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Report on Revision for Nutrient Expert (NE) Lite Digital Tool:

Enhancing Maize Agronomic Returns, Fertiliser Use Efficiency, and Soil Health in Nigeria

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1.0 Background/Justification

Nigeria's economy still heavily relies on agriculture, and maize is a major commercial and staple crop that is essential to both the nation's economy and food security. Nigerian maize acreage increased from 0.438 million hectares in 1981 to around 5.8 million hectares in 2022, while total production climbed during the same time period from 0.72 million tonnes to approximately 12.9 million tonnes (FAOSTAT, 2023). Still, yield levels are much below the crop's potential and remain extremely low (< 2.2 tonnes per hectare). Insufficient agronomic techniques, non-adherence to agronomic advise, adverse climates with intra- and inter-seasonal droughts, poor soil fertility, and insufficient extension services are a few of the main constraints (Shehu et al., 2022)781. The heterogeneity in soils, microclimates, and socioeconomic factors is frequently overlooked when developing extension plans to address soil fertility and nutrient management for large regions in Nigeria. While a generalised strategy can reasonably meet some of these constraints, the considerable heterogeneity in soil properties, yield response, fertilizer price and farmers' socioeconomic conditions necessitate a stricter approach when it comes to managing soil fertility to improve agronomic returns, fertilizer efficiency and soil health.

Through a project called Taking Agronomy to Scale in Africa (TAMASA), a digital tool called Nutrient Expert (NE) was developed between 2015 and 2018 to apply site-specific fertiliser recommendations and nutrient management for maize in Nigeria. At the time, the International Plant Nutrition Institute (IPNI) oversaw the tool's development in collaboration with the Nigeria Bayero University's Centre for Dryland Agriculture (CDA), International Maize and Wheat Improvement Centre (CIMMYT), and the International Institute for Tropical Agriculture (IITA). Even though the validation and dissemination exercises of the NE tool demonstrated a promising result in improving farmers' agronomic returns, some of the obstacles to the tool's effective use and dissemination in Nigeria include the need to understand certain agronomic and soil science terminologies to use the tool, subjectivism in assessing the farm's nutrient availability and soil fertility, and a limited area of operation (Aliyu et al., 2020). A lite version of the NE tool (henceforth referred to as ***NE Lite version***) was developed and evaluated between 2021 and 2022 through a Use Case (Sasakawa Nigeria Use Case; a sub-project) of the Excellence in Agronomy Initiative (EiA) in order to address these challenges as well as expand the tool to other maize growing areas in Nigeria and harmonise with other crops' site-specific nutrient and fertiliser management tools such as RiceAdvice Lite (for rice) and AKILIMO (for cassava).

A total of 47 on-farm evaluation trials of the ***NE Lite version*** were conducted in 2022 across the three states of Nigeria (Benue state = 30 trials, Kaduna state = 15 trials and Kano state = 2 trials). Three treatments were evaluated in the trials as follows: site-specific recommendation generated from the tool (called SSR), blanket regional based recommendation (called BRR) and zero fertilizer control treatment (called ZCC). Table 1 below gives the summary of fertilizer application rates across the treatments and across the states.

Table 1: Summary of fertilizer application rates by treatments across the three focal states

State	**SSR Rate (N kg/ha)**			**BRR Rate (N kg/ha)**		
	Min	Max	Mean	Min	Max	Mean
Benue	106	133	118	100	100	100
Kaduna	121	172	165	120	120	120
Kano	99	99	99	120	120	120
State	**SSR Rate (P_2O_5 or K_2O kg/ha)**			**BRR Rate (P_2O_5 or K_2O kg/ha)**		
	Min	Max	Mean	Min	Max	Mean
Benue	27	29	28	50	50	50
Kaduna	0	38	34	60	60	60
Kano	56	56	56	60	60	60

The trials' findings indicated that, although being much lower than the average predicted yield, the grain yield in SSR is greater in BRR in Benue state; in Kaduna, the yields are similar in SSR and BRR; and in Kano, BRR is marginally higher than SSR (Figure 1). Furthermore, in 47% of the fields throughout the three study states, the cumulative frequency distribution shows that grain yield in SSR is higher than BRR (Figure 2); this is significantly less than the 75% criteria defined by EiA project. While SSR is higher than BRR in 60% of the fields (Figure 3) throughout the three states when it comes to profit or cost-benefit of fertiliser use, this is less than the 90% of cases that the EiA project set as the benchmark. Across the three states, the partial factor productivity efficiency of the applied fertiliser revealed that BRR is considerably higher in N and vice versa in P and K (Figure 4). Since the N efficiency is lower than the current blanket or regionally based advice and the yield and agronomic profit gain are below the benchmark set by the EiA project, the ***NE Lite version*** needs to be revised to improve on these performance metrics before being disseminated.

