Maize under integrated manure and mineral N application (left) versus sole mineral N application in Embu (Jan 2022) (Moritz Laub)

Integrated soil fertility management (ISFM) (Kenya)

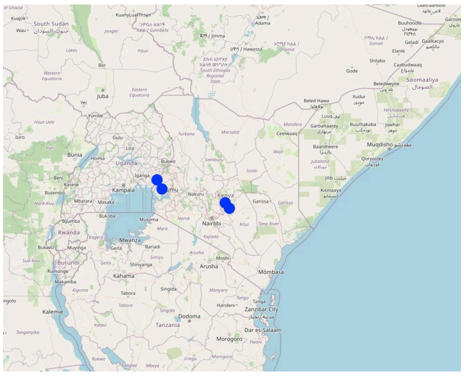
Machanganyiko ya mbolea ya ngombe na fertilizer

DESCRIPTION

Integrated soil fertility management constitutes a group of management practices aimed at increasing soil fertility and crop productivity with the local context in mind. These practices integrate the use of organic inputs, fertilizers, and better quality seeds with all inputs managed following good farming practices.

Integrated Soil Fertility Management (ISFM) is applied in arable cropping systems. In this example it was rigorously tested in maize cropping systems in Kenya. The main features of ISFM are the integration of organic inputs to increase or maintain soil fertility and provide a background of nutrient release, with mineral fertilizers to meet peak plant demand together with high quality seeds that can utilize the inputs well. The main objectives are to increase crop yield while maintaining or improving soil fertility. This is important because four long-term trials in Kenya have shown that long-term maize yields decline in both low-input systems and systems with high mineral N inputs but without organic inputs. In contrast, systems with farmyard manure application maintained yields over two decades and maintained significantly higher soil fertility. It has also been shown that the input of organic resources with a low C:N ratio, such as farmyard manure, is more effective in maintaining yields and soil fertility than mineral fertilizer inputs. Thus, the main inputs are organic resources with a low C:N ratio (ideally farmyard manure, but green manures such as Tithonia sp. or Calliandra sp. can also be used), while mineral fertilizers and high quality seeds are also needed. A major activity is the incorporation of organic resources before planting, which requires additional labour. ISFM offers significantly higher yields, and yield maintenance over time, while maintaining or increasing soil fertility. However, it is important to note that the advantage of ISFM over mineral fertilizer use becomes apparent only in the long term (e.g., after 5 to 10 years of continuous cropping). This is because mineral fertilizer inputs may initially mask the loss of soil fertility. This long-term perspective has to be kept in mind when considering the main perceived disadvantage of ISFM - that is the need for manure input and labour for its incorporation, which does not immediately result in higher yields compared to mineral fertilizer application alone.

LOCATION



Location: Embu city; Mavuria; close to Siaya; close to Busia, Embu County; Siaya County; Busia County, Kenya

No. of Technology sites analysed: 2-10 sites

Geo-reference of selected sites
- 37.45897, -0.51723
- 37.66346, -0.79304
- 34.19082, 0.57461
- 34.42122, 0.14272

Spread of the Technology: applied at specific points/ concentrated on a small area

In a permanently protected area?: No

Date of implementation: 2002

Type of introduction
- [ ] through land users' innovation
- [ ] as part of a traditional system (> 50 years)
- [x] during experiments/ research
- [ ] through projects/ external interventions

ISFM treatment with farmyard manure inputs of 4t carbon input per ha and year in combination with inputs of 120 mineral N per ha and season (as Ca NH4 NO3). The 4 t carbon correspond roughly to 17 t per ha of dry matter and 40 t of fresh matter. (Moritz Laub)

Treatment that received only mineral N input but no organic resources (Moritz Laub)

CLASSIFICATION OF THE TECHNOLOGY

Main purpose

- [x] improve production
- [x] reduce, prevent, restore land degradation
- [ ] conserve ecosystem
- [ ] protect a watershed/ downstream areas – in combination with other Technologies
- [ ] preserve/ improve biodiversity
- [ ] reduce risk of disasters
- [x] adapt to climate change/ extremes and its impacts
- [ ] mitigate climate change and its impacts
- [x] create beneficial economic impact
- [ ] create beneficial social impact

Land use

Land use mixed within the same land unit: No

Cropland

- Annual cropping: cereals - maize, cereals - millet, cereals - sorghum. Cropping system: Continuous maize/sorghum/millet

Number of growing seasons per year: 2
Is intercropping practiced? No
Is crop rotation practiced? No

Other - Specify: Mixed crop-livestock farms
Remarks: Manure can come from animals that are grazed or from animals kept in a zero-grazing system.

