Climate-smart soil protection and rehabilitation in Kenya

December 2016, Kisumu, Kenya

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Outline

- **Introduction and objectives of the climate-smart soils (CSS) project**
- Climate-smartness evaluation
  - Farm Typology
  - Rapid Climate Smartness Assessment (Kalkulator)
  - Evaluation of Land Management Options (ELMO)
  - Attainable impact
- Biophysical assessment
- CSA prioritization framework
  - CSA identification and prioritization workshop
  - Economic assessment, CBA
  - Revised framework
- Recommendations

Objective of the Climate Smart Soils Project

- **Assessment of climate smartness of ongoing and potentially suitable alternative agricultural soil conservation practices, including:**
  - **analysis of farm-level cost-benefit and tradeoffs**
  - **evaluation of the overall CSA impact and scope**
  - **adoption and scaling potentials**
- **Design of a CSA prioritization process and implementation strategy in Western Kenya**

> **"Agriculture has to be part of the solution to climate change."**
>
> ***Patrick Verkooijen, The World Bank, 2012***

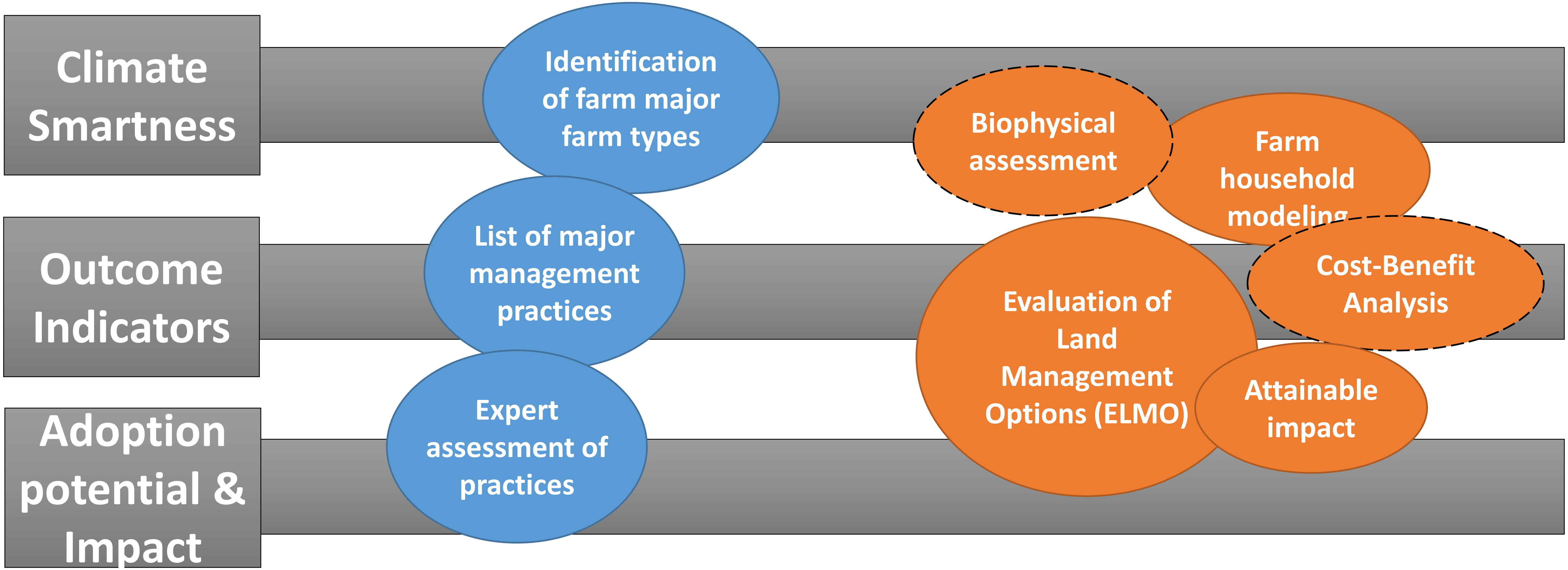
Climate smart agriculture

Triple-win goal – three pillars (FAO 2013):

1. Sustainably increasing agricultural productivity and incomes;
2. Adapting and building resilience to climate change;
3. Climate change mitigation: reducing greenhouse gases emissions, where possible.

"To ensure a food-secure future, farming must become climate resilient."

CIAT's approach to evaluate the climate smartness



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Rapid assessment - methodology

Stakeholder workshops → Farming system types → **Case study farmer interviews**

Stakeholder workshops ↓ Soil technology shortlist

Case study farmer interviews ↓ Input data

Modelling CSA indicators for baselines and scenarios

Farming system types

Factors: intensification, production orientation, commercialization, agro-ecological potential and resource endowment

Counties	Resource-poor female-headed	Small mixed subsistence	Medium dairy commercial	Medium horticulture commercial	Large commercial
Siaya	NA	70 %	5 %	20 %	5 %
Kakamega	NA	60 %	10 %	10 %	20 %
Bungoma	NA	50 %	5 %	10 %	35 %

Shortlisted/tested soil technologies

Stakeholders listed most relevant soil protection and rehabilitation technologies

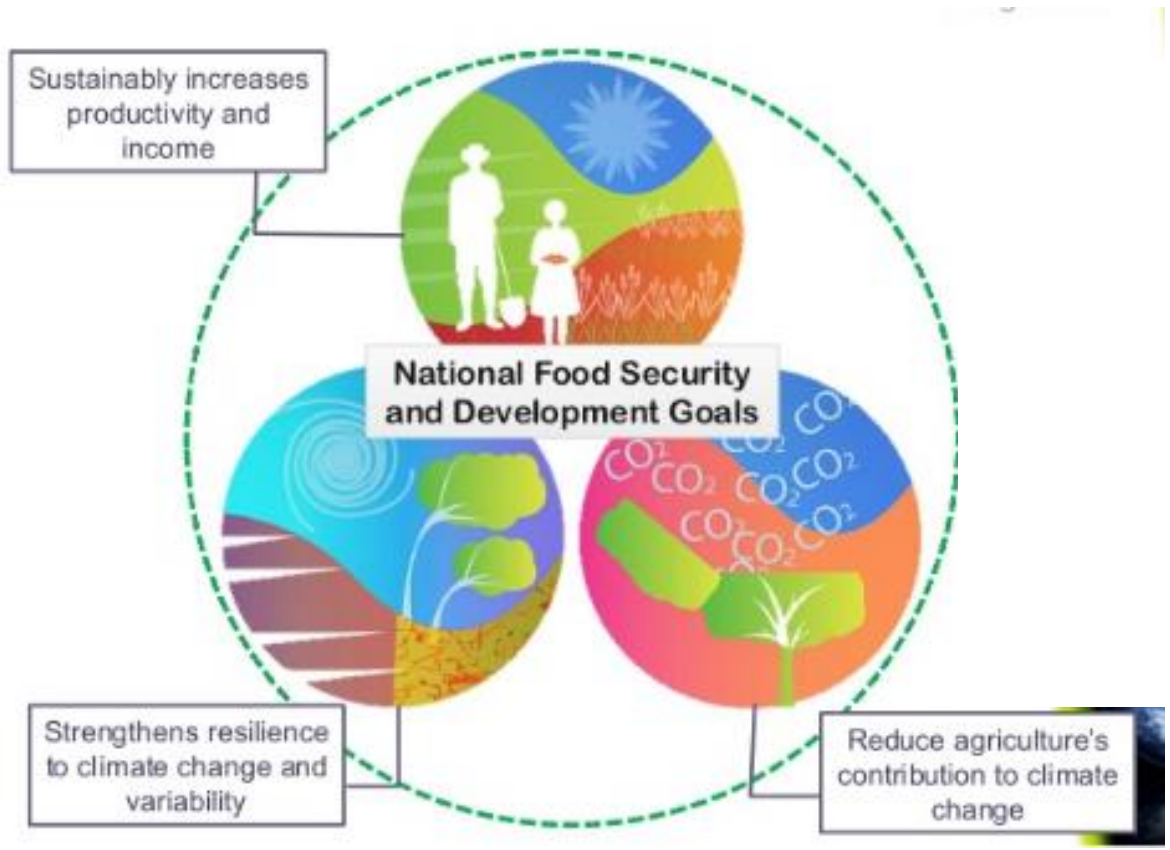
- Liming and DAP
- Compost only
- Lime and compost
- Conservation Agriculture
- Vegetative strips

