Feeding degraded soils in Ethiopia to feed the people and the environment

Precision fertilization improves food security and resilience

THE BENEFITS

Increased yields
Targeted fertilizer use with right agronomic practices increased yields by **40-200%**

Reduced costs
Fertilizer wastage reduced by **20-80%**

Increased crop response to fertilizer
Dominant yield response is from application of **NPK**

Improved grain quality
Application of **Sulfur** and **Zinc** improved grain quality

Improved soil health
Soil and water **conservation**, **organic amendments** and right dosage of fertilizers improved fertility

Photo: Simret Yasabu

The challenge

Centuries of nutrient mining on farms in the undulating landscape of Ethiopia has resulted in severely eroded and degraded soils that produce **40% less than the global average**.

The potential yield gap is huge. Yields in farmers' fields are three times less than what is recorded in research fields.

Soil fertility decline is considered as the major cause for decline in per-capita food production.

Low crop response to fertilizers is a major concern despite the Ethiopian government investing in accelerating fertilizer usage and creating soil maps with recommendations to guide farmers.

The need for fine tuning the recommendations was identified following feedback from farmers and regional governments.

The solution

Research organizations and development NGOs were consulted to address the issue.

This report brings to you
TWO STUDIES IN WHEAT-BASED FARMING SYSTEMS led by ICRISAT that offer solutions.

Key finding of the studies:
Site-specific nutrient management can double yields and reduce costs.

ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

BACKGROUND: FARMING IN ETHIOPIA

Soil-related problems

Low productivity
Average cereal yield:
Global **>3 t/ha**
Ethiopia **1.8 t/ha**[1]

Low fertilizer application
Accounts for one of the lowest in sub-Saharan Africa

Declining soil fertility
Cost of loss of soil and essential nutrients is estimated at **3%** of agricultural GDP

USD*106 million[2] **(*1994 $)**

Population pressure
Traditional soil fertility management practices such as **long-term fallows** have been diminishing. Farmers are forced to **farm non-cultivable lands**.

Undulating landscape
Fertility and topography varies widely between farms and within farms.

Soil erosion-degradation
Hillslopes are erosion prone. Appplied fertilizers are washed away when it rains.

[1] CSA, 2008; [2] Bojo & Cossells, 1995

STEPS TAKEN BY THE ETHIOPIAN GOVERNMENT

1

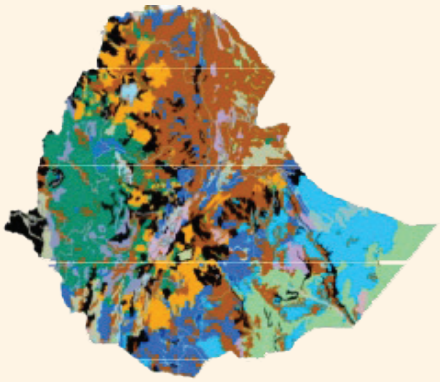
Imported fertilizer[3]
(Nitrogen and Phosphorus)

1994 200,000 t
2014 894,000 t

[3]International Livestock Research Institute, 2017

2

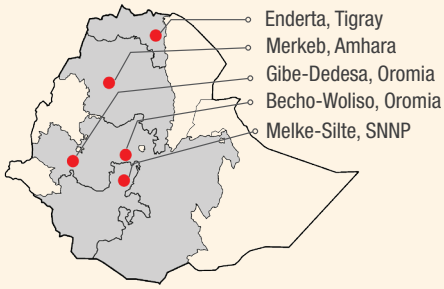
Soil fertility atlas
Work on maps* for 18,000 agricultural *kebeles* was started by the Agricultural Transformation Agency (ATA-Ethiosis) in 2012



*In close collaboration with the African Soils Information Services (AFSIS), under the Ministry of Agriculture and Natural Resources, Ethiopia.

3

5 fertilizer blend plants
These plants are managed by five Farmer Cooperative Unions for more customized fertilization recommendations



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Fine tuning earlier recommendations

Farmers and regional governments inform that soil maps are not yet accurate enough to assure potential benefits to farmers applying mineral fertilizers. There is a need to:

- Update them with **contemporary technologies** and analysis.
- **Fine tune recommendations** by consulting research organizations.

