Soil Fertility Mapping and Fertilizer Recommendation in Ethiopia: *Update of EthioSIS project and status of fertilizer blending plants*

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Ethiopian ATA
Agricultural Transformation Agency
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Agenda

Background Information

Major Soil Health and Fertility Issues

National Soil Health and Fertility Initiatives

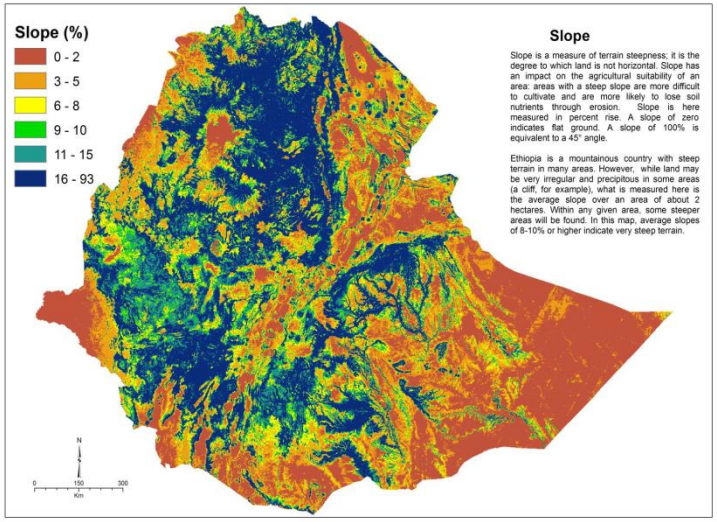
The EthioSIS Program

Establishing Fertilizer Blending Plants

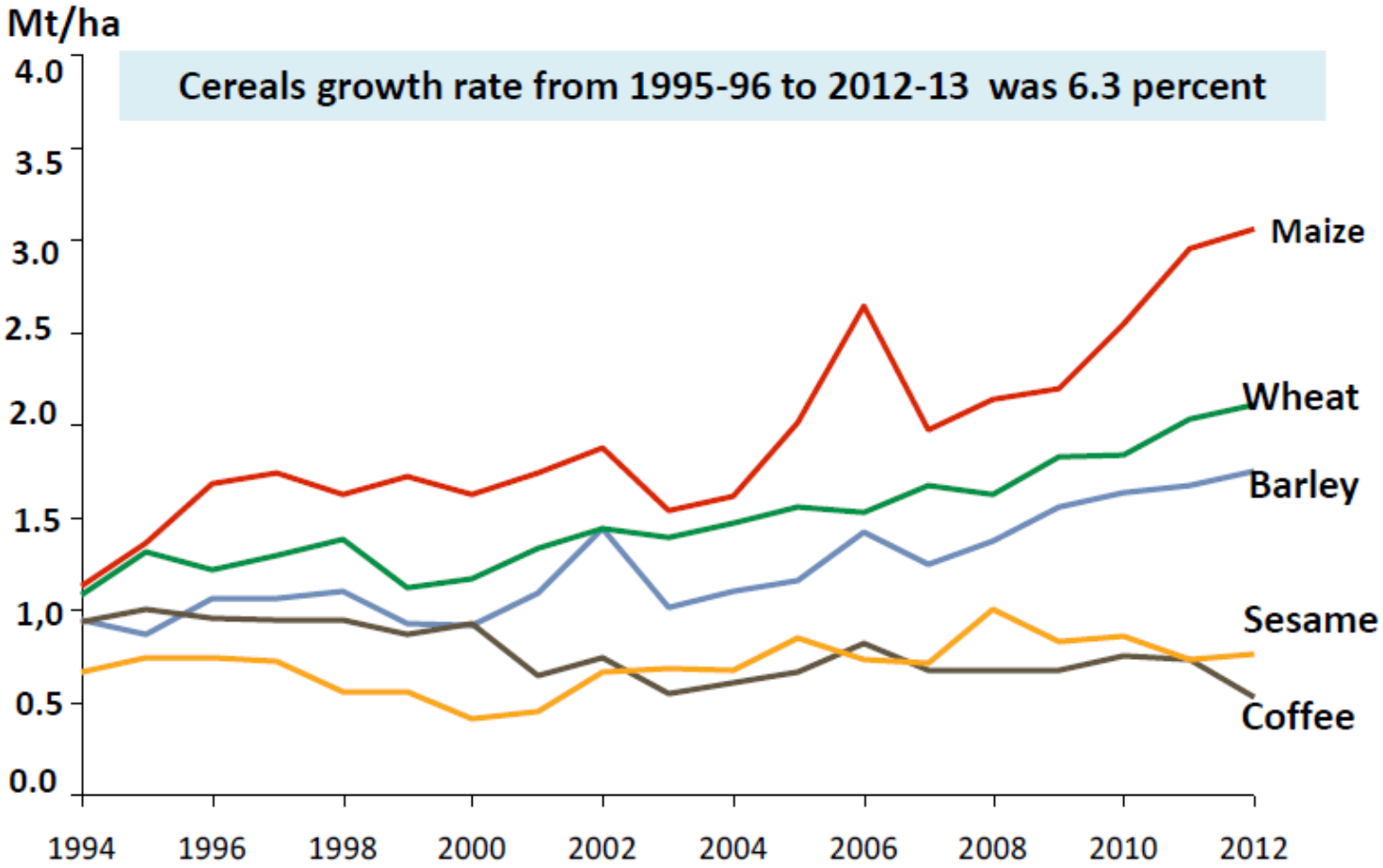
Background Information

Agriculture employs >80% of the population; Contributes ~40% to the GDP, and > 60% to export.

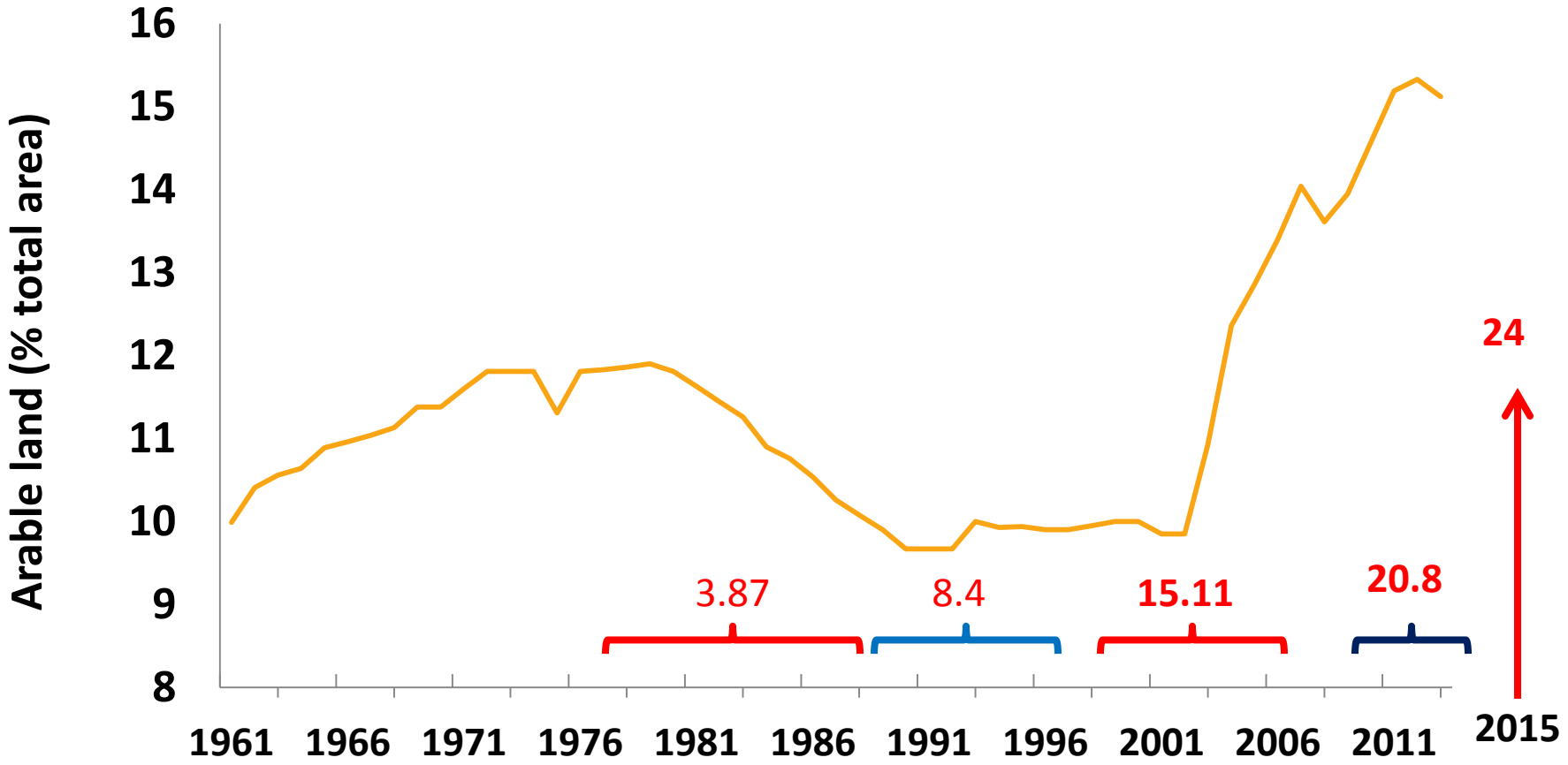
- Smallholders account for 96 % of total area cultivated.
- Most reside in the moisture reliable cereal based highlands (i.e. 59 % of total cultivated area)
- Teff, wheat, maize, sorghum, and barley), account for about 75% of total area cultivated
- > 80% of agricultural lands have undulating topography, with up to 60 percent slope.