Picture: Stephanie Malyon, CIAT

Modelling of CSA indicators and trade-offs

Calories produced on farm/hectare

- Cash crops and meat not taken into account
- ‘Potential supply’ only



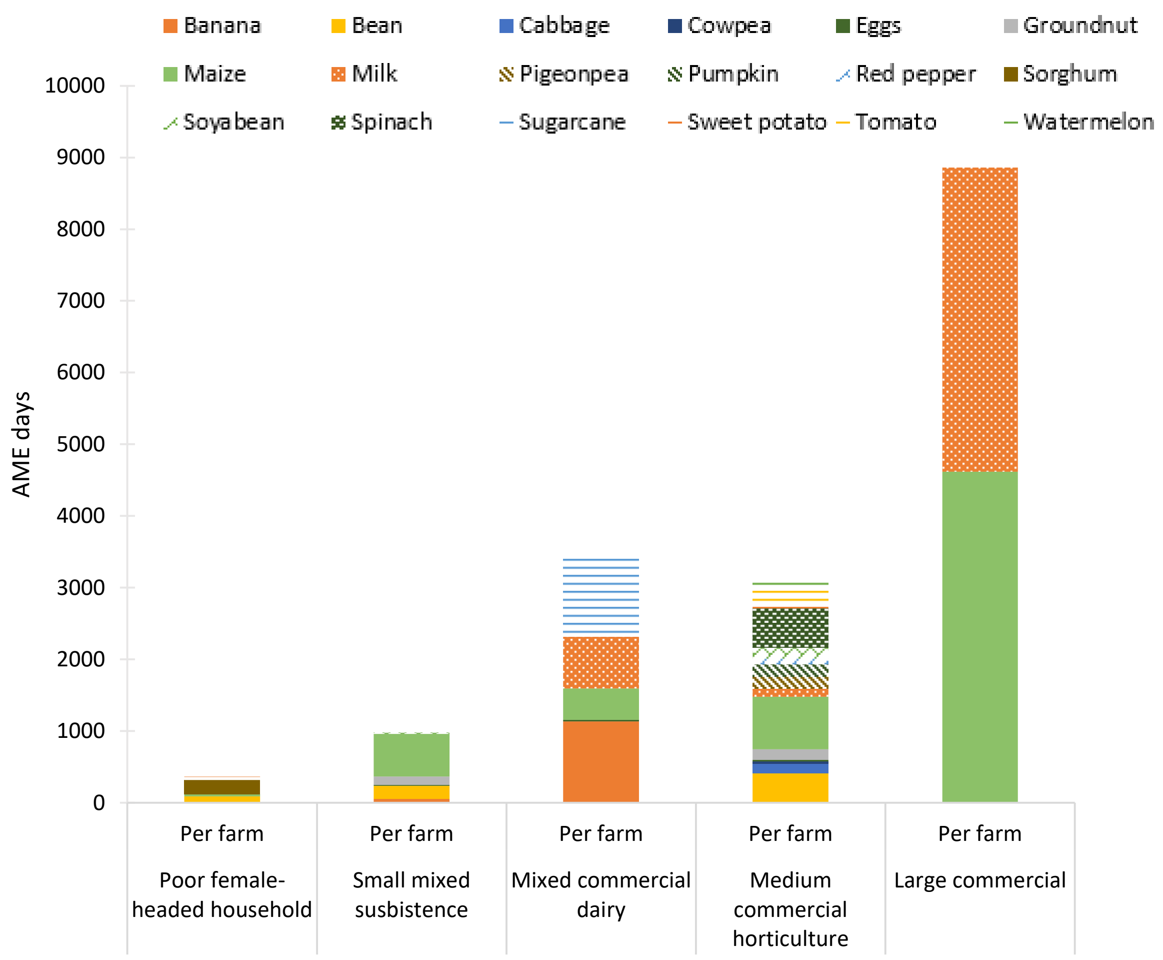
GHG emissions from agriculture per farm/hectare

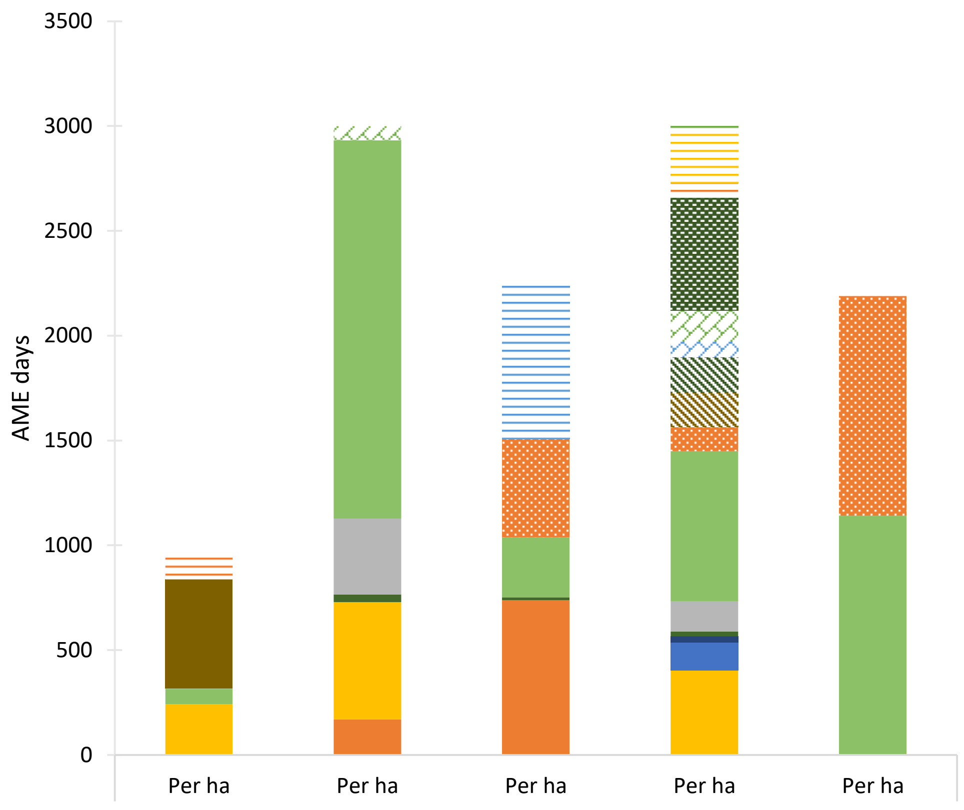
- Soil C stock changes not included
- IPCC tier 1/2 overestimating for SSA

Soil nitrogen balances farm/hectare

- Simplified, non-holistic indicators

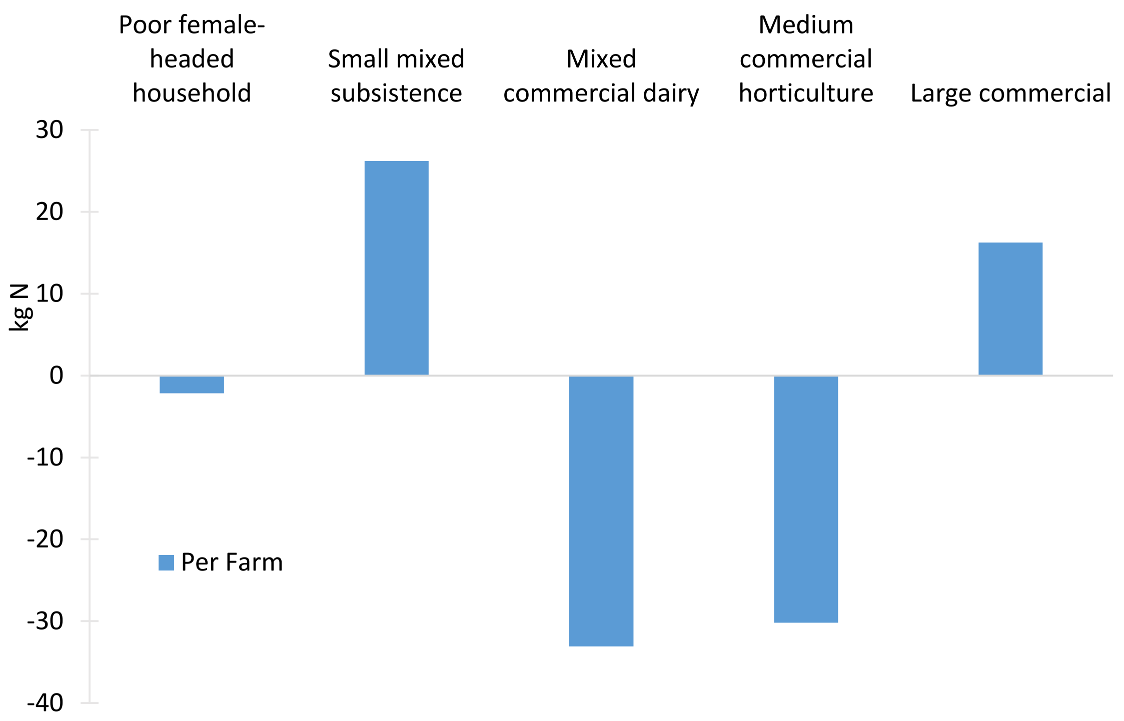
Calories produced on farm - baselines

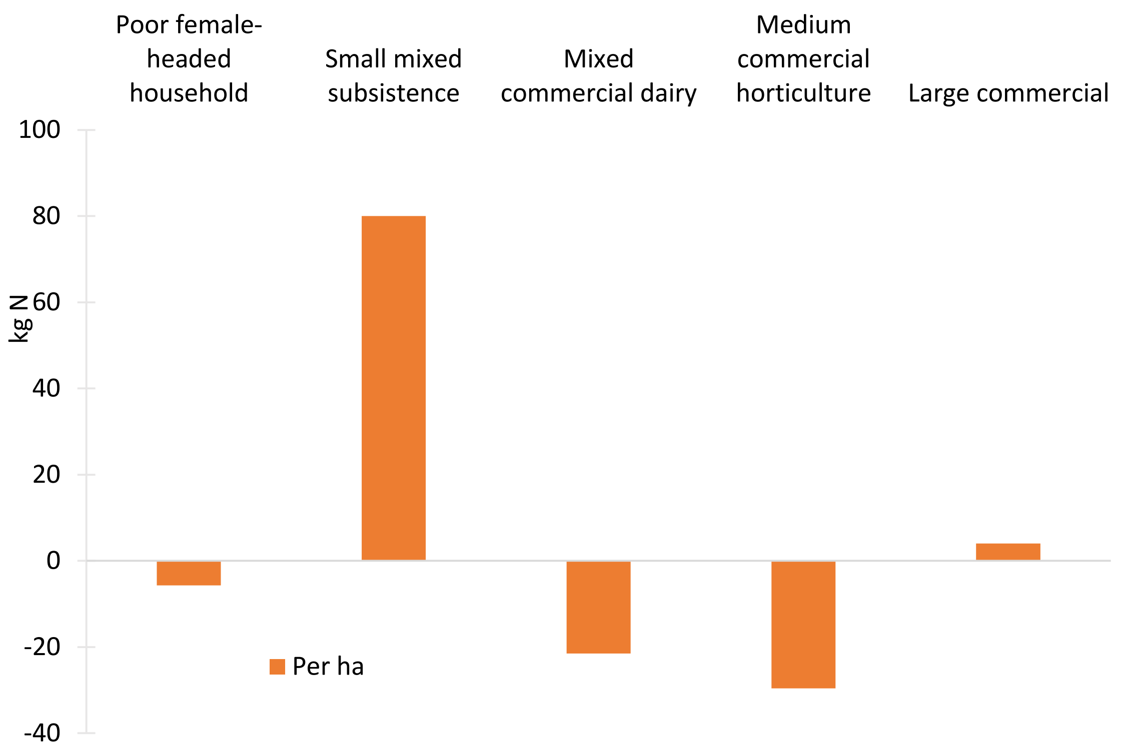




- Diversity of production
- Small mixed subsistence, low per farm, but high per ha
- Large commercial, high per farm from milk production, not highest per ha- coffee does contribute to calories

