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African Cassava Agronomy Initiative

2017 Annual Progress Report

The African Cassava Agronomy Initiative, ACAI, is a 5-year Bill & Melinda Gates Foundation funded project in 5 African countries (Nigeria, Tanzania, Democratic Republic of Congo, Ghana and Uganda) aiming to increase the availability of appropriate and affordable technologies to sustainably improve cassava productivity in the short – and long-term. The project is composed of six Work Streams: (i) Research on cassava growth dynamics, nutrient and water requirements, and responsiveness to inputs, (ii) Development of a geo-spatial cassava agronomy information base, (iii) Production and validation of demand-driven decision support tools for cassava agronomy, (iv) Facilitation of the use of decision support tools to farmers, extension services and other development initiatives, (v) Capacity development of national institutions to engage in transformative cassava agronomy R4D and (vi) Project governance, management, coordination, and ME&L. Within 5 years, building on effective partnerships and engaging national system scientists, ACAI will improve cassava root quality and yields, cassava supply to the processing sector as well as fertilizer sales. During this process, ACAI will engage over 150,000 households including at least 30% women farmers in the target countries and lead to the creation of a value of at least US$ 40 million.

2017 ANNUAL PROGRESS REPORT

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1. IITA
2. IPNI
3. ARI
4.FUNAAB
5. NRCRI
6. CABI

ACRONYMS

ACAI	African Cassava Agronomy Initiative
AfSIS	Africa Soil Information Service
ASH-C	African Soil Health Consortium
ARI	Agricultural Research Institute
CABI	Centre for Agriculture and Biosciences International
CAVA	Cassava Value Adding for Africa
CIAT	International Center for Tropical Agriculture
DSSAT	Decision Support System for Agro-technology Transfer
DST	Decision Support Tool
EA	Extension Agent
ETHZ	Swiss Federal Institute of Technology in Zurich
FB	Fertilizer Blending
FR	Fertilizer Recommendation
FUNAAB	Federal University of Agriculture in Abeokuta
HS	High Starch (Content)
IC	(Cassava) Intercropping
IPNI	International Plant Nutrition Institute
NARS	National Agricultural Research System
NRCRI	National Root Crops Research Institute
ODK	Open Data Kit
PAC	Project Advisory Committee
PMT	Project Management Team
PP	(Best) Planting Practices
SOP	Standard Operating Procedure
SP	Scheduled Planting
QUEFTS	Quantitative Evaluation of the Fertility of Tropical Soils
LINTUL	Light INTerception and UtiLisation
WUR	Wageningen University and Research

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Ritu Manzi, a cassava farmer from Bunda district in Mwanza Tanzania, is one of the lead farmers facilitating ACAI trials on their farms.

INTRODUCTION AND SUMMARY

The African Cassava Agronomy Initiative (ACAI) project aims at improving cassava root yield and quality and cassava supply to the processing sector. This improvement is expected to be achieved through effective partnerships with development partners in Nigeria and Tanzania, supported by National Agricultural Research System (NARS). ACAI will engage over 120,000 households in Nigeria and Tanzania including at least 30% women farmers and leading to the creation of over US$ 28 million. In the final year, tools developed will be tested with partners in Uganda, Ghana and the Democratic Republic of Congo.

The ACAI project is formulated around six 'use cases' that were prioritized during project inception with stakeholders actively engaged in cassava value chain. These use cases are specific sets of information on improved cassava agronomic practices, and their translation into tools and applications that are accessible to extension agents who provide recommendations to farmers and other beneficiaries. The six uses cases are:

- '**Site-specific fertilizer recommendations**' (FR) which targets nutrient management advice based on local soil conditions and crop calendars for sustainable cassava production intensification.
- '**Fertilizer blending**' (FB) recommendation tool which advises on appropriate fertilizer blends for cassava-producing areas based on soil fertility conditions, cost of inputs and potential demand
- '**Best planting practices**' (PP) which guides farmers in choosing best suited planting practices (with a focus on tillage operations) for cassava to reduce costs.
- '**Intercropping practices**' (IC) which recommends intensification options (planting density and arrangement, varietal choice, fertilizer application, etc.) in cassava-maize and cassava-sweet potatoes intercropping systems.
- '**Scheduled planting**' (SP), which provides recommendations on planting and harvest date to ensure a more continuous supply of fresh cassava roots to the processing industry.
- '**High starch content**' (HS), which recommends agronomic practices to optimize starch yields to maximize income for farmers supplying cassava roots to the processing industry.

Charles Nwokoro, ACAI PhD candidate, explaining moisture data logger to Dr. Guillaume Ezui of IITA/IPNI

The development and delivery of these support tools and the facilitation of their use happens through six Work Streams (WS) that form the structure of ACAI. These WS are:

1. Research on cassava growth dynamics, nutrient and water requirements, responsiveness to inputs and management practices.

2. Development of a geo-spatial cassava agronomy information base
3. Production and validation of demand-driven decision support tools for cassava agronomy
4. Facilitation of the use of the decision support tools to primary and other development partners
5. Capacity development of national institutions to engage in transformative cassava agronomy R4D
6. Project governance, management, coordination, and ME&L.

This report presents activities and achievements of the project during the period of January to December 2017. The report is organized around the six WS of the project and the deliverables under the various outputs of the project during this period.

Key accomplishments during this period include:

1. **Development of the modelling frameworks** to provide site-specific recommendations for the various use cases, and **delivery of the literature database, field trial results and survey data** required to populate and calibrate these frameworks
2. Functional **geospatial modelling algorithms using GIS information** to optimize sampling frames for maximal representativeness and extrapolating results across the target intervention areas
3. Operational V_1 versions of the decision support tools for each of the use cases, based on the datasets gathered and crop modelling frameworks developed, in a format evaluated by primary development partners and ready for field use and validation exercises

Jonathan Agbaimo is an extension agent working with ACAI in Edo central, Edo State, Nigeria.

Grace Mahende of CAVA II Tanzania in discussion with a cassava grower in Unguja Island, Zanzibar, Tanzania.

4. Strengthened and active primary partnerships, translating in commitments to contribute to validation and improvements of the decision support tools
5. An efficient data management system implemented, combining fully digitized data collection, barcode identification and semi-automated data analysis procedures to report incoming data from trials and surveys within 24 hours of data submission
6. Successful implementation of the agronomy at scale principles, combining collection of data at scale, crop modelling, GIS and geospatial modelling and integrating these into decision support tools, in collaboration with Taking Maize Agronomy to Scale in Africa (TAMASA) on various aspects of data collection systems and methodologies, co-development of scripts, tool development as well as the overall strategic thinking
7. Substantial progress with capacity building efforts, both as PhD and MSc research projects, and as training of national research partners in applying agronomy at scale methodologies

The use cases are the focal points for research and related activities towards improved agronomic practices to reduce the cassava yield gap and increase crop production and quality. Within each WS, specific activities have been identified to ensure delivery of the knowledge and tools necessary for the realization of the outputs associated with each use case. This report presents outputs per WS and provides details on the progress made, as well as highlights challenges, next steps and some of the opportunities identified.

WORK STREAM 1: RESEARCH ON CASSAVA GROWTH DYNAMICS, NUTRIENT AND WATER REQUIREMENTS AND RESPONSIVENESS TO INPUTS

OUTPUT 1.1

A review of existing knowledge on cassava agronomy conducted and used to refine work plans of other activities in WS1

OUTPUT 1.2

Response curves for cassava monocrop systems described for the different agro-ecologies and soil types

OUTPUT 1.3

Nutrient norms established, nutrient constraints assessed in the target regions

OUTPUT 1.4

Cassava growth models developed and used to advance field testing

OUTPUT 1.5

QUEFTS modelling framework developed and used as a basis for the site-specific fertilizer recommendation tool

OUTPUT 1.6

Impact of agronomic interventions on the dry matter and starch content of cassava produce determined

OUTPUT 1.7

Impact of improved weed control practices compared with current practice

WS1 contributes to Intermediate Outcome (IO) 1.1 of the project. By 2017, strategic research on cassava growth dynamics and nutrient requirements is integrated in the development of decision support tools for cassava intensification. For each of the use cases, a detailed report was presented during the annual review meeting, of which, the first part illustrates how the strategic research activities under WS1 have contributed to the development of the decision support tools.

These reports show details on the results from the literature review exercise, trial activities and surveys (following the SOPs and protocols presented in the 2016 report) and how these provided insights in the impact of agronomic practices on cassava yield and root quality, as well as the knowledge base to populate and calibrate the modelling frameworks underlying the decision support tools.

Output 1.1: A review of existing knowledge on cassava agronomy conducted and used to refine work plans of other activities in WS1

Data from literature (including published papers in scientific journals, annual project and research institute reports, unpublished datasets, books and book chapters, student theses, and conference papers) have been extracted and the database currently holds data from 183 studies (>4.400 data rows) covering 31 countries, with 70 experiments relevant to the FR/FB use cases, 49 for IC, 51 for PP, 36 for SP and 32 for HS. Learnings from this literature review have been integrated in or accelerated the development of the decision support tools and/or have enabled more focused field testing. Learnings for the individual use cases can be summarized as follows:

FR/FB: data extracted was used for parameterization of the QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils) model, in particular the estimates of internal nutrient supply from soil physico-chemical properties and the calculation of root yield (corrected for harvest index) based on principles of maximal accumulation and dilution of N, P and K in the biomass. In addition, overall response to fertilizer was assessed, showing significant responses to N, P and K but large variation depending on environmental and soil conditions, as well as positive interactions between N and K supply.

PP: While planting practices consists of many aspects, some of these seem to be well understood, such as the impact of planting stick orientation and length, others are much less understood, specifically the impact of primary tillage (zero-tillage, single plough or double plough passage) and secondary tillage (ridging vs flat), with variable effects depending on site conditions and large cost implications. We therefore applied best practice for the former aspects and focused trial activities on the latter aspects of tillage.

IC: Varietal choice and planting density have a major impact on land equivalent ratios (LER) in cassava-maize intercropping systems, with substantial reductions in cassava yield for maize varieties of medium and long duration and when planted at densities exceeding 50,000 plants ha^{-1}. Fertilizer application increase the intercrop yield, but data is insufficient to asses the residual effects on cassava. Only very limited literature on cassava-sweet potato intercropping is available but findings seem to indicate that Land Equivalent Ratio values > 1 are attainable in systems with compatible varieties and appropriate planting densities.

SP/HS: starch yield can be estimated from root yield, but large variation is observed, which is more related to environmental effects (72%) than to varietal effects (28%). Environmental effects are to a large extent related to rainfall received, particularly rainfall during the 3 months prior to harvest, which may cause flushes in carbohydrates from root to shoot. There appeared to be some negative impact of fertilizer N application on root starch content but benefits from root yield increases largely exceeded negative impacts on reduced starch content, resulting in substantial overall increases in starch yields.

Reports presented in Mwanza provide more details on the literature review and how these results feed into the development of the tools. In 2018, while continuing to build the database, these findings will be submitted as a research paper in an international, peer-reviewed journal.

Dr. Veronica Ne Uzokwe of IITA and DR. Mark Tokula of NRCRI confer during a field visit to one of ACAI trial plots in Tanzania.

Output 1.2: Response curves for cassava monocrop systems described for the different agro-ecologies and soil types

A total of 852 nutrient omission trials have been set up across the planting window in 2016 and 2017, of which 576 with an extended treatment setup to fit fertilizer response curves. Data from the first generation of trials (204 trials harvested: 89 in Nigeria and 115 in Tanzania) were used to assess cassava root yield response to N, P and K application. The results revealed majorly N and P deficiency with borderline deficiency in K and response to meso-/micronutrients in Nigeria, against mainly P deficiency in Tanzania, although responses were much less pronounced due to approximately half of trials suffering from insufficient rainfall. Statistical analysis revealed large variation in yield and substantial differences in yield response to N, P and K between trial locations in both countries. This stresses the importance of site-specific fertilizer recommendations for cassava production.

After harvest of the ~500 ongoing nutrient omission trials (planted in 2017), these results will be confirmed and fine-tuned. Root yield responses to individual nutrients will be related to soil analysis results (currently partially available) from samples collected at the trial locations, as well as GIS-based estimates of soil fertility status. This analysis will reveal to what extent site-specific responses can be predicted based on soil parameters, and to what extent the accuracy of these predictions suffers from relying on inferred rather than directly measured soil information.

Output 1.2. Fertilizer response curves for cassava monocrop systems described for the different agro-ecologies and soil types

A first series of nutrient omission trials were established in 2016 in Nigeria and Tanzania. Treatments included a reference NPK application at rates of 150 kg N, 40 kg P and 180 kg K per ha, applied twice, as well as a control without inputs, omissions of N, P, and K, respectively, addition of meso- and micronutrients (Ca, Mg, S, Zn and B) relative to the reference, and a treatment with N, P and K applied at half the rates of the reference.

Data from these first nutrient omission trials were used to assess cassava response to N, P and K applications in Tanzania and Nigeria. The dataset comprised 204 harvested fields with 89 from Nigeria and 115 from Tanzania. The results revealed majorly N and P deficiency with borderline deficiency in K and response to meso-/micronutrients in Nigeria, against P deficiency in Tanzania (Table 1, Fig. 1). Fig. 2 shows clearly how NPK outperformed compared to PK treatments in Nigeria and to NK treatments in Tanzania.

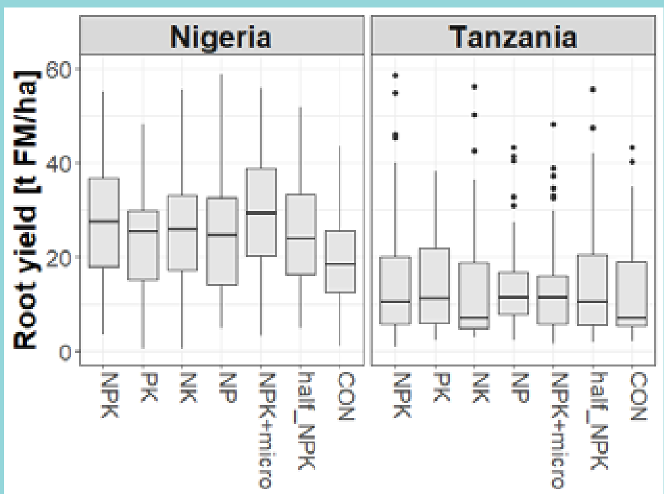


Figure 1 *Cassava yield response to fertilizer in Nigeria and Tanzania*

Table 1. Statistical analysis showing changes in yield in the PK, NK, NP, NPK+micronutrient, half NPK and control treatments, relative to the yield in the NPK reference treatment

Nigeria	Estimate [t/ha^{-1}]	S.E.	Pr(>|t|)
NPK(ref)	28.762	1.584	
PK	-4.318	1.416	**
NK	-2.662	1.242	*
NP	-2.291	1.526	ns
NPK+micro	1.909	1.318	ns
half_NPK	-3.518	1.286	**
CON	-8.208	1.404	***

Tanzania	Estimate [t/ha^{-1}]	S.E.	Pr(>|t|)
NPK(ref)	11.329	1.122	
PK	0.483	1.059	ns
NK	-2.173	1.079	*
NP	0.247	1.077	ns
NPK+micro	-0.511	1.073	ns
half_NPK	-0.281	1.075	ns
CON	-2.603	1.068	**

The Log-Likelihood Ratio test (Pr(>Chisq) = 6.14e-05) showed large variation in yield and significant differences in yield response to N, P and K between trial locations. This stresses the importance of site-specific fertilizer recommendations for cassava production in both countries.

Output 1.3: Nutrient norms established, nutrient constraints assessed in the target regions

A first set of draft norms are currently under development. A total of 2898 leaf samples were collected from the 2016 and 2017 nutrient omission trials in Nigeria and Tanzania. These samples are currently under analysis at the IITA and the World Agroforestry Centre (ICRAF) labs for analysis of nutrient contents using portable X-Ray Flouresence (pXRF) - a low-cost and fast analysis technique) and ICP-OES (for calibration and validation). These sample analysis results, along with soil analysis and root yield response data will be used for development of nutrient norms, comparing two methods, compositional nutrient diagnosis CND and diagnosis and recommendation integrated system (DRIS). While progress has been slower than anticipated, the development of the nutrient norms is now being fast-tracked through the work of two student projects as well as linked to similar work by another project in Central Africa, in order to have validated nutrient norms available by the end of 2018.

An analysis will be undertaken to evaluate whether nutrient norms and plant leaf collection campaigns can be used as an effective complementary methodology to improve the speed and cost-effectiveness to map nutrient deficiencies at scale and reduce the need for high numbers of costly and time-consuming nutrient omission trials. These nutrient norms will then be integrated in the geospatial predictions of indigenous nutrient supply as part of the QUEFTS framework to improve recommendations supplied by the fertilizer blending and site-specific fertilizer recommendation tools.

ACAI uses barcodes assigned to trial plots to enable efficient data collection.

Output 1.4: Cassava growth models developed and used to advance field testing

Efforts focused on the development and validation of models for cassava monocrop under African conditions (rather than for both monocrop and intercrop systems), following the decision at the end of 2016 based on the recommendation by the International Center for Tropical Agriculture (CIAT) and IITA modelling team. More intensive data collection was conducted in trials related to the Scheduled Planting and High Starch content use cases. For example, above- and belowground biomass partitioning was done at intermediate harvests at 3, 6, 8, 10 and 12 months after planting (MAP), as well as intensified non-destructive monitoring on shoot growth, leaf duration and leaf area.

The Decision Support System for Agrotechnology Transfer (DSSAT) cassava model has been tested, corroborating that the processes are properly programmed reflecting the expected results for all the outputs variables analysed. Some of the processes evaluated are leaf formation, branching appearance, stem weight, potential and attainable leaf size, leaf duration (senescence), and the effect of water stress on crop growth. This resulted in the release of a new cassava model (YCA for “yuca” or cassava in Spanish) on November 1st 2017, as part of the new version of DSSAT (Version 4.7) (Hoogenboom et al., 2017). This version also considers nitrogen restrictions, although the algorithms are still under evaluation. A total number of 12 trials were used to calibrate and evaluate the model. Previous research in Nigeria was used to obtain an initial estimation of the coefficients for the variety TMS 30572.

The information collected from year 1 and 2 in Nigeria and Tanzania will also be used to adjust the parameters of the varieties and evaluate the performance of the model to predict growth and yield for the soil and weather conditions observed at the trial locations. The model will then allow generating possible scenarios in terms of planting and harvesting dates and evaluate their effect on the final yield based on weather conditions and soil characteristics, and feature within the Decision Support Tool (DST).

Output 1.4. Performance of the cassava model in Nigeria for the variety TMS 30572

Approach

Considering that not all the information for year 1 and 2 of the project is currently available (crop, weather and soil data), the information from the PhD thesis of Schulthess (1987) used by Gutierrez et al. (1988), was translated to DSSAT format to be able to evaluate the performance of the variety TMS 30572 in Nigeria.

The trial was developed in IITA, Nigeria and to simulate the growth was used a default soil available in the WISE database (Batjes, 2009). The weather data was provided by IITA and it corresponds to the weather station located in IITA, Ibadan.

For this exercise the data were not divided for calibration and evaluation but instead the dataset from 1983 was used both to adjust the coefficients and evaluate the performance of the model in Nigeria. In this sense, this exercise cannot be considered as a proper evaluation of the model because it would require independent datasets for calibration and evaluation.

Results

The model shows a good fit for leaf area index (LAI) and leaf weight including the dry season period (Figure 2). However, at the end of the growing season both variables (LAI and leaf weight) are overestimated as it is occurring for other datasets in Colombia (data not shown). The main reason of this situation could be an overestimation of the total number of apices in the plant or the individual leaf size at the end of the growing period. In addition, the leaf duration of the simulations could be longer than the actual observed information affecting the leaf senescence and LAI values.

