Agronomy at scale

Principles and approaches with examples from ACAI

Research to Nourish Africa

Pieter Pypers, 22-11-2016

What is “agronomy at scale”?

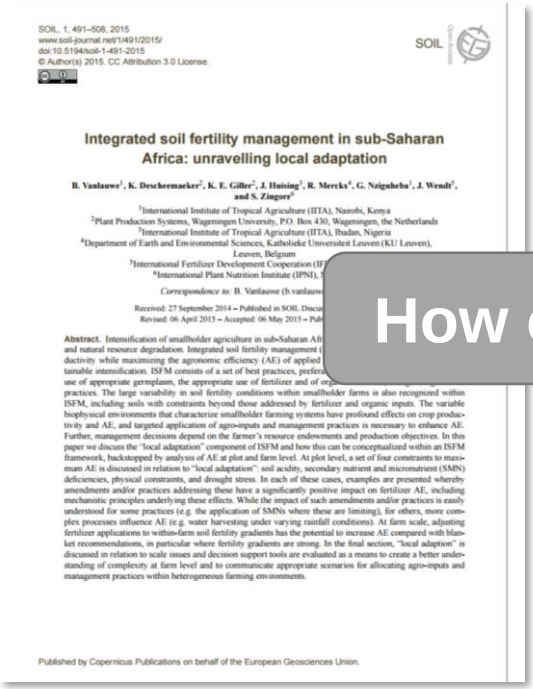
Definition:

“agronomy” = “the science of soil management and crop production”

“at scale” = “at the required size to solve the problem”

The problem?

- Increasing recognition of **variation in response** to interventions
- Need for **local adaptation** of ISFM components



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SOIL

Integrated soil fertility management in sub-Saharan Africa: unravelling local adaptation

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Abstract. Intensification of smallholder agriculture in sub-Saharan Af
and natural resource degradation. Integrated soil fertility management (
ductivity while maximizing the agronomic efficiency (AE) of applied
tainable intensification. ISFM consists of a set of best practices, prefera
use of appropriate germplasm, the appropriate use of fertilizer and of o
practices. The large variability in soil fertility conditions within smallholder farms is also recognized within ISFM, including soils with constraints beyond those addressed by fertilizer and organic inputs. The variable biophysical environments that characterize smallholder farming systems have profound effects on crop productivity and AE, and targeted application of agro-inputs and management practices is necessary to enhance AE. Further, management decisions depend on the farmer's resource endowments and production objectives. In this paper we discuss the "local adaptation" component of ISFM and how this can be conceptualized within an ISFM framework, backstopped by analysis of AE at plot and farm level. At plot level, a set of four constraints to maximum AE is discussed in relation to "local adaptation": soil acidity, secondary nutrient and micronutrient (SMN) deficiencies, physical constraints, and drought stress. In each of these cases, examples are presented whereby amendments and/or practices addressing these have a significantly positive impact on fertilizer AE, including mechanistic principles underlying these effects. While the impact of such amendments and/or practices is easily understood for some practices (e.g. the application of SMNs where these are limiting), for others, more complex processes influence AE (e.g. water harvesting under varying rainfall conditions). At farm scale, adjusting fertilizer applications to within-farm soil fertility gradients has the potential to increase AE compared with blanket recommendations, in particular where fertility gradients are strong. In the final section, "local adaption" is discussed in relation to scale issues and decision support tools are evaluated as a means to create a better understanding of complexity at farm level and to communicate appropriate scenarios for allocating agro-inputs and management practices within heterogeneous farming environments.

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BEYOND AVERAGES: NEW APPROACHES TO UNDERSTAND HETEROGENEITY AND RISK OF TECHNOLOGY SUCCESS OR FAILURE IN SMALLHOLDER FARMING

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INTRODUCTION

Agronomy research builds on a long-established tradition. It has delivered major increases in yields of all major food crops and other commodities, for example raising yields of the major cereals ten-fold from 1 t ha^{-1} in the early 19th Century to over 10 t ha^{-1} currently on some farms. The first experimental trials established by Lawes and Gilbert at Rothamsted in the 1840s, several of which still continue today, consisted of a single plot of each treatment (Poulton, 2006). It was only in the 1920s that research methods for experimentation were revolutionised through the work of Ronald Fisher. Fisher first introduced 'Analysis of Variance' (ANOVA) in 1925 in his book 'Statistical Methods for Research Workers' (Fisher, 1925). The design principles that Fisher introduced in his book 'The Design of Experiments' provided methods to ensure efficiency, eliminate bias in comparison of treatments and provide a measure

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Understanding variability in crop response to fertilizer and amendments in sub-Saharan Africa

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ABSTRACT

Improved understanding of soil fertility factors limiting crop productivity is important to develop appropriate soil and nutrient management recommendations in sub-Saharan Africa. Diagnostic trials were implemented in Kenya, Malawi, Mali, Nigeria and Tanzania, as part of the African Soils Information Service (AfSIS) project, to identify soil fertility constraints to crop production across various cropping systems and soil fertility conditions. In each country, one to three sites of 10 km × 10 km were included with each site having 12–31 field trials. The treatments tested included a control, an NPK treatment, three treatments in which the N, P and K nutrients were omitted one at a time from the NPK treatment, and three treatments in which secondary and micronutrients (Ca, Mg, S, Zn and B) simply referred here as multi-nutrients, manure and lime were added to the NPK. The field trials were conducted for 1–2 seasons; the test crop was maize except in Mali where sorghum was used. Nitrogen was limiting in all sites and generally the most limiting nutrient except in Sidindi (Kenya) and Kontela (Mali) where P was the most limiting. The general pattern in Kiberashi (Tanzania) shows none of the nutrients were limiting. K is mainly limiting in only one site (Mbinga) although incidences of K limitation were seen in almost all sites. Addition of multi-nutrients and manure further improved the yields of NPK in most sites. Cluster analyses revealed that maize crop in 11% of fields were highly responsive to nitrogen application, 23% (i.e., 21% poor and 4% fertile) 'non-responsive' to any nutrient or soil amendment, 28% being 'low responsive' and 36% of 'intermediate response'. This study indicates that constraints to crop production vary considerably even within a site, and that addressing limitations in secondary and micronutrients, and increasing soil carbon can improve response to fertilizers. For sustainable crop production intensification in smallholder farming systems in SSA, there is need to develop management strategies to improve efficiency of fertilizer use and of other inputs, recognizing the site-specific nutrient response patterns at various spatial scales.

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1. Introduction

Achieving food security is a key agenda that is eluding governments in sub-Saharan Africa (SSA) (Shapouri et al., 2010). Low productivity of food crops due to low nutrient application, in a region that has faced land degradation for several decades, is one of the major contributors to food insecurity in SSA (IFDC, 2006; Shapouri et al., 2010; Muller et al., 2012), besides post-harvest losses and inequitable food distribution. The use of fertilizers remains very low in SSA (IFDC, 2006; Liu et al., 2010) despite the resolution to increase fertilizer use to 50 kg ha^{-1} by 2016 by the Africa Fertilizer Summit in 2006. Limited access and high costs of fertilizers are among the major causes of the limited use of

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How can we advise farmers?

Why “working at scale”?