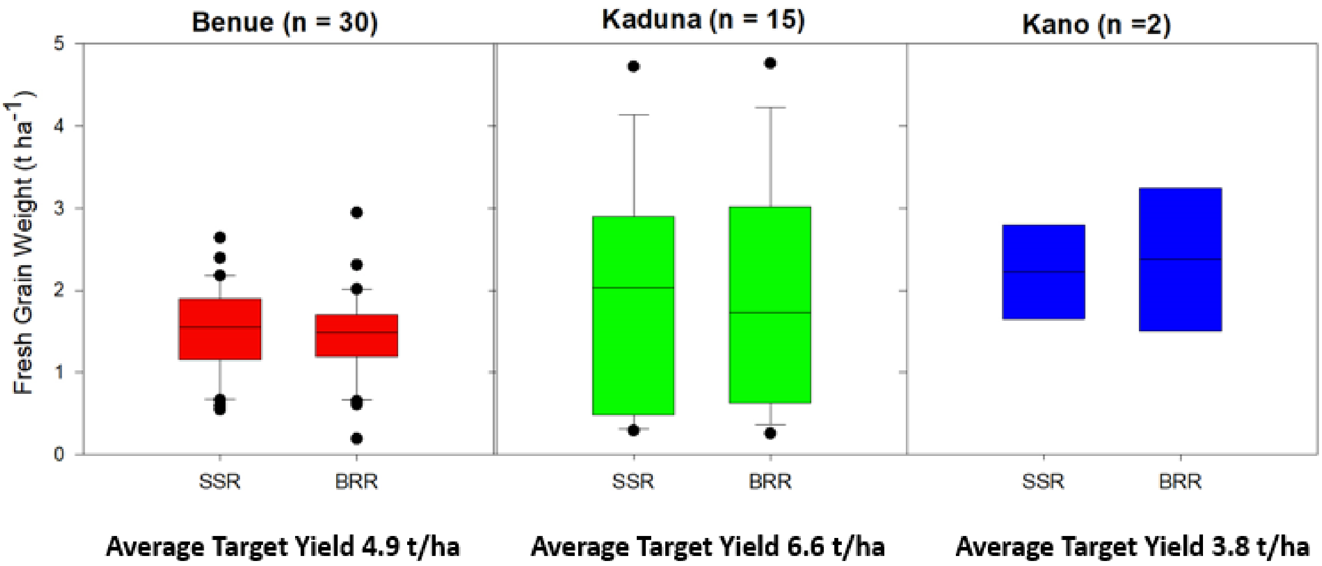

Figure 1: Boxplots comparing maize grain yield between the site-specific NE lite version recommendation (SSR) and blanket or regional based fertilizer recommendation (BRR) in evaluation trails conducted in 2022 under EiA project.

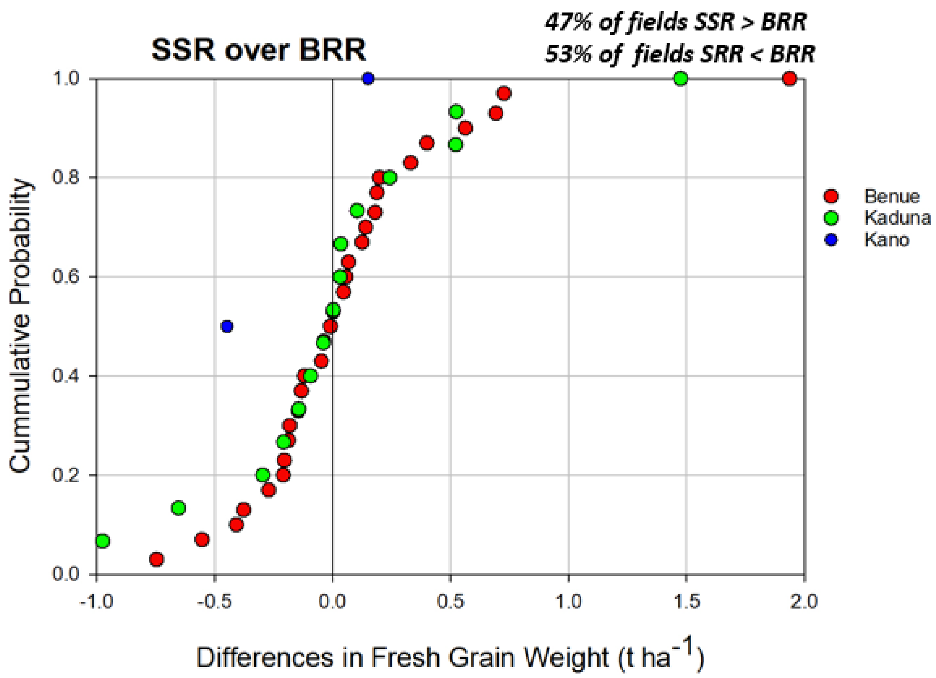

Figure 2: Cumulative frequency distribution curve comparing maize grain yield in the site-specific NE lite version recommendation (SSR) over the blanket or regional based fertilizer recommendation (BRR) in evaluation trails conducted in 2022 under EiA project.

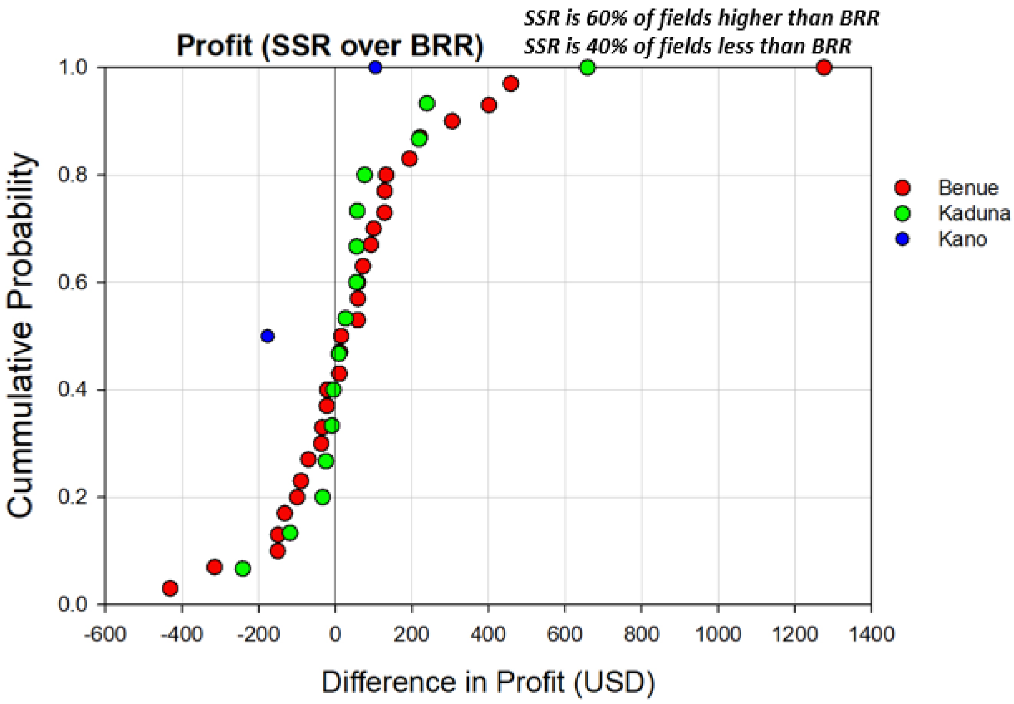

Figure 3: Cumulative frequency distribution curve comparing profit gain on fertilizer use in the site-specific NE lite version recommendation (SSR) over the blanket or regional based fertilizer recommendation (BRR) in evaluation trails conducted in 2022 under EiA project.

