contexts and regions would be valuable for informing future program expansion efforts. PCAAP offers a promising solution to the challenges facing smallholder farmers in Africa. By leveraging strategic partnerships, innovative technologies, and community participation, the program has the potential to catalyze transformative change in the agricultural food systems sector, leading to more resilient and sustainable food systems across the continent. ■

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REFERENCES

Alston, J.M., et al. 2022. Research and Productivity Growth in Agriculture: A Broader Perspective. Am. J. Ag. Econ. 104(3):763-780.

Bambio, Y., Agha, H. 2022. Adoption of Sustainable Agricultural Practices in Africa: The Role of Capacity Building. J. Dev. Studies. 58(6):925-940.

Camillone, J., et al. 2020. Certification and Agricultural Productivity: Evidence from a Field Experiment. World Dev. 130:104917.

Jayne, T.S., et al. 2023. Agriculture in Africa: Telling Myths from Facts. Food Policy 104:102102.

Masangano, C., Mthinda, C. 2017. Agricultural Extension in Africa: Experiences from Malawi. J. Agric. Ed. and Ext. 23(5):385-401.

Lessons from On-farm Experimentation on Climate-Smart Management for Upland Rice in Uganda

By Patrick Musinguzi, Lincolin Abasize, Paul Tamale, Tom Matila, Peter Ebanyat, Jackline Bonabana, James Mutegi, and Thomas Oberthür

A farmer-led field study in western Uganda revealed varied rice yield gap reduction with nutrient application to major upland soil types and different responses to the impacts of climate variability due to moisture stress. *Soil types are key factors for site-specific nutrient management and will influence the choice of climate-smart adaptation measures within this upland farming community.*

Western Ugandan farmers and researchers involved in rice field trial evaluations.

In Uganda, the high demand for rice has been mainly met through lowland production domains. However, government policies are encouraging farmers to shift away from growing rice in its fragile lowlands, including wetlands, and instead are targeting more intensive rice production in upland areas (Matovu et al., 2020). Upland rice productivity is typically lower and more variable. Some of the constraints to upland rice production are associated with low soil fertility and moisture stress due to a changing and increasingly variable climate (Alou et al., 2018).

The spatial variability of upland soils complicates the on-farm decision-making process for selecting the right crop management interventions for enhanced rice grain yield and quality. There is a lack of information on rice yield responses across soil types amidst the changing climatic patterns faced by farmers. This uncertainty constrains farmers' confidence during the selection of more innovative rice cropping strategies.

The development of agronomic and nutrient management information is critical to guide site-specific and climate-smart decisions based on soil type. This research explores rice yield responses, including grain quality, as influenced by improved nutrient applications under varying soil types, physiochemical properties, and moisture retention capacities amidst climate variability and climate change.

Farmer-led trial description

This three-year project was implemented in the Kikuube district located in western Uganda. The study was conducted on farmer's fields in a subcounty dominated by a bimodal rainfall distribution and mixed cropping system. The experiments were conducted for four seasons within two years with phase 1 during August-December (long rain season) 2022B and March-July (short rain season) 2023A, and phase 2 during August-December 2023B and March to July 2024A.

The study assessed the combined effect of soil type and improved nutrient management under a Good Agronomic and Climate-Smart Management (GACLIM) package for upland rice yield. Three dominant soil types (Ferralsols, Plinthisols, Gleysols) were selected in the study area that represented the varied soil physical and chemical characteristics of rice soils. An improved rice cultivar (NAMCHE 5) was grown across the three soil types. Various rates of N, P and K were applied considering the 4R Nutrient Stewardship Principles (right source, rate, time and place) in combination with climate-smart agronomic practices such as seed bed levelling, soil water conservation with bunds, timely planting by dry seeding, timely weeding, and good control of pests.

Initially, two treatment trials were laid out in a randomized complete block design under phase 1 (2022B and 2023A). The two plots measuring 20 m x 50 m included farmer practice (dominated by no fertilizer use) and a recommended nutrient application within a GACLIM package. A total of 60 kg N, 30 kg P, and 80 kg K per ha were split applied with diammonium phosphate (DAP) at planting, and later with urea and potassium chloride (MOP) at tillering and panicle initiation stages. Only P was applied at planting; N was applied in three splits at planting, tillering and panicle initiation in equal proportions (20 kg/ha) while K was applied twice in equal proportions at tillering and panicle initiation (40 kg/ha). The trials were established on 12 farm fields with soil type as the main plot and the two treatments as sub-plots for two seasons. Each of these treatments were replicated four times with farmers' field applied as replicates.

In the second year (2023B and 2024A seasons), the experiment expanded to four treatments evaluated on 12 farmer fields located on the same three soil types. The recommended NPK application rates in phase 1 were again tested as a full rate, along with a half rate (30 kg N, 15 kg P, 40 kg K per ha); one-quarter rate (15 kg N, 7.5 kg P, 20 kg K per ha), and farmer practice. The proportions for split application as applied in year 1 were followed for N, P and K. This second phase was designed to adjust to concerns of affordability and resource constraints among participating farmers due to the costs associated with fertilizer used in year 1.

Total biomass and grain yield data was determined by using total field data and sub-samples oven dried to compute the moisture correction factor. The grains were later milled to compute the milling recovery for each treatment.

Soil conditions

The three soil types had varied soil chemical and physical properties. The Plinthisol sites had characteristically shallow soils dominated by gravel in the deep layers (>30 cm) while the Ferralsol sites had deeper soils with varied but inherently high P fixation. Gleysol sites were defined as poorly drained soils with some incidences of redoximorphic features [i.e., spots differing in colour from the surrounding soil caused by the oxidation and reduction of iron (Fe) and manganese (Mn) compounds] in the low-lying areas near or within wetlands.

Generally, soil fertility varied across fields (**Table 1**). All soils had moderate pH <6.0, very low extractable P (<15 ppm), and moderate levels of total

Table 1. Selected soil parameters for soil types in Kikuube district (2022B season).

Soil type	pH	SOC (%)	Total N (%)	Extr. P (ppm)	Exch. K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)
Ferralsol	5.63	1.823	0.1422	12.74	0.239	8.5	2.742
Gleysol	5.63	2.602	0.2133	13.44	0.379	14.9	2.797
Plinthisol	5.65	2.719	0.1833	14.65	0.397	11.9	3.303
Fpr	*P>0.05*	*P>0.05*	*P>0.05*	*P>0.05*	*P>0.06*	*P>0.05*	*P>0.05*
LSD	*0.5941*	*0.8789*	*0.12664*	*3.488*	*0.1397*	*6.4*	*0.3446*
SED	*0.23*	*0.3419*	*0.04926*	*1.682*	*0.0674*	*3.09*	*0.1662*