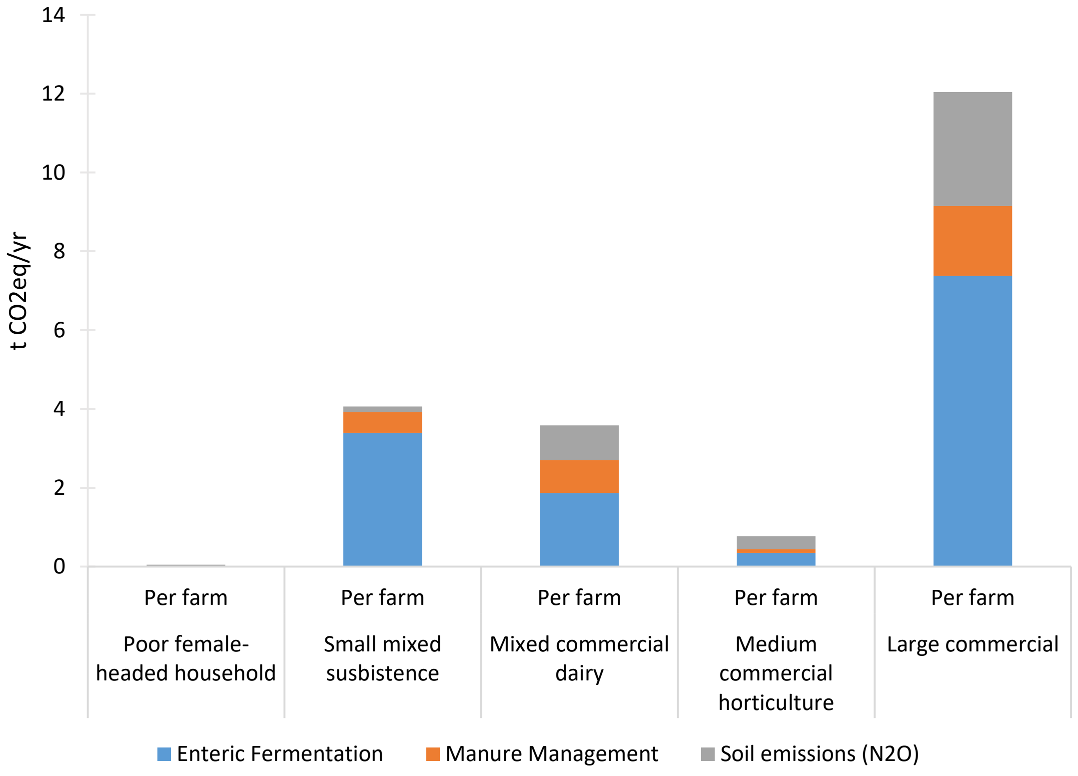
Nitrogen balance - baselines

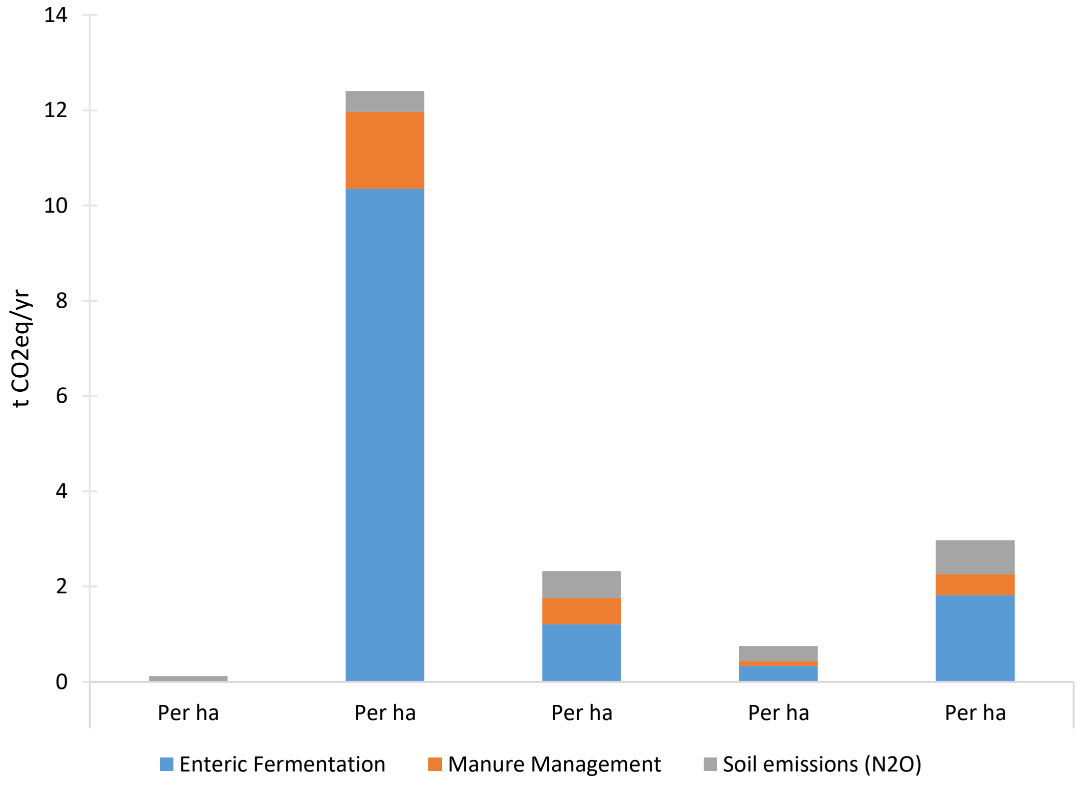




- Low inputs-low outputs
- Livestock density on the small mixed subsistence farm-> highest balance
- Negative on the medium commercial farms- not alarming; higher export of crop products (and milk).
- Positive on the large commercial farm because of use of inputs in larger quantities.