Yield pattern by crop is by far lower than the 3.6 Mt world average



Positive trend in overall fertilizer consumption is observer during the past years, but in no way implies cause for satisfaction



Major Soil Health and Fertility Issues

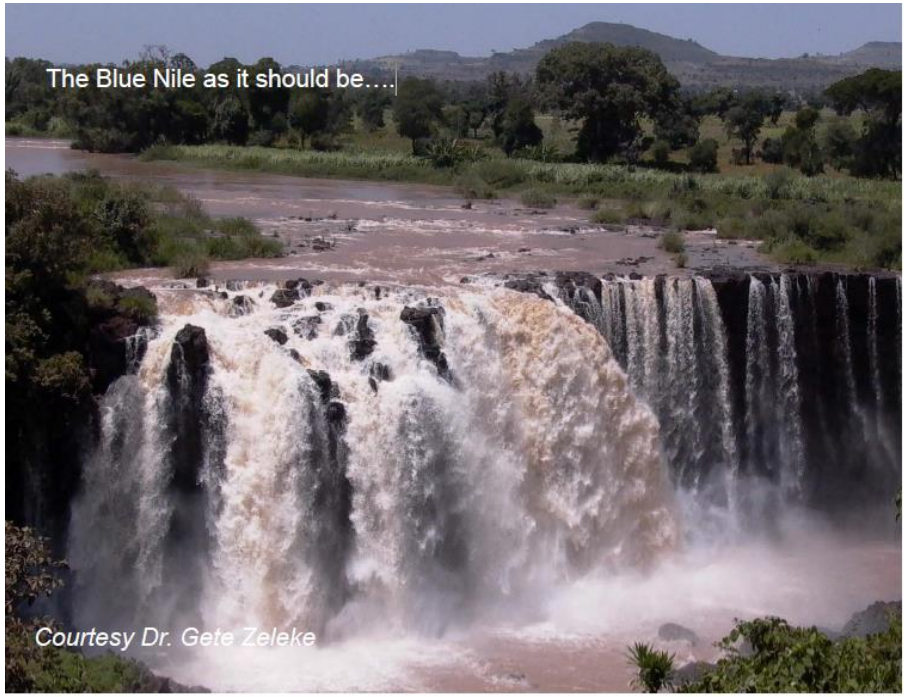
1. Soil Erosion

- Soil erosion and land degradation are major causes for low productivity and vulnerability of smallholders
- Annual soil loss from cultivated lands is about 42 tons ha^{-1}
- Reduce crop production up to 30% (Pimentel, 2003)

Soil erosion (cont'd)

- 16-50 % of the seasonal rainfall goes as a runoff

- Gully erosion increases the land connectivity



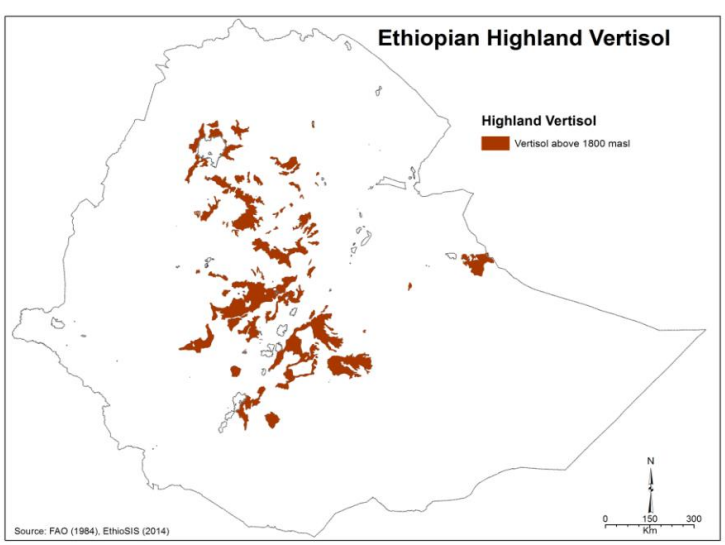
2. Nutrient depletion

- Nutrient export/ mining: Cow dung and stover are sold for energy source
- **L**oss of P and N resulting from the use of dung and crop residues for fuel is equivalent to the total amount of commercial fertilizer use (IFPRI, 2010)

3. Seasonally waterlogged soils

- Of the country's @12m ha Vertisols, about 7m ha are found in the highlands and their productivity constrained by waterlogging.

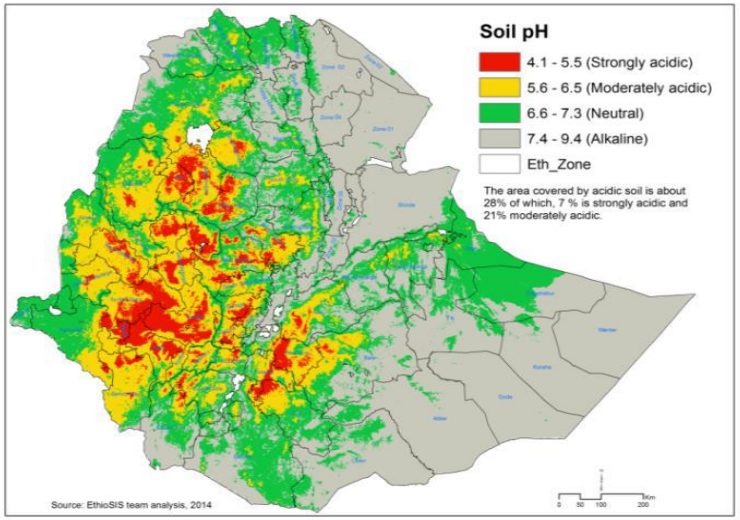
- Traditionally crops grow and mature on late season rainfall and residual soil moisture

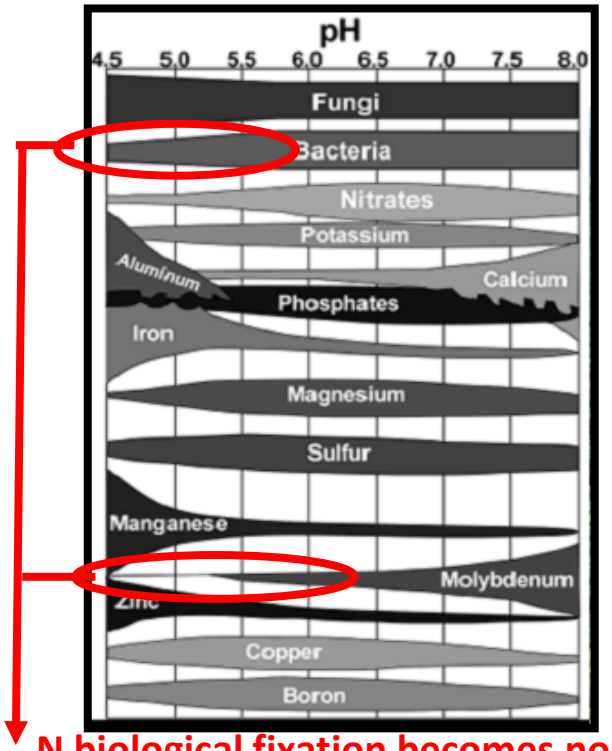


4. Soil Acidity

- Strong soil acidity affects @28.1% of the entire country. .

- @ 43% of the agricultural land in the three high potential regions is affected by acidity (mostly in highlands)





N biological fixation becomes no longer possible in acidic soils

5. Salt affected soils

- About 1.5 m ha of fertile valley bottom soils are affected by salinity
- The problem increasing in connection with expansion of irrigation owing to poor on farm water management
- Salt-affected soils must be restored to productivity and effective steps taken to prevent salinization of new areas being brought under irrigation at huge cost.

Awash river basin

6. Mismatch between fertilizer technology and environment

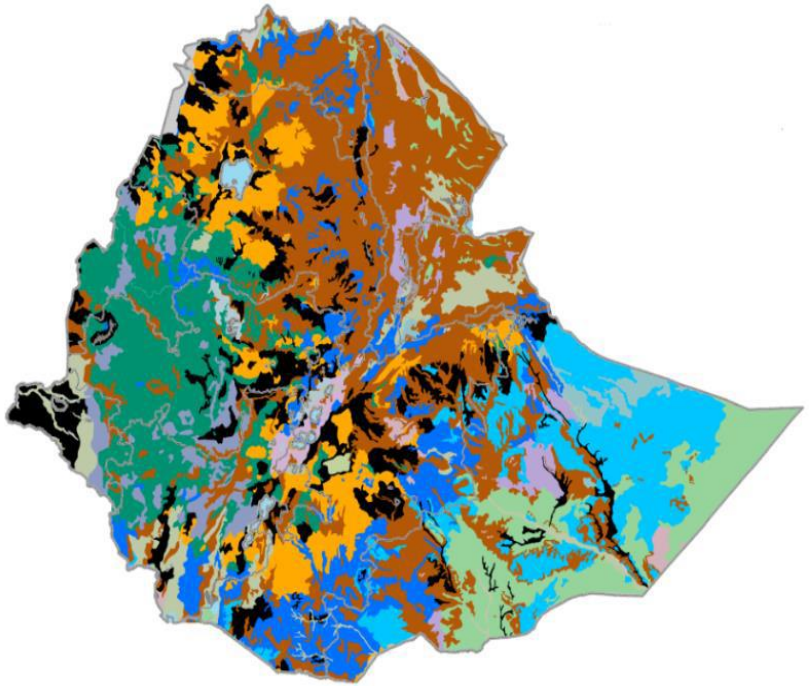
- Up-to-date and spatially explicit information about the condition and trend of soil fertility is necessary.
- Clearly, N and P were not the only yield constraining factors. S, Zn, B, Fe, Cu and K-deficiency are common

Soil fertility gradient due to inherent soil fertility status and/or management discourages the adoption of blanket fertilizer recommendation.

