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Progress Narrative

Use this form to provide updates to your foundation program officer regarding progress made toward achieving your project's stated outputs and outcomes.

The Progress Narrative must be submitted in Word, as PDFs will not be accepted.

General Information

Investment Title	TAMASA: Taking Maize Agronomy to Scale in Africa		
Grantee/Vendor	Centro Internacional de Mejoramiento de Maiz y Trigo		
Primary Contact	Peter Craufurd	**Investment Start Date**	November 4, 2014
Feedback Contact[1]	Peter Craufurd	**Investment End Date**	October 14, 2018
Feedback Email[1]	P.Craufurd@cgiar.org	**Reporting Period Start Date**	November 1, 2015
Program Officer	Christian Witt	**Reporting Period End Date**	October 31, 2016
Program Coordinator	Jeanne Bridgman	**Reporting Due Date**	April 30, 2017
Investment Total	$11,950,481.00	**Opportunity/Contract ID**	OPP1113374
Scheduled Payment Amount (If applicable)	$1,258,114.00		

[1] Feedback Contact/Email: The full name and email of the contact whom foundation staff queries for various surveys.

Submission Information

By submitting this report, I declare that I am authorized to certify, on behalf of the grantee or vendor identified on page 1, that I have examined the following statements and related attachments, and that to the best of my knowledge, they are true, correct and complete. I hereby also confirm that the grantee or vendor identified on page 1 has complied with all of the terms and conditions of the Grant Agreement or Contract for Services, as applicable, including but not limited to the clauses contained therein regarding Use of Funds, Anti-Terrorism, Subgrants and Subcontracts, and Regulated Activities.

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Progress and Results

1. Progress Details

Provide information regarding the current period's progress toward achieving the investment outputs and outcomes as well as the work planned or anticipated for the next period. In addition, submit the Results Tracker with actual results as requested.

This report covers progress realized in TAMASA during the second year, November 2015 to October 1206, as well as reflections on the first two years of the project. The Progress Narrative first summarizes the overall aim of TAMASA and key achievements to date. We then describe the current conceptual framework for agronomy at scale and how use-cases fit into this framework. This is followed by more detailed updates on Workstreams (WS) that include identification of challenges and opportunities.

OVERALL AIM OF TAMASA

The theory of change for TAMASA is that '*Newly emerging data streams (at different scales), from remote-sensing, crowdsourcing and other sources, supported by modern analytics and linked to a participatory co-development process with users, will result in improvements in agronomy at scale advice, contributing to maize productivity increases'*. Focusing on maize agronomy in Africa, TAMASA is designed to address four 'gaps' needed to transform agronomy at scale; the data gap, the knowledge gap, the adoption gap and the capacity/institutionalisation gap. TAMASA, in conjunction with other initiatives, will pilot innovations in agronomic and socio-economic data collection and decision-support tools (i.e. devices that are predominantly hand-held) that can deployed to both collect data and share knowledge at scale. Our aim is to:

(i) Use spatially representative farm panel data to better understand the spatial and temporal variability of management decisions and production outcomes. These data contain detailed and integrated information on farm household characteristics and farm management decisions, plot-level biophysical characteristics (e.g. soils), agronomic practices and outcomes (e.g. yields), as well as community and market contextual factors. These data include images derived from unmanned aerial vehicles (UAVs) and other proximal sensors, panel data combining household, community, soil, yield, agronomic practices and other socio-economic and market data. These data will also inform decision support tool development.

(ii) To work with service providers (i.e. input suppliers, government and private research and extension services, agro-dealers, and others) to identify and co-develop systems and applications that transform this data and information to useable products that support their businesses or programs, and enhance their capacity to reach clients more effectively. Our initial focus is a variety of decision-support tools aimed primarily, but not exclusively, at frontline service providers. The initial set of tools include: (a) nutrient management, (b) maize variety selection (including local seed availability and timing of management operations), and (c) optimal seeding rates and plant density.

(iii) To test rigorously the uptake and outcome of decision support based recommendations by using panel data to design unbiased comparisons. We will also work with others (e.g. NGOs or project teams) that share similar mandates to test interventions and their impact within their programs.

(iv) To increase the capacity in 'agronomy at scale' in each country through postgraduate training and training or partners in the use of spatial data collection tools and DSS tools. We will also work towards the institutionalisation of innovative data collection and decision support tools by identifying potential hosts and co-developing tools and processes with them.

KEY ACHIEVEMENTS

- During 2016, TAMASA restructured its WS to reflect lessons from Year 1. TAMASA now has seven WS that address a series of gaps around four use-cases; data, knowledge, adoption and capacity gaps. This provides a logical flow to activities within an agronomy at scale framework.
- TAMASA has revised its concept for agronomy at scale and developed a framework within which the use-cases and other activities are now mapped. All TAMASA activities are now placed within this framework and each is effectively a use-case, i.e. we have move beyond just the NE and VT use-cases in a much more integrated manner.
- TAMASA has a full complement of staff, partners and PhD students who have worked together on the project for more than 18 months. Two face-to-face meetings per year have been held plus cross-country visits to build a common understanding.
- All data in TAMASA is collected via ODK (Open Data Kit) and put on a central server and is available to project scientists in near real time. Our partners, such as CSA in ET, are successfully also using ODK on mobiles. This is a significant step forward that greatly speeds up data access.
- TAMASA identified, with University partners, nine PhD students (3 from Nigeria, 2 from Tanzania, 4 from Ethiopia) to work on a range of agronomy, socio-economic and spatial projects. BUK also supports one additional student in Nigeria. Three of the PhD students are women.
- Partners in Nigeria (SG2000, ADPs) and Ethiopia are piloting the nutrient management and variety tool in 2017

WS1

- Agronomic Panel Survey (APS) with C. 700 households designed and the first round completed in all three countries. This will be a unique data set with socio-economic, yield, soils and agronomic data repeated each year. Additional yield measurements are also available from other TAMASA activities resulting in approximately 1000 geo-referenced farmer yield and soil samples available for analysis and sharing.
- Spatial ex-ante analytical framework set up around site-specific nutrient management models; the framework has been conceptualized and an initial version exists (programmed in R) and is available to users as a Shiny app. Spatial data on prices, physical market access conditions, and other spatial variables have been collected and a methodology has been proposed for modeling spatial variation in input and output prices.

WS2

- More than 2500 geo-referenced crop cut, soil and grain samples were collected in Year 2 across the three countries, along with a few key agronomic explanatory factors, using standard operating procedures and ODK-based tools.

WS3

- Standard protocols and standard operating procedures were developed and completed for implementation of nutrient omission and NE performance trials, and soil and plant sample analyses across the three countries to generate data for understanding crop responses, recovery efficiencies and nutrient supply for calibration of Nutrient Expert (NE) and for development of a spatial framework for extrapolating experimental findings to larger spatial areas.

- Seven hundred and thirty five (735) Nutrient Omission Trials (NOTs) to parameterize Nutrient Expert [NE] (and other software) have been completed to date across the three countries. These data have been used to parameterize NE for all three countries and about 250 Performance Trials to compare the regional, NE and soil-test based NE recommendations completed in ET & NG. Awareness of nutrient management has been raised and partners are willing to try out revised recommendations, using their own resources, in NG.

WS4

- Predictive models for maize development/phenology have been successfully developed from STMA maize data in Kenya and applied to data collected in Ethiopia, Nigeria and Tanzania by TAMASA
- An Android application has been developed, the Maize Variety Selector, that helps service providers and farmers know what variety is suitable for their location and preferred planting/harvest date, as well as providing information about the varietal characteristics

WS5

- More than 4500 geo-referenced soil samples have been collected and data will be added to the AfSIS soils database

WS6

- The APS will enable RCTs or similar rigorous tests of agronomy innovations to be carried out, starting in Nigeria in 2017.

FRAMEWORK FOR AGRONOMY AT SCALE

The transformation of the agronomic R&D and knowledge delivery landscape that results from the integration of (geo-spatially explicit) data collection at scale with the (research/extension/input suppliers/farmers/policy makers, etc.

Taking agronomy to scale involves a transformation of agronomic research and knowledge delivery landscape, particularly the integration of data collection and synthesis of data, with the delivery of area or site specific agronomic advice by multiple service providers. The increased availability of satellite-derived biophysical data together with new ICT-based, geo-spatially representative data collection methods for farm management and socio-economic data will enable this. Agronomy at scale requires new partnerships and innovative geo-spatial analytics, data collection and knowledge sharing systems that are tailored to solutions for different users (e.g. farmers, service providers, industry and government) and at different scales (e.g. fields for farmers, AOIs for service providers, market and technology domains for industry and government). This transformation will enable more service providers and farmers to access the necessary knowledge and inputs to increase yields, increase profitability and/or reduce risk, and seize new opportunities. Some examples from TAMASA use-cases are outlined in the attached (Agronomy user Framework), using the framework (Fig 1).

AGRONOMY AT SCALE FRAMEWORK

- **What is the information gap (solution)? Need to understand**:
  - The decision-maker/user and
  - Scale of their operations/implementation
- **What data is needed and available at that scale?**
  - Data sources
  - Data collection at scale (incentives for collection)
  - Modelling to improve targeting/solution identification
  - Geo-spatial sampling frame
- **What analytics, models & tools are available or need to be developed?**
  - Product design and analytics need to consider the user & their institutional system
- **What data needs to be collected?**
  - Understand causes of variation and uncertainty
  - Scalable, low-cost and quick (accurate, repeatable and scale appropriate)

- Data management

- **How will feedback and learning for users and tool improvement be integrated?**
  - User experience of the interface to improve tool
  - Automated capture of how the tool is used (and decisions if possible)
  - Capture outcome

Figure 1. Agronomy at Scale Framework

The conceptual framework for agronomy at scale starts with an assessment of the institutional or user-demand for a solution based on the knowledge or information gap and potential solution. Key to this is understanding the decision, and hence the operating scale, that the user wants to make. This decision and scale will be different for different users, such as input suppliers or extension. Data limitations may also impose limits on the scale of the decision (i.e. minimising uncertainties). It is also very important to understand the institutional landscape if tools or products are to be sustained by partner institutions.

Data availability, data needs, modelling, sampling and product development follow in a co-development process with the user and hosting institution. Institutional capacity and product design is very important here, for tools with on-line, complex analytics or databases will not be easily hosted by national institutions. Co-development will also be an iterative process. At some scales or for some decisions the analytical method need not be complex and there is still a place for paper-based tools and not just ICT-based tools. Indeed a key hypothesis is *whether ICT-based tools can deliver desired outcomes*.

Data collection, at whatever defined scale, will need to be fast and cheap if it is to be scalable and collected by institutional partners. The use of ODK on phones or tablets already offers greater usability and speed. Agronomy at scale will require innovations in data collection, especially yield data or data that requires a physical observation. Although RS is improving, there will still be a need for ground-truthing and monitoring, especially in the development phase.

Lastly, automating feedback into tools and/or rigorous monitoring of outcomes is vital. Institutionalisation and training need to include this aspect as an integral part of the process and plan for collecting these data. Through the use and monitoring of tools by partners, the potential to collect spatial data at larger scales is greatly enhanced, especially where feedback contributes to institutions business.

TAMASA WORKSTREAMS AND SAMPLING FRAME

Context, approach, and objectives:

Workstreams

We revised the Workstreams (WS) in Year 2 and have revised again slightly to make yield related activities a use-case and to emphasize aspects of data collection, analysis and communication. One key features of this structure is the focus on use cases designed around data gaps, co-development and institutionalisation (WS2 to WS5). There are also workstreams that methods to support agronomy at scale (WS1), adoption and impact (WS6) and Project management (WS7). As discussed above, further refinements are proposed to develop a matrix of use-cases across the WS within an overall framework for agronomy at scale.