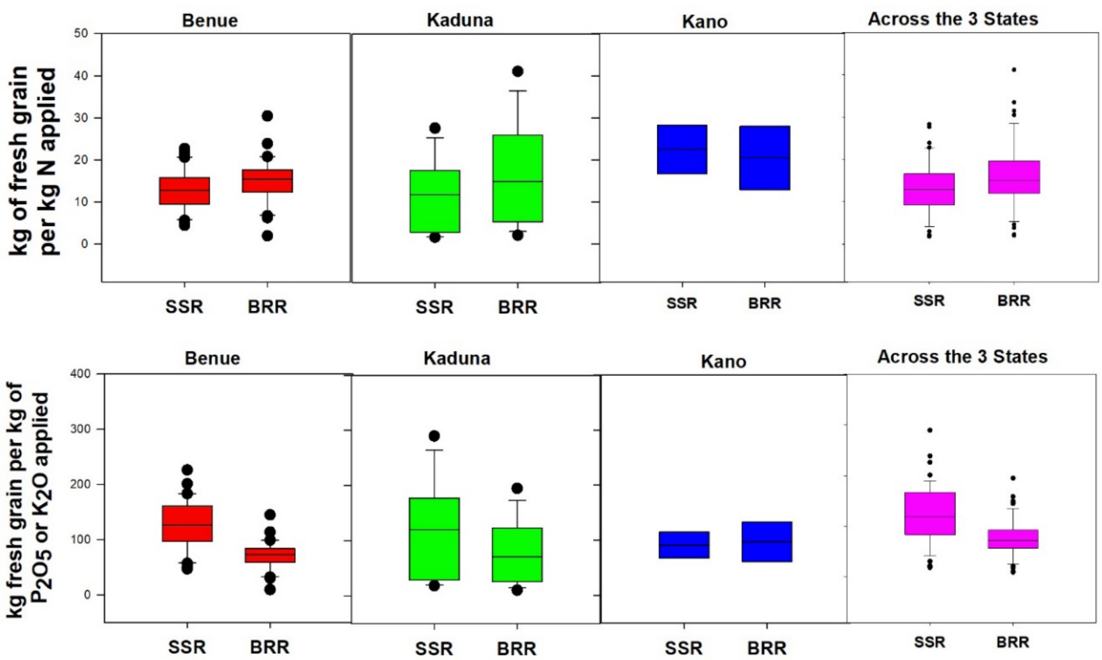

Figure 4: Boxplots compare partial factor productivity efficiency of nutrients between the site-specific NE lite version recommendation (SSR) and blanket or regional based fertilizer recommendation (BRR) in evaluation trials conducted in 2022 under EiA project.

2.0 Revised Nutrient Expert (NE) Lite

Following a series of meeting with representation of African Plant Nutrition Institute (APNI) between May 2023 to August 2024, the following observations and recommendations to improve the ***NE Lite version*** were discovered:

Table 2: Summary of Observations and Recommendations for Revision of the ***NE Lite version***

S. /No	Observation	Recommendations
1.	The results of validation testing revealed that yield was overestimated	• Attainable yield needs to be adjusted and possibly reduced by 30%, this is to avoid fertilizer recommendations at nutrient accumulation level that could reduce the agronomic returns on fertilizer use and fertilizer use efficiency. • Inclusion of yield risk or reducing factors such as flooding, drought, acidity, salinity, noxious weed, resistant pests etc. • This is also to account for possible suboptimal agronomic practices that reduce response to fertilizer and overall yields attained
2.	Agronomic Efficiency (AE) of N is small and less than the literature reported average in similar environments. Thus, leading to high N recommendations.	• Based on previous studies from the similar environments, increase in the value of AE by 25% is recommended. This is because Calculation of AE values from NOT data resulted in underestimations due to (i) very high rates of fertilizer use in NOTs aimed at achieving maximum attainable yields; and (ii) not accounting for production constraints.
3.	High P and K recommendations that operate at the nutrient accumulation level rather than the dilution level	• Maintenance fractions of the tool's algorithm should be ignored. • The relationship or data used to estimate native nutrient supply should be verified. • RE need to be increased to avoid operating at nutrient accumulation condition.

The ***NE Lite version*** is updated to produce a ***revised NE Lite version*** in light of the aforementioned observations and recommendations. The review process and the results of the fertiliser recommendations are described in detail in the sections that follow.

2.1 Attainable yield

After semi-variogram model fitting using secondary data sets of NPK fertiliser treatments of nutrient omission trials and fertiliser response trials conducted in TAMASA project, OCP project, and SARD SC project, the attainable yield in the ***NE Lite version*** tool was developed using interpolation (ordinary kriging). For the purpose of attainable yield geospatial analysis, only NPK grain yields with a harvest index (HI) of ≥ 0.4 were considered. This is because, as per Hay's (1995)concentrating on the literature from the last 20 years. Evidence from abstract journals indicates that the term has been applied most to small grain cereal crops and pulses, in India, Western Europe and the USA, and that it has been less useful for maize and tuber crops. Standard methods of measuring harvest index, the associated problems of measurement and interpretation, and representative values for a range of world species are reviewed. The values for modern varieties of most intensively-cultivated grain crops fall within the range 0.4 to 0.6. Variation between varieties of the same species is illustrated by trends in the harvest indices of old, outclassed and recent varieties of temperate and mediterranean wheat and barley (compared under uniform conditions findings, HI values less than 0.40 were regarded as anomalies in the dataset, suggesting that the crop may have experienced stresses other than nutrient deficiencies. In the ***revised NE Lite version*** similar approach was used after inclusion of nutrient omission trial data conducted in 2022 through the EiA project, as opposed to previous yield map where a random forest modelled data of Benue state based on soil properties and climate was used in the previous version of the tool**.** As a result, the attainable yield in general, and particularly in Benue state, which was significantly overstated in the previous version of the tool, has been improved with the inclusion of 2022 Benue Nutrient Omission Trial data (Figure 5). The attainable yield was then reduced by 10-30% as a result of a literature assessment and expert/stakeholder consultations throughout the target areas to avoid overestimation, as recommended. Furthermore, a decision meter of a 20% and 40% additional probable reduction adjustment in the attainable yield was provided for medium and high yield risk or reducing factors, respectively. Flooding, drought, acidity, salinity, noxious weeds, resistant pests, and diseases are all potential yield-reducing factors. Figure 6 is a graph comparing the old and new (updated) attainable yield maps. For example, in Kano state, the minimum, median, and maximum achievable yields are 2016, 3077, and 4565 kg/ha in the amended version, compared to 3084, 3240, and 5578 kg/ha in the previous edition. This indicates a significant drop in the yield target, which will prevent overestimation and operation under nutrient accumulation conditions. If medium and/or high yield risk factors are observed in the field, the yield will be lowered by 20% to 40%, respectively.