Objectives

- **Embrace** (quantify and understand) **variation**
- **Build models** (predict the next farmer’s response)
- **Provide customized advise** (poor the model into a decision support tool)

ACAI use cases

ACAI addresses questions identified by development partners

- Fertilizer blending
- **Fertilizer recommendations**

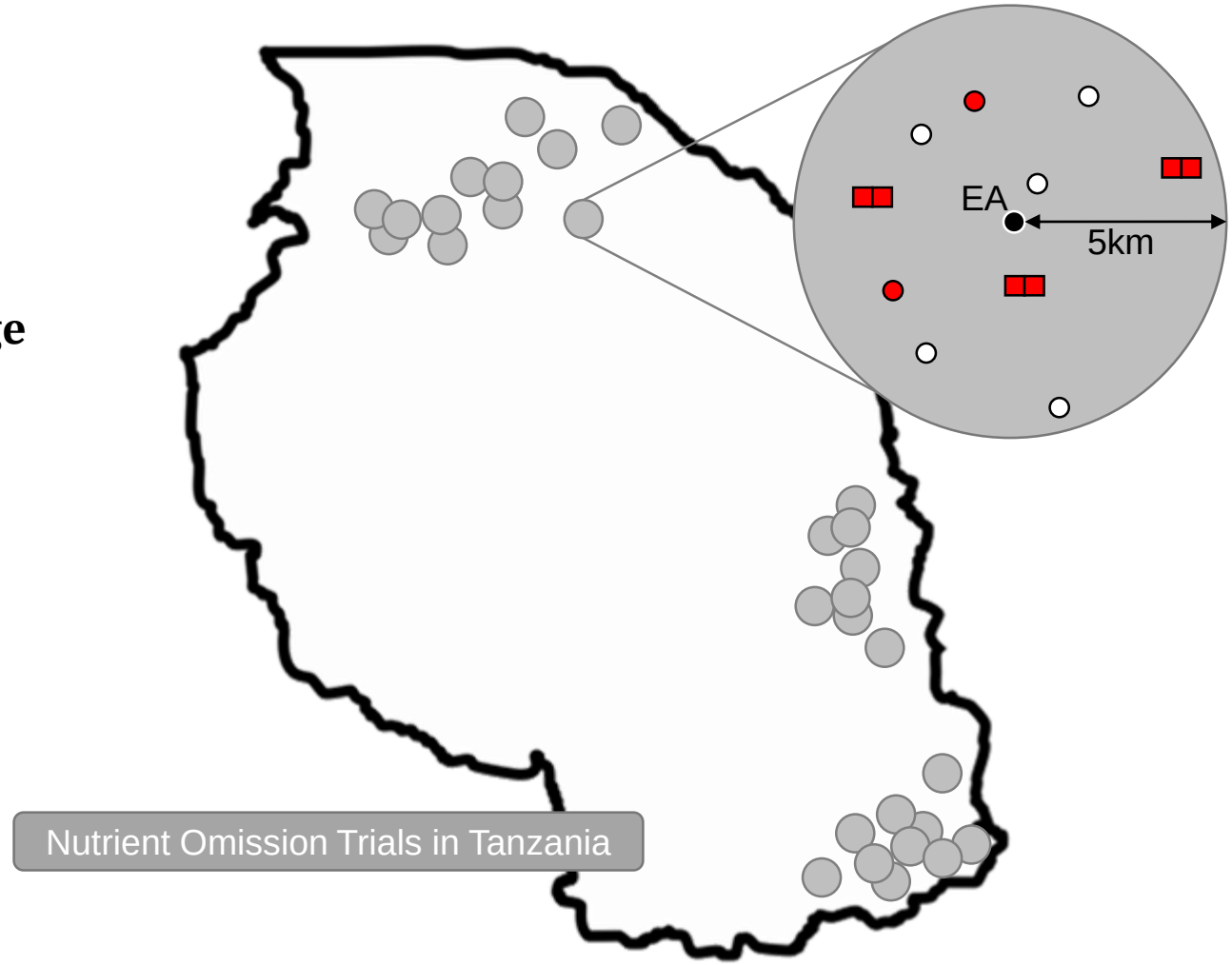
  What fertilizer, at what rate and following which regime should I apply to achieve a target yield / revenue gain?
- Best planting practices
- Cassava intercropping
- **Scheduled planting**

  When should I plant / harvest to achieve a maximal (starch) yield at a target harvest / given planting date?
- High starch content

Sampling frames

IMPORTANT An appropriate sampling frame to allow inter-/extrapolation of results:

- **Unbiased**
- **Representative**
- **Sufficiently large**
- **Cost-effective**



Sampling frames

IMPORTANT An appropriate sampling frame to allow inter-/extrapolation of results:

GIS-assisted approach

- **Unbiased**
- **Representative**
- **Sufficiently large**
- **Cost-effective**

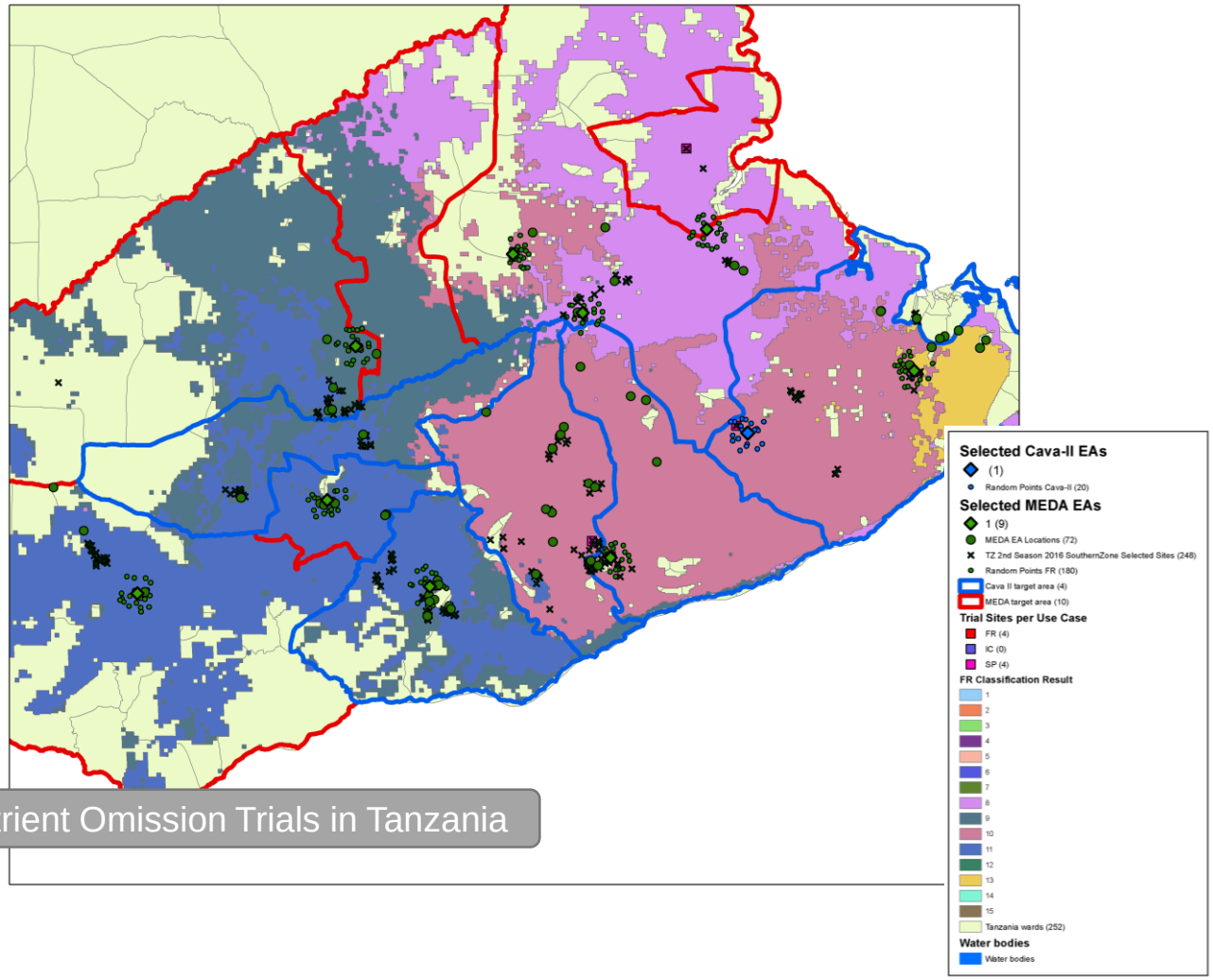
annmeant	1. Annual mean temperature (1960-1990) (1km)	Climatic factors
annpreciptn	2. Annual mean precipitation (1960-1990) (1km)	
ppdriestqt	3. Mean precipitation driest quarter (1960-1990) (1km)	
ppseasonlity	4. Seasonality (Coefficient of Variation) precipitation (1960-1990) (1km)	
ppwettestqt	5. Mean precipitation wettest quarter (1960-1990) (1km)	
tmcoldestqt	6. Mean temperature coldest quarter (1960-1990) (1km)	
tmseasonlity	7. Seasonality (Coefficient of Variation) temperature (1960-1990) (1km)	
tmwarmestqt	8. Mean temperature warmest quarter (1960-1990) (1km)	
af_CEC_T__M_sd2_250m.tif	9. AfSIS Cation exchange capacity for 5-15 cm depth (250m)	Soil factors
af_EACKCL_T__M_sd2_250m.tif	10. AfSIS Exchangeable acidity for 5-15 cm depth (250m)	
af_ECN_T__M_sd2_250m.tif	11. AfSIS Electrical conductivity for 5-15 cm depth (250m)	
af_EMGX_T__M_xd1_250m.tif	12. AfSIS Exchangeable Magnesium for 0-20 cm depth (250m)	
af_ENAX_T__M_xd1_250m.tif	13. AfSIS Exchangeable Sodium for 0-20 cm depth (250m)	
af_EXBX_T__M_sd2_250m.tif	14. AfSIS Sum of exchangeable bases for 5-15cm depth (250m)	
af_NTO_T__M_xd1_250m.tif	15. AfSIS Total nitrogen content for 0-20 cm depth (250m)	
af_ORCDRC_T__M_sd2_250m.tif	16. AfSIS soil organic carbon for 5-15 cm depth (250m)	
af_PHIHOX_T__M_sd2_250m.tif	17. AfSIS pH value for 5-15 cm depth (250m)	
af_SNDPPT_T__M_sd2_250m.tif	18. AfSIS Sand content for 5-15 cm depth (250m)	
M13EVIALT_200002_201403.tif	19. Enhanced Vegetation Index (2000-2014) (EVI) (250m)	Remote Sensing Products
M13RB3ALT_200002_201403.tif	20. Average MODIS Reflectance Red Band (2000-2014) (250m)	
M13RB7ALT_200002_201403.tif	21. Average MODIS Reflectance Blue Band (2000-2014) (250m)	
M15FPRALT.tif	22. Fraction of Photosyntetic active Radiation (FPAR) (2000-2014) (250m)	
M17GPPALT.tif	23. Gross Primary Production (250m)	
M17NPPALT.tif	24. Net Primary Production (250m)	

