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Strengthening site-specific nutrient management: Translating field evidence to better fertilizer advice

Regional Hub for Fertilizer and Soil Health for West Africa and the Sahel

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About the Regional Hub

The Regional Hub for Fertilizer and Soil Health for West Africa and the Sahel (Regional Hub) is a regional technical support unit, established in June 2024 in response to the priority actions outlined in the Fertilizers and Soil-Health Roadmap for West Africa and the Sahel (World Bank, 2023). The roadmap emerged from the Lome Roundtable, attended by Heads of State from the region and facilitated by ECOWAS and the World Bank. The Regional Hub was formally endorsed as an ECOWAS sub-program at the Africa Fertilizer and Soil Health Summit held in Nairobi in May 2024.

The Regional Hub provides technical assistance for fertilizer and soil health investments across 17 countries in West Africa and the Sahel (Figure 1). Its mandate is delivered through 20 functions organized into six thematic areas (Figure 2): soil information; knowledge management and sharing; agronomy; capacity development; policy support; and advocacy and awareness creation.

The Regional Hub is hosted at the IITA campus in Ibadan, Nigeria. It operates under the governance of ECOWAS and is managed by a consortium of technical partners, including International Institute of Tropical Agriculture (IITA), The African Plant Nutrition Institute (APNI), International Fertilizer Development Center (IFDC), University of Mohammed 6 Polytechnic (UM6P), and International Soil Reference and Information Centre (ISRIC), with financial support from the World Bank and OCP Africa.

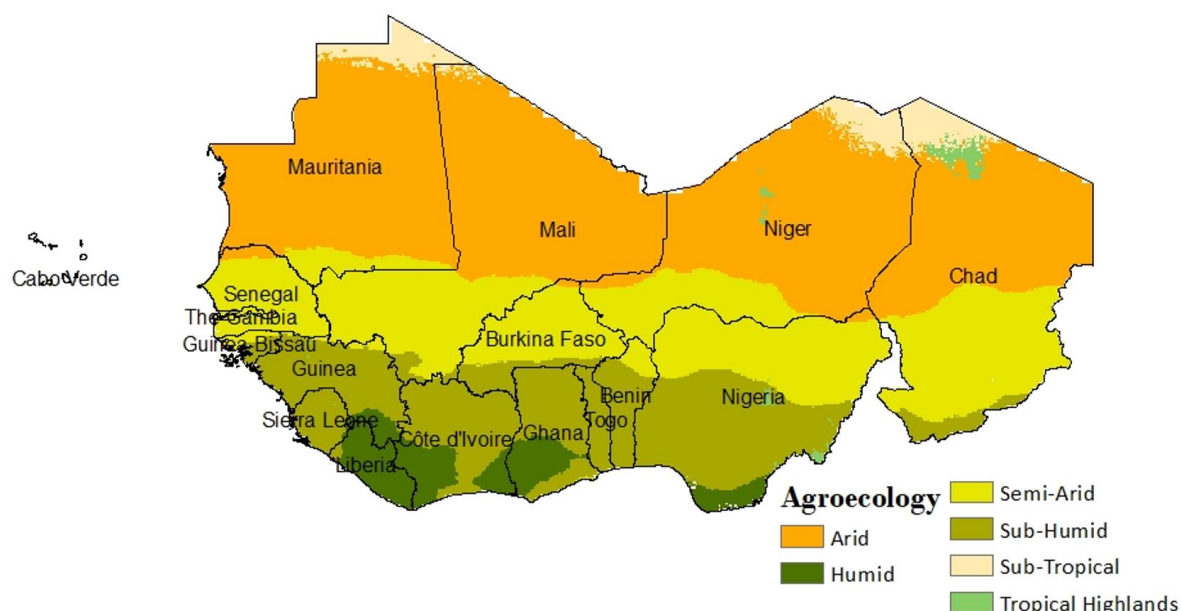


Figure 1. The 17 countries within the mandate of Regional Hub for Fertilizer and Soil Health for West and the Sahel



Figure 2. The 20 functions of the Regional Hub for Fertilizer and Soil Health for West and the Sahel organized across six thematic areas

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Why it matters

Across Africa, including West Africa and the Sahel, low fertilizer use and widespread soil degradation continue to be among the greatest barriers to agricultural productivity. Fertilizer use on the continent has grown, from an average of 8 kg per hectare in 2006 to a high of 42.5 kg/ha in 2019, but it has since declined to around 34.5 kg/ha in 2022 (Nduva et al., 2024). This remains far below the global average of about 136 kg/ha in the same year (World Bank, 2026). The problem is not only how little fertilizer is used, but also how efficiently it is

used. Farmers frequently obtain smaller yield gains and weaker returns on their investment than expected, largely because of poor crops and soil management practices (Vanlauwe et al., 2026). The consequences are visible in harvests: in 2023, cereal yields in Africa averaged 1.7 tonnes per hectare, less than half the global average of 4.24 t/ha (Yieke, 2025).

