AgWise

An analytical framework for tailored fertilizer advice

Meklit Chernet, Abera Wuletaw, Ahmed Kheir, Barasa Sammy, Bendito Eduardo, Chimonyo Vimbayi, Ghosh Ani, Kristin Persson, Leroux Louise, Lianos Lizeth, Mkuhlani Siyabusa, Mugo Jane, Moreno Patricia, Perez Camilo, Pypers Pieter, Ramirez Julian, Silva Joao, Srivastava Amit, Tilaye Amsalu , Urfels Anton, Devare Medha

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Agwise: a modelling framework to develop tailored fertilizer recommendations

Objective:

develop generic approaches to provide fertilizer advice across crops and geographies

- Current focus crops : Maize, rice, potato, wheat and beans
- Geographies: Primarily EiA target areas but where there is data and demand

EiA in action

- Across centers: IITA, Bioversity & CIAT, IRRI, CIMMYT, ICARDA, CIP, Africa Rice
- Enriched by diverse experience/expertise within EiA
  - Agronomists, crop modelers, data scientists, remote sensing and GIS specialists
- Several experts contributing at different levels
- High participation of demand partners
  - RAB, KALRO, World Bank

Organization becomes key to success

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Agwise: a modelling framework to develop tailored fertilizer recommendations

Organized by Modules

- Standalone components with a particular set of functionalities
- Promotes code reusability, organization and separation of concerns
- Making the code easier to understand/debug and by that promoting transferability
- A team of 4 – 7 people working tightly together
- Regularly meeting to evaluate progress and advance the analytics

Architecture and systems

- Use common development environment
    - CG Labs and GitHub
- Codes development and management
- Apply dataOps principles
    - manage data, models and configuration

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Module 0 - Coordination

Understanding the needs of the stakeholders and translating those needs into specific data and tool functionality requirements = use case specific blueprint

Module 1 - Data sourcing

Geo-spatial, field/survey, prices, fertilizer types, etc data based on blueprint

Module 2 - Data aggregation and curation

Aggregate and curate the data provided by module 1, check data quality, increase signal: noise ratio

Module 3 - Crop Models

Automate routines to run crop models: DSSAT, APSIM, Oryza used for yield ceiling estimation, optimal planting dates, best fit cultivar identification. Remote sensing support for spatial and temporal plantings dates variation.

Module 4 - Response Functions

Crop models, machine learning techniques applications to model response curves

Module 5 - Calculating the fertilizer requirements

Fertilizer rates at desired spatial resolution accounting for the relevant variables