Nutrient Omission Trials in Tanzania

Sampling frames

IMPORTANT An appropriate sampling frame to allow inter-/extrapolation of results:

- **Unbiased**
- **Representative**
- **Sufficiently large**
- **Cost-effective**

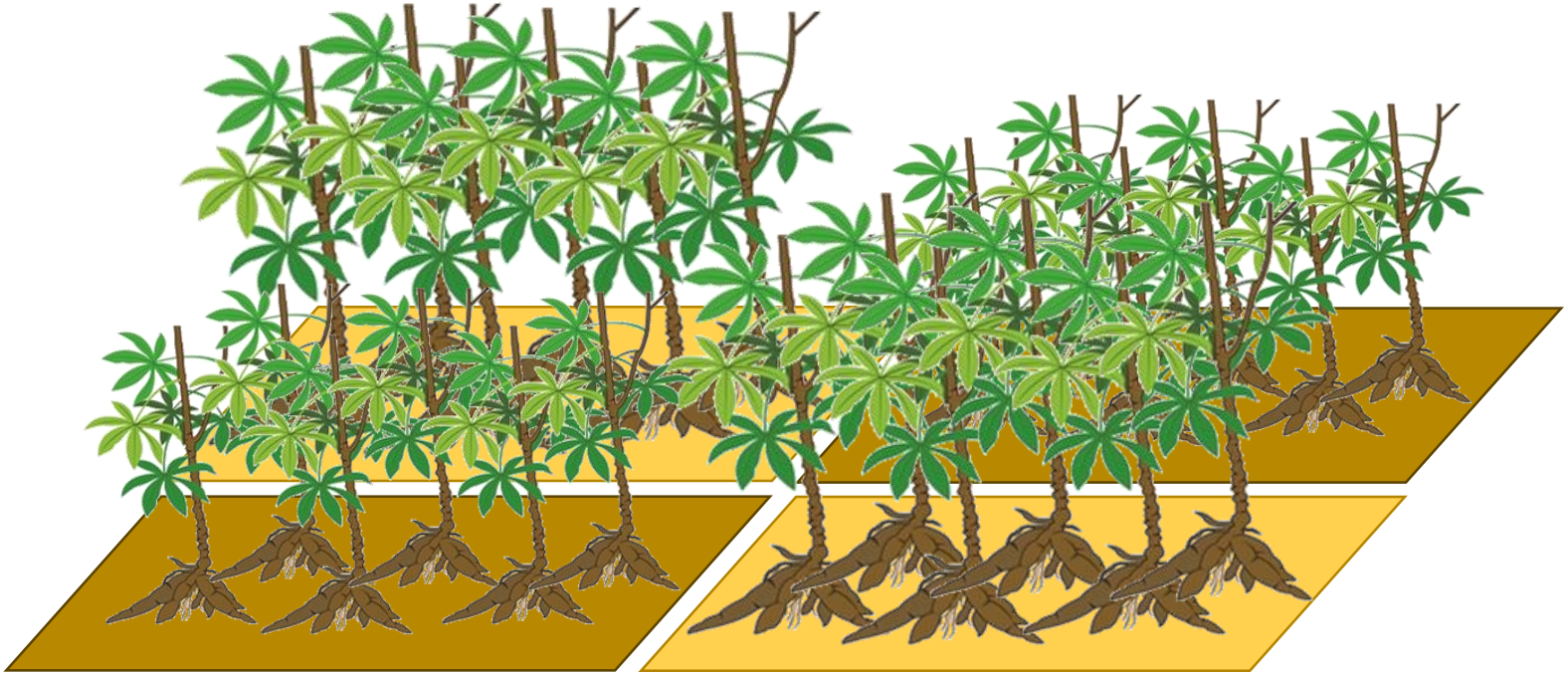


Nutrient Omission Trials in Tanzania

Field trials

Multi-locational field trials to test and develop best agronomic interventions:

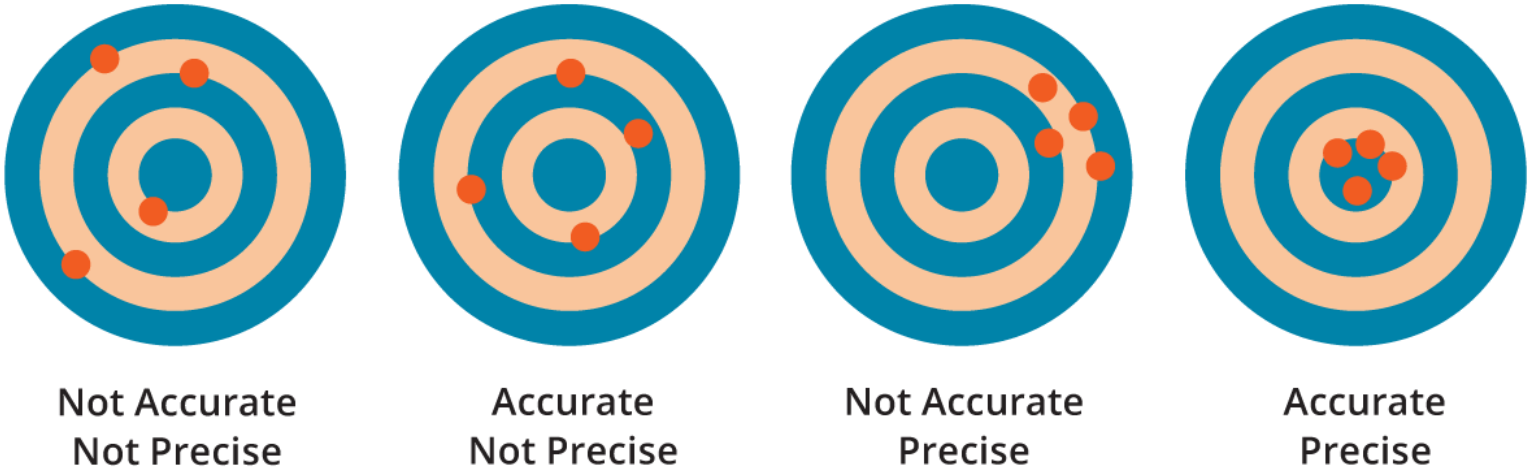
- **Objective: treatment × environment interactions**