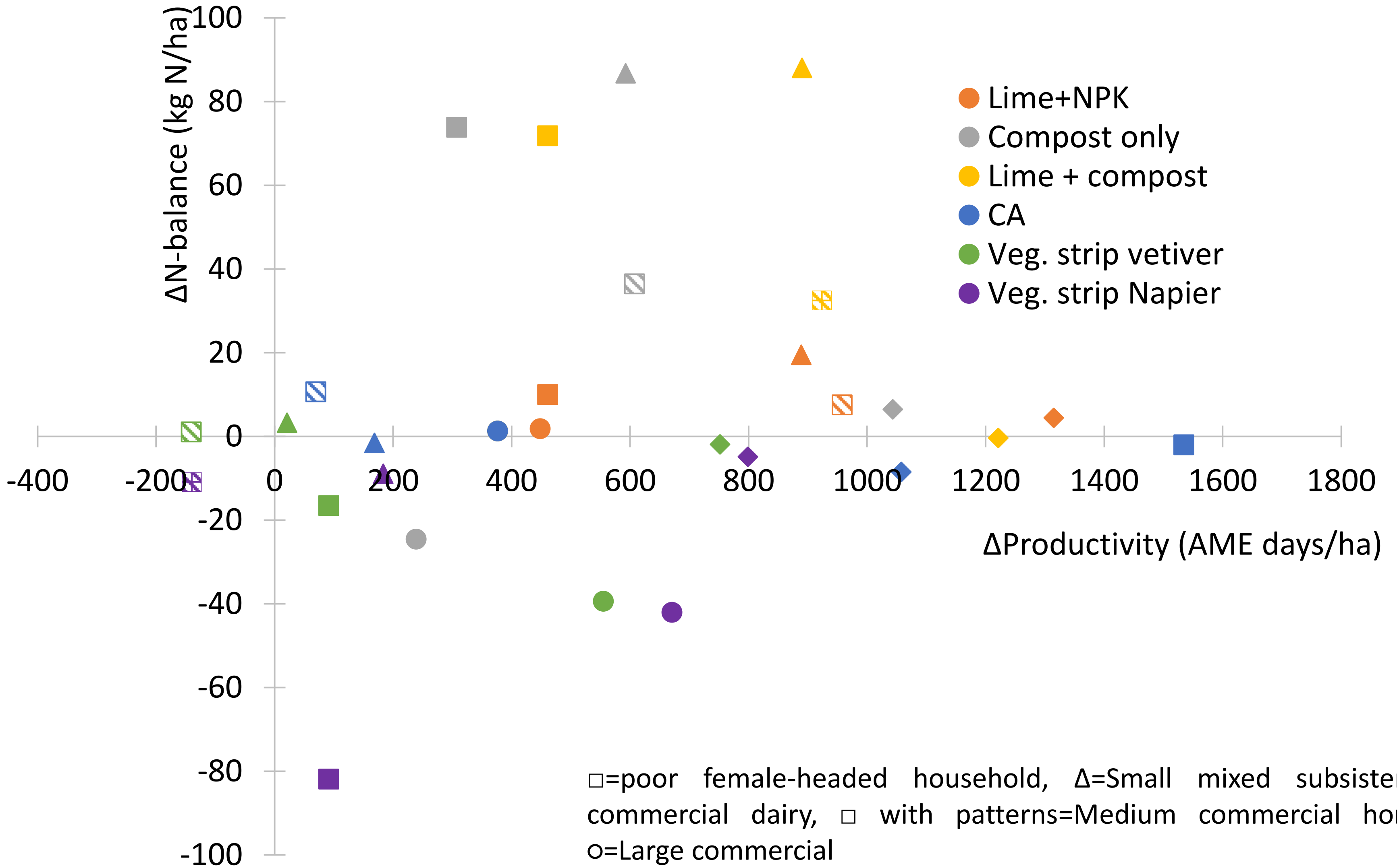
Greenhouse gas emissions - baselines





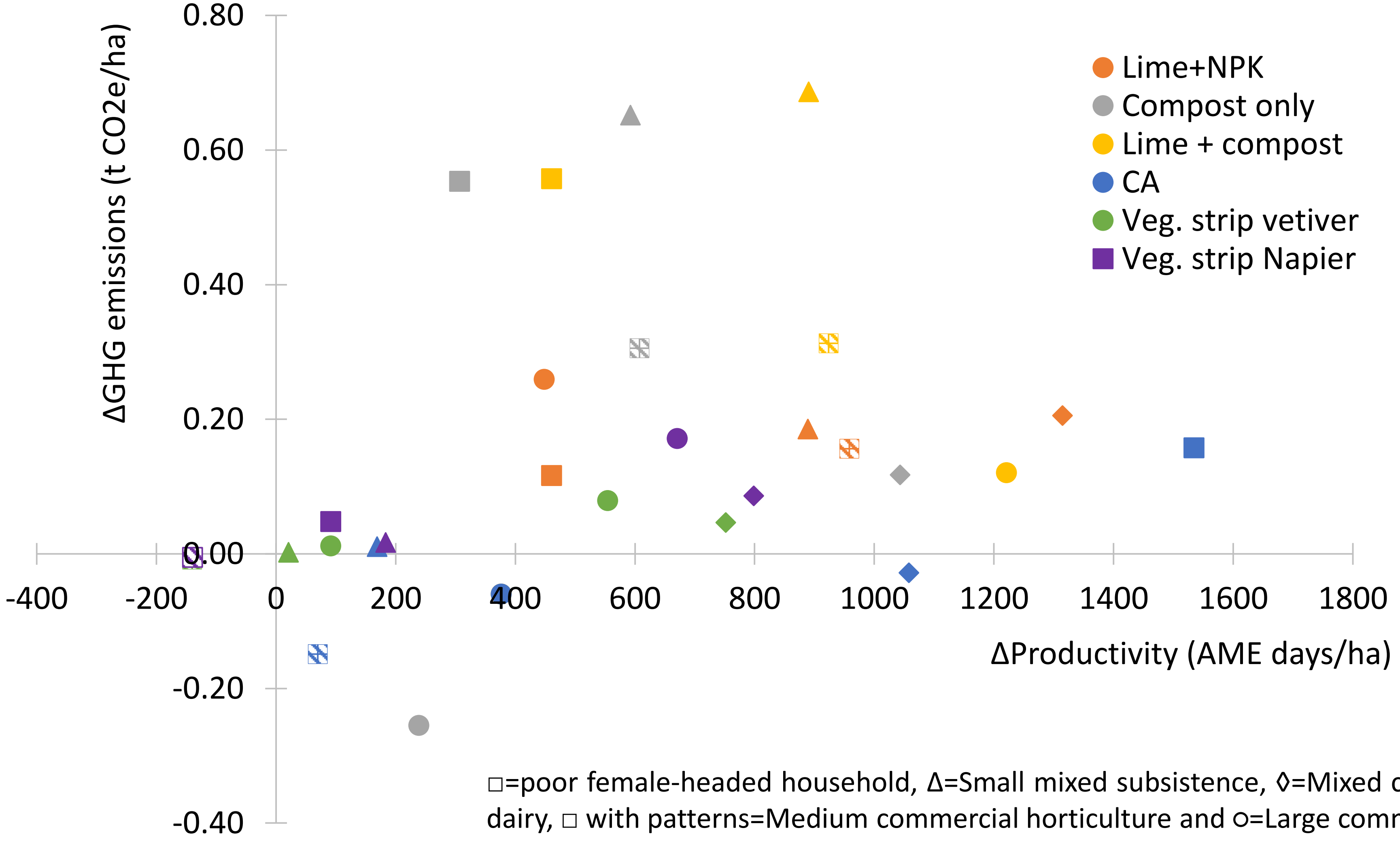
- low emissions
- livestock (ruminants) main source
- livestock density on the small mixed subsistence farm→ highest GHG intensity
- higher use of inputs on the large farm

Trade-offs: Productivity vs. N balance



□=poor female-headed household, Δ=Small mixed subsistence, ◊=Mixed commercial dairy, □ with patterns=Medium commercial horticulture and ○=Large commercial

Trade-offs: Productivity vs. GHG emissions



□=poor female-headed household, Δ=Small mixed subsistence, ◊=Mixed commercial dairy, □ with patterns=Medium commercial horticulture and ○=Large commercial

Evaluating Land Management Options (ELMO)

Participatory tool for assessing farmers' land management (LM) decisions, preferences & trade-offs

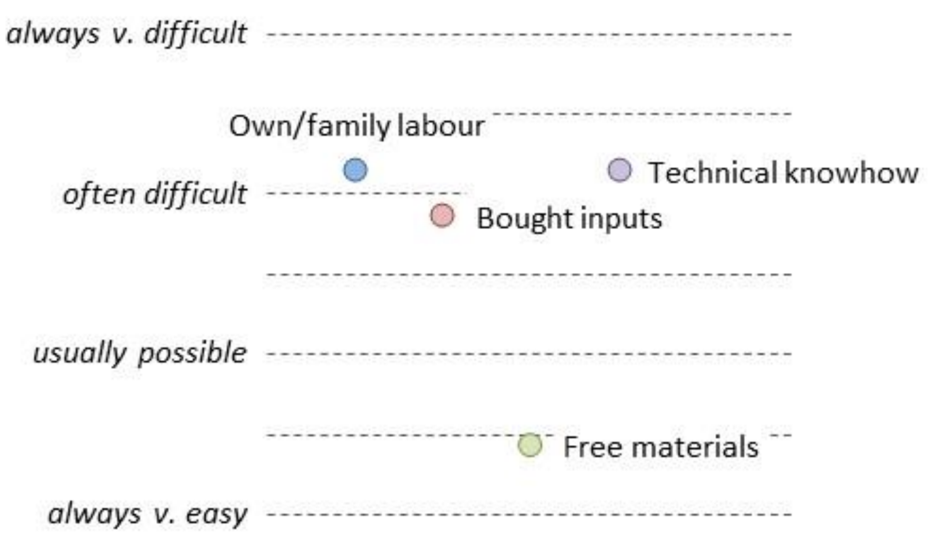
1. Identify techniques & attributes to be discussed
2. Record respondent characteristics
3. Define LM techniques & baseline
4. Rank & Score LM costs & input requirements
5. Rank & Score LM benefits & desired outcomes
6. Rank LM advantages & positive attributes
7. Rank LM disadvantages & negative attributes
8. Rank and weight LM alternatives overall

Individual discussions with farmers

Farmer's perceptions of cost & input requirements

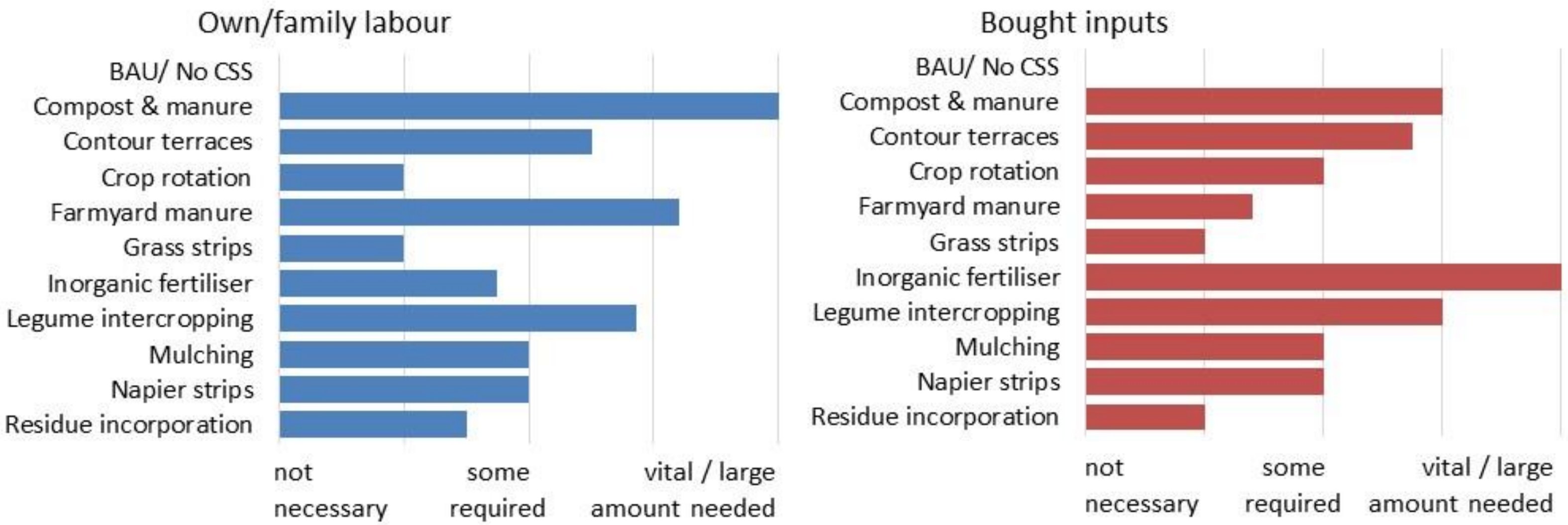
- Most farmers face difficulties in accessing labor, bought inputs and technical knowhow
- These requirements vary per practice and inform farmers' preferences