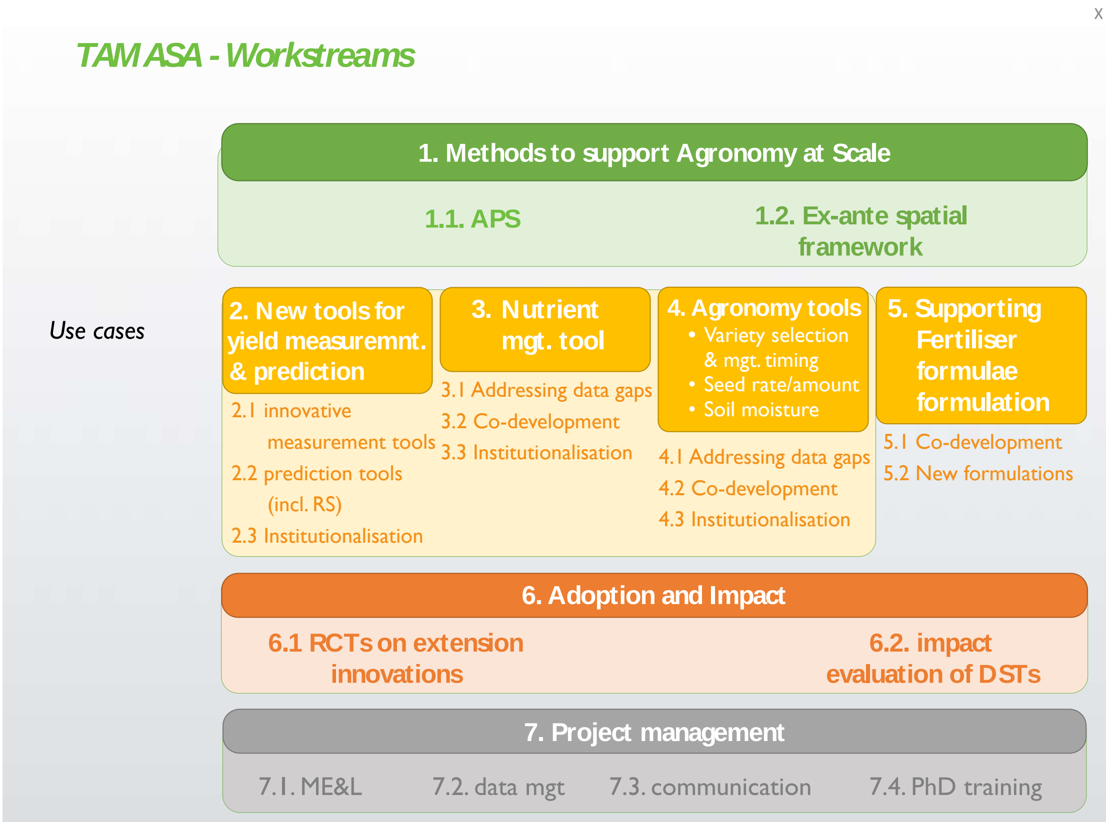


Figure 2. Revised TAMASA Workstreams (WS)

Sampling frame

At the start of TAMASA we had discussions with colleagues in AfSIS about spatial sampling frames and how to implement agronomy at scale. The hypothesis is that *by using a representative (of the AOI) sub-sample of pixels robust and scalable outputs could be produced*. AfSIS was undertaking digital soil mapping in Tanzania and Nigeria in parallel with TAMASA and the starting point was how to leverage and integrate with these activities through linking agronomy WS. We initially asked AfSIS to generate a 1000 point sampling frame within their cropland area map for each country, and in Year 1 in TZ (where the first opportunity to measure yield presented itself), set out to measure 1000 yields in farmers' fields. Based on this experience, wherein we only managed to collect about 25% of the proposed samples due to a combination of logistics × short sampling window, we realised we had to change the sampling frame. Accordingly, we first defined:

(i) the Area of Interest (AOI), which we defined as maize areas (using the AfSIS cropland map and other available data on maize-based cropping systems from Harvest Choice and within-country statistics) × population density (>25 km^2 as a measure of intensification) × distance to market (<4 hrs);
(ii) within that AOI we randomly selected about 15% of the AfSIS soil pixels and with partners ruled out any that did not have maize as the major crop or that were simply too inaccessible or outside their current domains;
(ii) the remaining pixels, roughly 20-25 in each country, were then compared against the larger AOI using four soil characteristics (OC, pH, CEC and %sand); finally
(iv) 20 to 25 pixels were selected. This was the number we and our partners thought we could reasonably manage given the AOI, especially in ET and TZ where the AOI is extensive and geographically separate. The location of these pixels is shown below. We agreed that all our data collection activities for WS 1 to 5 would be within these pixels to maximise efficiencies and synergies between WS. Within each pixel a stratified sampling strategy using *n* 1 x 1 km cells and *n* random points within those based on the desired '*n*'. The code for sampling was developed by AfSIS and is available on Github.

Figure 3 shows the current pixels used for TAMASA core activities. The hypothesis still needs to be tested.

Nigeria Ethiopia Tanzania

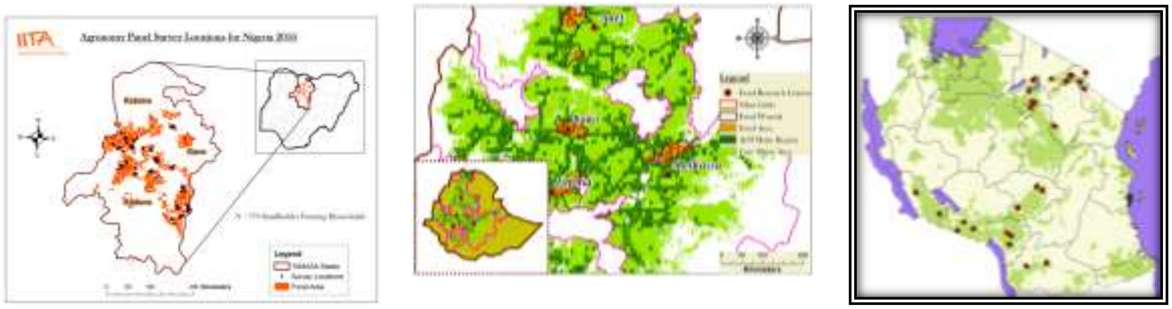


Figure 3. Pixels (10 x 10km) where primary TAMASA activities are undertaken

COUNTRY PARTNER STRATEGIES

Ethiopia

The Ethiopian government channels its efforts in agricultural growth through its comprehensive Growth and Transformation Plan (GTP). The GTP is the locus around which all national and regional governmental organizations and development partners work to achieve agricultural growth goals. This framework provides a good opportunity for TAMASA's engagement in contributing to GTP goals. In this regard, TAMASA has formed strategic partnerships to carry out joint initiatives over the next two years in efforts to meet its goals of achieving impact at scale.

Specific initiatives it plans to undertake are:

1. TAMASA has established agreements with the MoANR Soils and Crops Directorate to introduce the use of NE as a tool for development agents (DAs) to use in advising farmers in fertilizer choices and rates. This will engage focal persons from both the crop and soils directorates of MoANR, Regional Bureaus of Agriculture (RBoA) subject matter specialists (SMSs) and Woreda and Kebele office heads in addition to natural resource and crop DAs. The initiative will start with a small number of farmers (600) but with plans to expand to multiple districts in maize producing areas based on learnings from the pilot initiative.
2. TAMASA will be involved with ATA in two areas:
    a. ATA plans to conduct 1200 high yield maize demonstrations or innovation trials with model farmers in Oromia and Amhara regions. TAMASA will partner on this to develop ODK protocols and carry out co-located soil analysis and crop production information to build into a geo-referenced dataset that will provide useful information on maize production dynamics in the country. ATA is also providing access to similar data from the past two years of demonstrations, which will provide a robust information set on over 3000 trials/demos. The information gathered will also be useful for sharing with AfSIS to build its continent-wide information system linking soils and crop production.
    b. ATA has established the IVR – a very effective call-in service for providing information on agronomic best practices; with this service it is also piloting a survey mechanism to gather information from its user base. TAMASA will work with ATA's IVR initiative to test it as a platform for disseminating advice from its tools and will also work on jointly developing a mechanism for conducting geo-referenced surveys. CIMMYT already collaborates with ATA to use this system to collect survey data on the occurrence of rust diseases.
3. EthioSIS has developed detailed soil fertility and fertilizer recommendation atlases that can be linked with crop response trials to provide validated location specific fertilizer recommendations. TAMASA will work with EthioSIS to develop the modality in which this can be structured and piloted. The partnership provides unique opportunities for developing use cases for both EthioSIS and TAMASA.
4. ICRISAT has made significant contributions to understanding crop response in relationship to landscape position. This will be an important component in improving TAMASA's advisory tools, particularly with respect to location specific fertilizer/nutrient recommendations. The work that ICRISAT is carrying out in this area has been supported by GIZ. TAMASA will also engage with GIZ to explore joint efforts for developing maize advisory services at scale.
5. TAMASA already works with CSA who are collecting soil samples alongside their crop-cuts on about 400 plots in 2016. We will work towards adding value to the crop-cut based production estimates they provide in their census reports - these are usefully reported at a zonal level but with an agreement with them we could jointly work on getting data at enumeration area (EA) levels, link these to soil attributes at the same level, and get higher resolution relationships that could then be aggregated for meaningful decision making. They do engage with IFPRI's ESSP group for socio-economic work at the EA level so it is feasible. CIMMYT also work with CSA on DNA samples, also funded by BMGF. We will develop a joint approach to CSA in 2017 to move this relationship from a contractual one to an institutional support relationship, focusing on the added value we can bring to data collection and analysis.

Nigeria

Nigeria has huge potential to increase maize productivity but this opportunity has not been fully tapped because of the low efficiency of the national extension system due to low capacity and funding. Currently, the national agricultural system is being revived. The national extension delivery system is mostly dependent on the states' Agricultural Development Programmes (ADPs). Apart from the ADPs, few NGOs (like Sasakawa

Global 2000) and projects offer good extension delivery services for their target locations and crops. Both the ADPs and the private extension NGOs could be effective mechanism for TAMASA to operate at scale within Nigeria. Therefore, mainstreaming TAMASA approaches requires that ADPs be supported with training on innovative extension methods and approaches so that their efficiencies are enhanced. There is great potential for improved service delivery by the service providers in few years to come, and also a huge opportunity for scaling TAMASA tools.

Specific initiatives TAMASA NG plans to undertake are:

1. The collaboration of TAMASA with the ADPs has promoted the use of ODK in surveys. The just concluded Agro-dealer survey was conducted by these ADPs and are highly willing to adopt the use the MVS in their extension delivery system. More than 1,300 agro-dealers are now identified in the TAMASA focal area by the ADPs and they will facilitate linking TAMASA to local farmers for all the on-farm trials (VT, NOT, PT and UAV). TAMASA will continue to engage the ADPs so that its tools are deployed at scale. Our experience of the last few weeks (Agro dealer training) have shown that the ADPs can deliver with little training and financial support.
2. TAMASA is engaged with SG2000 in two fronts: a) Maize Variety Selector (MVS); and b) Nutrient Expert (NE):
   a. MVS – SG2000 have over two-thirds coverage of the maize belt of Nigeria and have being supportive in the tool co-development process. They have also indicated commitment to pilot the MVS tool in Kano, Gombe and Kaduna states, and will adopt the tool as part of their extension platforms.
   b. SG2000 will also test the recent version of NE and will pilot the tool in Kaduna with technical backstopping from IITA and BUK. More than 5,000 site-specific and group fertilizer recommendations are expected to be generated by SG2000 in the 2017 main cropping season. Training of Trainer (ToT) will be conducted to train ten SG2000 staff that will train another 50 people that will provide the fertilizer recommendation to farmers.
3. Institute of Agricultural Research. The Variety Selection tool will be hosted by IAR considering it has the national mandate for maize variety improvement. Two maize breeders from the institute have been co-opted in the tool co-development process. IAR will be linked with NACGRAB (National Center for Genetic Resources and Biotechnology), which has the mandate for varietal release in the country. The complementarity of the two organizations is expected to ensure an effective MVS hosting in the country.
4. Potential partners. Apart from the project service providers, other maize projects and NGOs have shown interest on the need for both the NE and the variety selection tools that TAMASA is co-developing. Currently the major constraints faced by such projects in maize agronomy advisory services are appropriate fertilizer rates and varieties for farmers' locations. Linkages have been established with OFRA, SARD-SC, N2Africa and efforts will be made to reach out to other projects so that the tools make the most impact. Presently GIZ and PropCom have indicated interest to validate the Nutrient Expert tool with their farmers in 2017. Therefore, TAMASA will engage with PropCom, GIZ and other partners to explore areas of scaling up the NE and MVS and other areas of mutual benefits.
5. National Agricultural Research and Extension Liaison Services (NAERLS). The institute is assisting TAMASA with on temporal geo-spatial maize prices within the country which is needed for price modelling. The baseline and Agronomy Panel Surveys were jointly conducted by NAERLS, which has the national mandate for Annual Crop Yields Survey. The TAMASA will continue to improve capacity of NAERLS staff on crop cut and soil collection techniques, and the project and NARELS jointly conducted the baseline and APS in 2015 and 2016 seasons. NAERLS have also established the farmer extension helpline that will be operating 18hrs daily - a very effective call-in service for providing information on agronomic best practices. This is an opportunity for TAMASA to explore and see how this initiative can promote the use of NE and MVS at scale.
6. In Nigeria, TAMASA is in partnership with OCP. The aim is to develop new fertilizer formulations for maize that are better adapted to the soil conditions in the maize belt of Nigeria that would result in more efficient and affordable fertilizer products for increased yields. It is a collaborative project between OCP Africa, the Africa Soil Information Services (AFSIS), IITA, and national partners in Nigeria, the outcome of which will assist in developing fertilizer blending tool for the industry.