Water supply

- [x] rainfed
- [ ] mixed rainfed-irrigated
- [ ] full irrigation

Purpose related to land degradation

- [x] prevent land degradation
- [x] reduce land degradation
- [ ] restore/ rehabilitate severely degraded land
- [ ] adapt to land degradation
- [ ] not applicable

Degradation addressed

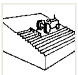
chemical soil deterioration - Cn: fertility decline and reduced organic matter content (not caused by erosion)

biological degradation - Bl: loss of soil life

SLM group

- integrated crop-livestock management
- integrated soil fertility management
- improved plant varieties/ animal breeds

SLM measures

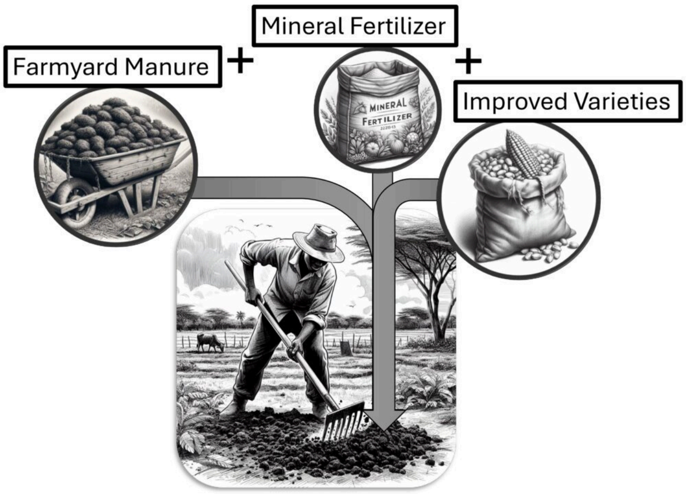


agronomic measures - A2: Organic matter/ soil fertility, A5: Seed management, improved varieties, A6: Residue management (A 6.2: grazed)

TECHNICAL DRAWING

Technical specifications

Organic resources are distributed equally across the field and then incorporated (usually by hand hoe). Full ISFM integrates this with improved maize varieties and small doses of mineral fertilizer.



Author: Moritz Laub

ESTABLISHMENT AND MAINTENANCE: ACTIVITIES, INPUTS AND COSTS

Calculation of inputs and costs

- Costs are calculated: per Technology area (size and area unit: **hectare**)
- Currency used for cost calculation: **KSH**
- Exchange rate (to USD): 1 USD = 135.0 KSH
- Average wage cost of hired labour per day: 500

Most important factors affecting the costs

Local labor prices. Local availability of livestock. Local fertilizer and seed prices.

Establishment activities

1. Training on (green/farmyard) manure handling and incorporation (Timing/ frequency: any)

Establishment inputs and costs (per hectare)

Specify input	Unit	Quantity	Costs per Unit (KSH)	Total costs per input (KSH)	% of costs borne by land users
Other					
Training on ISFM and organic resource management					

Maintenance activities

1. Organic resource preparation (e.g. chopping of green manure, farmyard manure management) (Timing/ frequency: Before planting)
2. Organic resource application and incorporation to about 15 cm soil depth (Timing/ frequency: Before planting)
3. Application of mineral fertilizer (Timing/ frequency: During peak demand)

Maintenance inputs and costs (per hectare)

Specify input	Unit	Quantity	Costs per Unit (KSH)	Total costs per input (KSH)	% of costs borne by land users
Labour					
Manual labor for manure incorporation	labor days per ha	10.0	500.0	5000.0	
Plant material					
Hybrid maize seeds	kg per ha	25.0	450.0	11250.0	
Fertilizers and biocides					
Manure (green/farmyard) per ha and season	t dry matter	2.0	5500.0	11000.0	
Mineral N (estimate ideal input)	kg per ha and season	30.0	300.0	9000.0	
Total costs for maintenance of the Technology				**36'250.0**	
Total costs for maintenance of the Technology in USD				*268.52*	

NATURAL ENVIRONMENT

Average annual rainfall

- ☐ < 250 mm
- ☐ 251-500 mm
- ☐ 501-750 mm
- ☐ 751-1,000 mm
- ☑ 1,001-1,500 mm
- ☑ 1,501-2,000 mm
- ☐ 2,001-3,000 mm
- ☐ 3,001-4,000 mm
- ☐ > 4,000 mm

Agro-climatic zone

- ☑ humid
- ☐ sub-humid
- ☐ semi-arid
- ☐ arid

Specifications on climate

ISFM can likely be used wherever it is feasible to grow maize. It proved most effective in high-rainfall areas > 1200 mm (for maize), because in areas where rainfall was limiting (e.g., Machanga site), the plants were mainly water limited and could not make good use of the additional soil fertility.