Relative difficulty in accessing or affording costs/inputs

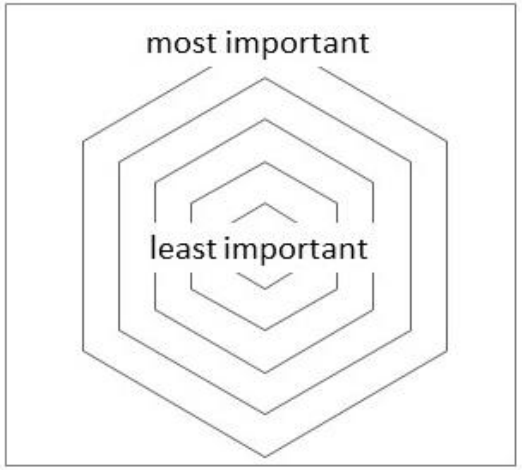


Shows average scoring by farmers

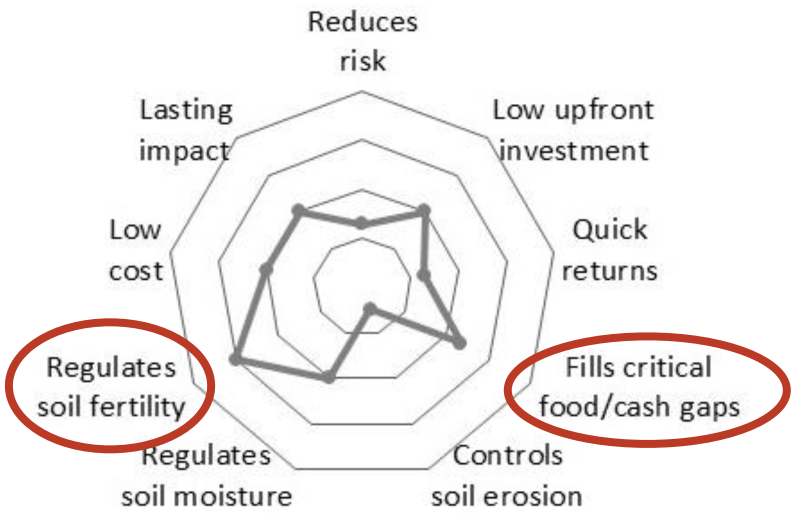
Land management cost/input requirements



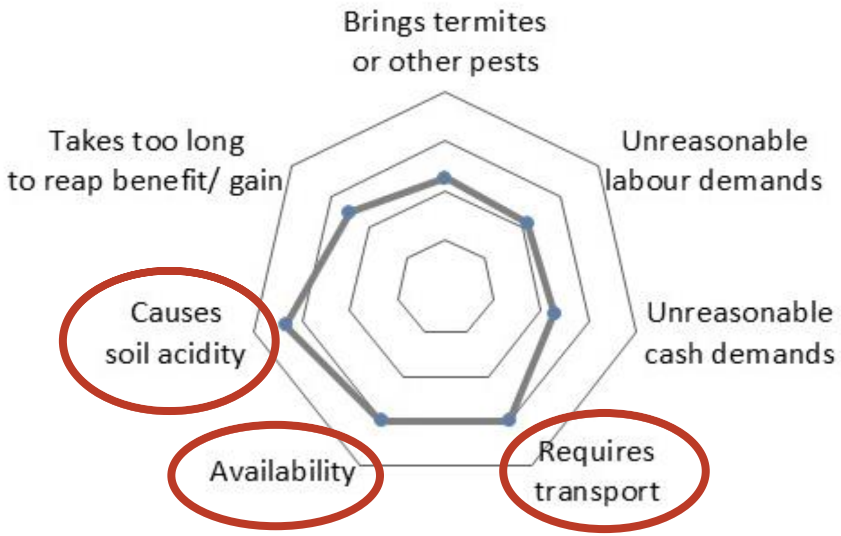
Relative importance of advantages & disadvantages of practices



Advantages



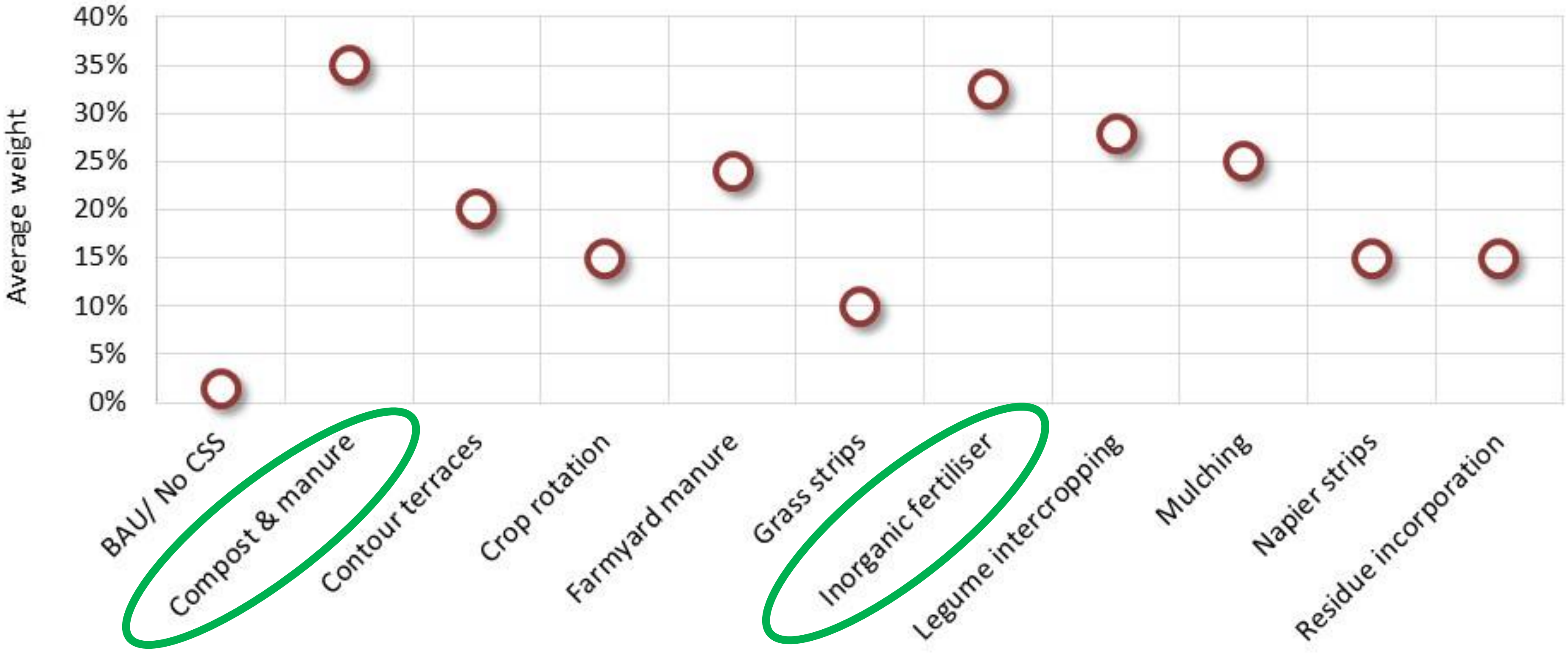
Disadvantages



Shows average scoring by farmers

- Farmers emphasize the **importance of soil fertility and food supply** effects in shaping the relative viability of practices
- Farmers prefer techniques which can assist in **evening out or overcoming food and cash shortages across the year.**

Overall preference of practices



Shows average weight attributed according to overall preference relative to other land management practices. Note that total exceeds 100%, because interviews cover different combinations of land management practices.

Calculating "attainable impact" across the five districts

1. Number of farm households of each farm type

   ~ rural population / HH-size * farm type %

	Poor female-headed	Small-scale subsistence	Medium-scale dairy	Medium-scale horticulture	Large-scale commercial
%	6	52	7	12	21
Number HHs	37,563	351,290	48,426	84,009	144,208

2. Adoption rates (% of the HHs likely to adopt the specific intervention) per farm type

3.

~ ELMO

20% or

Compost only	CA	Lime and compost	Lime and NPK	Napier strips	Vetiver strips
35	*15*	*30*	*27*	*15*	*10*
Compost and manure score	*Residue incorporation score (the lowest of the CA components)*	*Compost and manure score minus 5*	*Inorganic fertilizer score minus 5*	*Napier strips score*	*Grass strip score*

Calculating "attainable impact" across the five districts

3. Number of adopting farms x estimated impact per farm

	Compost only	Conservation Agriculture	Lime and compost	Lime and NPK	Napier strips	Vetiver strips
Large-scale commercial	0.32M	0.50M	0.50M	0.59M	0.88M	0.73M
Medium-scale dairy	0.67M	0.68M	0.78M	0.84M	0.51M	0.48M
Medium-scale horticulture	0.31M	0.04M	0.47M	0.49M	0.07M	0.07M
Poor female-headed	0.15M	0.75M	0.23M	0.23M	0.04M	0.04M
Small-scale subsistence	1.41M	0.40M	2.11M	2.11M	0.44M	0.05M

Importance of expected adoption rates

	Compost only	Conservation Agriculture	Lime and compost	Lime and NPK	Napier strips	Vetiver strips
Large-scale commercial	0.55M	0.37M	0.74M	0.80M	0.66M	0.37M
Medium-scale dairy	1.17M	0.51M	1.17M	1.14M	0.38M	0.24M
Medium-scale horticulture	0.55M	0.03M	0.71M	0.66M	0.05M	0.04M
Poor female-headed	0.26M	0.56M	0.34M	0.30M	0.03M	0.02M
Small-scale subsistence	2.46M	0.30M	3.17M	2.85M	0.33M	0.02M

Trade-offs with GHG emissions

AME days

	Compost only	Conservation Agriculture	Lime and compost	Lime and NPK	Napier strips	Vetiver strips
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Small-scale subsistence	2.46M	0.30M	3.17M	2.85M	0.33M	0.02M

GHG emissions

	Compost only	Conservation Agriculture	Lime and compost	Lime and NPK	Napier strips	Vetiver strips
Large-scale commercial	0.05M	0.00M	0.01M	0.04M	0.01M	0.00M
Medium-scale dairy	0.00M	0.00M	0.00M	0.00M	0.00M	0.00M
Medium-scale horticulture	0.01M	0.00M	0.01M	0.00M	0.00M	0.00M
Poor female-headed	0.00M	0.00M	0.00M	0.00M	0.00M	0.00M
Small-scale subsistence	0.02M	0.00M	0.02M	0.01M	0.00M	0.00M