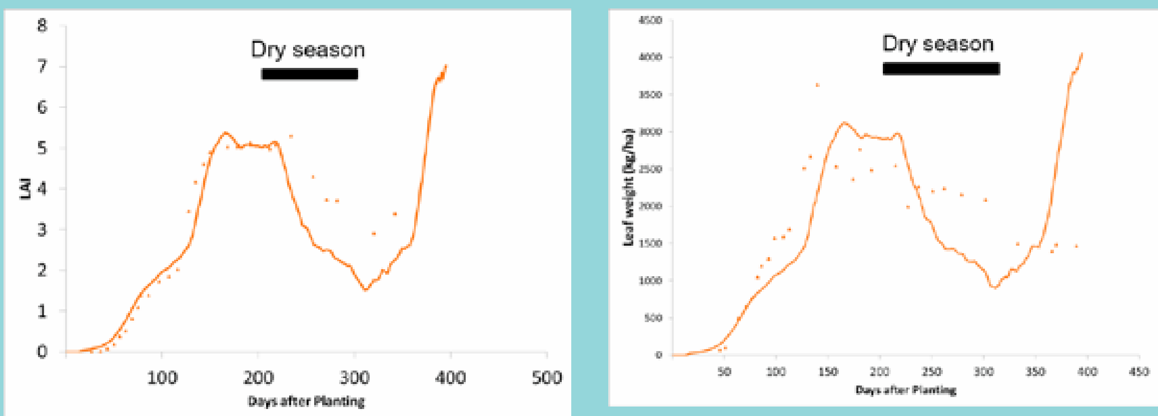


Figure 2 *Simulated and observed (a) Leaf area index (LAI) and (b) leaf weight (kg/ha) (Source: Schulthess (1987) and Gutierrez et al. (1988)).*

The model also registers good fit for the variables stem weight and yield (Figure 2), however this fit and the coefficients used required more revision because as a spillover model, the good fit on yield should also be represented with a good adjustment of the aboveground biomass (leaf and stems), which is not happening for the leaf weight.

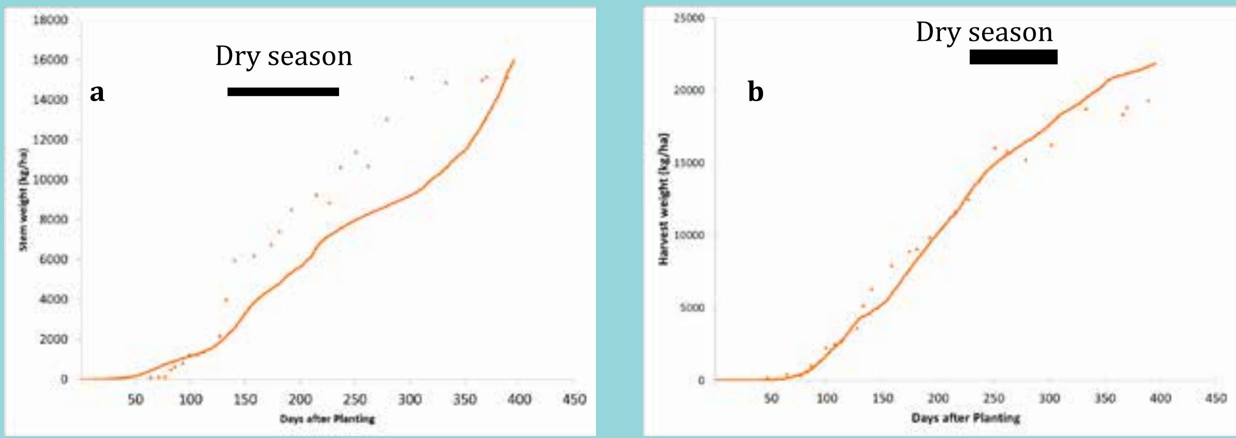


Figure 3 ***Simulated and observed (a) stem weight (kg/ha) and (b) yield (kg/ha) (Source: Schulthess (1987) and Gutierrez et al. (1988)).***

To evaluate the sensitivity of the model to different planting and harvesting dates, an additional simulation was done considering the planting dates of Schulthess (1987). The simulations show a similar trend to the reported by the publication in terms of yield change due to the moment and length of the dry period (Figure 3).

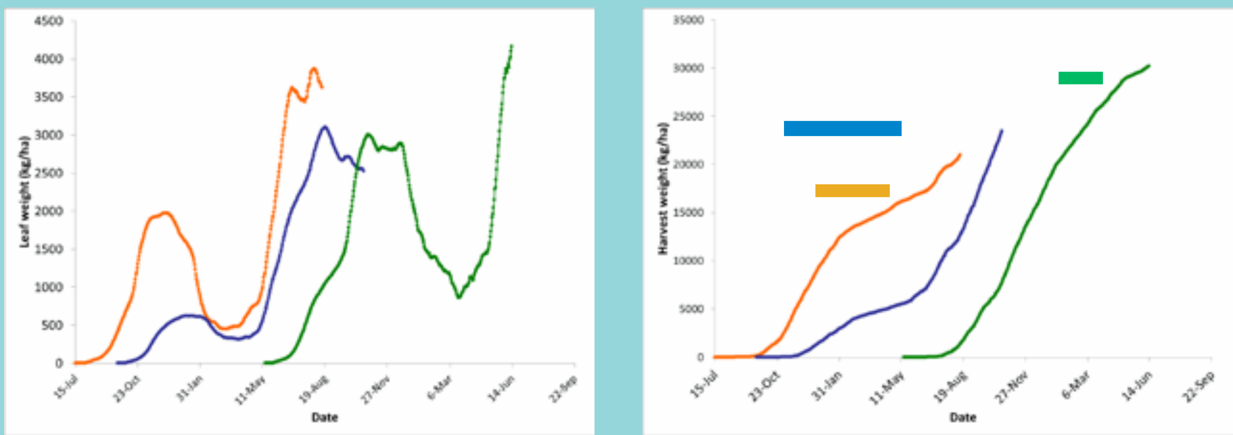


Figure 4 ***Simulated and observed (a) leaf weight (kg/ha) and (b) yield (kg/ha) (Source: Schulthess (1987) and Gutierrez et al. (1988)).***

Next steps

The next steps are to evaluate the performance of the model using the data collected from year 1 and 2 when all the weather and soil variables are available. In addition, the model needs further revision to avoid the overestimation of the leaf area index and leaf biomass at the end of the growing period.

Apart from DSSAT, another modelling approach, LINTUL (light interception and utilisation, developed by Wageningen University), has been implemented as a complementary tool for the QUEFTS modelling framework to support the site-specific fertilizer recommendation and scheduled planting tools. LINTUL simulates growth and yield based on intercepted photosynthetically active radiation and light use efficiency using daily weather data (rainfall, temperature and solar radiation), as well as crop characteristics and soil physical properties. It is used to estimate water-limited yields, which are used as boundary constraints input in QUEFTS modelling, and attainable yields for a given planting and harvest date in the scheduled planting tool. Simulated water-limited yield is achieved under optimal management practices in rainfed conditions without nutrient limitation. LINTUL has been calibrated for cassava under West-African coastal savanna conditions. Data from literature and field experiments (ACAI and other projects like SARD-SC) have been used to revise the model parameters.

Further model calibration is required to fully implement this model for the project countries. Focus will be put on sourcing more detailed data from breeding and physiology projects through collaboration with the respective partners. Another feature of LINTUL is the simulation of long drought stress effects leading to dormancy and recovery from dormancy at the onset of the rainy season causing storage root losses in favour of boosting the initiation of better leaves production. This feature allows the model to provide advice on the best time for harvesting to prevent dry matter losses, thus reducing starch losses.

Cassava intercropped with maize, at an ACAI trial plot in Benue State, Nigeria.

Output 1.5: QUEFTS modelling framework developed and used as a basis for the site-specific fertilizer recommendation tool

The QUEFTS modelling framework was used to predict response to additions of N, P and K, determined based on predictions of the indigenous soil nutrient supply (based on soil parameters, modified from Howeler, 2017), and the physiological nutrient use efficiency (NUE) of cassava (conversion of indigenous soil nutrient supply to nutrient uptake, and root yield). The latter conversion was calculated based on maximum dilution and accumulation curves within the QUEFTS framework, using the formulas to correct for harvest index as developed by Ezui et al. (2017) and Byju et al. (2012), using average harvest indices observed in the nutrient omission trials for the improved varieties used in both countries. The model was used to determine the current yield of a cassava crop relying solely on the soil nutrient supply, and the yield that was obtained with variable additions of variable N, P and K, applied through a set of available fertilizers. An optimization algorithm then iteratively computed the fertilizer rates that maximize net revenue, considering the NPK content and price of available fertilizers, and the unit price of cassava roots.

Next steps include further validation and improvements in the prediction algorithms, including relationships between indigenous nutrient supply and soil parameters (and to what extent GIS-based estimates are sufficiently accurate), impact of environmental conditions on the harvest index, and an overall better understanding of factors affecting physiological nutrient use efficiency of cassava.

Development and improvement of the scripts was done in close collaboration with colleagues from the International Plant Nutrition Institute (IPNI) and TAMASA, capitalizing on learnings and harmonizing procedures for further validation and calibration, setting up modules to plug various data sources, and coding efficiently to have a functional and generic (crop-independent) framework.

Output 1.5. QUEFTS modelling framework developed and used as a basis for fertilizer recommendation tool

The QUEFTS modelling framework for fertilizer recommendation is based on the balanced nutrient approach which optimizes the use efficiency of the three main nutrients N, P and K, reducing nutrient losses and generating higher yields. The development of the QUEFTS framework for the purposes of the project is being done in close collaboration with the TAMASA project team. The framework is set up in a modular way to allow gradual improvement of the framework, as data is coming in to calibrate and improve estimations of the input parameters (relationship between soil properties and soil nutrient stocks, physiological nutrient use efficiency envelop curves as a function of harvest index to estimate nutrient requirement to achieve target yields) and data (water-limited yield, soil information on pH, organic carbon, total nitrogen, available phosphorus, exchangeable potassium, and maximum recovery fraction). The water-limited yield is provided through a parallel modelling framework (LINTUL) based on light interception and utilization. This framework involving LINTUL and QUEFTS models is used as the basis for both the FR and FB DST.

Material and Methods

Since QUEFTS is a static model limited in assessing spatial and temporal variability in weather, the QUEFTS modelling framework has been enhanced by using location and planting date-specific water-limited yield provided through the dynamic model LINTUL. The key parameter of QUEFTS, the physiological nutrient use efficiency (PhE), was estimated using the envelope curves for maximum accumulation and maximum dilution as a function of harvest index (Figure 5. and Table 2).

QUEFTS was used to determine the current yield based on the (indigenous) soil nutrient supply at zero fertilizer input. The current yield was used as a reference to evaluate the profitability of additional investment to apply fertilizer. The QUEFTS model was used to determine the yield response to a given application rate of N, P, and K while the optimization algorithm iteratively computed the fertilizer rates that maximizes the net revenue considering the NPK content and prices of available fertilizers and cassava root price.

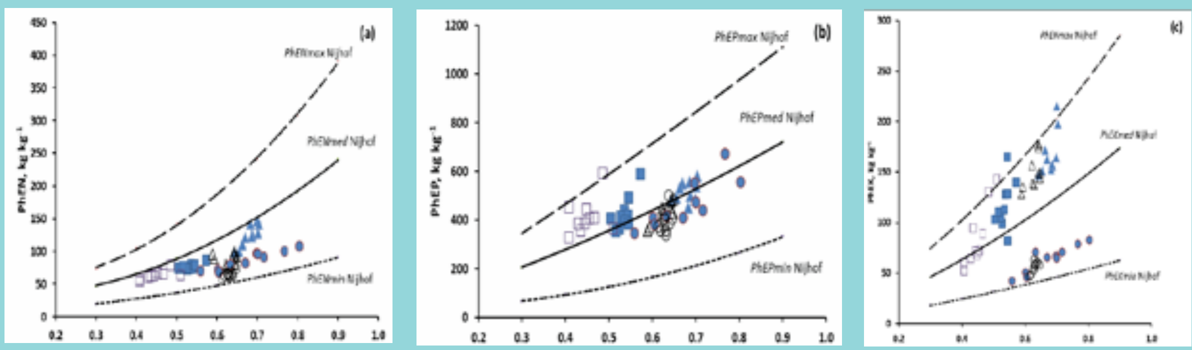


Figure 5 *The effect of harvest index on the nutrient use efficiency to convert indigenous nutrient soil supply to yield according to maximum dilution and accumulation curve (Nijhof, 1987).*

Table 2. Nutrient uptake requirement to produce one ton of storage root dry matter using balanced nutrient Principle depends on harvest index.

Cultivar	HI	PhEmin			PhEmax			R-Phe			Source
		aN	aP	aK	dN	dP	dK	kg N/ton DM	kg P/ton DM	kg K/ton DM	
India	0.40	35	250	32	80	750	102	17.4	2.0	14.9	Byju et al., 2012
	0.40	30	175	26	70	465	126	20.0	3.1	13.2	Ezui et al., 2017
Gbazekoute (TME419)	0.50	41	232	34	96	589	160	14.6	2.4	10.3	Ezui et al., 2017
	0.55	47	262	38	112	653	178	12.6	2.2	9.3	Ezui et al., 2017
	0.65	61	329	47	148	782	214	9.6	1.8	7.7	Ezui et al., 2017
Afisiafi	0.70	70	365	53	170	848	233	8.3	1.6	7.0	Ezui et al., 2017

Next steps

The next step includes improving input data quality. For instance, field observations showed that harvest index is less affected by fertilizer treatment than by environmental factors. To improve the prediction accuracy of the tool, it is important to have a better understanding of factors affecting physiological nutrient use efficiency of cassava and the assessment of the indigenous soil nutrient supply.

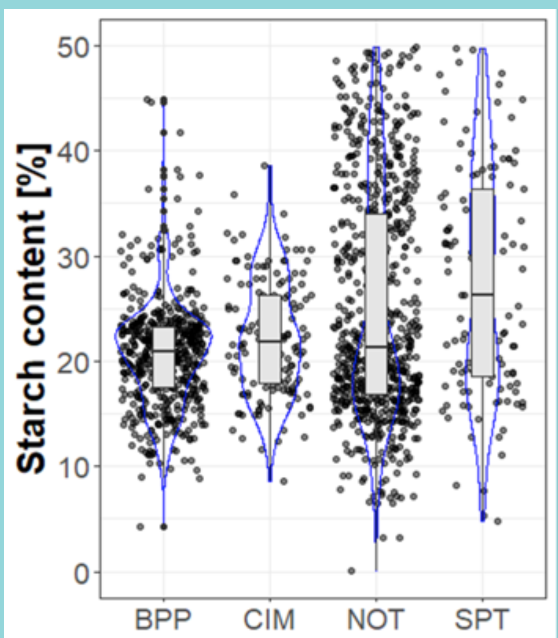
Output 1.6: Impact of agronomic interventions on the dry matter and starch content of cassava produce determined

A first analysis assessing the impact of agronomy interventions on starch content has been completed. In total, 1624 starch measurements have been conducted on root samples collected from various agronomy trials. We found a minor negative impact of nutrient additions on starch concentration, with reductions of maximally 4 % root starch when N or P were omitted from a full NPK treatment, but not when all nutrients were supplied in a balanced fertilizer regime. Land preparation, particularly first and primary tillage operations, affected root yields but not root starch concentration. The largest impact on root starch concentrations were caused by the harvest date, with highest starch concentrations of up to 40% during the dry season, versus 15-20% after the onset of the rains. While literature review revealed important genotypic differences in root starch content, differences in starch content between the improved varieties used in the project were minor or absent.

These findings, particularly the impact of harvest month, have been integrated in the scheduled planting and high starch content decision support tools, substantially improving the predictions of total revenue from roots supplied to processing factories, where prices of roots are disaggregated by root starch content. In 2018, the dataset will be expanded to validate these findings, and used to improve and validate growth models to predict starch content based on daily rainfall across the growth period, rather than based on time of harvest. This is particularly relevant for Tanzania, where rainfall is more erratic than in Nigeria.

Output 1.6: Impact of agronomic interventions on the dry matter and starch content of cassava roots determined

Currently, a total of 1624 starch samples were collected and analysed across the various trials conducted in Nigeria and Tanzania (BPP = best planting practices, CIM = cassava intercropped with maize, NOT = nutrient omission trial, SPT = scheduled planting trial). Large variation in starch content was observed, with average starch contents of 20%, but varying between 10 and >40%. A variance component analysis showed that most of the variation was attributed to the date of harvest (entered in the model as the harvest month), followed by variation observed between trials (environmental conditions), and less by variation within trials (treatments imposed within the trials and residual error).



	Nigeria	Tanzania
mean	21.9%	25.1%
CV	29.3%	44.7%
% variance attributed to…		
harvest time	64%	35%
between trials	21%	36%
within trial	15%	29%

Between trials = agro-ecology + soil + management,…
Within trials = treatment + random noise

Figure 6 *Variation in starch content observed across the various use case trials.*

In Nigeria, almost two thirds of the variation observed could be explained by the month of harvest, contrary to Tanzania, where only half as much of the variation was explained. This is most likely due to more erratic rainfall and differences in rainfall patterns across the agro-ecological zones in Tanzania, while rainfall patterns are more consistent across the target area in Nigeria.

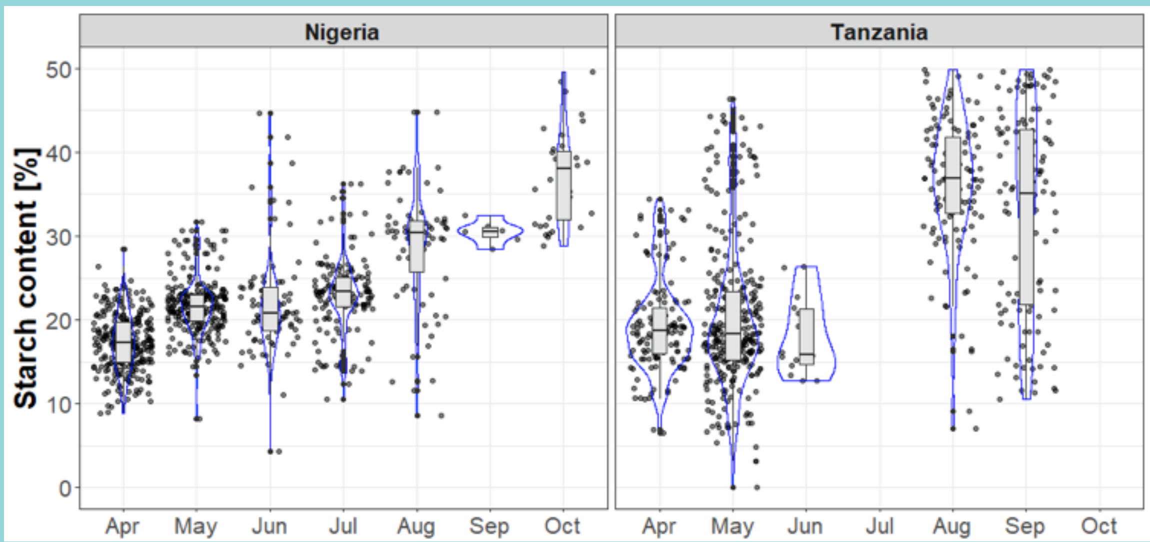
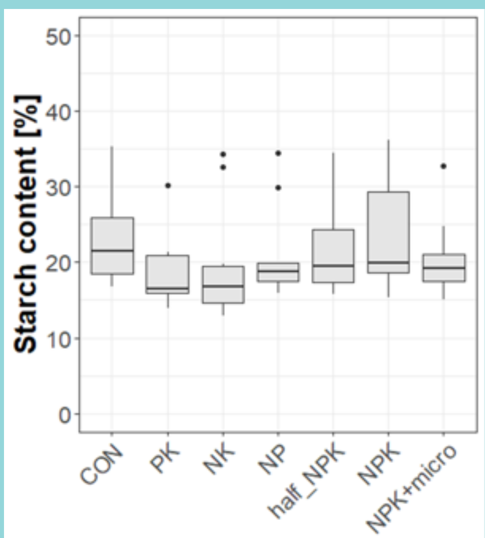


Figure 7 ***Variation in starch content across the various use case trials as affected by month of harvest.***

Evaluating the impact of fertilizer application on starch content, results seem to confirm the observations in the literature review. Application of N+K or P+K resulted in decreases in starch content by almost 4%, relative to the control, while application of NPK at half rate or full rate (150 kg N, 40 kg P, 180 kg K per ha) did not result in starch content decreases. This seems to indicate that unbalanced applications of especially N and P may result in reduced starch contents, but these effects are much smaller than effects of crop age and harvest date.