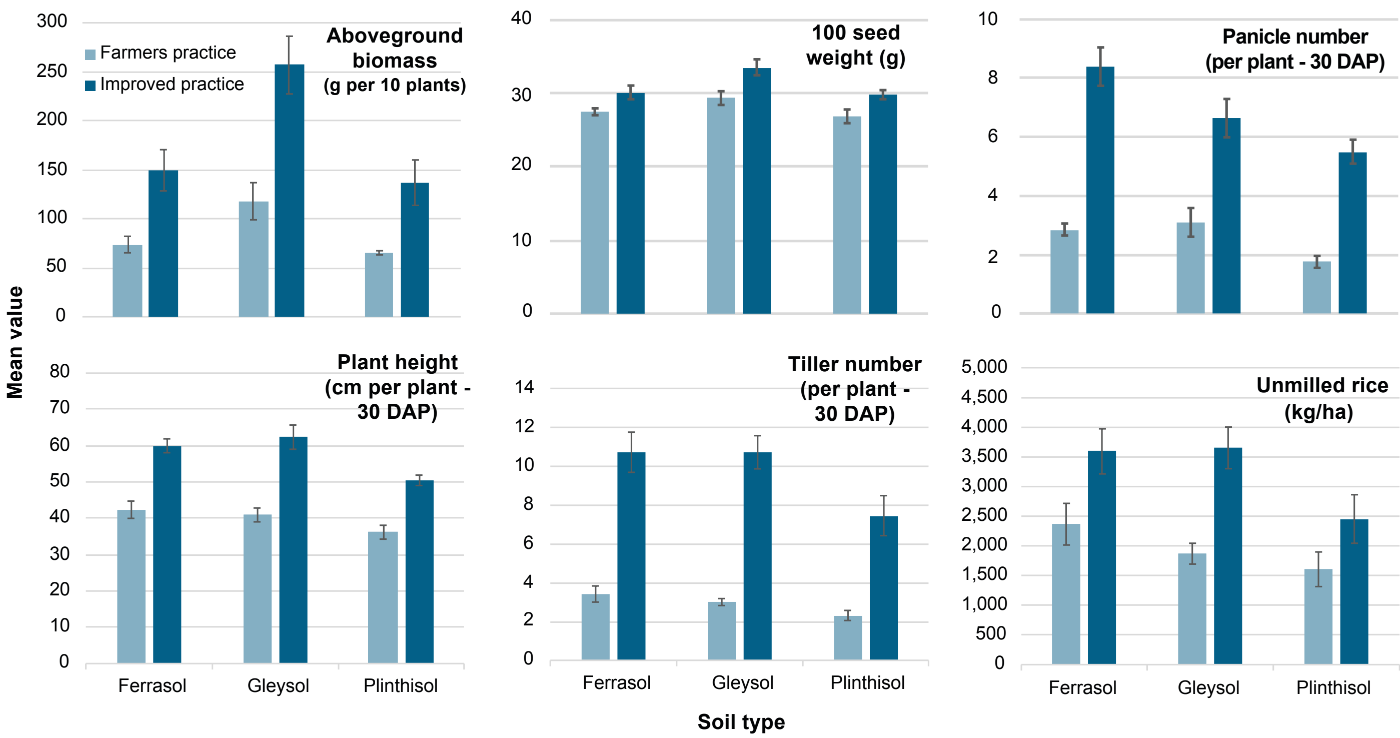

Figure 1. Upland rice yield response to soil type and good agronomic and climate-smart management package in mid-western Uganda, August-December 2022 and March-July 2023. DAP = days after planting.

N (some below the critical concentration <0.2%) and exchangeable K (<0.4 cmol/kg soil). Soil organic carbon was above 1.72%, a general indicator of good soil health, but varied within each field. Other parameters such as texture varied from loam to sandy loam. Exchangeable Ca, Mg and K varied across soil types and farmer fields, but on average these were above the critical levels.

Yield responses to farmers' practice and recommended nutrient treatments (Phase I)

The recommended nutrient applications under the GACLIM package resulted in significantly higher yields in seasons 2022B and 2023A (**Fig. 1**).

Gleysol and Ferralsol sites had higher grain yield compared to Plinthisol sites. Unmilled rice yield, tiller numbers, plant height, panicle number, biomass, and grain weight were strongly influenced by soil type and treatments applied (P<0.001; **Fig. 1**). Ferralsols sites resulted in highest mean unmilled grain yield (2,972 kg/ha) while Plinthisol sites had the lowest yield (1,986 kg/ha). Ferralsol sites recorded the highest tiller count (6.9 per plant) while Plinthisol sites had the lowest (4.8 per plant).

Rice grain quality and milling recovery

The recommended nutrient application delivered by the GLACLIM package resulted in better grain quality and high grain nutrient content (**Table 2**). Soil type and nutrient application affected the grain N, grain P, and grain K. There was a notable grain weight increase, and the rice milling recovery was also strongly influenced. The highest milling recovery percentage (59%) was obtained from Ferralsol sites while the lowest (47%) was obtained at Gleysol sites.

Table 2. Rice grain quality and milling recovery as influenced by soil type and nutrient applications under GACLIM package.

	Grain N	Grain P	Grain K	Milling recovery
		%		
Gleysol	1.7791^{ab}	0.74675^{b}	1.1323^{b}	47.1622^{c}
Plinthosol	1.8091^{a}	0.74675^{a}	1.37619^{a}	52.574^{b}
Ferralsol	1.6267^{b}	0.53328^{c}	0.8059^{c}	59.448^{a}
Farmers'	1.6547^{b}	0.43956^{b}	1.10923^{a}	37.386^{b}
Improved	1.8148^{a}	0.7315^{a}	1.0725^{a}	66.786^{a}
P value	*	***	*	***

*, ***Means denoted by the same letter within a column are not significantly different (at p=0.05, p=0.01).

Farmer assessment of established rice trial in Kikuube district Uganda.

Rice response to farmer practice and varied nutrient application rates (Phase II)

In seasons 2023B and 2024A, the application of the GACLIM package with varied nutrient applications rates (full recommendation, half rate, one-quarter rate) resulted in significantly different yields compared to the farmer practice (**Fig. 2**). The increase in grain yield was notable for full and half rate applications across all the three soil types ($p<0.001$), but not for the one-quarter rates or farmer practice. The full rates recorded the highest grain yield (2,809 kg/ha) and number of panicles (4.72 per plant) whereas farmer practice generated the lowest yield (2,039 kg/ha) and number of panicles (3.49 per plant). Among soil types, Gleysol sites recorded the highest (2,535 kg/ha) grain yield while Plinthosol sites recorded the lowest (2,372 kg/ha).

Application of the full GACLIM nutrient recommendation resulted in a higher recovery of grain (69.1%) after milling compared to the half (66.5%) or one-quarter (61.4%) rates. Farmer practice resulted in the lowest grain recovery (56.8%). Soil type did not significantly influence the milling recovery of grain.

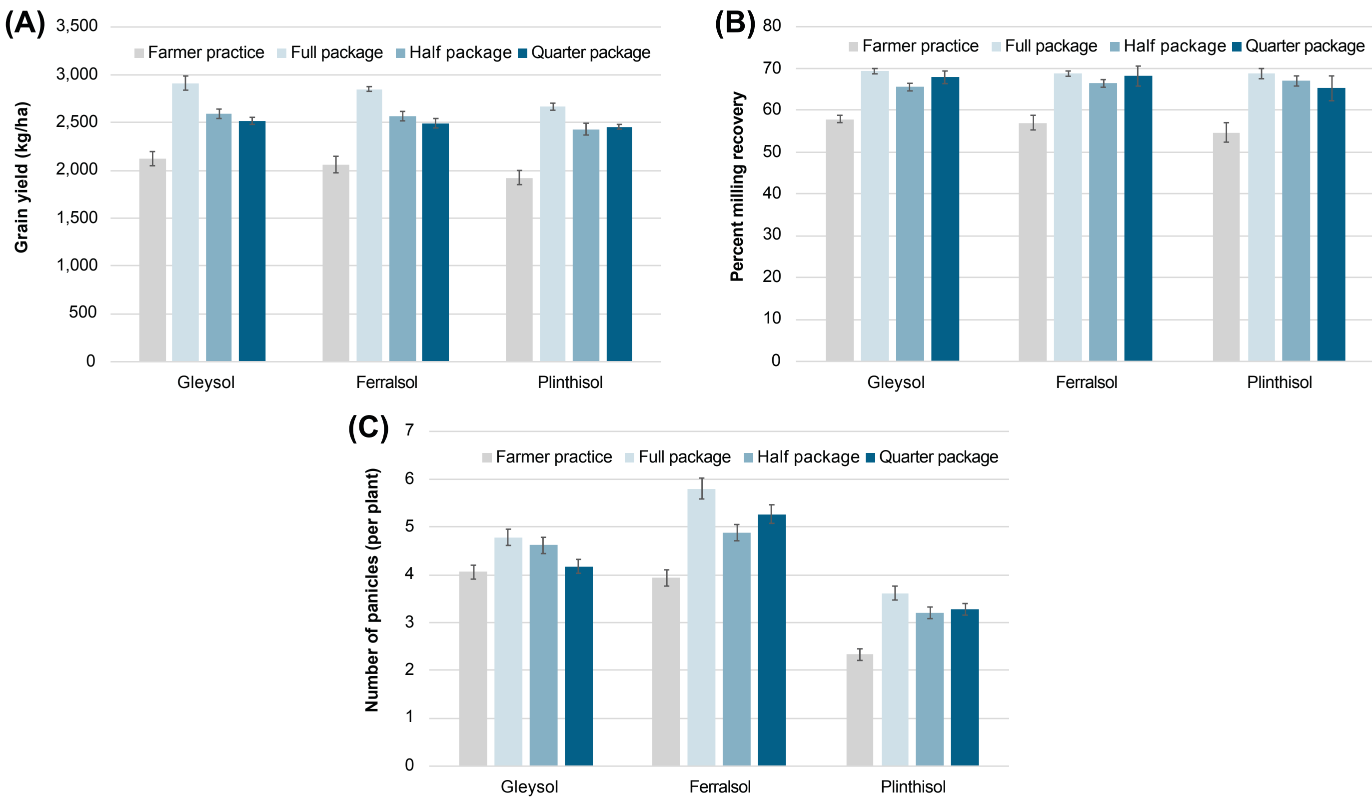

Figure 2. Upland rice yield (**A**), milling recovery (**B**), and panicle number (**C**) response to soil type and variable nutrient application rates under the GACLIM package in western Uganda, August-December 2023 and March to July 2024.