7. Lack of national soil information and unbalanced use of fertilizers; the past approach of fertilizer usage has not helped significantly increase yields

- **Existing soil maps in Ethiopia are obsolete with limited soil fertility information and need to be updated using contemporary technologies and analysis**
- **The world soil map was published in 1970s by FAO and UNESCO at a resolution of 1:5M, which was then focused to 1:2M for Ethiopia by 1984**
- **The soil map is based on soil surveys conducted in the 1930s to 1970s**
- **The map is generated using soil information and technology from the 1960s - spatial information technologies were not used**

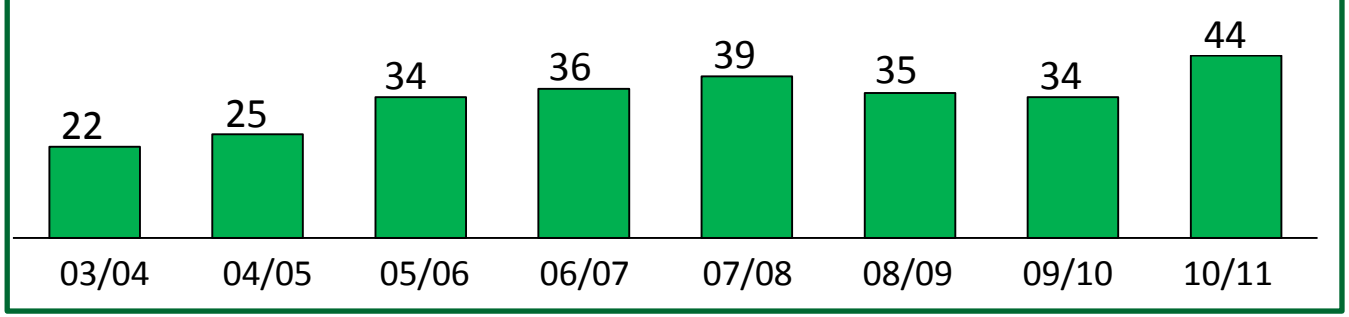
Extracted for Ethiopia at a scale of 1:2M from the world soil map of FAO/UNESCO



Blanket fertilizer application recommendations was the order of the day; a poor approach regardless of the diverse agro-ecological and soil characteristics of Ethiopia

Total fertilizer applied for cereal crop (DAP and Urea)

0000' tones from 2003/04-2010/11



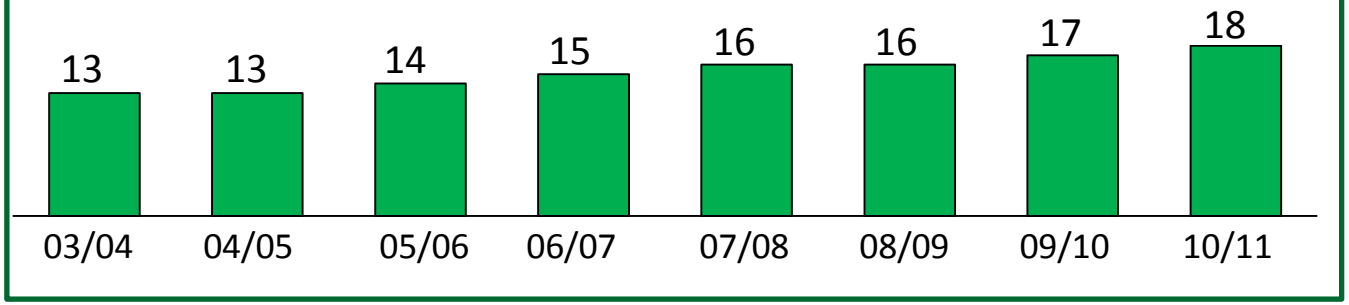
Annual Growth Rate (CAGR)

2003/04-10/11

≈ 10%

Total cereal yield

Qt/ht from 2003/04-2010/11



Annual Growth Rate (CAGR)

2003/04-10/11

≈ 5%

Source: CSA; Agricultural Sample Survey 2003/04-11,

National Soil Health and Fertility Initiatives

1. Improved Vertisol Management

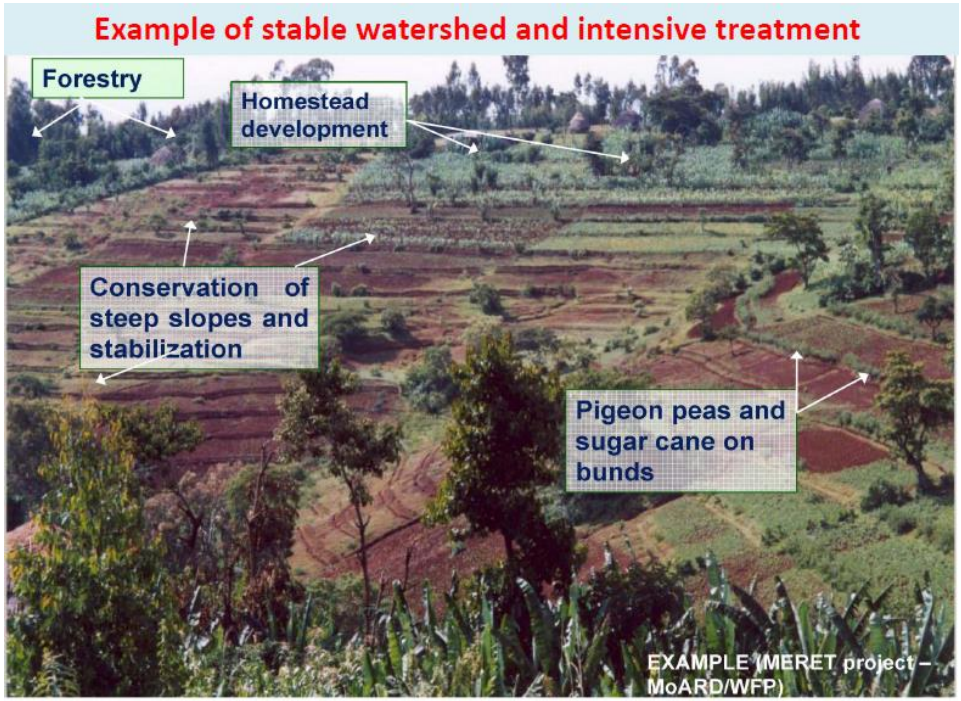
Up to 500% yield increment

2. Acid Soil Management

- Use of agricultural lime being promoted since 2006.
- Yield increments of more than **500%** registered.
- Production and distribution has been a major challenge

3. Community Watershed Development

- So far, **>15 M** ha degraded land rehabilitated
- Focus over time has shifted from food relief to land conservation and then to livelihoods



4. The EthioSIS Program

This systematic problem lead to the establishment of EthioSIS projects and other follow up initiatives. The GOE committed finance and logistics to implement this at a national scale

Mapping

- Launch Digital Soil mapping (Grid and soil fertility)

Validation

- New fertilizer demonstration activities (will be presented by collegue Mulugeta)

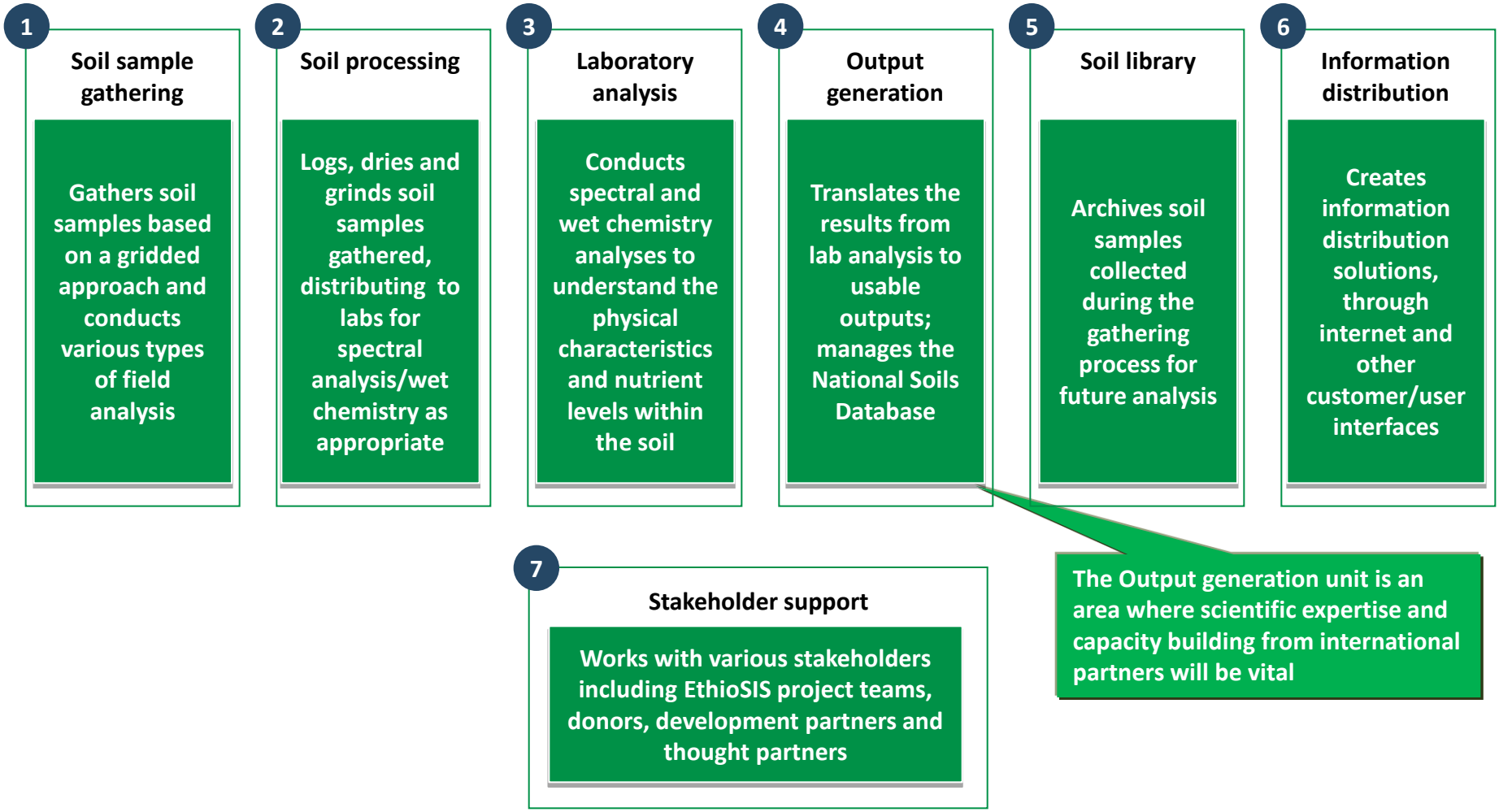
Results

- Urgent need to supply blended fertilizer to small holders has been identified hence decision to establish Fertilizer Blending Plants