Output: fertilizer rates advice in tables, maps, dashboard and API format

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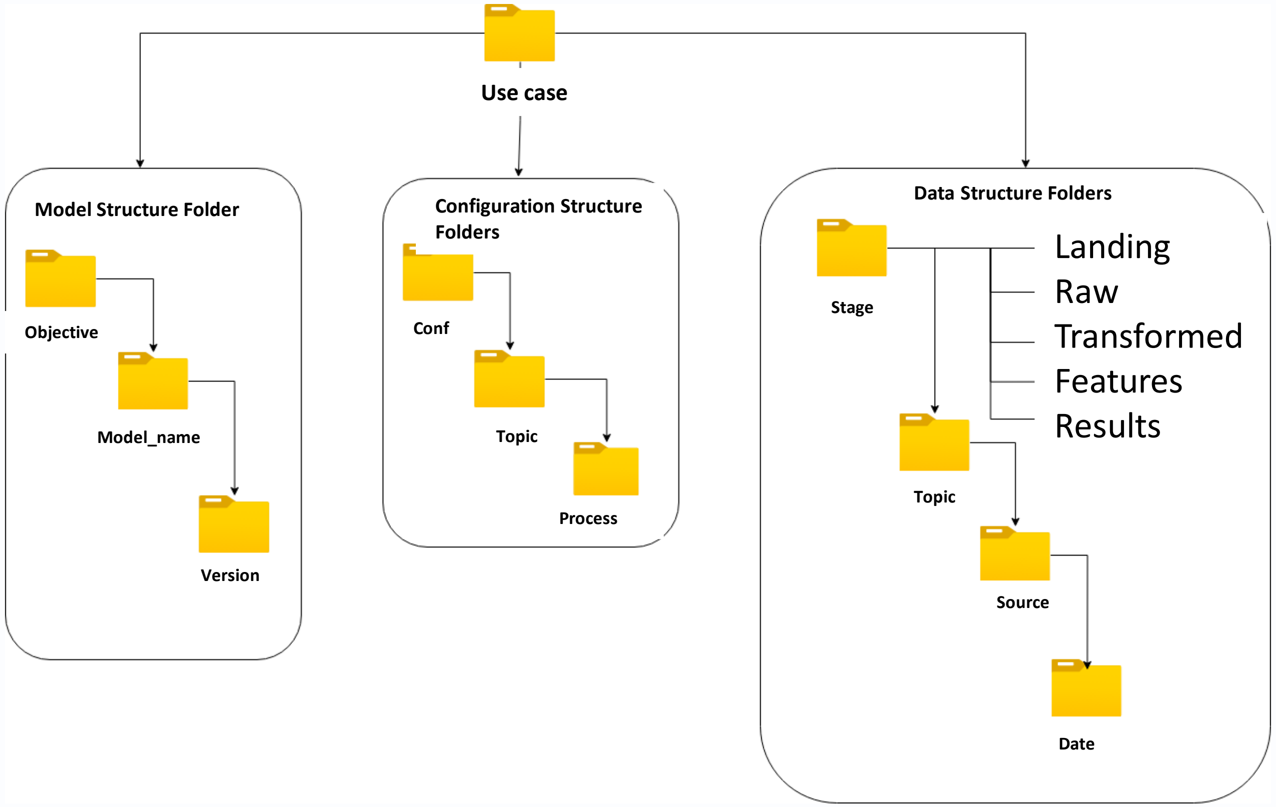
Architecture for highest level of standardization and scalability as a means of sustainability

DataOps:
- streamlining and automating the processes involved in the workflow
- promoting collaboration
- version control to secure reproducibility



Data Structure Folders:
- Stage: the current stage of the data
- Topic: the theme of the data
- Source: the data source, applicable to landing and raw data stages.
- Date: to indicates when the data was generated from the source system or by the process.

Configuration Structure Folders:
- Topic: which process requires the configuration file.
- Process: the name of the function or action that needs the configuration file.

Model Structure Folders:
- Objective: the objective of the model.
- Model_name: the name of the algorithm, software, or library used for building the model.
- Version: Specifies the version of the model, which must be v#.

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Building further upon previous efforts

- **Apply the experience and learnings from AKILIMO and similar efforts, e.g., tailored fertilizer advice for wheat in Ethiopia**

- **Make use of legacy and newly generated data**
    - Assimilate legacy data after being standardized using **Carob** (https://github.com/reagro/carob)
    - Partners data both generated within EiA use cases and/or proprietary data shared by partners

- **Different data structures triggering different pathways**
    - Dealing with random noise in the data
    - Modeling yield response versus yield effects
    - Model nutrient responses via soil nutrient supply estimation or relating yield to fertilizer rates

- **Expand the geo-spatial variables**
    - Include diverse data sources including rainfall forecast
        - Asses predictive values of variables , compare data from different sources
    - Leveraging remote sensing data to optimize planting date advice
        - Spatial and temporal variation within area of interest

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Refining recommendation framework

- **At what spatial scale are recommendations required**
  - The purpose of the advisory and how accurately can we predict responses?
  - What level of disaggregation is justified by the data?
  - What improvement can be obtained if recommendations are provided at field level?

- **Can we build in user-specified local field characteristics or crop management choices?**
  - Is there good evidence to justify including such variables? Can the tool/software handle such input?