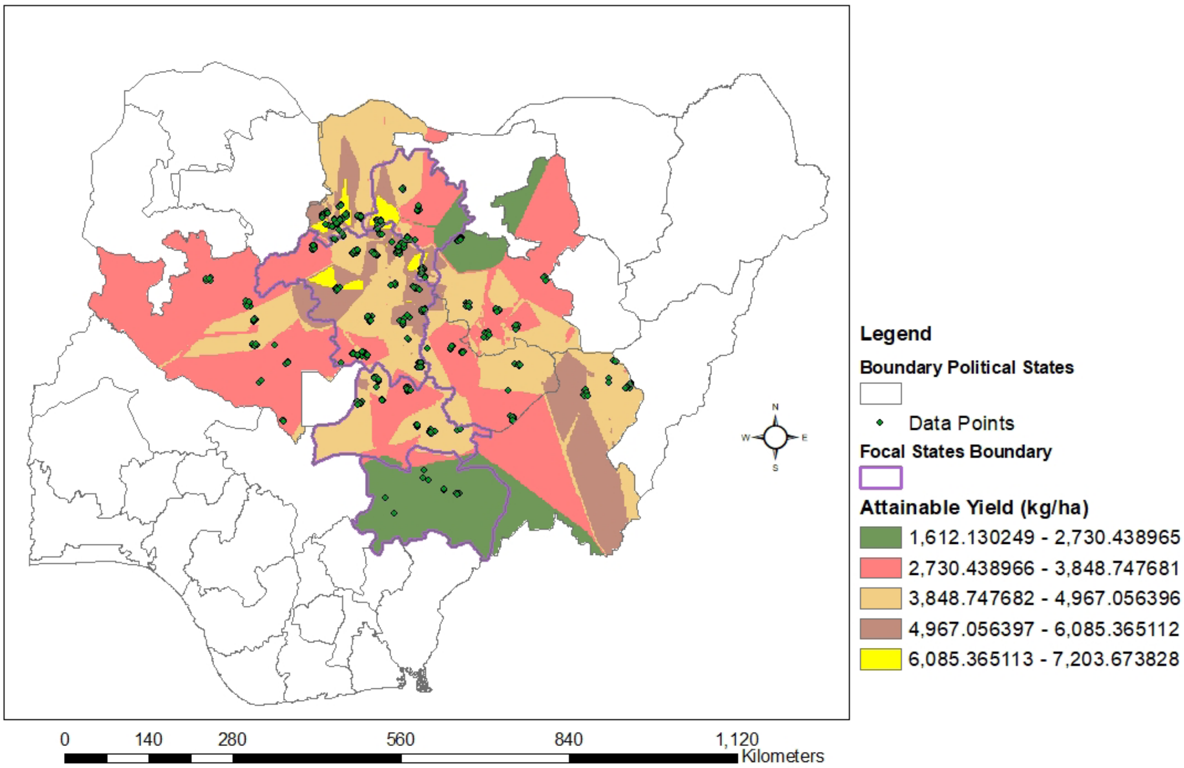

Figure 5: The updated attainable yield map

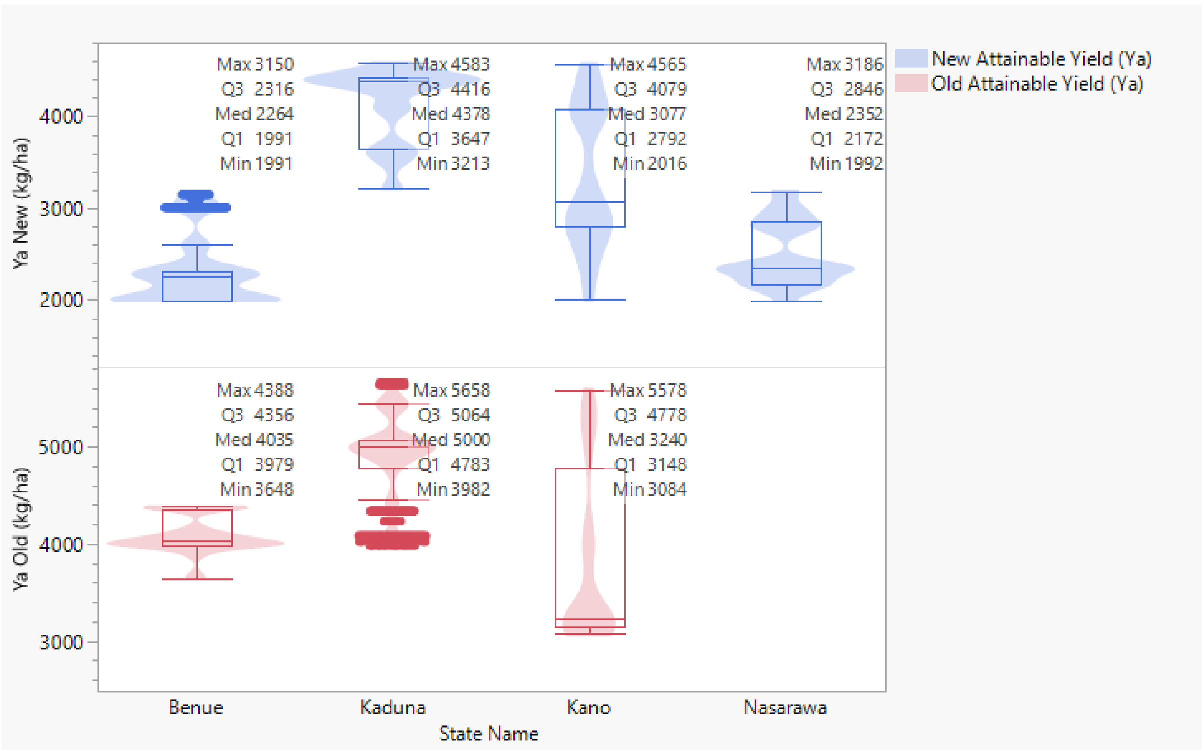

Figure 6: Boxplot and Contour graph comparing the old and new (revised) attainable yields across the focal states

2.2 Nitrogen Agronomic Efficiency (AE_N)

The TAMASA data used in the tool was supplemented by nutrient omission trial data from OCP, SARD SC, and EiA Benue. The computations were reviewed and validated twice to account for any potential inaccuracies. The initial average value of AEN in the tool aggregated across all locations (17.2 kg grain per kg N applied) was increased by 25% (i.e., 21.5 kg grain per kg N applied) because the average value is too low in comparison to the literature recommendations and range to avoid operating at the N accumulation rather than dilution level of the nutrient versus yield response curve.