Tanzania

The government of Tanzania has launched Agricultural Sector Development Strategy II (ASDP 2). The ADPS 2 has four strategic objectives, one of which is to improve agricultural productivity and profitability driven by improved research, extension, input access and mechanization. TAMASA's initiative to develop site specific nutrient management and variety selection tools is in tandem with the focus of ASDP 2:

- Bridging technological and economic information to smallholder farmers from research and through advisory services
- Building capacity of institution to coordinate and evaluate the programme impact
- Supporting agricultural statistics gathering and analysis processes. Such statistics, for example, in weather forecasts could support rural advisor services in providing relevant and specific extension and advisory services to farmers (like what to plant, when, etc.).

The ASDP 2 focuses in fostering pluralism in the provision of extension services. The extension services in the country include both public, FO/CSO and private entities. ASDP 2 wants to promote private sector process in extension services and use diverse communication methods (ICT) to leverage private sector service provision. This opens space for TAMASA to work with a landscape of service providers, which are already working in both regions of interest that TAMASA is working on. ASDP 2 mentions SAGCOT specifically; SAGGOT collaborates with TanSIS/AfSIS who are main partners of TAMASA in terms of soil resources information.

Specific initiatives that TAMASA already has and plans to undertake include:

1. TAMASA has agreement with two public institutions, SARI and ARI Uyole, who currently implement activities in the southern highlands and northern zones, which are AOI for TAMASA in Tanzania.

2. TAMASA through the two partners is also working with about 26 District Councils which host the public extension services. These are the major partners who can take agronomy to scale. They command extension workers to the lowest level (at village), making it easy to reach out to farmers.
3. TAMASA is currently in the process of developing an MoU with two other public institutions, ARI-Mlingano and TOSCI, in order to officially host the Nutrient Expert and Maize Variety Selection tools, respectively.
4. TAMASA is following up on initial discussions with One Acre Fund, as they operate in the southern part and have access to more than 10,000 farmers. TAMASA can tap into this resource to ensure large scale testing for the NE and MVS tools.
5. TAMASA is also looking to engage other NGOs that are working with farmers in the north like Farm Concern International (FCI), World Vision (WV) and RECODA – currently working with WVin testing their approach for technologies transfer in rural development known as RIPAT (Rural Initiative for Participatory Agricultural Transformation). Likewise, both CIMMYT and IITA have a number of other partnerships in Tanzania under projects such as AfricaRising, SIMLESA and DTMASS.
6. TAMASA is involved in a geospatial working group established by TanSIS/AfSIS to work on geospatial analysis of crop and soil data collected by TanSIS.
7. OCP is also planning to fund test its compound fertilizers in the country through ARI-Mlingano, the national soils research station. TAMASA is expected to contribute on the on-going performance trials, and also provide technical support to assist in setting up the trials that OCP is going to fund.

WORK STREAM 1: Methods to support Agronomy at Scale

This WS has been recast as a set of activities that support the use cases (WS2 to 5) and impact evaluation (WS6).

1.1 Agronomic Panel Survey

Context, approach, and objectives:

A major goal of TAMASA is to understand the spatial and temporal variability in maize yields. This has two main purposes: (i) to improve yield predictions spatially (nationally) that are of value for food security and other policy/planning institutions - as well as essential layers for yield gap and nutrient management tools for example; and (ii) to diagnose and identify opportunities to raise productivity or efficiency through agronomic interventions. The Agronomic Panel Survey (APS) is a detailed farm household survey with agronomic, yield and soils components for a focal field. This is a yearly panel survey, i.e. data are collected on the same households and fields every year for the duration of the project. The purpose of the data collection is several fold:

1. To better document spatial-temporal variability in agronomic management and yield outcomes
2. To facilitate research on:
   a. the drivers of yield outcomes (i.e. role of alternative agronomic practices)
   b. the determinants of farmer decision-making (i.e. in adopting particular agronomic practices) that contribute to observed yield outcomes
3. To test the hypothesis *that farm-level socioeconomic data adds value to our understanding of yield outcomes* (and, thus, our ability to predict such outcomes in the future, using geospatially explicit approaches)
4. To serve as a baseline for the evaluation of site-specific nutrient management tools, using randomized control experimental approaches, combined with econometric analysis of panel survey data.

Unique features of the dataset include: high temporal frequency, detailed agronomic management questions, management history questions, georeferenced location, crop cut and soil sample. We anticipate that these unique features will enable new insights to be generated about the agronomic determinants of observed yield outcomes, as well as the biophysical and socioeconomic conditioners of the agronomic management decisions that lead to such outcomes. Panel data also enable much more rigorous econometric analyses of determinants and impacts of different practices.

Research questions to be addressed by analysis of the APS data include the following:

- *What are the relative contributions to yield (gap) of alternative agronomic management practices? (e.g. seed variety, planting date, nutrient management, weed management, plant spacing, crop rotation and intercropping)*
- *What are current adoption and usage levels of improved maize varieties? What are the inter-temporal dynamics of adoption?*
- *How does plant spacing (sowing density) compare with recommended/optimal practices?*
- *How does soil variability contribute to fertilizer response rates?*
- *What is the profitability of fertilizer use across the AOI in each country?*
- *Do previous-season outcomes influence current-season management decisions?*

Progress in the reporting period:

The panel survey includes 700 households and maize plots in each country. The survey is spatialised in the TAMASA 10 x 10 km cells in the AOI in the respective countries. The APS includes measured yield, agronomy data, soil samples to 50 cm and a community and maize plot questionnaire.

The survey is implemented by our partners using ODK on mobile phones or tablets, though we may switch to other software to increase efficiency (tables and internal checks) and ease of processing. In ET in 2016 there were travel restrictions and we decided to only implement the APS in regions were access was permitted and our partners could work, i.e. Jimma and Bako, giving 346 HH. We did not conduct the APS in Amhara or in the Central Rift Valley (CRT). We are currently considering whether to extend the APS as originally planned in ET or to concentrate sampling in Jimma and Bako in Years 3 and 4.

We have successfully implemented the APS in all three countries, and have established teams and expertise which can be recycled in 2017 and 2018. Thus, many of the fixed costs associated with setting up the survey data collection activities in each country will not be incurred again, freeing up scientist time to focus more on research and other value-addition. The survey is a compromise between traditional listing approaches commonly used in surveys cf the stratified sampling for spatial representativeness. Training was given in each country and included the use of ODK and GPS. The APS was first implemented in Year 2 at harvest in each country, starting in TZ. The logistics and costs of more than one visit to fields that are often not easily accessible is prohibitive and very demanding on human resources. Household data will be processed and used by three PhD students (Banch, Oyinbo, Violeth), all of whom have contributed to the survey instrument (for their own research) and supervision of the survey in each country. Yield and agronomy data will be used by other students (Elias, Workneh, Adnan, Amsale, and Dagmawi). The APS will be repeated in Years 3 and 4 in each country to generate a temporal and spatial data set that will be unique.

Table 1: Number of households, plots, yield and fertilizer use in the three countries

Attribute	Ethiopia	Tanzania	Nigeria
No. households	336	607	774
Total no. plots	2078	1,602	2120
No. maize plots	1038	1,071	1328
Yield (t/ha, range)	4.9 (1.1-10.9)		2.8 (0.24-5.9)
NPS/k applied (kg/ha, range)	157 (17-704)	112 (30-250)	134 (4-525)
Urea applied (kg/ha, range)	179 (16-680)	90 (5-400)	112 (2-500)

In all countries plant density is a limitation, with, in the case of Bako in Ethiopia, both sub-optimal and supra-optimal densities (Fig 4). In Tanzania the data show an inverse relation between yield and farm size.

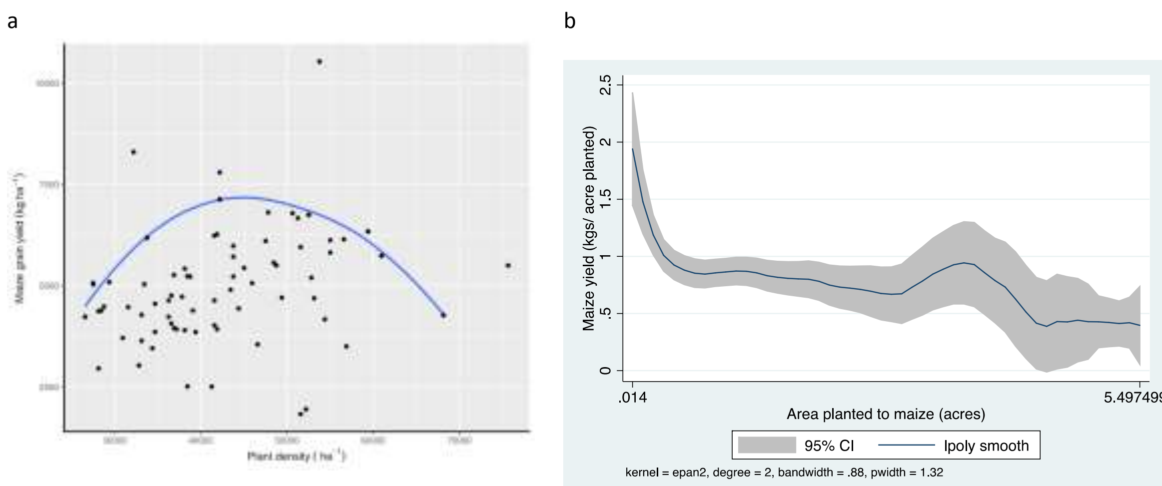


Figure 4. Relation between yield (kg/ha) and plant population density at Bako (a) and Non-parametric polynomial regression of relationship between maize yield and area planted to maize in Tanzania (b)

Over 1000 variables are included in the main questionnaire. Furthermore, household- and plot-level information is linked to laboratory analysis of physical crop cut and soil sample data.

Maize yield gaps and their mitigation in Ethiopia: an integrated assessment. Banch PhD

This research is built around the APS and activities under the WUR IMAGINE yield gap project and SIMLESA household surveys in the CRV of Ethiopia. The objectives are: *to assess and explain the maize yield gap in Ethiopia by incorporating crop management, technological and biophysical factors; to investigate the determinants of the decision to adopt and the extent of adoption of mineral fertilizer and modern maize varieties; to describe and explain the links between maize yield gap and household food security; and to explore the impact of fertilizer and modern maize* *varieties on household food security under resource constraints and different risk attitudes*. The research will use a combination of analytical techniques including stochastic frontier analysis, panel double hurdle methods and bio-economic modelling.

When farming becomes a risky business" How is risk influencing smallholders' decisions in Tanzania?" Violeth PhD
The main hypothesis of this research is: *Understanding socio economical and biophysical risks in maize intensification under different farming systems, is positively related to effective fertilizer investment, high yield and improved income to smallholder farmers*. The research will add value to the APS by focusing on risk and decision-making, including post-harvest aspects.

Maize Yield Gaps and their Mitigation in Ethiopia: Exploration and Redesign. Workneh PhD
This research will focus on agronomic management, rather than just nutrients or varieties, using on-station and participatory on-farm experiments to test improvements in crop management. The treatments are derived in large part from TAMASA surveys which emphasize poor establishment and poor management. Modelling will be used to assess these improvements in: (i) the context of whole farm systems (bio-economic modeling) and (ii) to look at scale questions using GYGA methodologies (Technology Domains).

1.2 Ex-ante spatial framework

Context, approach, and objectives:

The Gates Foundation has asked for *ex ante* impact analysis and related return on investment (ROI) analyses to be carried out as an integral part of TAMASA and similar projects. Given that many of the components of the project (e.g. a range of decision support tools, engagement with industry to develop new fertilizer blends) are still in the process of being defined, the exact scope of the ROI work is yet to be finalized. Nonetheless, what is clear is that a spatially-explicit framework for evaluating profitability of agronomic management decisions would enable a number of important *ex-ante* assessments.