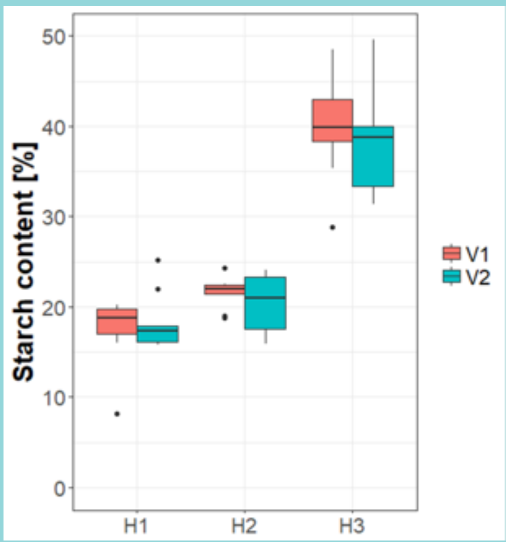



```
Linear mixed model fit by REML
Formula: starCont ~ treatCode + (1 | trialID)

             Estimate   Std. Error   Pr(>|t|)
(Intercept)  23.9362    2.4094       1.77e-08 ***
PK           -3.8166    1.7814       0.0371 *
NK           -3.9010    1.7431       0.0297 *
NP           -0.9004    1.7512       0.6095
half_NPK     -0.6770    1.7870       0.7064
NPK          -0.1340    1.5782       0.9327
NPK+micro    -1.7704    1.7512       0.3170
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 8 ***Starch content as affected by nutrient additions, as observed in nutrient omission trials across Tanzania and Nigeria.***

Starch contents may double when harvested in the dry season, relative to the end of the rainy period, and decrease by up to 10% if harvested after the dry season and the onset of the new rains, when starch is flushed to generate new leaf biomass. We observed at most marginal differences in starch content between the improved varieties used in the ACAI trials.




```
Linear mixed model fit by REML
Formula: starCont ~ variety*harvestTime + (1 | fieldID)

                      Estimate    Std. Error    Pr(>|t|)
(Intercept)            17.7253    1.2014        1.21e-08 ***
VarietyV2               0.4589    1.6667        0.7840
HarvestH2               4.1153    1.8771        0.0548 .
HarvestH3              22.3808    1.6574        5.84e-09 ***
VarietyV2:HarvestH2    -1.6738    2.3836        0.4854
VarietyV2:HarvestH3    -2.5796    2.2254        0.2511
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 9 *Starch content observed in scheduled planting trials in SW Nigeria, as affected by harvest at 9, 11 and 13 months after planting (H1, H2 and H3) for two improved varieties. (V_1 = TME 419, V_2 = TMS 30572)*

Next steps include confirming these results in ongoing trials, as well as further improvements to the predictions of starch content based on daily precipitation received during the growth period, to better grasp the variation observed between trials (especially in Tanzania).

Application of fertilizer, in one of the research trials in Oyo State, Nigeria.

Output 1.7: Impact of improved weed control practices compared with current practice

This output was introduced in 2017, based on the opportunity to expand products of the Cassava Weed Management Project (CWMP), which screened over 40 herbicides and evaluated various innovative weed control methods in Nigeria, to the conditions of cassava growers in Tanzania with interested development partners (CAVA-II and MEDA). An exploratory analysis was conducted to evaluate which integrated, sustainable weed control options would fit within farmers' current cassava cultivation practices in Tanzania. Survey results showed that manual weed control using hoe or cutlass is the predominant practice, but farmers commonly engage hired labour for weed control in cassava fields and are familiar with the use of herbicides. Based on learnings from CWMP and a survey with agro-dealers to identify commonly available pre- and postemergence herbicides, a set of best-bet weed control options were selected. These use combinations of manual weed control, herbicide-based weed control, mechanical weed control (using modified small mechanical tillers) and/or agronomic practices (tillage and intercropping). These will be compared with current practice in demonstration trials set up in contrasting environmental conditions across the Lake and Coastal region in Tanzania. Only combinations of weed control methods that are sensible will be demonstrated.

Preparatory activities to compile relevant weed control packages for demonstration required more time than anticipated, and implementation of the demo trials have been postponed to the first season of 2018.

Output 1.7. Demonstration on Alternative Weed Control Techniques (DAW-1) Demo Trials in Tanzania - 2017

Weed control demonstration trials will be set up in two zones where ACAI is currently working: Lake Zone [LZ] and Eastern Zone [EZ]. Alternative weed control options are selected based on learnings from the Cassava Weed Management Project (CWMP) and in clude (combinations of) herbicide-based land clearing, pre- and post-emergence herbicide based weed control, weeding using small mechanical weeders (Mantis tillers with modified tines), appropriate land preparation (tillage and ridging) and intercropping with a short-duration grain legume crop.

The demonstration will be set up as demonstrations with post-emergence weed control in main plots, and land clearing / tillage + pre-emergence weed control in subplots. Farmer's current practice (CP) will be included as a check (see Table 3. for details).

Table 3. Treatment structure of the weed contro demos in Tanzania.

nr	Code	Land clearing	Tillage	Pre-emergence weed control	Post-emergence weed control	Cropping System
1	CP	Slash or S&B	No-till	None	Manual (hand hoe)	Cassava Monocrop
2	Tillage	Slash	Tillage	None	Manual (hand hoe)	Cassava Monocrop
3	Ridges	Slash	Tillage+Ridging	None	Manual (hand hoe)	Cassava Monocrop
4	Intercrop	Slash	Tillage+Ridging	None	Manual (hand hoe)	Cassava-Grain Legume Intercrop
5	PrimeGold	Slash	Tillage+Ridging	PrimeGold	MaisterPower	Cassava Monocrop
6	Lagon	Slash	Tillage+Ridging	Lagon	MaisterPower	Cassava Monocrop
7	Gly+PG	Glyphosate	Tillage+Ridging	PrimeGold	MaisterPower	Cassava Monocrop
8	Gly+Lag	Glyphosate	Tillage+Ridging	Lagon	MaisterPower	Cassava Monocrop
9	Mech+Til	Slash	Tillage	None	Mechanical Weeder	Cassava Monocrop
10	Mech+Rid	Slash	Tillage+Ridging	None	Mechanical Weeder	Cassava Monocrop
11	Mech+PG	Glyphosate	Tillage+Ridging	PrimeGold	Mechanical Weeder	Cassava Monocrop
12	Mech+Lag	Glyphosate	Tillage+Ridging	Lagon	Mechanical Weeder	Cassava Monocrop

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Sylvia Okafor (right) supervising planting of a farmer-managed trial plot. She is an extension agent working with ACAI through NRCRI in Nando, Anambra East, Anambra State, Nigeria.

WORK STREAM 2: DEVELOPMENT OF A GEOSPATIAL CASSAVA AGRONOMY INFORMATION BASE

WS2 contributes to IO 1.2 of the project: ***By 2017, geo-spatial information to reduce the cassava yield gap are integrated in the development of decision support tools for cassava intensification.*** WS2 support the development of the DSTs by compiling and/or generating accurate and up-to-date relevant geospatial information, including crop maps, soil constraint maps, and historical and near-real-time weather information for two purposes: (i) to design sampling frames and guide site selection in order to maximize representativeness, and (ii) to enable extrapolation of trial and survey findings across the target intervention areas (use case-specific) with maximal predictive accuracy.

OUTPUT 2.1

Tools for deciding on sampling frames and extrapolation developed

OUTPUT 2.2

Recommendation domains for the deployment of specific tools and applications developed

OUTPUT 2.3

Geospatial layers to support the use cases (e.g., weather, soils) available

OUTPUT 2.4

Database infrastructure for capturing and storing agronomy information operationalized

In 2017, a total of 88 GIS layers have been compiled and used for both purposes. WS2 also hosts the development and maintenance of all data collection and management tools and software. In 2017, further investments were made to streamline data management, introducing barcode identifiers and switching entirely to digitized data collection, as well as applying generic and semi-automated methods for data storage, processing and reporting.

Output 2.1: Tools for deciding on sampling frames and extrapolation developed

A strategy for laying out trials and deciding on sample size was developed in 2016. This approach ensures representativeness and maximizes unbiasedness while at the same time maximizing operational efficiency. Each use case focuses on a well-defined target area where the primary development partner requesting a DST operates, and has an established network of extension agents. A two-step GIS-assisted approach was followed whereby first, a set of extension agents are selected semi-randomly to ensure that the area covered by this set of EAs has similar distributions in important soil and climate-related parameters as the entire target intervention areas. Then secondly, random locations for trials are identified within a practical range (radius of 5 km) around these EAs, restricting these locations to areas that are cropped. The number of EAs (clusters) and random locations (fields within clusters) depends on the exact objective and the anticipated impact of environmental conditions on performance of the technology tested.

Output 2.1: Tools for deciding on sampling frames and extrapolation developed

A strategy for laying out trials and deciding on sample size was developed in 2016. This approach ensures representativeness and maximizes unbiasedness while at the same time maximizing operational efficiency. Each use case focuses on a well-defined target area where the primary development partner requesting a DST operates, and has an established network of extension agents (EAs). A two-step GIS-assisted approach was followed whereby first, a set of EAs are selected semi-randomly to ensure that the area covered by this set of EAs has similar distributions in important soil and climate-related parameters as the entire target intervention areas. Then secondly, random locations for trials are identified within a practical range (radius of 5 km) around these EAs, restricting these locations to areas that are cropped.

Data and methods

24 GIS layers have been used for decision making on sampling frames. Target area was divided into homogeneous cluster using multivariate cluster analysis. These include long-term climatic data (annual mean rainfall, seasonality, and variation in rainfall and temperature), AfSIS soil layers (a.o., C content, N content, CEC, exchangeable acidity,) and several remote sensing variables (NDVI, EVI, GPP, NPP) which account for vegetation and primary biomass productivity of the environment.

The iterative self-organizing data analysis technique (ISODATA) as implemented in ArcGIS 10.5 was used to cluster the bioclimatic variables, soil fertility layers and vegetation indices into environmental strata. The Iso-Cluster tool uses a modified iterative optimization clustering procedure, also known as the migrating means technique. The algorithm separates all cells into the user-specified number of distinct unimodal groups in the multidimensional space of the input bands. This type of clustering uses a process in which, during each iteration, all samples are assigned to existing cluster centres and new means are recalculated for every class.

The iso-cluster algorithm is an iterative process for computing the minimum Euclidean distance when assigning each candidate cell to a cluster. The process starts with arbitrary means being assigned by the software, one for each cluster (user dictate the number of clusters). Every cell is assigned to the closest of these means (all in the multidimensional attribute space). New means are recalculated for each cluster based on the attribute distances of the cells that belong to the cluster after the first iteration. The process is repeated: each cell is assigned to the closest mean in multidimensional attribute space, and new means are calculated for each cluster based on the membership of cells from the iteration. Clusters are therefore homogeneous groups based on the multivariate inputs.

Results

The map below shows the results of multivariate cluster analysis for fertilizer recommendation use case for Nigeria. It shows that 12 homogeneous clusters were identified in the entire target area defined by the operational area of development partners. The 2nd map is an example of the use of environmental cluster map in selection of random points near the Extension agents (EAs) from which trial sites were selected using an iterative process.

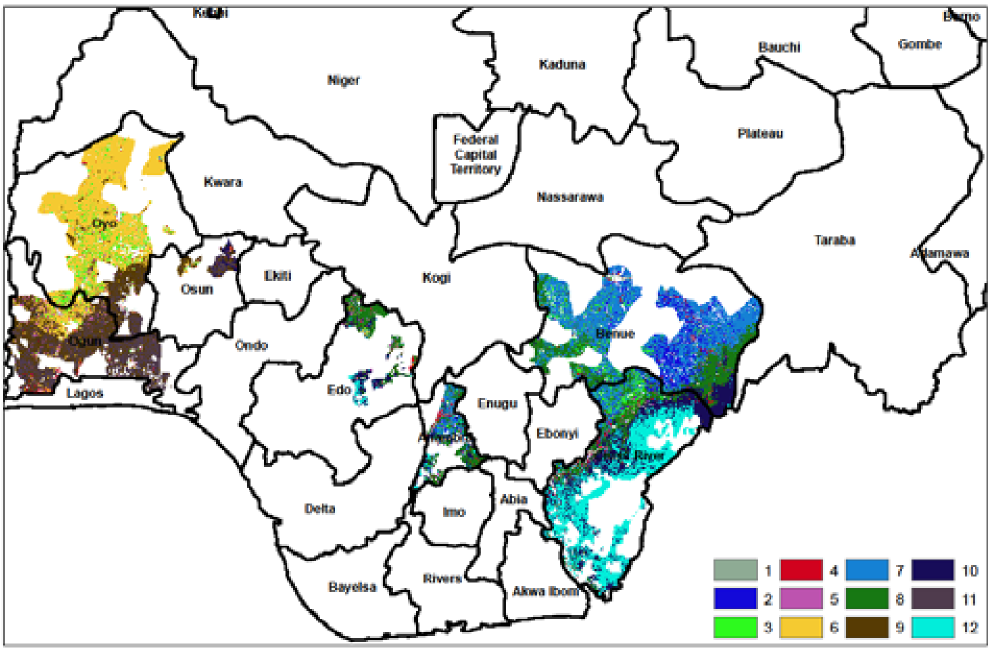


Figure 9 *Map showing results of cluster analysis for fertilizer recommendation target area*

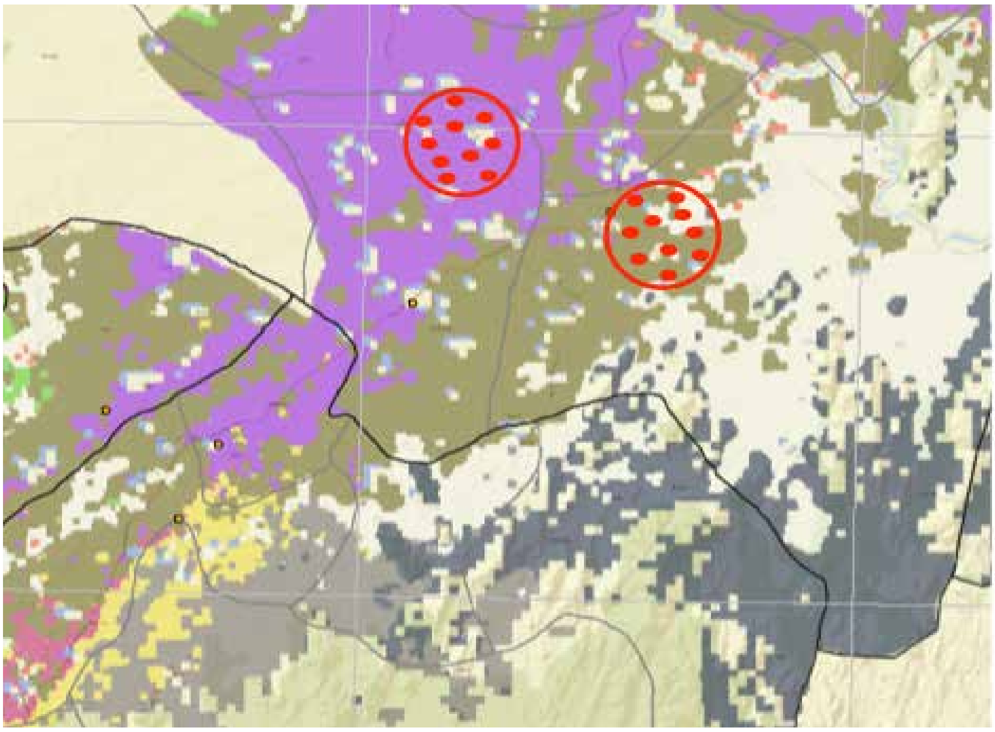
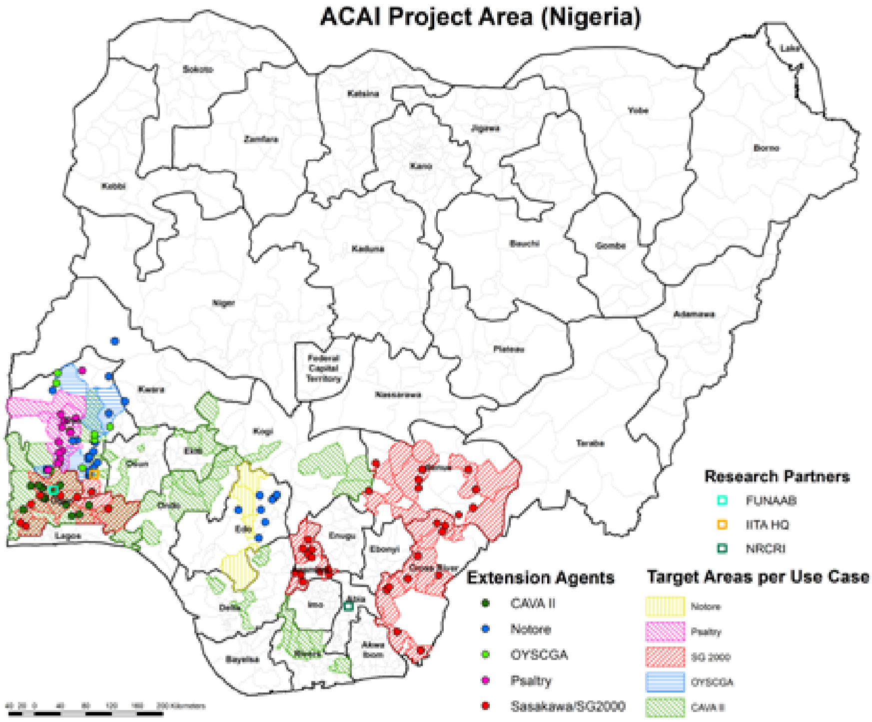
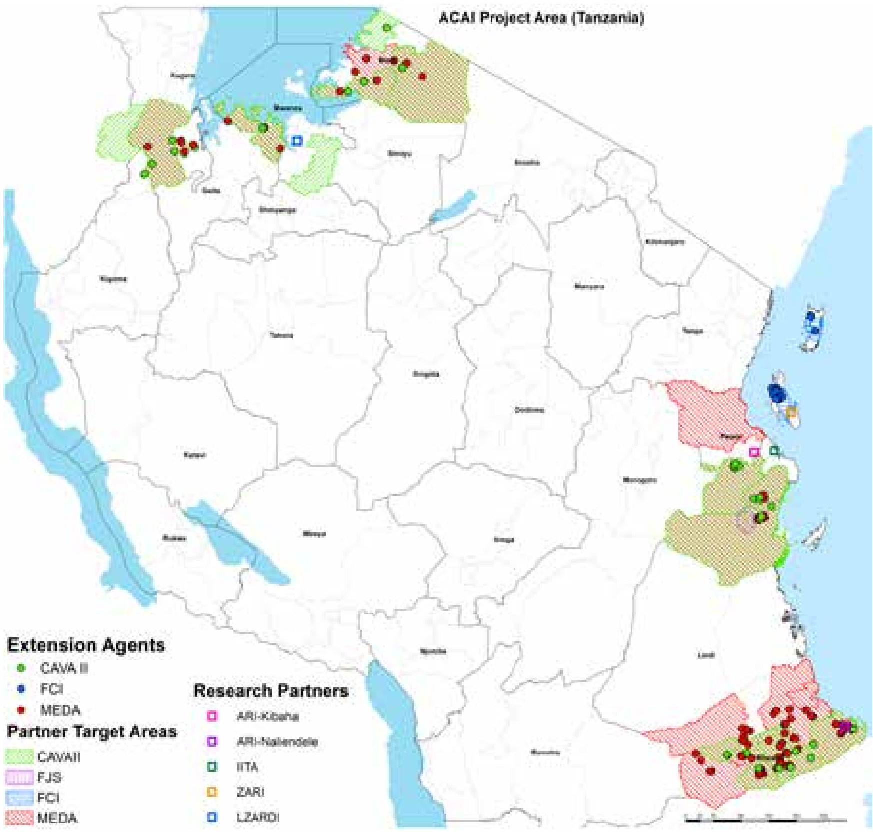


Figure 10 *Map showing random points around Extension Agents locations within environmental clusters*


ACAI Project Area (Nigeria)
Research Partners
FUNAAB
IITA HQ
NRCRI
Extension Agents
CAVA II
Notore
OYSCGA
Psaltry
Sasakawa/SG2000
Target Areas per Use Case


ACAI Project Area (Tanzania)
Extension Agents
CAVA II
FCI
MEDA
Partner Target Areas
CAVAII
FJS
FCI
MEDA
Research Partners
ARI-Kibaha
ARI-Naliendele
IITA
ZARI
LZARDI

As sufficient yield data and soil analysis results become available in the course of 2018, this strategy will be scrutinized and improved, to allow adjusting sampling frames to account for a higher/ lower influence of environmental conditions on technology performance than currently expected. The outcome of this exercise will enable optimizing investments in field activities while minimizing prediction error, when adapting the recommendations to new areas beyond the current target intervention areas. These improved tools will be implemented and tested in 2019 in the tier two countries (Uganda, Ghana and DR Congo).