- **Should we account for the choice of planting date and the expected rainfall, or should the recommendations target an optimal planting time?**
  - Use of weather forecast to provide climate smart advisory?

- **Should we include risk associated with drought?**
  - How do we do so?
  - Do we have sufficient data to evaluate uncertainty due to rainfall variation?

- **Should we differentiate users with different risk attitudes / investment capability?**

- **Should we rely on user-input price information? Or should we make use of spatial / temporal differences in input/output prices?**

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Collaborative framework for fertilizer recommendations

- **Collaborative partnership with use cases leads and national research organizations**
  - Data curation support
  - Integration of local expert knowledge
  - Objective setting for fertilizer optimization : setting specific targets to guide the advice generation
  - Obtain guidance on contextualizing the advice for different scenarios
  - Determine the appropriate level of generalization required for practical implementation

- **Currently supported initiatives:**
  - Rwanda Agricultural Board (RAB)
    - Supporting the development of tailored fertilizer advice for maize, rice and potato
  - Kenyan fertilizer subsidy program on Maize: providing advisory support
    - Flexible system accommodating different optimization targets and calculating total fertilizer need

Optimised fertiliser advice for increased agricultural productivity in Kenya

Purpose:

Develop evidence-based recommendations on fertiliser requirements and fertiliser types to achieve crop production targets at sub-county level

Requirements:

- Consider smallholder farming practices
- Map soil nutrient constraints
- Adjust based on seasonal weather forecasts
- Compare different fertiliser formulations
- Permit subcounty-specific production targets

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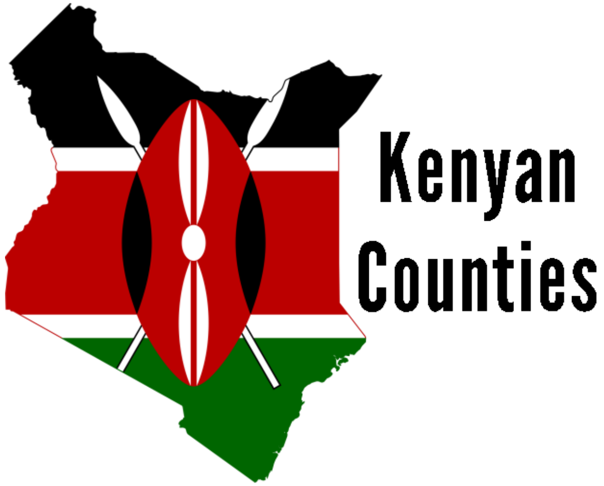
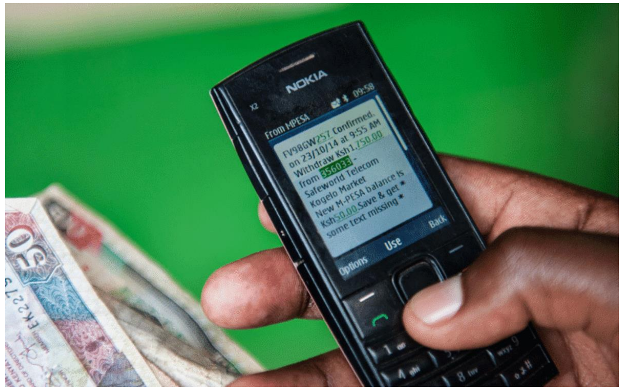
CGIAR

Use applications of the fertiliser optimisation tool



For the county governments:

- **Calculate total fertiliser quantities** needed to achieve crop production targets at subcounty level
- **Decide on best-suited fertiliser types** by compare total requirements and associated costs to achieve production targets using different fertiliser formulations



For the e-voucher fertiliser subsidy programme:

- **Determine maximal fertiliser quantities to subsidise** for individual farmers based on landholding and other profile information in the national farmer database
- **Reduce investment risks** by adjusting subsidies based on seasonal forecasts