Trade-offs with soil fertility

AME days

	Compost only	Conservation Agriculture	Lime and compost	Lime and NPK	Napier strips	Vetiver strips
Large-scale commercial	0.55M	0.37M	0.74M	0.80M	0.66M	0.37M
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N Balance

	Compost only	Conservation Agriculture	Lime and compost	Lime and NPK	Napier strips	Vetiver strips
Large-scale commercial	5.02M	0.11M	0.22M	0.29M	3.68M	2.33M
Medium-scale dairy	0.17M	0.10M	0.01M	0.09M	0.05M	0.02M
Medium-scale horticulture	0.39M	0.09M	0.18M	0.40M	0.09M	0.00M
Poor female-headed	0.37M	0.00M	0.31M	0.04M	0.18M	0.01M
Small-scale subsistence	3.50M	0.03M	3.04M	0.61M	0.15M	0.02M

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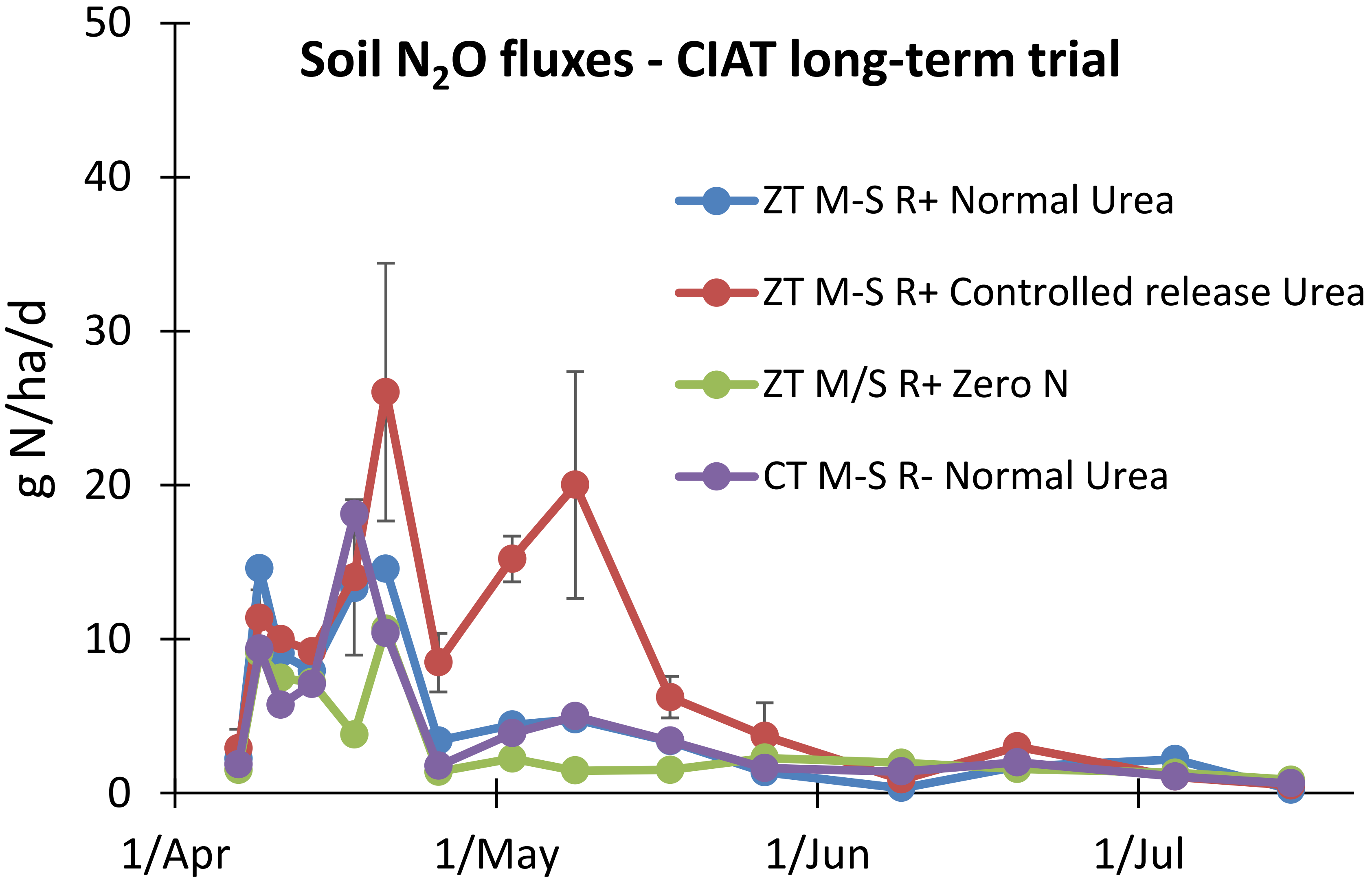
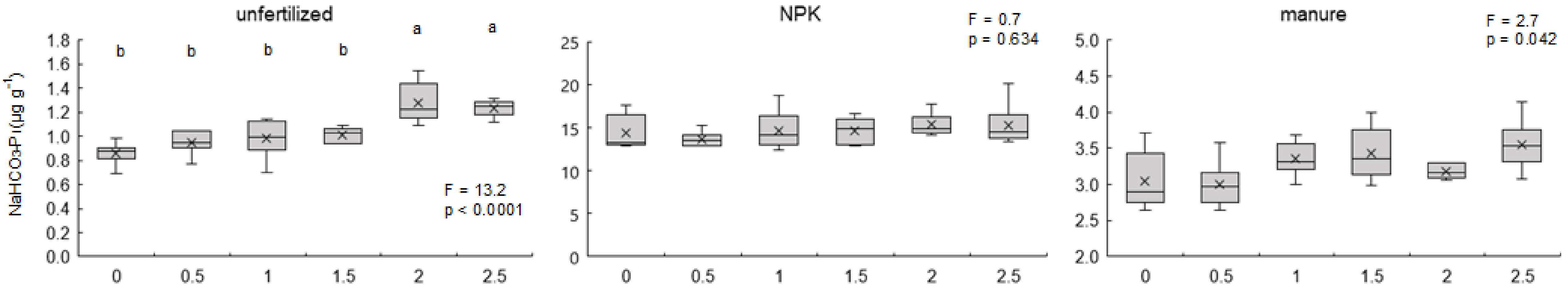
Biophysical monitoring and evaluation – N_2O fluxes

- Overall, nitrous oxide emissions were small
- Omitting tillage (ZT) or retaining residues did not have any impact on emissions.
- Retaining residues *and* applying manure increased emissions early in the season in April on farmer fields if not tilled (ZT).
- Use of controlled release urea fertilizer resulted in higher emissions in May.

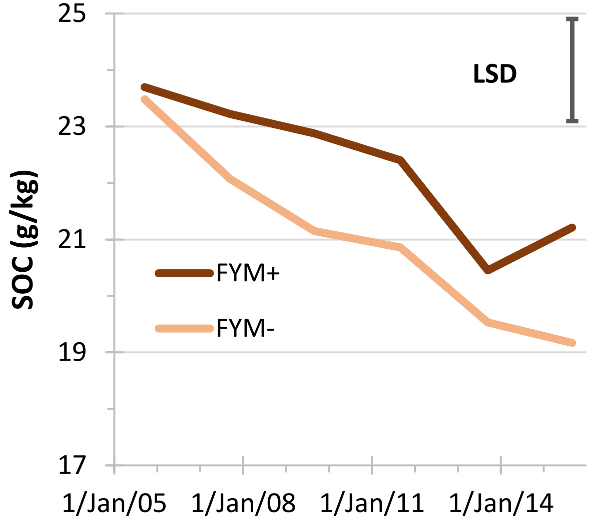


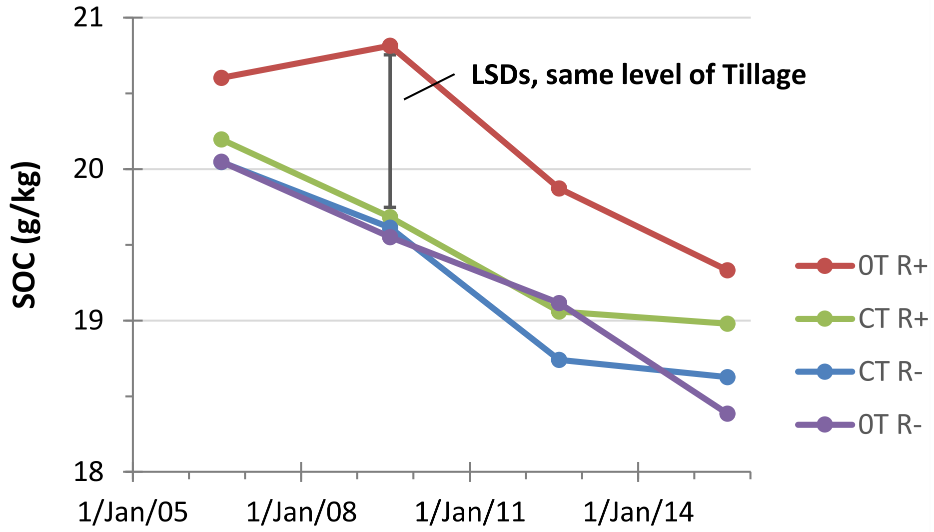
Biophysical monitoring and evaluation – soil liming

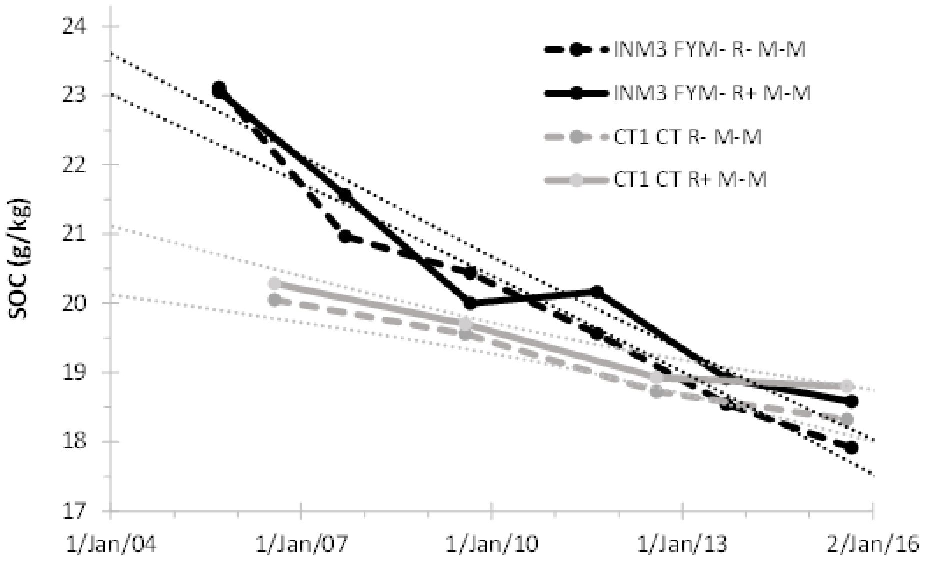


- Liming nearly doubled labile P in soils which had not received any fertilizer for 12 years. But, that still did not bring these soils out of severe P deficiency.
- Fertilized soils with comparably higher initial available P did not show such trend.
- Liming of acid and P-fixing soils is not a substitute for application of sufficient amounts of organic or inorganic P-fertilizer.