Where fertilizer is used, application rates are typically based on blanket national or regional recommendations that take no account of local differences in soil, climate, crop or management. As a result, some fields receive more fertilizer than they need while others receive too little, wasting money, sustaining yield gaps and allowing soil fertility to keep declining (Chivenge et al., 2022). Growing rainfall variability, longer dry spells and rising temperatures make it even harder for farmers to decide which fertilizer to apply, and in what quantity.

Moving from blanket to site-specific advice responds directly to the [2024 Nairobi Declaration on Africa Fertilizer and Soil Health](#), which commits African countries to increasing the availability and efficient use of quality fertilizers while restoring soil health, and to the [2025 Kampala CAADP Declaration](#), which recognizes stronger agricultural data systems as a continental priority for effective and informed decision making.

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What is it?

Site-Specific Nutrient Management (SSNM) aligns the supply of nutrients with what a crop actually needs in a given place. It applies the 4R nutrient stewardship principles—the right source, at the right rate, at the right time and in the right place—so that crops receive the nutrients they need, in the correct amounts, while losses to the environment are reduced (Johnston & Bruulsema, 2014).

SSNM is a core component of Integrated Soil Fertility Management (ISFM). ISFM combines the judicious use of mineral fertilizers with organic inputs, improved crop varieties and good agronomic practices, adapted to local conditions (Vanlauwe et al., 2010). Site-specific fertilizer rates make the mineral-fertilizer part of ISFM more precise and more profitable, while organic inputs and good agronomy help sustain soil organic matter, improve fertilizer response and build long-term soil health.

Achieving this precision at scale requires more than conventional soil testing, which is often costly, slow and out of reach for smallholder farmers. The Regional Hub combines field trials, legacy agronomic data, digital soil maps, climate information and machine learning to predict how crops respond to nutrients across whole landscapes. The output is a set of spatially explicit maps of nitrogen (N), phosphorus (P) and potassium (K) requirements that can be translated into fertilizer advice for individual farms and fields, and delivered through digital advisory tools such as AKILIMO tool.

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What do we do?

Developing site-specific fertilizer recommendations is the seventh of the Regional Hub's 20 core functions (Section 1). The work is demand-driven, with countries, target regions and crops selected based on requests from national and regional partners, alignment with country priorities, availability of legacy agronomic and soil data, and opportunities for scaling through existing programs and investments. Implementation is coordinated through Hub National Focal Points and National Technical Teams, ensuring national ownership and strong links to regional coordination.

Based on this approach, the work initially focused on three priority crops—maize, rice and cassava—in five Wave 1 countries: Nigeria, Ghana, Togo, Liberia and Sierra Leone. Key national partners include the Ministry of Food and Agriculture (Ghana), Institut Togolais de Recherche Agronomique (ITRA, Togo), Sierra Leone Agricultural Research Institute (SLARI), Central Agricultural Research Institute (CARI, Liberia), and the Centre for Dryland Agriculture at Bayero University Kano (Nigeria).

Recommendations are developed through a progressive, phased approach (version 0 to version 2) built on three steps:

- **Building the evidence:** 500 nutrient omission trials (NOTs) were established for maize, rice and cassava across the five Wave 1 countries under one common protocol (Figure 3). These were combined with more than 25,000 curated legacy crop-response records compiled through the CAROB data platform and national partners, and with soil properties drawn from the Regional Hub's enhanced digital soil maps.
- **Modelling crop response:** Within the developed machine learning (ML) decision-support framework, machine-learning models (gradient boosting, random forest, and generalized linear and additive models, combined into stacked ensembles) predict yield from soil properties and N, P and K rates. Models are tested with spatial cross-validation and an independent test dataset, and a recommendation is released only where a model explains at least 70% of yield variation ($R^2 \geq 0.70$).
- **Generating recommendations:** For each location, the models identify the smallest combination of N, P and K needed to raise yield by at least 30% above the site's unfertilized baseline. This maximizes the yield gained per kilogram of nutrient applied, which matters most where fertilizer costs constrain smallholder farmers. The target can be adjusted to local agronomic, economic and risk conditions.