Capacity

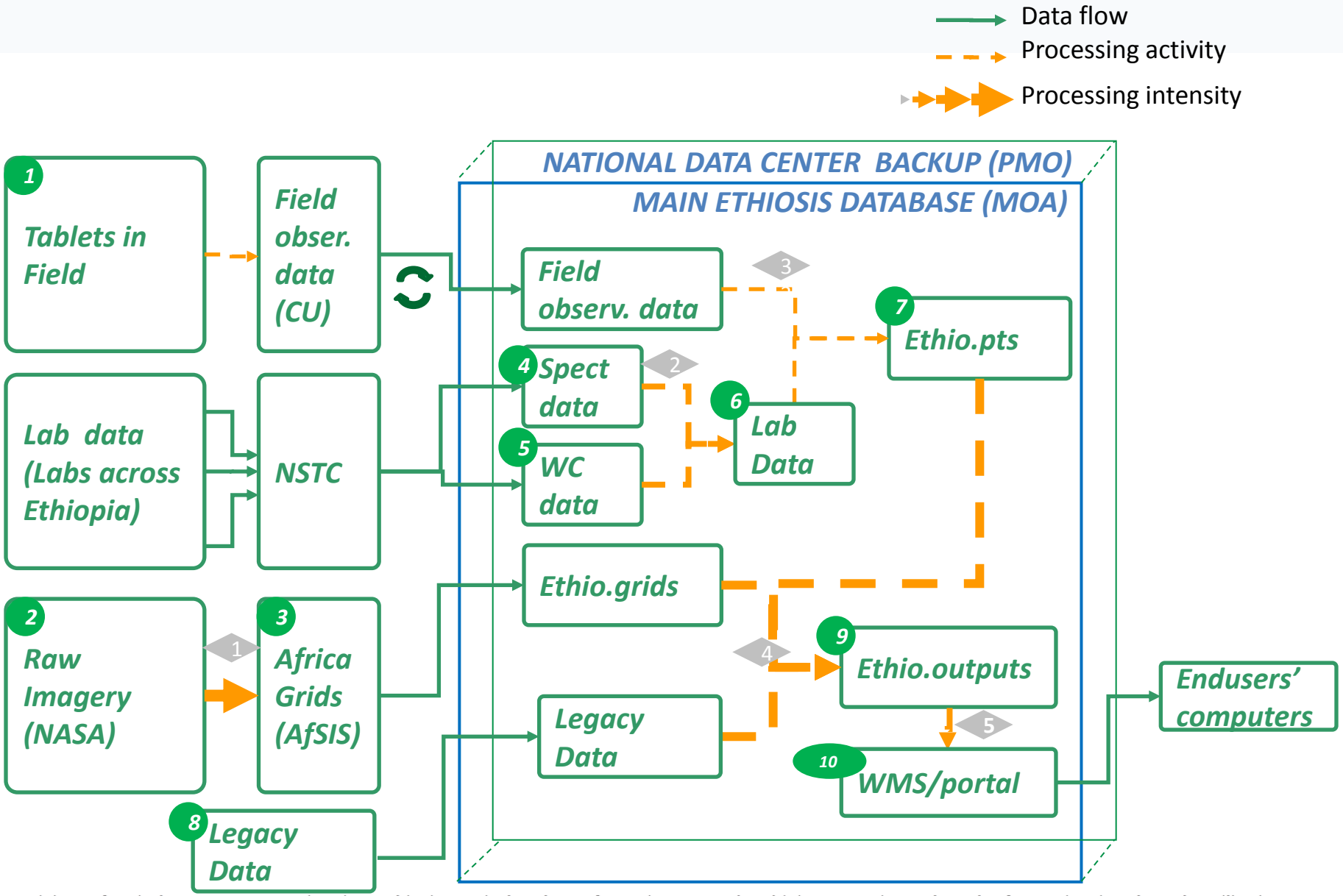
- Capacity building key factors in successful outcome of EthioSIS

There are seven components that come together to form the Ethiopian Soil Information System (EthioSIS)



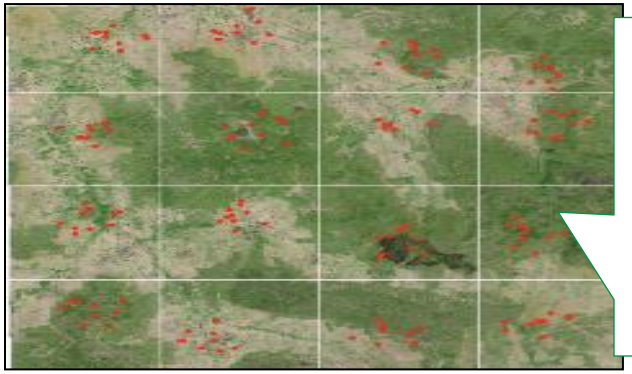
SOURCE: Team analysis

EthioSIS workflow, products & services overview

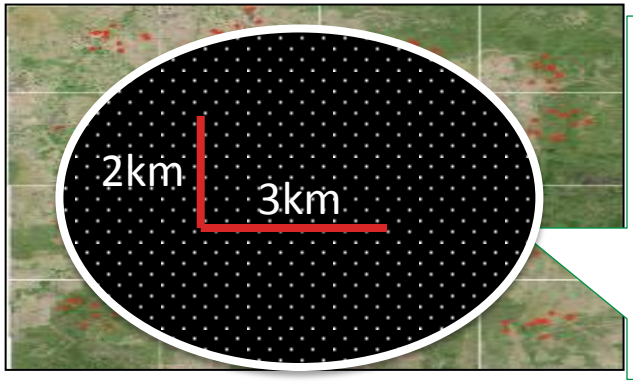


EthioSIS project objective is to map Ethiopian soil resources and fertility status while building a central soil information system. All information collected will be geo-referenced

EthioSIS initiative will provide a framework for geostatistical projections on soil characteristics using of existing remote sensing data and extensive physical soil sampling. Furthermore detailed fertility condition of the country will be mapped



Each 10 by 10 km sampling site is divided into randomly assigned clusters for soil sample collection.



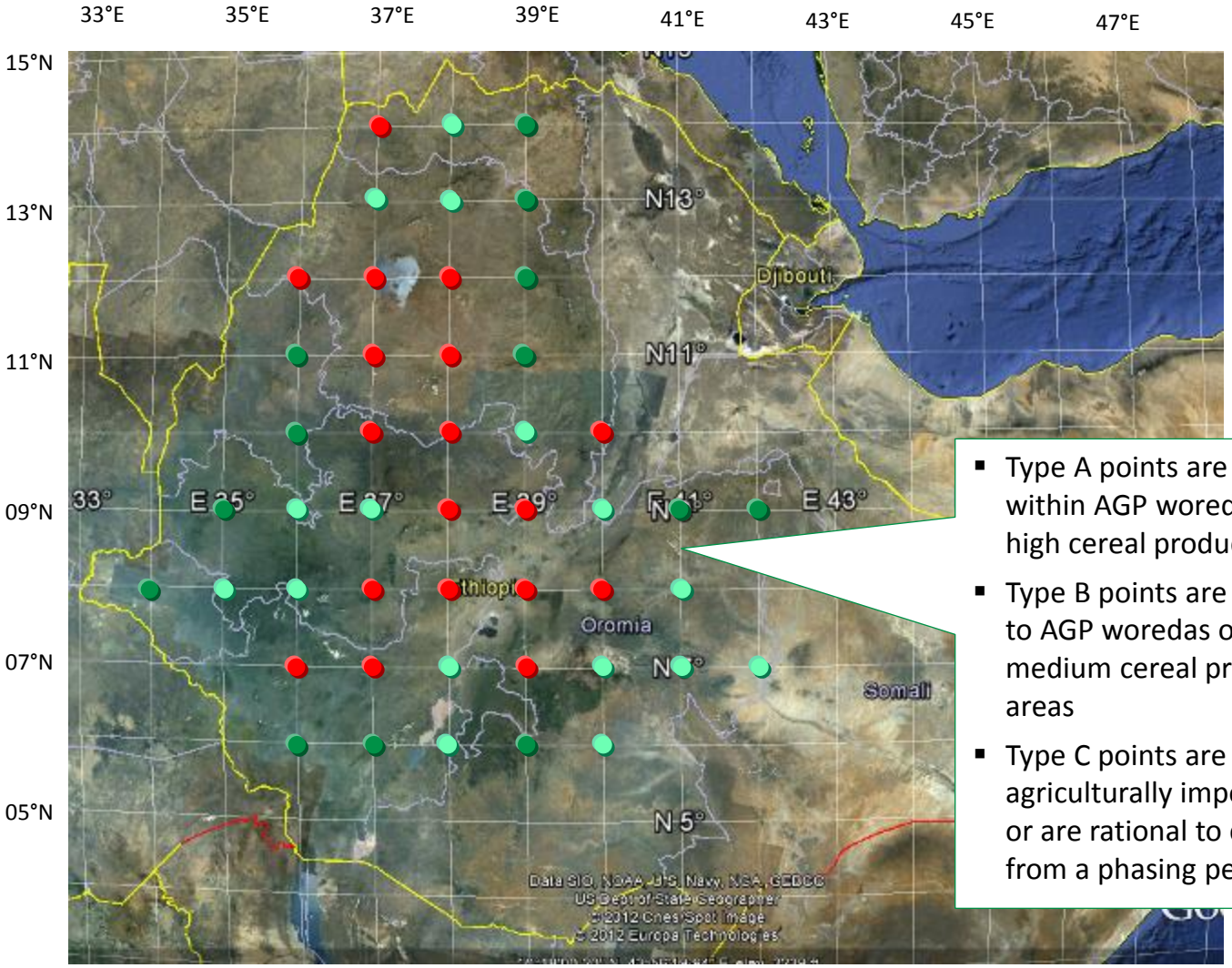
Over 500 woreda will be surveyed to learn about fertility status at 250 M resolution between 2,5 – 6 Km. interval