Seasonal effects and yield response to climate-smart management

The use of climate-smart practices provided an added advantage during both the phase 1 and 2 short rain seasons (March to July 2023) and (March to July 2024). There was a notable impact of soil type on yield performance as Gleysol produced higher yields compared to Plinthisol or Ferralsols with no management, but crop performance improved with better management (**Fig. 3**). For first short season of 2024 (Season 202A), rice growth was registered with variations across soil types but did not reach the physiological maturity due to severe drought. For 2023A, low grain yield was also registered due to limited rainfall distribution. Overall, the short seasons (first season of a year) did not favor the introduced NAMCHE 5 variety, but early maturing rice variety could be an option for such short seasons in the area.

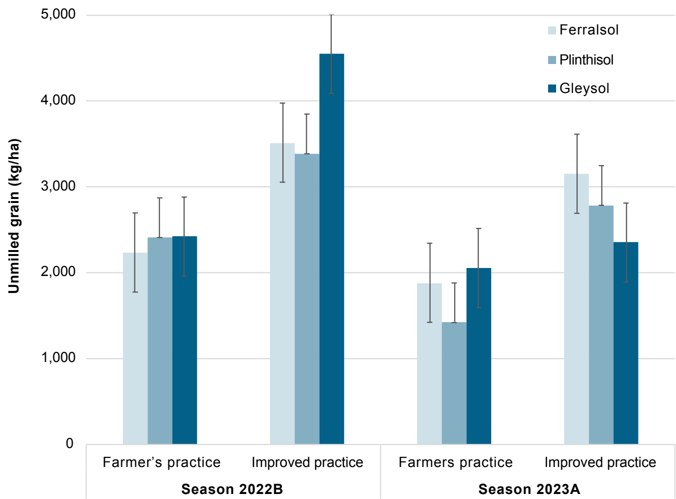

Figure 3. Comparing yield performance in the long and short seasons 2022/2023 trials.

Conclusion

Upland rice production is significantly affected by soil type and climate-smart nutrient management regimes. The Ferralsol sites were the most consistently productive between 2022 and 2024 with the highest yield and grain recovery after milling. Interventions with lower nutrient input registered yields that were comparable to the full nutrient application package suggesting that lower nutrient rates could be economically viable and affordable for farmers. There is potential for targeting soil-specific nutrient management in upland rice production for high milling recoveries and increased climate change adaptation. ■

Acknowledgement

This research was made possible with funding from APNI under the African Plant Nutrition Research Fund (APNRF). The rice project aimed at improving crop productivity through proper rice nutrition, sound agronomic and climate-smart agricultural options with a market responsive business strategy. Special thanks to the field teams that have supported field experiments, data collection, laboratory analyses and statistical analysis.

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https://doi.org/10.55693/ga41.WKDW5707

REFERENCES

Alou, I.N., et al. 2018. Growth, phenological, and yield response of upland rice (Oryza sativa L. cv. Nerica 4®) to water stress during different growth stages. Agric. Water Manage. 198:39-52.

Kaizzi, K.C., et al. 2014. Upland rice response to nutrient application in Uganda. Afr. J. Plant Sci. 89:416–425.

Matovu, B. et al. 2024. I. Navigating through Complexity by Profiling the Main Threats to Sustainable Tropical Wetlands Management and Governance: A Case Study of Mityana District, Uganda. Discov. Environ. 2, 18.

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NUTRIENT DEFICIENCY SYMPTOMS IN CROPS

PLANT NUTRITION RESEARCH IN ACTION

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We are excited to announce that the 2025 edition of APNI's **Annual Photo Contest** is open for entries!

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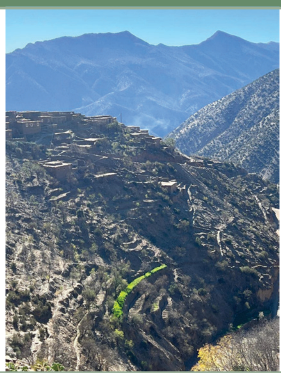
Our contest is accepting entries till **September 1, 2025.**

CATEGORY 1: Nutrient Deficiency Symptoms in Crops

Submit your examples of nutrient deficiency symptoms in African crops. Ideally, your images should be supported by a short description that includes the location and any key information or observations related to the image. For example, if you have any background on how the crop was managed, or any results from the lab, please include that in your description for the benefit of others, and to help our evaluation.

CATEGORY 2: Plant Nutrition Research in Action

This is a more wide-open category designed to gather on-the-ground examples of plant nutrition and soil health-related research in action for Africa. We are especially looking for images plus descriptive captions that tell us how your scene aligns with one of our R&D themes of 1) Climate & Weather Smart Plant Nutrition, 2) Soil Health & Improved Livelihoods, or 3) Precision Nutrient Management.



Advancing Agricultural Sustainability through Collaborative Data Growth

By Canon Norris Savala Engoke and Sarah Myers

The Open Data Crop Nutrition Platform (https://cropnutrientdata.net), a collaboration between the International Fertilizer Association (IFA), Agmatix, and the Consortium for Precision Crop Nutrition (CPCN), continues to make strides in supporting agricultural sustainability. The platform has seen exponential growth over the past year, attracting contributions from a diverse group of researchers and organizations. This influx of data has amplified the platform's impact on crop nutrition research and its influence on farm practice.

Since its inception in 2022, the Open Data Crop Nutrition Platform has evolved into a central repository for essential crop nutrition data for researchers and agronomists. This past year, the platform has undergone an especially significant transformation. The platform now boasts an extensive collection of over 3,000 datasets, a substantial increase from the previous year. These datasets originate from over 70 countries and involve the collaborative efforts of more than 100 researchers. This diversified growth provides opportunities to develop a range of critical insights into various crops, soil types, and climatic conditions. The data covers a broad spectrum of information including records on crop nutrient content, soil fertility, and nutrient omission trials (Ludemann et al., 2022). Presently, it has over 500 registered users from over 400 organizations including universities, research institutes, agribusiness companies, and governmental bodies. This expanding community reflects the increasing role for the platform in global agronomic research and fostering the development of data-driven solutions for crop nutrition (Ludemann et al., 2022).

New collaborations and contributions

Continuing Impact and New Insights

Anglo American, the first commercial contributor to the platform, has maintained its leadership by providing datasets to inform crop harvest index and nutrient removal models. In 2024, their contributions expanded to include data on nutrient use efficiency in various crop systems. This data is essential in refining predictive models that guide best practices for nutrient management, thus enhancing both productivity and sustainability (Kindred, 2020). The insights gained from this data help in developing tailored nutrient management strategies that account for specific crop requirements and environmental conditions.

The Crop Nutrient Database, a partnership between CPCN, Wageningen University, IFA, APNI, iSDA, and Agmatix, can be accessed at https://cropnutrientdata.net.

Enhancing Potassium Research

The International Potash Institute (IPI) has enriched the platform further by adding new trials that focus on potassium (K) fertilization and its impact on crop yields. The most recent contributions include data from previously underrepresented regions such as the Middle East and Eastern Europe. This expansion enables a more comprehensive analysis of K use efficiency, offering valuable insights into how K influences crop growth in different agro-ecological zones. The data supports the development of more sustainable fertilizer practices by providing region-specific recommendations for K application (Mey-Tal, 2023).