In order to evaluate alternative investment opportunities in rural development in maize-based agri-food systems, we need to know something about the profitability of proposed alternatives across the heterogeneous biophysical and economic landscapes that small producers occupy. Consider, for example, the question of how best to evaluate alternative investments in the development and dissemination of production technology – e.g. new seed varieties, new fertilizer blends, promotion of mechanized traction, promotion of conservation agriculture. In each of these cases, the success of a given technology will depend upon its profitability from the farmer's perspective. *This provides us with a basis for evaluating such questions as:*

- *Where would we expect site-specific nutrient management to perform better than (current) blanket recommendations?*
- *Where is closing the yield gap profitable under existing technology & prices?*
- *What is the optimal set of fertilizer blends to most efficiently meet the diverse nutrient management requirements of farms across the area of interest?*

Progress in the reporting period:

The initial version of the Spatial Ex Ante Framework (SpEx) has been built around a version of the QUEFTS model obtained from IPNI, which is also the analytical core of the NE tool. This framework is currently written in R, and is most directly accessible to researchers who understand how it is built. However, we have also developed a version of this tool, packaged as a Shiny app, which could be deployed on a server and accessible from any web browser. (https://econometricsbysimulation.shinyapps.io/dynamicquefts2/).

We have also initiated research into how empirical observations on input and output prices are varying over space. *A key question here is: how much of the observed price variation can be explained by modeling*? We are not yet finished with that evaluation, so the current SpEx setup uses very stylized price surfaces as a placeholder for the (hopefully) improved surfaces we are developing. We are engaged in this work in collaboration with IFPRI, who also have a longstanding interest is modeling prices over space. An example of net revenue benefits of NE is given in Figure 5.

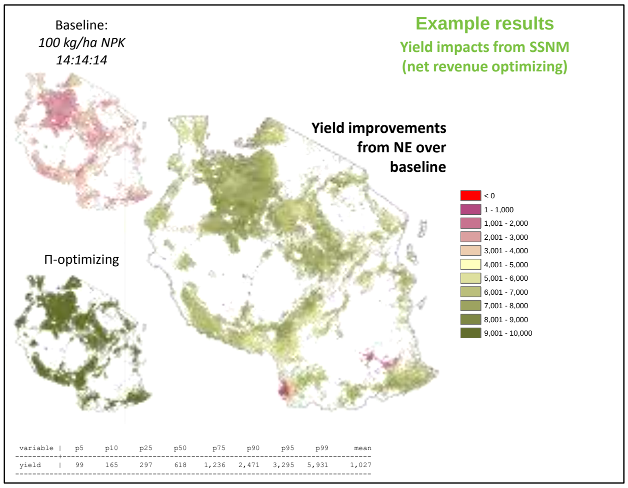


Figure 5. Outputs from initial version of Spatial Ex Ante Framework

WS Challenges:

A principle challenge for this WS has been internal resource constraints, in the form of researcher time. Now the APS is set up and should require less day-to-day supervision, more time should be available to work on data analysis and further development of the SpEx.

The establishment of the APS in each country has taken considerable internal resources. The APS is a complicated data collection activity – much more complicated than traditional household surveys – for several reasons. First, the timing is tricky: we have to try to reach each farm just prior to the expected harvest in order to take a meaningful crop cut. This has been challenging, given the large extent of the AOI in Tanzania and Ethiopia, and the fact that harvest times in different areas may fall quite close to one another. Second, the collection of multiple types of data has imposed logistical complications. Third, this is done through partner organisations and work plans and resources have to be negotiated. Fourth, large surveys are not easily implemented through ODK on smart-phones and some other survey software might be more efficient in the short term. Fifth, processing of the physical components of the data collection (crop cuts, tissue samples and soil samples) takes a considerable amount of time, delaying the analysis of these components. Sixth, project scientists and PhD students have thus far not been able to spend much time analyzing the 2016 APS data, due to other demands. Despite these challenges, we have much to celebrate in this activity in 2016. The fact that we have successfully collected the APS in three countries with such limited staff and resources represents a considerable achievement.

Emerging opportunities:

There is broad interest in improved understanding of yield constraints and gaps, and in spatial data generally. TAMASA certainly has an opportunity through shared visions and shared data to work with many others, starting with the other agronomy partners and their partners. TAMASA has direct links to yield gaps projects such as Imagine (in ET with WUR), GYGA (via a CRP grant), and WUR through a CCAFS grant. CIMMYT itself is trying to develop spatial sciences more across the regions and to invest in this area. We need to get more of our data and data analysis in the public domain to generate interest and additional resources.

The maturity of the NE-Field tool means that we may now use the APS as the basis for an experimental impact evaluation of the tool. This is currently being planned for Nigeria, with the active involvement of one of the project PhD students, Oyinbo, and his committee (see WS6). While setting up the experiment involves some challenges (e.g. coordinating the "treatment" or NE delivery across the APS sample in ways that respect the experimental design), if done well, this should result in high-impact peer-reviewed research outputs.

The data collected under the APS needs to feed into geospatial analyses. This will certainly include supplying georeferenced yield and soil measurements into the yield prediction activities [WS2]. Additionally, we have planned some exploratory work on alternative methods of characterizing the spatial determinants of management practices and resulting outcomes. Going forward, we also need to look for ways of lowering costs of data collection at scale. To this end, we are planning more research activities around alternative modes of data collection (WS2).

The Geospatial and Farming Systems Research Consortium via the Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL) will support of a data-science post-doctoral fellow with Dr Chamberlin. The post-doctoral fellow is expected to join CIMMYT's Ethiopia office in June of 2017 on an initial contract of two years.

WORKSTREAM2: METHODS FOR YIELD MEASUREMENT AND PREDICTION

Measuring, predicting and mapping current and potential farmer yields is a high priority, meeting the needs of planners and policy-makers, such as those in food security, as well as providing key input data for many models and tools. This new WS incorporates activities linked to yield measurement and prediction.

2.1 Innovative yield measurement tools

Context, approach, and objectives:

Current farmer yield, along with some key agronomic data to help explain observed variation, is required for predictive modelling and mapping spatially and temporally. This WS summarized yield and other samples collected by TAMASA across its various WS (i.e. surveys and experiments where yield is measured).

TAMASA uses a standard SOP for yield measurement based on replicated crop cuts and fresh and dry weight measurements. The SOPs are available in Drobox (Grain samples were also collected for the RRes/AfSIS geonutrition survey. Collecting physical samples and transporting these is a logistical challenge, especially within a short harvesting/maturity window, and the current method is not very scalable. Therefore simpler, less destructive and quicker methods are needed that provide a surrogate for direct yield measurement.

Progress in the reporting period:

In year 2 about 700 yield samples were collected and processed in each country (Table 2). In NG and TZ these were exclusively from the APS while in ET half were from the APS and half from CSA. This is realistically about the limit of what we can collect through our partners. Large numbers of soil, ear-leaf and grain samples were also collected and sent for processing (Table 2). In Tanzania stover samples were also collected and are being processed for the collaboration with MSU. Most samples are processed using MIRs and XRF through AfSIS or IITA. Soil and ear leaf samples from the NOTs are also analysed by wet chemistry. In Tanzania soil samples are being analysed using wet chemistry by MSU.

Table 2. Number of yield (crop cuts) and soil (0-20 & 20-50cm), grain, ear-leaf and stover samples in each country

Country	Type	2015	2016
Ethiopia	Yield	618	746
	Soil	1780	1492
	Grain	1148	1492
	Ear-leaf	562	
	Stover	402	
Nigeria	Yield	1212	1741
	Soil	327	1837
	Grain	838	2280
	Ear-leaf	1500	1140
	Stover	809	2184
Tanzania	Yield	167	610
	Soil	334	1498
	Grain	501	2593
	Ear-leaf		2016
	Stover		2922

In Year 3, three potentially quicker methods to assess yield will be tested in each country. These are: (i) taking five random ear/cob samples only from the crop-cut area and shelling to determine seed number and moisture content; (ii) plant height from mid-grain fill (see Tottonell et al, 2014) and (iii) digital analysis of ear photographs (CIMMYT and QED methods). In all cases fewer cobs have to be harvested and less material transported. The methods also increase the window for taking observations, which will help logistics. These methods will be assessed as part of the APS and alongside crop-cuts for direct comparison. Grain, ear-leaf and yield samples will continue to be collected wherever there is an opportunity through other partners and projects, such as OCP-funded activities in WS5 and the tool out-scaling by partners in WS3 and WS4.

2.2 Predictive tools

Context, approach, and objectives:

Measured yields are collected by TAMASA for the purpose of understanding and predicting observed temporal and spatial variation in yield within the sampling frame. These observed or ground truth data should also contribute to predictive mapping of yields at a larger scale, linked to RS and other spatial data.

Progress in the reporting period:

Measured grain yield

Grain yields varied substantially across farmers' fields in all countries, averaging 2 t/ha in Tanzania to 3.8 t/ha in Ethiopia (see below for 2015 data). In all cases yield was strongly influenced by plant density, which is a priority target for improving through a seed rate/ spacing tool (see WS1 for an example). Data were also collected on variety, fertilizer application and gender. The priority in Year 3 is to analyse these data within TAMASA (Tonnang, Chamberlin, and Adewopo) and to share and collaborate with others (Lobell, AfSIS, and CSISA). One Acre Fund have analysed c. 4000 yields with 100s of variables and been unable to account for more than 25% of the variation (Guerena *pers comm*). CSISA have been using model ensembles that include Random Forest and machine learning methods for their data (Zia *pers comm*) and we can leverage these models.

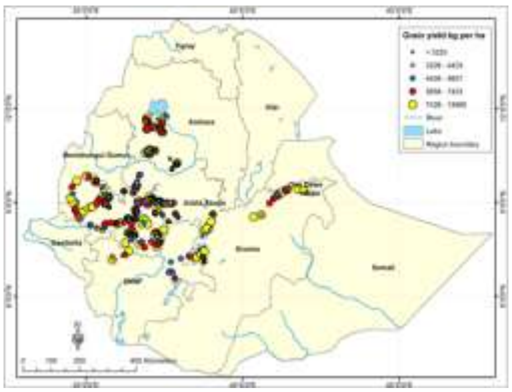


Figure 6. Maize grain yields from 2015 survey

Area or altitude zone	Min	Max	Mean
Tanzania			
Northern (n=18)	608	4347	2065
Eastern (n=27)	449	4219	2327
Southern Highlands (n=123)	232	5394	2069
Ethiopia			
Lowland (n=34)	1157	8552	4127
Mid-altitude (n=335)	363	14034	4176
Highland (n=222)	289	14351	2150

Grain yields in Ethiopia and Tanzania in 2015

Evaluation of integration of proximal and remote sensing technologies into yield and agronomy assessments

The objective of this activity is to investigate how to link or scale observed yield measurements with RS measurements such that yield can be predicted at scale far more cost effectively. The use of RS to predict yield has been relatively successfully demonstrated in India (with CSISA), but less successfully on smallholder fields in East Africa (Lobell and Burke, forthcoming). UAVs were procured for each country but this far have only been available for use in Nigeria. In Nigeria UAV training was orgainised through Metrisys (who provided the eBees) with NASRDA (National Space and Development Research Agency) and ICRISAT (who were part of the STARS project in West Africa). Regular flights were made at five sites over the NOT and PT trials and surrounding farmer fields. Preliminary analysis of some data suggests that there is a correlation between observed yield and NDVI, and that relations determined calibration of trial data can be used to predict the yield of the surrounding fields. UAVs will be used in TZ by one of the PhD students, Elias, in collaboration with Sokoine University of Agriculture (SUA).

In Nigeria a network of automatic weather stations, installed in partnership with Kukua (https://www.kukua.cc/) is contributing higher resolution real time data collection to TAMASA. Kukua also have plan for similar networks in Tanzania.