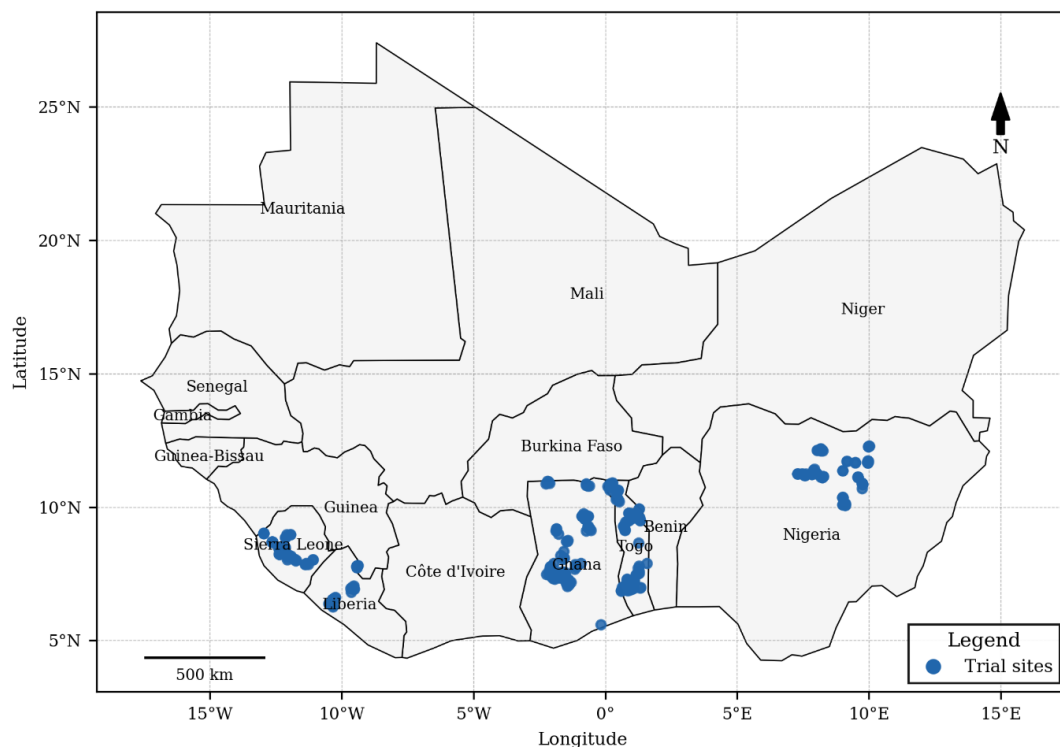


Figure 3. Distribution of nutrient omission trial sites across the Wave 1 countries

The trials confirm why a single rate cannot serve every field. In Nigeria, unfertilized maize yielded about 1.1 t/ha compared with about 4.2 t/ha under full NPK; for rice, yields rose from about 2.3 to 4.8 t/ha. Nitrogen was the most limiting nutrient almost everywhere, followed by phosphorus and then potassium, while secondary nutrients and micronutrients gave smaller and less consistent gains.

5a

What progress have we made? — Site-specific nutrient recommendations

From April 2025 to March 2026, the Regional Hub have produced the first version (V1) of site-specific N, P and K requirement maps for maize and rice in priority watersheds or regions in Ghana, Nigeria, and Liberia.

VERSION 0 to VERSION 1

Recommendations that met the accuracy threshold

Version 0 (V0) recommendations were initially developed using legacy agronomic data collected from national partners and crowdsourced data from peer-reviewed literature. New on-farm nutrient omission trial (NOT) data were subsequently integrated using a gradient boosting approach, with a weighting of 0.75 assigned to the new NOT data and 0.25 to the legacy data. This process refined V0 to produce Version 1 (V1), subject to an acceptance threshold of $R^2 > 0.70$.

Based on the current results, V1 maize recommendations cover approximately 5.1 million hectares across target watersheds in Nigeria and Ghana, while V1 rice recommendations cover approximately 5.2

million hectares across Nigeria, Ghana and Liberia. However, the rice models for Sierra Leone and Togo, and the maize model for Togo, did not meet the accuracy threshold (Table 1). Additional legacy data and new NOT data are therefore required to improve model performance and support the development of reliable recommendations for these areas.