Field trials

Multi-locational field trials to test and develop best agronomic interventions:

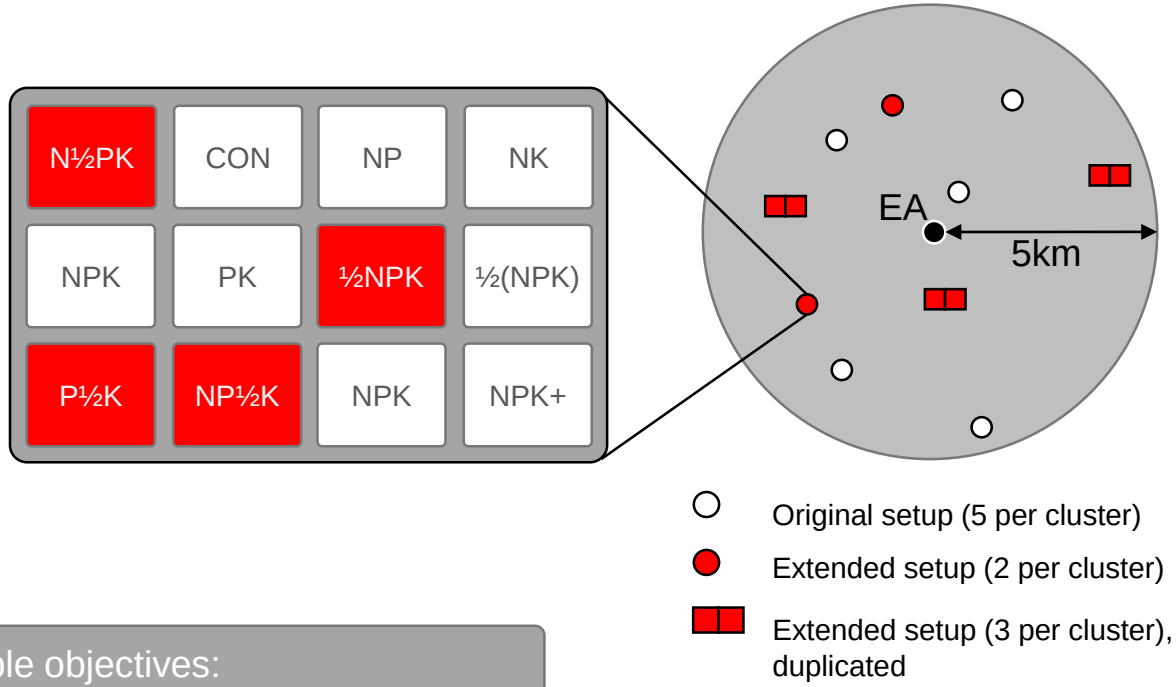
- **Objective: treatment × environment interactions**
- **Well-reasoned observation and measurement scheme**



Efficient field trial design

An appropriate design to extract maximal value from investments in trials:

- **Objective(s)**
- **Control**
- **Factor levels**
- **Interactions?**
- **Replication**
- **Balance**
- **Power**



Multiple objectives:
1. Yield response to nutrient inputs
2. Response curves
3. Data for model parametrisation

Nutrient Omission Trials in Tanzania

Statistics and geospatial modelling

Predict the performance across the entire target intervention area:

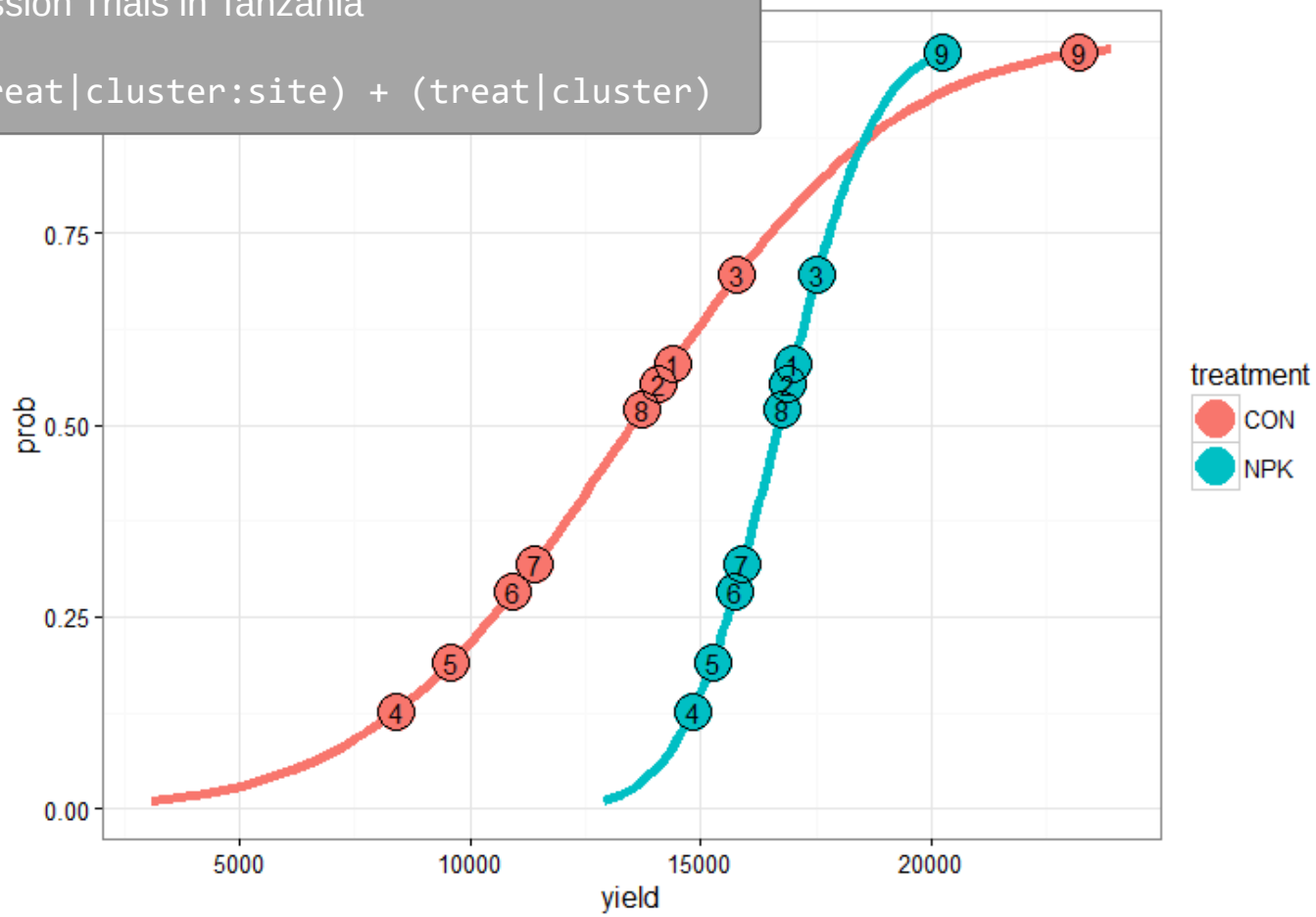
- Determine **variance at different scales**
- Extract **BLUPs**
- Relate BLUPS to **GIS covariates**
- **Cross-validate** prediction models
- Geospatial modelling techniques

Statistics and geospatial modelling

Predict the performance across the entire target intervention area:

Example: Nutrient Omission Trials in Tanzania

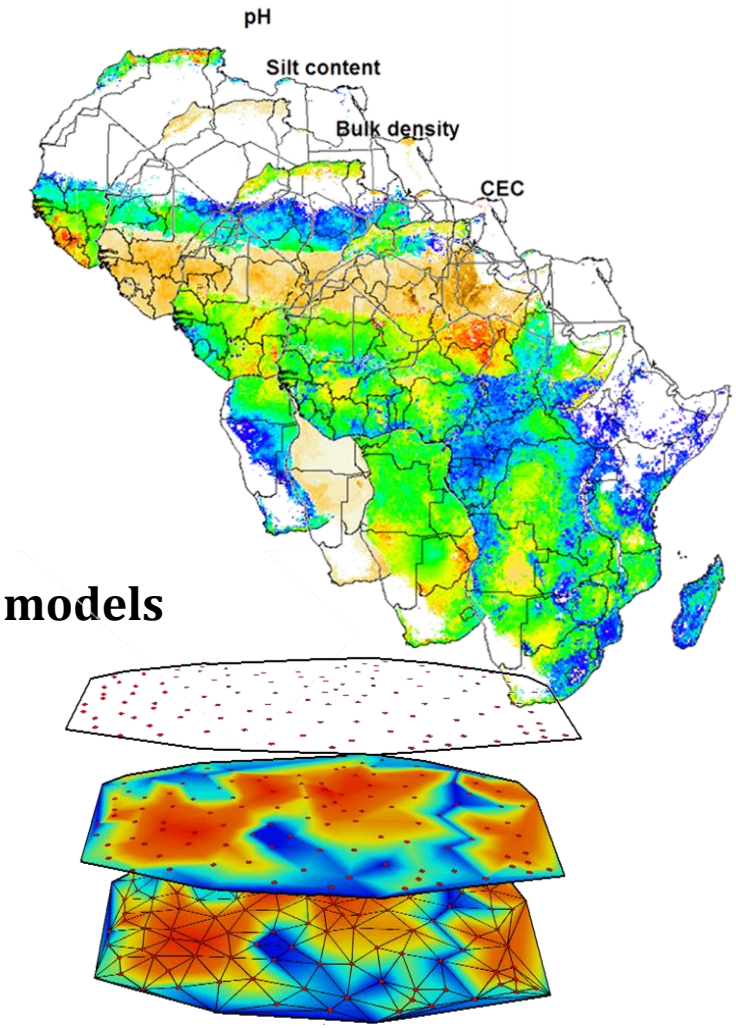
```
GY ~ treat -1 + (treat|cluster:site) + (treat|cluster)
```



Statistics and geospatial modelling

Predict the performance across the entire target intervention area:

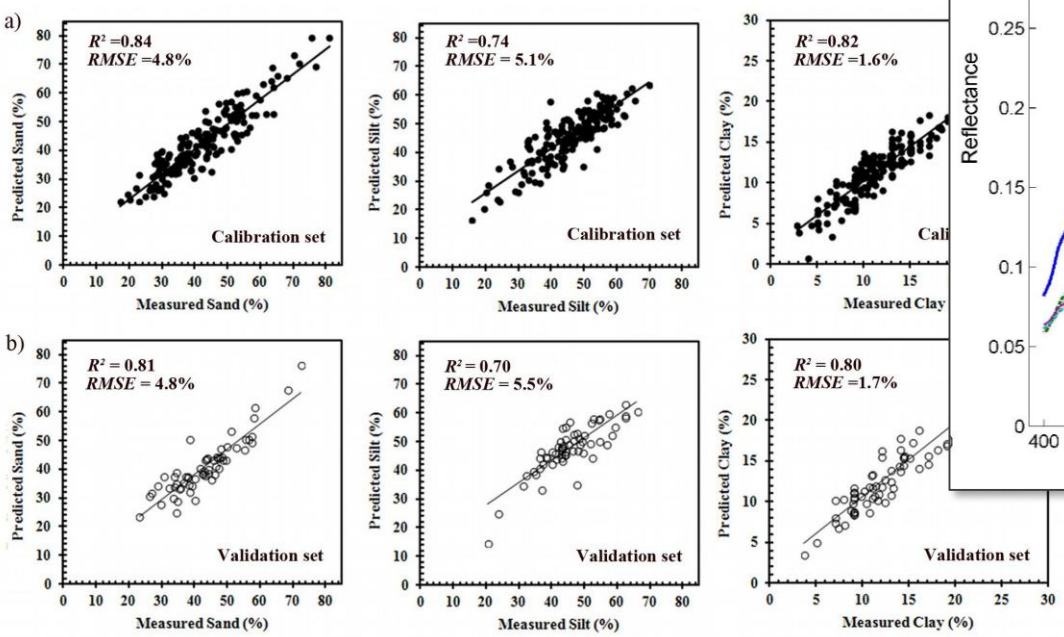
- Measures of **autocorrelation**
- **Machine learning** techniques
- Covariance function and **semivariogram**
- Spatial prediction and **kriging**
- Spatial regression and **linear mixed effects models**
- (spatially-correlated) **error structures**
- **Covariate prediction models**

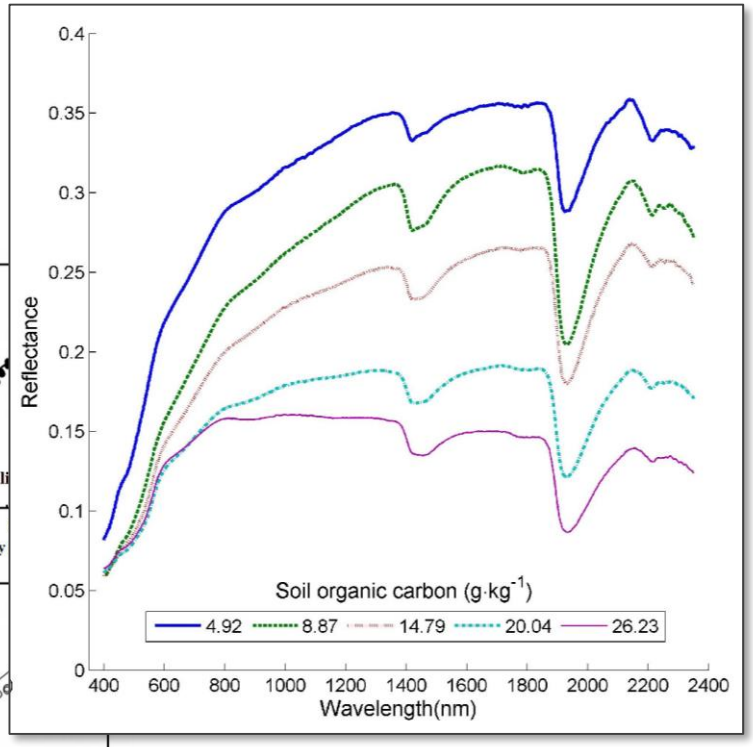


Soil and plant analyses

Faster (and cheaper) methods to assess soil and plant measurements:

- vis-NIR spectroscopy
- XRD

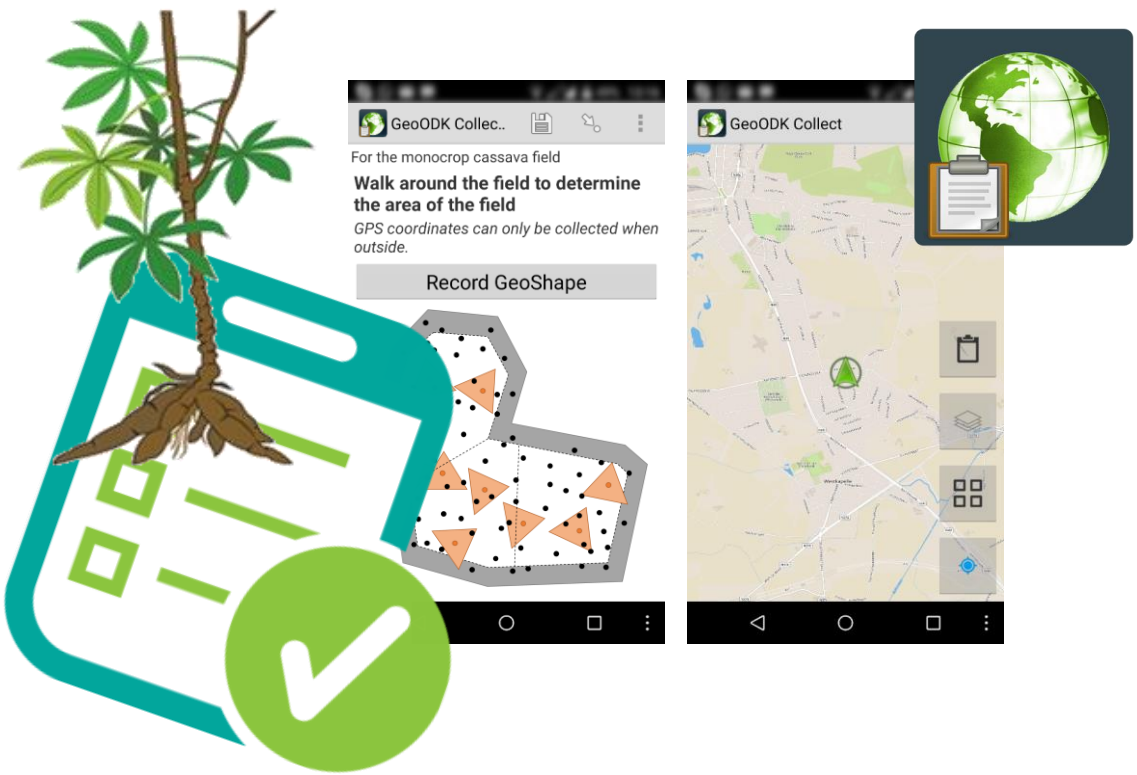




Field surveys and characterisation studies

Learn from characterizing farmers' current practices:

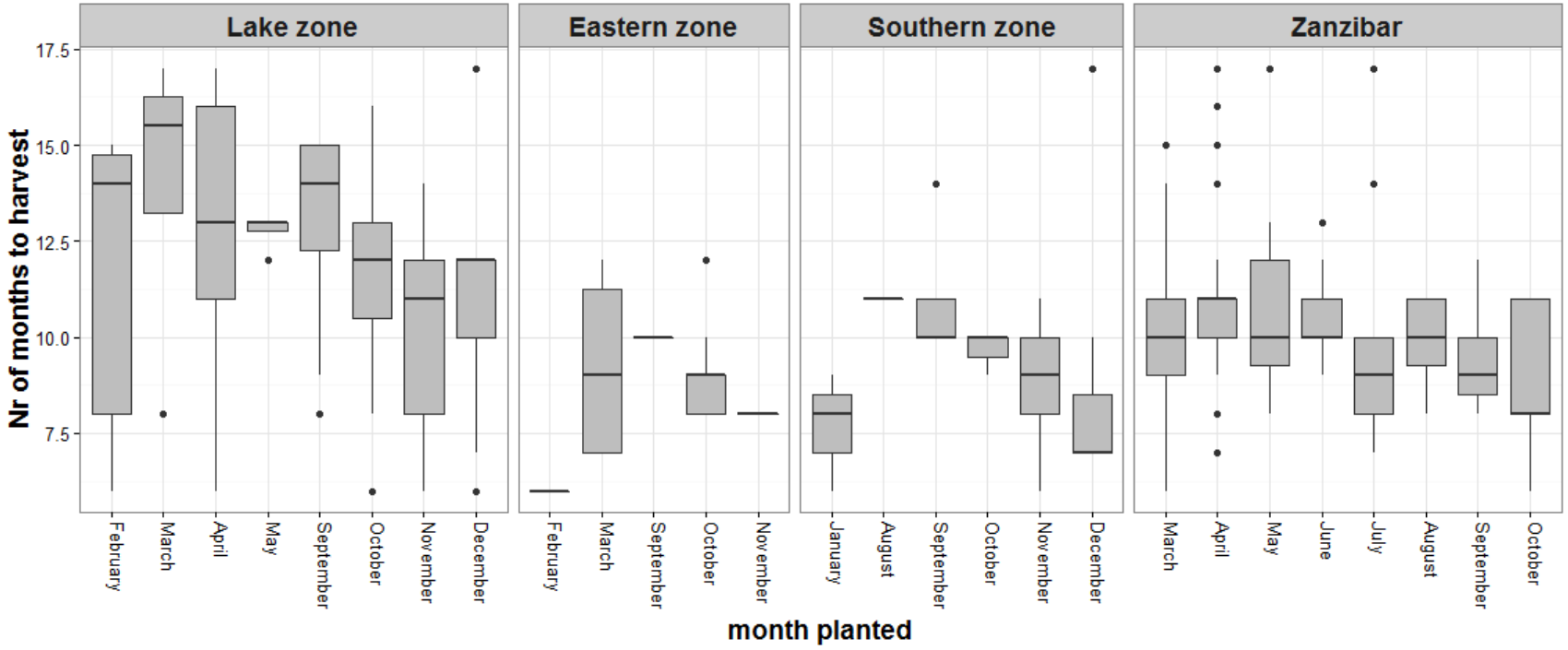
- **Ranges in environmental / management-related parameters**
- **Clustering**
- **Relationships**
- **Hypothesis generation**
- **Refine field trial designs**



Field surveys and characterisation studies

Learn from characterizing farmers' current practices:

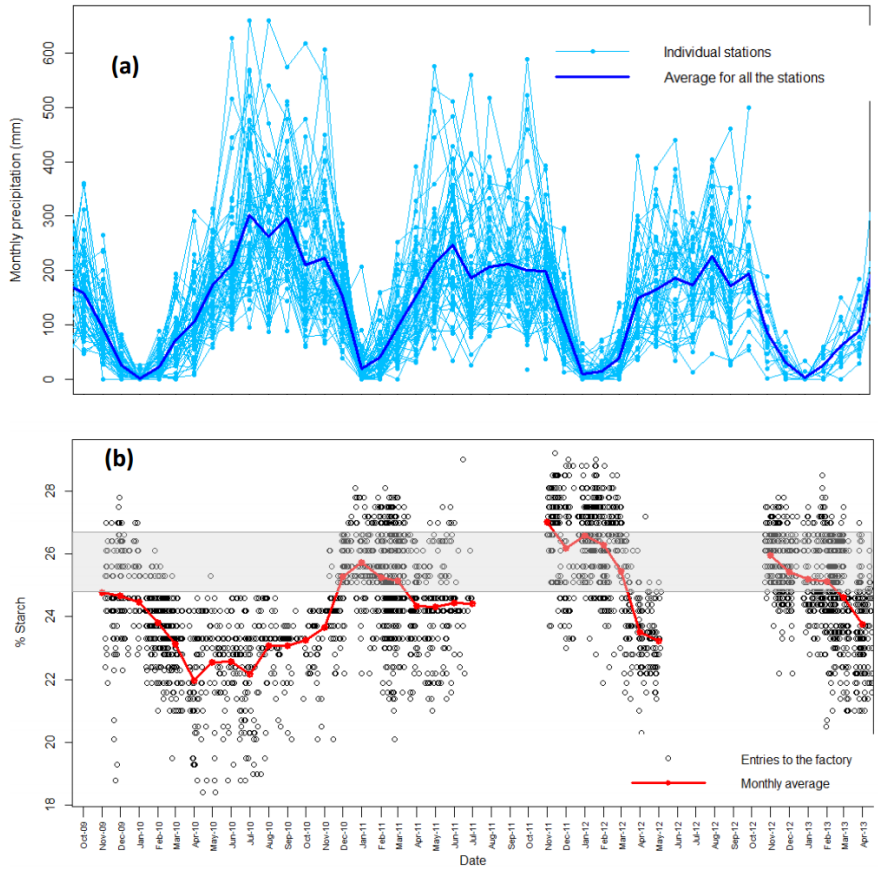
Example: Cropping calendar in Tanzania

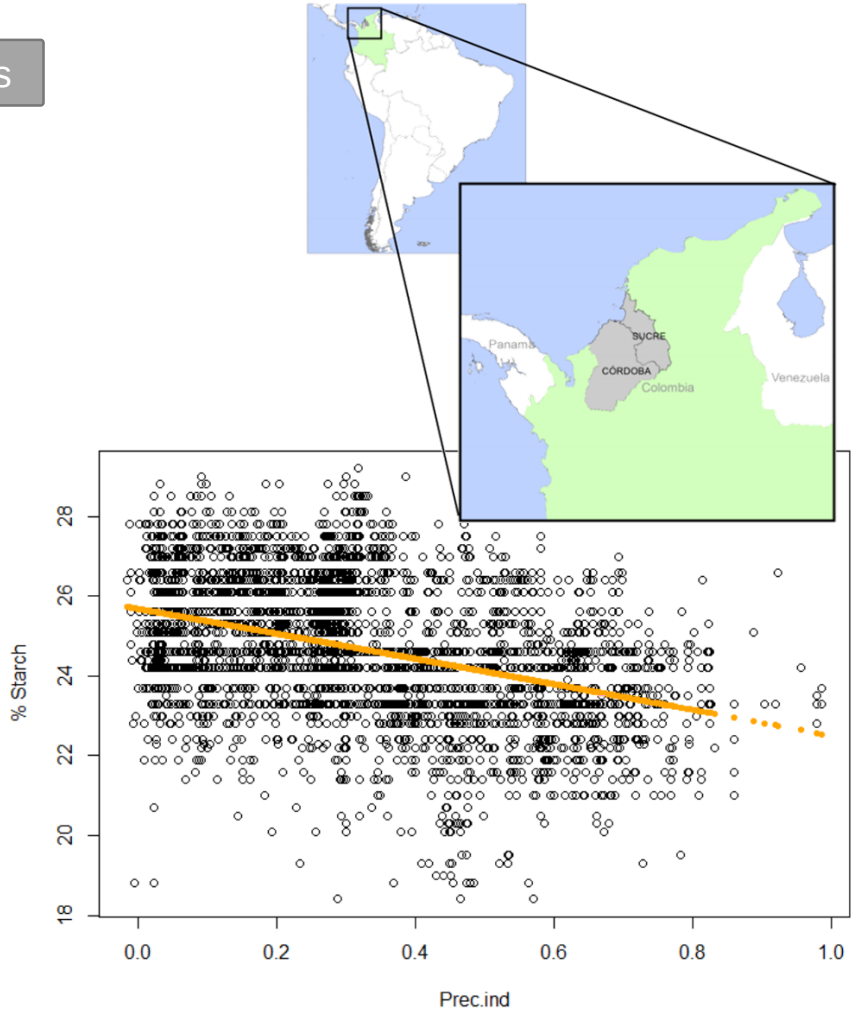


Field surveys and characterisation studies

Learn from characterizing farmers' current practices:

Example: Variation in starch content in harvested roots

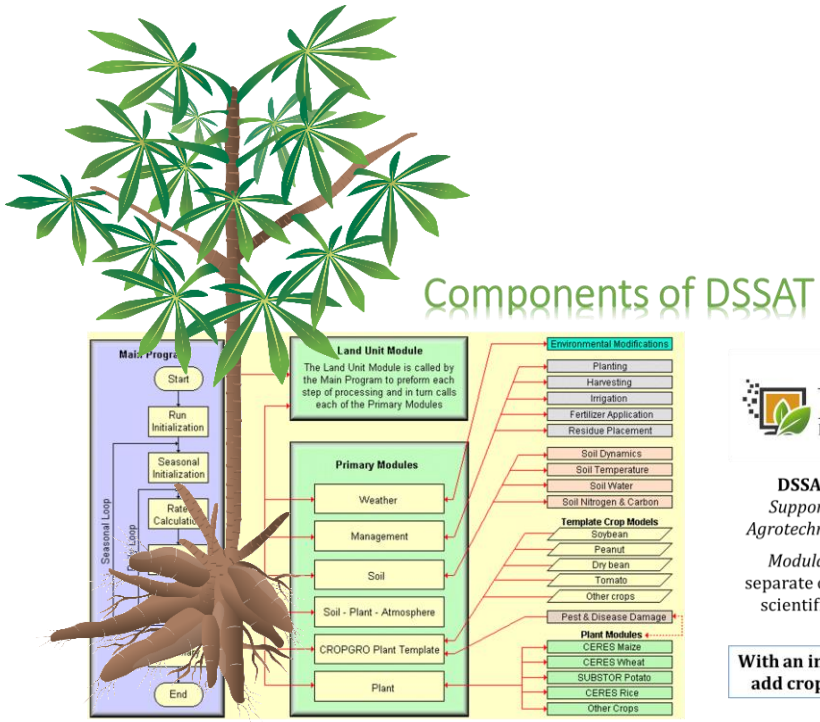




Crop and nutrient uptake modelling

Crop modelling for two reasons:

- **Focus and accelerate field trial testing**
- **Predict crop performance for site-specific recommendations**



Components of DSSAT

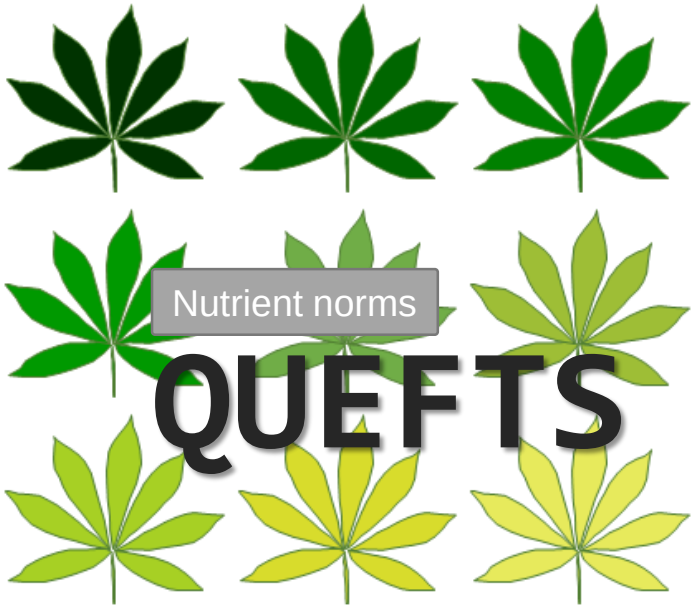
Figure 4. Structure of DSSAT model.
(Tomado de: http://www.stoorvogel.info/tradeoffs/course/course_4.html).

DSSAT FOUNDATION

DSSAT: *Decision Support System for Agrotechnology Transfer*

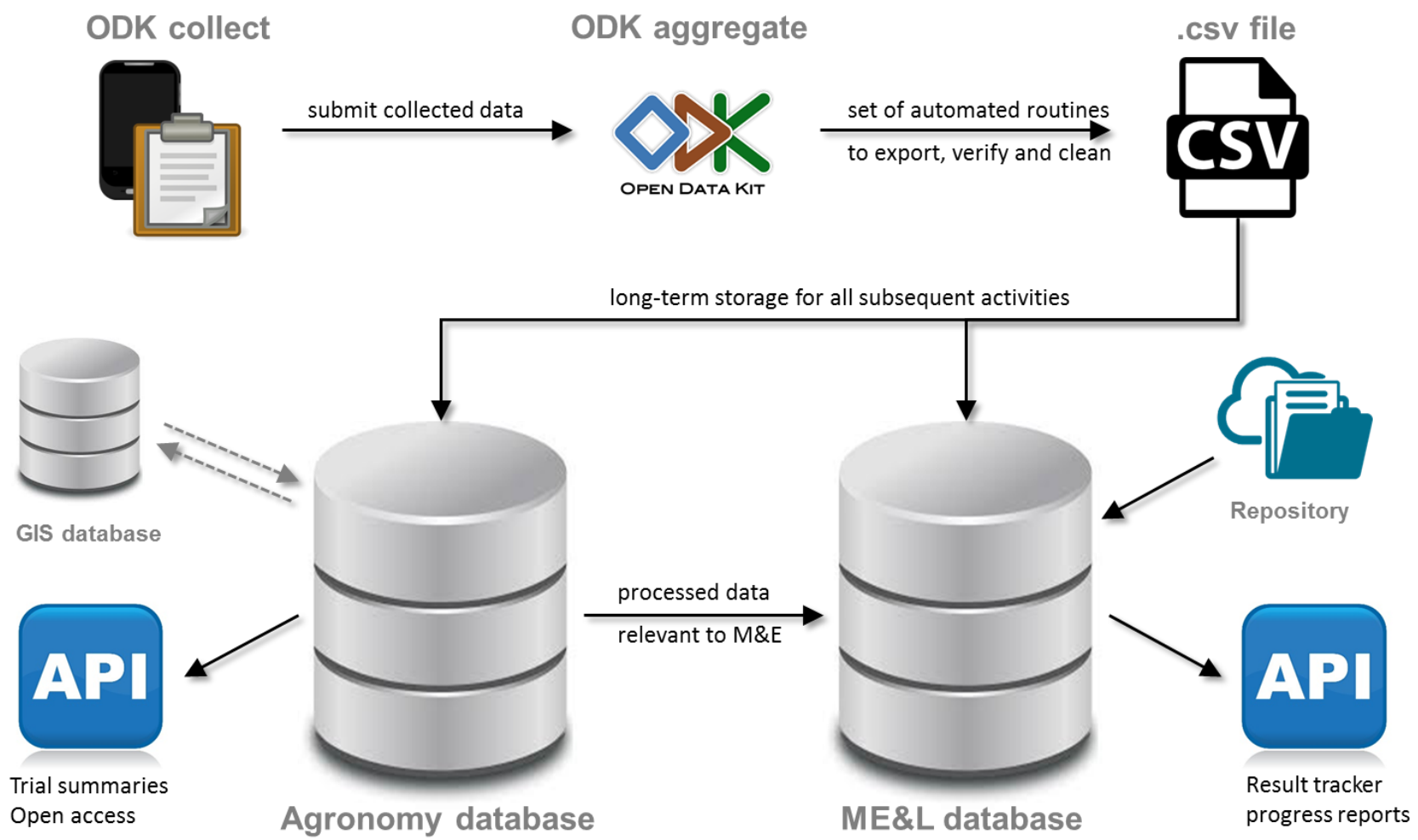
Modular structure: separate components by scientific disciplines