Global Nutrient Budgeting

The Food and Agricultural Organization (FAO)'s collaboration with the platform has also strengthened by their leveraging of the expanded database to enhance their Global and Regional Cropland Nutrient Budgets. The updated nutrient budgets now include more granular data on nutrient removal, efficiency and losses that offers a more precise understanding of global nutrient dynamics (FAO, 2024). This enhanced nutrient budgeting tool is seen as critical for policymakers and researchers to recognize nutrient imbalances and support the development of strategies to mitigate environmental risks associated with over, or imbalanced, nutrient use. By providing detailed data on nutrient cycling, the platform also aids in developing region-specific nutrient management practices that support both agricultural productivity and environmental health.

Enhanced Data Analysis Capabilities

Agmatix, the technology partner, has significantly expanded analytical capabilities for platform users. With the integration of advanced AI technologies, including Large Language Models (LLM), Generative AI, and Natural Language Processing (NLP), users can now query data, generate hypotheses, conduct analyses, and uncover insights more efficiently and accurately. This enhancement simplifies the process of uncovering emerging trends in agriculture and/or agronomic practice. Users are able to analyze trials across multiple parameters, create visualizations for more informed decision-making, and leverage insights for future research, contributing to a collective understanding of crop nutrition and fostering more sustainable agriculture (**Fig. 1**). Researchers, universities, private industries, and policymakers all benefit from such access to an advanced analytical tool that enhances their decision-making processes.

Contribution to agricultural sustainability

Improving Precision in Crop Nutrition

The platform's diverse datasets enable the development of more precise nutrient management models tailored to specific crops, soil types and climatic conditions. Such models optimize fertilizer application within productive and profitable cropping systems while minimizing environmental harm. By providing detailed data on nutrient uptake and soil fertility, the platform helps agronomists and farmers make informed decisions that enhance

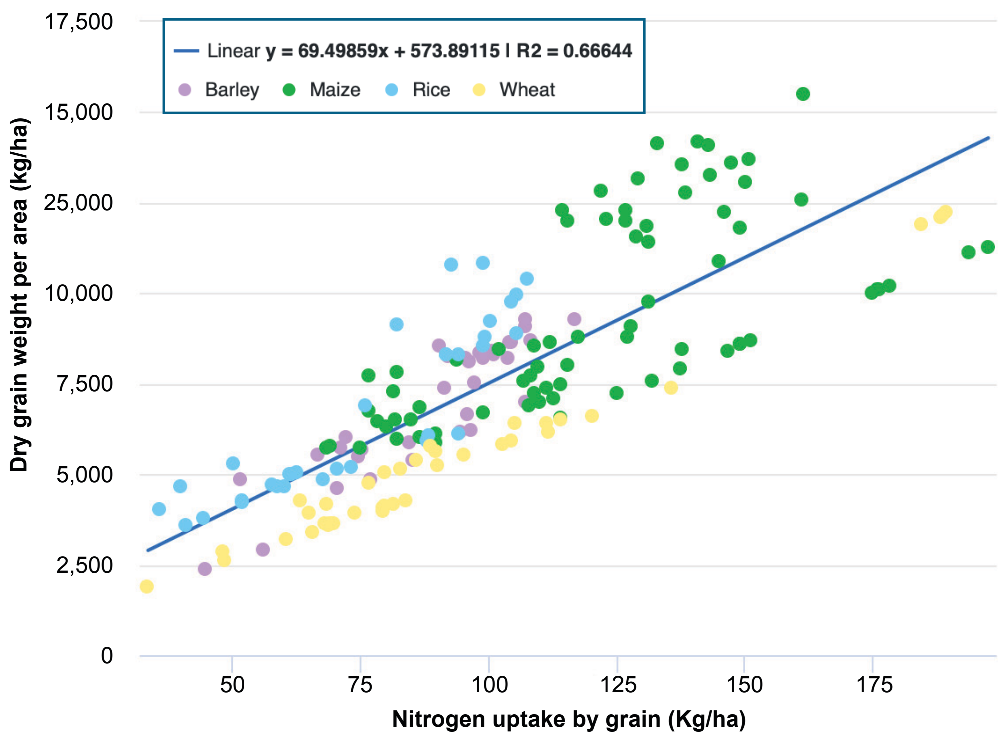


Figure 1. Cereal yield plotted against nitrogen uptake by grain. (CropNutrientData, 2025)

crop productivity while maintaining soil health (Ludemann et al., 2022).

Enhancing Nutrient Use Efficiency

Data from the platform has contributed to refining nutrient use efficiency metrics, guiding farmers and agronomists in implementing practices that maximize crop nutrient uptake. This focus on efficiency not only boosts crop yields but also reduces nutrient losses to the environment, thereby supporting sustainable farming systems. The platform's data-driven approach ensures that right nutrients are applied in the right amount, at the right time, and in the right place, aligning with the principles of 4R Nutrient Stewardship and precision agriculture (Zingore and Johnston, 2013).

Supporting Global Food Security

The above-mentioned collaboration with FAO on nutrient budgeting underscores the platform's role in addressing the challenge of producing more food within the context of the farmer's resources and landscape, a critical element of global food security, particularly under the pressures of changing climatic conditions (FAO, 2024).

A call for expansion of data contributions

To sustain and enhance the impact of the platform, there is a continued need for expanded contributions of data from all stakeholders. Individuals, researchers, private industries, and organizations are encouraged to join this global effort. Researchers and academics can further enrich the platform by sharing their data on crop nutrition, soil fertility and agronomic practices, thereby aiding in the development of more accurate and comprehensive models. Private industries and agribusinesses can contribute to a deeper understanding of crop nutrition by providing data on nutrient use efficiency, crop performance, and soil health. Governmental bodies and NGOs play a crucial role by offering data from national and international research initiatives, soil surveys and agricultural extension services, thereby creating a more robust and representative global dataset. Farmers and agronomists are also key contributors, as their practical insights and field-level data on crop nutrient management across various regions and farming systems can help tailor recommendations to local conditions, enhancing the platform's relevance and effectiveness. By expanding the breadth and depth of data contributions, we can collectively build a more comprehensive and actionable knowledge base.

Future directions

Looking forward, the Open Data Crop Nutrition Platform aims to further expand its datasets and user base, fostering a global network of contributors and users. Plans include integrating more data on emerging topics such as carbon sequestration in agricultural soils, nutrient cycling in organic farming systems, and the role of crop nutrition in climate resilience.

The platform has already made remarkable progress through the momentum gained in its recognition as a vital tool for researchers, agronomists and policymakers. Its growth in data contributions and user engagement reflects the global recognition of its value. As it evolves, the platform is poised to play an increasingly pivotal role in advancing our understanding of crop nutrition. By continuing to enhance its capabilities and expand its reach, the Open Data Crop Nutrition Platform will be at the forefront of efforts to develop innovative, data-driven solutions for a more sustainable and resilient agricultural future. ■

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REFERENCES

CPCN. 2025. Crop Nutrient Data. https://cropnutrientdata.net

Food and Agriculture Organization. 2024. Global Cropland Nutrient Budget. FAO. https://www.fao.org

Kindred, D. 2020. Crop nutrient data contribution. Anglo American.

Ludemann, C.I., et al. 2022. Estimation of crop nutrient removal and nitrogen concentrations in maize. Field Crops Res. 284-108578

Mey-Tal, S. 2023. IPI contribution to crop nutrient data. International Potash Institute.

Zingore, S., Johnston, A. 2013. The 4R Nutrient Stewardship in the context of smallholder Agriculture in Africa. In, Vanlauwe, B., Blomme, G., Van Asten, P. (eds.), Agro-ecological Intensification of Farming Systems in the East and Central African Highlands, Earthscan, UK: 77-84.

Our 2024 Annual Report marks the completion of five-years of operation at APNI. It is the time to talk about what we have accomplished, but also to reflect on how these achievements will shape our future.

From institutional growth to R&D outputs, capacity building efforts, strategic partnerships, this report speaks of many compelling stories and outputs. We are genuinely proud of that. Together we produced a convincing array of new ideas and evidence to champion plant nutrition for the Continent. These have created visibility for APNI and placed plant nutrition as a key lever for agricultural development.