APPROACH ADOPTED TO FINE TUNE RECOMMENDATIONS

1 Conducted fertilizer trials

- **>600 experiments** both on-farm and on-station in six wheat belts
- Capitalized on earlier attempts by ATA and other stakeholders

2 Tested fertilizer combinations and rates (2014-2017)

- Various combinations of Nitrogen (N), Phosphorus (P), Potassium (K), Sulfur (S) and Zinc (Zn) were used on different landscapes

3 Identified homogeneous cropping management zones

Used landscape positions as proxy indicators of differences in crop response. The indicator was developed by assessing the degree of correlation among soil and topography factors-

- **Fertility**
- **Slope**
- **Organic carbon**
- **Water-holding capacity**
- **Texture**

4 Zones identified

- Footslope
- Midslope
- Hillslope

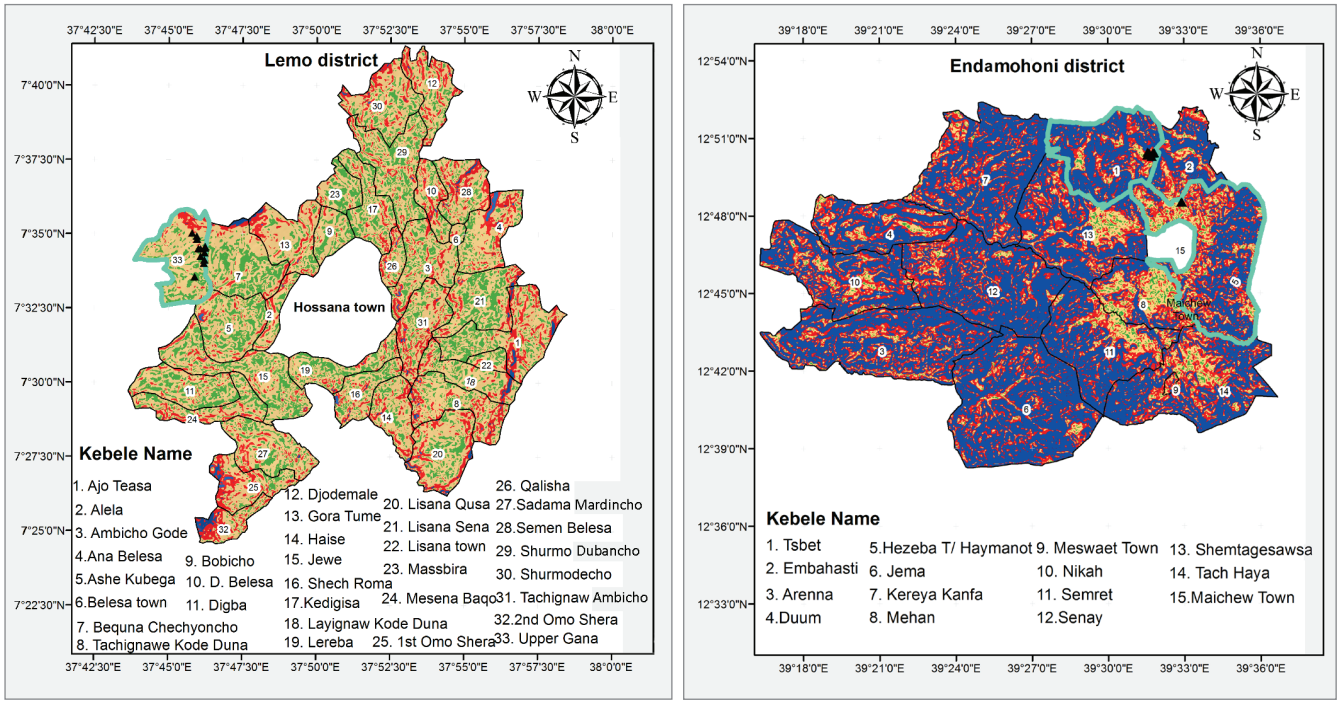
5 Decision support tools developed

Based on the findings, decision support tools were developed for the wheat-based farming systems to guide extension agents, district officers and farmers to target landscape niches with **specific soil fertility management options**, particularly mineral fertilizers

6 GIS-based analysis

Implemented to interpolate potential niches of the respective response levels

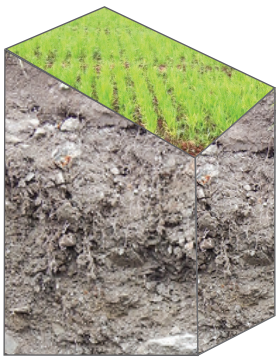
Spatial map of the nutrient response levels in Lemo and Endamohoni districts (study sites)

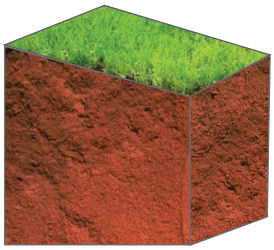


Nutrient Response Levels: High Moderate Low Very low *Kebele* boundaries Experimental sites