For extension services:

- **Disseminate optimised fertiliser advice** to farmers, providing recommendations on best fertiliser types and rates for individual crops and production targets
- **Inform subsequent interventions** by tracking fertiliser use, productivity and profitability as part of the national farmer database

Data sources used for current functionality

Current production levels

Ministry of Agriculture, Livestock, Fisheries and Cooperatives
DATA PORTAL

Data from the State Department for Crop Development (**kilimo.go.ke**)
Kenya Maize Production by Counties 2012-2018

Yields under smallholder management

ONE ACRE FUND

KALRO
Kenya Agricultural & Livestock Research Organization

Maize grain yield, current fertiliser use and crop management from **>16,000 smallholder farm surveys** used to estimate nutrient-limited (lower bound) and attainable yields (upper bound) by sub-county for fertiliser response

On-farm fertiliser response

CAROB

Data from digitised on-farm fertiliser experiments from **published scientific articles** using the carob workflow (https://github.com/reagro/carob):
4191 observations from 568 unique trial-seasons across East Africa

Digital soil information

iSDA AFRICA

SOILGRIDS

Open-access gridded soil information to predict soil nutrient supply capacity using machine learning algorithms, trained using on-farm fertiliser trial data

AgWise: a workflow estimating all processes underlying fertiliser response

- The stepwise process is **modular** and can be enriched with additional data, and custom functionality can be added.
- The workflow can be compiled and **integrated into existing platforms such as Kenya Agriculture Observatory Platform**.

01 – COMPILE ON-FARM FERTILISER RESPONSE DATA

Data from published scientific literature is assembled and standardised using the open-source carob workflow

02 – DERIVE SOIL INDIGENOUS NUTRIENT SUPPLY (INS)

Derive estimates for soil indigenous nutrient supply based on observed responses (under optimal management).

03 – PREDICT INS USING DIGITAL SOIL MAP INFORMATION

A multi-variate machine learning model is trained and cross-validated using iSDA's and ISRIC's public digital soil maps

04 – MAP INS FOR THE TARGET INTERVENTION AREA

The machine learning model is applied at scale and output is aggregated at the resolution set for the recommendations

05 – ASSEMBLE ON-FARM YIELD SURVEY DATA

Crop yields and fertiliser use data under smallholder conditions are gathered along with essential covariates for the target area

06 – ASSESS YIELD LIMITS UNDER SMALLHOLDER MANAGEMENT

Nutrient-limited (lower bound) and attainable (upper bound) yields are determined under suboptimal smallholder crop management

07 – QUANTIFY YIELD GAPS DUE TO SUBOPTIMAL MANAGEMENT

The INS is penalised based on the difference in expected yields for INS and observed nutrient-limited yields in on-farm surveys.

08 – SET YIELD TARGETS RELATIVE TO CURRENT PRODUCTION

Mean annual production levels and areas under maize are sourced from national data portals and a relative increase is set as yield target

09 – DECIDE ON FERTILISER COMBINATIONS

Scenarios are defined using preset combinations of basal and topdress fertilisers, with a high P and high N content, respectively.

10 – CALCULATE FERTILISER RECOMMENDATIONS

QUEFTS model using the penalised INS and attainable yield is used to determine the fertiliser rate required to achieve the set yield target

11 – VALIDATE FERTILISER ADVICE USING ON-FARM SURVEY DATA

Compare the obtained fertiliser recommendations with mean fertiliser responses observed under on-farm conditions at county level.

12 – RUN DESIRED SCENARIOS AND MAP RESULTS

Fertiliser requirements are determined at (sub-)county level for different yield targets and fertiliser combinations.