Biophysical monitoring and evaluation – SOC dynamics







- Neither ISFM nor CA could prevent soil organic carbon (SOC) topsoil contents from declining over time
- However, manure application (as part of ISFM), as well as residue retention and omitting tillage (as part of CA) decreased SOC losses
- Land use history prior to installation of CIAT's long-term trials, i.e. the state of soil health/degradation, plays a major role in the speed of decline of SOC

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CSA prioritization workshop

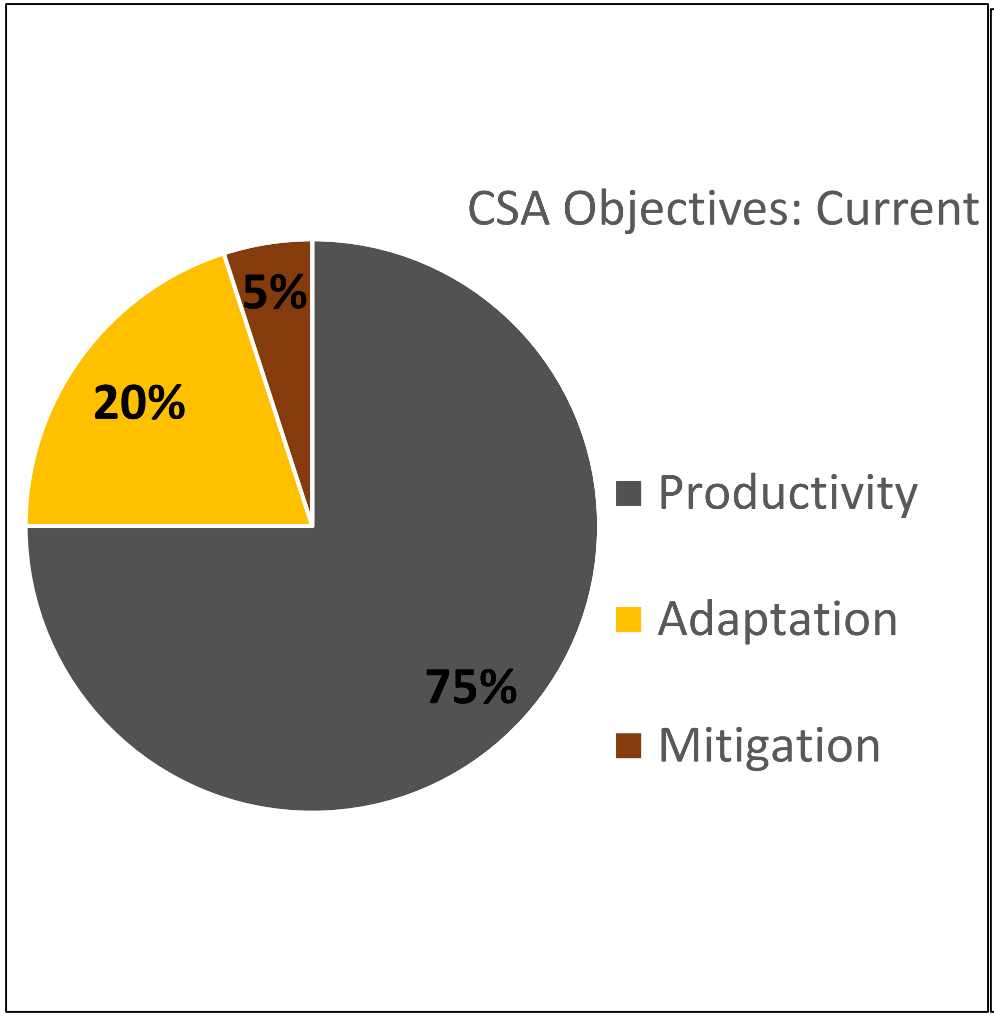
Workshop objectives

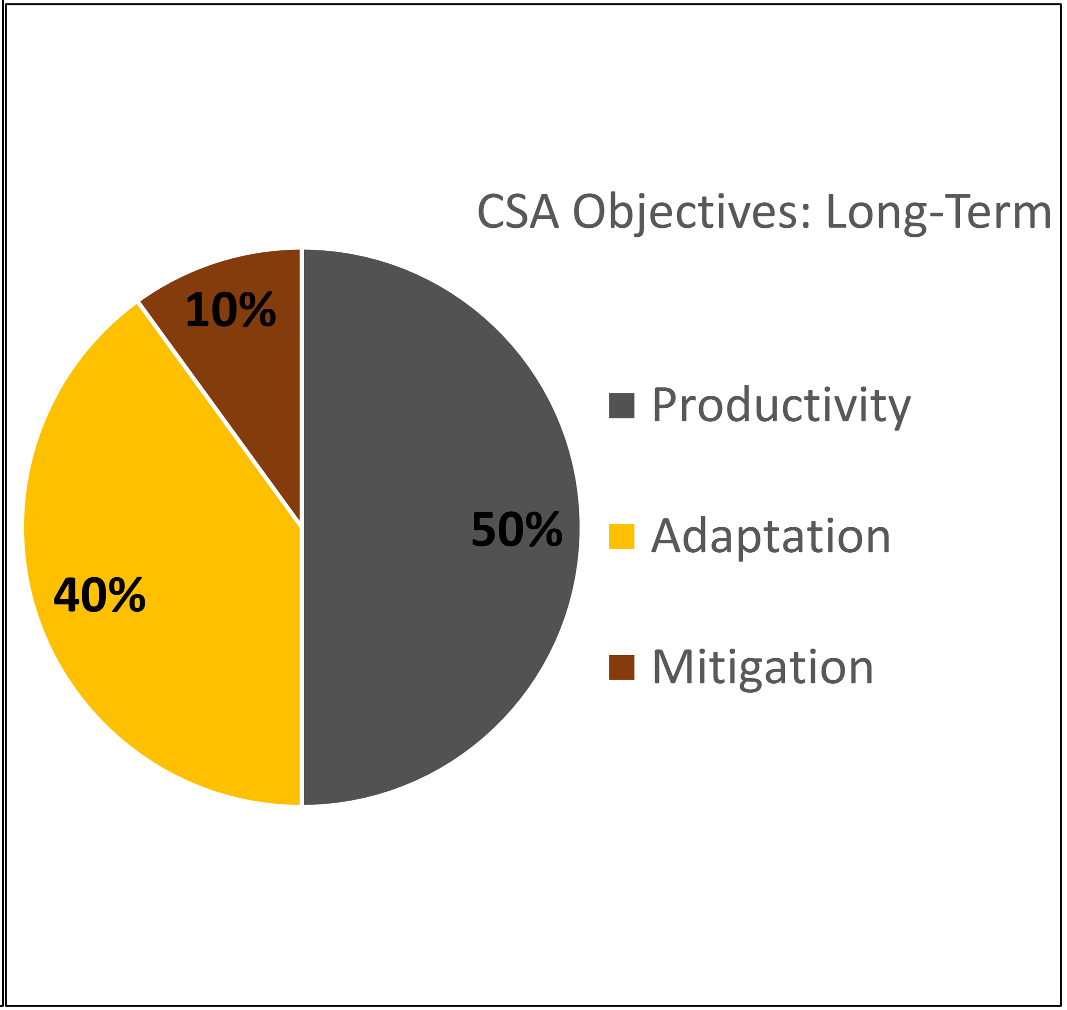
1. To understand the desired outcomes by different stakeholders used to prioritize agricultural practices across the 5 farm types in Western Kenya;
2. To develop a prioritized list of CSA practices farmers would like to implement;
3. To evaluate the climate smartness of prioritized practices
4. To understand benefits, challenges, barriers and tradeoffs in adopting prioritized practices

Long list of agricultural practices in Western Kenya

1. Push and pull
2. Fallowing
3. Dry planting
4. Certified seed
5. Grass strips e.g. vertiver grass
6. Organic manure
7. Cover crop
8. Conservation agriculture
9. Use of herbicides
10. Organic manure
11. Water harvesting
12. Intercropping
13. Crop rotation
14. Terracing
15. Mulching
16. Minimum tillage
17. Incorporate residue
18. Composting
19. Agroforestry
20. Liming

Current and long-term desired CSA objectives by stakeholders in Western Kenya





Pairwise ranking of practices

Small scale mixed subsistence	Medium scale mixed with commercial horticulture	Medium scale mixed with commercial dairy	Medium scale mixed with commercial cereal	Large scale commercial
1. Crop rotation **2. Composting** **3. Farm yard manure** **4. Intercropping** **5. Incorporate residues** **6. Conservation agriculture** **7. Inorganic fertilizer** **8. Mulching** **9. Organic manure**	1. Certified seed 2. Crop rotation 3. Intercropping 4. Agroforestry 5. Composting 6. Soil liming 7. Terracing 8. Water harvesting 9. Mulching 10. Conservation agriculture	1. Agroforestry 2. Farm yard manure 3. Inorganic fertilizer 4. Certified seed 5. Crop rotation 6. Intercropping 7. Composting 8. Fallowing	1. Crop rotation 2. Herbicides 3. Certified seed 4. Inorganic fertilizer 5. Terracing 6. Farm yard manure 7. Intercropping 8. Agroforestry 9. Liming 10. Dry planting	1. Conservation agriculture 2. Crop rotation 3. Agroforestry 4. Liming 5. Terracing 6. Fallowing 7. Inorganic fertilizer 8. Dry planting 9. Use of certified seed 10. Herbicides

CSA practices smartness' assessment

Individual (Expert) work

Production system: MAIZE | **Practice:** | **Region:**

By IMPLEMENTING the practice what are the expected changes in the following indicators?