2.3 Recovery Efficiency (RE) and Reciprocal Internal or Uptake to Grain Conversion Efficiency (RIE) of Phosphorus and Potassium

Calculations were reviewed for probable inaccuracies, considered at agroecology and cultivar type level. The 75th percentile of RE was used since reserved maintenance fractions were removed from the recommendation algorithms as recommended, although various studies recommended the use of maximum recovery fractions (such as Rurinda et al., 2020; Sattari et al., 2014)P and K application in different environments. QUEFTS was initially developed to simulate interactions between N, P and K for tropical soils under maize crop. We performed an extensive model analysis of crop yields in relation to soil and fertilizer nutrients for six field data sets with maize, rice, and wheat crops grown in tropical and temperate regions. The model equations had to be adapted to broaden the model applicability beyond the original boundary conditions of pH, rain-fed cropping systems, optimum harvest index and temperature. Recalibration and modification resulted in a good agreement between model predicted and observed yields. Our results indicate that the adjustments increased the applicability of the model. However, for application in global studies QUEFTS is data demanding and, also, further testing (and probably improvement. The old and new (revised) RE and RIE of P and K, respectively is presented in Table 3 and Table 4, respectively below.

2.4 Coefficients of Native Nutrient Supply

The coefficients of native nutrient supply were obtained using a quantile regression between nutrient omitted yield versus NPK yield at 75th, 50th and 25th percentile representing high, medium and low fertile conditions, respectively. Outliers were removed as recommended, and a new coefficient were calculated as presented in Table 5.

Table 3: Old and New (Revised) Recovery Efficiency (RE) and Reciprocal Internal or Uptake to Grain Conversion Efficiency (RIE) of Phosphorus

	OPV		Hybrid		OPV		Hybrid	
	Old RE_P value	New RE_P value	Old RE_P value	New RE_P value	Old RIE_P value	New RIE_P value	Old RIE_P value	New RIE_P value
Derived Savanna	0.15	0.23	0.15	0.23	0.003	0.004	0.003	0.004
Mid Altitude	0.15	0.23	0.15	0.23	0.003	0.004	0.003	0.004
Northern Guinea Savanna	0.15	0.23	0.15	0.23	0.003	0.004	0.003	0.004
Southern Guinea Savanna	0.15	0.23	0.15	0.23	0.003	0.004	0.003	0.004
Sudan Savanna	0.15	0.37	0.15	0.22	0.003	0.006	0.003	0.003

Table 4: Old and New (Revised) Recovery Efficiency (RE) and Reciprocal Internal or Uptake to Grain Conversion Efficiency (RIE) of Potassium

	OPV		Hybrid		OPV		Hybrid	
	Old RE_K value	New RE_K value	Old RE_K value	New RE_K value	Old RIE_K value	New RIE_K value	Old RIE_K value	New RIE_K value
Derived Savanna	0.52	0.65	0.52	0.47	0.013	0.013	0.013	0.013
Mid Altitude	0.52	0.65	0.52	0.47	0.013	0.013	0.013	0.013
Northern Guinea Savanna	0.52	0.65	0.52	0.47	0.013	0.013	0.013	0.013
Southern Guinea Savanna	0.52	0.65	0.52	0.47	0.013	0.013	0.013	0.013
Sudan Savanna	0.52	0.66	0.52	0.67	0.013	0.013	0.013	0.013

Table 5: Native yield coefficients for old and new (revised) calibrations

Percentile	Nitrogen		Phosphorus		Potassium	
	Old	New	Old	New	Old	New
25th Percentile (low condition)	0.34	0.40	0.40	0.54	0.54	0.55
50th Percentile (moderate condition)	0.44	0.58	0.57	0.61	0.60	0.60
75th Percentile (high condition)	0.47	0.68	0.50	0.68	0.55	0.65

2.5 Nutrient Recommendations between Old and New Revised NE Lite Tool

The average N fertiliser recommendation in the previous version of the NE Lite was 108 and 109 kg N per ha; in the revised version, it is 80 and 82 kg N per ha for OPV and hybrid crops, respectively (Figures 7 and 8). This indicates a large drop in N fertiliser recommendations. In a similar vein, the updated NE Lite version significantly reduced the maximum and minimum N recommendations over the previous version (Figures 7 and 8).

The previous version's average rates for both OPV and Hybrid were reduced from 31 and 32 kg P_2O_5 per ha to 25 and 26 kg P_2O_5 per ha, respectively. However, there has been a significant decline in P rates in Kano state, from a maximum of 85 to 27 kg P_2O_5 per ha and a median of 49 to 23 kg P_2O_5 per ha (Figure 9 and 10).

The average potassium recommendations rate throughout the states in OPV was 23 kg K_2O per ha, which has recently been lowered to 17 kg K_2O per ha. However, in the hybrid variety, the average rate of 23 kg K_2O per ha is comparable to the corrected version's rate of 22 kg K_2O per ha (Figure 11 and 12).