Output 2.2: Recommendation domains for the deployment of specific tools and applications developed

The baseline household survey was started in Nigeria and Tanzania, aiming to cover relevant aspects of cassava cultivation, yield and revenue to assess the impact of improved agronomic interventions introduced through the various use case tools at the end of the project.

Preparatory activities have been concluded and comprised establishing an updated partner database on Extension Agents (EAs), confirming the operational areas for the delineation of treated and control areas, creating the sample frame, determining the sample size, development of the baseline survey tool and training of enumerators on data collection procedures. Currently, implementation is underway (about 30%), and will be completed by mid-2018, before decision support tools are introduced and in use by EAs (hence very limited to no influence on current practices expected at this stage).

Maps depicting the extension network by the development partners have been developed using information collected during the Rapid Characterization study in 2017 and known/reported EA locations, and used to define treated and control areas in both Nigeria and Tanzania. The sample frame includes participating farmers within an EA's zone of influence and non-participating farmers in control areas.

A sample size of 3040 households (1810 in Nigeria and 1240 in Tanzania) will be included in the survey. Other processes and protocols for village and farmer selection, yield assessment, data collection have been developed and described in an SOP. The methodology for rapid yield assessment on farmers' field has been finalized and will be used for the yield data collection. The method is based on triangle method and harvesting of nine plants plus non-destructive measurements. The baseline survey tool has been finalized and tested and covers key areas such as general information and composition of sampled households, household

Salama Mhina is an extension agent working with ACAI through ARI in Kiimbwanindi-Mkuranga, Eastern Zone, Tanzania assets, farming practices of households, agronomic practices in selected plots of sampled households, costs associated with these practices, yield in farmers' fields and market and price information to estimate revenue. These aspects are key in defining and deploying appropriate and specific use case tools for application within partner areas. Market surveys were cancelled, as only price information at household level was directly relevant to the development of the tools.

A second activity under this output involves the development of code to perform geospatial analysis for the delineation of recommendation domains. These scripts have been modified based on similar requests from other projects and implemented in R in 2016, in close collaboration with AfSIS. These scripts allow quantifying "similarity" between areas covered (or selected point observations) and new areas beyond, based on a set of user-defined set of parameters and weighting factors. For example, cassava prediction maps have been continuously updated and used to refine areas relevant for formulating site-specific cassava agronomy interventions. Predictions are based on various GIS layers, including soil layers developed by AfSIS and Sentinel 2 satellite data. In the course of 2018, as sufficient data on yield and yield effects become available, these scripts will be tested, improved and used to generate recommendation domains for the various use case tools beyond the current partners' target intervention areas.

Output 2.3: Geospatial layers to support the use cases (e.g., weather, soils) available

This output relates directly to the IO of WS2. For the sampling frames and site selection procedures for research trials and survey activities, a standard set of 24 geospatial layers are used, and multivariate cluster analysis is used to delineate homogeneous environmental clusters per use case applied on the geographic extent of development partner's operational areas. Additional GIS layers are used for the delineation of the recommendation domains, using for example a cassava crop mask, satellite data, and as inputs to the decision support tools. In total, 88 GIS layers were compiled.

Soil and weather data required as inputs for the LINTUL and QUEFTS modelling framework are obtained from various opensource resources, including AfSIS (https://africasoils.net/) and ISRIC (ftp://ftp.soilgrids.org/data/recent/) for soil data, and NASA (https://power.larc.nasa.gov/cgi-bin/agro.cgi/) and CHIRPs (ftp://ftp.chg.ucsb.edu/pub/org/chg/products/CHIRPS-2.0/) for weather data. Soil data comprises both soil organic C, pH and available nutrient contents (total N, Mechlich-III extr. P and K, a.o.), as well as soil physical parameters to estimate water availability and storage (texture, bulk density, soil water content at saturation, wilting point and field

DR. Mutiu Busari from FUNAAB in a Nutrient Omissions Trial plot at Abata-Ogun village, Saki in Oyo state, Nigeria.

capacity, a.o.). Weather data includes daily precipitation (CHIRPs incorporates 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series data), daily minimum and maximum temperatures and daily solar radiation.

Adebiyi Ademola, (third right) ACAI research assistant showcasing how to capture data using ODK on an android tablet.

Output 2.4: Database infrastructure for capturing and storing agronomy information operationalized

All agronomy trial and survey data are directly collected in digital from and available on a common platform. The data management software and hardware set up in 2016 was further improved. A barcode system was implemented to streamline data collection procedures, labelling all entities at which data collection occurs, from households and extension agents with barcoded ID cards to fields, plots and plants with barcode tags and soil and plant samples with barcode labels. This greatly enhanced the efficiency and speed of data collection in the field, as well as improved the consistency and quality of the data, and allowed more standardized and faster analysis of incoming data. A suite of scripts has been developed that automatically downloads and processes incoming data, provides visual overviews and data reports, and allows agronomists to have insights in collected data within 24 hours after collection of data in the field. The system is set up using a combination of ODK collect, aggregate and briefcase, the ONA.io platform, shell scripts, R and R-shiny.

Next steps include expanding the ME&L project-level data collection procedures to align fully with the project data management system and provide near-real time progress on indicators against target milestones. Further, a mySQL database will be developed as an intermediate to OpenAccess platforms such as cassavabase and CKAN. The project Document Management System on LogicalDOC was discontinued and information stored was transferred to the ACAI SharePoint site, in line with the lead institute's (IITA) new policy.

WORK STREAM 3: PRODUCTION AND VALIDATION OF DEMAND-DRIVEN SUPPORT TOOLS FOR CASSAVA AGRONOMY

OUTPUT 3.1

Use cases identified based on specific demands from primary development partners engaged in cassava value chain activities in the target countries

OUTPUT 3.2

A cassava fertilizer blending decision support tool for the fertilizer blending industry developed and validated (in Nigeria and Tanzania).

OUTPUT 3.3

A cassava fertilizer site-specific recommendation decision support tool for extension agents developed and validated (in Nigeria and Tanzania)

OUTPUT 3.4

A best planting practice decision support tool for extension agents/farmers developed and validated (in Nigeria).

OUTPUT 3.5

A cassava intercropping decision support tool for extension agents/farmers developed and validated (in Nigeria and Tanzania)

OUTPUT 3.6 & 7

Scheduled planting and High Starch Content decision support tool for farmers supplying the processing sector developed and validated

OUTPUT 3.8

A specific decision support tools and applications developed within the context of cassava value chain initiatives managed by partners in Ghana, Uganda and DR Congo

WS3 contributes to IO 1.3 of the project: ***By 2018, cassava agronomy decision support tools (DSTs) are used by primary partners with target smallholder farmers.*** Under WS3, cassava agronomy decision support tools are developed based on specific requirements (use cases) from partners with active dissemination networks, engaged in the cassava value chain. These tools will be adapted to the skill sets of extension agents and the context within which they operate.

In 2017, six operative first versions (V1) of the decision support tools have been developed, demonstrated to the primary development partners during the annual review meeting in December 2017 in Mwanza, and evaluated and improved using first feedback. These V1 versions have evolved from the V0 versions (basically concepts built using data from literature) into tangible prototypes in various formats (smartphone apps, software or paper-based tools), ready for use in the field. In 2018, efforts will focus on testing these tools which will include (i) validating the recommendations supplied by the tools, and (ii) evaluating and improving the user experience (“look and feel”) to generate V2 (validated tools).

The roadmap for the development of the tools was modified from the initial setup, where the V0 framework documented in detail the functional requirements and architectural structure to guide software developers, and an iterative process involving graphical designers and user feedback was proposed to create the graphical user interface. Through interaction with the TAMASA team, dealing with very similar questions on maize agronomy, we concluded that an intermediary step was needed.

We opted to develop tools as ODK forms as this (i) allows researchers to derive and avail recommendations for validation exercises, (ii) implement and modify a simple interface in a fast and easy way. This interface will require more technical know-how from the end-user and is intended specifically for the NARS agronomists and trained EAs involved in validation exercises. Development of a customized user interface will follow a more gradual process, to allow testing of the format in a more cost-effective way.

Output 3.1: use cases identified based on specific demands from primary development partners engaged in cassava value chain activities in the target countries.

This milestone was achieved in 2015 and resulted in the selection of the primary development partners and the identification of the use cases and target intervention areas in Tanzania and Nigeria (see ACAI 2016 annual report).

Output 3.2: A cassava fertilizer blending decision support tool for the fertilizer blending industry developed and validated (in Nigeria and Tanzania).

The first version of fertilizer blending tool has been developed as a web-based software application using R shiny. It was presented to Notore and Minjingu fertilizer producing companies from Nigeria and Tanzania, respectively. The underlying modelling framework is identical to that of the site-specific fertilizer recommendation tool, estimating nutrient- and water-limited yields using the QUEFTS and LINTUL frameworks, at optimal planting date (giving highest yields averaged across 5 selected years selected from 22 years of historical rainfall data).

Next, the additional NPK requirement to obtain the maximum water limited yield or a 5, 10, 15 and 20 t ha^{-1} fresh root yield increase over the current yield was computed using the QUEFTS model. The result is incorporated in the FB tool designed to be able to identify best suited fertilizer blends based on site-specific nutrient constraints for cassava production and determine nutrient rates required for a given yield response.

Output 3.2. A cassava fertilizer blending decision support tool for the fertilizer blending industry developed and validated (in Nigeria and Tanzania)

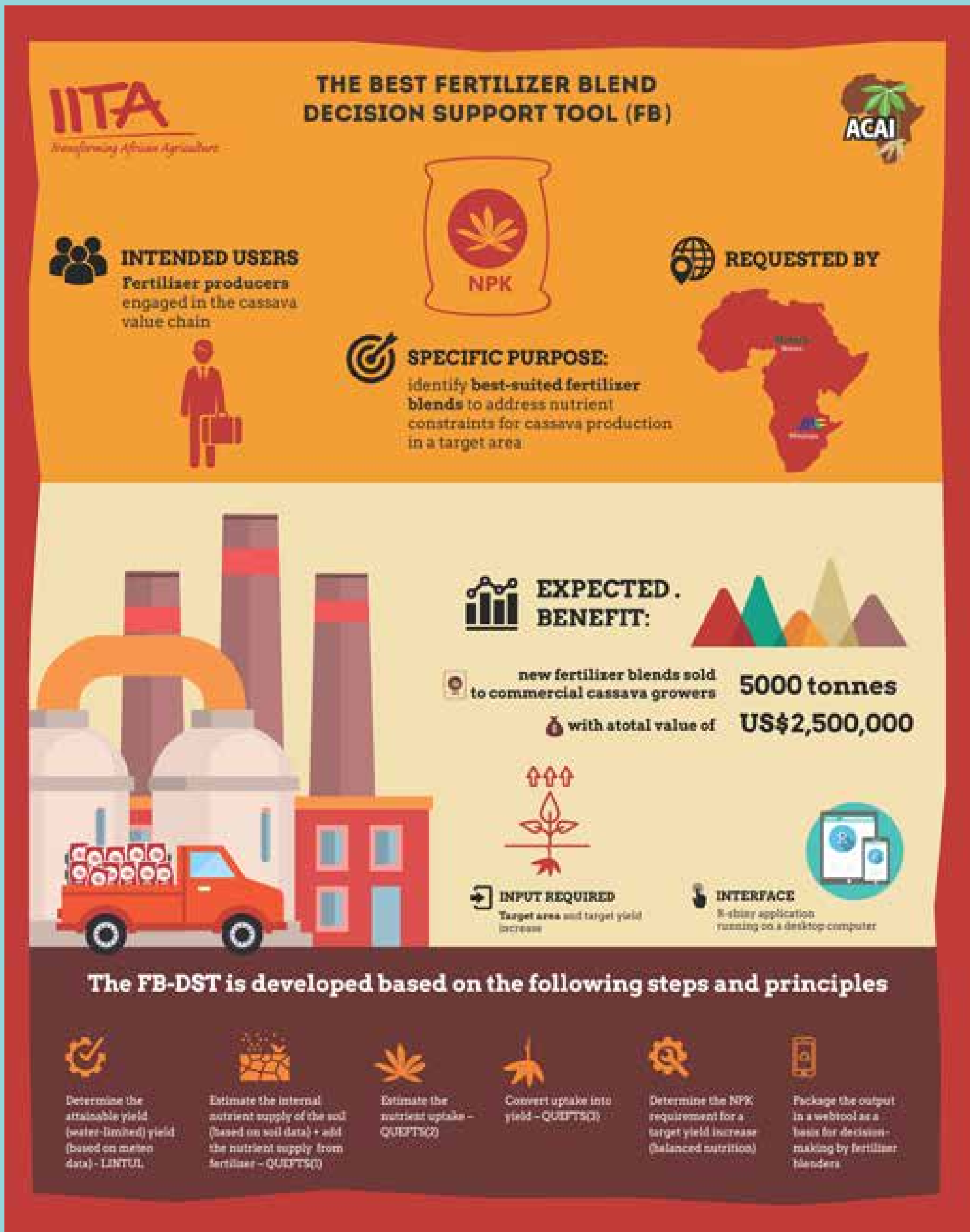
A fertilizer blending, FB-DST has been developed to support fertilizer producing companies to formulate best-suited fertilizer blends based on site-specific nutrient constraint for cassava production and determine nutrient rates required for a target yield response. Currently, ACAI partners Notore and Minjingu from Nigeria and Tanzania, respectively, are providing blends developed in line with blanket recommendations in the respective countries. The fertilizer blending tool is developed based on site- specific soil and weather measurements obtained from GIS layers and it is packaged as a web-based desktop application. The tool provides an intuitive way of visualizing how the nutrient rates are varying spatially and to determine the areas requiring a minimal nutrient supplement to obtain a user-defined cassava fresh root yield increase.

Material and Methods

The same GIS layers and data processing procedures to develop the site-specific fertilizer recommendation tool (Output 3.3) are used for fertilizer blending tool. The water-limited yield, the soil nutrient supply and the additional NPK requirement to realize a user-defined increase in cassava root fresh yield over the current yield were computed using LINTUL and QUEFTS. Since fertilizer producing companies operate in a wide region and are interested in assessing the size of the market they would serve with the new blends, computations were made for the entire crop-producing area in the agro-ecologies where cassava is grown. To address the increase in spatial variability of rainfall distribution across this wide area, five representative years of rainfall data were used (rather than three as for the fertilizer recommendation tool).

Result

The web-based FB tool is developed using R shiny as a desktop application and when presented, partners showed enthusiasm. The tool provides a visualization of how the nutrient rates are varying spatially in user selected regions in the two countries.



In the current version, the user can choose to observe the NPK required to increase the current cassava root yield, yield at zero fertilizer input, by a 5: 10: 15 or 20 t ha^{-1} or even to bridge the yield gap and attain water-limited yields for pixel size of 5 x 5 km^2. In addition to the required NPK overlaid on the map of the regions, the tool provides histograms to understand the distribution of NPK requirements. It also provides information at region/state level on the total NPK (tonnes) required and the total land area within region/state where the fertilizer application will be required (FFigure 11).

Next steps

One of the key factors determining the success of adoption and continuous use of the tool is the accuracy of the recommendations. For this reason, ACAI prioritized calibrating and validating the QUEFTS equations for estimating indigenous nutrient supply and conversion to biomass

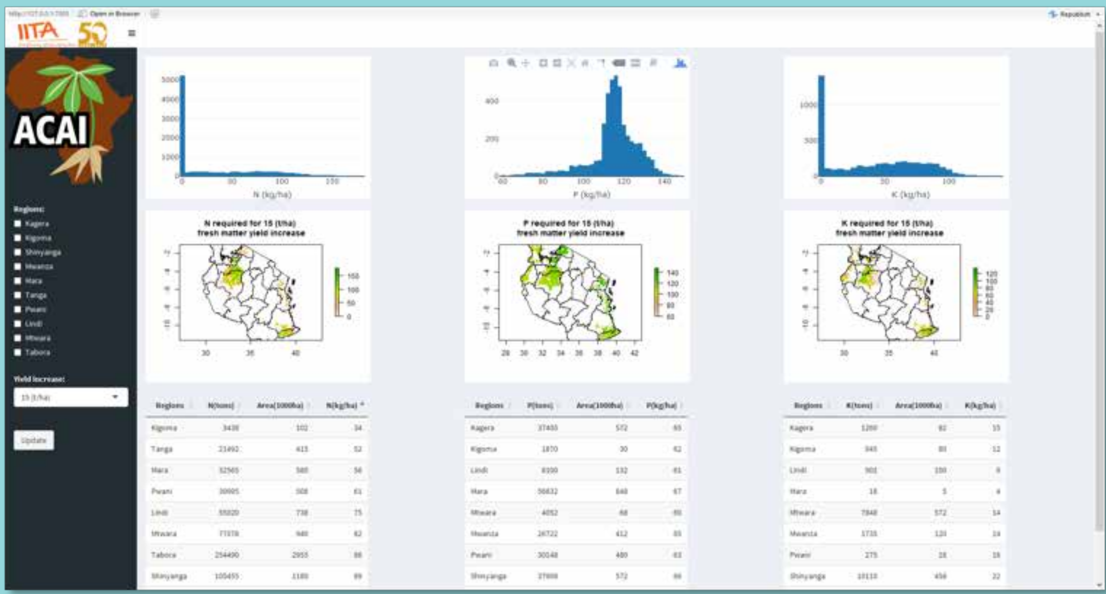


Figure 11 ***Web based Fertilizer Blending Decision Support Tool developed using R shiny.***

and yield, while conducting validation trials in collaboration with partners. Since this tool sources the same data as the site-specific fertilizer recommendation tool, the effort to be made for the FR tool are also expected to improve the prediction accuracy of FB tool.

Based on partners feedback to improve the functionality of the tool, the next development will attempt to incorporate suggested new fertilizer blends with corresponding spatial clusters where the blends could serve. Other requests like incorporating site-specific cassava meso- and micro-nutrient requirements and providing measure of market competitiveness of the new blend are found to be more challenging but not impossible. Estimation of micro-nutrients requirement is not currently possible to be made using LINTUL and QUEFTS. As an alternative, ACAI opts to analyze the NOT trial data and investigate relationship between responses and several micro-nutrients concentration in the leaf samples taken from these trials. The result of these analysis is expected to provide information to understand what micronutrients are deficient (or at low concentrations and may lead to deficiency under continuous cultivation), and should be included in fertilizer blends. Given the composition and the price of fertilizers available to farmers (which will be obtained from the baseline and agro-dealer surveys), it is possible to suggest at what price a new blend will be recommended over other available fertilizers.

The tool provides an intuitive way to visualize how nutrient requirements vary spatially, and to determine the areas requiring a minimal nutrient supplement, providing ACAI's partners with insights on best nutrient ratios for cassava-specific fertilizer formulations and the potential marketable fertilizer quantities.

Next steps focus primarily on improving the fertilizer response predictions and validating the tool within partners' networks and ongoing activities, as well as cross-validation using new data from ACAI nutrient omission and fertilizer response trials. In terms of functionality, the next version will incorporate partners feedback and integrate for example, suggested new blends and and spatial clusters for these blends that allow maximizing the area for a specific blend, as well as aspects of price competitiveness with existing fertilizers.

Omolara Olabisi, ACAI PhD student measuring soil resistance to penetration with penetrologger on a trial plot in Saki, Oyo State, Nigeria.

Dr. Geoffrey Mkamillo of ARI Tanzania makes a point during a visit to one of ACAI trial fields in Mwanza, Tanzania.