Slope

- ☑ flat (0-2%)
- ☐ gentle (3-5%)
- ☐ moderate (6-10%)

Landforms

- ☑ plateau/plains
- ☐ ridges
- ☐ mountain slopes

Altitude

- ☐ 0-100 m a.s.l.
- ☐ 101-500 m a.s.l.
- ☐ 501-1,000 m a.s.l.

Technology is applied in

- ☐ convex situations
- ☐ concave situations
- ☑ not relevant

- [ ] rolling (11-15%)
- [ ] hilly (16-30%)
- [ ] steep (31-60%)
- [ ] very steep (>60%)

- [ ] hill slopes
- [ ] footslopes
- [ ] valley floors

- [x] 1,001-1,500 m a.s.l.
- [x] 1,501-2,000 m a.s.l.
- [ ] 2,001-2,500 m a.s.l.
- [ ] 2,501-3,000 m a.s.l.
- [ ] 3,001-4,000 m a.s.l.
- [ ] > 4,000 m a.s.l.

Soil depth
- [ ] very shallow (0-20 cm)
- [ ] shallow (21-50 cm)
- [ ] moderately deep (51-80 cm)
- [x] deep (81-120 cm)
- [ ] very deep (> 120 cm)

Soil texture (topsoil)
- [ ] coarse/ light (sandy)
- [x] medium (loamy, silty)
- [x] fine/ heavy (clay)

Soil texture (> 20 cm below surface)
- [ ] coarse/ light (sandy)
- [x] medium (loamy, silty)
- [x] fine/ heavy (clay)

Topsoil organic matter content
- [ ] high (>3%)
- [x] medium (1-3%)
- [x] low (<1%)

Groundwater table
- [ ] on surface
- [ ] < 5 m
- [ ] 5-50 m
- [ ] > 50 m

Availability of surface water
- [ ] excess
- [ ] good
- [x] medium
- [ ] poor/ none

Water quality (untreated)
- [ ] good drinking water
- [ ] poor drinking water (treatment required)
- [x] for agricultural use only (irrigation)
- [ ] unusable

Water quality refers to: surface water

Is salinity a problem?
- [ ] Yes
- [x] No

Occurrence of flooding
- [ ] Yes
- [x] No

Species diversity
- [ ] high
- [x] medium
- [ ] low

Habitat diversity
- [ ] high
- [x] medium
- [ ] low

CHARACTERISTICS OF LAND USERS APPLYING THE TECHNOLOGY

Market orientation
- [ ] subsistence (self-supply)
- [x] mixed (subsistence/ commercial)
- [ ] commercial/ market

Off-farm income
- [x] less than 10% of all income
- [ ] 10-50% of all income
- [ ] > 50% of all income

Relative level of wealth
- [ ] very poor
- [x] poor
- [x] average
- [ ] rich
- [ ] very rich

Level of mechanization
- [x] manual work
- [x] animal traction
- [ ] mechanized/ motorized

Sedentary or nomadic
- [x] Sedentary
- [ ] Semi-nomadic
- [ ] Nomadic

Individuals or groups
- [x] individual/ household
- [ ] groups/ community
- [ ] cooperative
- [ ] employee (company, government)

Gender
- [ ] women
- [ ] men

Age
- [ ] children
- [ ] youth
- [x] middle-aged
- [ ] elderly

Area used per household
- [ ] < 0.5 ha
- [x] 0.5-1 ha
- [x] 1-2 ha
- [ ] 2-5 ha
- [ ] 5-15 ha
- [ ] 15-50 ha
- [ ] 50-100 ha
- [ ] 100-500 ha
- [ ] 500-1,000 ha
- [ ] 1,000-10,000 ha
- [ ] > 10,000 ha

Scale
- [ ] small-scale
- [x] medium-scale
- [ ] large-scale

Land ownership
- [ ] state
- [ ] company
- [ ] communal/ village
- [ ] group
- [x] individual, not titled
- [x] individual, titled

Land use rights
- [ ] open access (unorganized)
- [ ] communal (organized)
- [ ] leased
- [x] individual

Water use rights
- [ ] open access (unorganized)
- [ ] communal (organized)
- [ ] leased
- [ ] individual

Access to services and infrastructure

health	poor		✓		good
education	poor		✓		good
technical assistance	poor		✓		good
employment (e.g. off-farm)	poor		✓		good
markets	poor		✓		good
energy	poor		✓		good
roads and transport	poor		✓		good
drinking water and sanitation	poor	✓			good
financial services	poor		✓		good

IMPACTS

Socio-economic impacts

Crop production	decreased							✓	increased
expenses on agricultural inputs	increased			✓					decreased
farm income	decreased						✓		increased