The initiative will set up – A National Soils Database (NSD) that will run a terabyte information at a specific site granularity

Detailed soil characteristic maps for even one site run into terabytes. Ethiopia will have such sites

Source: ATA; AfSIS

97 latitude-longitude confluence points were expected to be covered across Ethiopia to allow for geo-statistics prediction of the country for land resource mapping



- Type A points are either within AGP woredas or are high cereal production areas
- Type B points are either close to AGP woredas or are medium cereal production areas
- Type C points are other agriculturally important areas or are rational to complete from a phasing perspective

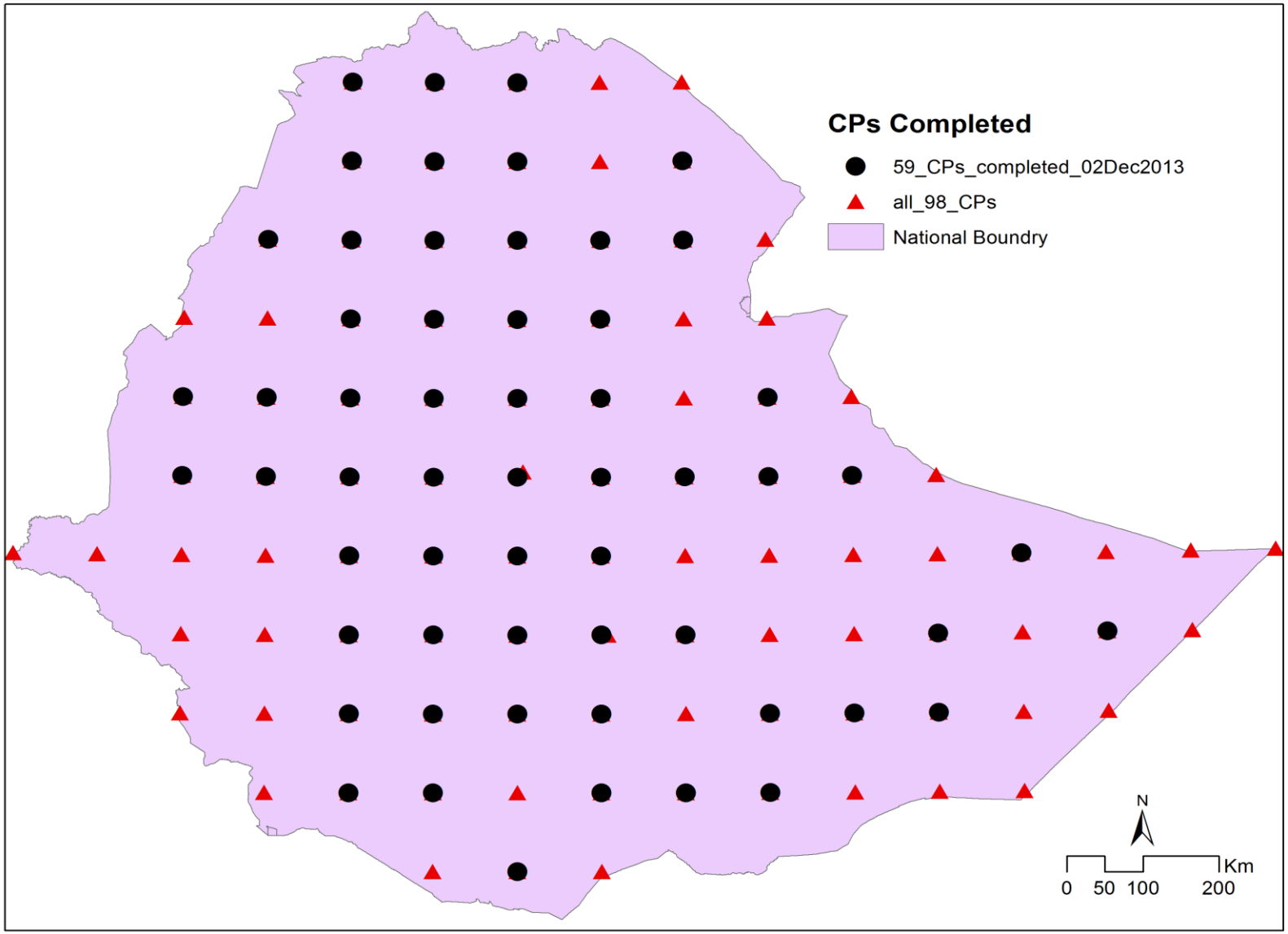
Type A (18)
- Oromia 7
- Amhara 7
- SNNP 3
- Tigray 1
- Gambella
- Benishangul

Type B (16)
- Oromia 11
- Amhara 3
- SNNP 1
- Tigray 1
- Gambella
- Benishangul

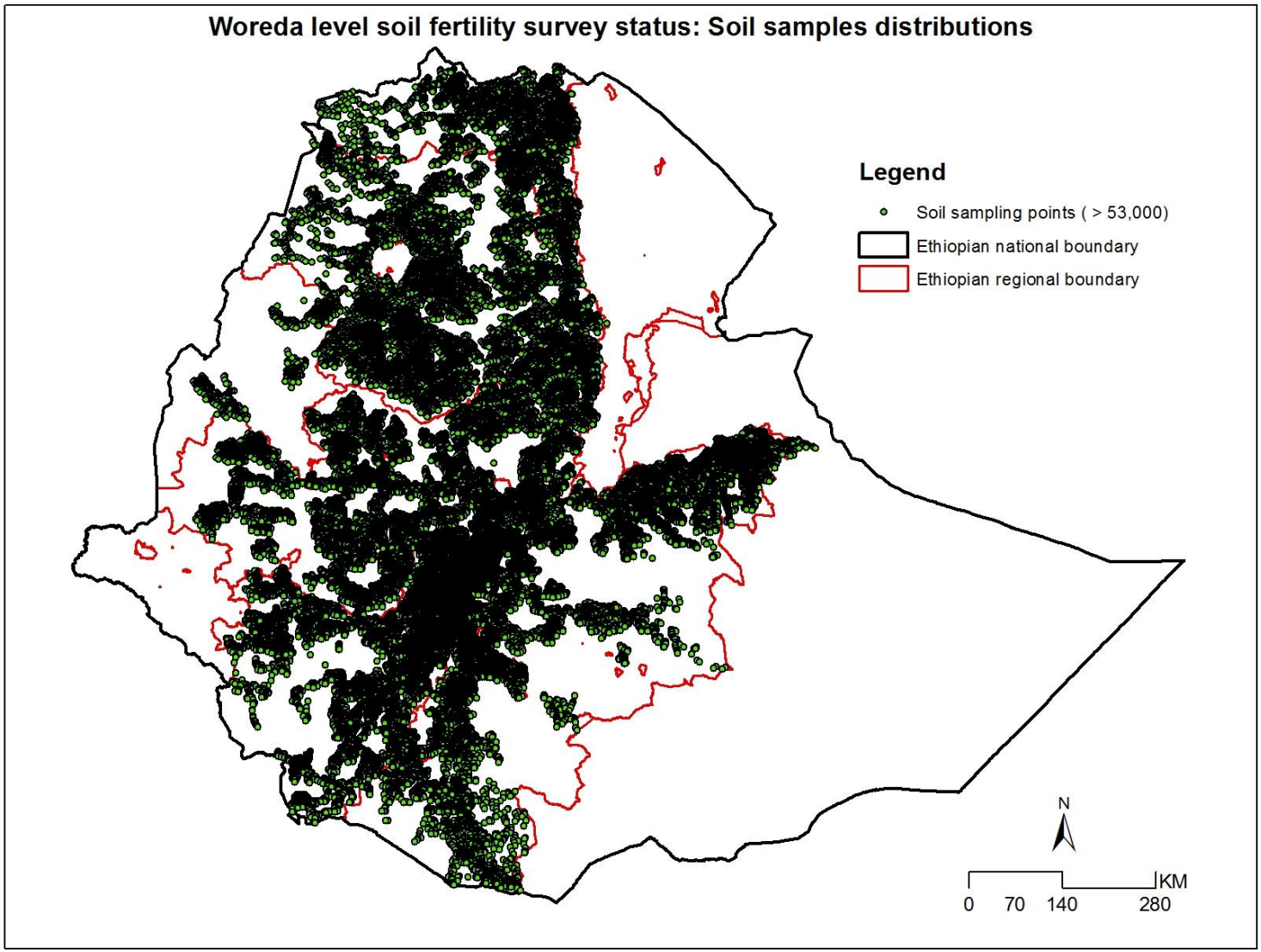
Type C (13)
- Oromia 4
- Amhara 3
- SNNP 2
- Tigray 1
- Gambella 1
- Benishangul 2