Output 3.3: A cassava fertilizer site-specific recommendation decision support tool for extension agents developed and validated (in Nigeria and Tanzania)

The first version of site-specific fertilizer recommendation tool has been developed using LINTUL and QUEFTS modelling frameworks and key literature review findings. The LINTUL model was used to estimate water-limited yields for weekly time steps in planting dates across the planting window and harvest at 10 months after planting. Next, the indigenous nutrient supply (INS) was determined using calibration equations modified from Howeler (2017), using soil data from GIS layers compiled under WS2, and most profitable yield responses for a given set of fertilizers (and their unit prices) calculated based on the physiological nutrient use efficiency (NUE) equations and an optimization algorithm described under WS1.

The tool was packaged as an ODK form accessible on a mobile phone with GPS capability, with GPS location, planting date, variety and land area as the only user-defined inputs. The tool provides output on the total amount of fertilizer recommended to be applied, as well as the increase in yield and net revenue anticipated from the fertilizer application, for an investment in fertilizer application not exceeding \$200 ha^{-1}. The V_1 of the tool operates with fixed values for several input parameters, mainly because of storage limitations for offline use, stored within the ODK application. Primary development partners (Notore and SG2000 in Nigeria, and Minjingu and MEDA in Tanzania) evaluated the tool and provided feedback during the annual review meeting in Mwanza, December 2017.

Next steps include allowing more user-defined variables, including expanding the set of available fertilizers and their prices, varying the harvest date, and specifying the maximal investment capacity and the fresh cassava root unit price received at the market. Also, better time- and location-specific default prices (obtained from the baseline study) will be provided to ensure relevant predictions, especially for users who refrain from providing detailed input on all parameters. Finally, estimates of uncertainty due to erratic rainfall or drought will be integrated, to allow end-users to be conscious of risks associated with fertilizer use. These developments will require investments in app development to accommodate within-app calculations (if offline use is preferred), or calculations on a central server (either online or through SMS-based requests, depending on network connectivity).

Output 3.3. A cassava site-specific fertilizer recommendation decision support tool for extension agents developed and validated (in Nigeria and Tanzania)

A decision support tool to recommend site-specific fertilizer rates was developed for extension agents of development partners working in Tanzania and Nigeria. This study combines GIS layers and spatial data from open data source, literature review learning, QUEFTS and LINTUL crop models, and statistical modeling for optimization. The information was packaged using open data kit (ODK) as a platform for mobile app tool development.

Material and Methods

Daily precipitation and soil data for the study area at 5 x 5 km^2 resolution was obtained from CHIRPs–UCSB and ISRIC, respectively (see Output 2.3). Data on temperature and solar radiation was obtained from NASA. Using these data and key literature review findings, the LINTUL and QUEFTS modeling frameworks were used to calculate water-limited yield, indigenous soil nutrient supply, crop nutrient uptake efficiency, and current and attainable yields. For the major cassava-growing regions in Tanzania and Nigeria, 22 years of daily precipitation data were analyzed and years reflecting the first, second and third quantiles in rainfall patterns (number of rainy days and total rainfall) were selected. For the selected years, site-specific water limited yield (WLY) given meteorological and soil data was calculated assuming planting in weekly steps within cassava planting windows. Figure 12 shows the temporal and spatial variation of WLY in the area of interest in Tanzania.

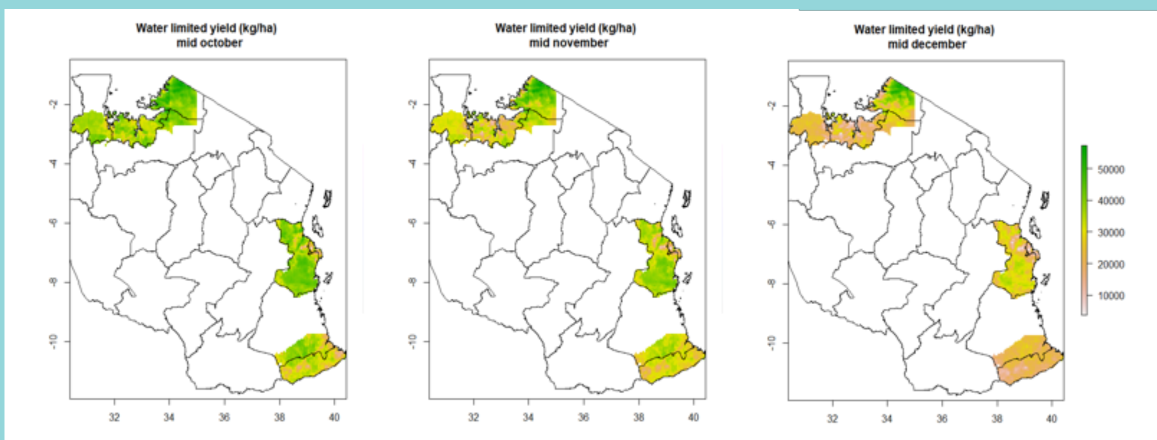
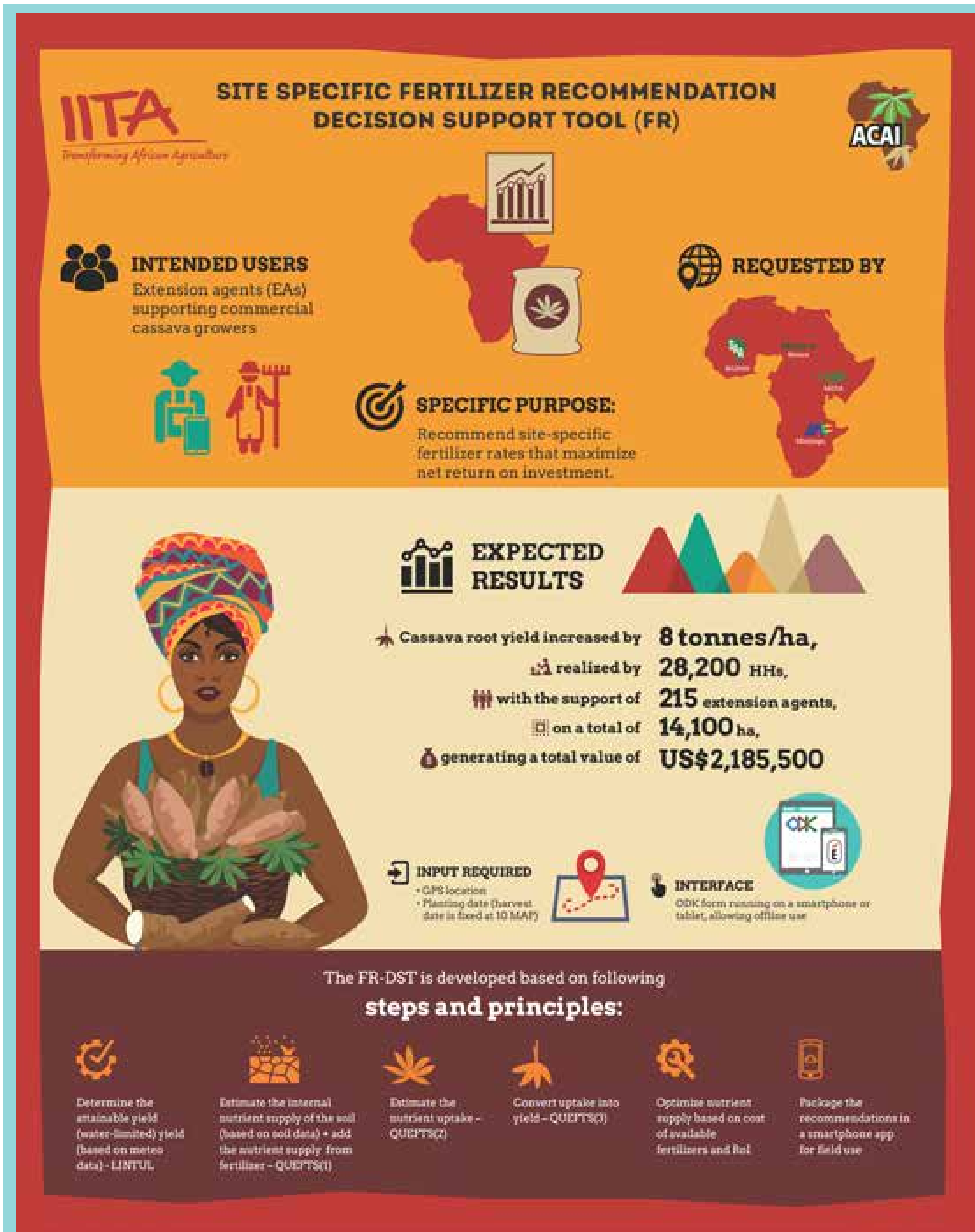


Figure 12 *Spatial water-limited yield (WLY) calculated for pixel size of 5 x 5 km² in target cassava growing areas, Tanzania.*

Next, the indigenous soil nutrient supply was determined from the soil organic C, and Mehlich-III extractable P and K using equations modified from Howeler (2017). The physiological nutrient use efficiency (PhE) of the crop defining conversion of nutrient uptake into yield was determined using maximum dilution and maximum accumulation curves as a function of harvest index (Ezui et al., 2017).

The site-specific fertilizer rates maximizing return on investment were computed using a combination of QUEFTS and an optimization algorithm with R statistical programming packages, optim (R Core Team, 2015) and limSolve (Soetaert K et.al., 2009; Van den Meersche, K et.al., 2009). The QUEFTS model was used to determine the yield response to a given application rate of N, P, and K while the optimization algorithm reiteratively computed the fertilizer rates that maximizes the net revenue considering the NPK content and prices of available fertilizers and cassava root price. It also enables spatial classification of the area in fertilizer application responsiveness and profitability of investment.



Results

For quick and easy use, the tool was packaged as an ODK form accessible on a mobile phone with GPS, planting date and land area size as the only user-defined inputs (Figure 13). For the referred planting date and GPS location recorded, the tool provides recommendation on rate and type of fertilizers, expected cassava root yield increase and the net return of the investment.

Next steps

The accuracy of prediction and functionality of the current version will be validated in collaboration with EAs of development partners requesting the tool. For accurate prediction of net revenue, it is important to consider the temporal and spatial price variation of both the fertilizers and cassava root price. The baseline survey on input and output prices is expected to provide the necessary data to add this functionality into the tool. The accuracy of the indigenous soil nutrient supply will also be cross-checked using data from over 250 nutrient omission trials conducted within the study area. Mixed effects models will be used to calculate site-related yield responses to only N, only P and only K and with reciprocal nutrient use efficiency the yield responses will be converted to indigenous N, P and K. As a second method, the soil data gathered from the NOT trials will be inserted into Howeler's equations and the indigenous soil N, P, K supplies estimated. After calibration, the new equations for assessing soil nutrient supplies will be used.

Improving the current version includes replacing the default values used by user defined values. Due to limitations in offline storage of recommendation, the analysis is currently done considering only the most commonly used fertilizers in the region, and for a cassava growing period of 10 months and an investment limitation of max. 200 USD ha^{-1}. We will investigate also other technical options such as within-app calculations, or using a central server / SMS-based requests and recommendations to allow users to define these factors.

Dr. Alves Afredo of Embrapa, Brazil, chatting with Joy Adiele, ACAI PhD candidate from NRCRI, Nigeria.

Output 3.4: A best planting practice decision support tool for extension agents/farmers developed and validated (in Nigeria).

Best Planting Practices (BPP) cover type and intensity of tillage (ploughing twice, once or nil) and ridging versus leaving the land flat and planting density: 10000 versus 12500 plants ha^{-1}. 81 BPP trials were established in South Western Nigeria in 2016. About 70% of the trials were fit for harvest and provided suitable data. Double ploughing generally resulted in yields about as high as single ploughing. Ridging after double ploughing did not affect root yields. By ridging on un-ploughed land at high plant density (12,500 ha^{-1} plants) and applying fertilizer, yields as high as in in the same treatments after a single plough passage can be attained. In single and zero plough treatments, fertilizer application resulted in large root yield increases. Response was less pronounced after double ploughing. The increased plant density had no effect on the root yield.

Site-specific variations in response to tillage interventions were observed, but these could not be related to any soil- or weather-related covariates. The site-dependency appeared most related to the general yield level, with effects of ridging being more pronounced in high-yielding fields than low-yielding fields. This dependency was built into the decision support tools through a simple decision tree model. The tool was implemented as a simple paper-based guide, allowing end-users to calculate the profitability of investing in additional tillage operations, or savings from reduced tillage operations (depending on the tillage intensity in the current practice). In parallel, the tool was also developed as an Enketo webform, with default (but changeable) price values for tillage operations as observed in Oyo State, Nigeria, to allow the target development partner (OYSCGA, Nigeria) to explore various approaches in obtaining recommendations.

Next steps involve confirming findings with the second season of BPP trial results, and re-evaluating the dependency of root yields on primary and secondary tillage on soil and weather-related covariates, as well as differences related to weed pressure and effectiveness of weed control operations. These findings will be used to refine recommendations, either based on simple decision tree models or more complex geospatial prediction models providing location-specific recommendations in follow-up validation activities.

Output 3.4: A best planting practices decision support tool for extension agents/farmers developed and validated (in Nigeria).

The best planting practices use case was requested by the Oyo State Cassava Growers Association (OYSCGA) and CAVA-II. The development partners expressed concerns about increasing production costs and were looking of methods to reduce costs for tillage without compromising root yields. Through interaction with farmers in Ogun and Oyo state, the basic and follow-up tillage operations were established as: double ploughing with 2-week interval or single ploughing or zero ploughing. As an additional secondary tillage ridging is considered yet ridgers are not generally available nor are harrows to smoothen the surface after ploughing, which leaves the surface often rather rough. In addition to the three basic ploughing treatments, ridging versus no ridging was implemented in each of the previous plough intensities and cassava was planted at 1 x 1 m (10,000 plants ha^{-1}) versus 1 x 0.8m (12,500 plants ha^{-1}) and with a fertilizer application of 75:20:90 kg ha^{-1} NPK. Farmers would provide the basic plough tillage thus trials were established in fields according to the farmers preference with ridging imposed across the ploughing regime. Crop husbandry specifically weeding and protecting against damage by fire and roaming animals was duty of the farmer. About 70% of the 2016 planted trials were managed sufficiently well to produce data. All trials were established in sites that farmers' had earmarked for their own cassava fields and were thus embedded in larger cassava fields.

Plant evaluations showed little differences between double and single ploughed plots while zero plough resulted in smaller plants yet with higher leaf retention towards the dry season. Final cassava fresh root yields showed a clear positive fertilizer effect, which was most pronounced in the single and zero plough treatments (Figure 14). Single plough followed by ridging and fertilizer application, irrespective of the planting density attained the highest root yields, followed by zero plough plus ridging and fertilizer. The increased plant density had the least effect on the root yield.

A major challenge encountered in these on-farm trials is farmers' perception of the trial plots being in some form different from the remaining part of the field. This caused differential treatment, specifically in weed control. Many farmers did not enter the plots to weed there as they were weeding the remaining field. Farmers who did weed the trial had a tendency to focus more on treatment plots which were performing well and neglected plots with poorer growth, thereby aggravating differences.

In the 2017 planting season, these issues were planned to be eliminated by moving to a herbicide-based weed control approach to be implemented by IITA and NARS partners, and following best practices developed by the CWMP, yet the lack of skilled personnel to conduct the spraying limited its success.

For the development of the BPP V1 the data analysis revealed that the effects of the tillage operations were related to the root yield level. At yield levels above 12 t ha^{-1}, ridging increased root yields after single and zero plough yet had a slight negative effect after double ploughing (Fig 15, Fig 16). At yield levels below 12 t/ ha^{-1}, ridging only had a positive effect when not ploughed. On double and single ploughed land, ridging had marginal positive effects on the yield.

These effects on yield were built into a paper-based decision support tool, allowing farmers to assess the profitability of by comparing the cost of individual tillage operations with their expected impact on yield (or gross revenue). The tool includes budget tables, and aids the farmer in calculating total cost of land preparation and planting practices. As an alternative, the tool was also developed as an ODK-based ENKETO webform, which includes the common prices of tillage interventions observed in Oyo as default (but changeable) values, and provides the user with the most cost-effective tillage practice.

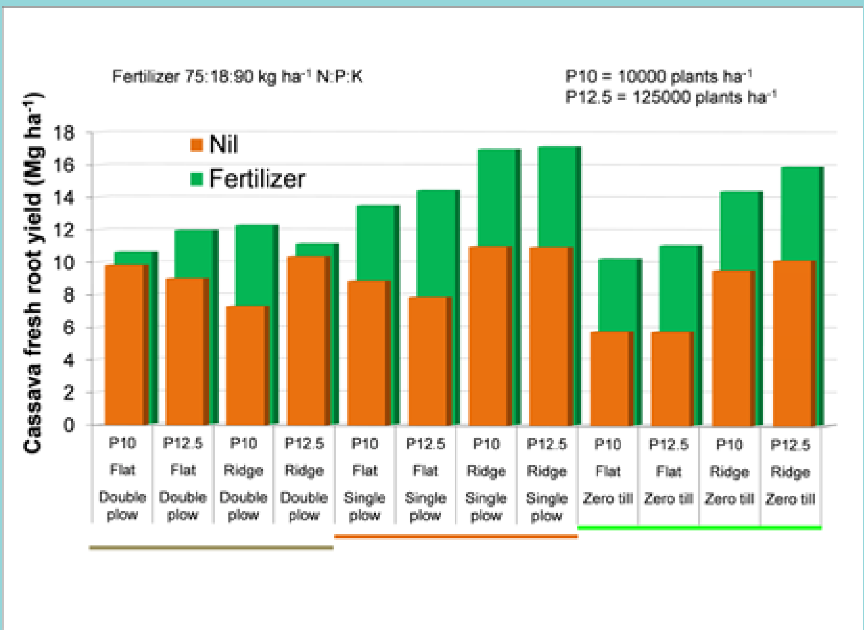


Figure 13 ***Cassava fresh root yield in the Best Planting Practices use case trials of the 2016 / 2017 season, in Nigeria.***


BEST PLANTING PRACTICES
DECISION SUPPORT TOOL (PP)
IITA
Transforming African Agriculture
ACAI
INTENDED USERS
Extension agents (EAs) and commercial cassava growers with access to tractors
REQUESTED BY
SPECIFIC PURPOSE:
recommend crop density, tillage and associated weed control that minimize total cost of production or maximize net revenue
FOCUS ON EFFECTS OF:
Tillage operations
Ridging vs flat
Crop density
EXPECTED BENEFIT:
Root yield increased by 4 tonnes/ha
equivalent cost saving of US$100/ha
realized by 29,100 HHs,
with the support of 266 extension agents,
on a total of 14,550 ha,
generating a total value of US$1,455,000
INPUT REQUIRED
Planting and harvest dates, cost of operations, Yield estimate, expected market price
INTERFACE
ODK form running on a smartphone or tablet, allowing offline use
The PP-DST is developed based on following steps and principles:
Obtain details on current practice
Identify alternative options within given constraints
Evaluate to what extent the performance of alternative options is location-dependent, based on analysis of multilocational field trial data
If so, identify GIS (or other) predictor variables to estimate location-specific effects of tillage practices on cassava root yield
Convert yield effects to changes in gross revenue using price of roots (default values or user input)
Estimate total cost based on costs of operations (default values or user input)
Recommend alternative options that either save on cost (without negative impact on yield) or maximize net revenue using a decision tree model