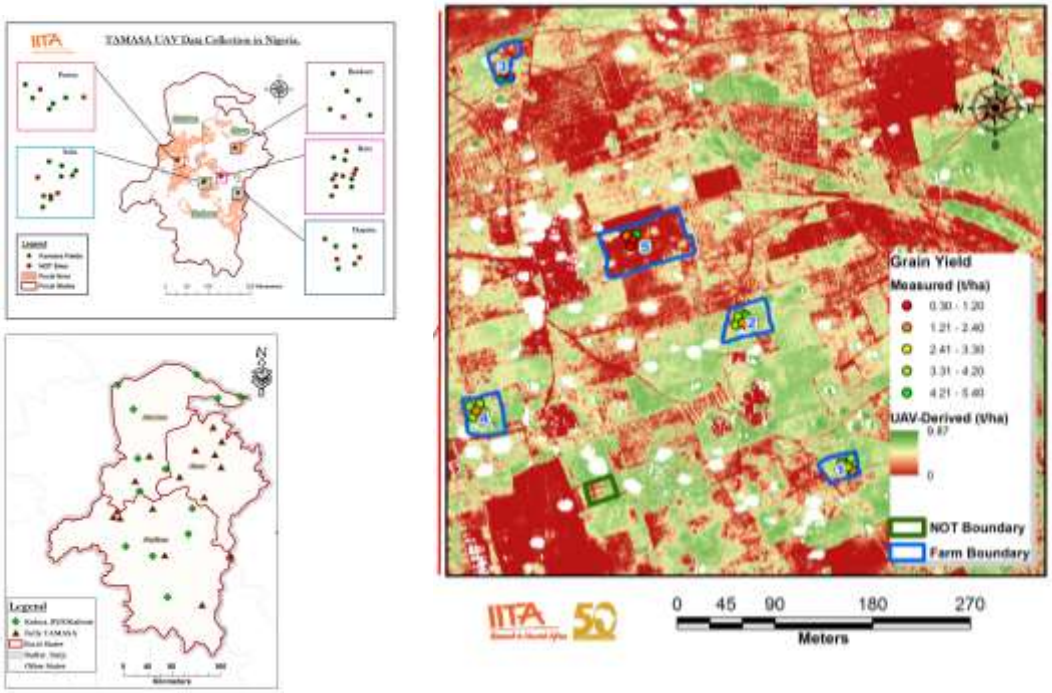


Figure 7. Maps showing sites where UAV flights were made in Nigeria (a), IITA and Kukua weather station network (b) and yield predictions based on UAV data

Sustainable intensification in Tanzania: towards a better understanding of spatial variability of input responses to reduce farmers' risks. Nagol PhD

This research is working in two soil catena in the south and north of Tanzania, within TAMASA pixels, combining field trials (fertilizer windows) with UAV imagery to upscale results. The hypotheses to be tested by Elias include: *high resolution imagery and field data allows fertilizer responses in heterogeneous fields to be accurately quantified; geo-referenced data can be used to evaluate spatially heterogeneous soil and agronomic management practices to improve field-specific soil fertility; UAV data products predict the fertilizer response differences within a soil catena; and fertility window trials will upscale nutrient recommendations.*

2.3 Institutionalisation

Context, approach, and objectives:

Improved methods and analytics, as well as research outputs, generated by TAMASA need to feed into and support national level institutions responsible for agricultural statistics and planning, including food security agencies.

Progress in the reporting period:

We concluded a second year agreement with CSA in Ethiopia for soil and yield samples in the AOI and provided more training on the use of ODK and the soil sampling protocol. CSA were relatively unrestricted in their annual sampling process and collected 410 yield and soil samples. The priority in Year 3 is to move this collaboration beyond contract research and towards a demand-led capacity development process around protocols and tools, and maybe also spatial analytics. CSA also collect DNA samples for CIMMYT and we will work with colleagues for a single approach. Likewise in Nigeria with NAERLS and Tanzania with the Food Security Bureau we need to identify entry-points (the value proposition) and a road map or action plan to support spatial data collection and curation.

Challenges:

Collecting data at scale has proved a major challenge, especially trying to be spatially representative. The logistics of moving away from essentially logistically convenient locations for trials that may not be very representative to more spatially dispersed and more random sites has been difficult. Many sites are distant, hard to access and cannot be easily supervised. We need to consider reducing the AOI in the case of ET and TZ. Processing samples has also been slower than expected, sometimes linked to lack of grinding facilities for example. This has delayed the availability of merged data sets with all the observed and processed sample data.

Institutionalisation is a key requirement, as this should drive the design and outputs. The yield related activities have been more closely aligned with research than institutional users to date, which will have a higher priority in Years 3 and 4.

Data analysis and analytics. The first two years have been very intensive on filling data gaps and data analysis has not advanced. TAMASA does have skills in spatial analysis and prediction, and Chamberlin (economics), Adewopo (UAV/RS) and Tonnang (modeling and prediction) will address this in Years 3 and 4.

Emerging opportunities:

Yield data collection by third parties. The active engagement of partners in the use of NE and VT tools is a good opportunity to collect yield data within their respective AOIs as part of the monitoring and evaluation process for the tools. This will be facilitated by a simple ODK form, SOP and appropriate training. Potentially partners could generate 500-1000 additional yield measurements in the AOI.

The yield challenge initiated by TAMASA and N2Africa, and *de facto* making all data open access asap, is a potentially great way to leverage existing skills across projects and outside projects. We are in contact with Lobell, who is also a partner for 1AF and CSISA for support in RS analysis of yields. Extra data collection within TAMASA pixels is planned for this collaboration.

Coalition of agronomy projects for institutionalisation. We need with others, to form a coalition based on common interest to engage with key national institutions in food security or national statistics.

WORK STREAM 3: Nutrient management tool

Soil fertility heterogeneity in African smallholder farming systems is a major factor that affects maize productivity and the suitability of crops and nutrient management recommendations for different geographic locations at various spatial scales (e.g. Kihara et al., 2016). The Nutrient Expert for Maize™ (NE) Decision Support Tool (DST) supports the development and dissemination of site-specific nutrient management (SSNM) options for maize production systems. NE provides a systematic framework for applying SSNM to develop strategies to optimize management of fertilizer N, P, K, secondary and micronutrients in heterogeneous maize production systems. The overall objective of this WS is to paramterise NE and co-develop validated versions of NE for each country with partners, and to support partners to use NE at scale and to institutionalise NE. Research questions for this WS include:

- *How many NOTs and validation experiments are needed to generate a robust, spatial recommendation?*
- *Can NE or components of NE such as QUEFTS be spatialised? What is the spatial scale at which NE can be most effectively used?*
- *What is the RoI on this investment?*
- *How do recovery fractions and crop nutrient responses differ with location?*
- *What type of decision tool(s) for nutrient management do users want?*

3.1 Addressing data gaps

Context, approach, and objectives:

The fertilizer requirement for a field or location is estimated from the expected yield response to each fertilizer nutrient, which is the difference between the attainable yield and the nutrient-limited yield. The N, P, and K requirements are based on the relationship between the balanced uptake of nutrients at harvest and grain yield, which are predicted using the quantitative evaluation of the fertility of tropical soils (QUEFTS) model (Janssen et al., 1990). The attainable yield (the yield for typical year at a location using best management practices without nutrient limitation) and yield responses to nutrients are determined from multi-location Nutrient Omission Trials (NOTs) established in farmers' fields.

Progress in the reporting period

Nutrient Omission Trials

Nutrient omission trials (NOTs) were conducted in farmers' fields in TAMASA focal areas in Ethiopia, Nigeria and Tanzania. The NOTs were conducted over two agricultural seasons in Ethiopia and Nigeria in the years 2015 and 2016, and over a season in Tanzania in 2015-2016 (Table 3). There will also be some additional NOTs as part of the OCP project in Nigeria.

Within the focal areas in Ethiopia and Nigeria in 2015, farmers and fields were carefully selected with guidance from existing crop and soil maps, and local maize researchers. In Tanzania the selection of field experimental sites were guided by statistical spatial models developed by AfSIS. In the second season in Ethiopia and Tanzania the NOTs were expanded to cover new geographic areas with guidance from maps developed by AfSIS. Sites were selected to be representative of major soil and cropping systems, using SOC, sand %, CEC and pH as mapping layers. In the second year of NOTs, cluster analysis was used to evaluate the yield response patterns to different nutrients in order to select repeat sites.

The trials were conducted in collaboration with national partners in each country. In Nigeria, Bayero University of Kano (BUK) was the major partner in the implementation of NOTs, with support from the SARD-SC project. In Ethiopia it was Ethiopian Institute of Agricultural Research (EIAR) with support from an IFA project in the CRV. In Tanzania it was Selian Agricultural Research Institute (SARI) for the northern region and Uyole Agricultural Research Institute for the Southern Highlands.

Table 3. Number of nutrient omission trials (NOTs) harvested in TAMASA focal areas in Ethiopia, Nigeria and Tanzania between 2015 and 2016

Country	Number of NOTs established in TAMASA focal areas			
	Season			
	2015		2016	
	Hybrid	OPV	Hybrid	OPV
Ethiopia	81	-	70	
Nigeria	118	119	103	103
Tanzania	-	-	174	-

The nutrient omission trials consisted of six treatments: a control (no nutrients applied), an NPK, three treatments with omission of N, P and K, from the NPK treatment, and secondary and micronutrients added to NPK (for detailed description of the protocols see NOTs implementation guideline, 2014 in the TAMASA folder on Dropbox). In Nigeria, the field trials consisted of two sets of treatments at each site: the first set was used to evaluate hybrid maize yields nutrient responses and the second set to evaluate OPV maize yield responses.

Overall, as expected, maize yield increased significantly compared to the zero fertilizer treatement when NPK fertilizers and micronutrients were applied in many study sites in all three countries (Fig. 8). In Nigeria only a few sites were not responsive to application of fertilizer where as in Ethiopia and Tanzania it varied from 11 to 43% of sites. (Table 4).

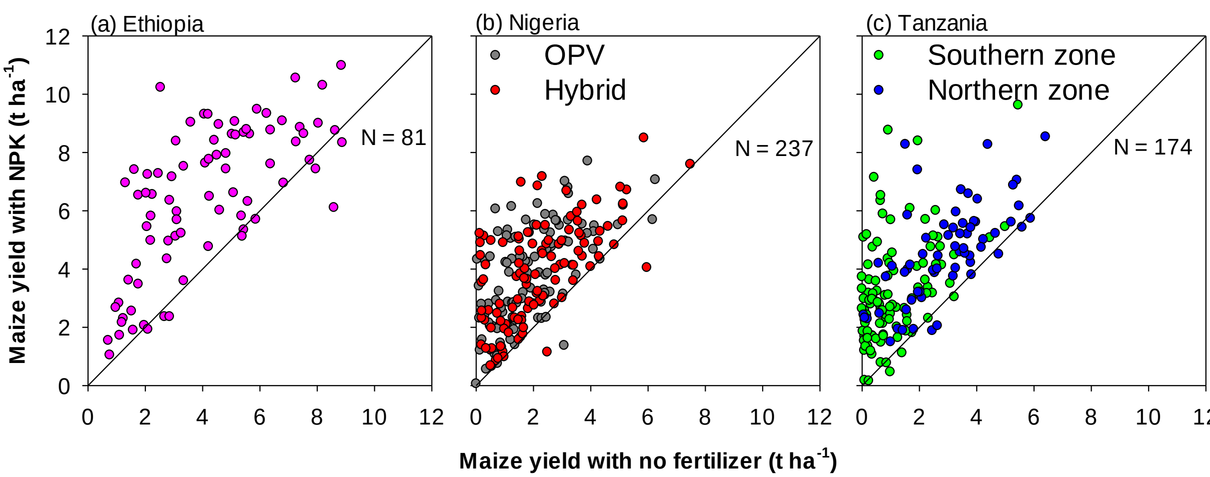


Figure. 8. Maize yield for the control (no fertilizer applied) compared with maize yield recorded when NPK fertilizer was applied in Ethiopia, Nigeria and Tanzania.

Table 4. Cluster analysis results of maize yield responses to different nutrients in Ethiopia, Nigeria and Tanzania (as percentage of number of experiments)

	Nigeria		**Ethiopia**		**Tanzania**	
			CRV	**mid-alt**	**SHigh**	**North**
Major determinant	**OPV**	**Hybrid**				
High response to N & P	58	48	18	29	23	12
High response to micro & secondary nutrients	42	24		11	17	13
High response K	-	10				
High response to N	-	6	15	33	15	30
High response to P					11	
High response to all nutrients applied	-	3			11	11
Low response to all nutrients applied	-	3	41	11	23	33

As an example of the data collected, some results from Nigeria are presented in Fig. 9. Soil nutrient content varied with study area and geographic location in Kaduna, Katsina and Kano States in northern Nigeria soil organic carbon (SOC) was relatively high (>1%) in Doguwa and Soba and low in

Bankure, <0.5%. Median values for SOC ranged between 0.4 and 1.2% across sites. All sites studied had median available P far below the critical limit value of 15 mg P kg^{-1} soil for maize production. Consequently, application of P fertilizers is needed for increased maize yields. There was only a very weak correlation between soil nutrient level and yield.