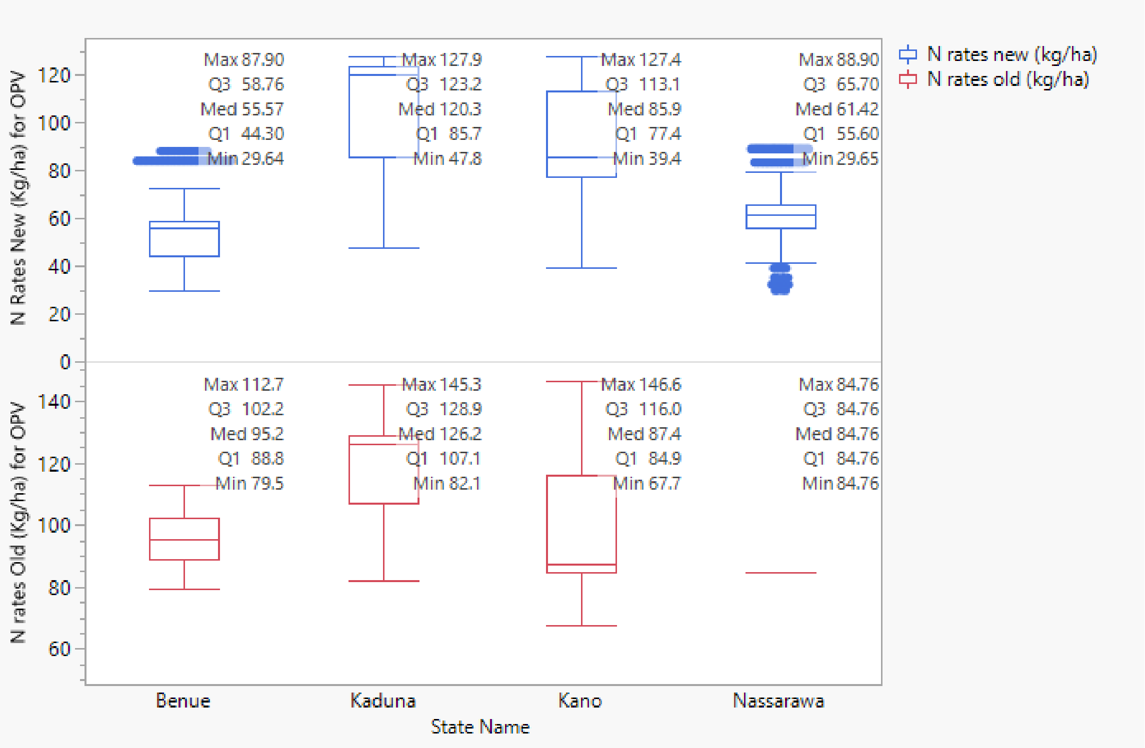

Figure 7: Nitrogen recommendation comparison between the original (old) in red color and reviewed (revised) in blue color for OPV

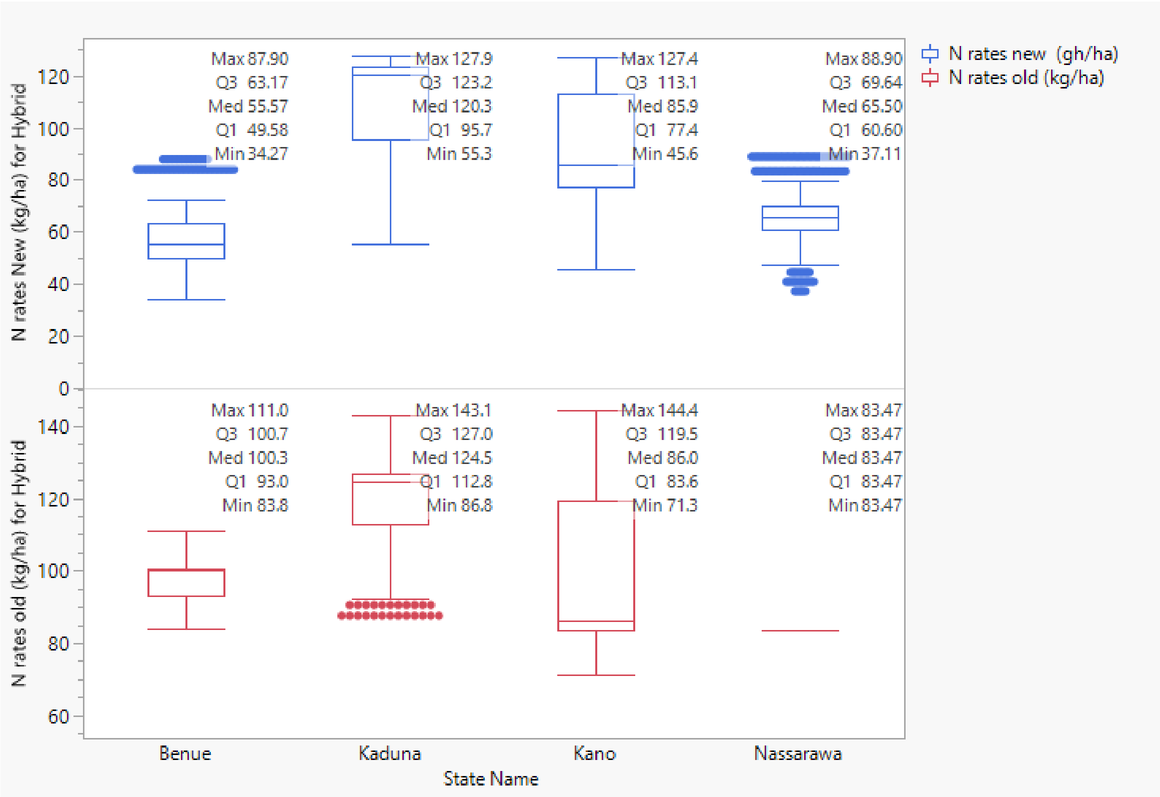

Figure 8: Nitrogen recommendation comparison between the original (old) in red color and reviewed (revised) in blue color for Hybrid

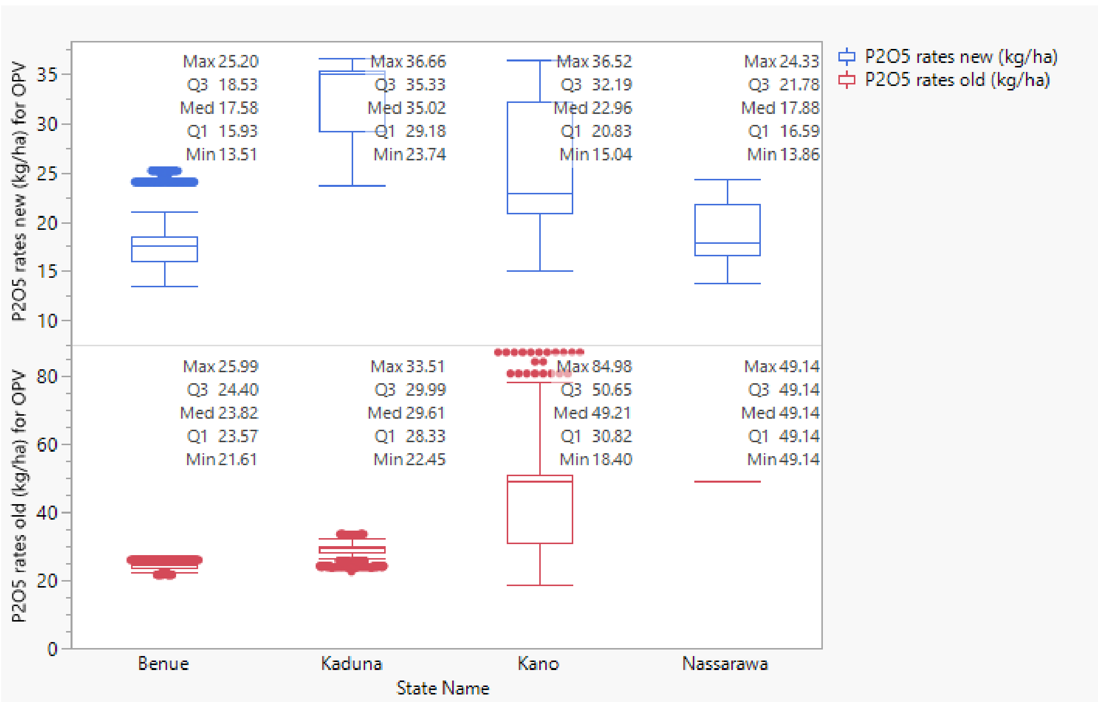

Figure 9: Phosphorus recommendation comparison between the original (old) in red color and reviewed (revised) in blue color for OPV