Recommendations can be customised to (sub-)county production targets

Example: Aldai, Nandi			**target +20%**
Mean annual maize grain production:	30,000 tonnes	→	36,000 tonnes
Mean area under maize:	11,000 hectares		
Mean annual yield:	2700 kg ha^{-1}	→	3300 kg ha^{-1}

Recommended application rates (kg ha^{-1}) for selected basal + top-dress fertiliser combinations to achieve a target % production increase, relative to the mean current production.

Target	DAP + CAN		NPK17:17:17 + CAN		NPK 23:23:0 + NPK 26:5:5+5S	
10%	81	106	80	96	79	92
15%	94	125	94	111	92	108
20%	**112**	**142**	**104**	**129**	**106**	**124**
25%	131	160	123	141	120	141
30%	146	187	133	162	134	160

Total amount of fertiliser required:

1232 tonnes of DAP
+
1562 tonnes of CAN

1166 tonnes of NPK 23:23:0
+
1364 tonnes of NPK 26:5:5+5S

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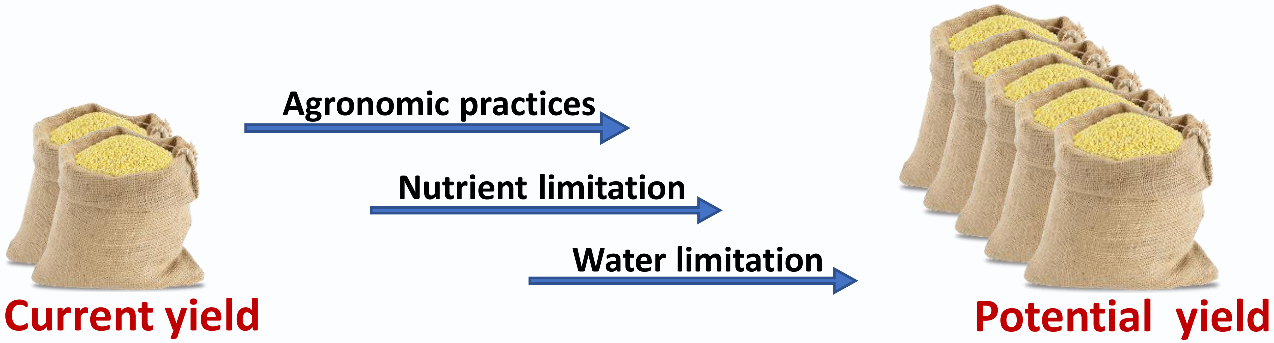
Current efforts in developing fertilizer advice



Similarity between different frameworks:

- Geo-spatial data sourced from common public data sources:
  - CHIRPS, AgEra5, NASA, digital soil maps from iSDA / Soil Grids, …
- Use of crop models (DSSAT, QUEFTS, WOFOST, …)
- Use field trials data to model response to nutrients
- Calculate fertilizer rates accounting for crop parameters

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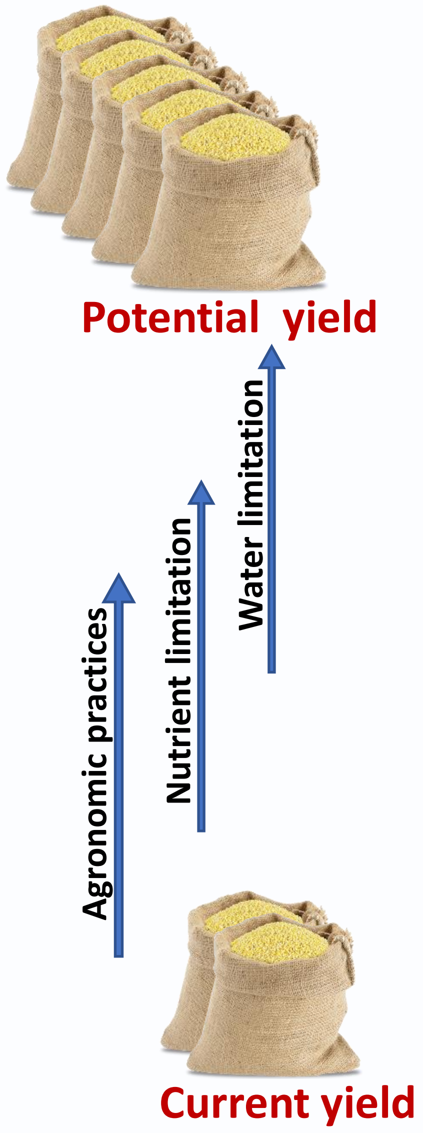
Current efforts in developing fertilizer advice