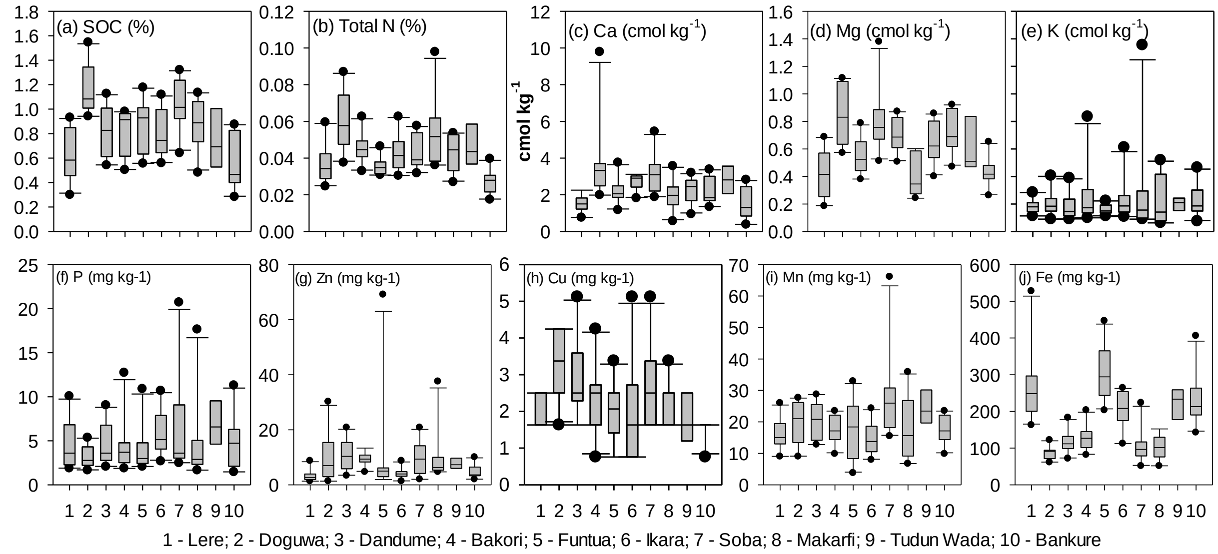


Figure. 9. Descriptive analysis of soil nutrients content across geographic locations in Kaduna, Katsina and Kano States in northern Nigeria. The soil was sampled from nutrient omission trials conducted in these areas in 2015.

Maize grain yield observed for OPV and hybrid varieties in Nigeria was similar regardless of nutrients applied. This suggests that similar nutrient management and fertilizer recommendations can be used for both OPV and hybrid maize varieties in northern Nigeria. Therefore only hybrid responses are presented and discussed. The highest average maize grain yield varied with study site, with about 4.5 t ha^{-1} recorded in Doguwa, Dandume and Bakori. The lowest average yields were in Bunkure with <2 tha^{-1}. Nitrogen and P were generally the most limiting nutrients for maize production in many areas studied in northern Nigeria (Fig. 10). Maize yield responses to N and P ranged between 0.5 t ha^{-1} and 2.5 t ha^{-1}. Maize yields were largest when secondary and micronutrients were applied in Dandume, Funtua, Bunkure and Soba (Fig. 10; Table 4), suggesting further research on micronutrients is needed in Nigeria. The yield response to K was generally small, < 0.5 t ha^{-1} across sites. Overall these results demonstrate highly variable yield responses to different nutrients, suggesting that site specific nutrient management is important for improved maize production in northern Nigeria. Maize response patterns to different nutrients varied from site to site, especially in the hybrid (Table 4). This difference between the OPV and hybrid requires further investigation.

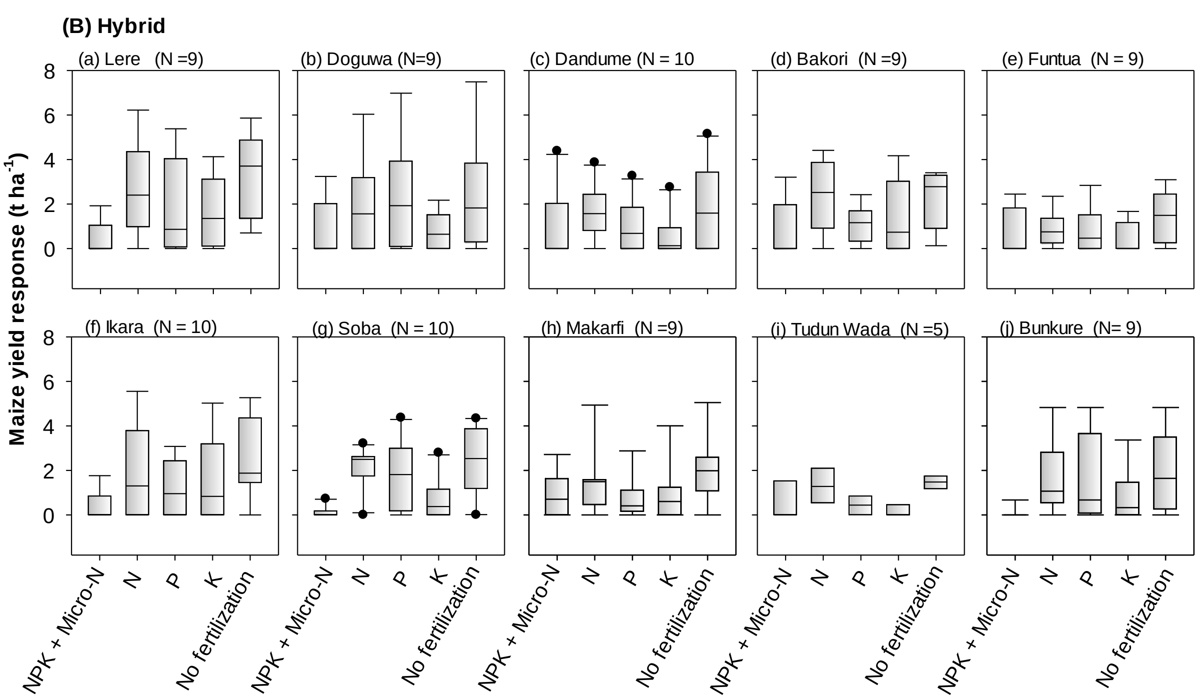


Figure. 10. Maize yield (OPV) responses to different nutrients across ten local government areas in northern Nigeria. Data was recorded from nutrient omission trials conducted in 2015 in Kaduna, Kano and Katsina States. NPK + Micro-N – NPK + secondary and micronutrients; N – Nitrogen, P – Phosphorus, K – Potassium.

Performance (validation) trials

Multi-location trials were conducted in farmers' fields in each TAMASA focal area in Ethiopia (n=50, Bako and Jimma only) and Nigeria (n=200) in 2016 to evaluate the agronomic and economic performance of fertilizer recommendations developed from the NE Version 1. Four treatments were compared in a randomized complete block design replicated across farmers' fields (Table 5). NE was used to generate recommendations using standard site specific inputs or using inputs plus a soil test. Sites were adjacent to previous NOT and within TAMASA pixels. A standard protocol was developed for a detailed approach for establishment of performance trials in farmers' fields.

In both Ethiopia and Nigeria the yield of the three fertilizer treatments was similar, suggesting the yield target approach had worked as expected. There was a lot of variation in the response across trials that needs investigation. Generally NE and NE-soil test used lower amounts of P and especially K, resulting in lower input costs. These data were used in the Value Proposition for discussions with partners in the respective countries,

Table 5. Recommended amounts of nutrients in kg/ha (median and interquartile range in parentheses) for Nigeria and Ethiopia

NE recommendation	Soil test based NE recommendation	Regional recommendation	Control (no fertilizer applied)
	Nigeria		
N: 110 (100 – 120)	N: 122 (100-134)	N: 120 (120 – 120)	N: 0 (0 – 0)
P_2O_5: 35 (25 - 42)	P_2O_5: 52 (40 -67)	P_2O_5: 60 (60 - 60)	P_2O_5: 0 (0 – 0)
K_2O: 15 (15 – 33)	K_2O: 40 (24-60)	K_2O: 60 (60 - 60)	K_2O: 0 (0 – 0)
	Ethiopia		
N: 120 (120 – 130)	N: 120 (120-120)	N: 92 (92-111)	N: 0 (0-0)
P_2O_5: 52 (39 - 75)	P_2O_5: 25 (0 -45)	P_2O_5: 69 (69-69)	P_2O_5: 0 (0-0)
K_2O: 27 (0 – 31)	K_2O: 0 (0-0)	K_2O: 0 (0-0)	K_2O: 0 (0-0)

Optimizing productivity of maize in the Nigerian savanna agro-ecological zone: influence of nutrient limitations and imbalances. Bello PhD

This research is based on the NOTs and adds value through additional soil and plant tissue analyses. The hypotheses to be tested in this research include: *Variability in soil fertility and productivity limits maize yield under current blanket fertilize recommendation in Nigerian Sudan Savanna agro-ecological zone and nutrient balances in maize production system in Nigerian Sudan Savanna agro-ecological zone are negative; QUEFTS model can be used as a site-specific nutrient recommendation decision tool for farmers to improve nutritional balances and yield in Nigerian Sudan Savanna agro-ecological zone.* Analyses in detail of the NOTs in Nigeria is in progress and this will include Compositional Nutrient Diagnosis (CND) to develop norms and evaluate nutrient imbalances and limitations.

Modeling site specific nutrient management technologies for improved maize production in the Northern Guinea and Sudan savanna of Nigeria. Bassam PhD

This research also adds value to the NOT and NE development process for Nigeria. The objectives are: *to assess the effects of soil fertility variability on maize productivity and maize nutrient requirement in smallholder farming systems; to revise the QUEFTS model by integrating algorithms for the inclusion of Sulphur in in predicting site-specific nutrient requirements (based on establishing the deficient nutrient among Ca, Mg, S, Zn and B); to assess the utility of revised QUEFTS model for predicting fertilizer requirements under specific soil and climatic conditions; and to adapt the Nutrient Expert Model (NE) decision support tool for application in developing fertilizer recommendations in Northern Guinea and Sudan savanna of Nigeria*. Evaluation of QUEFTs parameters has suggested that some changes are justified based on the NOT data to date. Future work will focus on adding micronutrient responses to NE. Two experiments are planned for 2017: one with the macro and micro nutrients applied singly alongside NPK (n==20); and NOTs with five treatments (NS, PS, KS, NPS, NKS, PKS and NPKS) (n=40).

Key messages drawn from NOTs conducted in Ethiopia, Nigeria and Tanzania

- Maize yield response to application of NPK fertilizers was significant in all three countries. This suggests that nutrient management and improved fertilizer recommendations is major entry point for increased maize productivity and profitability of smallholder maize farmers
- Maize response to different nutrients varied with study site and this was more pronounced in Nigeria where yield levels were lowest. This would suggest the opportunities for site specific nutrient management are greatest here

- Nitrogen was the nutrient most limiting maize production in almost all sites in Ethiopia and northern zone of Tanzania. Nitrogen and phosphorus were the nutrients most limiting maize production in Nigeria and southern zone of Tanzania. Secondary and micro-nutrients were important for enhancing maize production in a number of sites in Nigeria
- The impact of K on maize yield was generally small although some signs of K deficiency were observed in treatments where K was omitted. However, given a combination of maize's high demand for nutrients and removal of maize residues to feed livestock it is imperative to apply small amounts of K to minimum nutrients depletion and sustain maize production
- Overall, there was a poor correlation between nutrient responses and soil properties (in Nigeria at least). Similar results have been observed in other NOT data and suggest that current methods of soil analysis and soil/site characterization need improving
- The performance trials showed similar yields to the regional recommendation but with lower rates of P and K application and hence lower overall costs.

3.2 Co-development

Context, approach, and objectives:

The development of the Nutrient Expert (NE) decision support tool requires the active participation of target users (i.e. service provider partners), local leadership and relevant stakeholders, to ensure that NE meets users' needs and preferences – especially the user-interface. The identified user and host institutions are given in Table 6.

