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

Tegbaru Bellete

2nd IPI – MoANR – ATA- Hawassa University Joint Symposium

24th November 2015
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.

Cereals growth rate from 1995-96 to 2012-13 was 6.3 percent.
Positive trend in overall fertilizer consumption is observed 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

- Loss 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.
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

<table>
<thead>
<tr>
<th>Year</th>
<th>Tons</th>
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<tbody>
<tr>
<td>03/04</td>
<td>22</td>
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<tr>
<td>04/05</td>
<td>25</td>
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<tr>
<td>05/06</td>
<td>34</td>
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<td>06/07</td>
<td>36</td>
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<td>07/08</td>
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<td>09/10</td>
<td>34</td>
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<tr>
<td>10/11</td>
<td>44</td>
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**Annual Growth Rate (CAGR)**

2003/04-10/11

\[ \approx 10\% \]

### Total cereal yield
Qt/ht from 2003/04-2010/11

<table>
<thead>
<tr>
<th>Year</th>
<th>Yield</th>
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<tbody>
<tr>
<td>03/04</td>
<td>13</td>
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<tr>
<td>04/05</td>
<td>13</td>
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<tr>
<td>05/06</td>
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<td>06/07</td>
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<td>08/09</td>
<td>16</td>
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<tr>
<td>09/10</td>
<td>17</td>
</tr>
<tr>
<td>10/11</td>
<td>18</td>
</tr>
</tbody>
</table>

**Annual Growth Rate (CAGR)**

2003/04-10/11

\[ \approx 5\% \]

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.

<table>
<thead>
<tr>
<th>Mapping</th>
<th>• Launch Digital Soil mapping (Grid and soil fertility)</th>
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<tbody>
<tr>
<td>Validation</td>
<td>• New fertilizer demonstration activities (will be presented by colleague Mulugeta)</td>
</tr>
<tr>
<td>Results</td>
<td>• Urgent need to supply blended fertilizer to small holders has been identified hence decision to establish Fertilizer Blending Plants</td>
</tr>
<tr>
<td>Capacity</td>
<td>• Capacity building key factors in successful outcome of EthioSIS</td>
</tr>
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</table>
There are seven components that come together to form the Ethiopian Soil Information System (EthioSIS)

1. Soil sample gathering
   - Gathers soil samples based on a gridded approach and conducts various types of field analysis

2. Soil processing
   - Logs, dries and grinds soil samples gathered, distributing to labs for spectral analysis/wet chemistry as appropriate

3. Laboratory analysis
   - Conducts spectral and wet chemistry analyses to understand the physical characteristics and nutrient levels within the soil

4. Output generation
   - Translates the results from lab analysis to usable outputs; manages the National Soils Database

5. Soil library
   - Archives soil samples collected during the gathering process for future analysis

6. Information distribution
   - Creates information distribution solutions, through internet and other customer/user interfaces

7. Stakeholder support
   - Works with various stakeholders including EthioSIS project teams, donors, development partners and thought partners

The Output generation unit is an area where scientific expertise and capacity building from international partners will be vital.
EthioSIS workflow, products & services overview

1. Tablets in Field
   - Field obser. data (CU)

2. Lab data (Labs across Ethiopia)

3. Raw Imagery (NASA)
   - Africa Grids (AfSIS)

4. Spect data

5. WC data

6. Lab Data

7. Ethio.pts

8. Legacy Data

9. Ethio.outputs

10. WMS/portal

Data flow
- Lab data (Labs across Ethiopia)
- Africa Grids (AfSIS)
- Raw Imagery (NASA)
- Tablets in Field
- Field obser. data (CU)

Processing activity
- National Data Center Backup (PMO)
- Main Ethiosis Database (MOA)

Processing intensity
- 1
- 2
- 3
- 4
- 5

Endusers’ computers

NATIONAL DATA CENTER BACKUP (PMO)
MAIN ETHIOSIS DATABASE (MOA)

Field observ. data
- Spect data
- WC data

Ethio.grids
- Lab Data
- Ethio.outputs
- Legacy Data
- WMS/portal
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 existing remote sensing data and extensive physical soil sampling. Furthermore, detailed fertility condition of the country will be mapped.

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

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

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.