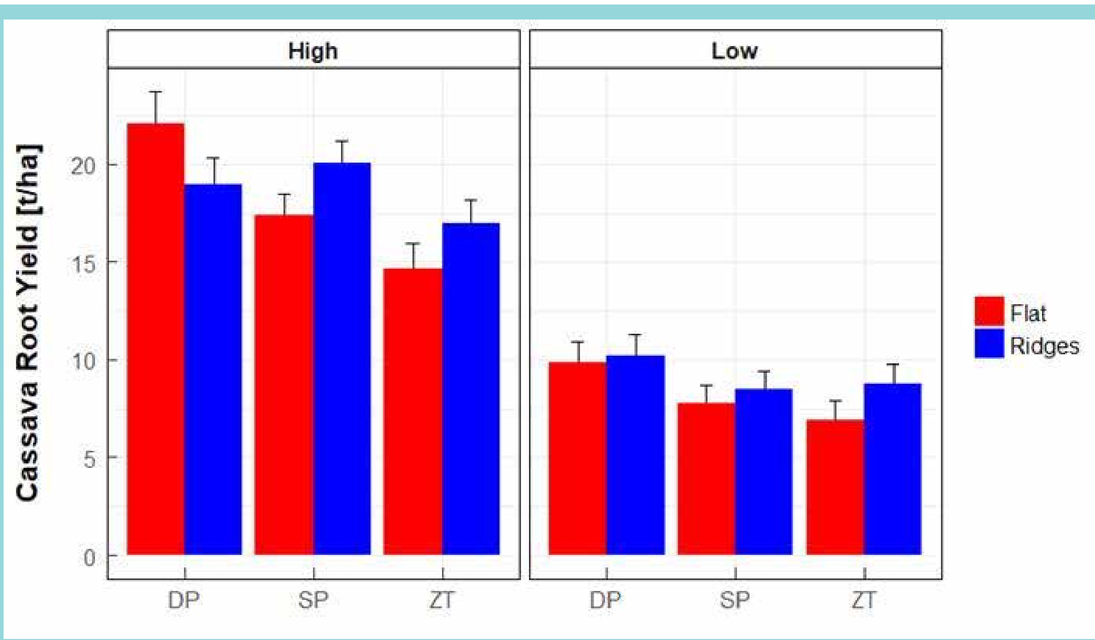


Figure 14 *Cassava fresh root yield is affected by ploughing and ridging, separated by yield level (High = control yield > 10 t ha^{-1}; Low = contro yield < 10 t ha^{-1}) (DP = Double Ploughing, SP = Single Ploughing, ZT = Zero Tillage)*

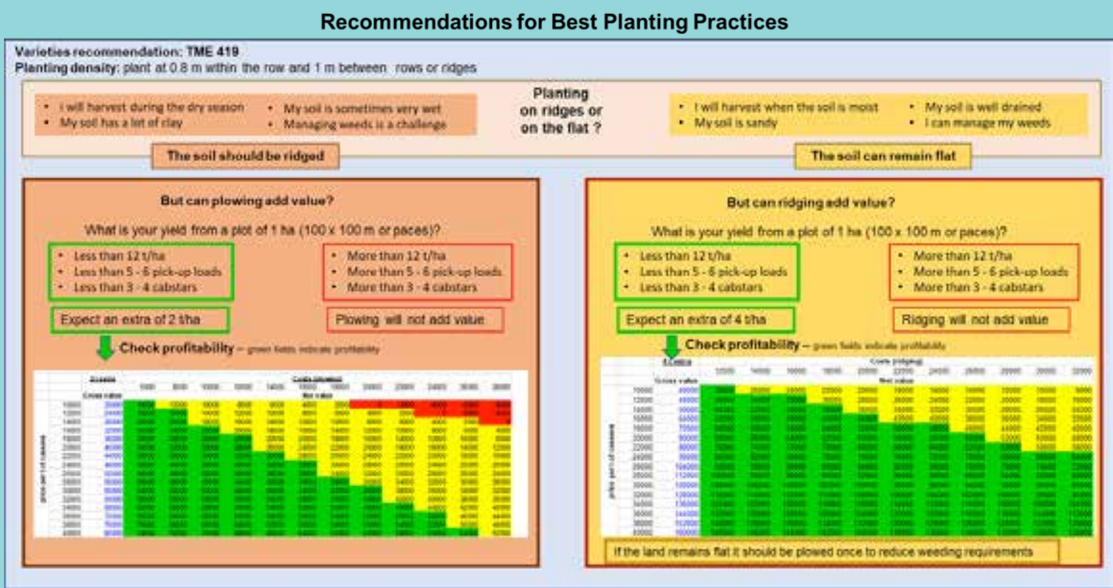


Figure 15 *Version 1 of the DST for best planting practices recommends a planting density of 12,500 cassava plants ha^{-1} with the variety TME 419. The farmer's decision making is then guided along his or her preference for the time of harvest (dry or wet season) and prevailing soil conditions (clay content, drainage, weeds) towards ridged or flat soil. For the recommendation of ridged soil, the added value of plowing is evaluated. When the farmer expects less than 12 t ha-^{1} he or she is encouraged to check the profitability of the plowing operation in the look-up table that lists a range of costs for plowing operations and expected root prices. Areas highlighted in green indicate that additional income from the sale of additional cassava roots is twice the cost of the tillage operation. If the expected net-return falls in this green area the investment is considered save, in the yellow area the risk increases and in the red area the economic net-return is zero or negative. Similarly, for the recommendation of flat soil, the added value of ridging is evaluated. Ploughing, however, is generally recommended to manage weeds. All calculations are based on a hypothetical plot size of 1 ha.*

Khatib Haji, (Left) with technicians from ARI-Zanzibar, weighing harvested samples at the Matangatwani research farm on Pemba Island , Tanzania.

Output 3.5: A cassava intercropping decision support tool for extension agents/farmers developed and validated (in Nigeria and Tanzania)

Cassava-maize intercropping in Nigeria. Of the intercropping trials established in 2016, 70 trials were used for pairwise comparisons of the response of maize and cassava to stepwise intensification through increased planting density and fertilizer application. In about 80% of the cases, the higher maize planting density increased total cob numbers. A fertilizer regime targeting primarily the needs of maize increased cob numbers and cassava root yield in about 80% of the cases, and there was no apparent advantage to a adjusting the fertilizer regime to the needs of cassava (cassava yields were similar while maize yields were lower, compared to the first fertilizer regime).

Maize yield or yield effects (or cob numbers) were not related to cassava fresh root yield. In 2017, a second set of trials (145 in total) were planted. These trials included evaluating the effect of maize planting density on fresh maize cob quality, by segregating cob yields according to size class. The higher planting density increased numbers of all marketable cobs but had no significant effect on the numbers of large cobs. Both fertilizer regimes (targeting maize or cassava) increased numbers of all marketable and large cobs in about 80 % of the cases, but the fertilizer regime that targets the maize appeared still superior.

Yield benefits from increased planting densities were concluded to be sufficiently robust to be provided as blanket recommendations. The maize-specific fertilizer regime was also recommended as a blanket rate but targeted to fields with moderate fertility (based on prior knowledge of maize performance). These recommendations were made available as a simple paper-based decision support tool, with a budget table to assess profitability of fertilizer investments depending on the price ratio of maize cobs and fertilizer unit price.

In 2018, the results from these 2 sets of trials that form the basis of the V_1 which will be further refined by integrating cassava yield data will be validated. In addition, the possibility of integrating site-specific fertilizer recommendations to the maize crop will be explored, by modifying the FR use case for maize (based on learnings from TAMASA).

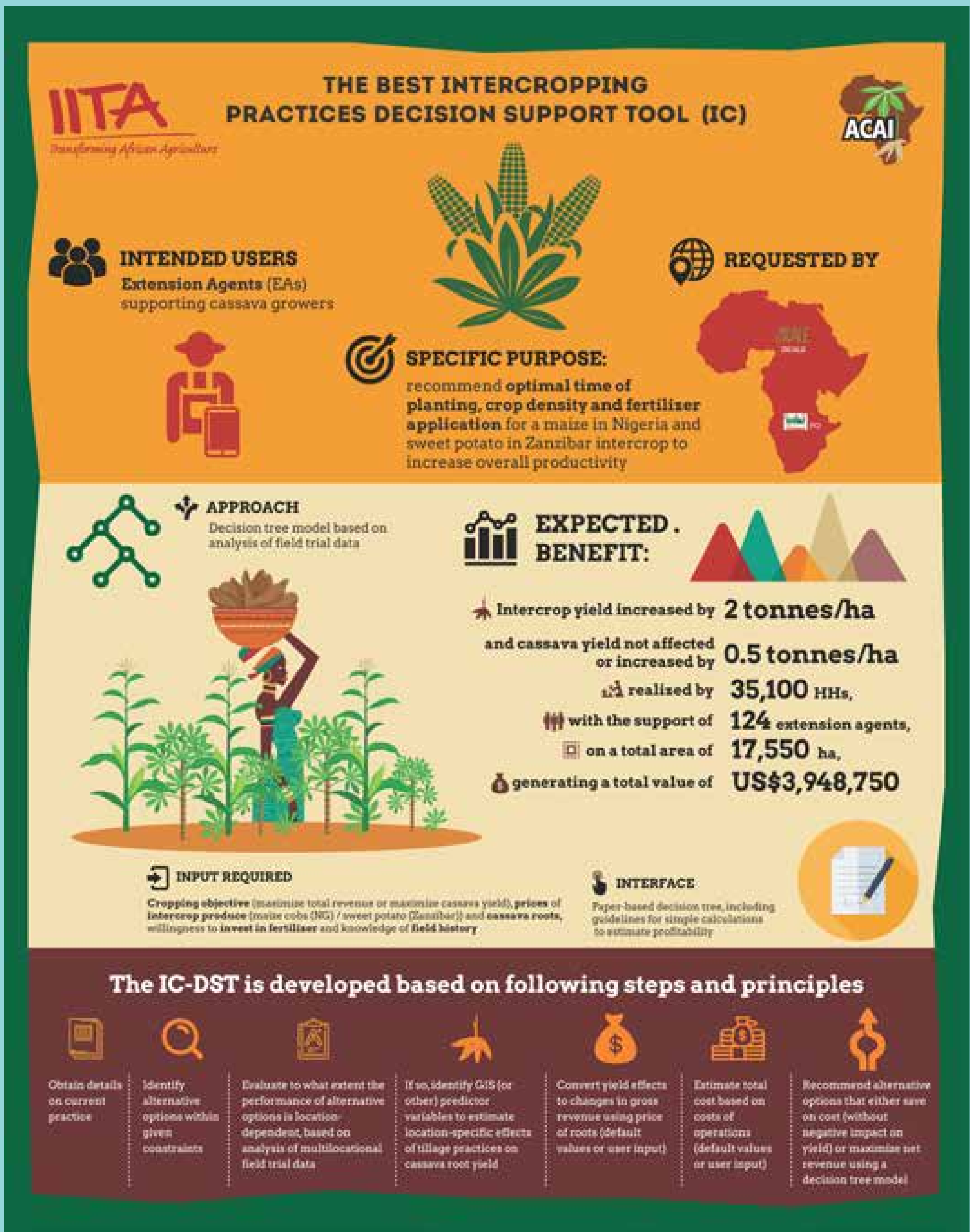
Cassava-sweet potato intercropping in Tanzania. The rapid characterization survey revealed that sweet potato is the most common intercrop in cassava systems on the Zanzibar islands. The development partner, FCI, aims to intensify this system to increase profitability and net income for smallholders. A total of 60 cassava/sweet potato trials were established in 2016 to evaluate various options, including increased planting density, delayed planting of sweet potato and fertilizer application, but erratic weather lead to loss of the sweet potato intercrop. Trials were repeated with 100 farmers in 2017, as well as on-station at the ARI stations on Unguja and Pemba islands. Results from the sweet potato harvest showed that increased sweet potato densities did not increase yields, on the contrary, highest yields were obtained with a low density of 10,000 plants ha^{-1}. A delay in planting of sweet potato (to favour the cassava crop) had minor to substantial negative impact on the sweet potato, depending on the date of planting. Delayed planting of sweet potato only appeared an option in cassava fields established early on in the rainy season. These results point in the direction of high competition between both crops (as expected) and need for judicious decision-making to maximize revenue.

After harvest of the cassava crop in 2018, impact on overall system productivity and profitability will be evaluated, and a first version of the decision support tool conceived (with likely a very similar structure as the maize intercropping tool in Nigeria).

Output 3.5: A Cassava – maize intercropping decision support tool for extension agents/farmers developed and validated in Nigeria

In 2016 and 2017, two sets of multi-location trials were planted in Anambra, Benue, Cross River, Ogun and Oyo states. The first set (CIM^{-2}) comprised the comparison of 3 stepwise intensification steps in 4 treatments: (i) low plant densities of cassava (10,000 plants ha^{-1}) and maize (20,000 plants ha^{-1}), (ii) high plant densities of cassava (12,500 plants ha-1) and maize (40,000 plants ha^{-1}), (iii) application of a fertilizer regime targeting the maize crop and (iv) application of a fertilizer regime targeting the cassava crop. For the maize fertilizer regime, we applied 90 kg N, 20 kg P and 37 kg K ha^{-1} as a basal application of the compound fertilizer NPK15:15:15 followed by two split applications of urea. The fertilizer regime for cassava comprised 75 kg N, 20 kg P and 90 kg K ha^{-1} equalling 50% of the full application amount in the NOT trials. Nutrients were applied as urea, TSP and MoP and application started at 3 weeks after planting followed by top dressings at 6, 10 and 16 weeks after planting. For the second set (CIM^{-3} and CIM^{-4}), planted in 2017, treatments were modified according to learnings from the CIM^{-2} trials: all plots were planted at high cassava density and fertilizer application at low maize plant densities was added to the treatments. The cassava fertilizer regime was amended by a basal urea application (15 kg N ha^{-1}) at planting of maize. Yield was determined as dry mature cobs in 2016. However, farmers prefer fresh maize cobs. In 2017, fresh cobs were harvested in 4 quality categories (unsuitable for use, small, medium and large-sized cobs).

Pairwise comparisons were done on 70 CIM^{-2} trials for their response of maize and cassava to stepwise intensification of planting density and fertilizer application. In about 80% of the cases, the higher maize planting density increased total cob numbers. Targeting fertilizer to the needs of maize increased cob numbers and cassava root yield in about 80% of the cases and this was not further improved by targeting fertilizer to the needs of cassava (Figure 17). There was no apparent relationship between cob numbers and cassava fresh root yield. Maize cobs were harvested from 89 CIM^{-3} and CIM^{-4} trials and segregated by quality in 2017. The higher planting density increased numbers of all marketable cobs but had no significant effect on the numbers of large cobs. Both fertilizer regimes (targeting maize or cassava) increased numbers of all marketable and large cobs in about 80 % of the cases. Nevertheless, the fertilizer regime that targets the maize still appeared superior.



The paper-based V_1 of the DST for cassava-maize intercropping recommends to plant cassava and maize at high density (12,500 and 40,000 plants ha^{-1}, respectively). Although fertilizer application generally increased maize cob yields and cassava root yields, economic returns on investment in fertilizer are not necessarily positive because yield responses were site-dependent and returns from the additional produce may not justify the cost of fertilizer. Therefore, we used the height of maize in the unfertilized high-density plots at tasselling as a predictor for response in large maize cob yield to fertilizer (large cobs fetch the highest prices and contribute most of the gross revenue) (Figure 18). In the DST (Figure 15), we use farmers' knowledge about their crops and ask for the height of last season's maize crop without fertilizer on the plot where he or she now wants to grow the cassava-maize intercrop. The final decision whether fertilizer application will be economic is then made by use of a look-up table which lists a range of expected fertilizer costs versus produce prices. This V_1 will be tested in 2018.

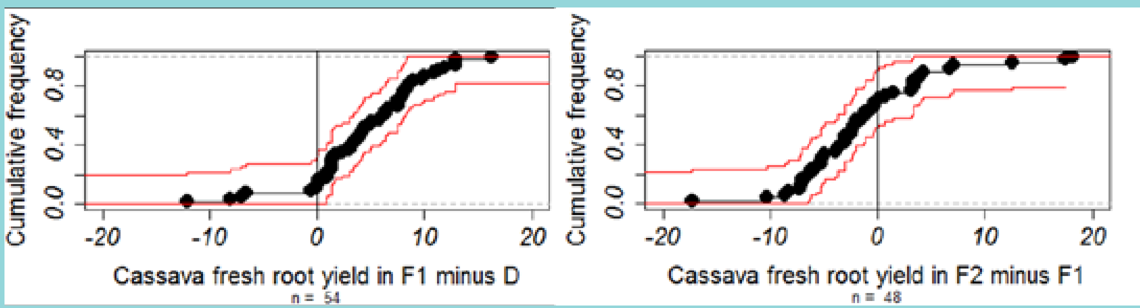


Figure 16 ***Pairwise comparison of cassava root yield from plots planted at high densities of cassava and maize with fertilizer application targeted at maize (F1) and from plots planted at high density of both crops without fertilizer application (D); expressed as cumulative frequency on the left. On the right, pairwise comparison of cassava root yield from plots planted at high density of cassava and maize with fertilizer application targeted at cassava (F2) and from plots planted at high density of both crops with fertilizer application targeted at maize (F1); expressed as cumulative frequency.***

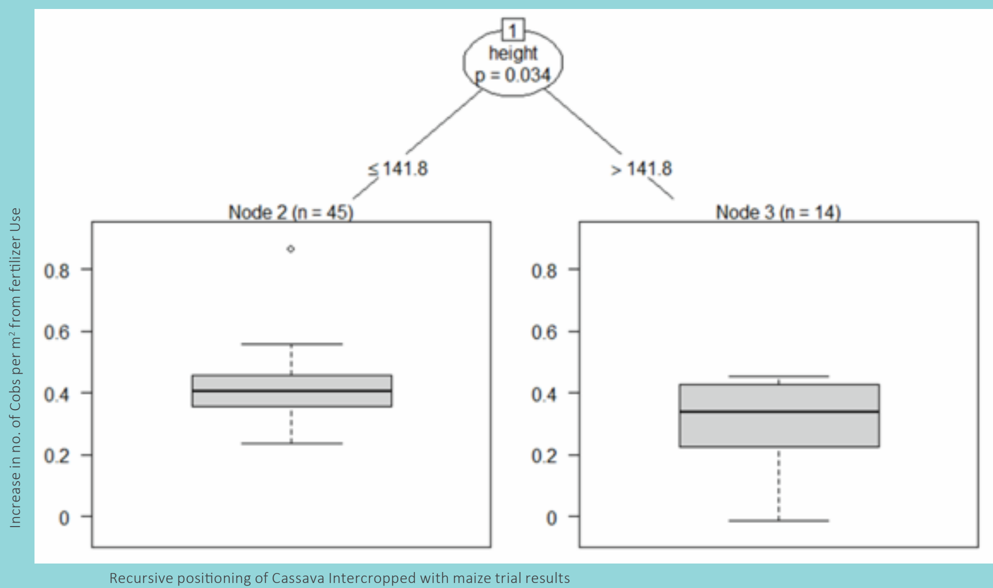
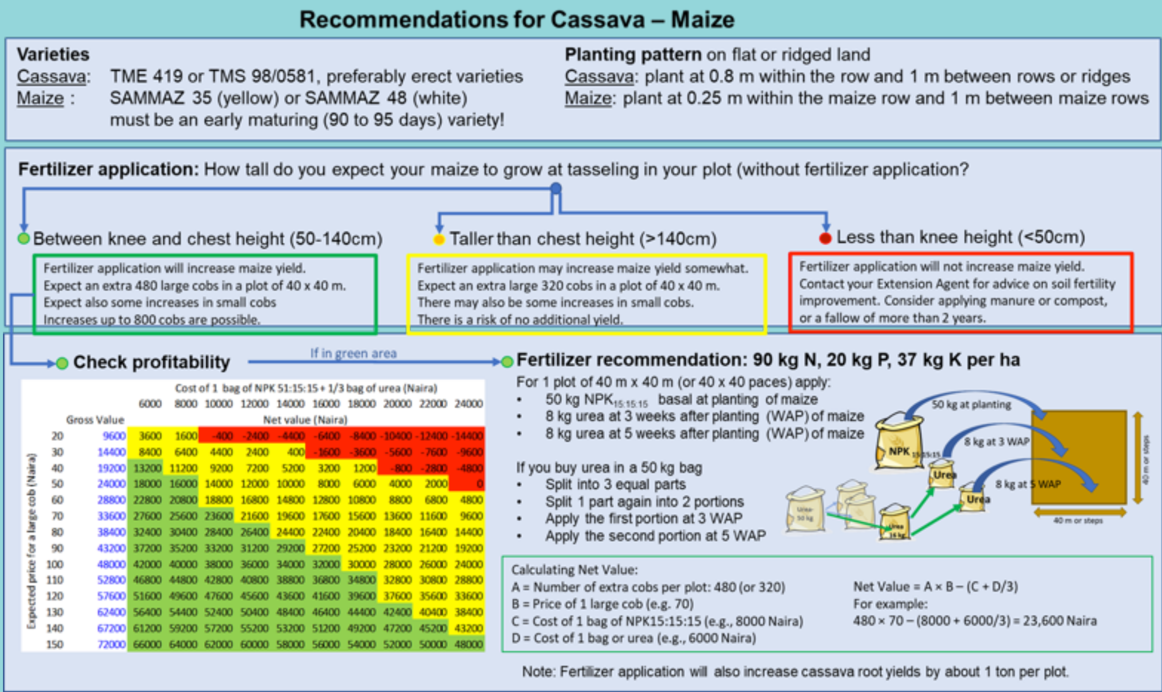


Figure 17 ***Fertilizer response as number of large maize cobs per M^2 in the CIM^{-3} and CIM^{-4} trials in 2017. The boxplot on the left shows the fertilizer response when the maize plants at tasselling in the neighbouring non-fertilized plot were smaller than 142 cm, the boxplot on the right shows the response when these maize plants were taller than 142 cm.***

In 2018, after the harvest of cassava in the CIM-3 and CIM-4 trials, we will verify whether the fertilizer regime that targets the maize crop remains superior and whether the height of the previous season maize crop as indicator for fertilizer application is indeed valid in the on-farm validation trials of the V_1. In 2016 (CIM-2), there was no apparent negative effect of increasing cob numbers on cassava root yield. However, this may have been a consequence of relatively low maize yields of the early maturing maize varieties in that year. Data on fertilizer response in 2017/18 and compatibility of the two crops will be included into the V_2 of the IC DST. The tested fertilizer regimes are currently blanket rates. In 2018, we will explore options to make these rates site-specific by integrating information from the FR use case and possibly use the QUEFTS framework developed for maize based on learnings from TAMASA.