Crop production: Quantity before SLM: 1-2 t maize grain yield per ha and season
Quantity after SLM: 3-4 t maize grain yield per ha and season
The presented yield values are measured data from long-term experiments. They represent the average across all sites.
See
https://www.sciencedirect.com/science/article/pii/S037842902200
for details

workload — increased ✓ decreased (rating: 3rd of 7 toward increased)

Socio-cultural impacts

Ecological impacts

nutrient cycling/ recharge — decreased / increased (rating: 6 of 7)

soil organic matter/ below ground C — decreased / increased (rating: 6 of 7)

Quantity before SLM: Annual decline of about 2% of initial SOM
Quantity after SLM: Annual decline reduced to about 0.5% of initial SOM
The presented soil organic carbon values are measured data from long-term experiments. They represent the average across all sites.The general loosing trajectory was a function of the sites being relatively newly established. In sites with low SOM, an increase is possible. Details in https://soil.copernicus.org/articles/9/301/2023/

acidity — increased / reduced (rating: 5 of 7)

Quantity before SLM: pH around 5
Quantity after SLM: pH around 6
The presented soil pH values are measured data from long-term experiments. They represent the average across all sites.Comparison between the control and farmyard manure treatments. Details in https://soil.copernicus.org/articles/9/301/2023/

Off-site impacts

impact of greenhouse gases — increased / reduced (rating: 6 of 7)

Quantity before SLM: about 2.5 kg CO2-eq emissions per kg of maize grain yield
Quantity after SLM: about 1.5 kg CO2-eq emissions per kg of maize grain yield
Note that GHG values are expressed in terms of emissions per yield.

COST-BENEFIT ANALYSIS

Benefits compared with establishment costs

Short-term returns — very negative / very positive (rating: 2 of 7)
Long-term returns — very negative / very positive (rating: 6 of 7)

Benefits compared with maintenance costs

Short-term returns — very negative / very positive (rating: 3 of 7)
Long-term returns — very negative / very positive (rating: 5 of 7)

CLIMATE CHANGE

Gradual climate change

annual temperature increase — not well at all / very well (rating: 3 of 5)

Climate-related extremes (disasters)

local rainstorm — not well at all / very well (rating: 3 of 5)
drought — not well at all / very well (rating: 2 of 5)

ADOPTION AND ADAPTATION

Percentage of land users in the area who have adopted the Technology

- [ ] single cases/ experimental
- [ ] 1-10%
- [x] 11-50%
- [ ] > 50%

Of all those who have adopted the Technology, how many have done so without receiving material incentives?

- [ ] 0-10%
- [ ] 11-50%
- [x] 51-90%
- [ ] 91-100%

Number of households and/ or area covered

Estimated to be around 20-25% both in Western and central Kenya. Currently increased uptake, mainly due to surges in mineral fertilizer prices.

Has the Technology been modified recently to adapt to changing conditions?

- [x] Yes
- [ ] No

The trials have been redesigned for intercropping with the MBILI system - results are expected in 2027/8. (Details on MBILI: https://www.sciencedirect.com/science/article/pii/S0378429009002809)

To which changing conditions?

- [x] climatic change/ extremes
- [ ] changing markets
- [ ] labour availability (e.g. due to migration)

CONCLUSIONS AND LESSONS LEARNT

Strengths: land user's view

- Maintenance of crop yields in integrated crop-livestock systems.

Strengths: compiler’s or other key resource person’s view

Weaknesses/ disadvantages/ risks: land user's viewhow to overcome

- Advantage compared to mineral fertilizer use not directly visible. Demonstration on the sites. Farmers training. Farmers trials.

- Maintaining soil fertility as the basis of crop production and sustained yields.

Weaknesses/ disadvantages/ risks: compiler's or other key resource person's viewhow to overcome

- Scarcity of organic inputs. Maintaining SOM requires very high input rates. Combining ISFM with improved inter-cropping systems. Research is currently ongoing.

REFERENCES

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Full description in the WOCAT database
https://qcat.wocat.net/en/wocat/technologies/view/technologies_7121/

Linked SLM data
n.a.

Documentation was faciliated by

Institution

- ETH-Zürich (ETH-Zürich) - Switzerland

Project

- Land Use Based Mitigation for Resilient Climate Pathways (LANDMARC)

Key references

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- Mucheru-Muna, M., Pypers, P., Mugendi, D., Kung'u, J., Mugwe, J., Merckx, R., Vanlauwe, B., 2010. A staggered maize–legume intercrop arrangement robustly increases crop yields and economic returns in the highlands of Central Kenya. Field Crops Research 115, 132–139.: https://doi.org/10.1016/j.fcr.2009.10.013

Links to relevant information which is available online

- Article on yield development in ISFM: https://doi.org/10.1016/j.fcr.2022.108788
- Article on soil organic matter development in ISFM: https://doi.org/10.5194/soil-9-301-2023