VERSION 2

Being explicit about uncertainty

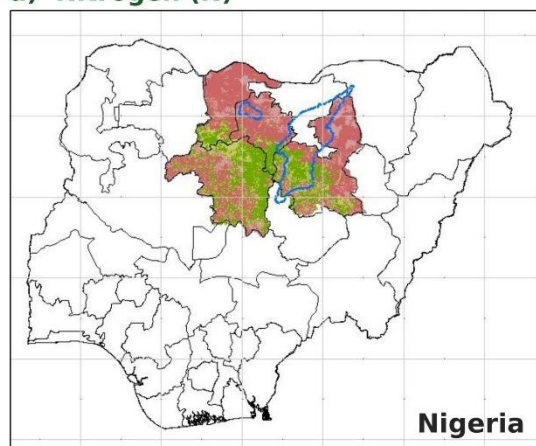
The V1 recommendations are first subjected to field validation and refinement trials to assess their performance under real-world conditions. Results from these trials, together with additional agronomic and environmental data, are then used to refine models. Mechanistic and linear hybrid approaches are integrated with ML models to improve prediction accuracy and quantify uncertainty. The validated and refined outputs are subsequently combined to produce enhanced Version 2 (V2) recommendations. Field validation and refinement trials are currently ongoing in Nigeria and Liberia.

Table 1: Predictive performance of V1 site-specific nutrient recommendations

Country	Crop	Model type	R ²	Mean Absolute Error (t ha ⁻¹)	Status
Nigeria	Maize	Ensemble model	 0.803	0.505	Finalized
	Rice	Gradient Boosting	 0.895	0.417	Finalized
Ghana	Maize	Ensemble model	 0.744	0.689	Finalized
	Rice	Ensemble model	 0.954	0.114	Finalized
Togo	Maize	Random forest	 0.371	1.050	In progress (need refinement with additional data)
	Rice	Ensemble model	 0.437	0.586	
Liberia	Rice	Gradient Boosting	 0.825	0.263	Finalized
Sierra Leone	Rice	Gradient Boosting	 0.698	0.268	In progress (need refinement with additional data)

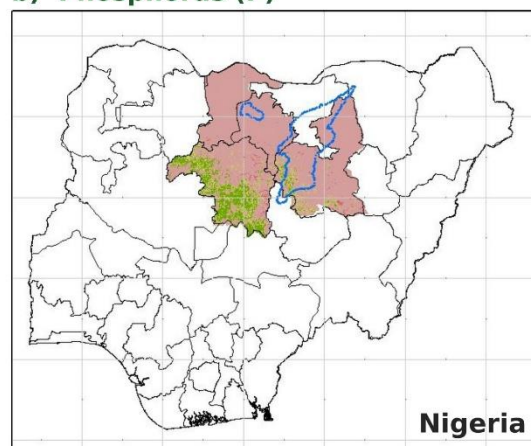
The results show substantial differences in nutrient requirements across countries and, within countries, across regions, watersheds and crops (Figures 4–6 provide a few examples). This demonstrates that a single fertilizer recommendation is unlikely to optimize nutrient use efficiency across all fields. The findings also have important implications for fertilizer supply and blending. For example, the generally low potassium requirements for maize in Nigeria suggest that routine use of high-potassium blends may not always be the most economical option. In contrast, the substantial variation in nitrogen and phosphorus requirements highlights the value of fertilizer blends and application rates tailored to local nutrient demand rather than driven primarily by product availability.

a) Nitrogen (N)



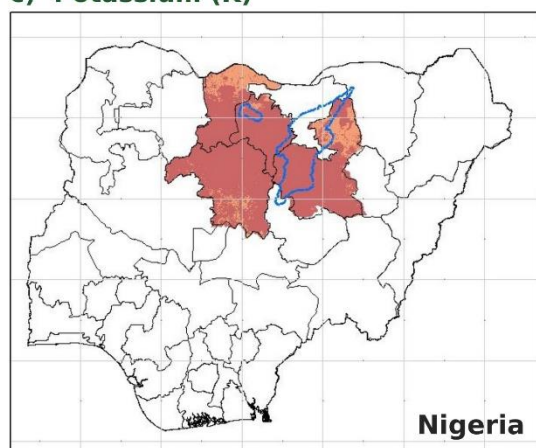
Requirement (kg/ha)
 17 - 40 40 - 80 80 - 120 120 - 142

b) Phosphorus (P)



Requirement (kg/ha)
 0 - 13 13 - 23 23 - 33 33 - 41

c) Potassium (K)