Expected price for a large cob (Naira)	Gross Value	Cost of 1 bag of NPK 51:15:15 + 1/3 bag of urea (Naira): 6000	8000	10000	12000	14000	16000	18000	20000	22000	24000
		Net value (Naira)									
20	9600	3600	1600	-400	-2400	-4400	-6400	-8400	-10400	-12400	-14400
30	14400	8400	6400	4400	2400	400	-1600	-3600	-5600	-7600	-9600
40	19200	13200	11200	9200	7200	5200	3200	1200	-800	-2800	-4800
50	24000	18000	16000	14000	12000	10000	8000	6000	4000	2000	0
60	28800	22800	20800	18800	16800	14800	12800	10800	8800	6800	4800
70	33600	27600	25600	23600	21600	19600	17600	15600	13600	11600	9600
80	38400	32400	30400	28400	26400	24400	22400	20400	18400	16400	14400
90	43200	37200	35200	33200	31200	29200	27200	25200	23200	21200	19200
100	48000	42000	40000	38000	36000	34000	32000	30000	28000	26000	24000
110	52800	46800	44800	42800	40800	38800	36800	34800	32800	30800	28800
120	57600	51600	49600	47600	45600	43600	41600	39600	37600	35600	33600
130	62400	56400	54400	52400	50400	48400	46400	44400	42400	40400	38400
140	67200	61200	59200	57200	55200	53200	51200	49200	47200	45200	43200
150	72000	66000	64000	62000	60000	58000	56000	54000	52000	50000	48000

Figure 18 ***Version 1 of the DST for cassava-maize intercropping with a blanket recommendation for erect cassava varieties, early maturing maize varieties and planting of both crops at high densities. Whether fertilizer application (targeting the maize crop) can be expected to be profitable depends on the height of the maize crop at tasselling in the previous season (without fertilizer application). If the maize was between knee and chest height, the farmer is encouraged to check the profitability in the look-up table that lists a range of fertilizer costs and expected maize cob prices. Areas highlighted in green indicate that additional income from the sale of additional maize cobs is at least twice the cost of fertilizer. If the expected net returns fall in this green area, the investment is considered safe. In the yellow area, the risk increases, and in the red area, the economic net returns are zero or negative. All calculations are based on a hypothetical plot size of 40 x 40 m.***

Output 3.6 & 3.7: A scheduled planting and High Starch Content decision support tool for farmers supplying the processing sector developed and validated

The Scheduled Planting and High Starch tools covers two ACAI use cases, being a decision support tool enabling EAs and development workers to recommend best timing of planting and harvest to cassava growers supplying roots to processors. The tool enables cassava growers to choose planting and harvest date in order to maximize gross revenue, and cassava processors to set prices for cassava produce to attract growers to produce roots during periods of scarcity, to enable a more continuous supply of roots for processing.

The LINTUL and QUEFTS frameworks were used to calculate water- and nutrient-limited yields for all combinations of planting date (in weekly time steps across the planting window) and harvest date (in weekly time steps covering a period of 8 to 12 months after planting), for every pixel of 2.5 x 2.5 km across the target intervention area of the development partners requesting the tool (Psaltry/2SCALE, Niji and CAVA-II in Nigeria, and CAVA-II and FJS in Tanzania). These yields are stored within an ODK form. The user records GPS coordination and provides the intended planting and harvest date. The tool then retrieves the yields in this location in a 1-2 months window around the proposed planting and harvest date. The user also provides expected price variations of fresh roots across the harvest window, or the price categories if the price is set according to starch content when selling to a starch factory. The tool then provides the planting and harvest date on which total revenue is highest.

Dennis Ndare, ACAI MSc student, collecting crop data in Butiama district, Bunda, Lake Zone, Tanzania.

The tool combines data obtained from scheduled planting trials, evaluating the impact of planting and harvest date on root and starch yield for selected improved varieties, and insights in how agronomic practices (particularly date of harvest) influences cassava root starch content (see WS1). A total of 17 scheduled planting trials were established in 2016 in Nigeria (4) and Tanzania (13). In 2017, and additional 10 trials were established in Nigeria. Results from the trials are primarily used to calibrate and validate the cassava growth models, predicting root yield as affected by soil and weather conditions during the growth period. In addition, observational studies within cassava fields planted across the year (especially with Niji and Psaltry) are being carried out to as a means to validating these models, and better predict the impact of planting and harvest date on root and starch yield.

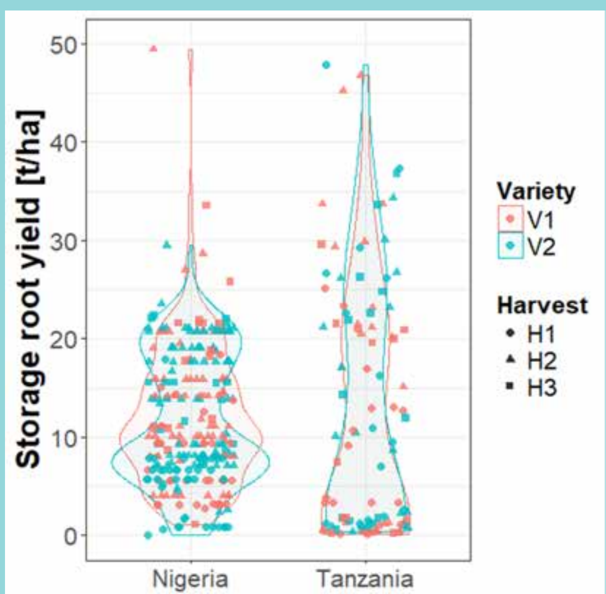
In 2018, field trial results will be used to further refine the models, and to compare model performance of the LINTUL and DSSAT frameworks. New insights into the impact of rainfall on cassava root starch will be integrated to better predict starch yields. Also, common price variations observed across the harvest window will be provided as default values (using the price information gathered through the baseline survey). Finally, possibilities to use actual rainfall received (for a crop currently in the field), rather than average rainfall (from historical) data will be explored, as well as possibilities to present risk and uncertainty associated with the recommendations due to erratic rainfall.

Output 3.6 & 3.7: A scheduled planting and High Starch Content decision support tool for farmers supplying the processing sector developed and validated

The Scheduled Planting and High Starch tool covers two ACAI use cases, being a decision support tool enabling EAs and development workers to recommend best timing of planting and harvest to cassava growers supplying roots to processors. The tool enables cassava growers to choose planting and harvest date in order to maximize gross revenue, and cassava processors to set prices for cassava produce to attract growers to produce roots during periods of scarcity, to enable a more continuous supply of roots for processing.

The tool is based on the LINTUL and QUEFTS modelling framework to calculate water-limited and nutrient-limited yields for each combination of planting date (in weekly intervals across the planting window, as observed during the rapid characterization survey) and harvest date (in weekly intervals for 8 – 12 months after planting) in each pixel of 2.5 x 2.5 km across the target intervention area of the target partners (Psaltry/2SCALE, Niji and CAVA-II in Nigeria, and CAVA-II and FJS in Tanzania), clipped using a crop mask GIS layer.

Data from the Scheduled Planting Trials were used to calibrate the LINTUL framework (see output 1.4). A total of 17 scheduled planting trials were established in 2016 in Nigeria (4) and Tanzania (13). In 2017, MLTs (7) and RMTs (3) were established in Nigeria in 2017. Currently available data shows large variation in root yields, and a variance component analysis indicates that this variability is mostly related to environmental conditions (rainfall, soil) and planting date (and to some extent management, though as much as possible standardized) (Fig. 20). Harvest age and variety contribute relatively much less, but can nevertheless be important, especially within a given agro-ecology to optimize crop yield.



Large variation in root yield (13.6 ± 94%)!

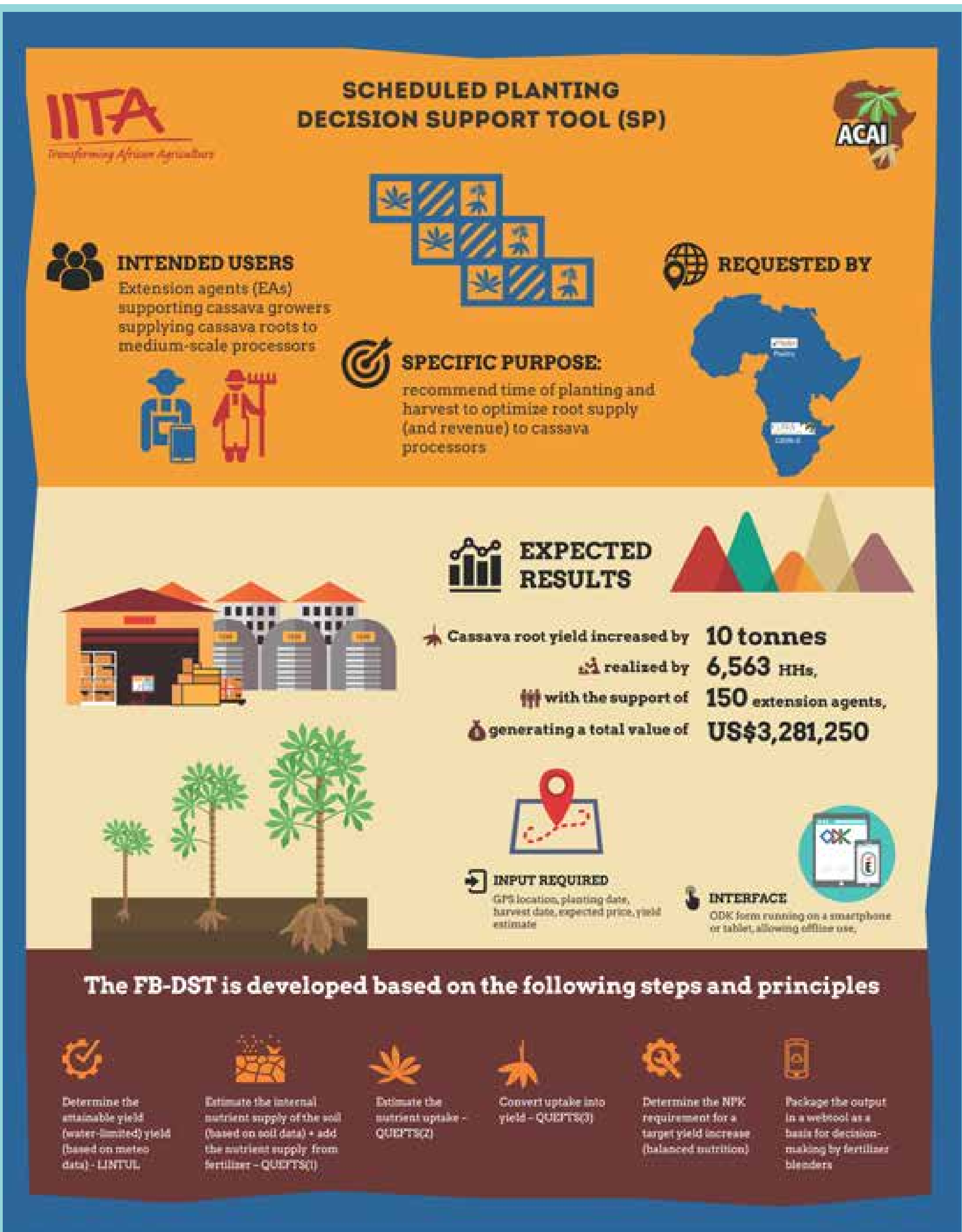
54% of total variance explained by:

Variety:	**6%**
Harvest age:	**9%**
Trial (planting date, management):	**36%**
Field (agro-ecology, soil,…):	**49%**

```
Analysis of Variance Table
                  Pr(>F)
Harvest           0.0001029 ***
Variety           0.8892715
country           0.5138284
Harvest:Variety   0.4631400
Harvest:country   0.0323079 *
Variety:country   0.0185752 *
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05
```

Figure 19 ***Storage root variation and variance component analysis on the yield data obtained from the Scheduled Planting Trials across Nigeria and Tanzania, with varying planting date, harvest age (H1, H2, H3 = harvest after 8, 10 and 12 months, respectively) and variety planted (V_1 = most common improved variety, V_2 = alternative improved variety – varieties differ between countries and agro-ecology within country).***

The water- and nutrient-limited yields obtained from the LINTUL and QUEFTS model runs were packaged within an ODK form (Fig. 21), which requests the user to propose a planting and harvest date, and a window of 1 or 2 months around which (s)he wishes to evaluate variations in planting and harvest date. The tool also records the GPS location, and then retrieves the simulated yields for this location and variation in planting and harvest date. Using a set of pictures of various root sizes, the user is asked what yield (s)he commonly obtains, as a means to scale and calculate the actual yields, confined between the nutrient-limited and water-limited yield. Subsequently, the user is asked whether (s)he markets the roots to a processor who pays for the roots according to starch content, or according to



weight of fresh roots. In the former case, the user is required to enter the price categories according to starch content, while in the latter case, the user is required to provide the root unit price variation around the intended harvest date. The tool then calculates gross revenue across the planting window, either using knowledge on variation in starch content (see output 1.6) or the price variations provided by the user, and recommends the planting and harvest date that is expected to result in the highest gross revenue.

To improve the dataset for the development of the decision support tools, MoUs have been signed with Psaltry and NIJI farms and processing factories. Past production data was obtained from these processing factories giving us more information on planting dates, starch contents and prices, which will be further analysed and used to improve the decision support tool. Currently ACAI has an SOP to obtain additional data on planting dates, harvest dates and starch content throughout the year from a number of farms not directly related to the ACAI research activities. These are major opportunities that will expand the knowledge base to develop the tool. At the same time, efforts in the trials will focus on improving the parametrization of the cassava growth models. In addition, price data (geo-referenced, varying across the year and by market type and produce volume) will be obtained through the baseline and built-in as default values (while leaving the option for users to specify the prices for their specific conditions). In 2018, the existing tool will be validated through validation exercises with side-by-side comparisons of two harvest dates, with a large number of volunteer farmers who planted cassava across the entire planting window.

Safia Shabaan Mohamed is one of the first cassava growers to express interest in working with ACAI on Pemba Island , Tanzania.

Output 3.8: A specific decision support tools and applications developed within the context of cassava value chain initiatives managed by partners in Ghana, Uganda and DR Congo

At the end of year 1, a decision was made to postpone identification of partners and use cases to 2019, and start activities in 2020, focusing purely on the groundwork, validation and adaptation of the existing tools. No new tools will be developed; rather, exercises will be carried out to identify, based on the experiences in Nigeria and Tanzania, what data and activities are necessary to adapt the tools to new areas (including the costing), and opportunities to accelerate the validation and adaptation of the tools to new areas will be explored and documented (see ACAI 2016 annual report).

Members of the Mitakawani Imara Women group in Zanzibar, Tanzania are partnering with ACAI to run trials on improved prediction for cassava intercropped with sweet potatoes.

WORK STREAM 4: FACILITATION OF THE USE OF DECISION SUPPORT TOOLS TO PRIMARY AND OTHER DEVELOPMENT INITIATIVES

OUTPUT 4.1

Grass root events organized around decision support tools and applications

OUTPUT 4.2

Farmer-friendly training videos and fact sheets developed and tested for efficiency

OUTPUT 4.3

Capacity of extension agents and last-mile delivery partners developed to use the decision support tools and applications and convey relevant information to farming households

OUTPUT 4.4

Awareness of ACAI DSTs created, and applications implemented in the target countries beyond the primary partners and their target areas

OUTPUT 4.5

Cassava clusters established with engagement of all major stakeholders operating within cassava value chains in the target countries

Developing tools based on specific partner demands is no guarantee for these to be used effectively by EAs engaging with cassava growers. WS4 aims at facilitating the use of the decision support tools within the dissemination networks of primary partners and beyond. Specific attention will be given to the direct engagement of women farmers and EAs. All outputs are related to the dissemination of tools, after these have been validated (i.e., after V2 has been delivered and validation exercises have been carried out under WS3 in 2018). Most WS4 activities will therefore only start in 2019 (year 4). The activities with primary partners contribute (similarly as WS3 activities) to IO 1.3: ***By 2018, cassava agronomy decision support tools are used by primary partners with target smallholder farmers.*** In addition, it is also important to create awareness around the tools beyond the primary partners directly engaged in project activities.

Activities in WS4 also contribute to IO 2.1: **By 2019, new partners/ initiatives are actively working with the project to adapt the decision support tools to their own needs.** This outcome is primarily covered through the cassava clusters, led by Centre for Agriculture and Bioscience International (CABI). To support this further, the core team met in Ibadan, Nigeria to discuss approaches, tools and strategies that can support scaling in ACAI. The workshop, held 24-25 April 2017, brought together ACAI and Scaling Readiness teams who both seek to support scaling of research products. The scaling readiness project is an Earmarked Funded project under RTB Cluster 5.4 and is implemented by Wageningen University, IITA, Bioversity International, CIAT and the International Potato Center (CIP), and aims to develop an approach that will accelerate the scaling of innovations in the CGIAR

Research Program on Roots, Tubers and Bananas (RTB). ACAI has been selected as one of the four projects that the Scaling Readiness team will collaborate with in supporting developing and scaling innovations, through network analysis on best partnerships, identification of bottlenecks for scaling and designing strategies to enhance the use of innovations. The workshop provided a forum for the Scaling Readiness team to test their toolset and for ACAI to reflect on the decision-making and investments in the project's scaling strategy.

Output 4.1: Grass root events organized around decision support tools and applications

This is an output to be delivered in year 4.

Output 4.2: Farmer-friendly training videos and fact sheets developed and tested for efficiency

This is an output to be delivered in year 4.

Output 4.3: Capacity of extension agents and last-mile delivery partners developed to use the decision support tools and applications and convey relevant information to farming households

This is an output to be delivered in year 4.

Output 4.4: Awareness of ACAI DSTs created and applications implemented in the target countries beyond the primary partners and their target areas

This is an output to be delivered in year 4.

Dr. Jacob Olalekan Olaoye from FUNAAB with Abdulsamad Adenle, a farmer at one of the ACAI trials in Alabata, Ogun State, Nigeria.

Rebecca Enesi, conducting a training with MSc Students in the presence of the current Vice Chancellor Prof Felix Salako,at the Federal University of Agriculture, Abeokuta, in Ogun State, Nigeria.