Upper Ghana *Kebele* (left) Tsibet and T/Haymanot *Kebeles* (right)

Identifying homogeneous cropping management zones





	HILLSLOPE 15-30°	MIDSLOPE 5-15°	FOOTSLOPE <5°
Soil character	• Low soil nutrient content • Undulated and prone to erosion • Shallow soils – sandy/gravelly • Crops dry fast during dry spells • Often low yield even in good seasons	• Moderately fertile • Moderately deep • Well drained • Moderate to strong acidity • Yield responsive to improved management	• Fertile and deep • Clay or loam • Higher water-holding capacity • Higher organic and nutrient content • Crops remain green during dry spells
Response to fertilizer	**Low - Very low** Very bad crop regardless of high rates of fertilizer application	**Medium - Low** Crop thrived well and significantly responds to fertilizer application (300%)	**High - Medium** Very good crop and responded to fertilizer application

Recommended agronomic practices for both districts

Soil and water conservation: Employ a physical soil bund/terrace to ensure that the soil, seed and fertilizer applied will not be washed away.

Integrated soil fertility management (ISFM): ISFM is an integrated approach employing concomitant application of chemical fertilizers with organic amendments, improved water management, improved agronomic practices along with nutrient-responsive crop varieties. ISFM should be given as much attention as input applications.

Split application of urea: To minimize nitrogen loss and increase fertilizer use efficiency, about one third of the urea should be applied at planting along with other fertilizers; the remaining two-third could be applied at 40-45 days after planting.

Weeding: Fertilizer application might trigger vigorous weed growth, hence, proper land preparation and weeding – at least twice per cropping season, is required. It could be done first at the time of split application of urea at 40-45 days after sowing and second a week before flowering.

Sowing in a row: It aids proper input placement and weeding that could improve productivity.

Use of high-yielding and adapting wheat varieties: Will facilitate increased yields and thereby the net return of applied fertilizer.

Soil amendment to decrease acidity: It is important to apply lime to further increase productivity.

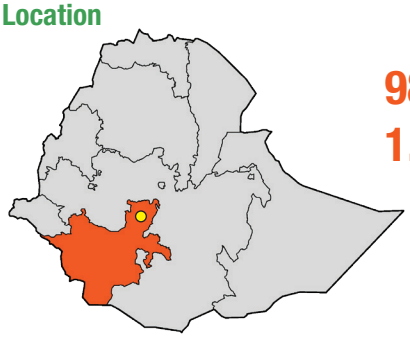
The recommendations suggested in this fact sheet could be used for crops with similar features such as **barley, sorghum** and **millets**.

Case study 1

Lemo District: SNNPR

Site-specific Nutrient Recommendation for Wheat-based Farming

Location



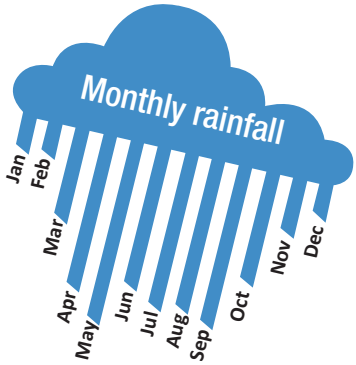
Hadiya Zone, SNNPR, Ethiopia

Major agroecologies

98.6% Tepid sub-moist mid highlands

1.4% Cool sub-moist mid highlands

Weather

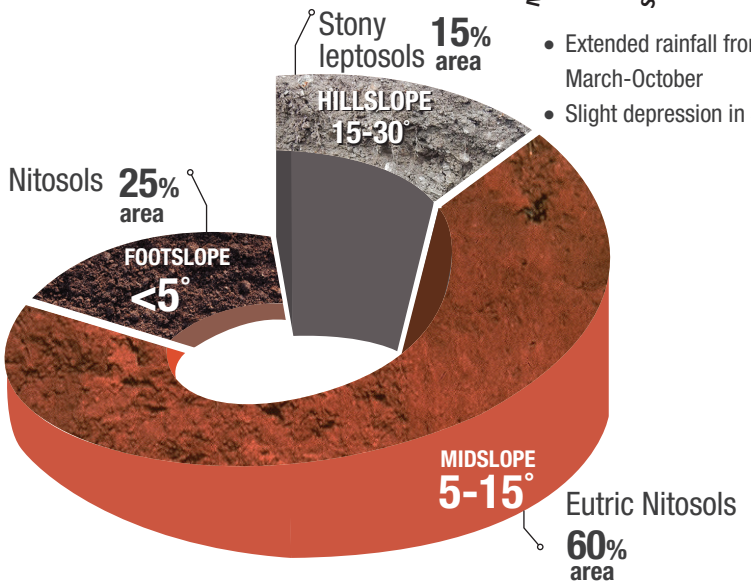


- Extended rainfall from March-October
- Slight depression in June.