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Comparing Laboratory and Remote Sensing Methods for Soil Nutrient Assessment in Northern Nigeria

By A.R. Garba, A.M. Yamusa, C.K. Daudu, S.L. Yau, M.I. Gaya, and A. Abdulkadir

Remote sensing shows significant potential for scaling the assessment, and mapping, soil fertility across African agricultural landscapes. *Still, the path forward likely lies in an integrated approach that combines the power of remote sensing for broad-scale assessment and planning with targeted laboratory analysis.*

For smallholder farmers across Africa, knowing which soil nutrient concentrations are adequate in their fields, and which are lacking, is one of the foundations for sustainable farming. Traditional soil testing through laboratory analysis has long been the gold standard, but its cost and limited accessibility present significant barriers. Remote sensing technologies offer promising alternatives that could revolutionize how farmers manage soil nutrients across vast agricultural landscapes.

An experiment was established to answer a practical question: **How well do satellite-based remote sensing methods compare with traditional laboratory analysis in assessing key soil nutrients?** By comparing these approaches, we aimed to determine whether remote sensing could provide a reliable, cost-effective alternative for assessing soil fertility at scale.

Why this matters for African agriculture

Precision agriculture and nutrient management represent transformative approaches that could help African farmers optimize inputs while improving yields and sustainability. However, the first step toward precision is gaining accurate information about soil conditions. Remote sensing technologies could democratize access to soil information by

1) providing wider coverage than laboratory sampling alone,
2) reducing costs associated with extensive field sampling,
3) enabling rapid assessment of soil properties, and
4) supporting more timely decision-making for fertilizer application.

Our approach

The study was conducted across four local government areas (LGAs) in Kaduna State, Nigeria. Kubau and Makarfi LGAs are in the northern Guinea savannah, and Kagarko and Lere LGAs are in the southern Guinea savannah (**Fig. 1**). This region experiences tropical Guinea savanna conditions with average annual temperatures of 25.2°C and annual rainfall averaging 1,323mm.

Researchers collected 16 soil samples from the top 20 cm of soil across different cropping systems (4 samples per location for 4 areas), recording precise

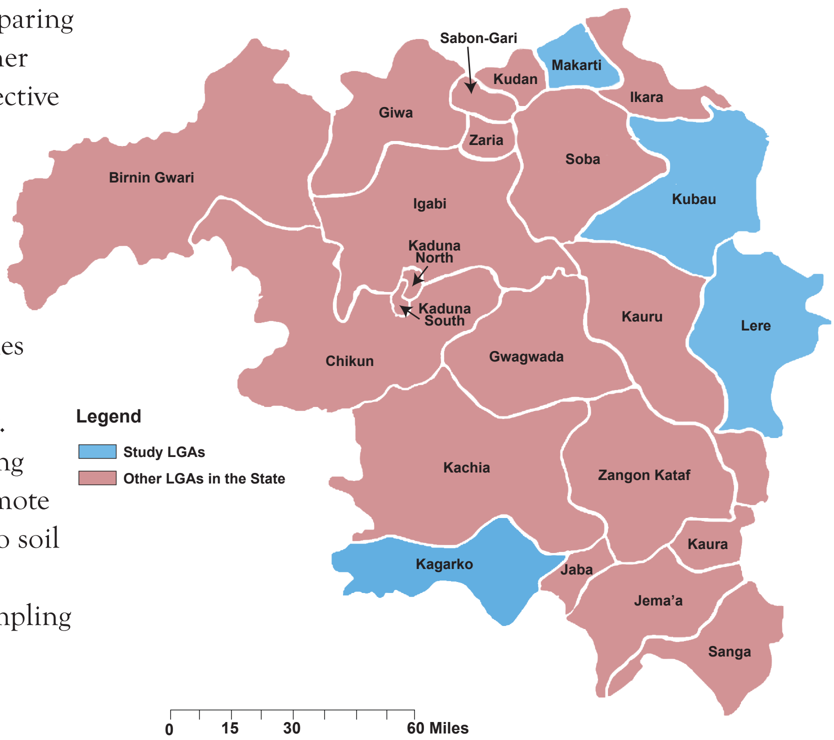

Figure 1. Map showing study locations in Kaduna State.

locations using GPS. Samples were taken pre-planting with two locations designated for maize, one for soybean, and the fourth for rice. Soil samples were analyzed for soil organic carbon (SOC), total nitrogen (N), soil organic matter (SOM), and available phosphorus (P) and potassium (K).

Simultaneously, Sentinel-2 satellite imagery was obtained at 20 meters resolution for data analysis through proprietary algorithms to estimate the same soil properties remotely. Results from the physical sampling and remote sensing were compared using correlation analysis (Pearson) to determine how well the remote sensing assessments matched laboratory findings.

Results

The analysis revealed significant differences in how well remote sensing performed across different soil properties. Remote sensing proved most reliable for estimating soil organic matter, showing a strong positive correlation (r=0.68) with laboratory results. This finding aligns with other African studies that have successfully used spectral data to map organic matter across agricultural landscapes (Vågen et al., 2016). Soil organic matter is a crucial indicator of overall soil health and influences water retention, nutrient cycling, and C sequestration. The ability to map organic matter through remote sensing offers farmers valuable insights into soil quality without extensive sampling.

Soil C, however, showed only a weak positive correlation (r=0.23) between remote sensing and laboratory measurements. This weaker relationship reflects the challenges of estimating total soil C from surface spectral properties alone. While remote sensing shows promise for soil C assessment, the correlation suggests we should use caution when relying solely on satellite data for precise soil C measurements. Integration of remote sensing with ground sampling is recommended to improve accuracy.

Interestingly, our analysis revealed varying correlations between laboratory-measured SOM and remotely sensed estimates of other soil properties (**Fig. 2**). Laboratory SOM showed a strong positive correlation with remotely sensed C (r=0.70), suggesting that remote sensing techniques that effectively capture SOM may also provide valuable insights into soil C content. This strong relationship is expected given that SOM is approximately 58% C by mass. The moderate correlation between lab SOM and remotely sensed N (r=0.32) indicates potential for using SOM as a proxy indicator for N status, though with less reliability than for C. The weak correlation with remotely sensed P (r=0.18) suggests limited utility in predicting P status from SOM measurements alone. These relationships merit further investigation, as they could potentially allow farmers to gain insights into multiple soil properties through remote sensing approaches that effectively capture SOM variability, thereby enhancing the efficiency of soil monitoring programs.

Total N also showed a weak positive correlation (r=0.14) between remote sensing and laboratory analysis. This modest relationship reflects nitrogen's complex and dynamic behavior in soils. Nitrogen management is vital for crop productivity, but its mobility and susceptibility to various N transformation processes and losses make it particularly challenging to directly assess soil N through remote soil sensing. Farmers may still need direct soil testing for accurate N fertilizer recommendations.

Negative correlations between remote sensing and laboratory measurements were found for both soil P (r=-0.48) and K (r=-0.42). A negative relationship indicates that values obtained through remote sensing may show trends that are opposite to laboratory measurements. The complexity of

Laboratory \ Remote Sensing	Nitrogen	Phosphorus	Potassium	Carbon	Organic Matter
Nitrogen	0.14	-0.39	-0.20	0.22	0.09
Phosphorus	0.15	-0.41	0.11	-0.01	0.07
Potassium	0.22	-0.48	-0.42	0.17	0.17
Carbon	0.12	0.03	-0.49	0.23	0.12
Organic Matter	0.32	0.18	-0.77	0.70	0.68

Figure 2. Heat map showing correlations between remote sensing and laboratory measurements for soil nutrients and organic matter.

soil P and K dynamics appears to limit current remote sensing capabilities for these nutrients. This highlights where traditional soil testing remains irreplaceable for precision nutrient management.

Practical implications for African farmers

Our findings have significant implications for how precision agriculture might be implemented across Africa. **Tiered Approach to Soil Assessment:** Remote sensing could provide initial, broad-scale assessments of organic matter and C, while targeted laboratory testing could fill gaps for P, K, and N. **Cost-Effective Mapping:** For resource-limited contexts, remote sensing offers valuable insights into organic matter distribution across landscapes at lower cost than comprehensive sampling. **Targeted Sampling Strategy:** Rather than random or grid sampling, farmers could use remote sensing to identify priority areas for detailed laboratory analysis. **Technology Integration:** The future of soil fertility assessment likely involves integrating multiple approaches combining satellite data, proximal (ground-based) sensors, and strategic laboratory testing.