Output 4.5: Cassava clusters established with engagement of all major stakeholders operating within cassava value chains in the target countries

Milestone 1: Cassava clusters established in Nigeria and Tanzania

The Centre for Agricultural Biosciences International (CABI) worked with the ACAI implementation team to hold the 2nd cassava value chain cluster meeting in Tanzania in June 2017. The meeting was held linked to the annual planning meeting for Tanzania and brought together 36 representatives from different organizations (i) to review ongoing and past work on cassava information packaging and dissemination across the value chain, (ii) to identify critical gaps in knowledge, products and information, appropriate dissemination pathways and key dissemination partners (and their geographical spread), and (iii) to develop roadmaps to support scaling up cassava information in Tanzania. The meeting also discussed and agreed on general activity areas for value chain clusters to focus on in 2018, and to hold the next value chain actors cluster meeting in Tanzania and Nigeria. The meeting facilitated mobilizing partners and mapping the potential reach through the process of promoting the use of ACAI decision support tools by new partners.

Throughout 2017, CABI also conducted a literature survey of the cassava value chain in Nigeria to establish information needs and sources that can facilitate mapping all processes involved from cassava production to consumption, assessing the roles and functions of the actors and their linkages and relationships, and identifying the weaknesses and improvement opportunities along the chain. This included identification of appropriate information dissemination pathways, packaging and key dissemination partners including input dealers for fertilizer. The survey also highlighted factors that influence value chain actors and critical gaps in knowledge products and information.

A draft data collection tool was also developed to guide the process of a field study whose findings would ensure that information is more equitably spread among farming households and all the other cassava value chain actors for improved cassava productivity, processing and marketing. The tool will be used to plan and undertake field data collection for Nigeria and Tanzania value chains in 2018.

IITA's field technitian displays ACAI cassava roots harvested at IITA trials in Ibadan , Nigeria.

WORK STREAM 5: CAPACITY DEVELOPMENT OF NATIONAL INSTITUTIONS TO ENGAGE IN TRANSFORMATIVE CASSAVA AGRONOMY R4D

OUTPUT 5.1

Capacity of research institutions to conduct effective Cassava agronomy research enhanced

OUTPUT 5.2

Institutions capacity to develop and manage standardized databases enhanced

OUTPUT 5.3

Skills in geospatial data analysis among institutions enhanced in coordination with AfSIS

OUTPUT 5.4

Strengthened capacity of national research institutions and primary development partner organizations in project management

OUTPUT 5.5

Standardized soil and plant analytical laboratories network including standard operating procedures to support cassava agronomy established

WS5 aims at institutionalizing new approaches for cassava agronomy within the national research systems and will be led by the project management team with direct engagement of the NARS scientists and other research partners. The aim of WS5 activities is to strengthen the capacity of NARS scientists to be able to participate in and independently conduct transformative agronomic research, and to enable these scientists to apply and integrate principles of agronomy at scale within their own initiatives and projects other than ACAI. These capacities not only focus on agronomy know-how, but also on aspects of data management, GIS and geospatial statistics, crop modelling and laboratory capacity for soil and plant analyses.

WS5 contributes to IO 3.1 of the project: ***By 2019 at least 5 scientists per national system have been leading the implementation of activities within the context of this initiative***.

Implementation of research activities in both Nigeria and Tanzania is led by NARS partners. In 2017, a total of 14 researchers are involved in the coordination of these activities. The key scientists directly leading the ACAI activities in Tanzania are Dr Geoffrey Mkamilo and Dr Peter Deusdeit Mlay both at the Agricultural Research Institute of Tanzania, while in Nigeria, Professor Felix Salako leads the team at the Federal University of Agriculture in Abeokuta (FUNAAB) together with Dr Mutiu Busari, while Dr Adeyemi Olojede leads the team at the National Roots Crop Research Institute (NRCRI). In each organization, local coordinators or representatives are assigned to supervise activities in the different zones (Tanzania) or functional areas (Nigeria), reporting to the lead scientists.

As part of the capacity building efforts, ACAI supports a total of 8 PhD projects and 13 MSc projects, fully integrated within the development of the use case tools.

Habai Rafael Masunga, Male, Tanzania

PhD KU Leuven, Belgium

Establishment of Nutrient Norms to Improve Cassava Yield and Quality

Objectives:

- Establish nutrient norms for cassava using DRIS and CND tools and use them to develop suitable fertilizer blending and recommendations.
- Evaluate the growth and yield response of cassava to mineral fertilizers across variable agro-ecologies in Tanzania and Nigeria in relation to local soil fertility levels.
- Assess the contribution of N and K nutrients under different rainfall patterns to cassava root bulking in order to time and optimize their applications for improved overall cassava yield.
- Determine the economic use of fertilizers to smallholder farmers in order to facilitate adoption for increased cassava root yield and profitability.

Onasanya Olabisi Omolara, Female, Nigeria

PhD, ETH Zurich, Switzerland

Evaluation of tillage practices and intensity on growth, yield of cassava and physical properties of soils in South Western Nigeria

Research questions:

- Does tillage intensification, fertilisation and higher planting density produce maximum cassava root yields?
- Does tillage intensification improve soil aggregate stability and are these related to cassava yield?
- What is the effect of tillage intensification on soil water dynamics?

Joy Adiele, Female, Nigeria,

PhD, Wageningen University, Netherlands

Improved crop management systems for sustainable cassava production in sub-Saharan Africa

Objectives:

- Understanding the yield capacity and the dynamic aspects of nutrient limitations in relation to water availability,
- Providing insight and theoretical understanding of the responses to fertilizers in a wide range of agro-ecological zones.

Thanni Bolaji M, Female, Nigeria

PhD, Federal University of Agriculture in Abeokuta (FUNAAB)

Evaluating effects of improved planting practices on soil nutrient dynamics and associated organisms under cassava production

Objectives:

- Determine the response of cassava yield and growth to individual and combined effect of tillage and fertilizer application.
- Evaluate the effect of split fertilizer application on nutrient uptake of cassava under two tillage regimes.
- Determine the effect of tillage on NPK dynamics in soils cultivated to cassava .
- Evaluate the effect of tillage and herbicides application on the diversity of major soil key players in N, P and K dynamics in the soil

Thanni Bolaji is a PhD candidate at the Federal University of Agriculture in Abeokuta, Ogun State, Nigeria.

Charles Nwokoro, Male, Nigeria

PhD, ETH Zurich, Switzerland

Improved cassava-maize intercropping system for sustainable cassava and maize production in Nigeria.

Objectives:

- Evaluate the effect of split application of various rates of mineral fertilizer nutrients (N:P:K) on the emergence, growth and development of cassava and maize;
- Evaluate the effect of plant population mixtures of cassava and 20,000 on light interception and microclimate improvement
- Determine the effect of fertilization and cassava genotype interaction on the yield of cassava and maize in cassava-maize intercropping system in six contrasting environments in Nigeria

Jeremiah Kabissa, Male, Tanzania

PhD KU Leuven, Belgium

Evaluating uptake of improved agronomic practices provided through decision support tools

Objectives: [to be developed]

A section of ACAI PhD students with their supervisors at the ACAI Annual Review meeting in Mwanza Tanzania

Patricia Moreno, Female, Colombia

PhD, Universtity of Florida, USA

Developing the DSSAT growth model for cassava under African conditions

- Understand the dynamics and mechanisms of modeling the dry matter distribution and starch content in cassava and other storage crops.
- Determine the relationships between starch and dry matter accumulation with environmental and management variables in cassava.
- Develop a module that simulates the dynamics of dry matter and starch content for cassava as a function of environmental variables and management
- Identify best management practices for small-holder farmers in East and West Africa that optimize dry matter and starch content in cassava

Rebecca Enesi Oiza, Female, Nigeria

PhD, ETH Zurich, Switzerland

Enabling sustainable cassava starch yield increase through scheduled planting/harvesting, appropriate smallholder mechanization, and the use of decision support tools

Objectives:

- Improve our understanding of the effects of an expanded range of planting plus harvest dates, fertilizer rates (with focus on K) on storage root yield and starch content of cassava.
- Assess the suitability and profitability of simple, available mechanization approaches for harvesting in dry soil conditions and improve the tools where required to recommend scale-dependent best harvest tools.
- Based on results from the previous objectives, in collaboration with ACAI, develop and validate a Decision Support Tool (DST) on scheduled planting / harvesting and corresponding fertilizer rates, to provide recommendations to smallholders to increase production, spread labour and stabilize an increased income across the year

Table 4. ACAI supported MSc students

	TANZANIA			
Name	**Gender**	**Institution**	**Use case**	**Thesis title**
Dennis Ndare	M	MSc, SUA	FR/FB	Effects of fertilizer applications on the growth, yields and quality of cassava in the lake zone of Tanzania
Ally Hamad Ally	M	MSc, SUA	IC	Productivity of cassava intercropped with sweet potato in Zanzibar, Tanzania
Festo Frank	M	MSc, SUA	SP/HS	Optimizing root and starch yield of cassava through scheduled planting in Tanzania.
Jonas Van Laere	M	MSc, KU Leuven	FR/FB	Nutrient norms for cassava using DRIS and CND to diagnose nutrient deficiencies in Tanzania
Yassin Mashuub	M	MSc, SUA	SP/FR	Evaluating yield increases and profitability of recommendations supplied through decision support tools in on-farm validation exercises
Victoria Morungu	F	MSc, SUA	Cross-cutting	Changes in knowledge, attitude, behaviour and practices of extension agents exposed to decision support tools on various improved agronomic practices for cassava production
Francisca Gwandu	F	MSc, SUA	Cross-cutting	Rapid yield assessment of cassava yields in farmers' fields
	NIGERIA			
Blessing Afolake Oyebade	F	MSc, (FUNAAB)	FR/FB	Effect of fertilizer types on soil chemical properties, cassava performance and root qualities in some south west Nigerian soils.
Sunday Olayinka Akinsumbo	M	MSc, (FUNAAB)	BPP	Farmers perception and quantitative assessment of soil conservation practices towards improving cassava production in South-West Nigeria.
Olewasegun Emmanuel Adebayo	M	MSc, (FUNAAB)	SP/HS	Effects of sequential planting and harvesting of cassava on aggregate stability and chemical properties of South Western Nigeria soils
Olarewaju Hameed Olongude	M	MSc, (FUNAAB)	SP/HS	Title: Effect of schedule planting and harvesting dates on soil physical properties, yield parameters and starch content of cassava.
Shola Ejalonibu	M	MSc, University of Ilorin	IC	Evaluation of cassava productivity under contrasting plant densities in cassava/maize intercrop.
Rob Vanden Beuken	M	MSc, WUR	FR/FB	Water Availability and Potassium Uptake of Cassava

Output 5.1: Capacity of research institutions to conduct effective Cassava agronomy research enhanced

A total of 139 (75 in Nigeria, 64 in Tanzania) persons of which 95 are male and 44 are female have been trained in various aspects of agronomy research. The participants were mainly researchers from National Root Crops Research Institute (NRCRI), the Federal University of Agriculture Abeokuta (FUNAAB), and International Institute of Tropical Agriculture IITA in Nigeria, and Agricultural Research Institute (ARI), and Zanzibar Agricultural Research institute (ZARI) in Tanzania, and some staff of ACAI development partners who are leading key activities of ACAI in their respective countries. This was achieved through a total of seven trainings sessions (four in Nigeria, three in Tanzania). Key areas covered in the trainings were harvesting procedures (for both cassava and intercrops), weed management for improving cassava productivity, use of digital data collection tools, soil and plant sampling, etc. The training workshops employed both plenary presentations and hands-on practical sessions which facilitated use of the skills by participants.

Output 5.2: Institutions capacity to develop and manage standardized databases enhanced

Two training workshops (one in each country) on database management have been held in Nigeria and Tanzania. A total of 46 participants (31 in Nigeria, and 15 in Tanzania) that consisted of 33 male and 13 female were trained in the workshops. The training workshops provided participants with knowledge and skills on how to use new ODK tools to collect data and upload on the project's platform, as well as the use of barcode labels to identify various entities (plants, plots, fields, samples,) in field activities, as well as the basics of statistical data analysis, using the data generated on the data platforms. These training workshops were follow-up sessions to the training organized in 2016 in which the partner institutions were taught how to electronically record data using ODK, processing data for analysis, and how to use standardized data collection tools to streamline storage and processing of data. Evaluations after the training workshops revealed that participants had increased capacity in managing, storing and accessing data. These trainings are generally very well received, and participants testified they are now using the skills acquired to collect and upload relevant project data with higher efficiency, speed and accuracy.

Output 5.3: Skills in geospatial data analysis among institutions enhanced in coordination with AfSIS

This training was postponed to 2018 to allow a more focused approach, training selected NARS scientists with basic skills in GIS and statistics. The training will be organized through supervised, on-the-job learning, and fully integrating these researchers into the geospatial modelling and validation activities which will be conducted in 2018 (rather than through classroom-type training).

Output 5.4: Strengthened capacity of national research institutions and primary development partner organizations in project management

A training was organized in both countries in 2016 (see annual report 2016). Further capacity building is done through on-the-job training, through regular interaction between IITA project management staff and key staff in the respective national research institutes, focusing on key aspects of project implementation, leadership and financial management to ensure timely, transparent and accurate reporting following to agreed guidelines.

Output 5.5: Standardized soil and plant analytical laboratories network including standard operating procedures to support cassava agronomy established

A total of 26 participants (16 in Nigeria and 10 in Tanzania) with 46% female participation were trained on standardized collection of soil and plant samples. The training workshops equipped the participants with enhanced knowledge and skills that enable them to execute procedures exactly as prescribed by standard protocols. The participants were from National Root Crops Research Institute (NRCRI), the Federal University of Agriculture Abeokuta (FUNAAB), and International Institute of Tropical Agriculture IITA in Nigeria, and Agricultural Research Institute (ARI), and Zanzibar Agricultural Research institute (ZARI) in Tanzania. The topics covered during the training were soil and plant sampling representativeness, soil and plant sample handling, preparation, labelling (including the use of barcodes) and storage, soil sampling, and also included practical sessions with augers and cores in small groups, the use of diagnostic instruments for assessing soil fertility, as well as lab procedures to determine moisture content, correct weighing of samples, and recording data.

Dr. Meklit Chernet, ACAI Data Scientist demostrating data analysis used in the crop growth modelling framework.

WORK STREAM 6: PROJECT GOVERNANCE, MANAGEMENT, COORDINATION AND ME&L

OUTPUT 6.1

Project staff and capital equipment available

OUTPUT 6.2

A technical and financial reporting framework available

OUTPUT 6.3

A gender-inclusive ME&L framework operationalized

OUTPUT 6.4

Yearly and seasonal planning and Scientific Advisory Committee meetings held

OUTPUT 6.5

An effective communication strategy fast-tracking the awareness and use of the decision support tools

WS6 will ensure that (i) the project is planned well, (ii) technical and financial reports are delivered in time, (iii) appropriate ME&L and communication channels are put in place and (iv) governance and decision-making processes are functional. A multi-locational, multi-partner, gender-inclusive initiative like ACAI requires proper reporting and ME&L tools to ensure consistency of project implementation and reporting as well as cross-learning between target countries. Various tools and strategies have been put in place to ensure smooth operations.

Output 6.1: Project staff and capital equipment available

The full complement of designated positions in the project has been filled. Recruitments in 2017 included the Communication Officer, ME&L Assistant, and the Data Scientist who joined the team in April, July and August respectively. The Project coordinator, Dr. Abdulai Jalloh, will be leaving IITA on 31st December and this necessitates a re-organization of the project's organization structure. A draft organogram (attached) has been developed for discussions and approval with BMGF before implementation in January 2018.

All capital equipment was purchased in 2016.

Output 6.2: A technical and financial reporting framework available

This was adopted from the Institute's technical and financial reporting system and has been used by partners to report. In addition, the project has developed an Annual Work Plan and Budget framework for partners. This framework is based on the project's Work Stream and the donor's budget lines. Partners have been trained to operate these frameworks (see ACAI 2016 annual report).

ACAI PROJECT MANAGEMENT TEAM (IITA)

Output 6.3: A gender-inclusive ME&L framework operationalized

The smooth implementation of the ME&L plan requires regular revision and update with feedback. The results tracker, which measures the project progress has been reviewed to ensure SMART indicators for the measurement of results. Based on the updated indicator matrix, new indicators have been defined in addition to the existing indicators in the results tracker which provide broader information and support measurement of targets/ progress.

The indicator matrix is currently being used for reporting and to update a semi-automated system for analysis and reporting in a framework developed in R-Shiny (https://acai.shinyapps.io/me-l/). The shiny dashboard requires a series of tools for data collection that ensure that all the information on the project milestone is captured in same manner (sources, frequency, and methodology as stated in the ME&L framework). To this effect, a set of data collection tools have been developed and aligned to the data matrix (although not fully functional yet to allow near-real time reporting). These tools include (i) Training tool (which is being used to collect information on all the trainings being conducted under ACAI project), (ii) WS leader tool (to collect information from WS leaders pertaining to overall WS progress against targets), (iii) Development partners tool (to collect data from development partners on their dissemination approach, specific use cases, engagement with EAs, farmers reached, etc.), EAs panel survey tool (to collect knowledge, attitude, behaviour and practices of the EAs on yearly basis). A HH panel survey tool is being developed (extracted from baseline questions) and will be used to collect annual information from farmers related to outcomes of the project. The above tools have been developed as ODK tools and accessible as webforms or on smart devices to facilitate data transmission. The information contained in the data matrix is more detailed than the Result Tracker (hence requires aggregation for reporting) but enables more in-depth tracking of progress and better insights for learning and adjusting project implementation strategies.

ACAI has introduced ID cards to standardize data collection of and by extension agents and households as well as foster collaboration in the project.

Output 6.4: Yearly and seasonal planning and Scientific Advisory Committee meetings held

The project has held monthly PMT meetings, each last Friday of the month. Country-level planning meetings were held in Nigeria (February 2017) and Tanzania (June 2017). The virtual PAC meeting was held in June 2017, and the in-person PAC meeting was held on 14 December, along with the annual review meeting in Mwanza, Tanzania on 11-15 December 2017. A detailed report of the annual review meeting can be found at (http://acai-project.org/organizations-events/). In addition, several in-country local meetings, usually around specific activities or field monitoring missions, and monthly virtual meetings have been held.

The project team has adopted the ASANA (www.asana.com) project management tool to facilitate coordination and communication. The tool is easy to use with a short learning curve which has made it possible for all team members to easily understand and use it. It allows team conversation in addition to enabling tracking of tasks with dashboards for quick review of status. The tool is increasingly enhancing collaboration among team members.

ACAI team visited some of the farmers working with project in Bunda, Lake Zone, Tanzania.

Output 6.5: An effective communication strategy fast-tracking the awareness and use of the decision support tools

To deliver on its scaling objectives, ACAI places a lot of emphasis on communication within and outside the project. ACAI has developed a comprehensive strategy that integrates with the project implementation strategy to promote project visibility, partner and internal team cohesion, to enhance learning and knowledge exchange and augment project scaling.

In 2017, ACAI has set up a website (http://www.acai-project.org) for weekly updates of project activities, a repository for open access to the project's public documents and promote public engagement through a feedback-based system. In line with the integration strategy of the Gates foundation-funded projects, ACAI and the CWMP are sharing a common website (www.cassavamatters.org), and a common newsletter (http://www.cassavamatters.org/media-center/newsletter/). We also have developed social media pages on

Facebook: https://www.facebook.com/ACAIproject/

Twitter: https://twitter.com/ACAI_IITA

LinkedIn: https://www.linkedin.com/company/acai-project/

Flickr: https://www.flickr.com/photos/153971246@N08

We have embedded the official IITA Youtube channel for out video and gif outputs riding on the channels established viewership (https://www.youtube.com/user/IITAPUBLISHING). Outside the project, ACAI has been prominently featured in the Citizen Newspaper in Tanzania by their leading columnist. In Nigeria, we have been featured on Channels TV, in the Vanguard and in the Guardian newspapers. We have also received honourable mentions through partner publications including RTB, IPNI blogs, ASH-C blogs, amongst others.

ACAI has also embarked on project activity documentation through video and recording farmer experiences working with ACAI researchers in the field. ACAI Communication is a fairly new activity in the project and 2017 has been the formative year for laying foundation that will form the basis of the work plan to reach more than 120,000 cassava growers, attract more last mile partners and explore new avenues of engaging key stakeholders in cassava intensification.

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Mwajuma Charles, a cassava grower offered her land for ACAI NOT trials in Butiama, Bunda district in the Lake Zone, Tanzania. Photo by David Ngome, ACAI

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