Table 6. Nutrient expert (NE) host and user institutions mapped in Ethiopia, Nigeria and Tanzania

Country	NE host institution	NE user institution
Ethiopia	EIAR (Land and Water Resources Directorate)/ ATA	Ministry of Agriculture and Natural Resources (Department of Soils and Extension)
Nigeria	Bayero University of Kano (BUK)	SG 2000; DOREO partners; NOTORE & ADP
Tanzania	ARI Mlingano	One Acre Fund; Ministry of Agriculture (locally via Selian Agricultural Research Institute (SARI) and ARI-Uyole)

Progress in the reporting period:

Nutrient Expert version 1 (NE v1) was developed in 2016 for all the three countries based on the NOT data, and consultation from TAMASA extension service partners and local researchers. An Android mobile phone based applications of the NE v1 tool was also developed for Ethiopia and Nigeria by IPNI. The demand for NE has been clearly articulated in all three countries. The development of NE was done in collaboration with various stakeholders (Table 6) through awareness and training events. The objectives were to:

(i) Orient extension partners on the scope and use of NE in the development of site-specific nutrient management and fertilizer recommendations

(ii) Evaluate the use of NE for different extension partners, and identify the adaptations required for its effective use in specific intervention areas and initiatives of partners

(iii) Identify extension service partners' specific needs and demands for using NE and to identify the training and support requirements for using NE at different spatial scales

(iv) Develop action plans for co-development of NE and other SSNM related applications

The co-development process will accelerate in 2017 now that: (i) NOT and performance trials data provides evidence on what NE can do (expressed as Value Propositions); (ii) calibrated NE versions are available for each country; and iii) an Android app is available for users to test and provide feedback on.

Out-scaling by partners

In February 2017, one day planning meetings were held in Nigeria, separately with SG2000, Baban Gona and three ADPs (Kano, Katsina, and Kaduna). The objective was to understand how partners currently make and use nutrient recommendations, and to plan with them how they would like to implement NE on a pilot basis within their framework and programs. A report of the meeting is available in the TAMASA folder in dropbox. SG2000 and their ADPs all want to make individual or group recommendations through their extension agents; Baban Gona in contrast, who provide inputs, want to make larger area recommendations. For the latter it became clear that a simpler version of NE would suffice that would allow then both to target new areas without extensive soil sampling as well as make larger area recommendations to existing fields. This process was repeated with MoANR (Crops, Soils and Extension directorates) in Ethiopia along with ATA in March.

Institutionalisation

The institutionalisation process has been initiated with partners by raising awareness of NE through annual meetings, workshops and training events. However, detailed roadmaps have not been developed. The extent to which institutions should be able to support the generation of recommendations cf hosting databases and applications has to be determined.

Lessons:

- Co-development has to be designed with and for partners who are the real users. One-to-one meetings in partner's offices are the most effective means to achieve this.

Challenges:

- Lack of awareness/appropriate nutrient management and fertilizer recommendations by National Research and Extension Systems is an overarching constraint. Extension service providers in all three pilot study countries lack systematic processes to develop and deliver field or area specific fertilizer recommendations
- The scope for scaling up nutrient management to new large areas without huge investment in multi-location nutrient omission trials and soil and plant analyses is still to be explored
- Data limitations for improved predictions of nutrient requirements both at field- and farm-level, and in larger spatial areas. Extrapolation to larger areas requires reliable soil, crop and climate data at appropriate scales. Data generated from NOTs and PTs is going to be integrated with data from other projects and analyzed (e.g. GYGA, etc.) to gain an understanding of the minimum data set required to extrapolate findings from experiments to larger spatial areas
- Establishment of many trials (> 200) across a wide range of locations was a challenge as many trials were not successfully harvested due to livestock damage (e.g. in Tanzania) and this has affected the quality of generated data. This suggests the need for innovate ways of establishing trials at scale.

Opportunities for scaling:

- A framework for application of NE to generate fertilizer recommendations at scale is under development (WS2). The framework is based on integration of information on crop nutrient requirements developed from nutrient omission trials with data available from soil and yield mapping projects initiatives. Up-to-date and reliable geospatial soil and crop data at appropriate scales (e.g. AfSIS datasets) will enable: (i) linking decision support tools to soil and crop information by integrating spatial data into decision support tool algorithms; (ii) reducing the requirements for new data measurement for calibration of decision support tools; and (iii) rapid and cost-effective adaptation of decision support tools to new geographies and crop production situations.

WORK STREAM 4: AGRONOMY TOOLS:

WS4 has been enlarged to include potential new tools, namely a crop management timing tool and a seed rate/plant density tool, as well as PhD research on data gaps to develop a soil moisture tool. The objective of developing tool or DSS is to: (i) translate existing knowledge into products that others can use to scale agronomy in a spatially explicit manner; (ii) through monitoring and learning processes improve the tools to meet users' needs; and (iii) through monitoring outcomes enable the collection of spatial data.

4.1 Variety selection & timing of crop management decisions;

Context, approach, and objectives:

In order to maximise biomass and yield, it is important that farmers opt for a maize variety that is well adapted to the length of the growing season in their location, and that has their preferred characteristics. Maize farmers in TAMASA target countries have access to scant information on the type of varieties that are available to plant (though note http://mbeguchoice.com/ in Kenya provides web-based variety information). Service providers, such as extension organisations/workers and agro-dealers, often also have limited (access to) up-to-date knowledge on the (latest) maize varieties on the market, which may contribute to low use of improved varities in some countries or regions. Product information on maize seed packages is usually very limited, with varieties being categorized in imprecise duration classes (i.e. early, medium, late maturing). Consequently, farmers and service providers cannot make informed choices about which maize variety to grow or recommend in their locations. In addition, in absence of adequate information on suitable varieties for their location and what farmers are successfully growing (i.e. feedback), agro-dealers and farmers cannot articulate their demands towards seed producers.

The hypotheses or research questions to be tested are:

1. Better information about variety characteristics within particular areas will result in

a. input suppliers changing their stocks to better match local conditions,
b. farmers switching to more appropriate varieties

2. Better information about phenological characteristics of varieties will enable farmers to improve their management (e.g. by better timing of weeding and fertilization)

a. Better management, in turn, will lead to higher productivity

4.1.1 Addressing data gaps

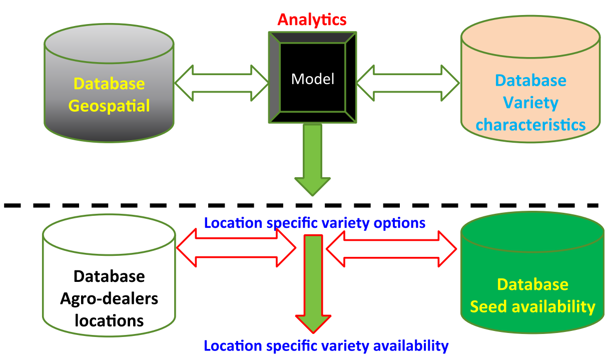
Context, approach, and objectives:

Maize crop development or phenology is variety specific and primarily determined by temperature. Therefore it is possible – for any given location – to predict key stages of crop development such as flowering and maturity based on planting date (or vice-a-verse). Furthermore, the timing of other key development stages, such as the appearance of the 5th leaf, can also be predicted and used to provide advice on the timing of crop management decisions such as fertilizer top-dressing. This WS has developed an analytical model to predict maize development based either on calibration experiments or more pragmatically using multi-location trial data sources that are readily available from plant breeders, seed companies and variety release systems.

Progress in the reporting period:

The variety tool V1 was developed using Eclipse Rich Client Platform (RCP) philosophy. Eclipse is an open and extensible integrated development environment (IDE). The main advantage of RCP is its modularity, which makes it easy to use a large set of available plug-ins; furthermore the application can run either on Windows, Linux or Mac platform. Data inputs formats into V1 is shown in Figure 11a.

(a)



(b)

Country	No. expts	No. varieties
Kenya	10	10
Ethiopia	15	20
Nigeria – BUK	15	22
Nigeria –IAR	15	12
Tanzania	15	40

Figure 11. Schematic representation of TAMASA's variety use case functionalities with links to small holders farmers and agro-dealers (a); and the number of experiments (sites x sowing dates) used to calibrate the major maize varieties in each country (b)

V1 was developed and calibrated initially from data on phenology from multi-location plant breeders trials in Kenya (courtesy Dr Makumbi, CIMMYT), showing the utility of this approach. In Ethiopia, Nigeria and Tanzania specific calibration experiments were carried out in each country in 2015/16 (Fig 11b). These experiments were designed to sample variation in average temperature and photoperiod by using altitude, sowing dates and different latitudes. Partners were consulted to choose currently grown varieties for inclusion in the experiments. Partners carried out the experiments following training in SOP and the use of ODK to collect data. Sowing, emergence, tassel and silk appearance, maturity and grain yield were measured. Daily weather data at sites was also collected or obtained from nearby meteorological stations.

An example of the response of maize to temperature across experiments is shown in Fig. 12a along with the predictive equation. The analytical process tests approximately 80 models to find the best fit. The initial version of the maize variety selector for Kenya (Fig 12b) allows user to select a county, the planting period and location (from a map). The app then lists maize varieties which should complete their life-cycle within the growing season at that location. Other characteristics such as color, drought/ disease resistance, N-efficiency, etc. are given as well as the name of the seed company. Following a co-development workshop it as agreed that the app had to include information about seed availability and this is being added, strating with the version for Nigeria.

a **b**

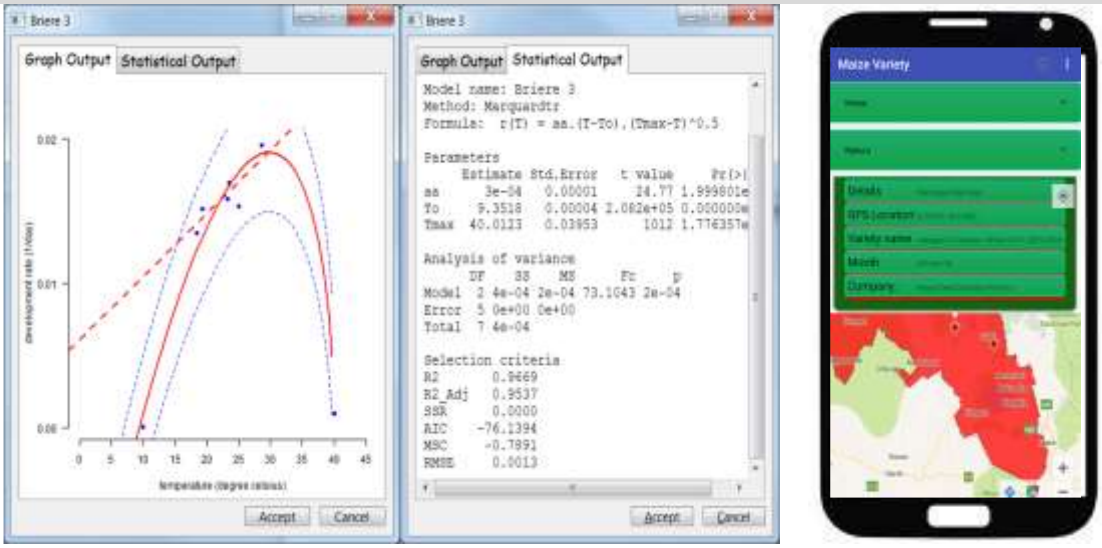


Figure 12. Example of points of data (blue) for a variety of maize at the vegetative phase fitted by a three parameter temperature dependent mathematical expression (red curve) in the left (a). Statistical criteria for model selection and its parameters are shown in the right (b). Screen shot of the app with map and variety information.

Matching maize varieties to different soils and agro-climatic conditions of the Northern Guinea and Sudan savannas of Nigeria using crop simulation models. Adnan PhD research

The hypotheses to be tested in the research include: *CERES-Maize Model can be used as a tool to aid selection of maize varieties and optimization of planting density in the NGS and SS of Nigeria; genetic coefficients generated by field trials lead to more accurate calibration of CERES-Maize model than those generated from yield evaluation trials; the sequential approach method, when optimized, can be used to generate accurate genetic coefficients of maize using the GENCALC program of DSSAT; and the planting density adopted for maize in Northern Guinea Savanna and Sudan Savanna of Nigeria is below the optimum.* In 2015 eight experiments were conducted with 22 varieties to calibrate CERES-Maize. In 2016 60 on-farm trials with 10 varieties and a plant density treatment were conducted to validate CERES-Maize for the AOI. Once the validation process is complete, new research questions will be prioritised; yield prediction, optimum sowing dates, densities, nutrient management under different climate variability and change scenarios. This work is also linked to the variety tool and the seed rate tool, and has potential to link to the ex-ante spatial framework (WS1).