While our research demonstrates both the promise and limitations of remote sensing for soil nutrient assessment, several important questions remain for future investigation:

- How do seasonal variations affect the accuracy of remote sensing for soil nutrients?
- Could machine learning algorithms improve the prediction of challenging nutrients like P and K?
- What combination of sensing technologies might provide the most comprehensive and cost-effective soil assessment?
- How can farmers without technical expertise access and use remote sensing information?

Conclusion

Remote sensing shows significant potential for revolutionizing how we assess and map soil fertility across African agricultural landscapes. For soil organic matter assessment particularly, it offers a valuable complement to traditional sampling methods. However, our research demonstrates that remote sensing cannot yet replace laboratory analysis entirely, especially for critical nutrients like P and K.

The path forward lies in developing integrated approaches that leverage the strengths of both methods using remote sensing for broad-scale assessment and strategic planning while employing targeted laboratory analysis where precision is most crucial. By combining these tools, African farmers can move closer to precision-based nutrient management that optimizes resources while maximizing productivity and sustainability. ■

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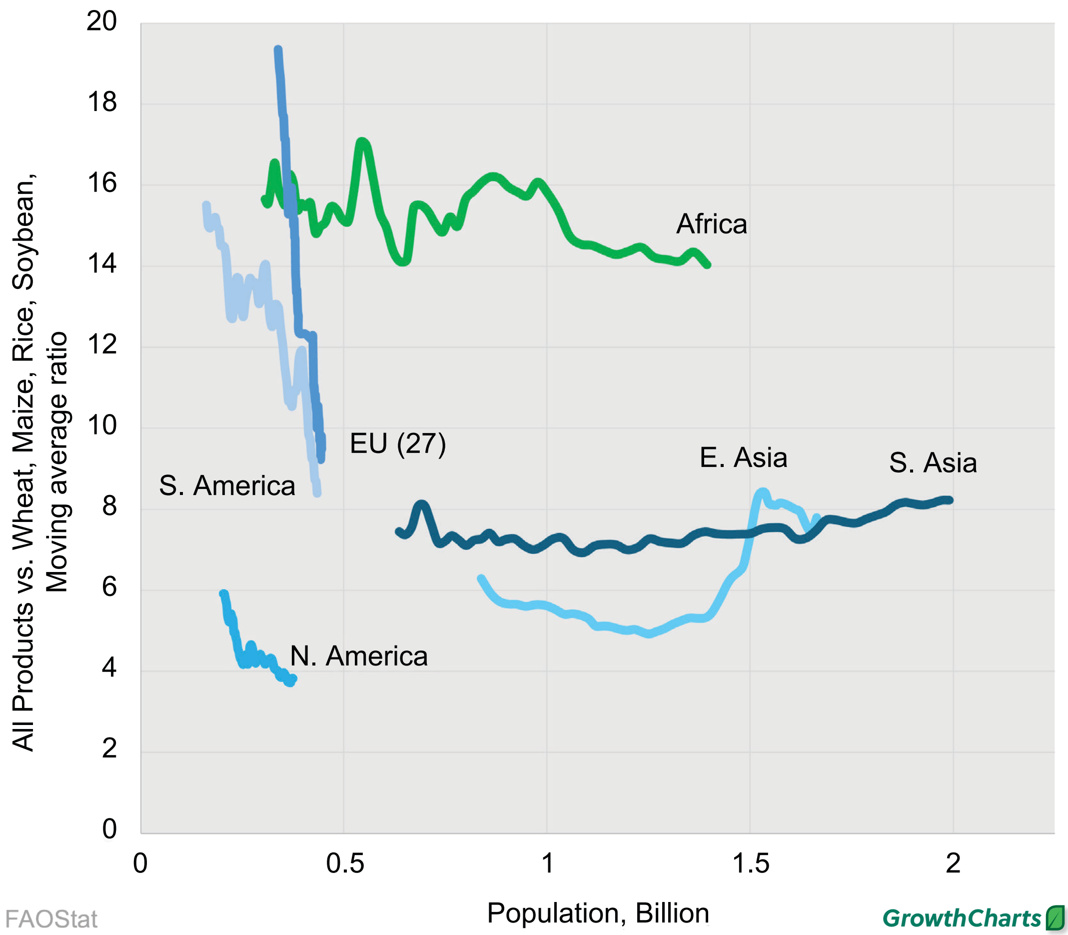
https://doi.org/10.55693/ga41.XVYN8680

REFERENCES

Garba, A.R. 2024. Assessing of Soil Nutrients Using Laboratory and Remote Sensing Methods in Northern Guinea Savannah. In, Proceeding of 3rd African Conference on Precision Agriculture (AfCPA 2024), African Plant Nutrition Institute, December 3-5, Marrakesh, Morocco. https://www.paafrica.org/Proceedings

Vågen, T.G., et al. 2016. Mapping of soil properties and land degradation risk in Africa using MODIS reflectance. Geoderma 263, 216-225.

Africa Crop Diversity is a Unique Strength to Explore



Regional crop production priorities ultimately govern the crop diversity achieved. Continents known for highly developed and large-scale production of wheat, maize, rice and soybean such as the Americas and Europe show rapid loss in harvested product diversity over the past 80 years—measured as the ratio of all products over the big four food grains produced globally. This reflects the importance these crops play in global trade and our daily diets. A different pattern in seen in Asia as crop diversity within this timeframe shows little decline, which is perhaps driven by the necessities of feeding a rapidly growing population. Crop diversity on the African continent shows a much different trend. The proportion of the big four food grains amongst all crop products is slowly declining but remains the highest amongst regions. Can Africa maintain this wealth of diversity in the face of the demands of its future population? This wider range of crops that are deeply rooted in its smallholder systems should represent a key consideration in terms of tradition, agro-biodiversity, and resilience.

GrowthCharts briefly explores perspectives on key issues, concepts and needs related to the development of African agriculture. For more visit: www.apni.net/GrowthCharts

On-farm Experimentation Process Triggers Kenyan Farmers' Zeal to Test Technologies in Maize Systems

By Onesmus Kitonyo, Evans Chimoita, Timothy Kamanu, Felister Nzuve, Esther Muindi, Alfred Micheni, James Muthomi, Vincent Kathumo, Grace Mureithi, George Chemining'wa, Ivan Adolwa, and James Mutegi

There is need to rethink the process of conducting on-farm research to better foster knowledge transfer and innovation. *Through a participatory on-farm experimentation (OFE) approach, this study was carried out to validate a package of soil moisture and fertilizer nitrogen management practices, and to track farmer adoption of better agronomic practices. The OFE process facilitated quick adoption and testing of technologies by farmers. At the onset of the third experimentation season, farmers had began to experiment on a range of practices, especially mulching and optimal plant density.*

Interests in co-creation and transfer of agricultural knowledge has led to re-orientation of conventional farmer-participatory research to an on-farm experimentation (OFE) approach (Lacoste et al., 2022). OFE embodies approaches in agricultural research and innovation that enable the researcher and the farmer to operate under real-world farm management to efficiently transfer knowledge and foster innovation (Lacoste et al., 2022). The approach generates feedback loops from all stakeholders that facilitate co-creation and design of experiments to validate technologies.

Researchers have traditionally used on-farm experiments to generate data, but without the involvement of the farmer for experimental design, data collection, or interpretation of the results (Kummer et al., 2017). Often, these experiments produce data and information that is not readily useful to the farmer. It is important to rethink the way experiments are conducted to bridge the gap in knowledge generation and transfer, and promote innovation by both researchers and farmers.

OFE offers a platform to develop locally relevant and actionable knowledge. However, this platform is not restricted to researchers and farmers as its co-learning environment provides valuable support for extension services, input providers, government agents, and policy makers working towards a set of shared goals (Richardson et al., 2022).