Source: Team analysis; AGP; CSA

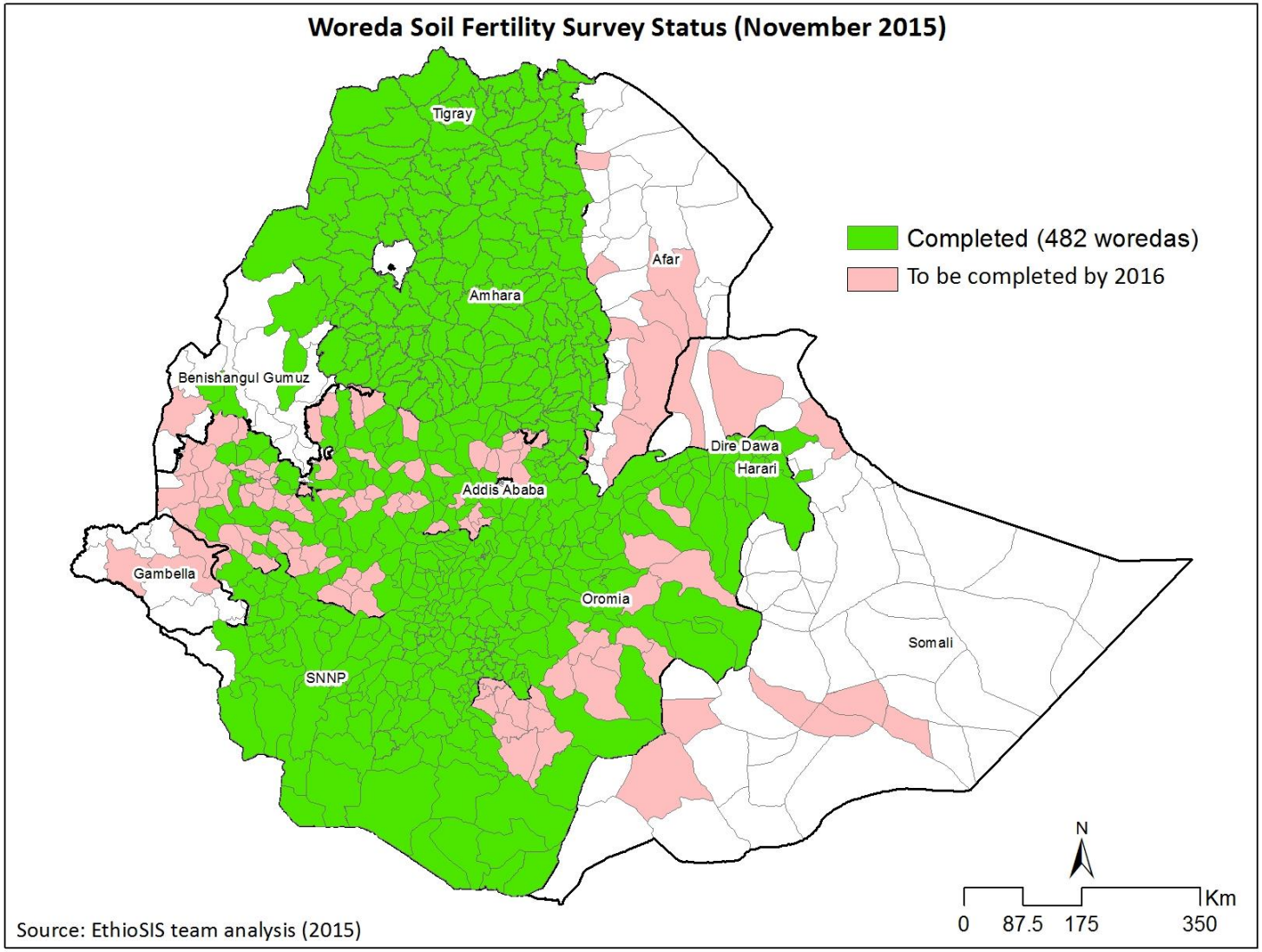
We have achieved soil collection only at 59 CP's. Various challenges have curtailed full performance that will be addressed in the future



Woreda level samples collected from over 53,000 sampling locations to be able to predict the fertility status of the country



Woreda Soil Fertility Mapping exercise has been progressing well and so far soil inventory of 360 Woreda is completed (Update)



Mobile/tablets assisted data collection is being implemented

Design

Feed-in Pre-defined points

Collect and send to server

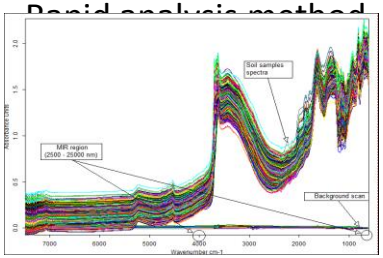
Retrieve, Clean and DB Update

- https://formhub.org/

State-of-the-art technologies are used to analyze soil samples, store and retrieve data

Infrared (IR) spectroscopy and LDPSD analysis

- Analyzing soils using light (IR)
- Rapid analysis method



Wet-chemistry analysis using instruments having high detection limits

- Analysing soils using chemical solutions
- Process is much **slower** than spectral analysis but helps for calibration

Field and laboratory data are being stored in the MOA server

Soil samples are being archived in Kality soil library

SOURCE: Team analysis;

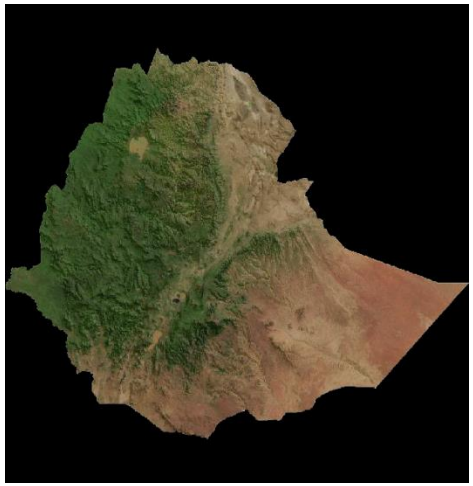
Data types and sources used for geostatistical mapping

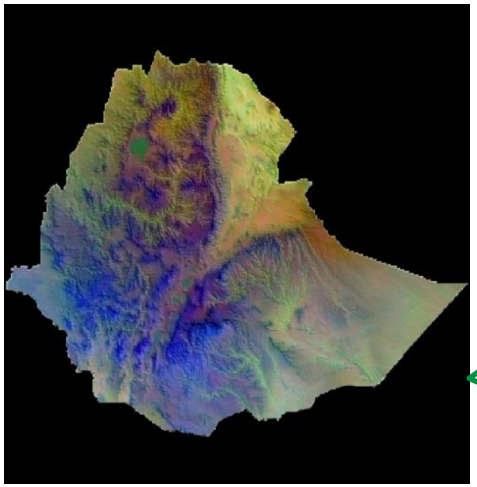
Data Types:

- Observations (Field Data – Geographic locations)
- Lab Data (wet chemistry and spectral data)
- Covariates (satellite imageries & other legacy data, 2000-2012 average from NASA & Columbia University via AfSIS)
- Admin boundaries (region, zone, woreda & kebele, CSA-2007)

Examples of useful remote sensing covariates for digital soil mapping

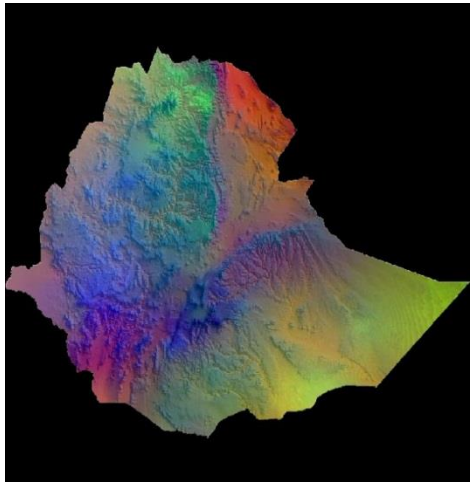
MODIS & Landsat reflectance & vegetation products

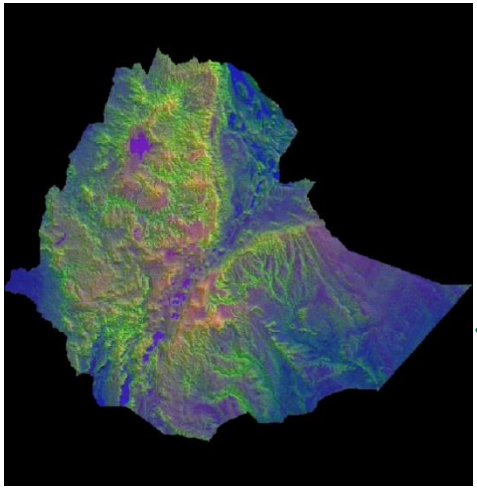




MODIS energy balance (e.g, LST, fPAR, albedo)

WorldClim & TRMM climatologies (e.g, MAP Fournier Index & PET)