Topography and soils

- Gentle and undulating topography
- Mid-altitude range: 1960 to 2720 masl*
- Soil derived from highly soft weathered rocks
- Susceptible to gully erosion
- Predominantly Nitosols, deep, well-drained and acidic

*Meters above sea level



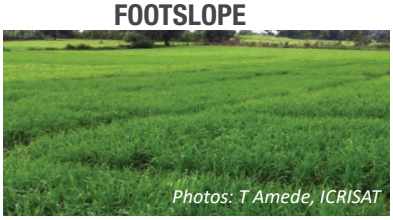
DECISION GUIDE for fertilizer application

If your farm is...

Fertile, flat, soil is deep, clay or loam, crops remain green during dry spells	Not fertile, undulated, shallow soils, sandy or gravelly, crops dry fast during dry spells

Landscape position is...

FOOTSLOPE



MIDSLOPE

HILLSLOPE

Fertilizer requirement is...

Urea	125 kg/ha	75 kg/ha	75 kg/ha
NPS	180 kg/ha	60 kg/ha	60 kg/ha
KCl	65 kg/ha	65 kg/ha	35 kg/ha
Response to fertilizer...	High - Medium	Medium - Low	Low - Very low
Expected yield is...	6.5 - 4.0 t/ha	4.0 - 2.5 t/ha	2.5 - 1.5 t/ha

■ Well managed* ■ Poorly managed

For poorly managed hillslopes with <1.5 t/ha yield: No mineral fertilizer, apply organic amendments only.

* Use of agronomic packages – appropriate variety, timely planting, weed management and water saving practices.

Major crops

- Barley • Wheat • Field pea • Faba bean • Potato • Teff
- Chickpea • Ensete (Ethiopian banana) • Haricot bean • Fenugreek
- Multipurpose legumes for grain (in good season), fertility management and livestock feed

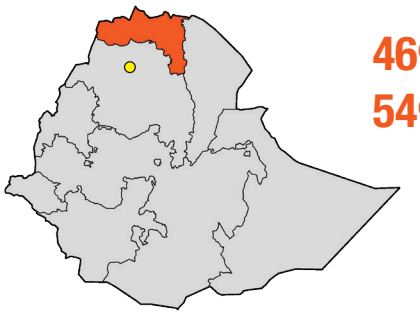
Major livestock

- Sheep • Goats • Cattle
- Poultry • Horses • Bees

Case study 2

Endamohoni District
Site-specific Nutrient Recommendation
for Wheat-based Farming