Other <-10	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	Other >10

- -10: Completely decreases (-100% compared to baseline)
- -5: Decreases by half (-50% compared to baseline)
- 0: No change (0% compared to baseline)
- 5: Increases by half (+50% compared to baseline)
- 10: Completely increases (+100% compared to baseline)

N/A: Not applicable
N/I No information

	Indicator (Average)	**Metric**	Indicator assessment (-10 to 10 scale)	Pillar Average
P	Yield (Maize)	Δ kg/ha		
P	Yield variability (Maize)	Standard Deviation (kg/ha/yr)		
P	Income generated from Maize production	$/kg/year		
A	Household income spent on food	$/month/ha		
A	Soil lost through erosion	t/acre/year		
A	Content of soil organic matter (SOM)	% SOM		
A	Quantity of water used per unit of product (water use efficiency)	L/kg product/season		
M	Aboveground Biomass	t/ha		
M	Belowground Biomass	t/ha		
M	Total Soil Carbon	% SOC		

Climate smartness assessment

Farm type	Practice	Productivity	Adaptation	Mitigation
Small scale mixed	Farm yard manure	5	2.5	0.9
Small scale mixed	Conservation agriculture	5.2	2.7	1.3
Small scale mixed	Composting	4.7	2.3	1.6
Medium-mixed-hort	Intercropping	3.5	1.3	1.1
Medium-mixed-hort	Certified seed	6.8	3.2	N/A
Medium-mixed-hort	Crop rotation	3.5	2.2	1
Medium-mixed-dairy	Farm yard manure	3.8	3.7	1.5
Medium-mixed-dairy	Agroforestry	4.5	2.6	2.3
Medium-mixed-dairy	Inorganic fertilizer	3.5	1.5	-3.3
Medium-mixed-cereal	Crop rotation	6.5	0.5	N/A
Medium-mixed-cereal	Herbicide	5	2.2	-0.3
Medium-mixed-cereal	Inorganic fertilizer	7	1.2	-4.3
Large scale commercial	Conservation agriculture	5.5	3.6	1.2
Large scale commercial	Liming	2.5	0.7	N/A
Large scale commercial	Agroforestry	5.5	3.5	2.7

Farmers preferred indicators

a) Yield
b) Yield variability
c) Income
d) income spent on food per season
e) soil organic matter
f) amount of water available for production

Cost-benefit analysis

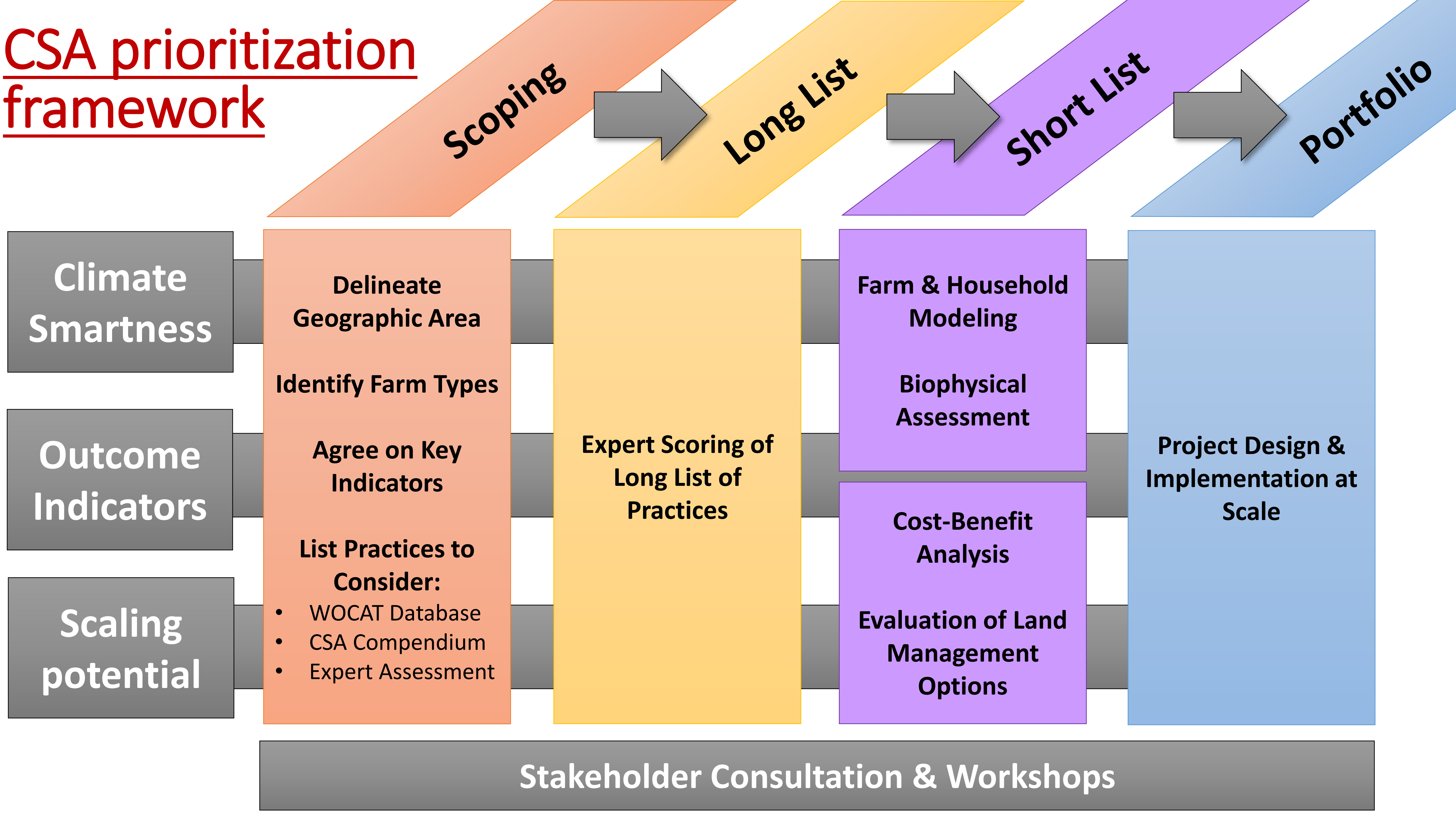
Farm typology	CSS Practice	NPV (9%)	IRR (%)	Payback Period (years)
Small-scale mixed subsistence	Farmyard manure	2,487	65	3
	Intercropping	6,718	67	3
Medium-scale mixed commercial dairy	Agroforestry	4429	47	4
Medium-scale mixed commercial horticulture	Improved seeds	5320	61	3
	Composting	2342	36	5
Medium-scale mixed commercial cereals	Improved seeds	7,733	60	4
	Inorganic fertilizer	6,949	60	5
Large-scale commercial	Liming	5656	44	4

Cost-benefit analysis

Estimated implementation, maintenance and operation cost by practice and farm typologies across all counties

Farm typology	CSS Practice	Implementation cost (US$ ha^{-1})	Maintenance (US$ ha^{-1} yr^{-1})	Operation cost (US$ ha^{-1})
Small-scale mixed subsistence farming	Organic manure	688	211	250
	Intercropping	582	413	294
Medium-scale mixed with commercial dairy	Agroforestry	616	294	173
Medium-scale mixed with commercial horticulture	Improved seeds	1,092	886	200
	Organic manure	1,049	209	316
Medium-scale mixed with commercial cereals	Improved seeds	1,560	410	271
	Inorganic fertilizer	1,659	787	270
Large-scale commercial farming	Liming	371	301	467

CSA prioritization framework



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Recommendations I

- Productivity similar, except female-headed much lower. Dairy also lower than others. Large commercial coffee farmer contributes less to food security
- Diversity of production base varies – dairy and horticulture higher number of calorie-producing activities
- Poor female-headed household dependent on off-farm activities for survival
- N balances tend to be negative except for commercial farmers using inputs, and farms with high livestock density. Nutrient input management of concern
- Soil erosion very little, concern only from 20t/ha -> but this is only true for the sampled farms which were not on slopes
- GHG emissions driven by livestock (enteric fermentation and manure mgt).
- Total emissions low: Germany 9t/capita, USA 16t/capita, Kenya 0.3t/capita

Recommendations II

- Grass strip interventions need additional nutrient inputs, otherwise trade-off with N balance.
- Synergy production and GHG is rare. Different impacts on different farm types – eg compost leads to GHG decrease on commercial farm, but increase on all others
- Increases in GHG emissions are small.
- With all agriculture you lose C – with CA you lose less
- No tillage without residue retention will lead to a yield penalty
- Most important: soil fertility, critical food/cash crops
- Most important challenges: soil acidity, availability, requires transport
- Most preferred practices: compost and manure, inorganic fertilizers – soil erosion techniques either not mentioned at all (tillage) or not preferred (grass strips)
- CA is perceived as a technology for commercial farmers due to herbicide use (weeds increase without tillage)

Questions

- Is this analysis useful and relevant to your work?
- How could you use these results in your work?
- Has this study influenced your thinking and practice already, and if yes how?


Thank you!