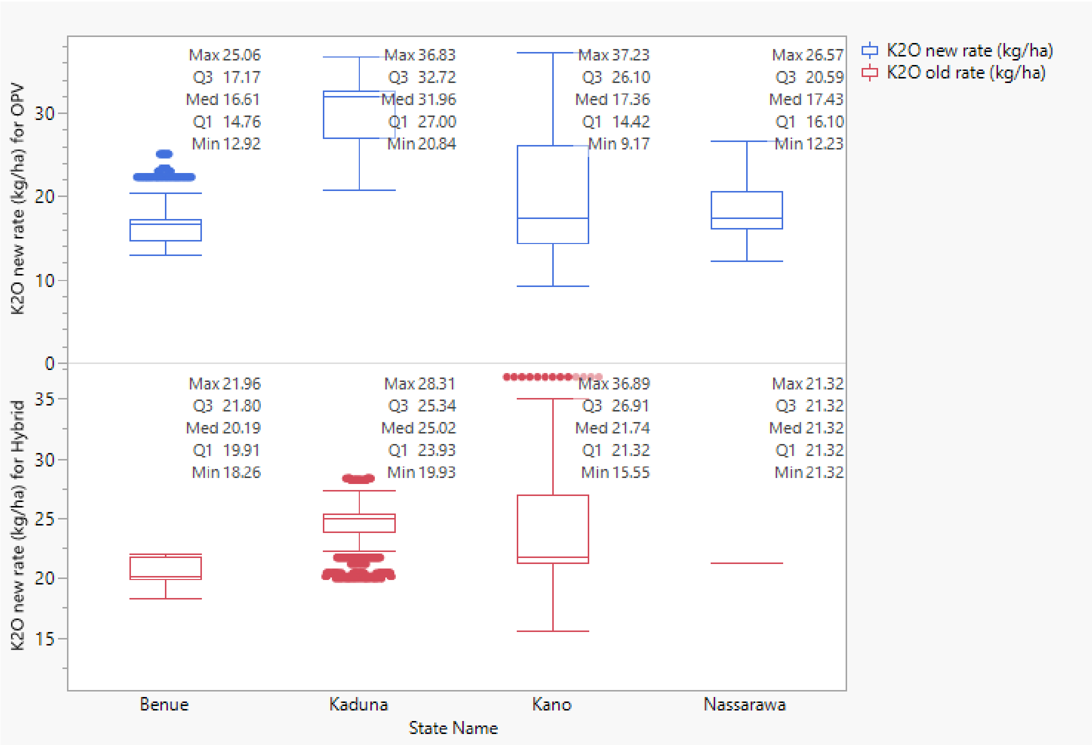

Figure 10: Phosphorus recommendation comparison between the original (old) in red color and reviewed (revised) in blue color for Hybrid

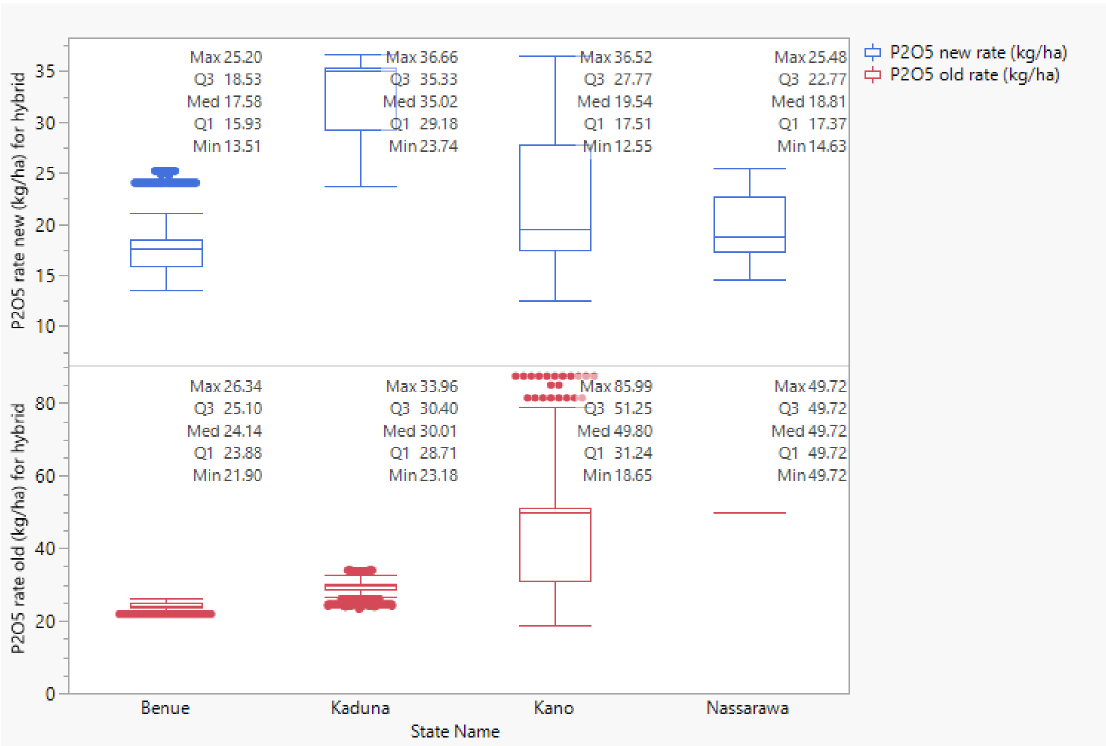

Figure 11: Potassium recommendation comparison between the original (old) in red color and reviewed (revised) in blue color for OPV