4.1.2 Tool co-development

A workshop was held in Addis in 2016 with a range of users, including scientists, supervisors and extension agents to evaluate different options for the design of the app user interface, focusing primarily on what questions the app should be able to answer. From this a revised version of the app was designed that now has options for different users, such as farmers, service providers and agro-dealers as well as a database searching facility. This is currently under development with consultants in Nairobi.

In Nigeria and Ethiopia meetings have been held with users to plan the implementation of the tool in their systems. In Nigeria SG2000 and the ADPs of Kano, Katsina and Kaduna will evaluate the tool through a small number of EAs. The plan is to provide advice to 600 farmers. SG2000 also collected information on where agro-dealers are and what seed they stock so this can be incorporated into the app.

4.1.3 Institutionalisation

Stakeholder meetings with potential users and host institution were held in all three countries of TAMASA in 2016. These meetings offered opportunity to identify host institutions. In Ethiopia the host will be EIAR – Crop Protection Directorate; in Nigeria the Institute for Agricultural Research (IAR); and in Tanzania the Tanzania Official Seed Certification Institute (TOSCI). These are the institutions that are responsible for variety release and therefore hold data on multi-location trials and variety characteristics (DUS).

We have considered with partners in Nigeria potential business models to sustain the variety tool. These include a fee for seed companies to have their variety included in the tool or a fee to agro-dealers to have their details included. These value propositions will have to be tested but potentially a variety tool could increase their market share and provide them with valuable feedback on users. More emphasis will be placed on institutionalisation in Year 3.

4.2 Seed rate/density

Context, approach, and objectives:

Low plant population density is a common problem identified by many partners and researchers (see Fig 13). We can hypothesize that this is the results of: (i) farmers not knowing the area of the plot or field to be planted and hence how much seed to purchase; (ii) not knowing what area their purchased bag or quantity of seed will plant; and (iii) not knowing the optimum density (row x in-row spacing) for their specific cropping system, environment and fertility level. This tool is designed to fill that gap. A wireframe has been developed and consultations held with many agronomists on optimum densities and the key factors that should be considered. The app will be developed as soon as possible for validation in Tanzania in 2017/18 season.

4.3 Soil moisture

Context, approach, and objectives:

Data assimilation for near-real time soil moisture estimates (Amsale PhD)
The availability of soil moisture estimates that can be used in DSS and models in SSA is very limited. Remote-sensed surface soil moisture is now available every 3 days from SMAP (Soil Moisture Active Passive). The objective of this research is to generate a soil moisture product using data assimilation techniques. The hypotheses are: (i) data assimilation can improve soil moisture estimates; (ii) data assimilation methods can work with ensembles based on land surface models; and (iii) understanding uncertainty in input and model data will improve data assimilation.

Simulation experiments have shown that the Darcy model for soil moisture, a variant of the method within the UK land surface model Jules, is dynamically stable but suffers from ensemble collapse in the absence of rainfall inputs. Therefore we modelled stochastically rainfall and showed that this improves the ensemble forecast and made it more stable. We are now using an Ensemble Transfer Kalman Filter, a data assimilation technique, to model SMAP and satellite rainfall data to produce soil moisture profile estimates.

Combining multiple stream of environmental data to develop a DSS (Dagmawi PhD)
Partners are always asking for climate forecasts and yields as part of DSS. This research, linked to the soil moisture data assimilation research above, will generate analytics that fill this knowledge gap with potential use in the agronomic and yield use cases. This research will also support a new use-case on crop insurance, identified in the Addis design meeting, which requires better spatial and temporal drought and yield estimates. The objective of this research is to generate soil moisture, planting date, yield and drought risk metrics based on probabilistic approaches that combine climatology, soil moisture and crop models with DSS. The research questions are: (i) How robustly do model outputs such as modeled soil moisture, and meteorologically based metrics such as SPI and SPEI represent agricultural drought and subsequent yield deficit?; (ii) How can such metrics of agricultural drought best be incorporated into a decision support framework, to give farmers access to accurate information on impending drought?; and (iii) How can satellite data, seasonal forecasts and in-situ observations be combined?

One immediate output that is being co-developed with 1AF is a planting date tool that calculates soil moisture in the surface layer using future climatology. We are also estimating yields with hindcasting and future climatology ensembles using the general large area model (GLAM) and data from Kitale western Kenya.

4.3.1 Addressing data gaps

Challenges:
TAMASA has made significant progress in developing V1 of the variety too, but we are limited by our technical skills and hence are not very agile. We have recently found a company in Nairobi to provide the necessary expertise and this should improve our product and speed of delivery

In the short-term, all tools on mobiles have to be off-line and able to run on older versions of Android. This requires a different approach to the analytics and databasing, and may limit our capacity to collect feedback on how the tool is used.

Emerging opportunities:

Mobile phone based tools have potential to help collect spatial data, especially where users see value in providing such information.

WORK STREAM 5: Value addition for the fertilizer industry

Context, approach, and objectives:

WS5 is a space for TAMASA to work with AfSIS and others on the processes and workflows for fertilizer formula development and testing.

5.1 Soil mapping

So far the only activity has been in Nigeria where AfSIS/IITA/BUK/ NARS collected 3000 soil samples in 2015 and OCP generated two formulas for testing in 2016. However, these could not be cleared in time for use in 2015.

5.2 Formula testing & value addition

In Nigeria in 2017, funded by OCP, 1500 trials in eight states will compare two formulas (NPKSZnB and NPSZnB) with a control and the current fertilizer recommendation (15:15:15 NPK). Soil samples, ear-leaf samples and yield will be measured and data used by WS2 and/or added to AfSIS databases.

In Tanzania OCP are also proposing to test formulas through the national program but with design and SOPs from AfSIS and TAMASA. Details are yet to be finalised but will include soil, ear-leaf grain tissue samples, and yield measurements.

WORK STREAM 6: Adoption and impact

Context, approach, and objectives:

WS6 is intended to create space for research on farmer responses to decision support tools, as well as to enable research more generally on responses to efforts to induce changes in agronomic decision making. The APS conducted in 2016 forms the basis for this set of activities. In 2016, we established plans for a randomized control trial (RCT) to evaluate farmer responses to site-specific nutrient management for maize in northern Nigeria. Oyinbo's PhD research contributes to this WS and indeed he will conduct the RCTs and choice experiments in Nigeria in Years 3 and 4. PhD students in Tanzania (Violeth) and Ethiopia (Banch) may also rigorously test innovations in 2018.

Some of the hypotheses to be tested in this workstream are:

1. Site-specific decision support tools will enable farmers to make better agronomic choices and associated investments (e.g. in fertilizer and seed). The underlying hypothesis is that better information is the key constraint
2. Improved management is conditioned not only by information, but also liquidity constraints and risk aversion. In other words, uptake of improved agronomic advice is conditioned by reducing credit constraints and/or risk exposure. *Note*: this hypothesis is only directly testable in an experimental setting if are able to provide "treatments" of credit and insurance. This will almost certainly require additional resources and implementing partnerships. As such, it may be beyond the scope of the project, at least during the first phase
3. The way in which information is presented affects uptake. More specifically, providing information about uncertainty surrounding predicted outcomes from tools (such as Nutrient Expert) will, *ceteris paribus*, improve the take-up of recommendations. *Note*: this is only testable if IPNI is able to develop a version of Nutrient Expert that offers such information.

6.1 RCTs on extension innovations

The main thrust of 6.1 is to evaluate the impacts of site-specific nutrient management recommendations, as embodied by NE-Field. This is important, because an implicit underlying assumption of the project is that *technical information is the primary constraint* to farmer productivity, and that better information should result in better farm-level outcomes. This assumption is testable: by carefully evaluating how farmers respond to SSNM recommendations, we can start to evaluate the extent to which this assumption is true. Furthermore, by varying our experimental design (probably in 2018), we may identify factors which condition the uptake of better agronomic information by farmers.

One of these factors, which came up again in discussions at the Mbale meeting, is variability and risk. We have general agreement that we need to pay more attention to risk and responses to risk by farmers. This work stream offers opportunities to systematically test how the uptake of agronomic advice (for example, nutrient management recommendations) are conditioned by: (a) the amount of uncertainty in expected returns; and (b) how information about that uncertainty is presented to the farmer. This is a critically important question, and rigorous research on this question is of real value to TAMASA, in so far as it seeks to develop tools for taking agronomy to scale which are of maximum viability. (*Note*: this is a non-spatial research activity, although the distribution of risk is certainly geo-spatial, and it could inform geo-spatial work related to evaluating risk under WS1.)

Agricultural Intensification through Nutrient Expert Decision Support Tools: Evidence from Maize-Based Systems of Nigeria (PhD Research of Oyinbo)

Oyinbo's PhD will use choice experiments and RCTs to answer research questions on NE. The hypotheses to be tested include: *Farmers' have strong adoption preferences for extension recommendation from NE tool relative to traditional extension recommendation; Extension agents'/service providers' are favourably disposed to the integration of NE tool in extension service delivery to farmers (both through choice experiments); and Introduction of NE tool recommendations in maize-based farming systems can contribute in improving maize yield; Farmers' exposure to NE tool recommendations can increase their fertilizer use and stimulate use of complementary inputs (both through RCTs).* In 2017 two options are being considered for an RCT based around the TAMASA APS. One option involves rollout of a single version of NE-field tool indicating the use of one treatment and a control in the RCT design. A second option is a two-treatment framework that can address the question of whether uptake of recommendations is conditioned by the way the information is presented to farmers - in addition to evaluating the impact of the tool. The first treatment is based on what NE tool currently does (recommendation without associated variability in yield and prices) and the second treatment is based on field-specific recommendations with possible variation in outcomes.

6.2 Impact evaluation of decision support tools

The second part of this WS has not yet had any activities defined for it, although several ideas have been suggested as possible research activities of relevance to TAMASA's overall objective. As an example, one of these ideas was to test the impact of packaging seed along with measuring string and spacing instructions, where the hypothesis is that such an intervention could nudge plant spacing decisions. There are tremendous opportunities here, but we need to collectively decide to prioritize one or more ideas for implementation, and allocate project resources accordingly.

Challenges:

RCTs are complicated to set up and great care is needed to 'protect' the APS set up so it can be used without contamination from other out-scaling activities.

Emerging opportunities:

Tools are becoming mature and are expected to be ready for testing starting in the 2017 main season. With other partners such as 1AF there are other opportunities to test agronomic interventions at scale beyond just nutrient and varieties.

WS7: PROJECT MANAGEMENT

During the meeting in Mbale, the team worked on identifying gaps and room for improvement in project management and communication.

We will use the project management software that CSISA use to increase communication and collaboration with those associated with TAMASA, as well as provide for better project schedule tracking. A detailed workplan with milestones and indicators has been developed for proper progress monitoring (to be shared on 30th). The team will have the ability to review and update the plan in the new tool (https://tamasa.teamwork.com) once it is populated with the final data.

It was also determined that the project needs to produce internal and external communication documents/ products. To that effect, a communication handbook articulating the guidelines for communicating the TAMASA identity as well as describing the structure and processes that we will follow for our different communications products and channels has been developed. This will help the team get the best results and value from our communication activities. A small communication team will be formed to ensure the work is carried out according to plan, and the progress will be evaluated on a quarterly bases to ensure we're on the right track. The country strategies identify key partners for communication.

A monthly skype meeting has been in place since the project manager joined where the core team (CIMMYT, IITA, IPNI, BUK, EIAR and DRD) discusses updates, progress, risks and issues. Additional face-to-face and skype meetings will be scheduled with different teams including partners within each country and cross regionally to ensure timely and appropriate project information sharing.

A TAMASA website was developed last year (in line with CIMMYT policies) and launched. The aim is to keep the website dynamic and informative with regularly updated content areas based around country activities. In order to ensure consistent updates we've and built in communication deliverables (blog posts, newsletters, information briefs etc.) in the workplan.

Printed materials and the APS survey in ODK have also been translated to the local language for ease of communication. All further workshops and training will be conducted in the local language whenever possible.

Emerging opportunities
As TAMASA starts to produce tangible products there is an opportunity to develop value propositions and to use these as entry-points. We will also seek to get more external inputs into TAMASA. We will set up country advisory committees that will meet twice a year to support communication and partnership. We will also convene small meetings or consultations with external experts as needed to support our work. The initial priority will be to support analysis of data, and especially yield prediction.