Apart from embodying multi-stakeholder involvement in co-creation of knowledge, OFE creates value for all participants. The value proposition of OFE fundamentally distinguishes it from other

Embu County farmers collectively evaluating on-farm experimentation plots.

participatory approaches in research. Value arises from farmers being able to access information they can trust (Lacoste et al., 2022). Despite enormous investment in research to improve the productivity of maize systems of Embu County, Kenya, farmers hardly adopt high-yielding agronomic practices. Low adoption could partly be attributed to the research process. In an effort to accelerate farmer experimentation and innovation, this study co-designed experiments with farmers and stakeholders to validate water and nitrogen (N) management practices in maize systems in Embu County.

Experimental design

OFE experiments were carried out in two environments in the maize-growing region of Embu County, in eastern Kenya. The OFE sites were established in upper midland (UM) zone (UM3 and UM4), and lower midland (LM) zone (LM3 and LM4).

Prior to the establishment of trials, farmers prioritized relevant and actionable nutrient and water management practices. Two best management practices were thereafter co-designed based on the outcomes of the researcher-farmer dialogue. The two co-designed (farmer/researcher) treatments were compared with farmer business-as-usual operations. In the first experimentation season, the first best management practice (BMP1) included a soil conditioner (hydrogel) and a slow-release N source (KynoPlus S®), while the second best management practice (BMP2) applied 3 t/ha crop residue as mulch plus calcium ammonium nitrate (CAN) as the N source. Additionally, based on learnings from the first experimental cycle, treatments were adjusted during the second season to include a uniform application of 5 t/ha of manure in both BMP1 and BMP2. Also, BMP1 was adjusted to include crop residue mulch. The farmer continued their business-as-usual operations but integrated their approach with learnings from the researcher plots.

Data were collected in both researcher and farmer managed plots. Prior to harvest, host farmers, neighbours, and stakeholders were invited to evaluate the performance of the experiments. Participants selected preferred treatment plots based on their own criteria. Three categories of choice per treatment plot were given: poor performance, average performance, or best performing treatment. The selection exercise was followed by focus discussions to document the criteria applied and perception about the demonstrated management practices.

Farmer prioritization of water and nutrient management practices

Figure 1 presents farmer prioritization of management practices that had potential to increase the yield of maize. Soil fertility and moisture management, and the need for better advisory services ranked highly among both men and women. The need for soil testing services ranked highly among male farmers.

Grain yield and farmer evaluations

The farmer-researcher co-designed BMP treatment combinations had higher maize grain yield compared with farmer practices (**Fig. 2**). During the first experiment cycle in lower midland zones (**Fig. 2a**), BMP2 out-yielded BMP1. However, from the second season onwards, yield differences between the two treatment combinations declined significantly after mulch was added to BMP1 plots.

Similar trends were observed in the in wet and cool upper midland zones as BMP2 significantly out-performed BMP1 during the first season (**Fig. 2b**). Across the two environments, yields exceeded the average farm yield in the region, which is estimated at 1 t/ha. Results of the farmer evaluation of experimental plots mirrored yield performance. Overall, farmer plots were least preferred by the respondents, and BMP1 was frequently voted better than BMP2.

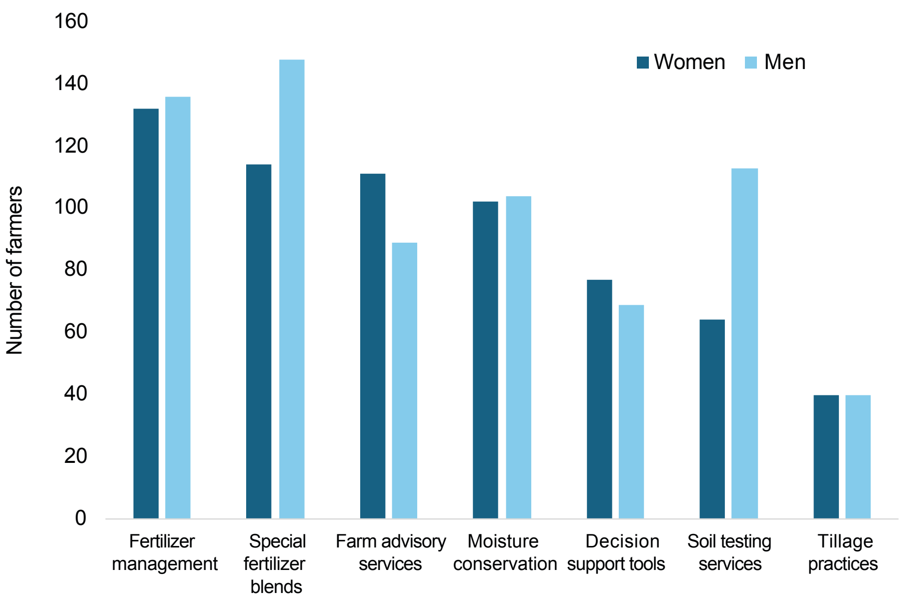


Figure 1. Farmer prioritization of crop management practices in Embu County, Kenya.

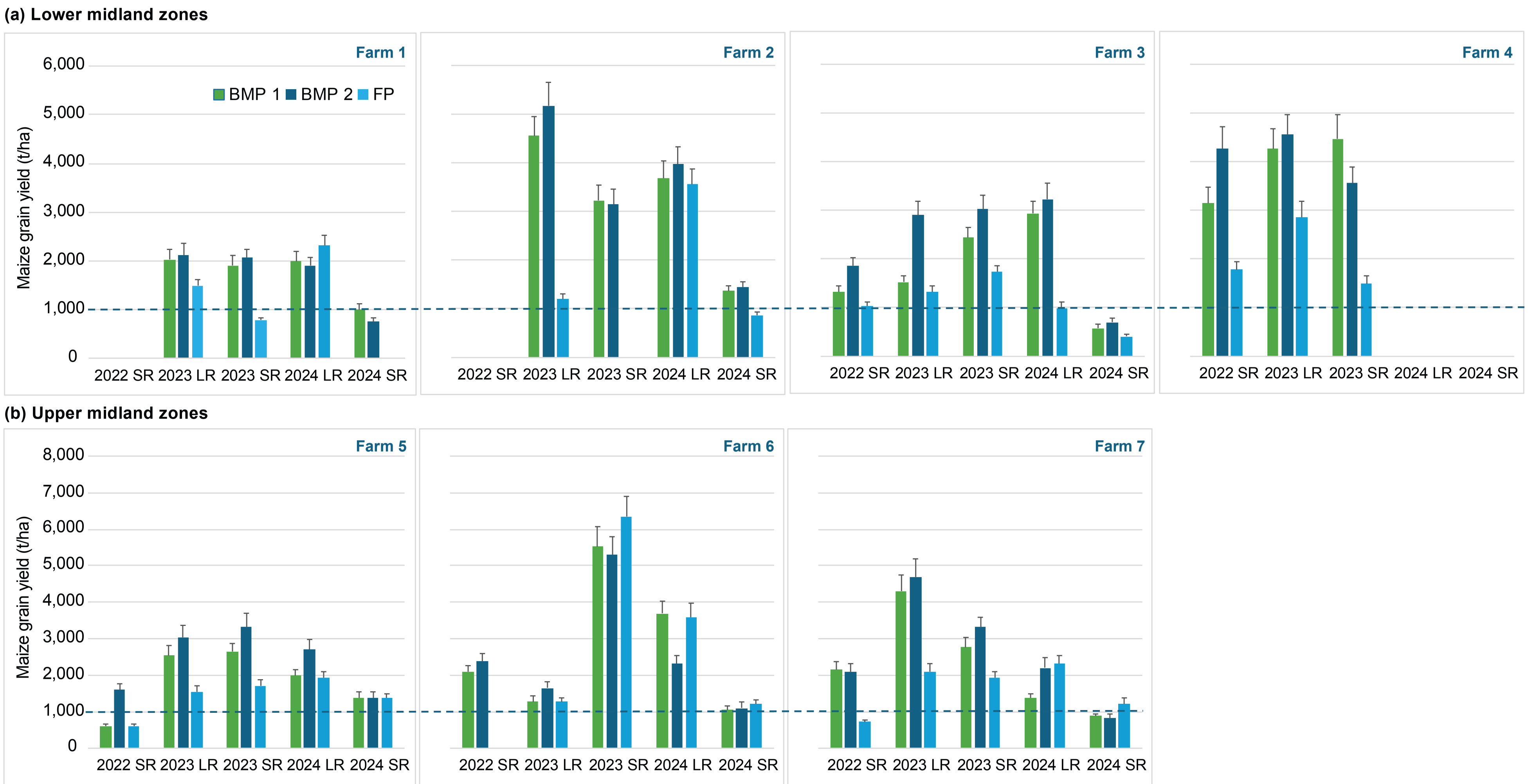


Figure 2. Grain yield of maize (kg/ha) in OFE host farms in the lower midland zones **(a)** and upper midland zones **(b)** during short rain (SR) and long rain (LR) seasons. BMP1 = hydrogel + crop residue mulch + slow-release urea fertilizer. BMP2 = crop residue mulch + calcium ammonium nitrate fertilizer. The dashed line is the average farm yield in Embu (1,000 kg/ha).