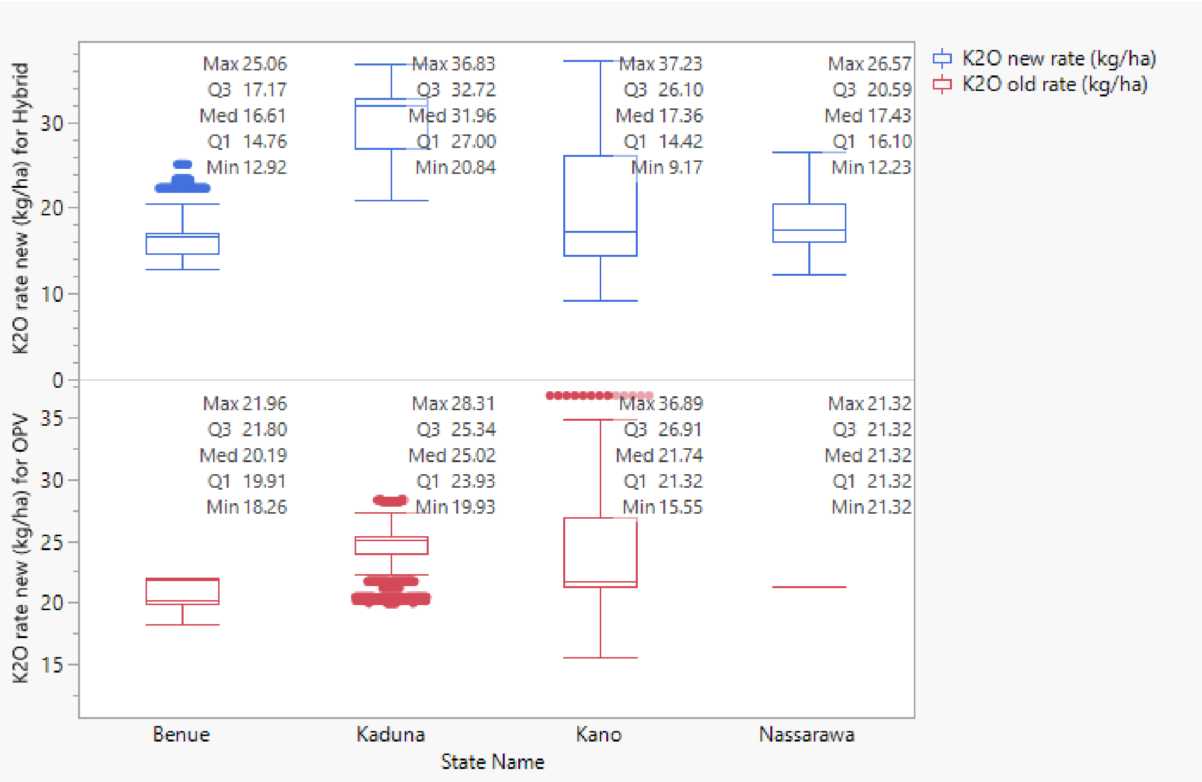

Figure 12: Potassium recommendation comparison between the original (old) in red color and reviewed (revised) in blue color for Hybrid

3.0 Conclusion and Recommendations

Adjusting the attainable yield map and significantly lowering the high nutrient recommendation—which should be in the nutrient dilution curve rather than accumulation—should allow the updated NE light tool to improve soil health, fertiliser resource efficiency, and maize agronomic gains. As a result, field testing the ***Revised Nutrient Expert Lite*** is a vital first step in providing Nigerian maize farmers with accurate and easily available fertiliser recommendations. The field evaluation is required to verify the effectiveness of the updated tool and enable its broader adoption, which would improve maize yields, profitability, and soil health in the focal or target states. This will be accomplished through rigorous field trials and stakeholder participation.

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References

Aliyu, K. T., Kamara, A. Y., Jibrin, J. M., Huising, J. E., Shehu, B. M., Adewopo, J. B., Mohammed, I. B., Solomon, R., Adam, A. M., & Samndi, A. M. (2020). Delineation of soil fertility management zones for site-specific nutrient management in the maize belt region of Nigeria. ***Sustainability (Switzerland)***, ***12***(21). https://doi.org/10.3390/su12219010

FAOSTAT. (2023). Food and Agriculture Organization of the United Nations, Nigerias agricultural profile (crops and livestock Produts). https://www.fao.org/faostat/en/#data/QCL

Hay, R. K. M. (1995). Harvest index: a review of its use in plant breeding and crop physiology. ***Annals of Applied Biology***, ***126***(1), 197–216. https://doi.org/10.1111/j.1744-7348.1995.tb05015.x

Kurwakumire, N., Chikowo, R., Mtambanengwe, F., Mapfumo, P., Snapp, S., Johnston, A., & Zingore, S. (2014). Field Crops Research Maize productivity and nutrient and water use ef fi ciencies across soil fertility domains on smallholder farms in Zimbabwe. ***Field Crops Research***, ***164***, 136–147. https://doi.org/10.1016/j.fcr.2014.05.013

Pasuquin, J. M., Pampolino, M. F., Witt, C., Dobermann, A., Oberthür, T., Fisher, M. J., & Inubushi, K. (2020). Field Crops Research Closing yield gaps in maize production in Southeast Asia through site-specific nutrient management. ***Field Crops Research***, ***156***(2014), 219–230. https://doi.org/10.1016/j.fcr.2013.11.016

Rurinda, J., Zingore, S., Jibrin, J. M., Balemi, T., Masuki, K., Andersson, J. A., Pampolino, M. F., Mohammed, I., Mutegi, J., Kamara,A.Y., Vanlauwe, B., & Craufurd, P. Q. (2020). Science-based decision support for formulating crop fertilizer recommendations in sub-Saharan Africa. ***Agricultural Systems***, ***180***(July 2019), 102790. https://doi.org/10.1016/j.agsy.2020.102790

Sattari, S. Z., van Ittersum, M. K., Bouwman, A. F., Smit, A. L., & Janssen, B. H. (2014). Crop yield response to soil fertility and N, P, K inputs in different environments: Testing and improving the QUEFTS model. ***Field Crops Research***, ***157***, 35–46. https://doi.org/10.1016/j.fcr.2013.12.005

Shehu, B. M., Garba, I. I., Jibrin, J. M., Kamara, A. Y., Adam, A. M., Craufurd, P., Aliyu, K. T., Rurinda, J., & Merckx, R. (2022). Compositional nutrient diagnosis and associated yield predictions in maize: A case study in the northern Guinea savanna of Nigeria. ***Soil Science Society of America Journal***, ***n/a***(n/a). https://doi.org/https://doi.org/10.1002/saj2.20472