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.
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

<table>
<thead>
<tr>
<th>Design</th>
<th>Feed-in Pre-defined points</th>
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</thead>
<tbody>
<tr>
<td>• KML</td>
<td>• xls</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Collect and send to server</th>
<th>Retrieve, Clean and DB Update</th>
</tr>
</thead>
<tbody>
<tr>
<td>• KML</td>
<td>• <a href="https://formhub.org/">https://formhub.org/</a></td>
</tr>
</tbody>
</table>
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

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

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

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

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

\[ pH = \beta_0 + \beta_1 Elevation_i + \beta_2 (Slope_i) + \beta_3 (RF_i) + \beta_4 (Temp_i) + \ldots + \epsilon_i \]
Tigray soil fertility map recommends 11 types of blended fertilizer and data at kebele level has been distributed to the regional BOA.
Preliminary fertilizer blend formulas requires basic NPS and the addition of micronutrients

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: NPS</td>
<td></td>
<td>19 N – 38 P₂O₅ + 7S</td>
</tr>
<tr>
<td>2: NPSB</td>
<td></td>
<td>18.1 N – 36.1 P₂O₅ + 6.7S + 0.71B</td>
</tr>
<tr>
<td>3: NPKSB</td>
<td></td>
<td>13.7 N – 27.4 P₂O₅ – 14.4 K₂O + 5.1S + 0.54B</td>
</tr>
<tr>
<td>4: NPSZnB</td>
<td></td>
<td>16.9 N – 33.8 P₂O₅ + 7.3S + 2.23Zn + 0.67B</td>
</tr>
<tr>
<td>5: NPKSZnB</td>
<td></td>
<td>13.0 N – 26.1 P₂O₅ – 13.7 K₂O + 5.6S + 1.72Zn + 0.51B</td>
</tr>
<tr>
<td>6: NPSZn</td>
<td></td>
<td>17.7 N – 35.3 P₂O₅ + 6.5S + 2.5 Zn</td>
</tr>
</tbody>
</table>
Preliminary fertilizer blend formulas requires basic NPS and the addition of micronutrients (continued)

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>7:</strong> NPSZn</td>
<td>15 N –31 P₂O₅ –8 K₂O + 7 S+ 2.2 Zn</td>
<td></td>
</tr>
<tr>
<td><strong>8:</strong> NPSFeZn</td>
<td>17 N –35 P₂O₅ +8 S+ 0.3 Fe+ 2.2Zn</td>
<td></td>
</tr>
<tr>
<td><strong>9:</strong> NPSFeZnB</td>
<td>17 N –33 P₂O₅ –0 K₂O + 7 S+ 2.2 Zn+ 0.3 Fe+0.5 B</td>
<td></td>
</tr>
<tr>
<td><strong>10:</strong> NPSFeZn</td>
<td>15 N –30 P₂O₅–8 K₂O +7.0 S+ 0.3 Fe-chelate+ 2.2Zn</td>
<td></td>
</tr>
<tr>
<td><strong>11:</strong> NPKSFeZn</td>
<td>17 N –20 P₂O₅ –8 K₂O + 11 S+ 2.2 Zn+ 0.3 Fe + 0.5 B</td>
<td></td>
</tr>
<tr>
<td><strong>12:</strong> NPKS</td>
<td>15 N –29 P₂O₅–8 K₂O +10S</td>
<td></td>
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</table>

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Production (kton)</th>
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</thead>
<tbody>
<tr>
<td>2014</td>
<td>50</td>
</tr>
<tr>
<td>2015</td>
<td>214</td>
</tr>
<tr>
<td>2016</td>
<td>458</td>
</tr>
<tr>
<td>2017</td>
<td>524</td>
</tr>
<tr>
<td>2018</td>
<td>524</td>
</tr>
</tbody>
</table>

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.
<table>
<thead>
<tr>
<th>Partners in the implementation of EthioSIS and Fertilizer Blending Initiatives</th>
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</thead>
<tbody>
<tr>
<td><strong>Federal and regional institutions</strong></td>
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<tr>
<td>Provided soil surveyors, laboratory experts, project support</td>
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<tr>
<td><strong>AfSIS</strong></td>
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<tr>
<td>Technological platform</td>
</tr>
<tr>
<td><strong>WU-CASCAPE-Altera</strong></td>
</tr>
<tr>
<td>EthioSIS has benefitted from Wageningen University in technical support (IT and Geo-statistics) and funding of 30 woredas’ soil mapping.</td>
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<tr>
<td><strong>FAO</strong></td>
</tr>
<tr>
<td>Training of geo-statisticians (finance) by sending them to Arusha for four weeks to be able to develop the soil fertility maps.</td>
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<tr>
<td><strong>Yara</strong></td>
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<tr>
<td>International Laboratory in London has volunteered to analyze all soil samples at reduced cost</td>
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<tr>
<td><strong>OCP</strong></td>
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<tr>
<td>Soil fertility mapping and new fertilizer demonstrations</td>
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<tr>
<td><strong>Hawassa/Haramaya University</strong></td>
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<tr>
<td>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.</td>
</tr>
<tr>
<td><strong>AGP/AMDe</strong></td>
</tr>
<tr>
<td>Co-funding one fertilizer blending facility and providing capacity building for staff and management of the five plants.</td>
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<tr>
<td><strong>ICL</strong></td>
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<tr>
<td>Soil fertility mapping and new fertilizer demonstrations</td>
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Innovations to help our country grow