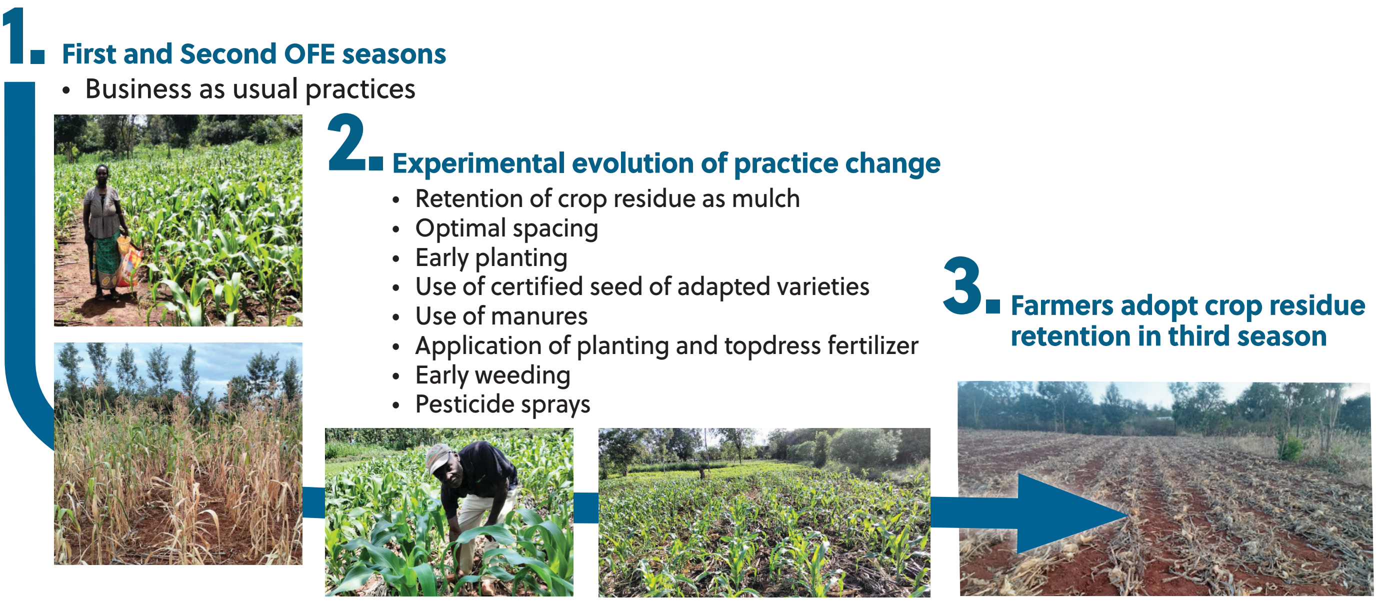


Figure 3. Evolution of farmer management practices as they progress into the third season.

Learnings and evolution of farmer practice

Evolution of farmer learning from business-as-usual operations to the implementation of better management practices for improved water and N management was impressive (**Fig. 3**). Farmers provided diverse feedback on their learnings, and presented a range of practices they were willing to test and implement in their plots. At the on-set of the third experimentation season (2023 short rains), a majority of farmers implemented at least one practice learned from the project.

This experimentation process was built around a co-learning environment between the farmers and researchers, as described by Lacoste et al. (2022). In this environment, researchers were able to better understand farmers' socio-economic constraints and their decision-making processes, particularly those related to choice of management practices. For example, during the first pre-harvest stakeholder dialogue, both parties prioritized the need to use manure during the succeeding seasons. Typically, farmers apply low amounts of manure due to unavailability on-farm and lack of resources to purchase the input (Laub et al., 2023). However, while most farmers in Embu County produce manure on-farm, this input is reserved for high value crops such as banana and khat (miraa) (Mwaura et al., 2021).

The two researcher-managed plots optimized crop management practices unlike in the farmer plots where there were occasional delays in weeding, fertilizer application, and pest control. Nevertheless, farmer

Farmers scoring maize treatment performance.

practices improved significantly during the five experiment cycles, which demonstrated knowledge transfer.

The lack of significant differences between BMP1 and BMP2 implied that hydrogel and mulch were equally effective in conserving soil moisture. Similarly, the application of CAN or the slow-release N fertilizer formulation did not show differences in maize yield. However, based on the unit price of N in each formulation, gross margin analyses (not shown) pointed to significantly higher returns per unit area with the use of slow-release fertilizer compared with CAN. Even so, either of the fertilizer formulation ought to be applied at an optimal rate, at the right stage of the crop, and placed near the root zone to maximize plant uptake (Bruulsema, 2022).

Adoption of residue retention among smallholder farmers, and especially those in mixed crop-livestock systems of Embu, is constrained by the competing uses of crop residue (Jaleta et al., 2012; Baudron et

Farmers and researchers in Embu County, Nairobi, gathered for a group focus session to collect perceptions and evaluate the effectiveness of demonstrated management practices.

al., 2014). In Embu, crop residues are primarily used as animal feed or sold to improve household income. However, through this OFE process farmers discovered the benefits of mulch in improving maize yield, which was an outcome that fundamentally changed the farmers' mindset. In addition, farmers learnt the importance of better agronomic practices to improve maize yield. Chiefly, they experimented with early planting, optimal plant density, early weeding, optimal fertilization based on the weather forecast, and the use of manure.

Conclusion

The aim of this research was to co-design experiments to validate water and N management practices, and to document the evolution of practice change in maize systems of Embu County, Kenya. The OFE approach created an open forum for farmers and researchers to foster knowledge creation and accelerate practice change by farmers. This was exemplified in the ability of farmers to take only two seasons of experimentation to start to adopt and test improved management practices such as mulching soils with crop residue. This challenged the status quo where farmers remove crop residue for livestock feed or sale. ■

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REFERENCES

Baudron, F., et al. 2014. Conservation agriculture in African mixed crop-livestock systems: expanding the niche. Agric., Ecosys & Env., 187:171-182.

Bruulsema, T. 2022. Nutrient stewardship: Taking 4R further. Crops & Soils 55(1), 34-40.

Jaleta, M., et al. 2013. Tradeoffs in crop residue utilization in mixed crop–livestock systems and implications for conservation agriculture. Agric. Sys., 121:96-105.

Kummer, S., et al. 2017. Farmers' own research: Organic farmers' experiments in Austria and implications for agricultural innovation systems. Sustain. Agric. Res., 6(526-2017-2663).

Lacoste, M., et al. 2022. On-Farm Experimentation to transform global agriculture. Nature Food 3(1):11-18.

Laub, M., et al. 2023. Combining manure with mineral N fertilizer maintains maize yields: Evidence from four long-term experiments in Kenya. Field Crops Res., 291:108788.

Mwaura, G.G., et al. 2021. Adoption intensity of selected organic-based soil fertility management technologies in the Central Highlands of Kenya. Front. Sus. Food Sys., 4:570190.

Richardson, M., et al. 2022. Farmer research networks in principle and practice. Intl. J. Agric. Sus., 20(3):247-264.

Toffolini, Q., M. Jeuffroy. 2022. On-farm experimentation practices and associated farmer-researcher relationships: a systematic literature review. Agron. Sus. Dev., 42(144):1-16.

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Knowledge generates on-farm innovation as farmers from Gashoka Village, Embu County, Kenya, participate in a water and nitrogen management learning forum that serves as an opportunity to assess best practice options for their maize crops.

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