With an interface to add crop models



Data management system

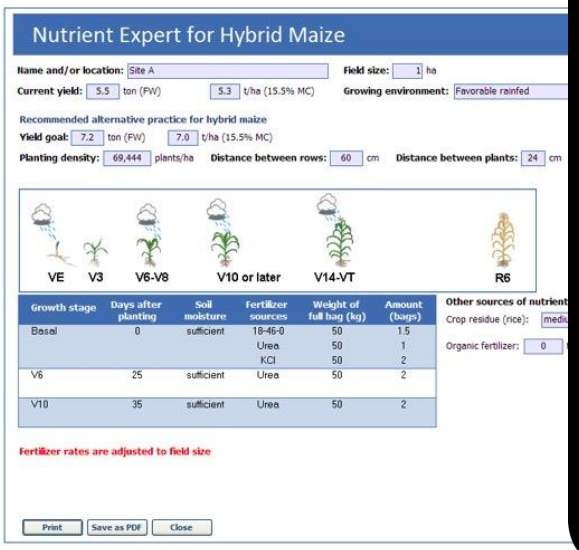
Data input and storage infrastructure:

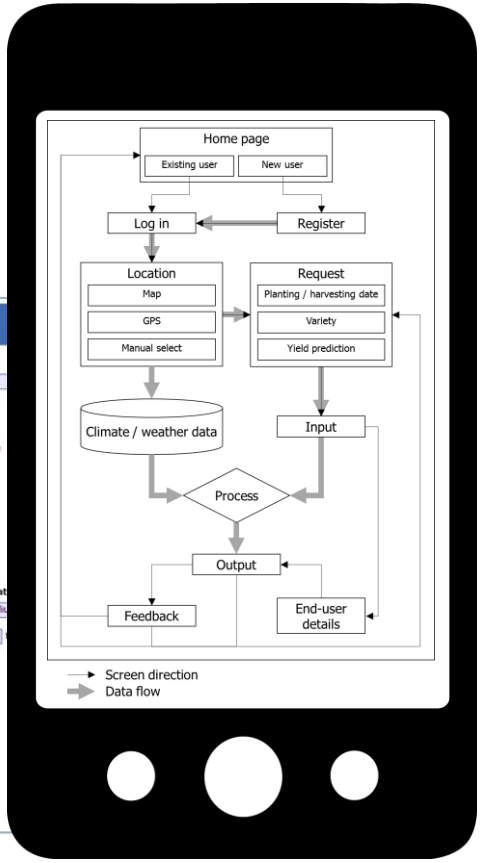


Decision support systems

Provide extension agents and farmers with site-specific recommendations:

- **Co-develop** with clients / end-users
  - Decide on the **format**
  - Understand the **situation**
  - Narrow down the **question**
- Collect / infer required **input**
- Process and provide **advice**

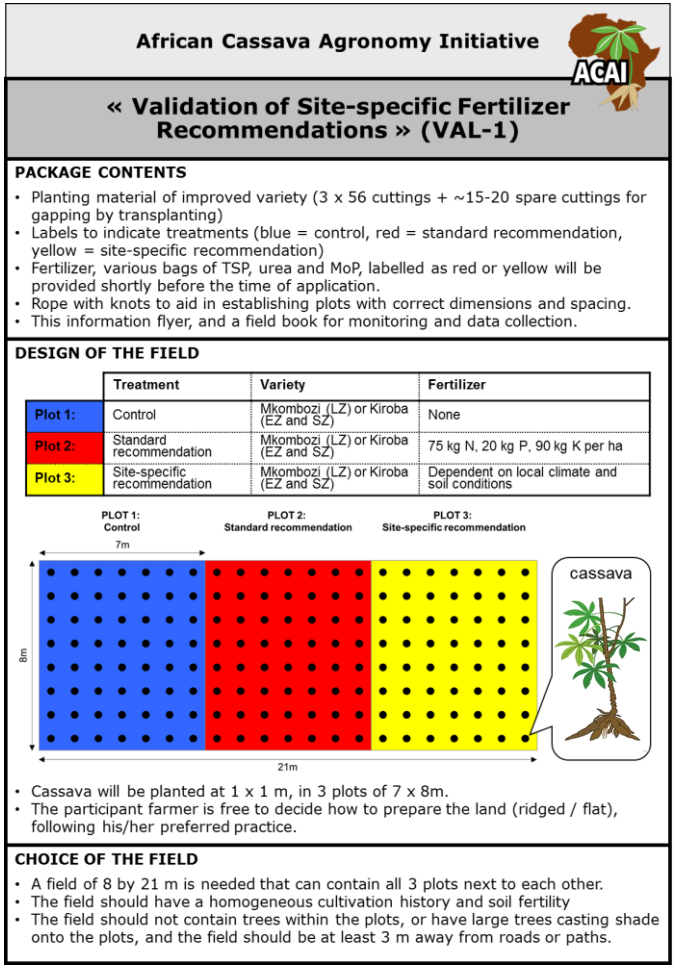




Validation activities

Validate and co-develop DSTs with target development agents:

- Feedback on format
- Feedback on performance
- Improve and update (V_0, V_1, … , V_F)



African Cassava Agronomy Initiative

« Validation of Site-specific Fertilizer Recommendations » (VAL-1)

PACKAGE CONTENTS

- Planting material of improved variety (3 x 56 cuttings + ~15-20 spare cuttings for gapping by transplanting)
- Labels to indicate treatments (blue = control, red = standard recommendation, yellow = site-specific recommendation)
- Fertilizer, various bags of TSP, urea and MoP, labelled as red or yellow will be provided shortly before the time of application.
- Rope with knots to aid in establishing plots with correct dimensions and spacing.
- This information flyer, and a field book for monitoring and data collection.

DESIGN OF THE FIELD

	Treatment	Variety	Fertilizer
Plot 1:	Control	Mkombozi (LZ) or Kiroba (EZ and SZ)	None
Plot 2:	Standard recommendation	Mkombozi (LZ) or Kiroba (EZ and SZ)	75 kg N, 20 kg P, 90 kg K per ha
Plot 3:	Site-specific recommendation	Mkombozi (LZ) or Kiroba (EZ and SZ)	Dependent on local climate and soil conditions

- Cassava will be planted at 1 x 1 m, in 3 plots of 7 x 8m.
- The participant farmer is free to decide how to prepare the land (ridged / flat), following his/her preferred practice.

CHOICE OF THE FIELD

- A field of 8 by 21 m is needed that can contain all 3 plots next to each other.
- The field should have a homogeneous cultivation history and soil fertility
- The field should not contain trees within the plots, or have large trees casting shade onto the plots, and the field should be at least 3 m away from roads or paths.

Summary

Agronomy at scale involves:

- GIS-assisted **sampling frames**
- Field trials with **effective experimental designs**
- Statistics and **geospatial analyses**
- **Surveys** to learn about inherent variation
- **Fast and accurate** (but less precise) measurements
- **Crop modelling** to accelerate field testing
- Efficient **data management** systems
- Focus on **decision support tools** and **validation** exercises


Thank you