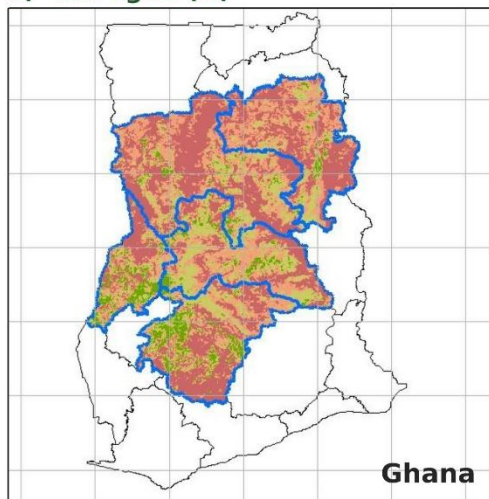


Requirement (kg/ha)
 0 - 10 10 - 20 20 - 29

--- Boundary of target watersheds
 State boundaries

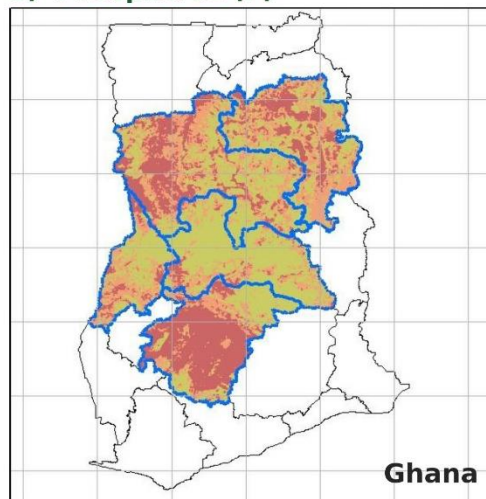
Figure 4. Version 1 site-specific recommendations for maize (kg/ha) across target watersheds in Nigeria. Reddish areas need less quantity of nutrient to reach the target yield; greenish areas need more. Equivalent V1 nutrient recommendation maps were produced for rice for the same target watersheds.

a) Nitrogen (N)



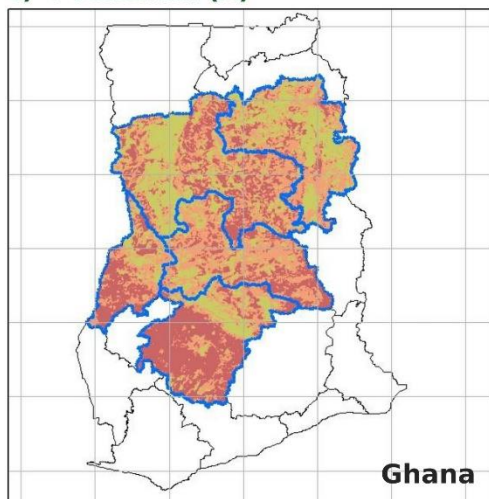
Requirement (kg/ha)
 8 – 40 40 – 60 60 – 80 80 – 119

b) Phosphorus (P)



Requirement (kg/ha)
 0 – 20 20 – 40 40 – 61

c) Potassium (K)