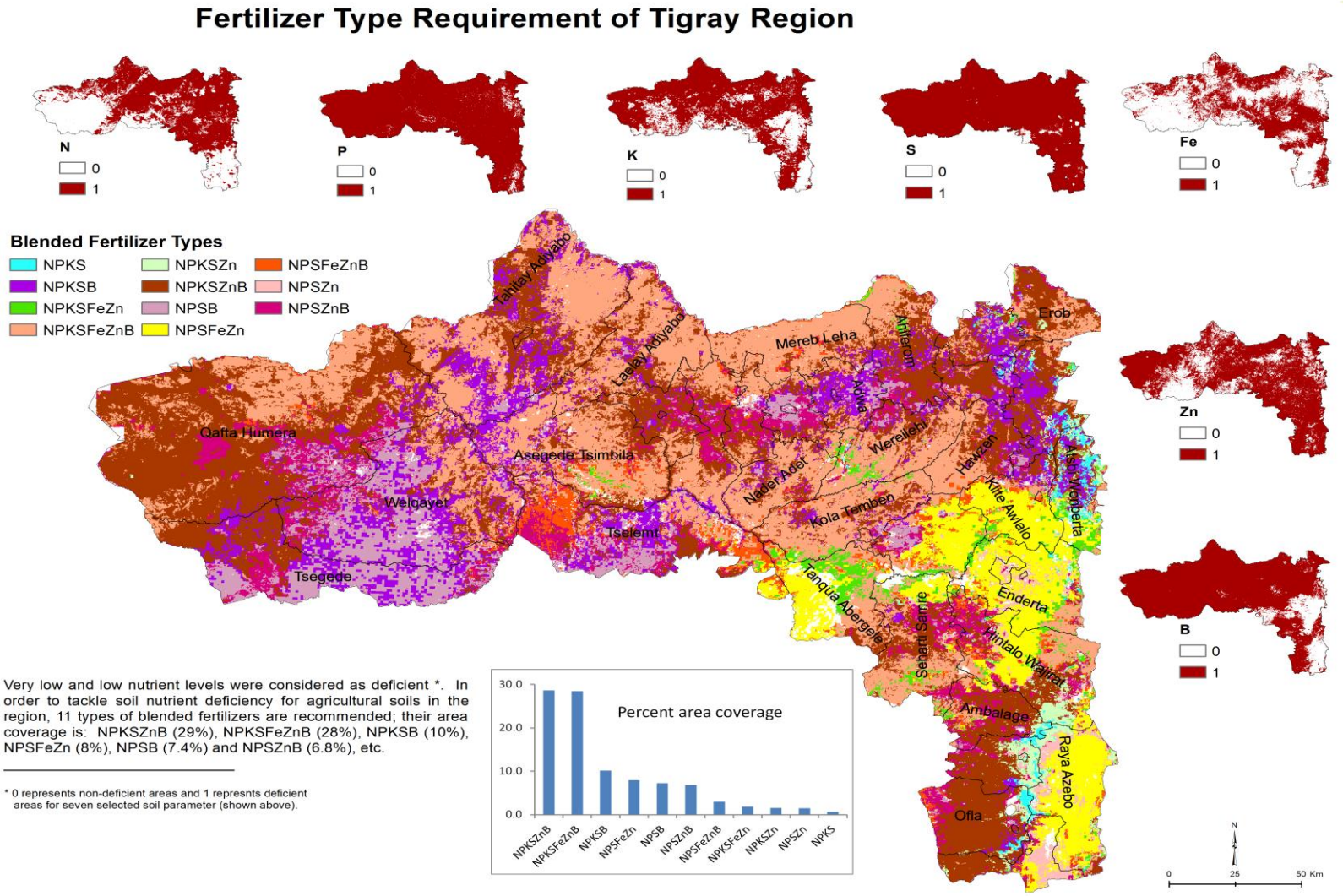
SRTM & ASTER terrain models (e.g, elevation, CTI, slope, relief)

available at: ftp://africagrids.net

- **Using geo-statistical modelling:** Predicted soil nutrients <- as a function of soil nutrient results from lab and other relevant covariates
- **Predict at 250m grid size:** comparing with 1km cell

$$pH = \beta_0 + \beta_1 Elevation_i + \beta_2(Slope_i) + \beta_3(RF_i) + \beta_4(Temp_i) + ... + \varepsilon_i$$

Tigray soil fertility map recommends 11 types of blended fertilizer and data at kebele level has been distributed to the regional BOA



Very low and low nutrient levels were considered as deficient *. In order to tackle soil nutrient deficiency for agricultural soils in the region, 11 types of blended fertilizers are recommended; their area coverage is: NPKSZnB (29%), NPKSFeZnB (28%), NPKSB (10%), NPSFeZn (8%), NPSB (7.4%) and NPSZnB (6.8%), etc.

* 0 represents non-deficient areas and 1 represnts deficient areas for seven selected soil parameter (shown above).

CHAPTER 1: TIGRAY REGION AND ZONE ONE

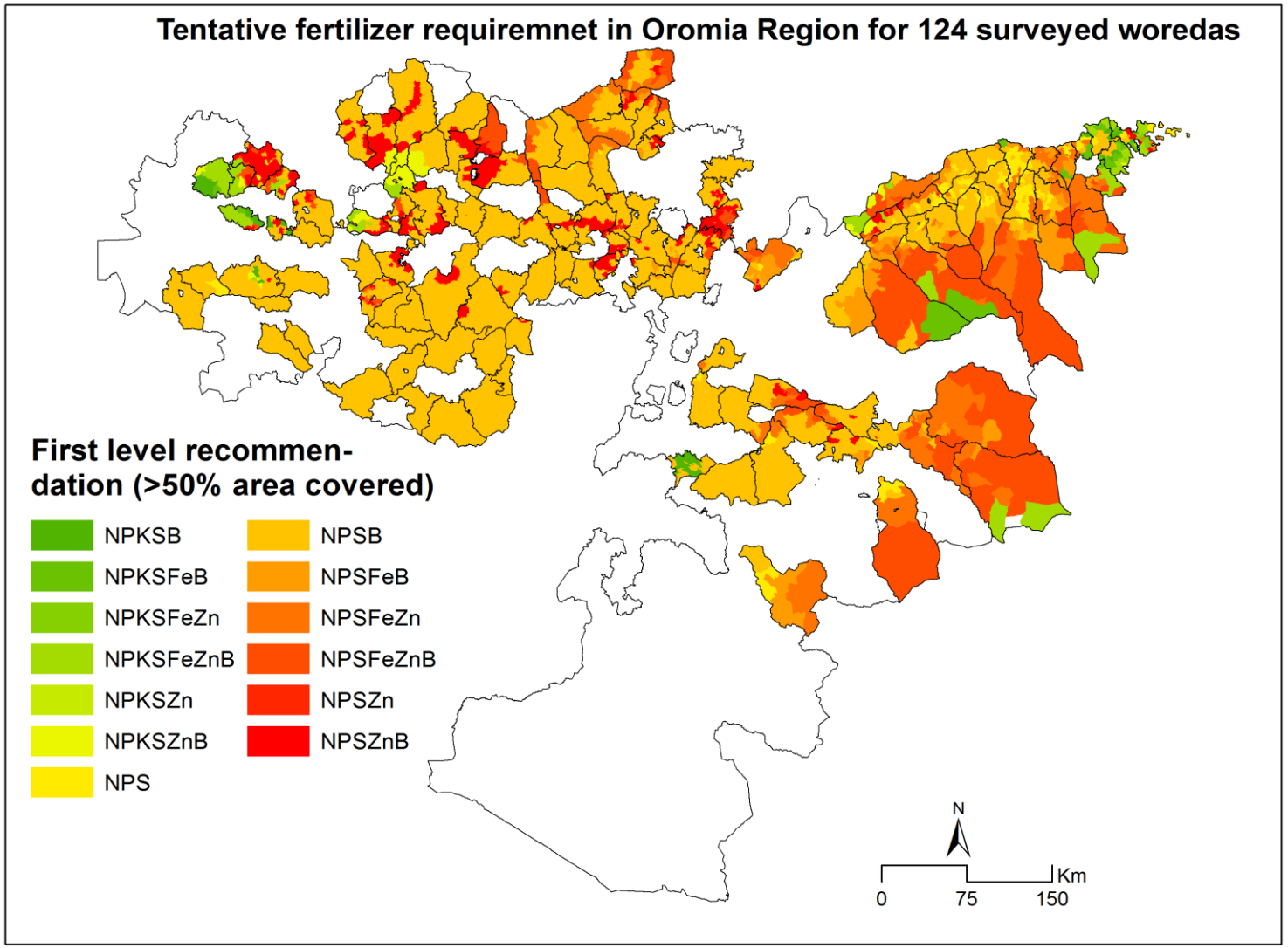
Preliminary fertilizer blend formulas requires basic NPS and the addition of micronutrients

Formula 1: NPS	19 N – 38 P_2O_5 +7S
Formula 2 : NPSB	18. 1 N – 36.1 P_2O_5 + 6.7S + 0.71B
Formula 3 : NPKSB	13.7 N – 27.4 P_2O_5 – 14.4 K_2O + 5.1S + 0.54B
Formula 4 : NPSZnB	16.9 N – 33.8 P_2O_5 + 7.3S + 2.23Zn + 0.67B
Formula 5 : NPKSZnB	13.0 N – 26.1 P_2O_5 – 13.7 K_2O + 5.6S+ 1.72Zn + 0.51B
Formula 6 : NPSZn	17.7 N – 35.3 P_2O_5 + 6.5S + 2.5 Zn