Location



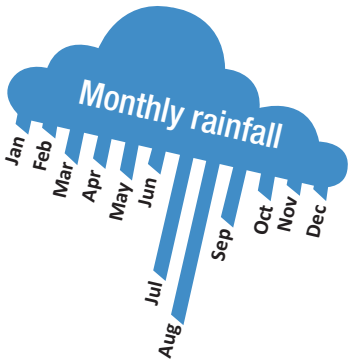
Tigray, Northern Ethiopia

Major agroecologies

46% Tepid sub-moist mid highlands

54% Cool sub-moist mid highlands

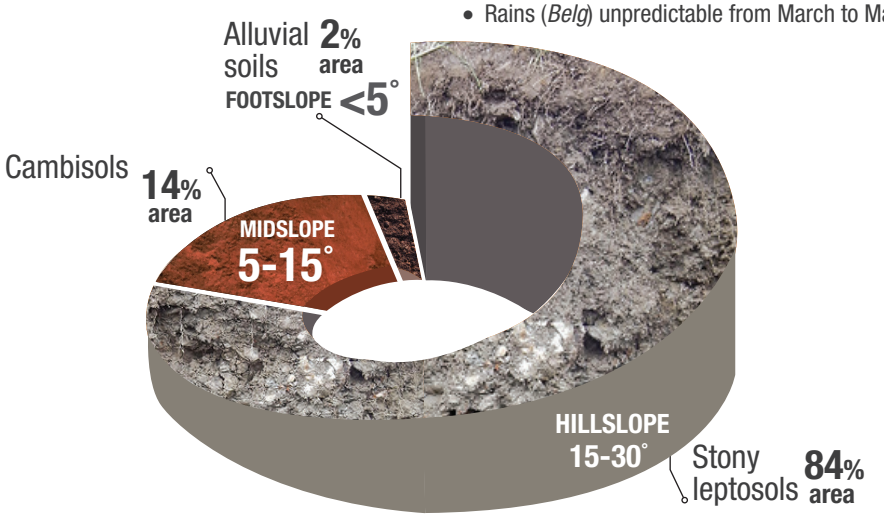
Weather



- Recurrent drought and extreme events.
- Main growing season (*Meher*)- July to Sep
- Rains (*Belg*) unpredictable from March to May

Topography and soils

- Mountainous landscapes
- Altitudinal range: 1690-3890 masl
- Soil fertility is dependent on
  - Erosion deposition
  - Presence of conservation structures



DECISION GUIDE for fertilizer application

If your farm is...

Fertile, flat, soil is deep, clay or loam, crops remain green during dry spells	Not fertile, undulated, shallow soils, sandy or gravelly, crops dry fast during dry spells

Landscape position is...

FOOTSLOPE	MIDSLOPE	HILLSLOPE
		

Photos: T Amede, ICRISAT

Fertilizer requirement is...

Urea	250 kg/ha	150 kg/ha	75 kg/ha
NPS	180 kg/ha	120 kg/ha	60 kg/ha
KCl	65 kg/ha	35 kg/ha	–
Response to fertilizer...	High - Medium	Medium - Low	Low - Very low
Expected yield is...	8.0 - 4.5 t/ha	4.5 - 2.5 t/ha	2.5 - 1.5 t/ha

Well managed* Poorly managed

For poorly managed hillslopes with <1.5 t/ha yield: No mineral fertilizer, apply organic amendments only.

* Use of agronomic packages – appropriate variety, timely planting, weed management and water saving practices.

Major crops

- Barley
- Wheat
- Field pea
- Faba bean
- Potato
- Neug (an oilseed crop)
- Grass pea
- Lentil

Major livestock

- Sheep
- Goats
- Cattle
- Poultry
- Horses
- Bees

Key findings

Why location-specific targeted fertilizer recommendation is needed:

- **Gaps in present system:** Existing fertilizer recommendations do not take into account farming systems, landscape positions and cropping systems.
- **Diverse altitude and agroecology:** Mountain peaks and valley bottoms can be found within very short proximity.
- **Landscape positions dictate fertilizer needs:** Distinct features in terms of slope, water-holding capacity and inherent soil fertility dictate the amount and type of fertlizer to be used.
- **Human factors:** Farms around homesteads and valley bottoms are favored for application of fertilizer, organic manure and crop residue due to proximity and limited risk of crop failure.
- **Differing soil fertility gradients:** This was created over time by the combination of natural and human factors. It requires appropriate and site-specific management practices.

Photos: T Amede, ICRISAT

Water management interventions

Exponential yield benefits from application of mineral fertilizers was noticed when accompanied by enhanced water management interventions at farm and landscape scales.

Soil and water conservation as well as use of organic amendments would be important to improve soil health and thereby increase the yield response to applied nutrients.

Application of fertilizers and soil ammendments

Nitrogen, Phosphorus and Potassium

- Showed dominant yield response
- Highest benefit is obtained in the footslopes

Sulfur and Zinc:

- Crop yield response was limited, with yield advantage <5%
- Improvement in grain quality

Lime

- Majority of the soils are moderately to strongly acidic. Application of lime is advised to further increase yield response to applied nutrients.

Organic amendments

Hillslopes experience heavy erosion. Improving the soil quality through soil and water conservation structures and planting **legumes as a precursor crop** could sustainably improve the soil health/productivity. Our experimentation demonstrated that seasonal rains here are sufficient enough to get a good deal of biomass from legumes such as lablab, lupin and vetch (using root and above ground biomass) for better yield of succeeding crops.

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The Local Partners include:

- Academic institutions: Wachemo, Mekelle, Madawolabu, Debre Berhan and Hawassa universities; Maichew Agricultural College
- Regional research institutions: Amhara Regional Agricultural Research Institute, Southern Agricultural Research Institute, Tigray Agricultural Research Institute, Oromia Agricultural Research Institute
- Federal research institutions: Ethiopian Institute for Agricultural Research
- Bureau of Agriculture: Endamekoni (Tigray), Basona Worena (Amhara), Lemo (SNNPR), Worreilu (Amhara) and Sinana (Oromia)

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