Differences between different frameworks

- Analytical framework setup
  - Open access vs proprietary ~ determining business and sustainability plan
  - Advances in data analytics,
- Objective setting
  - Generalized versus flexible to attend to end users' specifications
    - Filling a gap between soil supply and crop agronomic potential
    - Yield increase by x t/ha from current yield
    - Maximizing profit, …
- Ground presence: network with local institutes and systems
  - Demand partners level of participation
  - Contextualizing the ag advisory to relevant factors
  - Knowledge transferability and capacity building



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Collaboration beyond differences for lasting impact

1. **Data discovery**

Most common efforts strategize to discover, pull, standardize and store

Pros = avoid silos and could be done faster

Cons = prone to resistance and dose not motivate cross-learning between several efforts

Gap: develop data standardization guidelines and tools in collaboration

Allow standardization to go to silos

Provide capacity building for local staff = lasting impact

Motivate best use of data to improve research output locally where it is relevant

Immediately demonstrate value to data owner and more reasons to collaborate

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AfricaRice
Bioversity International
CIAT
CIMMYT
CIP INTERNATIONAL POTATO CENTER
World Agroforestry Centre
ICARDA
ICRISAT
IFPRI
IITA
IRRI
IWMI International Water Management Institute

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Collaboration beyond differences for lasting impact

2. Demand mapping

Insufficient involvement of demand partners at design stage

- Setting the objective of the agro-advisory ~ site specific advisory?
  - field level, agro-ecology, land-scape, regional, …
    - Dissemination mechanism, tools, capacities, infrastructure, …
- Optimized to what? Aggregated at what level?
  - X t/ha increase from control/current yield, filling the yield gap
    - Systems and tools capacity to source user input data
  - Maximize the return on investment
    - Price data agro-input/crop, fertilizer types
      - Real time versus default values (spatial and temporal variation)
    - farmers typology (risk attitude, investment capacity)
  - Comparing different blends and evaluate types and amounts of fertilizes recommended at different prices
- Build climate smart/soil health intelligence in the analytics
  - Seasonal variation, guided by weather forecast data
  - Soil acidity, use of organic matter, …

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Collaboration beyond differences for lasting impact

2. Demand mapping

… As a result …

- Partners are not sufficiently informed about the implications of the choices they make
- Not correct assumptions / not ideal decisions are made
- Not contextualized advice and tools are developed resulting in limited impact

Gap: Develop a conceptual framework to be used at due diligence step:

- Formulate teams with relevant experience of developing and using tailored ag advice
- Develop workflow that can be used to detail the demand with regard to:
  - Defining the current status and support required
  - The available/required capacity both for the research and the delivery
  - Assesses delivery mechanisms in relation to local constraints and
  - Sustainable access and feedback loops to recalibrate and improve and guide future research areas

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Collaboration beyond differences for lasting impact

3. Data analytics

Be FAIR and build local data analytics capacity

- Intelligence to process raw data to information should be transferable
- Institutes with advanced data analytics platform should have a space to operate but ultimately real change is possible only when the institutes and researchers with local mandate are able to sustain and diversify the system
- How should we organize ourselves to foster collaboration at technical level?

4. Role of the different stakeholders

How do we make best use of our diversity

- Different organizations:
  - Fertilizer companies
  - Overseas universities
  - International research centers
  - National research centers
- Different interest and expertise

5. Sustainability

Thank you in advance for contributing positively