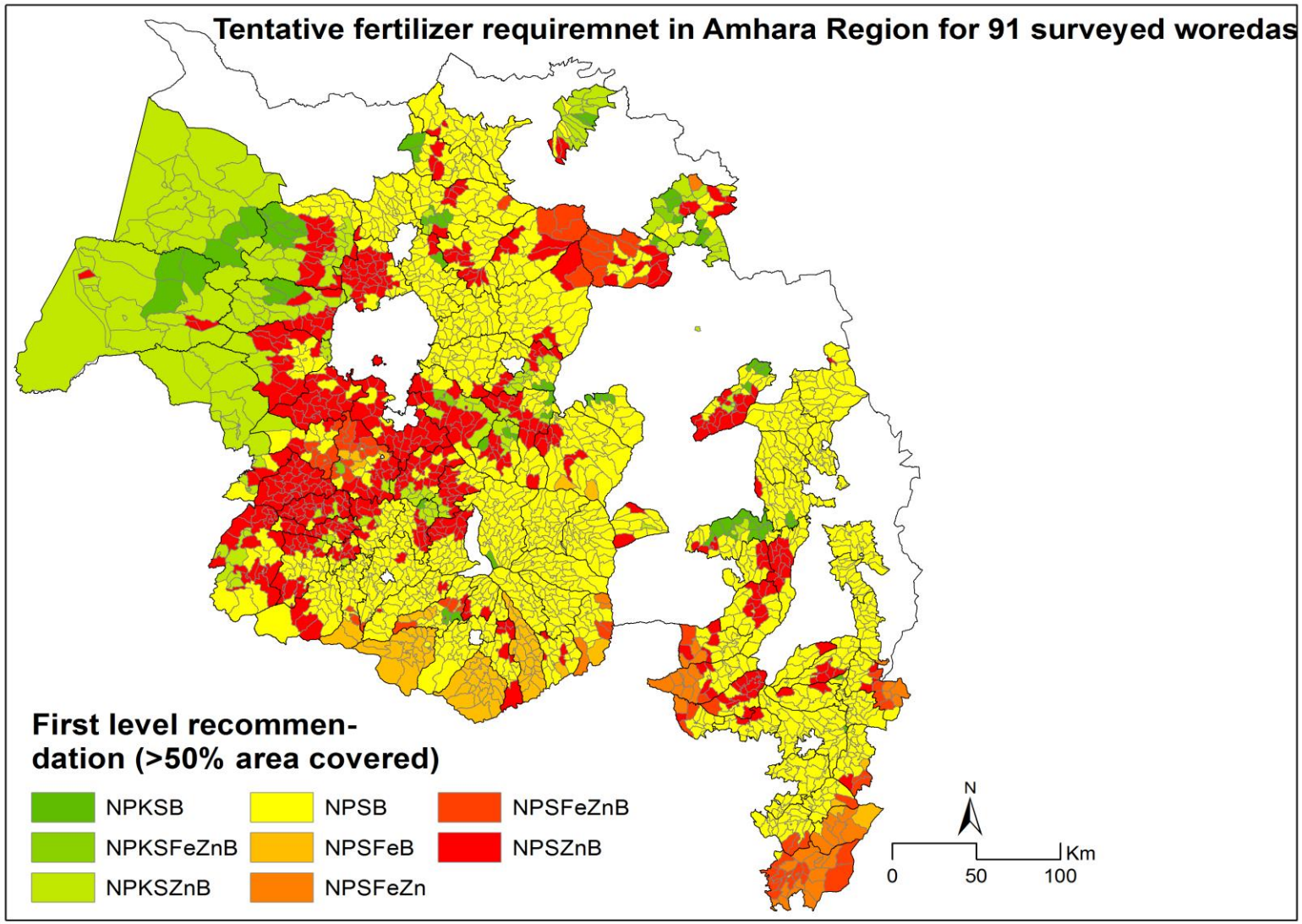
Preliminary fertilizer blend formulas requires basic NPS and the addition of micronutrients (continued)

Formula 7: NPSZn	15 N –31 P_2O_5 –8 K_2O + 7 S+ 2.2 Zn
Formula 8 : NPSFeZn	17 N –35 P_2O_5 +8 S+ 0.3 Fe+ 2.2Zn
Formula 9 : NPSFeZnB	17 N –33 P_2O_5 –0 K_2O + 7 S+ 2.2 Zn+ 0.3 Fe+0.5 B
Formula 10: NPSFeZn	15 N –30 P_2O_5–8 K_2O +7.0 S+ 0.3 Fe-chelate+ 2.2Zn
Formula 11: NPKSFeZn	17 N –20 P_2O_5 –8 K_2O + 11 S+ 2.2 Zn+ 0.3 Fe + 0.5 B
Formula 12: NPKS	15 N –29 P_2O_5–8 K_2O +10S

Oromia soil fertility map recommends 13 types of blended fertilizer and data at kebele level has been distributed to the regional BOA



Amhara soil fertility map recommends 8 types of blended fertilizer and data at kebele level has been distributed to the regional BOA



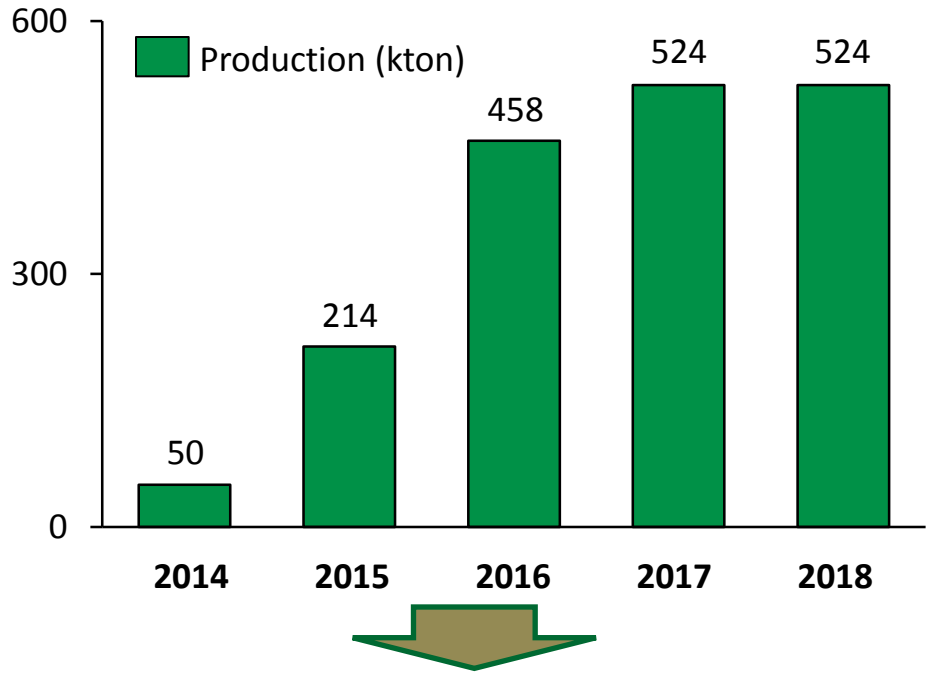
Establishing Fertilizer Blending Plants

The Fertilizer Blending initiative will make it possible for Ethiopia to locally produce up to 500k ton of blends

The Fertilizer Blending initiative

Where	Tigray, Amhara, Oromia(2) & SNNP
Capacity	100kton per plant (500kton total)
When	Production started in June 2014
Status	All the factories are operational

Expected production of local plants (kton)



Blended fertilizer is expected to be distributed this planting season

In line with the above facts, two key approaches have been considered for fertilizer use changes in Ethiopia

APPROACHES FOR DIVERSIFYING FERTILIZER USAGE

1 Locally blended fertilizers

What is it?	Blends are mixes of fertilizers at appropriate ratios to supply multiple nutrients for a crop
Coverage	Available on the **four regions** where plants has been built
Advantages	• **Flexibility** to define formulas • Develops **local industry**
Risks	• Limited production **capacity** • Lack of regional ownership

2 Straight application of compounds

What is it?	Application of compound fertilizers directly imported from the international market
Coverage	Imported compounds can be made available **nation wide**
Advantages	• Readily available for import • Similarity to Urea/DAP • Less cost
Risks	• **Not optimized** for real needs

Five fertilizer blending facilities have been established in major four regions; one each in Amhara, SNNP and Tigray, and two in Oromia.

- Production capacity of **500k tonnes per year** has been built in each FCU (Tulu Bolo, Nekemte, Mekele, Bahir Dar and Worabe)
- Since the fertilizer blending business is new for the country, ATA in collaboration with AGP-AMDe, three international expats has been recruited for knowledge transfer
- Procurement and installation of the blending and bagging equipment are completed at each site
- Capacity building of local staffs have been done in all aspects of the blending & bagging operation.

All blending plants are operational. As such, Becho Woliso blending plant alone produced more than 30,000MT of different blends and distributed to smallholder farmers during the last planting season for Oromia region

Partners in the implementation of EthioSIS and Fertilizer Blending Initiatives

Federal and regional institutions	Provided soil surveyors , laboratory experts, project support
AfSIS	Technological platform
WU-CASCAPE-Altera	EthioSIS has benefitted from Wageningen University in technical support (IT and Geo-statistics) and funding of 30 woredas' soil mapping.
FAO	Training of geo-statisticians (finance) by sending them to Arusha for four weeks to be able to develop the soil fertility maps.
Yara	International Laboratory in London has volunteered to analyze all soil samples at reduced cost
OCP	Soil fertility mapping and new fertilizer demonstrations
Hawassa/Haramaya University	The EthioSIS team has worked with Haramaya University and extended funding for 9 MSC and 4 PhD students to work on soil mapping and potassium research.
AGP/AMDe	Co-funding one fertilizer blending facility and providing capacity building for staff and management of the five plants.
ICL	Soil fertility mapping and new fertilizer demonstrations

Innovations to help our country grow