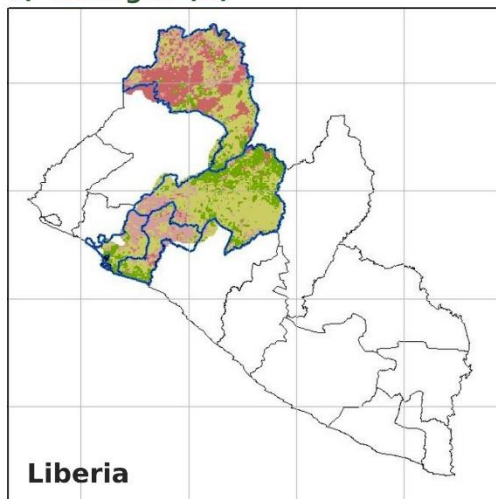


Requirement (kg/ha)
 0 – 20 20 – 40 40 – 60

— Boundary of target watersheds
 □ Administrative regions

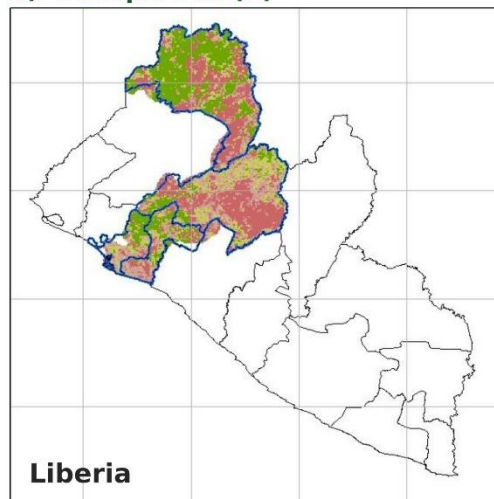
Figure 5. Version 1 site-specific recommendations for rice (kg/ha) across target watersheds in Ghana. Reddish areas need less quantity of nutrient to reach the target yield; greenish areas need more. Equivalent V1 nutrient recommendation maps were produced for maize for the same target watersheds.

a) Nitrogen (N)



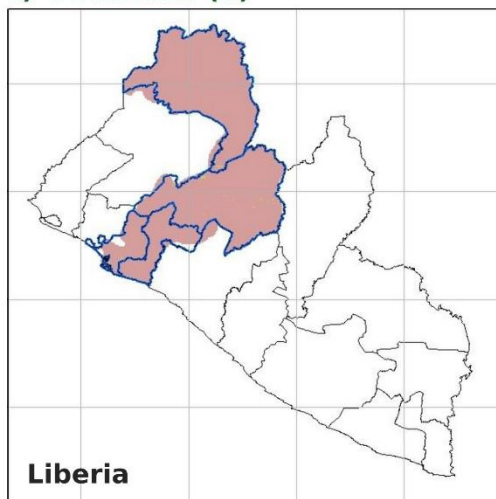
Requirement (kg/ha)
 20 - 45 45 - 69 69 - 83 83 - 111

b) Phosphorus (P)



Requirement (kg/ha)
 0 - 13 13 - 29 29 - 48 48 - 69

c) Potassium (K)



Requirement (kg/ha)
 0 - 8 8 - 16

— Boundary of target watersheds
 □ Administrative regions

Figure 6. Version 1 site-specific recommendations for rice (kg/ha) across target watersheds in Liberia. Reddish areas need less quantity of nutrient to reach the target yield; greenish areas need more.

5b

What progress have we made? — Taking recommendations to farmers

The Regional Hub is enhancing the AKILIMO advisory tool to strengthen its functionality and user interface, while integrating site-specific nutrient recommendations with other

integrated soil fertility management (ISFM) and good agronomic practices. This integrated approach will enable the delivery of comprehensive, context-specific and practical recommendations to farmers and other users on scale.

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What comes next

Looking ahead, the Regional Hub will focus on five complementary priorities:

- Moving from V1 to V2: Field validation trials in Liberia, Ghana and Nigeria will compare V1 recommendations with farmers' current practices and existing blanket recommendations under real farm conditions. The results will inform the refinement and finalization of V2 nutrient recommendations for operational use. In Sierra Leone and Togo, additional nutrient omission trials will be conducted to strengthen the evidence base before developing the next version.
- Strengthening model accuracy and transparency: Future versions will incorporate weather and climate variables and combine machine-learning approaches with crop-nutrient models such as QUEFTS and crop-simulation models such as DSSAT. Recommendations will also include estimates of uncertainty and economic risk, enabling users to better understand the confidence and potential returns associated with each recommendation.
- Scaling through AKILIMO and other scaling regional and national platforms: Validated recommendations will be integrated into AKILIMO and other digital advisory platforms for delivery at scale.
- Integrating recommendations with broader ISFM services: Fertilizer recommendations will be combined with advice on input access, organic resource management and good agronomic practices. These integrated packages will be tested through farmer-led experimentation and monitored using the Regional Hub's the Agronomic Gain Assessment Toolkit.
- Expanding across crops and countries: The approaches, tools and lessons developed through the initial Wave 1 countries will be adapted and replicated across additional crops and wider areas within the Regional Hub's 17-country mandate, while taking account of country-specific priorities, data availability and scaling opportunities.

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Join us

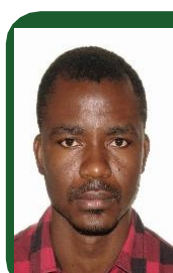
Making every kilogram of fertilizer count is a shared responsibility. The Regional Hub invites governments, development partners, the private sector and investors to support calibration and validation trials, data sharing, digital delivery and the integration of site-specific advice into national programs and input supply. Together, we can turn field evidence into fertilizer

advice that raises yields, improves farmers' incomes and restores soil health across West Africa and the Sahel.

Suggested citation

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